Fig. 0.1

Chapter 0
Vectors

Introduction of Vector

Physical quantities having magnitude, direction and obeying laws of vector algebra are called vectors.

Example : Displacement, velocity, acceleration, momentum, force, impulse, weight, thrust, torque, angular momentum, angular velocity *etc.*

If a physical quantity has magnitude and direction both, then it does not always imply that it is a vector. For it to be a vector the third condition of obeying laws of vector algebra has to be satisfied.

Example : The physical quantity current has both magnitude and direction but is still a scalar as it disobeys the laws of vector algebra.

Types of Vector

(1) **Equal vectors :** Two vectors $\vec{A}$ and $\vec{B}$ are said to be equal when they have equal magnitudes and same direction.

(2) **Parallel vector :** Two vectors $\vec{A}$ and $\vec{B}$ are said to be parallel when

(i) Both have same direction.

(ii) One vector is scalar (positive) non-zero multiple of another vector.

(3) **Anti-parallel vectors :** Two vectors $\vec{A}$ and $\vec{B}$ are said to be anti-parallel when

(i) Both have opposite direction.

(ii) One vector is scalar non-zero negative multiple of another vector.

(4) **Collinear vectors :** When the vectors under consideration can share the same support or have a common support then the considered vectors are collinear.

(5) **Zero vector** $(\vec{0})$**:** A vector having zero magnitude and arbitrary direction (not known to us) is a zero vector.

(6) **Unit vector :** A vector divided by its magnitude is a unit vector. Unit vector for $\vec{A}$ is $\hat{A}$ (read as A cap or A hat).

Since, $\hat{A} = \dfrac{\vec{A}}{A} \Rightarrow \vec{A} = A\hat{A}$.

Thus, we can say that unit vector gives us the direction.

(7) **Orthogonal unit vectors** $\hat{i}, \hat{j}$ and $\hat{k}$ are called orthogonal unit vectors. These vectors must form a Right Handed Triad (It is a coordinate system such that when we Curl the fingers of right hand from x to y then we must get the direction of z along thumb). The

$$\hat{i} = \frac{\vec{x}}{x}, \hat{j} = \frac{\vec{y}}{y}, \hat{k} = \frac{\vec{z}}{z}$$

$$\therefore \ \vec{x} = x\hat{i}, \ \vec{y} = y\hat{j}, \ \vec{z} = z\hat{k}$$

(8) **Polar vectors :** These have starting point or point of application . Example displacement and force *etc.*

(9) **Axial Vectors :** These represent rotational effects and are always along the axis of rotation in accordance with right hand screw rule. Angular velocity, torque and angular momentum, etc., are example of physical quantities of this type.

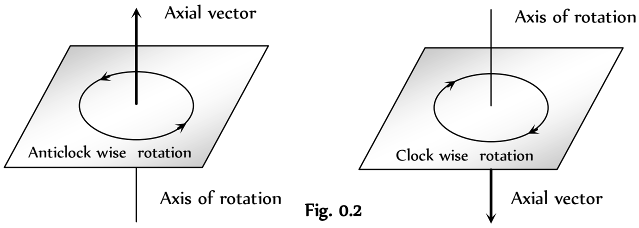


Fig. 0.2

(10) **Coplanar vector** : Three (or more) vectors are called coplanar vector if they lie in the same plane. Two (free) vectors are always coplanar.

Triangle Law of Vector Addition of Two Vectors

If two non zero vectors are represented by the two sides of a triangle taken in same order then the resultant is given by the closing side of triangle in opposite order. *i.e.* $\vec{R} = \vec{A} + \vec{B}$

$$\because \ \overrightarrow{OB} = \overrightarrow{OA} + \overrightarrow{AB}$$

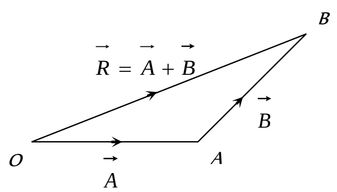


Fig. 0.3

(1) **Magnitude of resultant vector**

In ΔABN, $\cos\theta = \frac{AN}{B}$ $\therefore AN = B\cos\theta$

$\sin\theta = \frac{BN}{B}$ $\therefore BN = B\sin\theta$

In ΔOBN, we have $OB^2 = ON^2 + BN^2$

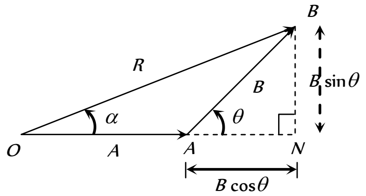


Fig. 0.4

$\Rightarrow R^2 = (A + B\cos\theta)^2 + (B\sin\theta)^2$

$\Rightarrow R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$

$\Rightarrow R^2 = A^2 + B^2(\cos^2\theta + \sin^2\theta) + 2AB\cos\theta$

$\Rightarrow R^2 = A^2 + B^2 + 2AB\cos\theta$

$\Rightarrow R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

(2) **Direction of resultant vectors :** If θ is angle between $\vec{A}$ and $\vec{B}$, then

$|\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

If $\vec{R}$ makes an angle α with $\vec{A}$, then in ΔOBN,

$\tan\alpha = \frac{BN}{ON} = \frac{BN}{OA + AN}$

$\tan\alpha = \frac{B\sin\theta}{A + B\cos\theta}$

Parallelogram Law of Vector Addition

If two non zero vectors are represented by the two adjacent sides of a parallelogram then the resultant is given by the diagonal of the parallelogram passing through the point of intersection of the two vectors.

(1) **Magnitude**

Since, $R^2 = ON^2 + CN^2$

$\Rightarrow R^2 = (OA + AN)^2 + CN^2$

$\Rightarrow R^2 = A^2 + B^2 + 2AB\cos\theta$

$\therefore \quad R = |\vec{R}| = |\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

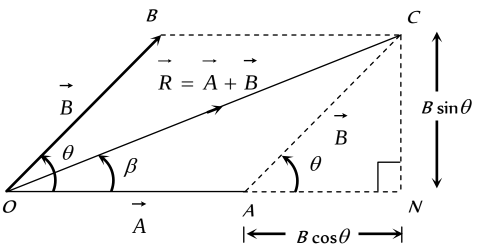


Fig. 0.5

Special cases : $R = A + B$ when $\theta = 0^\circ$

$R = A - B$ when $\theta = 180^\circ$

$R = \sqrt{A^2 + B^2}$ when $\theta = 90^\circ$

(2) **Direction**

$\tan\beta = \frac{CN}{ON} = \frac{B\sin\theta}{A + B\cos\theta}$

Polygon Law of Vector Addition

If a number of non zero vectors are represented by the $(n - 1)$ sides of an n-sided polygon then the resultant is given by the closing side or the n side of the polygon taken in opposite order. So,

$\vec{R} = \vec{A} + \vec{B} + \vec{C} + \vec{D} + \vec{E}$

$\overrightarrow{OA} + \overrightarrow{AB} + \overrightarrow{BC} + \overrightarrow{CD} + \overrightarrow{DE} = \overrightarrow{OE}$

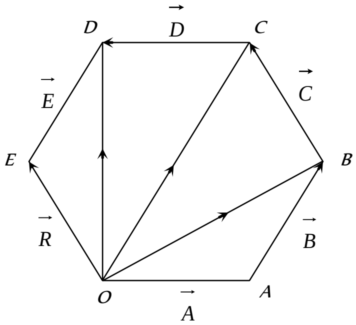


Fig. 0.6

Note : ❑ Resultant of two unequal vectors can not be zero.

❑ Resultant of three co-planar vectors may or may not be zero

❑ Resultant of three non co- planar vectors can not be zero.

Subtraction of vectors

Since, $\vec{A} - \vec{B} = \vec{A} + (-\vec{B})$ and

$|\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

$\Rightarrow |\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos(180^o - \theta)}$

Since, $\cos(180 - \theta) = -\cos\theta$

$\Rightarrow |\vec{A} - \vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

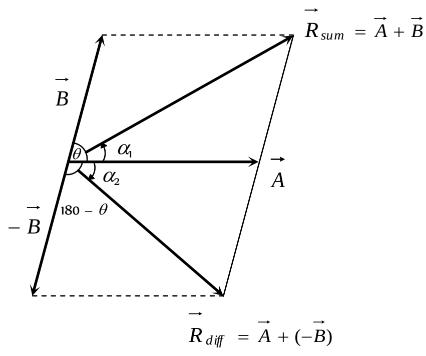


Fig. 0.7

$\tan\alpha_1 = \frac{B\sin\theta}{A + B\cos\theta}$

and $\tan\alpha_2 = \frac{B\sin(180 - \theta)}{A + B\cos(180 - \theta)}$

But $\sin(180-\theta)=\sin\theta$ and $\cos(180-\theta)=-\cos\theta$

$$\Rightarrow \tan\alpha_2 = \frac{B\sin\theta}{A-B\cos\theta}$$

Resolution of Vector Into Components

Consider a vector $\vec{R}$ in *X-Y* plane as shown in fig. If we draw orthogonal vectors $\vec{R}_x$ and $\vec{R}_y$ along *x* and *y* axes respectively, by law of vector addition, $\vec{R}=\vec{R}_x+\vec{R}_y$

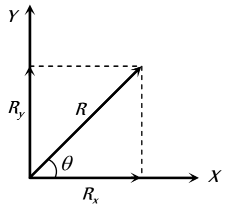


Fig. 0.8

Now as for any vector $\vec{A}=A\hat{n}$ so, $\vec{R}_x=\hat{i}R_x$ and $\vec{R}_y=\hat{j}R_y$

so $\vec{R}=\hat{i}R_x+\hat{j}R_y$ ...(i)

But from figure $R_x=R\cos\theta$ ...(ii)

and $R_y=R\sin\theta$ ...(iii)

Since R and θ are usually known, Equation (ii) and (iii) give the magnitude of the components of $\vec{R}$ along *x* and *y*-axes respectively.

Here it is worthy to note once a vector is resolved into its components, the components themselves can be used to specify the vector as

(1) The magnitude of the vector $\vec{R}$ is obtained by squaring and adding equation (ii) and (iii), *i.e.*

$$R=\sqrt{R_x^2+R_y^2}$$

(2) The direction of the vector $\vec{R}$ is obtained by dividing equation (iii) by (ii), *i.e.*

$$\tan\theta=(R_y/R_x) \text{ or } \theta=\tan^{-1}(R_y/R_x)$$

Rectangular Components of 3-D Vector

$$\vec{R}=\vec{R}_x+\vec{R}_y+\vec{R}_z q \text{ or } \vec{R}=R_x\hat{i}+R_y\hat{j}+R_z\hat{k}$$

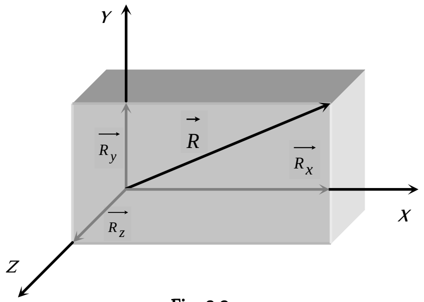


Fig. 0.9

If $\vec{R}$ makes an angle α with *x* axis, β with *y* axis and γ with *z* axis, then

$$\Rightarrow \cos\alpha=\frac{R_x}{R}=\frac{R_x}{\sqrt{R_x^2+R_y^2+R_z^2}}=l$$

$$\Rightarrow \cos\beta=\frac{R_y}{R}=\frac{R_y}{\sqrt{R_x^2+R_y^2+R_z^2}}=m$$

$$\Rightarrow \cos\gamma=\frac{R_z}{R}=\frac{R_z}{\sqrt{R_x^2+R_y^2+R_z^2}}=n$$

Where *l, m, n* are called Direction Cosines of the vector $\vec{R}$ and

$$l^2+m^2+n^2=\cos^2\alpha+\cos^2\beta+\cos^2\gamma=\frac{R_x^2+R_y^2+R_z^2}{R_x^2+R_y^2+R_z^2}=1$$

Note : ❑ When a point *P* have coordinate (*x, y, z*) then its position vector $\overrightarrow{OP}=x\hat{i}+y\hat{j}+z\hat{k}$

❑ When a particle moves from point (*x, y, z*) to (*x, y, z*) then its displacement vector

$$\vec{r}=(x_2-x_1)\hat{i}+(y_2-y_1)\hat{j}+(z_2-z_1)\hat{k}$$

Scalar Product of Two Vectors

(1) **Definition :** The scalar product (or dot product) of two vectors is defined as the product of the magnitude of two vectors with cosine of angle between them.

Thus if there are two vectors $\vec{A}$ and $\vec{B}$ having angle θ between them, then their scalar product written as $\vec{A}.\vec{B}$ is defined as $\vec{A}.\vec{B}=AB\cos\theta$

(2) **Properties :** (i) It is always a scalar which is positive if angle between the vectors is acute (*i.e.*, < 90°) and negative if angle between them is obtuse (*i.e.* 90°<θ < 180°).

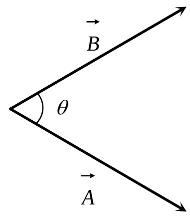


Fig. 0.10

(ii) It is commutative, *i.e.* $\vec{A}.\vec{B}=\vec{B}.\vec{A}$

(iii) It is distributive, *i.e.* $\vec{A}.(\vec{B}+\vec{C})=\vec{A}.\vec{B}+\vec{A}.\vec{C}$

(iv) As by definition $\vec{A}.\vec{B}=AB\cos\theta$

The angle between the vectors $\theta=\cos^{-1}\left[\frac{\vec{A}.\vec{B}}{AB}\right]$

(v) Scalar product of two vectors will be maximum when $\cos\theta=\max=1$, *i.e.* $\theta=0^o$, *i.e.*, vectors are parallel

$$(\vec{A}.\vec{B})_{\max}=AB$$

(vi) Scalar product of two vectors will be minimum when $|\cos\theta|=\min=0$, *i.e.* $\theta=90^o$

$$(\vec{A}.\vec{B})_{\min}=0$$

i.e. if the scalar product of two nonzero vectors vanishes the vectors are orthogonal.

(vii) The scalar product of a vector by itself is termed as self dot product and is given by $(\vec{A})^2=\vec{A}.\vec{A}=AA\cos\theta=A^2$

i.e. $A = \sqrt{\vec{A}.\vec{A}}$

(viii) In case of unit vector $\hat{n}$

$\hat{n}.\hat{n} = 1 \times 1 \times \cos 0 = 1$ so $\hat{n}.\hat{n} = \hat{i}.\hat{i} = \hat{j}.\hat{j} = \hat{k}.\hat{k} = 1$

(ix) In case of orthogonal unit vectors $\hat{i}, \hat{j}$ and $\hat{k}$, $\hat{i}.\hat{j} = \hat{j}.\hat{k} = \hat{k}.\hat{i} = 1 \times 1 \cos 90° = 0$

(x) In terms of components

$\vec{A}.\vec{B} = (\hat{i}A_x + \hat{j}A_y + \hat{k}A_z).(\hat{i}B_x + \hat{j}B_y + \hat{k}B_z) = [A_xB_x + A_yB_y + A_ZB_z]$

(3) **Example :** (i) Work W : In physics for constant force work is defined as, $W = Fs\cos\theta$ ...(i)

But by definition of scalar product of two vectors, $\vec{F}.\vec{s} = Fs\cos\theta$ ...(ii)

So from *eq* (i) and (ii) $W = \vec{F}.\vec{s}$ *i.e.* work is the scalar product of force with displacement.

(ii) Power P :

As $W = \vec{F}.\vec{s}$ or $\frac{dW}{dt} = \vec{F}.\frac{d\vec{s}}{dt}$ [As $\vec{F}$ is constant]

or $P = \vec{F}.\vec{v}$ *i.e.,* power is the scalar product of force with velocity. $\left[\text{As}\frac{dW}{dt} = P \text{ and } \frac{d\vec{s}}{dt} = \vec{v}\right]$

(iii) Magnetic Flux ϕ :

Magnetic flux through an area is given by $d\phi = B\,ds\cos\theta$ ...(i)

But by definition of scalar product $\vec{B}.d\vec{s} = Bds\cos\theta$ ...(ii)

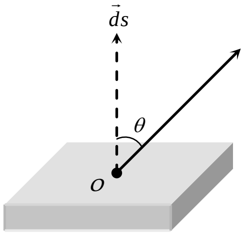


Fig. 0.11

So from *eq* (i) and (ii) we have

$d\phi = \vec{B}.d\vec{s}$ or $\phi = \int \vec{B}.d\vec{s}$

(iv) Potential energy of a dipole U : If an electric dipole of moment $\vec{p}$ is situated in an electric field $\vec{E}$ or a magnetic dipole of moment $\vec{M}$ in a field of induction $\vec{B}$, the potential energy of the dipole is given by :

$U_E = -\vec{p}.\vec{E}$ and $U_B = -\vec{M}.\vec{B}$

Vector Product of Two Vectors

(1) **Definition** : The vector product or cross product of two vectors is defined as a vector having a magnitude equal to the product of the magnitudes of two vectors with the sine of angle between them, and direction perpendicular to the plane containing the two vectors in accordance with right hand screw rule.

$$\vec{C} = \vec{A} \times \vec{B}$$

Thus, if $\vec{A}$ and $\vec{B}$ are two vectors, then their vector product written as $\vec{A} \times \vec{B}$ is a vector $\vec{C}$ defined by

$$\vec{C} = \vec{A} \times \vec{B} = AB\sin\theta\,\hat{n}$$

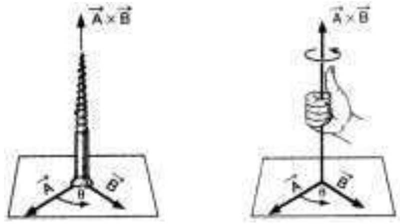


Fig. 0.12

The direction of $\vec{A} \times \vec{B}$, *i.e.* $\vec{C}$ is perpendicular to the plane containing vectors $\vec{A}$ and $\vec{B}$ and in the sense of advance of a right handed screw rotated from $\vec{A}$ (first vector) to $\vec{B}$ (second vector) through the smaller angle between them. Thus, if a right handed screw whose axis is perpendicular to the plane framed by $\vec{A}$ and $\vec{B}$ is rotated from $\vec{A}$ to $\vec{B}$ through the smaller angle between them, then the direction of advancement of the screw gives the direction of $\vec{A} \times \vec{B}$ *i.e.* $\vec{C}$

(2) **Properties**

(i) Vector product of any two vectors is always a vector perpendicular to the plane containing these two vectors, *i.e.,* orthogonal to both the vectors $\vec{A}$ and $\vec{B}$, though the vectors $\vec{A}$ and $\vec{B}$ may or may not be orthogonal.

(ii) Vector product of two vectors is not commutative, *i.e.,* $\vec{A} \times \vec{B} \neq \vec{B} \times \vec{A}$ [but $= -\vec{B} \times \vec{A}$]

Here it is worthy to note that

$|\vec{A} \times \vec{B}| = |\vec{B} \times \vec{A}| = AB\sin\theta$

i.e. in case of vector $\vec{A} \times \vec{B}$ and $\vec{B} \times \vec{A}$ magnitudes are equal but directions are opposite.

(iii) The vector product is distributive when the order of the vectors is strictly maintained, *i.e.*

$$\vec{A} \times (\vec{B} + \vec{C}) = \vec{A} \times \vec{B} + \vec{A} \times \vec{C}$$

(iv) The vector product of two vectors will be maximum when $\sin\theta = \max = 1$, *i.e.,* $\theta = 90^o$

$[\vec{A} \times \vec{B}]_{\max} = AB\,\hat{n}$

i.e. vector product is maximum if the vectors are orthogonal.

(v) The vector product of two non- zero vectors will be minimum when $|\sin\theta| =$ minimum = 0, *i.e,* $\theta = 0^o$ or 180^o

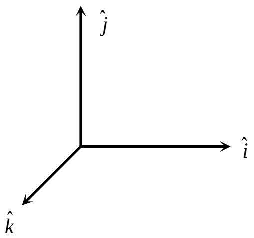
$[\vec{A} \times \vec{B}]_{\min} = 0$

i.e. if the vector product of two non-zero vectors vanishes, the vectors are collinear.

(vi) The self cross product, *i.e.,* product of a vector by itself vanishes, *i.e.,* is null vector $\vec{A} \times \vec{A} = AA\sin 0^o\,\hat{n} = \vec{0}$

(vii) In case of unit vector $\hat{n} \times \hat{n} = \vec{0}$ so that $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = \vec{0}$

(viii) In case of orthogonal unit vectors, $\hat{i}, \hat{j}, \hat{k}$ in accordance with right hand screw rule :



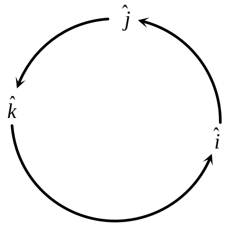


Fig. 0.13

$\hat{i}\times\hat{j}=\hat{k},\ \hat{j}\times\hat{k}=\hat{i}$ and $\hat{k}\times\hat{i}=\hat{j}$

And as cross product is not commutative,

$\hat{j}\times\hat{i}=-\hat{k},\ \hat{k}\times\hat{j}=-\hat{i}$ and $\hat{i}\times\hat{k}=-\hat{j}$

(x) In terms of components

$$\vec{A}\times\vec{B}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ A_x & A_y & A_z\\ B_x & B_y & B_z\end{vmatrix}$$

$$=\hat{i}(A_yB_z-A_zB_y)+\hat{j}(A_zB_x-A_xB_z)+\hat{k}(A_xB_y-A_yB_x)$$

(3) **Example :** Since vector product of two vectors is a vector, vector physical quantities (particularly representing rotational effects) like torque, angular momentum, velocity and force on a moving charge in a magnetic field and can be expressed as the vector product of two vectors. It is well – established in physics that :

(i) Torque $\vec{\tau}=\vec{r}\times\vec{F}$

(ii) Angular momentum $\vec{L}=\vec{r}\times\vec{p}$

(iii) Velocity $\vec{v}=\vec{\omega}\times\vec{r}$

(iv) Force on a charged particle q moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is given by $\vec{F}=q(\vec{v}\times\vec{B})$

(v) Torque on a dipole in a field $\vec{\tau_E}=\vec{p}\times\vec{E}$ and $\vec{\tau_B}=\vec{M}\times\vec{B}$

Lami's Theorem

In any ΔABC with sides $\vec{a},\vec{b},\vec{c}$

$$\frac{\sin\alpha}{a}=\frac{\sin\beta}{b}=\frac{\sin\gamma}{c}$$

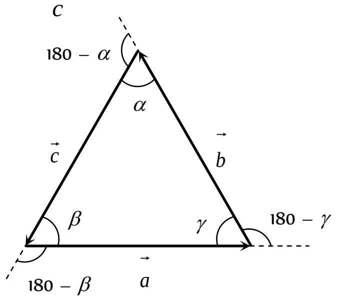


Fig. 0.14

i.e. for any triangle the ratio of the sine of the angle containing the side to the length of the side is a constant.

For a triangle whose three sides are in the same order we establish the Lami's theorem in the following manner. For the triangle shown

$\vec{a}+\vec{b}+\vec{c}=\vec{0}$ [All three sides are taken in order] ...(i)

$\Rightarrow\ \vec{a}+\vec{b}=-\vec{c}$ ...(ii)

Pre-multiplying both sides by $\vec{a}$

$\vec{a}\times(\vec{a}+\vec{b})=-\vec{a}\times\vec{c}\ \Rightarrow\ \vec{0}+\vec{a}\times\vec{b}=-\vec{a}\times\vec{c}$

$\Rightarrow\ \vec{a}\times\vec{b}=\vec{c}\times\vec{a}$ ...(iii)

Pre-multiplying both sides of (ii) by $\vec{b}$

$\vec{b}\times(\vec{a}+\vec{b})=-\vec{b}\times\vec{c}\ \Rightarrow\ \vec{b}\times\vec{a}+\vec{b}\times\vec{b}=-\vec{b}\times\vec{c}$

$\Rightarrow\ -\vec{a}\times\vec{b}=-\vec{b}\times\vec{c}\ \Rightarrow\ \vec{a}\times\vec{b}=\vec{b}\times\vec{c}$ ...(iv)

From (iii) and (iv), we get $\vec{a}\times\vec{b}=\vec{b}\times\vec{c}=\vec{c}\times\vec{a}$

Taking magnitude, we get $|\vec{a}\times\vec{b}|=|\vec{b}\times\vec{c}|=|\vec{c}\times\vec{a}|$

$\Rightarrow\ ab\sin(180-\gamma)=bc\sin(180-\alpha)=ca\sin(180-\beta)$

$\Rightarrow\ ab\sin\gamma=bc\sin\alpha=ca\sin\beta$

Dividing through out by *abc,* we have

$$\Rightarrow\ \frac{\sin\alpha}{a}=\frac{\sin\beta}{b}=\frac{\sin\gamma}{c}$$

Relative Velocity

(1) **Introduction :** When we consider the motion of a particle, we assume a fixed point relative to which the given particle is in motion. For example, if we say that water is flowing or wind is blowing or a person is running with a speed *v*, we mean that these all are relative to the earth (which we have assumed to be fixed).

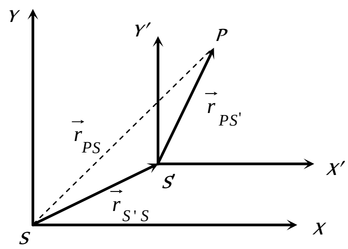


Fig. 0.15

Now to find the velocity of a moving object relative to another moving object, consider a particle *P* whose position relative to frame *S* is $\vec{r}_{PS}$ while relative to S' is $\vec{r}_{PS'}$.

If the position of frames S' relative to *S* at any time is $\vec{r}_{S'S}$ then from figure, $\vec{r}_{PS}=\vec{r}_{PS'}+\vec{r}_{S'S}$

Differentiating this equation with respect to time

$$\frac{d\vec{r}_{PS}}{dt}=\frac{d\vec{r}_{PS'}}{dt}+\frac{d\vec{r}_{S'S}}{dt}$$

or $\vec{v}_{PS}=\vec{v}_{PS'}+\vec{v}_{S'S}$ [as $\vec{v}=d\vec{r}/dt$]

or $\vec{v}_{PS'}=\vec{v}_{PS}-\vec{v}_{S'S}$

(2) **General Formula :** The relative velocity of a particle P_1 moving with velocity $\vec{v}_1$ with respect to another particle P_2 moving with velocity $\vec{v}_2$ is given by, $\vec{v}_{r_{12}} = \vec{v}_1 - \vec{v}_2$

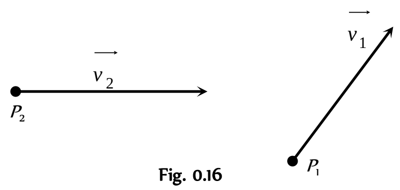


Fig. 0.16

(i) If both the particles are moving in the same direction then :

$\upsilon_{r_{12}} = \upsilon_1 - \upsilon_2$

(ii) If the two particles are moving in the opposite direction, then :

$\upsilon_{r_{12}} = \upsilon_1 + \upsilon_2$

(iii) If the two particles are moving in the mutually perpendicular directions, then:

$$\upsilon_{r_{12}} = \sqrt{\upsilon_1^2 + \upsilon_2^2}$$

(iv) If the angle between $\vec{\upsilon}_1$ and $\vec{\upsilon}_2$ be θ, then $\upsilon_{r_{12}} = \left[\upsilon_1^2 + \upsilon_2^2 - 2\upsilon_1\upsilon_2 \cos\theta\right]^{1/2}$.

(3) **Relative velocity of satellite :** If a satellite is moving in equatorial plane with velocity $\vec{v}_s$ and a point on the surface of earth with $\vec{v}_e$ relative to the centre of earth, the velocity of satellite relative to the surface of earth

$$\vec{v}_{se} = \vec{v}_s - \vec{v}_e$$

So if the satellite moves form west to east (in the direction of rotation of earth on its axis) its velocity relative to earth's surface will be $v_{se} = v_s - v_e$

And if the satellite moves from east to west, *i.e.,* opposite to the motion of earth, $v_{se} = v_s - (-v_e) = v_s + v_e$

(4) **Relative velocity of rain :** If rain is falling vertically with a velocity $\vec{v}_R$ and an observer is moving horizontally with speed $\vec{v}_M$ the velocity of rain relative to observer will be $\vec{v}_{RM} = \vec{v}_R - \vec{v}_M$

which by law of vector addition has magnitude

$$v_{RM} = \sqrt{v_R^2 + v_M^2}$$

direction $\theta = \tan^{-1}(v_M / v_R)$ with the vertical as shown in fig.

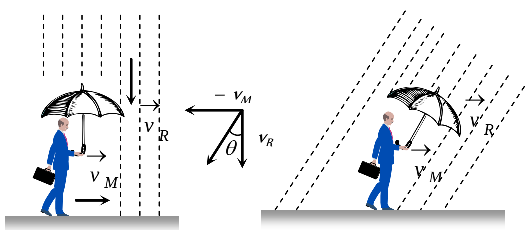


Fig. 0.17

(5) **Relative velocity of swimmer :** If a man can swim relative to water with velocity $\vec{v}$ and water is flowing relative to ground with velocity $\vec{v}_R$ velocity of man relative to ground $\vec{v}_M$ will be given by:

$$\vec{v} = \vec{v}_M - \vec{v}_R, \text{ i.e., } \vec{v}_M = \vec{v} + \vec{v}_R$$

So if the swimming is in the direction of flow of water, $v_M = v + v_R$

And if the swimming is opposite to the flow of water, $v_M = v - v_R$

(6) **Crossing the river :** Suppose, the river is flowing with velocity $\vec{\upsilon}_r$. A man can swim in still water with velocity $\vec{\upsilon}_m$. He is standing on one bank of the river and wants to cross the river, two cases arise.

(i) To cross the river over shortest distance : That is to cross the river straight, the man should swim making angle θ with the upstream as shown.

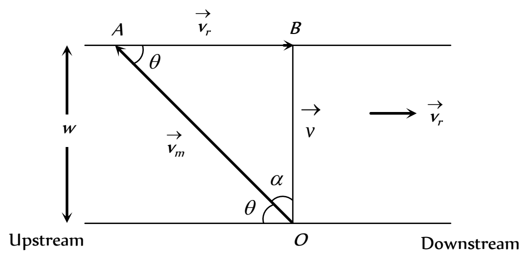


Fig. 0.18

Here *OAB* is the triangle of vectors, in which $\vec{OA} = \vec{v}_m, \vec{AB} = \vec{\upsilon}_r$. Their resultant is given by $\vec{OB} = \vec{\upsilon}$. The direction of swimming makes angle θ with upstream. From the triangle *OBA*, we find,

$$\cos\theta = \frac{\upsilon_r}{\upsilon_m} \quad \text{Also} \quad \sin\alpha = \frac{\upsilon_r}{\upsilon_m}$$

Where α is the angle made by the direction of swimming with the shortest distance (*OB*) across the river.

Time taken to cross the river : If w be the width of the river, then time taken to cross the river will be given by

$$t_1 = \frac{w}{\upsilon} = \frac{w}{\sqrt{\upsilon_m^2 - \upsilon_r^2}}$$

(ii) To cross the river in shortest possible time : The man should swim perpendicular to the bank.

The time taken to cross the river will be:

$$t_2 = \frac{w}{\upsilon_m}$$

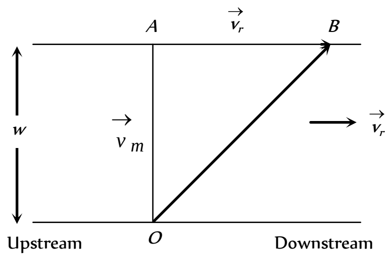


Fig. 0.19

In this case, the man will touch the opposite bank at a distance AB down stream. This distance will be given by:

$$AB = \upsilon_r t_2 = \upsilon_r \frac{w}{\upsilon_m} \quad \text{or} \quad AB = \frac{\upsilon_r}{\upsilon_m} w$$

Tips & Tricks

✍ All physical quantities having direction are not vectors. For example, the electric current possesses direction but it is a scalar quantity because it can not be added or multiplied according to the rules of vector algebra.

✍ A vector can have only two rectangular components in plane and only three rectangular components in space.

✍ A vector can have any number, even infinite components. (minimum 2 components)

✍ Following quantities are neither vectors nor scalars : Relative density, density, viscosity, frequency, pressure, stress, strain, modulus of elasticity, poisson's ratio, moment of inertia, specific heat, latent heat, spring constant loudness, resistance, conductance, reactance, impedance, permittivity, dielectric constant, permeability, susceptibility, refractive index, focal length, power of lens, Boltzman constant, Stefan's constant, Gas constant, Gravitational constant, Rydberg constant, Planck's constant etc.

✍ Distance covered is a scalar quantity.

✍ The displacement is a vector quantity.

✍ Scalars are added, subtracted or divided algebraically.

✍ Vectors are added and subtracted geometrically.

✍ Division of vectors is not allowed as directions cannot be divided.

✍ Unit vector gives the direction of vector.

✍ Magnitude of unit vector is 1.

✍ Unit vector has no unit. For example, velocity of an object is 5 ms^{-1} due East.

i.e. $\vec{v} = 5ms^{-1}$ due east.

$$\hat{v} = \frac{\vec{v}}{|\vec{v}|} = \frac{5ms^{-1}(\text{East})}{5ms^{-1}} = \text{East}$$

So unit vector $\hat{v}$ has no unit as East is not a physical quantity.

✍ Unit vector has no dimensions.

✍ $\hat{i}.\hat{i} = \hat{j}.\hat{j} = \hat{k}.\hat{k} = 1$

✍ $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = \vec{0}$

✍ $\hat{i} \times \hat{j} = \hat{k},\ \hat{j} \times \hat{k} = \hat{i},\ \hat{k} \times \hat{i} = \hat{j}$

✍ $\hat{i}.\hat{j} = \hat{j}.\hat{k} = \hat{k}.\hat{i} = 0$

✍ $\vec{A} \times \vec{A} = \vec{0}$. Also $\vec{A} - \vec{A} = \vec{0}$ But $\vec{A} \times \vec{A} \neq \vec{A} - \vec{A}$

Because $\vec{A} \times \vec{A} \perp \vec{A}$ and $\vec{A} - \vec{A}$ is collinear with $\vec{A}$

✍ Multiplication of a vector with –1 reverses its direction.

If $\vec{A} = \vec{B}$, then $A = B$ and $\hat{A} = \hat{B}$.

If $\vec{A} + \vec{B} = \vec{0}$, then $A = B$ but $\hat{A} = -\hat{B}$.

✍ Minimum number of collinear vectors whose resultant can be zero is two.

✍ Minimum number of coplaner vectors whose resultant is zero is three.

✍ Minimum number of non coplaner vectors whose resultant is zero is four.

✍ Two vectors are perpendicular to each other if $\vec{A}.\vec{B} = 0$.

✍ Two vectors are parallel to each other if $\vec{A} \times \vec{B} = 0$.

✍ Displacement, velocity, linear momentum and force are polar vectors.

✍ Angular velocity, angular acceleration, torque and angular momentum are axial vectors.

✍ Division with a vector is not defined because it is not possible to divide with a direction.

✍ Distance covered is always positive quantity.

✍ The components of a vectors can have magnitude than that of the vector itself.

✍ The rectangular components cannot have magnitude greater than that of the vector itself.

✍ When we multiply a vector with 0 the product becomes a null vector.

✍ The resultant of two vectors of unequal magnitude can never be a null vector.

✍ Three vectors not lying in a plane can never add up to give a null vector.

✍ A quantity having magnitude and direction is not necessarily a vector. For example, time and electric current. These quantities have magnitude and direction but they are scalar. This is because they do not obey the laws of vector addition.

✍ A physical quantity which has different values in different directions is called a tensor. For example : Moment of inertia has different values in different directions. Hence moment of inertia is a tensor. Other examples of tensor are refractive index, stress, strain, density etc.

✍ The magnitude of rectangular components of a vector is always less than the magnitude of the vector

✍ If $\vec{A} = \vec{B}$, then $A_x = B_x$, $A_y = B_y$ and $A_z = B_z$.

✍ If $\vec{A} + \vec{B} = \vec{C}$. Or if $\vec{A} + \vec{B} + \vec{C} = \vec{0}$, then $\vec{A}$, $\vec{B}$ and $\vec{C}$ lie in one plane.

✍ If $\vec{A} \times \vec{B} = \vec{C}$, then $\vec{C}$ is perpendicular to $\vec{A}$ as well as $\vec{B}$.

✍ If $|\vec{A} \times \vec{B}| = |\vec{A} - \vec{B}|$, then angle between $\vec{A}$ and $\vec{B}$ is 90°.

✍ Resultant of two vectors will be maximum when θ = 0° *i.e.* vectors are parallel.

$R_{max} = \sqrt{P^2 + Q^2 + 2PQ\cos 0°} = |P + Q|$

✍ Resultant of two vectors will be minimum when θ = 180° *i.e.* vectors are anti-parallel.

$R_{min} = \sqrt{P^2 + Q^2 + 2PQ\cos 180°} = |P - Q|$

Thus, minimum value of the resultant of two vectors is equal to the difference of their magnitude.

✍ Thus, maximum value of the resultant of two vectors is equal to the sum of their magnitude.

When the magnitudes of two vectors are unequal, then

$R_{min} = P - Q \neq 0$

$[\because |\vec{P}| \neq |\vec{Q}|]$

Thus, two vectors $\vec{P}$ and $\vec{Q}$ having different magnitudes can never be combined to give zero resultant. From here, we conclude that the minimum number of vectors of unequal magnitude whose resultant can be zero is three. On the other hand, the minimum number of vectors of equal magnitude whose resultant can be zero is two.

✍ Angle between two vectors $\vec{A}$ and $\vec{B}$ is given by

$$\cos\theta = \frac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|}$$

✍ Projection of a vector $\vec{A}$ in the direction of vector $\vec{B}$

$$= \frac{\vec{A}.\vec{B}}{|\vec{B}|}$$

✍ Projection of a vector $\vec{B}$ in the direction of vector $\vec{A}$

$$= \frac{\vec{A}.\vec{B}}{|\vec{A}|}$$

✍ If vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are represented by three sides *ab, bc* and *ca* respectively taken in a order, then

$$\frac{|\vec{A}|}{ab} = \frac{|\vec{B}|}{bc} = \frac{|\vec{C}|}{ca}$$

✍ The vectors $\hat{i} + \hat{j} + \hat{k}$ is equally inclined to the coordinate axes at an angle of 54.74 degrees.

✍ If $\vec{A} \pm \vec{B} = \vec{C}$, then $\vec{A}.\vec{B} \times \vec{C} = 0$.

✍ If $\vec{A}.\vec{B} \times \vec{C} = 0$, then $\vec{A}.\vec{B}$ and $\vec{C}$ are coplanar.

✍ If angle between $\vec{A}$ and $\vec{B}$ is 45°,

then $\vec{A}.\vec{B} = |\vec{A} \times \vec{B}|$

✍ If $\vec{A}_1 + \vec{A}_2 + \vec{A}_3 + ... + \vec{A}_n = \vec{0}$ and $A_1 = A_2 = A_3 = ... = A_n$ then the adjacent vector are inclined to each other at angle $2\pi / n$.

✍ If $\vec{A} + \vec{B} = \vec{C}$ and $A^2 + B^2 = C^2$, then the angle between $\vec{A}$ and $\vec{B}$ is 90°. Also *A, B* and *C* can have the following values.

(i) $A = 3$, $B = 4$, $C = 5$

(ii) $A = 5$, $B = 12$, $C = 13$

(iii) $A = 8$, $B = 15$, $C = 17$.

Ordinary Thinking

Objective Questions

Fundamentals of Vectors

1. The vector projection of a vector $3\hat{i}+4\hat{k}$ on y-axis is [RPMT 2004]
(a) 5 (b) 4
(c) 3 (d) Zero

2. Position of a particle in a rectangular-co-ordinate system is (3, 2, 5). Then its position vector will be
(a) $3\hat{i}+5\hat{j}+2\hat{k}$ (b) $3\hat{i}+2\hat{j}+5\hat{k}$
(c) $5\hat{i}+3\hat{j}+2\hat{k}$ (d) None of these

3. If a particle moves from point P (2,3,5) to point Q (3,4,5). Its displacement vector be
(a) $\hat{i}+\hat{j}+10\hat{k}$ (b) $\hat{i}+\hat{j}+5\hat{k}$
(c) $\hat{i}+\hat{j}$ (d) $2\hat{i}+4\hat{j}+6\hat{k}$

4. A force of 5 N acts on a particle along a direction making an angle of 60° with vertical. Its vertical component be
(a) 10 N (b) 3 N
(c) 4 N (d) 2.5 N

5. If $A=3\hat{i}+4\hat{j}$ and $B=7\hat{i}+24\hat{j}$, the vector having the same magnitude as B and parallel to A is
(a) $5\hat{i}+20\hat{j}$ (b) $15\hat{i}+10\hat{j}$
(c) $20\hat{i}+15\hat{j}$ (d) $15\hat{i}+20\hat{j}$

6. Vector $\vec{A}$ makes equal angles with x, y and z axis. Value of its components (in terms of magnitude of $\vec{A}$) will be
(a) $\frac{A}{\sqrt{3}}$ (b) $\frac{A}{\sqrt{2}}$
(c) $\sqrt{3}A$ (d) $\frac{\sqrt{3}}{A}$

7. If $\vec{A}=2\hat{i}+4\hat{j}-5\hat{k}$ the direction of cosines of the vector $\vec{A}$ are
(a) $\frac{2}{\sqrt{45}},\frac{4}{\sqrt{45}}$ and $\frac{-5}{\sqrt{45}}$ (b) $\frac{1}{\sqrt{45}},\frac{2}{\sqrt{45}}$ and $\frac{3}{\sqrt{45}}$
(c) $\frac{4}{\sqrt{45}}$, 0 and $\frac{4}{\sqrt{45}}$ (d) $\frac{3}{\sqrt{45}},\frac{2}{\sqrt{45}}$ and $\frac{5}{\sqrt{45}}$

8. The vector that must be added to the vector $\hat{i}-3\hat{j}+2\hat{k}$ and $3\hat{i}+6\hat{j}-7\hat{k}$ so that the resultant vector is a unit vector along the y-axis is
(a) $4\hat{i}+2\hat{j}+5\hat{k}$ (b) $-4\hat{i}-2\hat{j}+5\hat{k}$
(c) $3\hat{i}+4\hat{j}+5\hat{k}$ (d) Null vector

9. How many minimum number of coplanar vectors having different magnitudes can be added to give zero resultant
(a) 2 (b) 3
(c) 4 (d) 5

10. A hall has the dimensions $10\,m\times 12\,m\times 14\,m$. A fly starting at one corner ends up at a diametrically opposite corner. What is the magnitude of its displacement
(a) 17 m (b) 26 m
(c) 36 m (d) 20 m

11. 100 coplanar forces each equal to 10 N act on a body. Each force makes angle $\pi/50$ with the preceding force. What is the resultant of the forces
(a) 1000 N (b) 500 N
(c) 250 N (d) Zero

12. The magnitude of a given vector with end points (4, – 4, 0) and (– 2, – 2, 0) must be
(a) 6 (b) $5\sqrt{2}$
(c) 4 (d) $2\sqrt{10}$

13. The expression $\left(\frac{1}{\sqrt{2}}\hat{i}+\frac{1}{\sqrt{2}}\hat{j}\right)$ is a
(a) Unit vector (b) Null vector
(c) Vector of magnitude $\sqrt{2}$ (d) Scalar

14. Given vector $\vec{A}=2\hat{i}+3\hat{j}$, the angle between $\vec{A}$ and y-axis is [CPMT 1993]
(a) $\tan^{-1}3/2$ (b) $\tan^{-1}2/3$
(c) $\sin^{-1}2/3$ (d) $\cos^{-1}2/3$

15. The unit vector along $\hat{i}+\hat{j}$ is
(a) $\hat{k}$ (b) $\hat{i}+\hat{j}$
(c) $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$ (d) $\frac{\hat{i}+\hat{j}}{2}$

16. A vector is represented by $3\hat{i}+\hat{j}+2\hat{k}$. Its length in XY plane is
(a) 2 (b) $\sqrt{14}$
(c) $\sqrt{10}$ (d) $\sqrt{5}$

17. Five equal forces of 10 N each are applied at one point and all are lying in one plane. If the angles between them are equal, the resultant force will be [CBSE PMT 1995]
(a) Zero (b) 10 N
(c) 20 N (d) $10\sqrt{2}N$

18. The angle made by the vector $A=\hat{i}+\hat{j}$ with x- axis is [EAMCET (Engg.) 1999]
(a) 90° (b) 45°
(c) 22.5° (d) 30°

19. Any vector in an arbitrary direction can always be replaced by two (or three)
(a) Parallel vectors which have the original vector as their resultant
(b) Mutually perpendicular vectors which have the original vector as their resultant

(c) Arbitrary vectors which have the original vector as their resultant

(d) It is not possible to resolve a vector

20. Angular momentum is [MNR 1986]

(a) A scalar (b) A polar vector

(c) An axial vector (d) None of these

21. Which of the following is a vector

(a) Pressure (b) Surface tension

(c) Moment of inertia (d) None of these

22. If $\vec{P} = \vec{Q}$ then which of the following is NOT correct

(a) $\hat{P} = \hat{Q}$ (b) $|\vec{P}| = |\vec{Q}|$

(c) $P\hat{Q} = Q\hat{P}$ (d) $\vec{P} + \vec{Q} = \hat{P} + \hat{Q}$

23. The position vector of a particle is $\vec{r} = (a\cos\omega t)\hat{i} + (a\sin\omega t)\hat{j}$. The velocity of the particle is [CBSE PMT 1995]

(a) Parallel to the position vector

(b) Perpendicular to the position vector

(c) Directed towards the origin

(d) Directed away from the origin

24. Which of the following is a scalar quantity [AFMC 1998]

(a) Displacement (b) Electric field

(c) Acceleration (d) Work

25. If a unit vector is represented by $0.5\hat{i} + 0.8\hat{j} + c\hat{k}$, then the value of '$c$' is [CBSE PMT 1999; EAMCET 1994]

(a) 1 (b) $\sqrt{0.11}$

(c) $\sqrt{0.01}$ (d) $\sqrt{0.39}$

26. A boy walks uniformally along the sides of a rectangular park of size 400 $m \times$ 300 m, starting from one corner to the other corner diagonally opposite. Which of the following statement is incorrect [HP PMT 1999]

(a) He has travelled a distance of 700 m

(b) His displacement is 700 m

(c) His displacement is 500 m

(d) His velocity is not uniform throughout the walk

27. The unit vector parallel to the resultant of the vectors $\vec{A} = 4\hat{i} + 3\hat{j} + 6\hat{k}$ and $\vec{B} = -\hat{i} + 3\hat{j} - 8\hat{k}$ is [EAMCET 2000]

(a) $\frac{1}{7}(3\hat{i} + 6\hat{j} - 2\hat{k})$ (b) $\frac{1}{7}(3\hat{i} + 6\hat{j} + 2\hat{k})$

(c) $\frac{1}{49}(3\hat{i} + 6\hat{j} - 2\hat{k})$ (d) $\frac{1}{49}(3\hat{i} - 6\hat{j} + 2\hat{k})$

28. Surface area is [J&K CET 2002]

(a) Scalar (b) Vector

(c) Neither scalar nor vector (d) Both scalar and vector

29. With respect to a rectangular cartesian coordinate system, three vectors are expressed as

$\vec{a} = 4\hat{i} - \hat{j}$, $\vec{b} = -3\hat{i} + 2\hat{j}$ and $\vec{c} = -\hat{k}$

where $\hat{i}, \hat{j}, \hat{k}$ are unit vectors, along the X, Y and Z-axis respectively. The unit vectors $\hat{r}$ along the direction of sum of these vector is [Kerala CET (Engg.) 2003]

(a) $\hat{r} = \frac{1}{\sqrt{3}}(\hat{i} + \hat{j} - \hat{k})$ (b) $\hat{r} = \frac{1}{\sqrt{2}}(\hat{i} + \hat{j} - \hat{k})$

(c) $\hat{r} = \frac{1}{3}(\hat{i} - \hat{j} + \hat{k})$ (d) $\hat{r} = \frac{1}{\sqrt{2}}(\hat{i} + \hat{j} + \hat{k})$

30. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ is [DPMT 2000]

(a) 60° (b) Zero

(c) 90° (d) None of these

31. The position vector of a particle is determined by the expression $\vec{r} = 3t^2\hat{i} + 4t^2\hat{j} + 7\hat{k}$

The distance traversed in first 10 sec is [DPMT 2002]

(a) 500 m (b) 300 m

(c) 150 m (d) 100 m

32. Unit vector parallel to the resultant of vectors $\vec{A} = 4\hat{i} - 3\hat{j}$ and $\vec{B} = 8\hat{i} + 8\hat{j}$ will be [BHU 1995]

(a) $\frac{24\hat{i} + 5\hat{j}}{13}$ (b) $\frac{12\hat{i} + 5\hat{j}}{13}$

(c) $\frac{6\hat{i} + 5\hat{j}}{13}$ (d) None of these

33. The component of vector $A = 2\hat{i} + 3\hat{j}$ along the vector $\hat{i} + \hat{j}$ is [KCET 1997]

(a) $\frac{5}{\sqrt{2}}$ (b) $10\sqrt{2}$

(c) $5\sqrt{2}$ (d) 5

34. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ will be [Pb. CET 2001]

(a) 90° (b) 0°

(c) 60° (d) 45°

Addition and Subtraction of Vectors

1. There are two force vectors, one of 5 N and other of 12 N at what angle the two vectors be added to get resultant vector of 17 N, 7 N and 13 N respectively

(a) 0°, 180° and 90° (b) 0°, 90° and 180°

(c) 0°, 90° and 90° (d) 180°, 0° and 90°

2. If $\vec{A} = 4\hat{i} - 3\hat{j}$ and $\vec{B} = 6\hat{i} + 8\hat{j}$ then magnitude and direction of $\vec{A} + \vec{B}$ will be

(a) $5, \tan^{-1}(3/4)$ (b) $5\sqrt{5}, \tan^{-1}(1/2)$

(c) $10, \tan^{-1}(5)$ (d) $25, \tan^{-1}(3/4)$

3. A truck travelling due north at 20 *m/s* turns west and travels at the same speed. The change in its velocity be [UPSEAT 1999]

(a) 40 *m/s N–W* (b) $20\sqrt{2}$ *m/s N–W*

(c) 40 *m/s S–W* (d) $20\sqrt{2}$ *m/s S–W*

4. If the sum of two unit vectors is a unit vector, then magnitude of difference is [CPMT 1995; CBSE PMT 1989]

(a) $\sqrt{2}$ (b) $\sqrt{3}$

(c) $1/\sqrt{2}$ (d) $\sqrt{5}$

5. $\vec{A} = 2\hat{i} + \hat{j}, B = 3\hat{j} - \hat{k}$ and $\vec{C} = 6\hat{i} - 2\hat{k}$.

Value of $\vec{A} - 2\vec{B} + 3\vec{C}$ would be

(a) $20\hat{i} + 5\hat{j} + 4\hat{k}$ (b) $20\hat{i} - 5\hat{j} - 4\hat{k}$

(c) $4\hat{i} + 5\hat{j} + 20\hat{k}$ (d) $5\hat{i} + 4\hat{j} + 10\hat{k}$

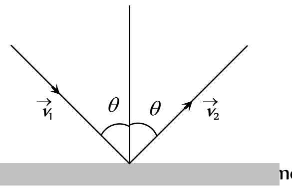
6. An object of *m kg* with speed of *v m/s* strikes a wall at an angle θ and rebounds at the same speed and same angle. The magnitude of the change in momentum of the object will be

(a) $2mv\cos\theta$

(b) $2mv\sin\theta$

(c) 0

(d) $2mv$



7. Two forces, each of magnitude ne magnitude *F*. The angle between the two forces is [CBSE PMT 1990]

(a) 45° (b) 120°

(c) 150° (d) 60°

8. For the resultant of the two vectors to be maximum, what must be the angle between them

(a) 0° (b) 60°

(c) 90° (d) 180°

9. A particle is simultaneously acted by two forces equal to 4 *N* and 3 *N*. The net force on the particle is [CPMT 1979]

(a) 7 *N* (b) 5 *N*

(c) 1 *N* (d) Between 1 *N* and 7 *N*

10. Two vectors $\vec{A}$ and $\vec{B}$ lie in a plane, another vector $\vec{C}$ lies outside this plane, then the resultant of these three vectors *i.e.,* $\vec{A} + \vec{B} + \vec{C}$

(a) Can be zero

(b) Cannot be zero

(c) Lies in the plane containing $\vec{A} + \vec{B}$

(d) Lies in the plane containing $\vec{C}$

11. If the resultant of the two forces has a magnitude smaller than the magnitude of larger force, the two forces must be

(a) Different both in magnitude and direction

(b) Mutually perpendicular to one another

(c) Possess extremely small magnitude

(d) Point in opposite directions

12. Forces F_1 and F_2 act on a point mass in two mutually perpendicular directions. The resultant force on the point mass will be [CPMT 1991]

(a) $F_1 + F_2$ (b) $F_1 - F_2$

(c) $\sqrt{F_1^2 + F_2^2}$ (d) $F_1^2 + F_2^2$

13. If $|\vec{A} - \vec{B}| = |\vec{A}| = |\vec{B}|$, the angle between $\vec{A}$ and $\vec{B}$ is

(a) 60° (b) 0°

(c) 120° (d) 90°

14. Let the angle between two nonzero vectors $\vec{A}$ and $\vec{B}$ be 120° and resultant be $\vec{C}$

(a) $\vec{C}$ must be equal to $|\vec{A} - \vec{B}|$

(b) $\vec{C}$ must be less than $|\vec{A} - \vec{B}|$

(c) $\vec{C}$ must be greater than $|\vec{A} - \vec{B}|$

(d) $\vec{C}$ may be equal to $|\vec{A} - \vec{B}|$

15. The magnitude of vector $\vec{A}, \vec{B}$ and $\vec{C}$ are respectively 12, 5 and 13 units and $\vec{A} + \vec{B} = \vec{C}$ then the angle between $\vec{A}$ and $\vec{B}$ is

(a) 0 (b) π

(c) $\pi/2$ (d) $\pi/4$

16. Magnitude of vector which comes on addition of two vectors, $6\hat{i} + 7\hat{j}$ and $3\hat{i} + 4\hat{j}$ is [BHU 2000]

(a) $\sqrt{136}$ (b) $\sqrt{13.2}$

(c) $\sqrt{202}$ (d) $\sqrt{160}$

17. A particle has displacement of 12 *m* towards east and 5 *m* towards north then 6 *m* vertically upward. The sum of these displacements is

(a) 12 (b) 10.04 *m*

(c) 14.31 *m* (d) None of these

18. The three vectors $\vec{A} = 3\hat{i} - 2\hat{j} + \hat{k}$, $\vec{B} = \hat{i} - 3\hat{j} + 5\hat{k}$ and $\vec{C} = 2\hat{i} + \hat{j} - 4\hat{k}$ form

(a) An equilateral triangle (b) Isosceles triangle

(c) A right angled triangle (d) No triangle

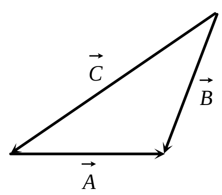
19. For the figure

(a) $\vec{A} + \vec{B} = \vec{C}$

(b) $\vec{B} + \vec{C} = \vec{A}$

(c) $\vec{C} + \vec{A} = \vec{B}$

(d) $\vec{A} + \vec{B} + \vec{C} = 0$ [CPMT 1983]



20. Let $\vec{C} = \vec{A} + \vec{B}$ then

(a) $|\vec{C}|$ is always greater then $|\vec{A}|$

(b) It is possible to have $|\vec{C}| < |\vec{A}|$ and $|\vec{C}| < |\vec{B}|$

(c) *C* is always equal to *A* + *B*

(d) *C* is never equal to *A* + *B*

21. The value of the sum of two vectors $\vec{A}$ and $\vec{B}$ with θ as the angle between them is [BHU 1996]

(a) $\sqrt{A^2 + B^2 + 2AB\cos\theta}$ (b) $\sqrt{A^2 - B^2 + 2AB\cos\theta}$

(c) $\sqrt{A^2+B^2-2AB\sin\theta}$ (d) $\sqrt{A^2+B^2+2AB\sin\theta}$

22. Following sets of three forces act on a body. Whose resultant cannot be zero [CPMT 1985]
(a) 10, 10, 10 (b) 10, 10, 20
(c) 10, 20, 23 (d) 10, 20, 40

23. When three forces of 50 *N*, 30 *N* and 15 *N* act on a body, then the body is
(a) At rest
(b) Moving with a uniform velocity
(c) In equilibrium
(d) Moving with an acceleration

24. The sum of two forces acting at a point is 16 *N*. If the resultant force is 8 *N* and its direction is perpendicular to minimum force then the forces are [CPMT 1997]
(a) 6 *N* and 10 *N* (b) 8 *N* and 8 *N*
(c) 4 *N* and 12 *N* (d) 2 *N* and 14 *N*

25. If vectors *P*, *Q* and *R* have magnitude 5, 12 and 13 units and $\vec{P}+\vec{Q}=\vec{R}$, the angle between *Q* and *R* is [CEET 1998]
(a) $\cos^{-1}\frac{5}{12}$ (b) $\cos^{-1}\frac{5}{13}$
(c) $\cos^{-1}\frac{12}{13}$ (d) $\cos^{-1}\frac{7}{13}$

26. The resultant of two vectors *A* and *B* is perpendicular to the vector *A* and its magnitude is equal to half the magnitude of vector *B*. The angle between *A* and *B* is
(a) 120° (b) 150°
(c) 135° (d) None of these

27. What vector must be added to the two vectors $\hat{i}-2\hat{j}+2\hat{k}$ and $2\hat{i}+\hat{j}-\hat{k}$, so that the resultant may be a unit vector along *x*-axis [BHU 1990]
(a) $2\hat{i}+\hat{j}-\hat{k}$ (b) $-2\hat{i}+\hat{j}-\hat{k}$
(c) $2\hat{i}-\hat{j}+\hat{k}$ (d) $-2\hat{i}-\hat{j}-\hat{k}$

28. What is the angle between $\vec{P}$ and the resultant of $(\vec{P}+\vec{Q})$ and $(\vec{P}-\vec{Q})$
(a) Zero (b) $\tan^{-1}(P/Q)$
(c) $\tan^{-1}(Q/P)$ (d) $\tan^{-1}(P-Q)/(P+Q)$

29. The resultant of $\vec{P}$ and $\vec{Q}$ is perpendicular to $\vec{P}$. What is the angle between $\vec{P}$ and $\vec{Q}$
(a) $\cos^{-1}(P/Q)$ (b) $\cos^{-1}(-P/Q)$
(c) $\sin^{-1}(P/Q)$ (d) $\sin^{-1}(-P/Q)$

30. Maximum and minimum magnitudes of the resultant of two vectors of magnitudes *P* and *Q* are in the ratio $3:1$. Which of the following relations is true
(a) $P=2Q$ (b) $P=Q$
(c) $PQ=1$ (d) None of these

31. The resultant of two vectors $\vec{P}$ and $\vec{Q}$ is $\vec{R}$. If *Q* is doubled, the new resultant is perpendicular to *P*. Then *R* equals
(a) *P* (b) (*P*+*Q*)
(c) *Q* (d) (*P*–*Q*)

32. Two forces, F_1 and F_2 are acting on a body. One force is double that of the other force and the resultant is equal to the greater force. Then the angle between the two forces is
(a) $\cos^{-1}(1/2)$ (b) $\cos^{-1}(-1/2)$
(c) $\cos^{-1}(-1/4)$ (d) $\cos^{-1}(1/4)$

33. Given that $\vec{A}+\vec{B}=\vec{C}$ and that $\vec{C}$ is $\perp$ to $\vec{A}$. Further if $|\vec{A}|=|\vec{C}|$, then what is the angle between $\vec{A}$ and $\vec{B}$
(a) $\frac{\pi}{4}$ *radian* (b) $\frac{\pi}{2}$ *radian*
(c) $\frac{3\pi}{4}$ *radian* (d) π *radian*

34. A body is at rest under the action of three forces, two of which are $\vec{F}_1=4\hat{i}, \vec{F}_2=6\hat{j}$, the third force is [AMU 1996]
(a) $4\hat{i}+6\hat{j}$ (b) $4\hat{i}-6\hat{j}$
(c) $-4\hat{i}+6\hat{j}$ (d) $-4\hat{i}-6\hat{j}$

35. A plane is revolving around the earth with a speed of 100 *km/hr* at a constant height from the surface of earth. The change in the velocity as it travels half circle is [RPET 1998; KCET 2000]
(a) 200 *km/hr* (b) 150 *km/hr*
(c) $100\sqrt{2}\ km/hr$ (d) 0

36. What displacement must be added to the displacement $25\hat{i}-6\hat{j}\ m$ to give a displacement of 7.0 *m* pointing in the *x*-direction
(a) $18\hat{i}-6\hat{j}$ (b) $32\hat{i}-13\hat{j}$
(c) $-18\hat{i}+6\hat{j}$ (d) $-25\hat{i}+13\hat{j}$

37. A body moves due East with velocity 20 *km/hour* and then due North with velocity 15 *km/hour*. The resultant velocity [AFMC 1995]
(a) 5 *km/hour* (b) 15 *km/hour*
(c) 20 *km/hour* (d) 25 *km/hour*

38. The magnitudes of vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are 3, 4 and 5 units respectively. If $\vec{A}+\vec{B}=\vec{C}$, the angle between $\vec{A}$ and $\vec{B}$ is [CBSE PMT 1990]
(a) $\frac{\pi}{2}$ (b) $\cos^{-1}(0.6)$
(c) $\tan^{-1}\left(\frac{7}{5}\right)$ (d) $\frac{\pi}{4}$

39. While travelling from one station to another, a car travels 75 *km* North, 60 *km* North-east and 20 *km* East. The minimum distance between the two stations is [AFMC 1993]
(a) 72 *km* (b) 112 *km*
(c) 132 *km* (d) 155 *km*

40. A scooter going due east at 10 *ms* turns right through an angle of 90°. If the speed of the scooter remains unchanged in taking turn, the change is the velocity of the scooter is

[BHU 1994]

(a) 20.0 *ms* south eastern direction

(b) Zero

(c) 10.0 *ms* in southern direction

(d) 14.14 *ms* in south-west direction

41. A person goes 10 *km* north and 20 *km* east. What will be displacement from initial point [AFMC 1994, 2003]

(a) 22.36 *km* (b) 2 *km*

(c) 5 *km* (d) 20 *km*

42. Two forces $\vec{F_1} = 5\hat{i} + 10\hat{j} - 20\hat{k}$ and $\vec{F_2} = 10\hat{i} - 5\hat{j} - 15\hat{k}$ act on a single point. The angle between $\vec{F_1}$ and $\vec{F_2}$ is nearly [AMU 1995]

(a) 30° (b) 45°

(c) 60° (d) 90°

43. Which pair of the following forces will never give resultant force of 2 *N* [HP PMT 1999]

(a) 2 *N* and 2 *N* (b) 1 *N* and 1 *N*

(c) 1 *N* and 3 *N* (d) 1 *N* and 4 *N*

44. Two forces 3*N* and 2 *N* are at an angle θ such that the resultant is *R*. The first force is now increased to 6*N* and the resultant become 2*R*. The value of θ is [HP PMT 2000]

(a) 30° (b) 60°

(c) 90° (d) 120°

45. Three concurrent forces of the same magnitude are in equilibrium. What is the angle between the forces ? Also name the triangle formed by the forces as sides [JIPMER 2000]

(a) 60° equilateral triangle

(b) 120° equilateral triangle

(c) 120°, 30°, 30° an isosceles triangle

(d) 120° an obtuse angled triangle

46. If $|\vec{A} + \vec{B}| = |\vec{A}| + |\vec{B}|$, then angle between $\vec{A}$ and $\vec{B}$ will be [CBSE PMT 2001]

(a) 90° (b) 120°

(c) 0° (d) 60°

47. The maximum and minimum magnitude of the resultant of two given vectors are 17 *units* and 7 *unit* respectively. If these two vectors are at right angles to each other, the magnitude of their resultant is [Kerala CET (Engg.) 2000]

(a) 14 (b) 16

(c) 18 (d) 13

48. The vector sum of two forces is perpendicular to their vector differences. In that case, the forces [CBSE PMT 2003]

(a) Are equal to each other in magnitude

(b) Are not equal to each other in magnitude

(c) Cannot be predicted

(d) Are equal to each other

49. *y* component of velocity is 20 and *x* component of velocity is 10. The direction of motion of the body with the horizontal at this instant is

(a) $\tan^{-1}(2)$ (b) $\tan^{-1}(1/2)$

(c) 45° (d) 0°

50. Two forces of 12 *N* and 8 *N* act upon a body. The resultant force on the body has maximum value of [Manipal 2003]

(a) 4 *N* (b) 0 *N*

(c) 20 *N* (d) 8 *N*

51. Two equal forces (*P* each) act at a point inclined to each other at an angle of 120°. The magnitude of their resultant is

(a) $P/2$ (b) $P/4$

(c) P (d) 2*P*

52. The vectors $5i + 8j$ and $2i + 7j$ are added. The magnitude of the sum of these vector is [BHU 2000]

(a) $\sqrt{274}$ (b) 38

(c) 238 (d) 560

53. Two vectors $\vec{A}$ and $\vec{B}$ are such that $\vec{A} + \vec{B} = \vec{A} - \vec{B}$. Then [AMU (Med.) 2000]

(a) $\vec{A}.\vec{B} = 0$ (b) $\vec{A} \times \vec{B} = 0$

(c) $\vec{A} = 0$ (d) $\vec{B} = 0$

Multiplication of Vectors

1. If a vector $2\hat{i} + 3\hat{j} + 8\hat{k}$ is perpendicular to the vector $4\hat{j} - 4\hat{i} + \alpha\hat{k}$. Then the value of α is [CBSE PMT 2005]

(a) –1 (b) $\frac{1}{2}$

(c) $-\frac{1}{2}$ (d) 1

2. If two vectors $2\hat{i} + 3\hat{j} - \hat{k}$ and $-4\hat{i} - 6\hat{j} - \lambda\hat{k}$ are parallel to each other then value of λ be

(a) 0 (b) 2

(c) 3 (d) 4

3. A body, acted upon by a force of 50 *N* is displaced through a distance 10 *meter* in a direction making an angle of 60° with the force. The work done by the force be

(a) 200 *J* (b) 100 *J*

(c) 300 (d) 250 *J*

4. A particle moves from position $3\hat{i} + 2\hat{j} - 6\hat{k}$ to $14\hat{i} + 13\hat{j} + 9\hat{k}$ due to a uniform force of $(4\hat{i} + \hat{j} + 3\hat{k})N$. If the displacement in meters then work done will be [CMEET 1995; Pb. PMT 2002, 03]

(a) 100 *J* (b) 200 *J*

(c) 300 *J* (d) 250 *J*

5. If for two vector $\vec{A}$ and $\vec{B}$, sum $(\vec{A} + \vec{B})$ is perpendicular to the difference $(\vec{A} - \vec{B})$. The ratio of their magnitude is [Manipal 2003]

(a) (b) 2

(c) 3 (d) None of these

6. The angle between the vectors $\vec{A}$ and $\vec{B}$ is θ. The value of the triple product $\vec{A}.(\vec{B}\times\vec{A})$ is [CBSE PMT 1991, 2005]

(a) A^2B (b) Zero

(c) $A^2B\sin\theta$ (d) $A^2B\cos\theta$

7. If $\vec{A}\times\vec{B}=\vec{B}\times\vec{A}$ then the angle between A and B is [AIEEE 2004]

(a) $\pi/2$ (b) $\pi/3$

(c) π (d) $\pi/4$

8. If $\vec{A}=3\hat{i}+\hat{j}+2\hat{k}$ and $\vec{B}=2\hat{i}-2\hat{j}+4\hat{k}$ then value of $|\vec{A}\times\vec{B}|$ will be

(a) $8\sqrt{2}$ (b) $8\sqrt{3}$

(c) $8\sqrt{5}$ (d) $5\sqrt{8}$

9. The torque of the force $\vec{F}=(2\hat{i}-3\hat{j}+4\hat{k})N$ acting at the point $\vec{r}=(3\hat{i}+2\hat{j}+3\hat{k})\,m$ about the origin be [CBSE PMT 1995]

(a) $6\hat{i}-6\hat{j}+12\hat{k}$ (b) $17\hat{i}-6\hat{j}-13\hat{k}$

(c) $-6\hat{i}+6\hat{j}-12\hat{k}$ (d) $-17\hat{i}+6\hat{j}+13\hat{k}$

10. If $\vec{A}\times\vec{B}=\vec{C}$, then which of the following statements is wrong

(a) $\vec{C}\perp\vec{A}$ (b) $\vec{C}\perp\vec{B}$

(c) $\vec{C}\perp(\vec{A}+\vec{B})$ (d) $\vec{C}\perp(\vec{A}\times\vec{B})$

11. If a particle of mass m is moving with constant velocity v parallel to x-axis in x-y plane as shown in fig. Its angular momentum with respect to origin at any time t will be

(a) $mvb\,\hat{k}$ (b) $-mvb\,\hat{k}$

(c) $mvb\,\hat{i}$ (d) $mv\,\hat{i}$

12. Consider two vectors $\vec{F}_1=2\hat{i}+5\hat{k}$ and $\vec{F}_2=3\hat{j}+4\hat{k}$. The magnitude of the scalar product of these vectors is [MP PMT 1987]

(a) 20 (b) 23

(c) $5\sqrt{33}$ (d) 26

13. Consider a vector $\vec{F}=4\hat{i}-3\hat{j}$. Another vector that is perpendicular to $\vec{F}$ is

(a) $4\hat{i}+3\hat{j}$ (b) $6\hat{i}$

(c) $7\hat{k}$ (d) $3\hat{i}-4\hat{j}$

14. Two vectors $\vec{A}$ and $\vec{B}$ are at right angles to each other, when

(a) $\vec{A}+\vec{B}=0$ (b) $\vec{A}-\vec{B}=0$

(c) $\vec{A}\times\vec{B}=0$ (d) $\vec{A}.\vec{B}=0$

15. If $|\vec{V}_1+\vec{V}_2|=|\vec{V}_1-\vec{V}_2|$ and V_2 is finite, then [CPMT 1989]

(a) V_1 is parallel to V_2

(b) $\vec{V}_1=\vec{V}_2$

(c) V_1 and V_2 are mutually perpendicular

(d) $|\vec{V}_1|=|\vec{V}_2|$

16. A force $\vec{F}=(5\hat{i}+3\hat{j})$ Newton is applied over a particle which displaces it from its origin to the point $\vec{r}=(2\hat{i}-1\hat{j})$ *metres*. The work done on the particle is [MP PMT 1995]

(a) $-7\,J$ (b) $+13\,J$

(c) $+7\,J$ (d) $+11\,J$

17. The angle between two vectors $-2\hat{i}+3\hat{j}+\hat{k}$ and $\hat{i}+2\hat{j}-4\hat{k}$ is

(a) 0° (b) 90°

(c) 180° (d) None of the above

18. The angle between the vectors $(\hat{i}+\hat{j})$ and $(\hat{j}+\hat{k})$ is [EAMCET 1995]

(a) 30° (b) 45°

(c) 60° (d) 90°

19. A particle moves with a velocity $6\hat{i}-4\hat{j}+3\hat{k}\,m/s$ under the influence of a constant force $\vec{F}=20\hat{i}+15\hat{j}-5\hat{k}\,N$. The instantaneous power applied to the particle is [CBSE PMT 2000]

(a) 35 *J/s* (b) 45 *J/s*

(c) 25 *J/s* (d) 195 *J/s*

20. If $\vec{P}.\vec{Q}=PQ$, then angle between $\vec{P}$ and $\vec{Q}$ is [AIIMS 1999]

(a) 0° (b) 30°

(c) 45° (d) 60°

21. A force $\vec{F}=5\hat{i}+6\hat{j}+4\hat{k}$ acting on a body, produces a displacement $\vec{S}=6\hat{i}-5\hat{k}$. Work done by the force is [KCET 1999]

(a) 10 units (b) 18 units

(c) 11 units (d) 5 units

22. The angle between the two vectors $\vec{A}=5\hat{i}+5\hat{j}$ and $\vec{B}=5\hat{i}-5\hat{j}$ will be [CPMT 2000]

(a) Zero (b) 45°

(c) 90° (d) 180°

23. The vector $\vec{P}=a\hat{i}+a\hat{j}+3\hat{k}$ and $\vec{Q}=a\hat{i}-2\hat{j}-\hat{k}$ are perpendicular to each other. The positive value of a is [AFMC 2000; AIIMS 2002]

(a) 3 (b) 4

(c) 9 (d) 13

24. A body, constrained to move in the Y-direction is subjected to a force given by $\vec{F}=(-2\hat{i}+15\hat{j}+6\hat{k})N$. What is the work done by this force in moving the body a distance 10 m along the Y-axis [AIIMS 1987]

(a) 20 J (b) 150 J

(c) 160 J (d) 190 J

25. A particle moves in the x-y plane under the action of a force $\vec{F}$ such that the value of its linear momentum $(\vec{P})$ at anytime t is $P_x = 2\cos t, p_y = 2\sin t$. The angle θ between $\vec{F}$ and $\vec{P}$ at a given time t. will be [MNR 1991; UPSEAT 2000]

(a) $\theta = 0°$ (b) $\theta = 30°$
(c) $\theta = 90°$ (d) $\theta = 180°$

26. The area of the parallelogram represented by the vectors $\vec{A} = 2\hat{i} + 3\hat{j}$ and $\vec{B} = \hat{i} + 4\hat{j}$ is

(a) 14 units (b) 7.5 units
(c) 10 units (d) 5 units

27. A vector $\vec{F}_1$ is along the positive X-axis. If its vector product with another vector $\vec{F}_2$ is zero then $\vec{F}_2$ could be [MP PMT 1987]

(a) $4\hat{j}$ (b) $-(\hat{i} + \hat{j})$
(c) $(\hat{j} + \hat{k})$ (d) $(-4\hat{i})$

28. If for two vectors $\vec{A}$ and $\vec{B}$, $\vec{A} \times \vec{B} = 0$, the vectors

(a) Are perpendicular to each other
(b) Are parallel to each other
(c) Act at an angle of 60°
(d) Act at an angle of 30°

29. The angle between vectors $(\vec{A} \times \vec{B})$ and $(\vec{B} \times \vec{A})$ is

(a) Zero (b) π
(c) $\pi / 4$ (d) $\pi / 2$

30. What is the angle between $(\vec{P} + \vec{Q})$ and $(\vec{P} \times \vec{Q})$

(a) 0 (b) $\frac{\pi}{2}$
(c) $\frac{\pi}{4}$ (d) π

31. The resultant of the two vectors having magnitude 2 and 3 is 1. What is their cross product

(a) 6 (b) 3
(c) 1 (d) 0

32. Let $\vec{A} = \hat{i}A\cos\theta + \hat{j}A\sin\theta$ be any vector. Another vector $\vec{B}$ which is normal to A is [BHU 1997]

(a) $\hat{i}\,B\cos\theta + j\,B\sin\theta$ (b) $\hat{i}\,B\sin\theta + j\,B\cos\theta$
(c) $\hat{i}\,B\sin\theta - j\,B\cos\theta$ (d) $\hat{i}\,B\cos\theta - j\,B\sin\theta$

33. The angle between two vectors given by $6\bar{i} + 6\bar{j} - 3\bar{k}$ and $7\bar{i} + 4\bar{j} + 4\bar{k}$ is [EAMCET (Engg.) 1999]

(a) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (b) $\cos^{-1}\left(\frac{5}{\sqrt{3}}\right)$
(c) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (d) $\sin^{-1}\left(\frac{\sqrt{5}}{3}\right)$

34. A vector $\vec{A}$ points vertically upward and $\vec{B}$ points towards north. The vector product $\vec{A} \times \vec{B}$ is [UPSEAT 2000]

(a) Zero (b) Along west
(c) Along east (d) Vertically downward

35. Angle between the vectors $(\hat{i} + \hat{j})$ and $(\hat{j} - \hat{k})$ is

(a) 90° (b) 0°
(c) 180° (d) 60°

36. The position vectors of points A, B, C and D are $A = 3\hat{i} + 4\hat{j} + 5\hat{k}$, $B = 4\hat{i} + 5\hat{j} + 6\hat{k}$, $C = 7\hat{i} + 9\hat{j} + 3\hat{k}$ and $D = 4\hat{i} + 6\hat{j}$ then the displacement vectors AB and CD are

(a) Perpendicular
(b) Parallel
(c) Antiparallel
(d) Inclined at an angle of 60°

37. If force $(\vec{F}) = 4\hat{i} + 5\hat{j}$ and displacement $(\vec{s}) = 3\hat{i} + 6\hat{k}$ then the work done is [Manipal 1995]

(a) 4×3 (b) 5×6
(c) 6×3 (d) 4×6

38. If $|\vec{A} \times \vec{B}| = |\vec{A}.\vec{B}|$, then angle between $\vec{A}$ and $\vec{B}$ will be [AIIMS 2000; Manipal 2000]

(a) 30° (b) 45°
(c) 60° (d) 90°

39. In an clockwise system [CPMT 1990]

(a) $\hat{j} \times \hat{k} = \hat{i}$ (b) $\hat{i}.\hat{i} = 0$
(c) $\hat{j} \times \hat{j} = 1$ (d) $\hat{k}.\hat{j} = 1$

40. The linear velocity of a rotating body is given by $\vec{v} = \vec{\omega} \times \vec{r}$, where $\vec{\omega}$ is the angular velocity and $\vec{r}$ is the radius vector. The angular velocity of a body is $\vec{\omega} = \hat{i} - 2\hat{j} + 2\hat{k}$ and the radius vector $\vec{r} = 4\hat{j} - 3\hat{k}$, then $|\vec{v}|$ is

(a) $\sqrt{29}$ units (b) $\sqrt{31}$ units
(c) $\sqrt{37}$ units (d) $\sqrt{41}$ units

41. Three vectors $\vec{a}, \vec{b}$ and $\vec{c}$ satisfy the relation $\vec{a}.\vec{b} = 0$ and $\vec{a}.\vec{c} = 0$. The vector $\vec{a}$ is parallel to [AIIMS 1996]

(a) $\vec{b}$ (b) $\vec{c}$
(c) $\vec{b}.\vec{c}$ (d) $\vec{b} \times \vec{c}$

42. The diagonals of a parallelogram are $2\hat{i}$ and $2\hat{j}$. What is the area of the parallelogram

(a) 0.5 units (b) 1 unit
(c) 2 units (d) 4 units

43. What is the unit vector perpendicular to the following vectors $2\hat{i} + 2\hat{j} - \hat{k}$ and $6\hat{i} - 3\hat{j} + 2\hat{k}$

(a) $\frac{\hat{i}+10\hat{j}-18\hat{k}}{5\sqrt{17}}$ (b) $\frac{\hat{i}-10\hat{j}+18\hat{k}}{5\sqrt{17}}$

(c) $\frac{\hat{i}-10\hat{j}-18\hat{k}}{5\sqrt{17}}$ (d) $\frac{\hat{i}+10\hat{j}+18\hat{k}}{5\sqrt{17}}$

44. The area of the parallelogram whose sides are represented by the vectors $\hat{j}+3\hat{k}$ and $\hat{i}+2\hat{j}-\hat{k}$ is

(a) $\sqrt{61}$ sq.unit (b) $\sqrt{59}$ sq.unit

(c) $\sqrt{49}$ sq.unit (d) $\sqrt{52}$ sq.unit

45. The position of a particle is given by $\vec{r}=(\vec{i}+2\vec{j}-\vec{k})$ momentum $\vec{P}=(3\vec{i}+4\vec{j}-2\vec{k})$. The angular momentum is perpendicular to [EAMCET (Engg.) 1998]

(a) *x*-axis

(b) *y*-axis

(c) *z*-axis

(d) Line at equal angles to all the three axes

46. Two vector *A* and *B* have equal magnitudes. Then the vector *A* + *B* is perpendicular to

(a) $A\times B$ (b) $A-B$

(c) $3A-3B$ (d) All of these

47. Find the torque of a force $\vec{F}=-3\hat{i}+\hat{j}+5\hat{k}$ acting at the point $\vec{r}=7\hat{i}+3\hat{j}+\hat{k}$

[CPMT 1997; CBSE PMT 1997; CET 1998; DPMT 2004]

(a) $14\hat{i}-38\hat{j}+16\hat{k}$ (b) $4\hat{i}+4\hat{j}+6\hat{k}$

(c) $21\hat{i}+4\hat{j}+4\hat{k}$ (d) $-14\hat{i}+34\hat{j}-16\hat{k}$

48. The value of $(\vec{A}+\vec{B})\times(\vec{A}-\vec{B})$ is

[RPET 1991, 2002; BHU 2002]

(a) 0 (b) A^2-B^2

(c) $\vec{B}\times\vec{A}$ (d) $2(\vec{B}\times\vec{A})$

49. If $\vec{A}$ and $\vec{B}$ are perpendicular vectors and vector $\vec{A}=5\hat{i}+7\hat{j}-3\hat{k}$ and $\vec{B}=2\hat{i}+2\hat{j}-a\hat{k}$. The value of *a* is

[EAMCET 1991]

(a) – 2 (b) 8

(c) – 7 (d) – 8

50. A force vector applied on a mass is represented as $\vec{F}=6\hat{i}-8\hat{j}+10\hat{k}$ and accelerates with $1\ m/s^2$. What will be the mass of the body in kg.

[CMEET 1995]

(a) $10\sqrt{2}$ (b) 20

(c) $2\sqrt{10}$ (d) 10

51. Two adjacent sides of a parallelogram are represented by the two vectors $\hat{i}+2\hat{j}+3\hat{k}$ and $3\hat{i}-2\hat{j}+\hat{k}$. What is the area of parallelogram

[AMU 1997]

(a) 8 (b) $8\sqrt{3}$

(c) $3\sqrt{8}$ (d) 192

52. The position vectors of radius are $2\hat{i}+\hat{j}+\hat{k}$ and $2\hat{i}-3\hat{j}+\hat{k}$ while those of linear momentum are $2\hat{i}+3\hat{j}-\hat{k}$. Then the angular momentum is [BHU 1997]

(a) $2\hat{i}-4\hat{k}$ (b) $4\hat{i}-8\hat{k}$

(c) $2\hat{i}-4\hat{j}+2\hat{k}$ (d) $4\hat{i}-8\hat{k}$

53. What is the value of linear velocity, if $\vec{\omega}=3\hat{i}-4\hat{j}+\hat{k}$ and $\vec{r}=5\hat{i}-6\hat{j}+6\hat{k}$ [CBSE PMT 1999; CPMT 1999, 2001; Pb. PMT 2000; Pb. CET 2000]

(a) $6\hat{i}-2\hat{j}+3\hat{k}$ (b) $6\hat{i}-2\hat{j}+8\hat{k}$

(c) $4\hat{i}-13\hat{j}+6\hat{k}$ (d) $-18\hat{i}-13\hat{j}+2\hat{k}$

54. Dot product of two mutual perpendicular vector is

[Haryana CEET 2002]

(a) 0 (b) 1

(c) ∞ (d) None of these

55. When $\vec{A}.\vec{B}=-|A||B|$, then [Orissa JEE 2003]

(a) $\vec{A}$ and $\vec{B}$ are perpendicular to each other

(b) $\vec{A}$ and $\vec{B}$ act in the same direction

(c) $\vec{A}$ and $\vec{B}$ act in the opposite direction

(d) $\vec{A}$ and $\vec{B}$ can act in any direction

56. If $|\vec{A}\times\vec{B}|=\sqrt{3}\vec{A}.\vec{B}$, then the value of $|\vec{A}+\vec{B}|$ is

[CBSE PMT 2004]

(a) $\left(A^2+B^2+\frac{AB}{\sqrt{3}}\right)^{1/2}$ (b) $A+B$

(c) $(A^2+B^2+\sqrt{3}AB)^{1/2}$ (d) $(A^2+B^2+AB)^{1/2}$

57. A force $\vec{F}=3\hat{i}+c\hat{j}+2\hat{k}$ acting on a particle causes a displacement $\vec{S}=-4\hat{i}+2\hat{j}-3\hat{k}$ in its own direction. If the work done is 6*J*, then the value of *c* will be [DPMT 1997]

(a) 12 (b) 6

(c) 1 (d) 0

58. A force $\vec{F}=(5\hat{i}+3\hat{j})\ N$ is applied over a particle which displaces it from its original position to the point $\vec{s}=(2\hat{i}-1\hat{j})\ m$. The work done on the particle is [BHU 2001]

(a) + 11 *J* (b) + 7 *J*

(c) + 13 *J* (d) – 7 *J*

59. If a vector $\vec{A}$ is parallel to another vector $\vec{B}$ then the resultant of the vector $\vec{A} \times \vec{B}$ will be equal to

[Pb. CET 1996]

(a) A (b) $\vec{A}$

(c) Zero vector (d) Zero

Lami's Theorem

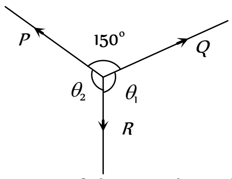
1. *P, Q* and *R* are three coplanar forces acting at a point and are in equilibrium. Given $P = 1.9318$ *kg wt,* $\sin\theta_1 = 0.9659$, the value of *R* is (in *kg wt*) [CET 1998]

(a) 0.9659

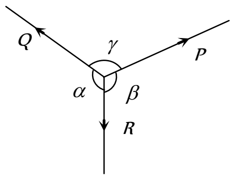
(b) 2

(c) 1

(d) $\frac{1}{2}$



2. A body is in equilibrium under the action of three coplanar forces *P, Q* and *R* as shown in the figure. Select the correct statement



(a) $\frac{P}{\sin\alpha} = \frac{Q}{\sin\beta} = \frac{R}{\sin\gamma}$

(b) $\frac{P}{\cos\alpha} = \frac{Q}{\cos\beta} = \frac{R}{\cos\gamma}$

(c) $\frac{P}{\tan\alpha} = \frac{Q}{\tan\beta} = \frac{R}{\tan\gamma}$

(d) $\frac{P}{\sin\beta} = \frac{Q}{\sin\gamma} = \frac{R}{\sin\alpha}$

3. If a body is in equilibrium under a set of non-collinear forces, then the minimum number of forces has to be

[AIIMS 2000]

(a) Four (b) Three

(c) Two (d) Five

4. How many minimum number of non-zero vectors in different planes can be added to give zero resultant

(a) 2 (b) 3

(c) 4 (d) 5

5. As shown in figure the tension in the horizontal cord is 30 *N*. The weight *W* and tension in the string *OA* in Newton are

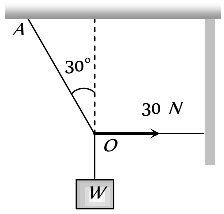
[DPMT 1992]

(a) $30\sqrt{3}$, 30

(b) $30\sqrt{3}$, 60

(c) $60\sqrt{3}$, 30

(d) None of these



Relative Velocity

1. Two cars are moving in the same direction with the same speed 30 *km/hr*. They are separated by a distance of 5 *km*, the speed of a car moving in the opposite direction if it meets these two cars at an interval of 4 minutes, will be

(a) 40 *km/hr* (b) 45 *km/hr*

(c) 30 *km/hr* (d) 15 *km/hr*

2. A man standing on a road hold his umbrella at 30° with the vertical to keep the rain away. He throws the umbrella and starts running at 10 *km/hr*. He finds that raindrops are hitting his head vertically, the speed of raindrops with respect to the road will be

(a) 10 *km/hr* (b) 20 *km/hr*

(c) 30 *km/hr* (d) 40 *km/hr*

3. In the above problem, the speed of raindrops *w.r.t.* the moving man, will be

(a) $10/\sqrt{2}\, km/h$ (b) 5 *km/h*

(c) $10\sqrt{3}\, km/h$ (d) $5/\sqrt{3}\, km/h$

4. A boat is moving with a velocity $3i + 4j$ with respect to ground. The water in the river is moving with a velocity $-3i - 4j$ with respect to ground. The relative velocity of the boat with respect to water is

(a) $8j$ (b) $-6i - 8j$

(c) $6i + 8j$ (d) $5\sqrt{2}$

5. A 150 m long train is moving to north at a speed of 10 m/s. A parrot flying towards south with a speed of 5 m/s crosses the train. The time taken by the parrot the cross to train would be: [AFMC 1994]

(a) 30 s (b) 15 s

(c) 8 s (d) 10 s

6. A river is flowing from east to west at a speed of 5 m/min. A man on south bank of river, capable of swimming 10m/min in still water, wants to swim across the river in shortest time. He should swim

(a) Due north

(b) Due north-east

(c) Due north-east with double the speed of river

(d) None of these

7. A person aiming to reach the exactly opposite point on the bank of a stream is swimming with a speed of 0.5 *m/s* at an angle of 120° with the direction of flow of water. The speed of water in the stream is [CBSE PMT 1999]

(a) 1 *m/s* (b) 0.5 *m/s*

(c) 0.25 *m/s* (d) 0.433 *m/s*

8. *A* moves with 65 *km/h* while *B* is coming back of *A* with 80 *km/h*. The relative velocity of *B* with respect to *A* is

[AFMC 2000]

(a) 80 *km/h* (b) 60 *km/h*

(c) 15 *km/h* (d) 145 *km/h*

9. A thief is running away on a straight road on a jeep moving with a speed of 9 *m/s*. A police man chases him on a motor cycle moving at a speed of 10 *m/s*. If the instantaneous separation of jeep from the motor cycle is 100 *m*, how long will it take for the policemen to catch the thief

(a) 1 second (b) 19 second

(c) 90 second (d) 100 second

10. A man can swim with velocity *v* relative to water. He has to cross a river of width *d* flowing with a velocity *u* ($u > v$). The distance through which he is carried down stream by the river is *x*. Which of the following statement is correct

(a) If he crosses the river in minimum time $x = \frac{du}{v}$

(b) x can not be less than $\frac{du}{v}$

(c) For x to be minimum he has to swim in a direction making an angle of $\frac{\pi}{2} + \sin^{-1}\left(\frac{v}{u}\right)$ with the direction of the flow of water

(d) x will be max. if he swims in a direction making an angle of $\frac{\pi}{2} + \sin^{-1}\frac{v}{u}$ with direction of the flow of water

11. A man sitting in a bus travelling in a direction from west to east with a speed of 40 *km/h* observes that the rain-drops are falling vertically down. To the another man standing on ground the rain will appear [HP PMT 1999]

(a) To fall vertically down

(b) To fall at an angle going from west to east

(c) To fall at an angle going from east to west

(d) The information given is insufficient to decide the direction of rain.

12. A boat takes two hours to travel 8 *km* and back in still water. If the velocity of water is 4 *km/h*, the time taken for going upstream 8 *km* and coming back is [EAMCET 1990]

(a) 2*h*

(b) 2*h* 40 *min*

(c) 1*h* 20 *min*

(d) Cannot be estimated with the information given

13. A 120 *m* long train is moving towards west with a speed of 10 *m/s*. A bird flying towards east with a speed of 5 *m/s* crosses the train. The time taken by the bird to cross the train will be

(a) 16 *sec* (b) 12 *sec*

(c) 10 *sec* (d) 8 *sec*

14. A boat crosses a river with a velocity of 8 *km/h*. If the resulting velocity of boat is 10 *km/h* then the velocity of river water is

(a) 4 *km/h* (b) 6 *km/h*

(c) 8 *km/h* (d) 10 *km/h*

Critical Thinking

Objective Questions

1. If a vector $\vec{P}$ making angles α, β, and γ respectively with the *X*, *Y* and *Z* axes respectively.

Then $\sin^2\alpha + \sin^2\beta + \sin^2\gamma =$

(a) 0 (b) 1

(c) 2 (d) 3

2. If the resultant of *n* forces of different magnitudes acting at a point is zero, then the minimum value of *n* is [SCRA 2000]

(a) 1 (b) 2

(c) 3 (d) 4

3. Can the resultant of 2 vectors be zero [IIIT 2000]

(a) Yes, when the 2 vectors are same in magnitude and direction

(b) No

(c) Yes, when the 2 vectors are same in magnitude but opposite in sense

(d) Yes, when the 2 vectors are same in magnitude making an angle of $\frac{2\pi}{3}$ with each other

4. The sum of the magnitudes of two forces acting at point is 18 and the magnitude of their resultant is 12. If the resultant is at 90° with the force of smaller magnitude, what are the, magnitudes of forces [Roorkee 199

(a) 12, 5 (b) 14, 4

(c) 5, 13 (d) 10, 8

5. A vector $\vec{a}$ is turned without a change in its length through a small angle $d\theta$. The value of $|\Delta\vec{a}|$ and Δa are respectively

(a) $0, a\,d\theta$ (b) $a\,d\theta, 0$

(c) 0, 0 (d) None of these

6. Find the resultant of three vectors $\overrightarrow{OA}, \overrightarrow{OB}$ and $\overrightarrow{OC}$ shown in the following figure. Radius of the circle is *R*.

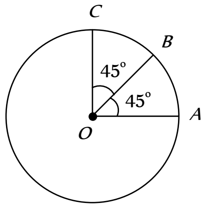
(a) 2*R*

(b) $R(1+\sqrt{2})$

(c) $R\sqrt{2}$

[Manipal 2002]

(d) $R(\sqrt{2}-1)$



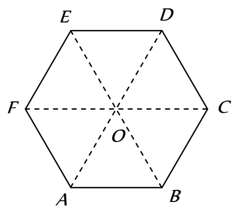
7. Figure shows *ABCDEF* as a regular hexagon. What is the value of $\overrightarrow{AB} + \overrightarrow{AC} + \overrightarrow{AD} + \overrightarrow{AE} + \overrightarrow{AF}$ [CPMT 2001]

(a) $\overrightarrow{AO}$

(b) $2\overrightarrow{AO}$

(c) $4\overrightarrow{AO}$

(d) $6\overrightarrow{AO}$



8. The length of second's hand in watch is 1 *cm*. The change in velocity of its tip in 15 seconds is [MP PMT 1987]

(a) Zero (b) $\frac{\pi}{30\sqrt{2}}\,cm/\sec$

(c) $\frac{\pi}{30}\,cm/\sec$ (d) $\frac{\pi\sqrt{2}}{30}\,cm/\sec$

9. A particle moves towards east with velocity 5 *m/s*. After 10 seconds its direction changes towards north with same velocity. The average acceleration of the particle is

[CPMT 1997; IIT-JEE 1982]

(a) Zero (b) $\frac{1}{\sqrt{2}} m/s^2\ N-W$

(c) $\frac{1}{\sqrt{2}} m/s^2\ N-E$ (d) $\frac{1}{\sqrt{2}} m/s^2\ S-W$

10. A force $\vec{F} = -K(y\hat{i} + x\hat{j})$ (where K is a positive constant) acts on a particle moving in the x-y plane. Starting from the origin, the particle is taken along the positive x- axis to the point (a, 0) and then parallel to the y-axis to the point (a, a). The total work done by the forces $\vec{F}$ on the particle is

[IIT-JEE 1998]

(a) $-2Ka^2$ (b) $2Ka^2$

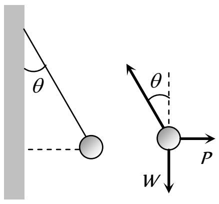
(c) $-Ka^2$ (d) Ka^2

11. The vectors from origin to the points A and B are $\vec{A} = 3\hat{i} - 6\hat{j} + 2\hat{k}$ and $\vec{B} = 2\hat{i} + \hat{j} - 2\hat{k}$ respectively. The area of the triangle OAB be

(a) $\frac{5}{2}\sqrt{17}$ *sq.unit* (b) $\frac{2}{5}\sqrt{17}$ *sq.unit*

(c) $\frac{3}{5}\sqrt{17}$ *sq.unit* (d) $\frac{5}{3}\sqrt{17}$ *sq.unit*

12. A metal sphere is hung by a string fixed to a wall. The sphere is pushed away from the wall by a stick. The forces acting on the sphere are shown in the second diagram. Which of the following statements is wrong



(a) $P = W\tan\theta$

(b) $\vec{T} + \vec{P} + \vec{W} = 0$

(c) $T^2 = P^2 + W^2$

(d) $T = P + W$

13. The speed of a boat is 5 km/h in still water. It crosses a river of width 1 km along the shortest possible path in 15 minutes. The velocity of the river water is

[IIT 1988; CBSE PMT 1998, 2000]

(a) 1 km/h (b) 3 km/h

(c) 4 km/h (d) 5 km/h

14. A man crosses a 320 m wide river perpendicular to the current in 4 minutes. If in still water he can swim with a speed 5/3 times that of the current, then the speed of the current, in m/min is

[Roorkee 1998]

(a) 30 (b) 40

(c) 50 (d) 60.

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*

(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*

(c) *If assertion is true but reason is false.*

(d) *If the assertion and reason both are false.*

(e) *If assertion is false but reason is true.*

1. Assertion : $\vec{A} \times \vec{B}$ is perpendicular to both $\vec{A} + \vec{B}$ as well as $\vec{A} - \vec{B}$.

Reason : $\vec{A} + \vec{B}$ as well as $\vec{A} - \vec{B}$ lie in the plane containing $\vec{A}$ and $\vec{B}$, but $\vec{A} \times \vec{B}$ lies perpendicular to the plane containing $\vec{A}$ and $\vec{B}$.

2. Assertion : Angle between $\hat{i} + \hat{j}$ and $\hat{i}$ is 45°

Reason : $\hat{i} + \hat{j}$ is equally inclined to both $\hat{i}$ and $\hat{j}$ and the angle between $\hat{i}$ and $\hat{j}$ is 90°

3. Assertion : If θ be the angle between $\vec{A}$ and $\vec{B}$, then $\tan\theta = \frac{\vec{A} \times \vec{B}}{\vec{A}.\vec{B}}$

Reason : $\vec{A} \times \vec{B}$ is perpendicular to $\vec{A}.\vec{B}$

4. Assertion : If $|\vec{A} + \vec{B}| = |\vec{A} - \vec{B}|$, then angle between $\vec{A}$ and $\vec{B}$ is 90°

Reason : $\vec{A} + \vec{B} = \vec{B} + \vec{A}$

5. Assertion : Vector product of two vectors is an axial vector

Reason : If $\vec{v}$ = instantaneous velocity, $\vec{r}$ = radius vector and $\vec{\omega}$ = angular velocity, then $\vec{\omega} = \vec{v} \times \vec{r}$.

6. Assertion : Minimum number of non-equal vectors in a plane required to give zero resultant is three.

Reason : If $\vec{A} + \vec{B} + \vec{C} = \vec{0}$, then they must lie in one plane

7. Assertion : Relative velocity of A *w.r.t.* B is greater than the velocity of either, when they are moving in opposite directions.

Reason : Relative velocity of A *w.r.t.* $B = \vec{v}_A - \vec{v}_B$

8. Assertion : Vector addition of two vectors $\vec{A}$ and $\vec{B}$ is commutative.

Reason : $\vec{A} + \vec{B} = \vec{B} + \vec{A}$

9. Assertion : $\vec{A}.\vec{B} = \vec{B}.\vec{A}$

Reason : Dot product of two vectors is commutative.

10. Assertion : $\vec{\tau} = \vec{r} \times \vec{F}$ and $\vec{\tau} \neq \vec{F} \times \vec{r}$

Reason : Cross product of vectors is commutative.

11. Assertion : A negative acceleration of a body is associated with a slowing down of a body.

Reason : Acceleration is vector quantity.

12. Assertion : A physical quantity cannot be called as a vector if its magnitude is zero.

Reason : A vector has both, magnitude and direction.

13. Assertion : The sum of two vectors can be zero.

Reason : The vector cancel each other, when they are equal and opposite.

14. Assertion : Two vectors are said to be like vectors if they have same direction but different magnitude.

Reason : Vector quantities do not have specific direction.

15. Assertion : The scalar product of two vectors can be zero.

Reason : If two vectors are perpendicular to each other, their scalar product will be zero.

16. Assertion : Multiplying any vector by an scalar is a meaningful operations.

Reason : In uniform motion speed remains constant.

17. Assertion : A null vector is a vector whose magnitude is zero and direction is arbitrary.

Reason : A null vector does not exist.

18. Assertion : If dot product and cross product of $\vec{A}$ and $\vec{B}$ are zero, it implies that one of the vector $\vec{A}$ and $\vec{B}$ must be a null vector.

Reason : Null vector is a vector with zero magnitude.

19. Assertion : The cross product of a vector with itself is a null vector.

Reason : The cross-product of two vectors results in a vector quantity.

20. Assertion : The minimum number of non coplanar vectors whose sum can be zero, is four.

Reason : The resultant of two vectors of unequal magnitude can be zero.

21. Assertion : If $\vec{A}.\vec{B} = \vec{B}.\vec{C}$, then $\vec{A}$ may not always be equal to $\vec{C}$

Reason : The dot product of two vectors involves cosine of the angle between the two vectors.

22. Assertion : Vector addition is commutative.

Reason : $(\vec{A}+\vec{B}) \neq (\vec{B}+\vec{A})$.

Answers

Fundamentals of Vectors

1	d	2	b	3	c	4	d	5	d
6	a	7	a	8	b	9	b	10	d
11	d	12	d	13	a	14	b	15	c
16	c	17	a	18	b	19	c	20	c
21	d	22	d	23	b	24	d	25	b
26	b	27	a	28	a	29	a	30	d
31	a	32	b	33	a	34	a		

Addition and Subtraction of Vectors

1	a	2	b	3	d	4	b	5	b
6	a	7	b	8	a	9	d	10	b
11	d	12	c	13	a	14	c	15	c
16	c	17	c	18	c	19	c	20	b
21	a	22	d	23	d	24	a	25	c
26	b	27	b	28	a	29	b	30	a
31	c	32	c	33	c	34	d	35	a
36	c	37	d	38	a	39	c	40	d
41	a	42	b	43	d	44	d	45	a
46	c	47	d	48	a	49	a	50	c
51	c	52	a	53	d				

Multiplication of Vectors

1	c	2	b	3	d	4	a	5	a
6	b	7	c	8	b	9	b	10	d
11	b	12	d	13	c	14	d	15	c
16	c	17	b	18	c	19	b	20	a
21	a	22	c	23	a	24	b	25	c
26	d	27	d	28	b	29	b	30	b
31	d	32	c	33	d	34	b	35	d
36	b	37	a	38	b	39	a	40	a
41	d	42	d	43	c	44	b	45	a
46	a	47	a	48	d	49	d	50	a
51	b	52	b	53	d	54	a	55	c
56	d	57	a	58	b	59	c		

Lami's Theorem

1	c	2	a	3	b	4	c	5	b

Relative Velocity

1	b	2	b	3	c	4	c	5	d
6	a	7	c	8	c	9	d	10	ac
11	b	12	b	13	d	14	b		

Critical Thinking Questions

1	c	2	c	3	c	4	c	5	b
6	b	7	d	8	d	9	b	10	c
11	a	12	d	13	b	14	d		

Assertion and Reason

1	a	2	a	3	d	4	b	5	c
6	b	7	a	8	b	9	a	10	c
11	b	12	e	13	a	14	c	15	a
16	b	17	c	18	b	19	b	20	c
21	a	22	c						

Answers and Solutions

Fundamentals of Vectors

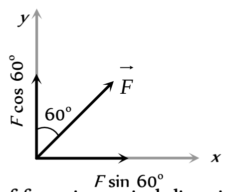
1. (d) As the multiple of $\hat{j}$ in the given vector is zero therefore this vector lies in *XZ* plane and projection of this vector on *y*-axis is zero.

2. (b) If a point have coordinate (x, y, z) then its position vector $= x\hat{i} + y\hat{j} + z\hat{k}$.

3. (c) Displacement vector $\vec{r} = \Delta x\hat{i} + \Delta y\hat{j} + \Delta z\hat{k}$

$$= (3-2)\hat{i} + (4-3)\hat{j} + (5-5)\hat{k} = \hat{i} + \hat{j}$$

4. (d)



The component of force in vertical direction

$$= F\cos\theta = F\cos 60° = 5 \times \frac{1}{2} = 2.5\ N$$

5. (d) $|B| = \sqrt{7^2 + (24)^2} = \sqrt{625} = 25$

Unit vector in the direction of *A* will be $\hat{A} = \dfrac{3\hat{i} + 4\hat{j}}{5}$

So required vector $= 25\left(\dfrac{3\hat{i} + 4\hat{j}}{5}\right) = 15\hat{i} + 20\hat{j}$

6. (a) Let the components of $\vec{A}$ makes angles α, β and γ with *x, y* and *z* axis respectively then $\alpha = \beta = \gamma$

$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$

$\Rightarrow 3\cos^2\alpha = 1 \Rightarrow \cos\alpha = \dfrac{1}{\sqrt{3}}$

$\therefore A_x = A_y = A_z = A\cos\alpha = \dfrac{A}{\sqrt{3}}$

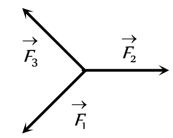
7. (a) $\vec{A} = 2\hat{i} + 4\hat{j} - 5\hat{k} \therefore |\vec{A}| = \sqrt{(2)^2 + (4)^2 + (-5)^2} = \sqrt{45}$

$\therefore \cos\alpha = \dfrac{2}{\sqrt{45}}, \quad \cos\beta = \dfrac{4}{\sqrt{45}}, \quad \cos\gamma = \dfrac{-5}{\sqrt{45}}$

8. (b) Unit vector along y axis $= \hat{j}$ so the required vector $= \hat{j} - [(\hat{i} - 3\hat{j} + 2\hat{k}) + (3\hat{i} + 6\hat{j} - 7\hat{k})] = -4\hat{i} - 2\hat{j} + 5\hat{k}$

9. (b) $\vec{F}_3 = \vec{F}_1 + \vec{F}_2$

There should be minimum three coplaner vectors having different magnitude which should be added to give zero resultant

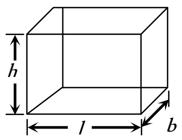


10. (d) Diagonal of the hall = $\sqrt{l^2 + b^2 + h^2}$

$= \sqrt{10^2 + 12^2 + 14^2}$

$= \sqrt{100 + 144 + 196}$

$= \sqrt{400} = 20m$



11. (d) Total angle = $100 \times \dfrac{\pi}{50} = 2\pi$

So all the force will pass through one point and all forces will be balanced. *i.e.* their resultant will be zero.

12. (d) $\vec{r} = \vec{r}_2 - \vec{r}_1 = (-2\hat{i} - 2\hat{j} + 0\hat{k}) - (4\hat{i} - 4\hat{j} + 0\hat{k})$

$\Rightarrow \vec{r} = -6\hat{i} + 2\hat{j} + 0\hat{k}$

$\therefore |\vec{r}| = \sqrt{(-6)^2 + (2)^2 + 0^2} = \sqrt{36 + 4} = \sqrt{40} = 2\sqrt{10}$

13. (a) $\vec{P} = \dfrac{1}{\sqrt{2}}\hat{i} + \dfrac{1}{\sqrt{2}}\hat{j} \therefore |\vec{P}| = \sqrt{\left(\dfrac{1}{\sqrt{2}}\right)^2 + \left(\dfrac{1}{\sqrt{2}}\right)^2} = 1$

$\therefore$ It is a unit vector.

14. (b)

15. (c) $\hat{R} = \dfrac{\vec{R}}{|\vec{R}|} = \dfrac{\hat{i} + \hat{j}}{\sqrt{1^2 + 1^2}} = \dfrac{1}{\sqrt{2}}\hat{i} + \dfrac{1}{\sqrt{2}}\hat{j}$

16. (c) $\vec{R} = 3\hat{i} + \hat{j} + 2\hat{k}$

$\therefore$ Length in *XY* plane = $\sqrt{R_x^2 + R_y^2} = \sqrt{3^2 + 1^2} = \sqrt{10}$

17. (a) If the angle between all forces which are equal and lying in one plane are equal then resultant force will be zero.

18. (b) $\vec{A} = \hat{i} + \hat{j} \Rightarrow |\vec{A}| = \sqrt{1^2 + 1^2} = \sqrt{2}$

$\cos\alpha = \dfrac{A_x}{|\vec{A}|} = \dfrac{1}{\sqrt{2}} = \cos 45° \therefore \alpha = 45°$

19. (c)

20. (c)

21. (d) All quantities are tensors.

22. (d) $\vec{P} + \vec{Q} = P\hat{P} + Q\hat{Q}$

23. (b) $\vec{r} = (a\cos\omega t)\hat{i} + (a\sin\omega t)\hat{j}$

$\vec{v} = \dfrac{d\vec{r}}{dt} = -a\omega\sin\omega t\,\hat{i} + a\omega\cos\omega t\,\hat{j}$

As $\vec{r}.\vec{v} = 0$ therefore velocity of the particle is perpendicular to the position vector.

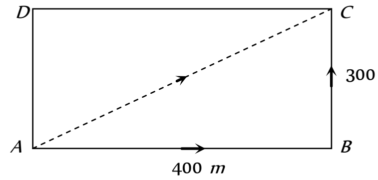
24. (d) Displacement, electrical and acceleration are vector quantities.

25. (b) Magnitude of unit vector = 1

$\Rightarrow \sqrt{(0.5)^2 + (0.8)^2 + c^2} = 1$

By solving we get $c = \sqrt{0.11}$

26. (b)



Displacement $\overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC}$

$AC = \sqrt{(AB)^2 + (BC)^2} = \sqrt{(400)^2 + (300)^2} = 500m$

Distance $= AB + BC = 400 + 300 = 700m$

27. (a) Resultant of vectors $\vec{A}$ and $\vec{B}$

$\vec{R} = \vec{A} + \vec{B} = 4\hat{i} + 3\hat{j} + 6\hat{k} - \hat{i} + 3\hat{j} - 8\hat{k}$

$\vec{R} = 3\hat{i} + 6\hat{j} - 2\hat{k}$

$\hat{R} = \dfrac{\vec{R}}{|\vec{R}|} = \dfrac{3\hat{i} + 6\hat{j} - 2\hat{k}}{\sqrt{3^2 + 6^2 + (-2)^2}} = \dfrac{3\hat{i} + 6\hat{j} - 2\hat{k}}{7}$

28. (a) $\phi = \vec{B}.\vec{A}$. In this formula $\vec{A}$ is a area vector.

29. (a) $\vec{r} = \vec{a} + \vec{b} + \vec{c} = 4\hat{i} - \hat{j} - 3\hat{i} + 2\hat{j} - \hat{k} = \hat{i} + \hat{j} - \hat{k}$

$\hat{r} = \dfrac{\vec{r}}{|\vec{r}|} = \dfrac{\hat{i} + \hat{j} - \hat{k}}{\sqrt{1^2 + 1^2 + (-1)^2}} = \dfrac{\hat{i} + \hat{j} - \hat{k}}{\sqrt{3}}$

30. (d) $\cos\theta = \dfrac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|} = \dfrac{9 + 16 + 25}{\sqrt{9 + 16 + 25}\sqrt{9 + 16 + 25}} = \dfrac{50}{50} = 1$

$\Rightarrow \cos\theta = 1 \therefore \theta = \cos^{-1}(1)$

31. (a) $\vec{r} = 3t^2\hat{i} + 4t^2\hat{j} + 7\hat{k}$

at $t = 0$, $\vec{r}_1 = 7\hat{k}$

at $t = 10\,\text{sec}$, $\vec{r}_2 = 300\hat{i} + 400\hat{j} + 7\hat{k}$,

$\overrightarrow{\Delta r} = \vec{r}_2 - \vec{r}_1 = 300\hat{i} + 400\hat{j}$

$|\overrightarrow{\Delta r}| = |\vec{r}_2 - \vec{r}_1| = \sqrt{(300)^2 + (400)^2} = 500m$

32. (b) Resultant of vectors $\vec{A}$ and $\vec{B}$

$\vec{R} = \vec{A} + \vec{B} = 4\hat{i} - 3\hat{j} + 8\hat{i} + 8\hat{j} = 12\hat{i} + 5\hat{j}$

$\hat{R} = \dfrac{\vec{R}}{|\vec{R}|} = \dfrac{12\hat{i} + 5\hat{j}}{\sqrt{(12)^2 + (5)^2}} = \dfrac{12\hat{i} + 5\hat{j}}{13}$

33. (a) $\frac{\vec{A}.\vec{B}}{|\,\hat{i}+\hat{j}\,|} = \frac{(2\hat{i}+3\hat{j})(\hat{i}+\hat{j})}{\sqrt{2}} = \frac{2+3}{\sqrt{2}} = \frac{5}{\sqrt{2}}$

34. (a) $\cos\theta = \frac{\vec{A}.\vec{B}}{|\,A||\,B|} = \frac{(3\hat{i}+4\hat{j}+5\hat{k})(3\hat{i}+4\hat{j}-5\hat{k})}{\sqrt{9+16+25}\sqrt{9+16+25}}$

$= \frac{9+16-25}{50} = 0$

$\Rightarrow \cos\theta = 0\,,\ \therefore\ \theta = 90°$

Addition and Subtraction of Vectors

1. (a) For 17 *N* both the vector should be parallel *i.e.* angle between them should be zero.

For 7 *N* both the vectors should be antiparallel *i.e.* angle between them should be 180°

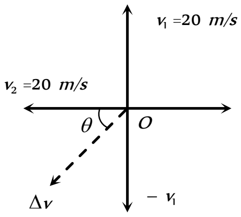
For 13 *N* both the vectors should be perpendicular to each other *i.e.* angle between them should be 90°

2. (b) $\vec{A}+\vec{B} = 4\hat{i}-3\hat{j}+6\hat{i}+8\hat{j} = 10\hat{i}+5\hat{j}$

$|\,\vec{A}+\vec{B}| = \sqrt{(10)^2+(5)^2} = 5\sqrt{5}$

$\tan\theta = \frac{5}{10} = \frac{1}{2}\ \Rightarrow \theta = \tan^{-1}\left(\frac{1}{2}\right)$

3. (d) From figure



$\vec{v}_1 = 20\hat{j}$ and $\vec{v}_2 = -20\hat{i}$

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1 = -20(\hat{i}+\hat{j})$

$|\,\Delta\vec{v}| = 20\sqrt{2}$ and direction

$\theta = \tan^{-1}(1) = 45°$ *i.e. S–W*

4. (b) Let $\hat{n}_1$ and $\hat{n}_2$ are the two unit vectors, then the sum is

$\vec{n}_s = \hat{n}_1 + \hat{n}_2$ or $n_s^2 = n_1^2 + n_2^2 + 2n_1n_2\cos\theta$

$= 1 + 1 + 2\cos\theta$

Since it is given that n_s is also a unit vector, therefore

$1 = 1 + 1 + 2\cos\theta \Rightarrow \cos\theta = -\frac{1}{2}\ \ \therefore \theta = 120°$

Now the difference vector is $\hat{n}_d = \hat{n}_1 - \hat{n}_2$ or

$n_d^2 = n_1^2 + n_2^2 - 2n_1n_2\cos\theta = 1 + 1 - 2\cos(120°)$

$\therefore\ n_d^2 = 2 - 2(-1/2) = 2 + 1 = 3 \Rightarrow n_d = \sqrt{3}$

5. (b) $\vec{A} - 2\vec{B} + 3\vec{C} = (2\hat{i}+\hat{j}) - 2(3\hat{j}-\hat{k}) + 3(6\hat{i}-2\hat{k})$

$= 2\hat{i}+\hat{j}-6\hat{j}+2\hat{k}+18\hat{i}-6\hat{k} = 20\hat{i}-5\hat{j}-4\hat{k}$

6. (a) $\vec{P}_1 = mv\sin\theta\,\hat{i} - mv\cos\theta\,\hat{j}$

and $\vec{P}_2 = mv\sin\theta\,\hat{i} + mv\cos\theta\,\hat{j}$

So change in momentum

$\overrightarrow{\Delta P} = \vec{P}_2 - \vec{P}_1 = 2mv\cos\theta\,\hat{j}, |\,\Delta\vec{P}| = 2mv\cos\theta$

7. (b) $R = \sqrt{A^2+B^2+2AB\cos\theta}$

By substituting, $A = F,\ B = F$ and $R = F$ we get

$\cos\theta = \frac{1}{2}\ \therefore \theta = 120°$

8. (a)

9. (d) If two vectors $\vec{A}$ and $\vec{B}$ are given then the resultant R_{max} = $A + B = 7N$ and $R_{min} = 4 - 3 = 1N$

i.e. net force on the particle is between 1 *N* and 7 *N*.

10. (b) If $\vec{C}$ lies outside the plane then resultant force can not be zero.

11. (d)

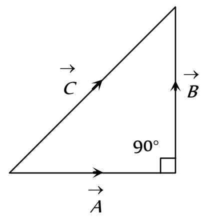
12. (c) $F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 90°} = \sqrt{F_1^2 + F_2^2}$

13. (a)

14. (c)

15. (c) $C = \sqrt{A^2+B^2}$

The angle between *A* and *B* is $\frac{\pi}{2}$



16. (c) $\vec{R} = \vec{A} + \vec{B} = 6\hat{i}+7\hat{j}+3\hat{i}+4\hat{j} = 9\hat{i}+11\hat{j}$

$\therefore\ |\,\vec{R}| = \sqrt{9^2+11^2} = \sqrt{81+121} = \sqrt{202}$

17. (c) $R = \sqrt{12^2+5^2+6^2} = \sqrt{144+25+36} = \sqrt{205} = 14.31\ m$

18. (c) $\vec{A} = 3\hat{i}-2\hat{j}+\hat{k}\ ,\ \vec{B} = \hat{i}-3\hat{j}+5\hat{k}\ ,\ \vec{C} = 2\hat{i}-\hat{j}+4\hat{k}$

$|\,\vec{A}| = \sqrt{3^2+(-2)^2+1^2} = \sqrt{9+4+1} = \sqrt{14}$

$|\,\vec{B}| = \sqrt{1^2+(-3)^2+5^2} = \sqrt{1+9+25} = \sqrt{35}$

$|\,\vec{A}| = \sqrt{2^2+1^2+(-4)^2} = \sqrt{4+1+16} = \sqrt{21}$

As $B = \sqrt{A^2+C^2}$ therefore *ABC* will be right angled triangle.

19. (c)

20. (b) $\vec{C} + \vec{A} = \vec{B}$.

The value of *C* lies between $A - B$ and $A + B$

$\therefore\ |\,\vec{C}| < |\,\vec{A}|$ or $|\,\vec{C}| < |\,\vec{B}|$

21. (a)

22. (d)

23. (d) Here all the three force will not keep the particle in equilibrium so the net force will not be zero and the particle will move with an acceleration.

24. (a) $A + B = 16$ (given) ...(i)

$\tan\alpha = \frac{B\sin\theta}{A + B\cos\theta} = \tan 90°$

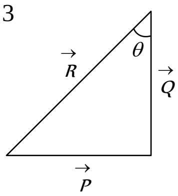
$\therefore\ \ A + B\cos\theta = 0 \Rightarrow \cos\theta = \frac{-A}{B}$ ...(ii)

$8 = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ ...(iii)

By solving eq. (i), (ii) and (iii) we get $A = 6N, \; B = 10N$

25. (c) $|\vec{P}| = 5$, $|\vec{Q}| = 12$ and $|\vec{R}| = 13$

$\cos\theta = \frac{Q}{R} = \frac{12}{13}$



$\therefore \; \theta = \cos^{-1}\left(\frac{12}{13}\right)$

26. (b) $\frac{B}{2} = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ ...(i)

$\therefore \; \tan 90° = \frac{B\sin\theta}{A + B\cos\theta} \Rightarrow A + B\cos\theta = 0$

$\therefore \; \cos\theta = -\frac{A}{B}$

Hence, from (i) $\frac{B^2}{4} = A^2 + B^2 - 2A^2 \Rightarrow A = \sqrt{3}\,\frac{B}{2}$

$\Rightarrow \cos\theta = -\frac{A}{B} = -\frac{\sqrt{3}}{2} \; \therefore \; \theta = 150°$

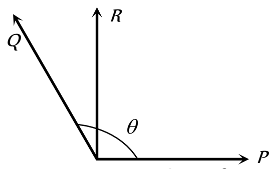
27. (b) $(\hat{i} - 2\hat{j} + 2\hat{k}) + (2\hat{i} + \hat{j} - \hat{k}) + \vec{R} = i$

$\therefore$ Required vector $\vec{R} = -2\hat{i} + \hat{j} - \hat{k}$

28. (a) Resultant $\vec{R} = \vec{P} + \vec{Q} + \vec{P} - \vec{Q} = 2\vec{P}$

The angle between $\vec{P}$ and $2\vec{P}$ is zero.

29. (b)



$\Rightarrow \tan 90° = \frac{Q\sin\theta}{P + Q\cos\theta} \Rightarrow P + Q\cos\theta = 0$

$\cos\theta = \frac{-P}{Q} \; \therefore \; \theta = \cos^{-1}\left(\frac{-P}{Q}\right)$

30. (a) According to problem $P + Q = 3$ and $P - Q = 1$

By solving we get $P = 2$ and $Q = 1$ $\therefore$ $\frac{P}{Q} = 2 \Rightarrow P = 2Q$

31. (c)

32. (c)

33. (c)

34. (d) $F_1 + F_2 + F_3 = 0 \Rightarrow 4\hat{i} + 6\hat{j} + F_3 = 0$

$\therefore \vec{F}_3 = -4\hat{i} - 6\hat{j}$

35. (a) $\Delta v = 2v\sin\left(\frac{\theta}{2}\right) = 2 \times v \times \sin 90°$

$= 2 \times 100 = 200 \; km/hr$

36. (c)

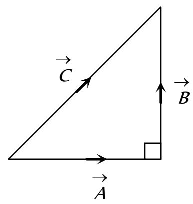
37. (d) Resultant velocity $= \sqrt{20^2 + 15^2}$

$= \sqrt{400 + 225} = \sqrt{625} = 25 \; km/hr$

38. (a) $C = \sqrt{A^2 + B^2}$

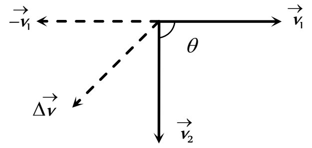
$= \sqrt{3^2 + 4^2} = 5$

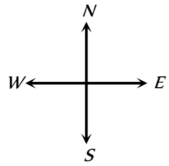
$\therefore$ Angle between $\vec{A}$ and $\vec{B}$ is $\frac{\pi}{2}$



39. (c)

40. (d)





If the magnitude of vector remains same, only direction change by θ then

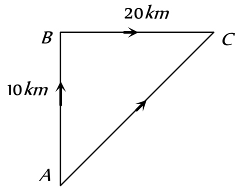
$\overrightarrow{\Delta v} = \overrightarrow{v_2} - \overrightarrow{v_1}$, $\overrightarrow{\Delta v} = \overrightarrow{v_2} + (\overrightarrow{-v_1})$

Magnitude of change in vector $|\overrightarrow{\Delta v}| = 2v\sin\left(\frac{\theta}{2}\right)$

$|\overrightarrow{\Delta v}| = 2 \times 10 \times \sin\left(\frac{90°}{2}\right) = 10\sqrt{2} = 14.14 \, m/s$

Direction is south-west as shown in figure.

41. (a) $\overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC}$



$AC = \sqrt{(AB)^2 + (BC)^2}$

$= \sqrt{(10)^2 + (20)^2}$

$= \sqrt{100 + 400} = \sqrt{500} = 22.36 \, km$

42. (b) $\cos\theta = \frac{\vec{F_1}.\vec{F_2}}{|F_1||F_2|}$

$= \frac{(5\hat{i} + 10\hat{j} - 20\hat{k}).(10\hat{i} - 5\hat{j} - 15\hat{k})}{\sqrt{25 + 100 + 400}\sqrt{100 + 25 + 225}} = \frac{50 - 50 + 300}{\sqrt{525}\sqrt{350}}$

$\Rightarrow \cos\theta = \frac{1}{\sqrt{2}} \; \therefore \; \theta = 45°$

43. (d) If two vectors A and B are given then Range of their resultant can be written as $(A - B) \le R \le (A + B)$.

i.e. $R_{\max} = A + B$ and $R_{\min} = A - B$

If $B = 1$ and $A = 4$ then their resultant will lies in between $3N$ and $5N$. It can never be $2N$.

44. (d) $A = 3N$, $B = 2N$ then $R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

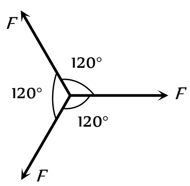
$R = \sqrt{9 + 4 + 12\cos\theta}$ ...(i)

Now $A = 6N$, $B = 2N$ then

$2R = \sqrt{36 + 4 + 24\cos\theta}$ ...(ii)

from (i) and (ii) we get $\cos\theta = -\frac{1}{2} \; \therefore \; \theta = 120°$

45. (a) In N forces of equal magnitude works on a single point and their resultant is



zero then angle between any two forces is given $\theta = \frac{360}{N} = \frac{360}{3} = 120°$

If these three vectors are represented by three sides of triangle then they form equilateral triangle

46. (c) Resultant of two vectors $\vec{A}$ and $\vec{B}$ can be given by $\vec{R} = \vec{A} + \vec{B}$

$|\vec{R}| = |\vec{A} + \vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

If $\theta = 0°$ then $|\vec{R}| = A + B = |\vec{A}| + |\vec{B}|$

47. (d) $R_{max} = A + B = 17$ when $\theta = 0°$

$R_{min} = A - B = 7$ when $\theta = 180°$

by solving we get $A = 12$ and $B = 5$

Now when $\theta = 90°$ then $R = \sqrt{A^2 + B^2}$

$\Rightarrow R = \sqrt{(12)^2 + (5)^2} = \sqrt{169} = 13$

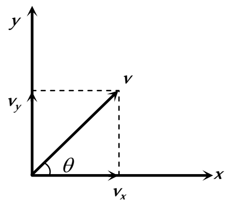
48. (a) If two vectors are perpendicular then their dot product must be equal to zero. According to problem

$(\vec{A} + \vec{B}).(\vec{A} - \vec{B}) = 0 \Rightarrow \vec{A}.\vec{A} - \vec{A}.\vec{B} + \vec{B}.\vec{A} - \vec{B}.\vec{B} = 0$

$\Rightarrow A^2 - B^2 = 0 \Rightarrow A^2 = B^2$

$\therefore$ $A = B$ *i.e.* two vectors are equal to each other in magnitude.

49. (a) $v_y = 20$ and $v_x = 10$



$\therefore$ velocity $\vec{v} = 10\hat{i} + 20\hat{j}$

direction of velocity with x axis

$\tan\theta = \frac{v_y}{v_x} = \frac{20}{10} = 2$

$\therefore$ $\theta = \tan^{-1}(2)$

50. (c) $R_{max} = A + B$ when $\theta = 0°$ $\therefore$ $R_{max} = 12 + 8 = 20N$

51. (c) $R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$

If $A = B = P$ and $\theta = 120°$ then $R = P$

52. (a) Sum of the vectors $\vec{R} = 5\hat{i} + 8\hat{j} + 2\hat{i} + 7\hat{j} = 7\hat{i} + 15\hat{j}$

magnitude of $\vec{R} = |\vec{R}| = \sqrt{49 + 225} = \sqrt{274}$

53. (d)

Multiplication of Vectors

1. (c) Given vectors can be rewritten as $\vec{A} = 2\hat{i} + 3\hat{j} + 8\hat{k}$ and $\vec{B} = -4\hat{i} + 4\hat{j} + \alpha\hat{k}$

Dot product of these vectors should be equal to zero because they are perpendicular.

$\therefore$ $\vec{A}.\vec{B} = -8 + 12 + 8\alpha = 0 \Rightarrow 8\alpha = -4 \Rightarrow \alpha = -1/2$

2. (b) Let $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$ and $\vec{B} = -4\hat{i} - 6\hat{j} + \lambda\hat{k}$

$\vec{A}$ and $\vec{B}$ are parallel to each other

$\frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3}$ *i.e.* $\frac{2}{-4} = \frac{3}{-6} = \frac{-1}{\lambda} \Rightarrow \lambda = 2$.

3. (d) $W = \vec{F}.\vec{S} = FS\cos\theta$

$= 50 \times 10 \times \cos 60° = 50 \times 10 \times \frac{1}{2} = 250\ J.$

4. (a) $S = \vec{r}_2 - \vec{r}_1$

$W = \vec{F}.\vec{S} = (4\hat{i} + \hat{j} + 3\hat{k}).(11\hat{i} + 11\hat{j} + 15\hat{k})$

$= (4 \times 11 + 1 \times 11 + 3 \times 15) = 100\ J.$

5. (a) $(\vec{A} + \vec{B})$ is perpendicular to $(\vec{A} - \vec{B})$. Thus

$(\vec{A} + \vec{B}).(\vec{A} - \vec{B}) = 0$

or $A^2 + \vec{B}.\vec{A} - \vec{A}.\vec{B} - B^2 = 0$

Because of commutative property of dot product $\vec{A}.\vec{B} = \vec{B}.\vec{A}$

$\therefore A^2 - B^2 = 0$ or $A = B$

Thus the ratio of magnitudes $A/B = 1$

6. (b) Let $\vec{A}.(\vec{B} \times \vec{A}) = \vec{A}.\vec{C}$

Here $\vec{C} = \vec{B} \times \vec{A}$ Which is perpendicular to both vector $\vec{A}$ and $\vec{B}$ $\therefore$ $\vec{A}.\vec{C} = 0$

7. (c) We know that $\vec{A} \times \vec{B} = -(\vec{B} \times \vec{A})$ because the angle between these two is always 90°.

But if the angle between $\vec{A}$ and $\vec{B}$ is 0 or π. Then $\vec{A} \times \vec{B} = \vec{B} \times \vec{A} = 0$.

8. (b) $\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 1 & 2 \\ 2 & -2 & 4 \end{vmatrix}$

$= (1 \times 4 - 2 \times -2)\hat{i} + (2 \times 2 - 4 \times 3)\hat{j} + (3 \times -2 - 1 \times 2)\hat{k}$

$= 8\hat{i} - 8\hat{j} - 8\hat{k}$

$\therefore$ Magnitude of $\vec{A} \times \vec{B} = |\vec{A} \times \vec{B}| = \sqrt{(8)^2 + (-8)^2 + (-8)^2}$

$= 8\sqrt{3}$

9. (b) $\vec{\tau} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 2 & 3 \\ 2 & -3 & 4 \end{vmatrix}$

$= [(2 \times 4) - (3 \times -3)]\hat{i} + [(2 \times 3) - (3 \times 4)]\hat{j}$

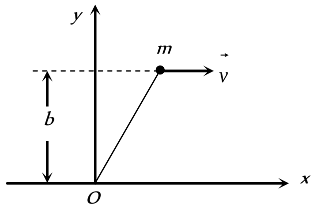
$+ [(3 \times -3) - (2 \times 2)]\hat{k} = 17\hat{i} - 6\hat{j} - 13\hat{k}$

10. (d) From the property of vector product, we notice that $\vec{C}$ must be perpendicular to the plane formed by vector $\vec{A}$ and $\vec{B}$. Thus $\vec{C}$ is perpendicular to both $\vec{A}$ and $\vec{B}$ and $(\vec{A} + \vec{B})$ vector also, must lie in the plane formed by vector $\vec{A}$ and $\vec{B}$. Thus $\vec{C}$ must be perpendicular to $(\vec{A} + \vec{B})$ also but the cross product $(\vec{A}\times\vec{B})$ gives a vector $\vec{C}$ which can not be perpendicular to itself. Thus the last statement is wrong.

11. (b) We know that, Angular momentum

$\vec{L}=\vec{r}\times\vec{p}$ in terms of component becomes

$$\vec{L}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ x & y & z\\ p_x & p_y & p_z\end{vmatrix}$$



As motion is in *x-y* plane (z = 0 and $P_z=0$), so

$\vec{L}=\vec{k}(xp_y-yp_x)$

Here $x = vt$, $y = b$, $p_x=mv$ and $p_y=0$

$\therefore\ \vec{L}=\vec{k}\left[vt\times 0-b\,mv\right]=-mvb\,\hat{k}$

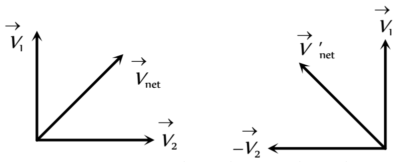
12. (d) $\vec{F_1}.\vec{F_2}=(2\hat{j}+5\hat{k})(3\hat{j}+4\hat{k})$

$=6+20=20+6=26$

13. (c) Force F lie in the *x-y* plane so a vector along *z*-axis will be perpendicular to F.

14. (d) $\vec{A}.\vec{B}=|\vec{A}|.|\vec{B}|.\cos\theta=A.B.\cos 90°=0$

15. (c)



According to problem $|\vec{V_1}+\vec{V_2}|=|\vec{V_1}-\vec{V_2}|$

$\Rightarrow|\vec{V}_{net}|=|\vec{V}'_{net}|$

So V_1 and V_2 will be mutually perpendicular.

16. (c) $W=\vec{F}.\vec{r}=(5\hat{i}+3\hat{j})(2\hat{i}-\hat{j})=10-3=7\,J.$

17. (b) $\cos\theta=\dfrac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|}=\dfrac{-2+6-4}{\sqrt{14}\sqrt{21}}=0\ \therefore\ \theta=90°$

18. (c) $(\hat{i}+\hat{j}).(\hat{j}+\hat{k})=0+0+1+0=1$

$\cos\theta=\dfrac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|}=\dfrac{1}{\sqrt{2}\times\sqrt{2}}=\dfrac{1}{2}\ \therefore\ \theta=60°$

19. (b) $P=\vec{F}.\vec{v}=20\times6+15\times(-4)+(-5)\times3$

$=120-60-15=120-75=45\,J/s$

20. (a) $\cos\theta=\dfrac{\vec{P}.\vec{Q}}{PQ}=1\ \therefore\ \theta=0°$

21. (a) $W=\vec{F}.\vec{s}=(5\hat{i}+6\hat{j}+4\hat{k})(6\hat{i}-5\hat{k})=30-20=10\,J$

22. (c) $\vec{A}.\vec{B}=0\ \therefore\ \theta=90°$

23. (a) $\vec{P}.\vec{Q}=0\ \therefore\ a^2-2a-3=0\Rightarrow a=3$

24. (b) $W=\vec{F}.\vec{r}=(-2\hat{i}+15\hat{j}+6\hat{k})(10\hat{j})=150$

25. (c) $P_x=2\cos t,\ P_y=2\sin t\ \therefore\ \vec{P}=2\cos t\,\hat{i}+2\sin t\,\hat{j}$

$\vec{F}=\dfrac{d\vec{P}}{dt}=-2\sin t\,\hat{i}+2\cos t\,\hat{j}$

$\vec{F}.\vec{P}=0\ \therefore\ \theta=90°$

26. (d) $|\vec{A}\times\vec{B}|=|(2\hat{i}+3\hat{j})\times(\hat{i}+4\hat{j})|=|5\hat{k}|=5\ units$

27. (d)

28. (b) $\vec{A}\times\vec{B}=0\ \therefore\ \sin\theta=0\ \therefore\ \theta=0°$

Two vectors will be parallel to each other.

29. (b) $\vec{A}\times\vec{B}$ and $\vec{B}\times\vec{A}$ are parallel and opposite to each other. So the angle will be π.

30. (b) Vector $(\vec{P}+\vec{Q})$ lies in a plane and vector $(\vec{P}\times\vec{Q})$ is perpendicular to this plane *i.e.* the angle between given vectors is $\dfrac{\pi}{2}$.

31. (d) $\sqrt{2^2+3^2+2\times2\times3\times\cos\theta}=1$

By solving we get $\theta=180°\ \therefore\ \vec{A}\times\vec{B}=0$

32. (c) Dot product of two perpendicular vector will be zero.

33. (d) $\cos\theta=\dfrac{\vec{A}\vec{B}}{AB}=\dfrac{42+24-12}{\sqrt{36+36+9}\sqrt{49+16+16}}=\dfrac{56}{9\sqrt{71}}$

$\cos\theta=\dfrac{56}{9\sqrt{71}}\ \therefore\ \sin\theta=\dfrac{\sqrt{5}}{3}$ or $\theta=\sin^{-1}\left(\dfrac{\sqrt{5}}{3}\right)$

34. (b) Direction of vector A is along z-axis $\therefore\ \vec{A}=a\hat{k}$

Direction of vector B is towards north $\therefore\ \vec{B}=b\hat{j}$

Now $\vec{A}\times\vec{B}=a\hat{k}\times b\hat{j}=ab(-\hat{j})$

$\therefore$ The direction is $\vec{A}\times\vec{B}$ is along west.

35. (d) $\cos\theta=\dfrac{\vec{A}.\vec{B}}{|\vec{A}||\vec{B}|}=\dfrac{1}{\sqrt{2}\sqrt{2}}=\dfrac{1}{2}\ \therefore\ \theta=60°$

36. (d) $\overrightarrow{AB}=(4\hat{i}+5\hat{j}+6\hat{k})-(3\hat{i}+4\hat{j}+5\hat{k})=\hat{i}+\hat{j}+\hat{k}$

$\overrightarrow{CD}=(4\hat{i}+6\hat{j})-(7\hat{i}+9\hat{j}+3\hat{k})=-3\hat{i}-3\hat{j}-3\hat{k}$

$\overrightarrow{AB}$ and $\overrightarrow{CD}$ are parallel, because its cross-products is 0.

37. (a) $W=\vec{F}\,\vec{S}=(4\hat{i}+5\hat{j})(3\hat{i}+6\hat{j})=12$

38. (b) $|\vec{A}\times\vec{B}|=\vec{A}.\vec{B}\Rightarrow AB\sin\theta=AB\cos\theta\Rightarrow\tan\theta=1$

$\therefore\ \theta=45°$

39. (a)

40. (a) $\vec{v}=\vec{\omega}\times\vec{r}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 1 & -2 & 2\\ 0 & 4 & -3\end{vmatrix}=\hat{i}(6-8)-\hat{j}(-3)+4\hat{k}$

$-2\vec{i}+3\vec{j}+4\vec{k}$

$|\vec{v}|=\sqrt{(-2)^2+(3)^2+4^2}=\sqrt{29}\ unit$

41. (d) $\vec{a}.\vec{b}=0$ *i.e.* $\vec{a}$ and $\vec{b}$ will be perpendicular to each other

$\vec{a}.\vec{c}=0$ *i.e.* $\vec{a}$ and $\vec{c}$ will be perpendicular to each other

$\vec{b}\times\vec{c}$ will be a vector perpendicular to both $\vec{b}$ and $\vec{c}$

So $\vec{a}$ is parallel to $\vec{b}\times\vec{c}$

42. (d) Area $=\left|2\hat{i}\times 2\hat{j}\right| = \left|4\hat{k}\right| = 4\ unit.$

43. (c) $\vec{A}=2\hat{i}+2\hat{j}-\hat{k}$ and $\vec{B}=6\hat{i}-3\hat{j}+2\hat{k}$

$\vec{C}=\vec{A}\times\vec{B}=\left(2\hat{i}+2\hat{j}-\hat{k}\right)\times\left(6\hat{i}-3\hat{j}+2\hat{k}\right)$

$$=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 2 & 2 & -1\\ 6 & -3 & 2\end{vmatrix}=\hat{i}-10\hat{j}-18\hat{k}$$

Unit vector perpendicular to both $\vec{A}$ and $\vec{B}$

$$=\frac{\hat{i}-10\hat{j}-18\hat{k}}{\sqrt{1^2+10^2+18^2}}=\frac{\hat{i}-10\hat{j}-18\hat{k}}{5\sqrt{17}}$$

44. (b) $\vec{A}=\hat{j}+3\hat{k}$, $\vec{B}=\hat{i}+2\hat{j}-\hat{k}$

$$\vec{C}=\vec{A}\times\vec{B}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 0 & 1 & 3\\ 1 & 2 & -1\end{vmatrix}=-7\hat{i}+3\hat{j}-\hat{k}$$

Hence area = $|\vec{C}|=\sqrt{49+9+1}=\sqrt{59}\ squnit$

45. (a) $$\vec{L}=\vec{r}\times\vec{p}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 1 & 2 & -1\\ 3 & 4 & -2\end{vmatrix}=-\hat{j}-2\hat{k}$$

i.e. the angular momentum is perpendicular to *x*-axis.

46. (a) $\vec{A}\times\vec{B}$ is a vector perpendicular to plane $\vec{A}+\vec{B}$ and hence perpendicular to $\vec{A}+\vec{B}$.

47. (a) $\vec{\tau}=\vec{r}\times\vec{F}=(7\hat{i}+3\hat{j}+\hat{k})(-3\hat{i}+\hat{j}+5\hat{k})$

$$\vec{\tau}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 7 & 3 & 1\\ -3 & 1 & 5\end{vmatrix}=14\hat{i}-38\hat{j}+16\hat{k}$$

48. (d) $(\vec{A}+\vec{B})\times(\vec{A}-\vec{B}) = \vec{A}\times\vec{A}-\vec{A}\times\vec{B}+\vec{B}\times\vec{A}-\vec{B}\times\vec{B}$

$=0-\vec{A}\times\vec{B}+\vec{B}\times\vec{A}-0 = \vec{B}\times\vec{A}+\vec{B}\times\vec{A}=2(\vec{B}\times\vec{A})$

49. (d) For perpendicular vector $\vec{A}.\vec{B}=0$

$\Rightarrow (5\hat{i}+7\hat{j}-3\hat{k}).(2\hat{i}+2\hat{j}-a\hat{k})=0$

$\Rightarrow 10+14+3a=0 \Rightarrow a=-8$

50. (a) $\text{Mass}=\dfrac{\text{Force}}{\text{Acceleration}}=\dfrac{|\vec{F}|}{a}$

$=\dfrac{\sqrt{36+64+100}}{1}=10\sqrt{2}\ kg$

51. (a) Area of parallelogram $=\vec{A}\times\vec{B}$

$=(\hat{i}+2\hat{j}+3\hat{k})\times(3\hat{i}-2\hat{j}+\hat{k})$

$$=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 1 & 2 & 3\\ 3 & -2 & 1\end{vmatrix}=(8)\hat{i}+(8)\hat{j}-(8)\hat{k}$$

Magnitude $=\sqrt{64+64+64}=8\sqrt{3}$

52. (b) Radius vector $\vec{r}=\vec{r_2}-\vec{r_1}=(2\hat{i}-3\hat{j}+\hat{k})-(2\hat{i}+\hat{j}+\hat{k})$

$\therefore\ \vec{r}=-4\hat{j}$

Linear momentum $\vec{p}=2\hat{i}+3\hat{j}-\hat{k}$

$\vec{L}=\vec{r}\times\vec{p}=(-4\hat{j})\times(2\hat{i}+3\hat{j}-\hat{k})$

$$=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 0 & -4 & 0\\ 2 & 3 & -1\end{vmatrix}=4\hat{i}-8\hat{k}$$

53. (d) $$\vec{v}=\vec{\omega}\times\vec{r}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & -4 & 1\\ 5 & -6 & 6\end{vmatrix}=-18\hat{i}-13\hat{j}+2\hat{k}$$

54. (a)

55. (c) $\vec{A}.\vec{B}=AB\cos\theta$

In the problem $\vec{A}.\vec{B}=-AB$ i.e. $\cos\theta=-1\ \therefore\ \theta=180^\circ$

i.e. $\vec{A}$ and $\vec{B}$ acts in the opposite direction.

56. (d) $|\vec{A}\times\vec{B}|=\sqrt{3}(\vec{A}.\vec{B})$

$AB\sin\theta=\sqrt{3}AB\cos\theta \Rightarrow \tan\theta=\sqrt{3}\ \therefore\ \theta=60^\circ$

Now $|\vec{R}|=|\vec{A}+\vec{B}|=\sqrt{A^2+B^2+2AB\cos\theta}$

$=\sqrt{A^2+B^2+2AB\left(\dfrac{1}{2}\right)}=(A^2+B^2+AB)^{1/2}$

57. (a) $W=\vec{F}.\vec{s}=(3\hat{i}+c\hat{j}+2\hat{k}).(-4\hat{i}+2\hat{j}-3\hat{k})=-12+2c-6$

Work done $=6J$ (given)

$\therefore\ -12+2c-6=6 \Rightarrow c=12$

58. (b) $W=\vec{F}.\vec{s}=(5\hat{i}+3\hat{j}).(2\hat{i}-\hat{j})=10-3=7\ J$

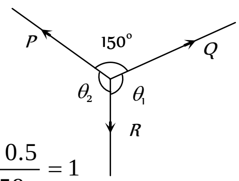
59. (c) $\vec{A}\times\vec{B}=AB\sin\theta\,\hat{n}$

for parallel vectors $\theta=0^\circ$ or 180°, $\sin\theta=0$

$\therefore\ \vec{A}\times\vec{B}=\hat{0}$

Lami's Theorem

1. (c) $\frac{P}{\sin\theta_1}=\frac{Q}{\sin\theta_2}=\frac{R}{\sin 150°}$



$\Rightarrow\frac{1.93}{\sin\theta_1}=\frac{R}{\sin150°}$

$\Rightarrow R=\frac{1.93\times\sin150°}{\sin\theta_1}=\frac{1.93\times0.5}{0.9659}=1$

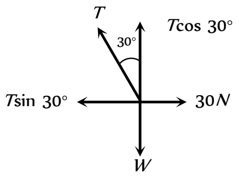
2. (a) According to Lami's theorem

$\frac{P}{\sin\alpha}=\frac{Q}{\sin\beta}=\frac{R}{\sin\gamma}$

3. (b)

4. (c)

5. (b)



From the figure $T\sin30^o=30$ ...(i)

$T\cos30^o=W$ ...(ii)

By solving equation (i) and (ii) we get

$W=30\sqrt{3}N$ and $T=60N$

Relative Velocity

1. (b) The two car (say *A* and *B*) are moving with same velocity, the relative velocity of one (say B) with respect to the other $A, \vec{v}_{BA}=\vec{v}_B-\vec{v}_A=v-v=0$

So the relative separation between them (= 5 *km*) always remains the same.

Now if the velocity of car (say *C*) moving in opposite direction to *A* and *B*, is $\vec{v}_C$ relative to ground then the velocity of car *C* relative to *A* and B will be $\vec{v}_{rel.}=\vec{v}_C-\vec{v}$

But as $\vec{v}$ is opposite to v_c

So $v_{rel}=v_c-(-30)=(v_C+30)km/hr.$

So, the time taken by it to cross the cars *A* and *B*

$t=\frac{d}{v_{rel}}\ \Rightarrow\ \frac{4}{60}=\frac{5}{v_C+30}$

$\Rightarrow v_C=45\,km/hr.$

2. (b) When the man is at rest *w.r.t.* the ground, the rain comes to him at an angle 30° with the vertical. This is the direction of the velocity of raindrops with respect to the ground.

Here $\vec{v}_{rg}$ = velocity of rain with respect to the ground

$\vec{v}_{mg}$ = velocity of the man with respect to the ground.

and $\vec{v}_{rm}$ = velocity of the rain with respect to the man,

We have $\vec{v}_{rg}=\vec{v}_{rm}+\vec{v}_{mg}$ ......(i)

Taking horizontal components equation (i) gives

$v_{rg}\sin30°=v_{mg}=10\,km/hr$

or $v_{rg}=\frac{10}{\sin30°}=20\,km/hr$

3. (c) Taking vertical components equation (i) gives

$v_{rg}\cos30°=v_{rm}=20\frac{\sqrt{3}}{2}=10\sqrt{3}\,km/hr$

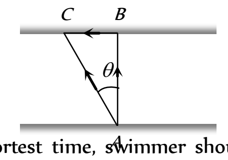
4. (c) Relative velocity = $(3\hat{i}+4\hat{j})-(-3\hat{i}-4\hat{j})=6\hat{i}+8\hat{j}$

5. (d) Relative velocity of parrot with respect to train

$=5-(-10)=5+10=15\,m/\sec$

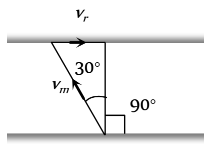
Time taken by the parrot $=\frac{d}{v_{rel.}}=\frac{150}{15}=10\sec.$

6. (a)



For shortest time, swimmer should swim along *AB*, so he will reach at point *C* due to the velocity of river.
i.e. he should swim due north.

7. (c)



$\sin30^o=\frac{v_r}{v_m}=\frac{1}{2}\Rightarrow v_r=\frac{v_m}{2}=\frac{0.5}{2}=0.25\,m/s$

8. (c) $\vec{v}_B+\vec{v}_A=\vec{v}_B+\vec{v}_A=80+65=145\,km/hr$

9. (d) Relative speed of police with respect to thief

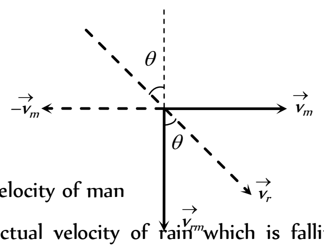
$=10-9=1\,m/s$

Instantaneous separation = 100 *m*

Time = $\frac{\text{distance}}{\text{veclotiy}}=\frac{100}{1}=100\sec.$

10. (a,c)

11. (b) A man is sitting in a bus and travelling from west to east, and the rain drops are appears falling vertically down.



v_m = velocity of man

v_r = Actual velocity of rain which is falling at an angle θ with vertical

v_{rm} = velocity of rain *w.r.t.* to moving man

If the another man observe the rain then he will find that actually rain falling with velocity v_r at an angle going from west to east.

12. (b) Boat covers distance of 16 *km* in a still water in 2 hours.

i.e. $v_B = \frac{16}{2} = 8\,km/hr$

Now velocity of water $\Rightarrow v_w = 4km/hr$.

Time taken for going upstream

$t_1 = \frac{8}{v_B - v_w} = \frac{8}{8-4} = 2hr$

(As water current oppose the motion of boat)

Time taken for going down stream

$t_2 = \frac{8}{v_B + v_w} = \frac{8}{8+4} = \frac{8}{12}hr$

(As water current helps the motion of boat)

$\therefore$ Total time $= t_1 + t_2 = \left(2 + \frac{8}{12}\right)hr$ or $2hr\,40min$

13. (d) Relative velocity $= 10 + 5 = 15\,m/s$.

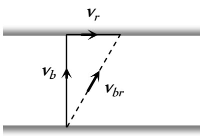
Time taken by the bird to cross the train $= \frac{120}{15} = 8$ sec

14. (b) $\overrightarrow{v_{br}} = \overrightarrow{v_b} + \overrightarrow{v_r}$

$\Rightarrow v_{br} = \sqrt{v_b^2 + v_r^2}$

$\Rightarrow 10 = \sqrt{8^2 + v_r^2}$

$\Rightarrow v_r = 6km/hr$.



Critical Thinking Questions

1. (c) $\sin^2\alpha + \sin^2\beta + \sin\gamma$

$= 1 - \cos^2\alpha + 1 - \cos^2\beta + 1 - \cos^2\gamma$

$= 3 - (\cos^2\alpha + \cos^2\beta + \cos^2\gamma) = 3 - 1 = 2$

2. (c) If vectors are of equal magnitude then two vectors can give zero resultant, if they works in opposite direction. But if the vectors are of different magnitudes then minimum three vectors are required to give zero resultant.

3. (c)

4. (c) Let P be the smaller force and Q be the greater force then according to problem –

$P + Q = 18$ ......(i)

$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta} = 12$ ....(ii)

$\tan\phi = \frac{Q\sin\theta}{P + Q\cos\theta} = \tan 90 = \infty$

$\therefore\ P + Q\cos\theta = 0$ ....(iii)

By solving (i), (ii) and (iii) we will get $P = 5$, and $Q = 13$

5. (b) From the figure $|\overrightarrow{OA}| = a$ and $|\overrightarrow{OB}| = a$

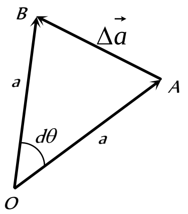
Also from triangle rule $\overrightarrow{OB} - \overrightarrow{OA} = \overrightarrow{AB} = \Delta\vec{a}$

$\Rightarrow |\Delta\vec{a}| = AB$

Using angle $= \frac{\text{arc}}{\text{radius}}$

$\Rightarrow\ AB = a\,.\,d\theta$

So $|\Delta\vec{a}| = a\,d\theta$



Δa means change in magnitude of vector *i.e.* $|\overrightarrow{OB}| - |\overrightarrow{OA}|$

$\Rightarrow\ a - a = 0$

So $\Delta a = 0$

6. (b) $R_{net} = R + \sqrt{R^2 + R^2} = R + \sqrt{2}R = R(\sqrt{2} + 1)$

7. (d)

8. (d) $\Delta v = 2v\sin\left(\frac{90°}{2}\right) = 2v\sin 45° = 2v \times \frac{1}{\sqrt{2}} = \sqrt{2}v$

$= \sqrt{2} \times r\omega = \sqrt{2} \times 1 \times \frac{2\pi}{60} = \frac{\sqrt{2}\pi}{`30}\ cm/s$

9. (b) $\Delta v = 2v\sin\left(\frac{\theta}{2}\right) = 2 \times 5 \times \sin 45° = \frac{10}{\sqrt{2}}$

$\therefore\ a = \frac{\Delta v}{\Delta t} = \frac{10/\sqrt{2}}{10} = \frac{1}{\sqrt{2}}\ m/s^2$

10. (c) For motion of the particle from (0, 0) to (*a*, 0)

$\vec{F} = -K(0\hat{i} + a\hat{j}) \Rightarrow \vec{F} = -Ka\hat{j}$

Displacement $\vec{r} = (a\hat{i} + 0\hat{j}) - (0\hat{i} + 0\hat{j}) = a\hat{i}$

So work done from (0, 0) to (*a*, 0) is given by

$W = \vec{F}.\vec{r} = -Ka\hat{j}.a\hat{i} = 0$

For motion (*a*, 0) to (*a*, *a*)

$\vec{F} = -K(a\hat{i} + a\hat{j})$ and displacement

$\vec{r} = (a\hat{i} + a\hat{j}) - (a\hat{i} + 0\hat{j}) = a\hat{j}$

So work done from (*a*, 0) to (*a*, *a*) $W = \vec{F}.\vec{r}$

$= -K(a\hat{i} + a\hat{j}).a\hat{j} = -Ka^2$

So total work done $= -Ka^2$

11. (a) Given $\overrightarrow{OA} = \vec{a} = 3\hat{i} - 6\hat{j} + 2\hat{k}$ and $\overrightarrow{OB} = \vec{b} = 2\hat{i} + \hat{j} - 2\hat{k}$

$\therefore\ (\vec{a} \times \vec{b}) = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & -6 & 2 \\ 2 & 1 & -2 \end{vmatrix}$

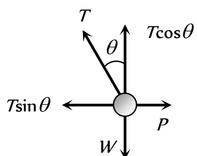
$= (12 - 2)\hat{i} + (4 + 6)\hat{j} + (3 + 12)\hat{k}$

$= 10\hat{i} + 10\hat{j} + 15\hat{k} \Rightarrow |\vec{a} \times \vec{b}| = \sqrt{10^2 + 10^2 + 15^2}$

$= \sqrt{425} = 5\sqrt{17}$

Area of $\Delta OAB = \frac{1}{2}|\vec{a} \times \vec{b}| = \frac{5\sqrt{17}}{2}$ *sq.unit.*

12. (d)



As the metal sphere is in equilibrium under the effect of three forces therefore $\vec{T} + \vec{P} + \vec{W} = 0$

From the figure $T\cos\theta = W$ ...(i)

$T\sin\theta = P$ ...(ii)

From equation (i) and (ii) we get $P = W\tan\theta$

and $T^2 = P^2 + W^2$

13. (b)

14. (d)

Assertion and Reason

1 (a) Cross product of two vectors is perpendicular to the plane containing both the vectors.

2 (a) $\cos\theta = \frac{(\hat{i}+\hat{j}).(\hat{i})}{|\hat{i}+\hat{j}||\hat{i}|} = \frac{1}{\sqrt{2}}$. Hence $\theta = 45°$.

3 (d) $\frac{\vec{A}\times\vec{B}}{\vec{A}.\vec{B}} = \frac{AB\sin\theta\,\hat{n}}{AB\cos\theta} = \tan\theta\,\hat{n}$

where $\hat{n}$ is unit vector perpendicular to both $\vec{A}$ and $\vec{B}$.

However $\frac{|\vec{A}\times\vec{B}|}{\vec{A}.\vec{B}} = \tan\theta$

4 (b) $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$

$\Rightarrow A^2+B^2+2AB\cos\theta = A^2+B^2+2AB\cos\theta$

Hence $\cos\theta = 0$ which gives $\theta = 90°$

Also vector addition is commutative.

Hence $\vec{A}+\vec{B} = \vec{B}+\vec{A}$.

5 (c) $\vec{v} = \vec{\omega}\times\vec{r}$

The expression $\vec{\omega} = \vec{v}\times\vec{r}$ is wrong.

6 (b) For giving a zero resultant, it should be possible to represent the given vectors along the sides of a closed polygon and minimum number of sides of a polygon is three.

7 (a) Since velocities are in opposite direction, therefore $v_{AB} = |\vec{v}_A - \vec{v}_B| = v_A + v_B$.

Which is greater than v_A or v_B

8 (b) Vector addition of two vectors is commutative *i.e.* $\vec{A}+\vec{B} = \vec{B}+\vec{A}$.

9 (a)

10 (c) Cross-product of two vectors is anticommutative.

i.e. $\vec{A}\times\vec{B} = -\vec{B}\times\vec{A}$

11 (b)

12 (e) If a vector quantity has zero magnitude then it is called a null vector. That quantity may have some direction even if its magnitude is zero.

13 (a) Let $\vec{P}$ and $\vec{Q}$ are two vectors in opposite direction, then their sum $\vec{P}+(-\vec{Q}) = \vec{P}-\vec{Q}$

If $\vec{P} = \vec{Q}$ then sum equal to zero.

14 (c) If two vectors are in opposite direction, then they cannot be like vectors.

15 (a) If θ be the angle between two vectors $\vec{A}$ and $\vec{B}$, then their scalar product, $\vec{A}.\vec{B} = AB\cos\theta$

If $\theta = 90°$ then $\vec{A}.\vec{B} = 0$

i.e. if $\vec{A}$ and $\vec{B}$ are perpendicular to each other then their scalar product will be zero.

16 (b) We can multiply any vector by any scalar.

For example, in equation $\vec{F} = m\vec{a}$ mass is a scalar quantity, but acceleration is a vector quantity.

17 (c) If two vectors equal in magnitude are in opposite direction, then their sum will be a null vector.

A null vector has direction which is intermediate (or depends on direction of initial vectors) even its magnitude is zero.

18 (b) $\vec{A}.\vec{B} = |\vec{A}||\vec{B}|\cos\theta = 0$

$\vec{A}\times\vec{B} = |\vec{A}||\vec{B}|\sin\theta = 0$

If $\vec{A}$ and $\vec{B}$ are not null vectors then it follows that $\sin\theta$ and $\cos\theta$ both should be zero simultaneously. But it cannot be possible so it is essential that one of the vector must be null vector.

19 (b)

20 (c) The resultant of two vectors of unequal magnitude given by $R = \sqrt{A^2+B^2+2AB\cos\theta}$ cannot be zero for any value of θ.

21 (a) $\vec{A}.\vec{B} = \vec{B}.\vec{C} \Rightarrow AB\cos\theta_1 = BC\cos\theta_2$

$\therefore$ $A = C$, only when $\theta_1 = \theta_2$

So when angle between $\vec{A}$ and $\vec{B}$ is equal to angle between $\vec{B}$ and $\vec{C}$ only then $\vec{A}$ equal to $\vec{C}$

22 (c) Since vector addition is commutative, therefore $\vec{A}+\vec{B} = \vec{B}+\vec{A}$.

Vectors

SET Self Evaluation Test - 0

1. $0.4i + 0.8j + ck$ represents a unit vector when c is

(a) – 0.2 (b) $\sqrt{0.2}$

(c) $\sqrt{0.8}$ (d) 0

2. The angles which a vector $\hat{i} + \hat{j} + \sqrt{2}\,\hat{k}$ makes with *X, Y* and *Z* axes respectively are

(a) 60°, 60°, 60° (b) 45°, 45°, 45°

(c) 60°, 60°, 45° (d) 45°, 45°, 60°

3. The value of a unit vector in the direction of vector $A = 5\hat{i} - 12\hat{j}$, is

(a) $\hat{i}$ (b) $\hat{j}$

(c) $(\hat{i} + \hat{j})/13$ (d) $(5\hat{i} - 12\hat{j})/13$

4. Which of the following is independent of the choice of co-ordinate system

(a) $\vec{P} + \vec{Q} + \vec{R}$ (b) $(P_x + Q_x + R_x)\hat{i}$

(c) $P_x\hat{i} + Q_y\hat{j} + R_z\hat{k}$ (d) None of these

5. A car travels 6 *km* towards north at an angle of 45° to the east and then travels distance of 4 *km* towards north at an angle of 135° to the east. How far is the point from the starting point. What angle does the straight line joining its initial and final position makes with the east

(a) $\sqrt{50}\ km$ and $\tan^{-1}(5)$

(b) 10 *km* and $\tan^{-1}(\sqrt{5})$

(c) $\sqrt{52}\ km$ and $\tan^{-1}(5)$

(d) $\sqrt{52}\ km$ and $\tan^{-1}(\sqrt{5})$

6. Given that $\vec{A} + \vec{B} + \vec{C} = 0$ out of three vectors two are equal in magnitude and the magnitude of third vector is $\sqrt{2}$ times that of either of the two having equal magnitude. Then the angles between vectors are given by

(a) 30°, 60°, 90° (b) 45°, 45°, 90°

(c) 45°, 60°, 90° (d) 90°, 135°, 135°

7. Two forces $F_1 = 1\ N$ and $F_2 = 2\ N$ act along the lines $x = 0$ and $y = 0$ respectively. Then the resultant of forces would be

(a) $\hat{i} + 2\hat{j}$ (b) $\hat{i} + \hat{j}$

(c) $3\hat{i} + 2\hat{j}$ (d) $2\hat{i} + \hat{j}$

8. At what angle must the two forces $(x + y)$ and $(x - y)$ act so that the resultant may be $\sqrt{(x^2 + y^2)}$

(a) $\cos^{-1}\left(-\dfrac{x^2 + y^2}{2(x^2 - y^2)}\right)$ (b) $\cos^{-1}\left(-\dfrac{2(x^2 - y^2)}{x^2 + y^2}\right)$

(c) $\cos^{-1}\left(-\dfrac{x^2 + y^2}{x^2 - y^2}\right)$ (d) $\cos^{-1}\left(-\dfrac{x^2 - y^2}{x^2 + y^2}\right)$

9. Following forces start acting on a particle at rest at the origin of the co-ordinate system simultaneously

$\vec{F}_1 = -4\hat{i} - 5\hat{j} + 5\hat{k}$, $\vec{F}_2 = 5\hat{i} + 8\hat{j} + 6\hat{k}$, $\vec{F}_3 = -3\hat{i} + 4\hat{j} - 7\hat{k}$ and $\vec{F}_4 = 2\hat{i} - 3\hat{j} - 2\hat{k}$ then the particle will move

(a) In $x - y$ plane (b) In $y - z$ plane

(c) In $x - z$ plane (d) Along x -axis

10. The resultant of $\vec{A} + \vec{B}$ is $\vec{R}_1$. On reversing the vector $\vec{B}$, the resultant becomes $\vec{R}_2$. What is the value of $R_1^2 + R_2^2$

(a) $A^2 + B^2$ (b) $A^2 - B^2$

(c) $2(A^2 + B^2)$ (d) $2(A^2 - B^2)$

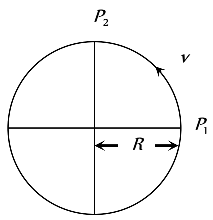
11. Figure below shows a body of mass *M* moving with the uniform speed on a circular path of radius, *R*. What is the change in acceleration in going from P_1 to P_2

(a) Zero

(b) $v^2 / 2R$

(c) $2v^2 / R$

(d) $\dfrac{v^2}{R} \times \sqrt{2}$



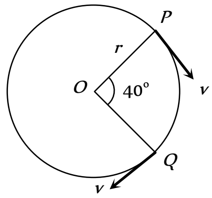
12. A particle is moving on a circular path of radius r with uniform velocity v. The change in velocity when the particle moves from *P* to *Q* is $(\angle POQ = 40°)$

(a) $2v \cos 40°$

(b) $2v \sin 40°$

(c) $2v \sin 20°$

(d) $2v \cos 20°$



13. $\vec{A} = 2\hat{i} + 4\hat{j} + 4\hat{k}$ and $\vec{B} = 4\hat{i} + 2\hat{j} - 4\hat{k}$ are two vectors. The angle between them will be

(a) 0° (b) 45°

(c) 60° (d) 90°

14. If $\vec{A} = 2\hat{i} + 3\hat{j} - \hat{k}$ and $\vec{B} = -\hat{i} + 3\hat{j} + 4\hat{k}$ then projection of $\vec{A}$ on $\vec{B}$ will be

(a) $\dfrac{3}{\sqrt{13}}$ (b) $\dfrac{3}{\sqrt{26}}$

(c) $\sqrt{\frac{3}{26}}$ (d) $\sqrt{\frac{3}{13}}$

15. In above example a unit vector perpendicular to both $\vec{A}$ and $\vec{B}$ will be

(a) $+\frac{1}{\sqrt{3}}(\hat{i}-\hat{j}-\hat{k})$ (b) $-\frac{1}{\sqrt{3}}(\hat{i}-\hat{j}-\hat{k})$

(c) Both (a) and (b) (d) None of these

16. Two constant forces $F_1 = 2\hat{i} - 3\hat{j} + 3\hat{k}$ (*N*) and $F_2 = \hat{i} + \hat{j} - 2\hat{k}$ (*N*) act on a body and displace it from the position $r_1 = \hat{i} + 2\hat{j} - 2\hat{k}$ (m) to the position $r_2 = 7\hat{i} + 10\hat{j} + 5\hat{k}$ (m). What is the work done

(a) 9 *J* (b) 41 *J*

(c) – 3 *J* (d) None of these

17. For any two vectors $\vec{A}$ and $\vec{B}$, if $\vec{A}.\vec{B} = |\vec{A} \times \vec{B}|$, the magnitude of $\vec{C} = \vec{A} + \vec{B}$ is equal to

(a) $\sqrt{A^2 + B^2}$ (b) $A + B$

(c) $\sqrt{A^2 + B^2 + \frac{AB}{\sqrt{2}}}$ (d) $\sqrt{A^2 + B^2 + \sqrt{2} \times AB}$

18. Which of the following is the unit vector perpendicular to $\vec{A}$ and $\vec{B}$

(a) $\frac{\hat{A} \times \hat{B}}{AB\sin\theta}$ (b) $\frac{\hat{A} \times \hat{B}}{AB\cos\theta}$

(c) $\frac{\vec{A} \times \vec{B}}{AB\sin\theta}$ (d) $\frac{\vec{A} \times \vec{B}}{AB\cos\theta}$

19. Two vectors $P = 2\hat{i} + b\hat{j} + 2\hat{k}$ and $Q = \hat{i} + \hat{j} + \hat{k}$ will be parallel if

(a) $b = 0$ (b) $b = 1$

(c) $b = 2$ (d) $b = -4$

20. Which of the following is not true ? If $\vec{A} = 3\hat{i} + 4\hat{j}$ and $\vec{B} = 6\hat{i} + 8\hat{j}$ where *A* and *B* are the magnitudes of $\vec{A}$ and $\vec{B}$

(a) $\vec{A} \times \vec{B} = 0$ (b) $\frac{A}{B} = \frac{1}{2}$

(c) $\vec{A}.\vec{B} = 48$ (d) A = 5

21. The area of the triangle formed by $2\hat{i} + \hat{j} - \hat{k}$ and $\hat{i} + \hat{j} + \hat{k}$ is

(a) 3 sq.unit

(b) $2\sqrt{3}$ sq. unit

(c) $2\sqrt{14}$ sq. unit

(d) $\frac{\sqrt{14}}{2}$ sq. unit

22. Two trains along the same straight rails moving with constant speed 60 *km/hr* and 30 *km/hr* respectively towards each other. If at time $t = 0$, the distance between them is 90 *km*, the time when they collide is

(a) 1 *hr* (b) 2 *hr*

(c) 3 *hr* (d) 4 *hr*

23. A steam boat goes across a lake and comes back (a) On a quite day when the water is still and (b) On a rough day when there is uniform air current so as to help the journey onward and to impede the journey back. If the speed of the launch on both days was same, in which case it will complete the journey in lesser time

(a) Case (a)

(b) Case (b)

(c) Same in both

(d) Nothing can be predicted

24. To a person, going eastward in a car with a velocity of 25 *km/hr*, a train appears to move towards north with a velocity of $25\sqrt{3}$ *km/hr*. The actual velocity of the train will be

(a) 25 *km/hr* (b) 50 *km/hr*

(c) 5 *km/hr* (d) $5\sqrt{3}$ *km/hr*

25. A swimmer can swim in still water with speed υ and the river is flowing with velocity *v*/2. To cross the river in shortest distance, he should swim making angle θ with the upstream. What is the ratio of the time taken to swim across the shortest time to that is swimming across over shortest distance

(a) cos θ (b) sin θ

(c) tan θ (d) cot θ

26. A bus is moving with a velocity 10 m/s on a straight road. A scooterist wishes to overtake the bus in 100 *s*. If the bus is at a distance of 1 *km* from the scooterist, with what velocity should the scooterist chase the bus

(a) 50 *m/s* (b) 40 *m/s*

(c) 30 *m/s* (d) 20 *m/s*

Answers and Solutions

(SET -0)

1. (b) $\sqrt{(0.4)^2+(0.8)^2+c^2}=1$

$\Rightarrow 0.16+0.64+c^2=1 \Rightarrow c=\sqrt{0.2}$

2. (c) $\vec{R}=\hat{i}+\hat{j}+\sqrt{2}\hat{k}$

Comparing the given vector with $R=R_x\hat{i}+R_y\hat{j}+R_z\hat{k}$

$R_x=1, R_y=1, R_z=\sqrt{2}$ and $|\vec{R}|=\sqrt{R_x^2+R_y^2+R_z^2}=2$

$\cos\alpha=\frac{R_x}{R}=\frac{1}{2}\Rightarrow\alpha=60°$

$\cos\beta=\frac{R_y}{R}=\frac{1}{2}\Rightarrow\beta=60°$

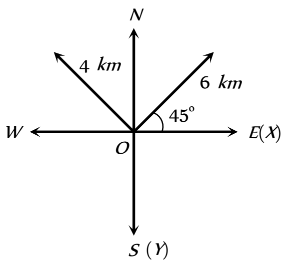
$\cos\gamma=\frac{R_z}{R}=\frac{1}{\sqrt{2}}\Rightarrow\gamma=45°$

3. (d) $\vec{A}=5\hat{i}+12\hat{j}, |\vec{A}|=\sqrt{5^2+(-12)^2}=\sqrt{25+144}=13$

Unit vector $\hat{A}=\frac{\vec{A}}{|\vec{A}|}=\frac{5\hat{i}-12\hat{j}}{13}$

4. (a)

5. (c)



Net movement along x-direction $S_x=(6-4)\cos 45°\ \hat{i}$

$=2\times\frac{1}{\sqrt{2}}=\sqrt{2}\ km$

Net movement along y-direction $S_y=(6+4)\sin 45°\ \hat{j}$

$=10\times\frac{1}{\sqrt{2}}=5\sqrt{2}\ km$

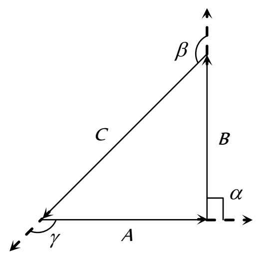
Net movement from starting point

$|\vec{S}|=\sqrt{S_x^2+S_y^2}=\sqrt{(\sqrt{2})^2+(5\sqrt{2})^2}=\sqrt{52}\ km$

Angle which makes with the east direction

$\tan\theta=\frac{\text{Y-component}}{\text{X-component}}=\frac{5\sqrt{2}}{\sqrt{2}}\ \therefore\ \theta=\tan^{-1}(5)$

6. (d)



From polygon law, three vectors having summation zero should form a closed polygon. (Triangle) since the two vectors are having same magnitude and the third vector is $\sqrt{2}$ times that of either of two having equal magnitude. *i.e.* the triangle should be right angled triangle

Angle between A and B, $\alpha=90°$

Angle between B and C, $\beta=135°$

Angle between A and C, $\gamma=135°$

7. (d) $x=0$ means y-axis $\Rightarrow \vec{F}_1=\hat{j}$

$y=0$ means x-axis $\Rightarrow \vec{F}_2=2\hat{i}$

so resultant $\vec{F}=\vec{F}_1+\vec{F}_2=2\hat{i}+\hat{j}$

8. (a) $R^2=A^2+B^2+2AB\cos\theta$

Substituting, $A=(x+y)$, $B=(x-y)$ and $R=\sqrt{(x^2+y^2)}$

we get $\theta=\cos^{-1}\left(-\frac{(x^2+y^2)}{2(x^2-y^2)}\right)$

9. (b) $\vec{F}_1+\vec{F}_2+\vec{F}_3+\vec{F}_4$

$=(-4\hat{i}+5\hat{i}-3\hat{i}+2\hat{i})+(-5\hat{j}+8\hat{j}+4\hat{j}-3\hat{j})$

$+(5\hat{k}+6\hat{k}-7\hat{k}-2\hat{k})=4\hat{j}+2\hat{k}$

$\therefore$ the particle will move in $y-z$ plane.

10. (c) $\vec{R}_1=\vec{A}+\vec{B},\ \vec{R}_2=\vec{A}-\vec{B}$

$R_1^2+R_2^2=\left(\sqrt{A^2+B^2}\right)^2+\left(\sqrt{A^2+B^2}\right)^2=2(A^2+B^2)$

11. (d) $\Delta a=2a\sin\left(\frac{\theta}{2}\right)=2a\times\sin 45°=\sqrt{2}a=\sqrt{2}\frac{v^2}{R}$

12. (b) $\Delta v=2v\sin\left(\frac{\theta}{2}\right)=2v\sin 20°$

13. (c) $\cos\theta=\frac{\vec{A}.\vec{B}}{|\vec{A}|.|\vec{B}|}=\frac{a_1b_1+a_2b_2+a_3b_3}{|\vec{A}|.|\vec{B}|}$

$=\frac{2\times4+4\times2-4\times4}{|\vec{A}|.|\vec{B}|}=0$

$\therefore\theta=\cos^{-1}(0°)\Rightarrow\theta=90°$

14. (b) $|\vec{A}|=\sqrt{2^2+3^2+(-1)^2}=\sqrt{4+9+1}=\sqrt{14}$

$|\vec{B}|=\sqrt{(-1)^2+3^2+4^2}=\sqrt{1+9+16}=\sqrt{26}$

$\vec{A}.\vec{B}=2(-1)+3\times3+(-1)(4)=3$

The projection of $\vec{A}$ on $\vec{B}$ $=\frac{\vec{A}.\vec{B}}{|\vec{B}|}=\frac{3}{\sqrt{26}}$

15. (c) $\hat{n}=\frac{\vec{A}\times\vec{B}}{|\vec{A}\times\vec{B}|}=\frac{8\hat{i}-8\hat{j}-8\hat{k}}{8\sqrt{3}}=\frac{1}{\sqrt{3}}(\hat{i}-\hat{j}-\hat{k})$

There are two unit vectors perpendicular to both $\vec{A}$ and $\vec{B}$ they are $\hat{n}=\pm\frac{1}{\sqrt{3}}(\hat{i}-\hat{j}-\hat{k})$

16. (a) $W = \bar{F}(\bar{r}_2 - \bar{r}_1)$

$= (3\hat{i} - 2\hat{j} + \hat{k})(6\hat{i} + 8\hat{j} + 7\hat{k}) = 18 - 16 + 7 = 9\,J$

17. (d) $AB\cos\theta = AB\sin\theta \Rightarrow \tan\theta = 1 \therefore \theta = 45°$

$\therefore |\bar{C}| = \sqrt{A^2 + B^2 + 2AB\cos 45°} = \sqrt{A^2 + B^2 + \sqrt{2}AB}$

18. (c) Vector perpendicular to A and B, $\vec{A} \times \vec{B} = AB\sin\theta\,\hat{n}$

$\therefore$ Unit vector perpendicular to A and B

$$\hat{n} = \frac{\vec{A} \times \vec{B}}{|\vec{A}| \times |\vec{B}|\ \sin\theta}$$

19. (c) P and Q will be parallel if $\frac{2}{1} = \frac{b}{1} = \frac{2}{1}$ $\therefore b = 2$

20. (b) $|\vec{A}| = 5$, $|\vec{B}| = 10 \Rightarrow \frac{A}{B} = \frac{1}{2}$

21. (d) $\vec{A} = 2\hat{i} + \hat{j} - \hat{k}$, $\vec{B} = \hat{i} + \hat{j} + \hat{k}$

Area of the triangle $= \frac{1}{2}\left(\vec{A} \times \vec{B}\right)$

$$= \frac{1}{2}\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 1 & -1 \\ 1 & 1 & 1 \end{vmatrix} = \frac{1}{2}\left|2\hat{i} - 3\hat{j} + \hat{k}\right| = \frac{1}{2}\sqrt{4 + 9 + 1}$$

$$= \frac{\sqrt{14}}{2}\ sq.unit$$

22. (a) The relative velocity $v_{rel.} = 60 - (-30) = 90\ km/hr.$

Distance between the train $s_{rel.} = 90\ km$,

$\therefore$ Time when they collide $= \frac{s_{rel.}}{v_{rel.}} = \frac{90}{90} = 1\,hr.$

23. (b) If the breadth of the lake is l and velocity of boat is v_b. Time in going and coming back on a quite day

$$t_Q = \frac{l}{v_b} + \frac{l}{v_b} = \frac{2l}{v_b} \quad .....(i)$$

Now if v_a is the velocity of air- current then time taken in going across the lake,

$$t_1 = \frac{l}{v_b + v_a} \quad \text{[As current helps the motion]}$$

and time taken in coming back $t_2 = \frac{l}{v_b - v_a}$

[As current opposes the motion]

So $t_R = t_1 + t_2 = \frac{2l}{v_b[1 - (v_a/v_b)^2]}$ .....(ii)

From equation (i) and (ii)

$$\frac{t_R}{t_Q} = \frac{1}{[1 - (v_a/v_b)^2]} > 1 \ \left[\text{as } 1 - \frac{v_a^2}{v_b^2} < 1\right] \quad i.e.\ t_R > t_Q$$

i.e. time taken to complete the journey on quite day is lesser than that on rough day.

24. (a) $v_T = \sqrt{v_{TC}^2 + v_C^2} = \sqrt{(25\sqrt{3})^2 + (25)^2}$

$= \sqrt{1875 + 625} = \sqrt{2500} = 25\ km/hr$

25. (b)

26. (d) Let the velocity of the scooterist $= v$

Relative velocity of scooterist with respect to bus $= (v - 10)$

$\Rightarrow S = (v - 10) \times 100 \Rightarrow 1000 = (v - 10) \times 100$

$\therefore v = 10 + 10 = 20\,m/s$

***

Chapter

1

Units, Dimensions and Measurement

Physical Quantity

A quantity which can be measured and by which various physical happenings can be explained and expressed in the form of laws is called a physical quantity. For example length, mass, time, force *etc.*

On the other hand various happenings in life *e.g.*, happiness, sorrow *etc.* are not physical quantities because these can not be measured.

Measurement is necessary to determine magnitude of a physical quantity, to compare two similar physical quantities and to prove physical laws or equations.

A physical quantity is represented completely by its magnitude and unit. For example, 10 *metre* means a length which is ten times the unit of length. Here 10 represents the numerical value of the given quantity and *metre* represents the unit of quantity under consideration. Thus in expressing a physical quantity we choose a unit and then find that how many times that unit is contained in the given physical quantity, *i.e.*

Physical quantity (Q) = Magnitude × Unit $= n \times u$

Where, n represents the numerical value and u represents the unit. Thus while expressing definite amount of physical quantity, it is clear that as the unit(u) changes, the magnitude(n) will also change but product 'nu' will remain same.

i.e. $n\,u$ = constant, or $n_1u_1 = n_2u_2 = \text{constant}$; $\therefore \quad n \propto \frac{1}{u}$

i.e. magnitude of a physical quantity and units are inversely proportional to each other .Larger the unit, smaller will be the magnitude.

(1) **Ratio (numerical value only) :** When a physical quantity is the ratio of two similar quantities, it has no unit.

e.g. Relative density = Density of object/Density of water at $4^{\circ}C$

Refractive index = Velocity of light in air/Velocity of light in medium

Strain = Change in dimension/Original dimension

(2) **Scalar (magnitude only) :** These quantities do not have any direction *e.g.* Length, time, work, energy *etc.*

Magnitude of a physical quantity can be negative. In that case negative sign indicates that the numerical value of the quantity under consideration is negative. It does not specify the direction.

Scalar quantities can be added or subtracted with the help of ordinary laws of addition or subtraction.

(3) **Vector (magnitude and direction) :** These quantities have magnitude and direction both and can be added or subtracted with the help of laws of vector algebra *e.g.* displacement, velocity, acceleration, force *etc.*

Fundamental and Derived Quantities

(1) **Fundamental quantities :** Out of large number of physical quantities which exist in nature, there are only few quantities which are independent of all other quantities and do not require the help of any other physical quantity for their definition, therefore these are called absolute quantities. These quantities are also called fundamental or basic quantities, as all other quantities are based upon and can be expressed in terms of these quantities.

(2) **Derived quantities :** All other physical quantities can be derived by suitable multiplication or division of different powers of fundamental quantities. These are therefore called derived quantities.

If length is defined as a fundamental quantity then area and volume are derived from length and are expressed in term of length with power 2 and 3 over the term of length.

Note : ❑ In mechanics, Length, Mass and Time are arbitrarily chosen as fundamental quantities. However this set of fundamental quantities is not a unique choice. In fact any three quantities in mechanics can be termed as fundamental as all other quantities in mechanics can be expressed in terms of these. *e.g.* if speed and time are taken as fundamental quantities, length will become a derived quantity because then length will be expressed as Speed × Time. and if force and acceleration are taken as fundamental quantities, then mass will be defined as Force / acceleration and will be termed as a derived quantity.

Fundamental and Derived Units

Normally each physical quantity requires a unit or standard for its specification so it appears that there must be as many units as there are physical quantities. However, it is not so. It has been found that if in *mechanics* we choose arbitrarily units of any *three* physical quantities we can express the units of all other physical quantities in mechanics in terms of these. Arbitrarily the physical quantities *mass*, *length* and *time* are chosen for this purpose. *So any unit of mass, length and time in mechanics is called a* **fundamental, absolute or base unit.** *Other units which can be expressed in terms of fundamental units, are called derived units.* For example light year or *km* is a fundamental unit as it is a unit of length while s^{-1}, m^{-2} or kg/m are derived units as these are derived from units of time, mass and length.

System of units : A complete set of units, both fundamental and derived for all kinds of physical quantities is called system of units. The common systems are given below

(1) **CGS system :** This system is also called Gaussian system of units. In this length, mass and time have been chosen as the fundamental quantities and corresponding fundamental units are centimetre (*cm*), gram (*g*) and second (*s*) respectively.

(2) **MKS system :** This system is also called Giorgi system. In this system also length, mass and time have been taken as fundamental quantities, and the corresponding fundamental units are *metre*, kilogram and second.

(3) **FPS system :** In this system foot, pound and second are used respectively for measurements of length, mass and time. In this system force is a derived quantity with unit poundal.

(4) **S. I. system :** It is known as International system of units, and is extended system of units applied to whole physics. There are seven fundamental quantities in this system. These quantities and their units are given in the following table

Table 1.1 : Unit and symbol of quantities

Quantity	Unit	Symbol
Length	metre	*m*
Mass	kilogram	*kg*
Time	second	*s*
Electric Current	ampere	*A*
Temperature	Kelvin	*K*
Amount of Substance	mole	*mol*
Luminous Intensity	candela	*cd*

Besides the above seven fundamental units two supplementary units are also defined –

Radian (*rad*) for plane angle and Steradian (*sr*) for solid angle.

Note : ❑ Apart from fundamental and derived units we also use practical units very frequently. These may be fundamental or derived units *e.g.*, light year is a practical unit (fundamental) of distance while horse power is a practical unit (derived) of power.

❑ Practical units may or may not belong to a system but can be expressed in any system of units

e.g., 1 mile = 1.6 *km* = 1.6×10^{3} *m*.

S.I. Prefixes

In physics we deal from very small (*micro*) to very large (*macro*) magnitudes, as one side we talk about the atom while on the other side of universe, *e.g.*, the mass of an electron is 9.1×10^{-31} *kg* while that of the sun is 2×10^{30} *kg*. To express such large or small magnitudes we use the following prefixes :

Table 1.2 : Prefixes and symbol

Power of 10	Prefix	Symbol
10^{18}	exa	*E*
10^{15}	peta	*P*
10^{12}	tera	*T*
10^{9}	giga	*G*
10^{6}	mega	*M*
10^{3}	kilo	*k*
10^{2}	hecto	*h*
10^{1}	deca	*da*
10^{-1}	deci	*d*
10^{-2}	centi	*c*
10^{-3}	milli	*m*
10^{-6}	micro	μ
10^{-9}	nano	*n*
10^{-12}	pico	*p*
10^{-15}	femto	*f*
10^{-18}	atto	*a*

Standards of Length, Mass and Time

(1) **Length :** Standard metre is defined in terms of wavelength of light and is called atomic standard of length.

The metre is the distance containing 1650763.73 wavelength in vacuum of the radiation corresponding to orange red light emitted by an atom of krypton-86.

Now a days metre is defined as length of the path travelled by light in vacuum in 1/299,7792, 45 part of a second.

(2) **Mass :** The mass of a cylinder made of platinum-iridium alloy kept at International Bureau of Weights and Measures is defined as 1 *kg*.

On atomic scale, 1 *kilogram* is equivalent to the mass of 5.0188×10^{25} atoms of $_6C^{12}$ (an isotope of carbon).

(3) **Time :** 1 *second* is defined as the time interval of 9192631770 vibrations of radiation in *Cs*-133 atom. This radiation corresponds to the transition between two hyperfine level of the ground state of *Cs*-133.

Practical Units

(1) **Length**

(i) 1 fermi = 1 *fm* = 10^{-15} *m*

(ii) 1 *X*-ray unit = 1*XU* = 10^{-13} *m*

(iii) 1 angstrom = 1Å = 10^{-10} *m* = 10^{-8} *cm* = 10^{-7} *mm* = 0.1 μmm

(iv) 1 micron = μm = 10^{-6} *m*

(v) 1 astronomical unit = 1 *A.U.* = 1.49×10^{11} *m*

$\approx 1.5 \times 10^{11}$ *m* $\approx 10^{8}$ *km*

(vi) 1 Light year = 1 *ly* = 9.46×10^{15} *m*

(vii) 1 *Parsec* = 1*pc* = 3.26 light year

(2) **Mass**

(i) Chandra Shekhar unit : 1 *CSU* = 1.4 times the mass of sun = 2.8×10^{30} *kg*

(ii) Metric tonne : 1 Metric tonne = 1000 *kg*

(iii) Quintal : 1 Quintal = 100 *kg*

(iv) Atomic mass unit (*amu*) : *amu* = 1.67×10^{-27} *kg*

Mass of proton or neutron is of the order of 1 *amu*

(3) **Time**

(i) Year : It is the time taken by the Earth to complete 1 revolution around the Sun in its orbit.

(ii) Lunar month : It is the time taken by the Moon to complete 1 revolution around the Earth in its orbit.

1 *L.M.* = 27.3 days

(iii) Solar day : It is the time taken by Earth to complete one rotation about its axis with respect to Sun. Since this time varies from day to day, average solar day is calculated by taking average of the duration of all the days in a year and this is called Average Solar day.

1 Solar year = 365.25 average solar day

or average solar day $= \frac{1}{365.25}$ the part of solar year

(iv) Sedrial day : It is the time taken by earth to complete one rotation about its axis with respect to a distant star.

1 Solar year = 366.25 Sedrial day

= 365.25 average solar day

Thus 1 Sedrial day is less than 1 solar day.

(v) Shake : It is an obsolete and practical unit of time.

1 Shake = 10^{-8} *sec*

Dimensions

When a derived quantity is expressed in terms of fundamental quantities, it is written as a product of different powers of the fundamental quantities. The powers to which fundamental quantities must be raised in order to express the given physical quantity are called its dimensions.

To make it more clear, consider the physical quantity force

Force = mass × acceleration

$= \frac{\text{mass} \times \text{velocity}}{\text{time}}$

$= \frac{\text{mass} \times \text{length/time}}{\text{time}}$

= mass × length × $(\text{time})^{-2}$ ... (i)

Thus, the dimensions of force are 1 in mass, 1 in length and – 2 in time.

Here the physical quantity that is expressed in terms of the basic quantities is enclosed in square brackets to indicate that the equation is among the dimensions and not among the magnitudes.

Thus equation (i) can be written as [force] = $[MLT^{-2}]$.

Such an expression for a physical quantity in terms of the fundamental quantities is called the dimensional equation. If we consider only the R.H.S. of the equation, the expression is termed as dimensional formula.

Thus, dimensional formula for force is, $[MLT^{-2}]$.

Quantities Having same Dimensions

Dimension	Quantity
$[M^0L^0T^{-1}]$	Frequency, angular frequency, angular velocity, velocity gradient and decay constant
$[ML^2T^{-2}]$	Work, internal energy, potential energy, kinetic energy, torque, moment of force
$[ML^{-1}T^{-2}]$	Pressure, stress, Young's modulus, bulk modulus, modulus of rigidity, energy density
$[MLT^{-1}]$	Momentum, impulse
$[M^0LT^{-2}]$	Acceleration due to gravity, gravitational field intensity
$[MLT^{-2}]$	Thrust, force, weight, energy gradient
$[ML^2T^{-1}]$	Angular momentum and Planck's constant
$[ML^0T^{-2}]$	Surface tension, Surface energy (energy per unit area)
$[M^0L^0T^0]$	Strain, refractive index, relative density, angle, solid angle, distance gradient, relative permittivity (dielectric constant), relative permeability etc.
$[M^0L^2T^{-2}]$	Latent heat and gravitational potential
$[ML^2T^{-2}\theta^{-1}]$	Thermal capacity, gas constant, Boltzmann constant and entropy
$[M^0L^0T^1]$	$\sqrt{l/g}, \sqrt{m/k}, \sqrt{R/g}$, where l = length g = acceleration due to gravity, m = mass, k = spring constant, R = Radius of earth
$[M^0L^0T^1]$	L/R, $\sqrt{LC}$, RC where L = inductance, R = resistance, C = capacitance
$[ML^2T^{-2}]$	$I^2Rt, \frac{V^2}{R}t, VIt, qV, LI^2, \frac{q^2}{C}, CV^2$ where I = current, t = time, q = charge, L = inductance, C = capacitance, R = resistance

Important Dimensions of Complete Physics

Heat

Quantity	Unit	Dimension
Temperature (T)	*Kelvin*	$[M^0L^0T^0\theta^1]$
Heat (Q)	*Joule*	$[ML^2T^{-2}]$
Specific Heat (c)	*Joule/kg-K*	$[M^0L^2T^{-2}\theta^{-1}]$
Thermal capacity	*Joule/K*	$[ML^2T^{-2}\theta^{-1}]$
Latent heat (L)	*Joule/kg*	$[M^0L^2T^{-2}]$
Gas constant (R)	*Joule/mol-K*	$[ML^2T^{-2}\theta^{-1}]$
Boltzmann constant (k)	*Joule/K*	$[ML^2T^{-2}\theta^{-1}]$
Coefficient of thermal conductivity (K)	*Joule/m-s-K*	$[MLT^{-3}\theta^{-1}]$
Stefan's constant (σ)	*Watt/m^2-K^4*	$[ML^0T^{-3}\theta^{-4}]$
Wien's constant (b)	*Metre-K*	$[M^0LT^0\theta]$
Planck's constant (h)	*Joule-s*	$[ML^2T^{-1}]$
Coefficient of Linear Expansion (α)	*Kelvin^{-1}*	$[M^0L^0T^0\theta^{-1}]$
Mechanical equivalent of Heat (J)	*Joule/Calorie*	$[M^0L^0T^0]$
Vander wall's constant (a)	*Newton-m^4*	$[ML^5T^{-2}]$
Vander wall's constant (b)	*m^3*	$[M^0L^3T^0]$

Electricity

Quantity	Unit	Dimension
Electric charge (q)	*Coulomb*	$[M^0L^0TA]$
Electric current (I)	*Ampere*	$[M^0L^0T^0A]$
Capacitance (C)	*Coulomb/volt or Farad*	$[M^{-1}L^{-2}T^4A^2]$
Electric potential (V)	*Joule/coulomb*	$[ML^2T^{-3}A^{-1}]$
Permittivity of free space (ε)	$\frac{Coulomb^2}{Newton - metre^2}$	$[M^{-1}L^{-3}T^4A^2]$
Dielectric constant (K)	Unitless	$[M^0L^0T^0]$
Resistance (R)	*Volt/Ampere* or *ohm*	$[ML^2T^{-3}A^{-2}]$

Quantity	Unit	Dimension
Resistivity or Specific resistance (ρ)	*Ohm-metre*	$[ML^{3}T^{-3}A^{-2}]$
Coefficient of Self-induction (L)	$\frac{volt-second}{ampere}$ or *henry* or *ohm-second*	$[ML^{2}T^{-2}A^{-2}]$
Magnetic flux (ϕ)	*Volt-second* or *weber*	$[M^{1}L^{2}T^{-2}A^{-1}]$
Magnetic induction (B)	$\frac{newton}{ampere-metre}$ $\frac{Joule}{ampere-metre^2}$ $\frac{volt-\text{second}}{metre^2}$ or *Tesla*	$[M^{1}L^{0}T^{-2}A^{-1}]$
Magnetic Intensity (H)	*Ampere/metre*	$[M^{0}L^{-1}T^{0}A^{1}]$
Magnetic Dipole Moment (M)	*Ampere-metre*	$[M^{0}L^{2}T^{0}A^{1}]$
Permeability of Free Space (μ_0)	$\frac{Newton}{ampere^2}$ or $\frac{Joule}{ampere^2-metre}$ or $\frac{Volt-\text{second}}{ampere-metre}$ or $\frac{Ohm-\text{second}}{metre}$ or $\frac{henry}{metre}$	$[M^{1}L^{1}T^{-2}A^{-2}]$
Surface charge density (σ)	$Coulomb\,metre^{-2}$	$[M^{0}L^{-2}T^{1}A^{1}]$
Electric dipole moment (p)	$Coulomb-metre$	$[M^{0}L^{1}T^{1}A^{1}]$
Conductance (G) (1/R)	ohm^{-1}	$[M^{-1}L^{-2}T^{3}A^{2}]$
Conductivity (σ) (1/ρ)	$ohm^{-1}metre^{-1}$	$[M^{-1}L^{-3}T^{3}A^{2}]$
Current density (J)	*Ampere/m²*	$M^{0}L^{-2}T^{0}A^{1}$
Intensity of electric field (E)	*Volt/metre, Newton/coulomb*	$M^{1}L^{1}T^{-3}A^{-1}$
Rydberg constant (R)	m^{-1}	$M^{0}L^{-1}T^{0}$

Application of Dimensional Analysis

(1) **To find the unit of a physical quantity in a given system of units** : To write the definition or formula for the physical quantity we find its dimensions. Now in the dimensional formula replacing *M*, *L* and *T* by the fundamental units of the required system we get the unit of physical quantity. However, sometimes to this unit we further assign a specific name,

e.g., Work = Force × Displacement

So $[W] = [MLT^{-2}] \times [L] = [ML^{2}T^{-2}]$

So its unit in C.G.S. system will be *g cm²/s²* which is called *erg* while in M.K.S. system will be *kg-m²/s²* which is called *joule*.

(2) **To find dimensions of physical constant or coefficients** : As dimensions of a physical quantity are unique, we write any formula or equation incorporating the given constant and then by substituting the dimensional formulae of all other quantities, we can find the dimensions of the required constant or coefficient.

(i) Gravitational constant : According to Newton's law of gravitation

$$F = G\frac{m_1m_2}{r^2} \text{ or } G = \frac{Fr^2}{m_1m_2}$$

Substituting the dimensions of all physical quantities

$$[G] = \frac{[MLT^{-2}][L^2]}{[M][M]} = [M^{-1}L^{3}T^{-2}]$$

(ii) Plank constant : According to Planck $E = h\nu$ or $h = \frac{E}{\nu}$

Substituting the dimensions of all physical quantities

$$[h] = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$$

(iii) Coefficient of viscosity : According to Poiseuille's formula

$$\frac{dV}{dt} = \frac{\pi pr^4}{8\eta l} \text{ or } \eta = \frac{\pi pr^4}{8l(dV/dt)}$$

Substituting the dimensions of all physical quantities

$$[\eta] = \frac{[ML^{-1}T^{-2}][L^4]}{[L][L^3/T]} = [ML^{-1}T^{-1}]$$

(3) **To convert a physical quantity from one system to the other** : The measure of a physical quantity is nu = constant

If a physical quantity *X* has dimensional formula $[M^aL^bT^c]$ and if (derived) units of that physical quantity in two systems are $[M_1^aL_1^bT_1^c]$ and $[M_2^aL_2^bT_2^c]$ respectively and n_1 and n_2 be the numerical values in the two systems respectively, then $n_1[u_1] = n_2[u_2]$

$$\Rightarrow n_1[M_1^aL_1^bT_1^c] = n_2[M_2^aL_2^bT_2^c]$$

$$\Rightarrow n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

where M_1, L_1 and T_1 are fundamental units of mass, length and time in the first (known) system and M_2, L_2 and T_2 are fundamental units of mass, length and time in the second (unknown) system. Thus knowing the values of fundamental units in two systems and numerical value in one system, the numerical value in other system may be evaluated.

Example : (i) conversion of *Newton* into *Dyne*.

The Newton is the S.I. unit of force and has dimensional formula $[MLT^{-2}]$.

So 1 *N* = 1 *kg-m/sec²*

By using $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$

$$= 1\left[\frac{kg}{gm}\right]^1\left[\frac{m}{cm}\right]^1\left[\frac{sec}{sec}\right]^{-2}$$

$$= 1\left[\frac{10^3\,gm}{gm}\right]^1\left[\frac{10^2\,cm}{cm}\right]^1\left[\frac{sec}{sec}\right]^{-2} = 10^5$$

∴ 1 *N* = 10^5 *Dyne*

(ii) Conversion of gravitational constant (*G*) from C.G.S. to M.K.S. system

The value of G in C.G.S. system is 6.67×10^{-8} C.G.S. units while its dimensional formula is $[M^{-1}L^{3}T^{-2}]$

So $G = 6.67 \times 10^{-8}\ cm^3/g\ s^2$

By using $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$

$= 6.67\times10^{-8}\left[\frac{gm}{kg}\right]^{-1}\left[\frac{cm}{m}\right]^{3}\left[\frac{sec}{sec}\right]^{-2}$

$= 6.67\times10^{-8}\left[\frac{gm}{10^3 gm}\right]^{-1}\left[\frac{cm}{10^2 cm}\right]^{3}\left[\frac{sec}{sec}\right]^{-2}$

$= 6.67\times10^{-11}$

$\therefore$ $G = 6.67 \times 10^{-11}$ M.K.S. units

(4) **To check the dimensional correctness of a given physical relation :** This is based on the '*principle of homogeneity*'. According to this principle the dimensions of each term on both sides of an equation must be the same.

If $X = A \pm (BC)^2 \pm \sqrt{DEF}$,

then according to principle of homogeneity

$[X] = [A] = [(BC)^2] = [\sqrt{DEF}]$

If the dimensions of each term on both sides are same, the equation is dimensionally correct, otherwise not. A dimensionally correct equation may or may not be physically correct.

Example : (i) $F = mv^2/r^2$

By substituting dimension of the physical quantities in the above relation, $[MLT^{-2}] = [M][LT^{-1}]^2/[L]^2$

i.e. $[MLT^{-2}] = [MT^{-2}]$

As in the above equation dimensions of both sides are not same; this formula is not correct dimensionally, so can never be physically.

(ii) $s = ut - (1/2)at^2$

By substituting dimension of the physical quantities in the above relation

$[L] = [LT^{-1}][T] - [LT^{-2}][T^2]$

i.e. $[L] = [L] - [L]$

As in the above equation dimensions of each term on both sides are same, so this equation is dimensionally correct. However, from equations of motion we know that $s = ut + (1/2)at^2$

(5) **As a research tool to derive new relations :** If one knows the dependency of a physical quantity on other quantities and if the dependency is of the product type, then using the method of dimensional analysis, relation between the quantities can be derived.

Example : (i) Time period of a simple pendulum.

Let time period of a simple pendulum is a function of mass of the bob (m), effective length (l), acceleration due to gravity (g) then assuming the function to be product of power function of m, l and g

i.e., $T = Km^x l^y g^z$; where K = dimensionless constant

If the above relation is dimensionally correct then by substituting the dimensions of quantities –

$[T] = [M]^x [L]^y [LT^{-2}]^z$ or $[M^0L^0T^1] = [M^xL^{y+z}T^{-2z}]$

Equating the exponents of similar quantities $x = 0$, $y = 1/2$ and $z = -1/2$

So the required physical relation becomes $T = K\sqrt{\frac{l}{g}}$

The value of dimensionless constant is found (2π) through experiments so $T = 2\pi\sqrt{\frac{l}{g}}$

(ii) Stoke's law : When a small sphere moves at low speed through a fluid, the viscous force F, opposes the motion, is found experimentally to depend on the radius r, the velocity of the sphere v and the viscosity η of the fluid.

So $F = f(\eta, r, v)$

If the function is product of power functions of η, r and v, $F = K\eta^x r^y v^z$; where K is dimensionless constant.

If the above relation is dimensionally correct

$[MLT^{-2}] = [ML^{-1}T^{-1}]^x[L]^y[LT^{-1}]^z$

or $[MLT^{-2}] = [M^xL^{-x+y+z}T^{-x-z}]$

Equating the exponents of similar quantities

$x = 1$; $-x + y + z = 1$ and $-x - z = -2$

Solving these for x, y and z, we get $x = y = z = 1$

So equation (i) becomes $F = K\eta rv$

On experimental grounds, $K = 6\pi$; so $F = 6\pi\eta rv$

This is the famous Stoke's law.

Limitations of Dimensional Analysis

Although dimensional analysis is very useful it cannot lead us too far as,

(1) If dimensions are given, physical quantity may not be unique as many physical quantities have same dimensions. For example if the dimensional formula of a physical quantity is $[ML^2T^{-2}]$ it may be work or energy or torque.

(2) Numerical constant having no dimensions $[K]$ such as (1/2), 1 or 2π *etc.* cannot be deduced by the methods of dimensions.

(3) The method of dimensions can not be used to derive relations other than product of power functions. For example,

$$s = ut + (1/2)at^2 \text{ or } y = a\sin\omega t$$

cannot be derived by using this theory (try if you can). However, the dimensional correctness of these can be checked.

(4) The method of dimensions cannot be applied to derive formula if in mechanics a physical quantity depends on more than 3 physical quantities as then there will be less number (= 3) of equations than the unknowns (>3). However still we can check correctness of the given equation dimensionally. For example $T = 2\pi\sqrt{I/mgl}$ can not be derived by theory of dimensions but its dimensional correctness can be checked.

(5) Even if a physical quantity depends on 3 physical quantities, out of which two have same dimensions, the formula cannot be derived by theory of dimensions, *e.g.*, formula for the frequency of a tuning fork $f = (d / L^2) v$ cannot be derived by theory of dimensions but can be checked.

Significant Figures

Significant figures in the measured value of a physical quantity tell the number of digits in which we have confidence. Larger the number of significant figures obtained in a measurement, greater is the accuracy of the measurement. The reverse is also true.

The following rules are observed in counting the number of significant figures in a given measured quantity.

(1) All non-zero digits are significant.

Example : 42.3 has three significant figures.

243.4 has four significant figures.

24.123 has five significant figures.

(2) A zero becomes significant figure if it appears between two non-zero digits.

Example : 5.03 has three significant figures.

5.604 has four significant figures.

4.004 has four significant figures.

(3) Leading zeros or the zeros placed to the left of the number are never significant.

Example : 0.543 has three significant figures.

0.045 has two significant figures.

0.006 has one significant figure.

(4) Trailing zeros or the zeros placed to the right of the number are significant.

Example : 4.330 has four significant figures.

433.00 has five significant figures.

343.000 has six significant figures.

(5) In exponential notation, the numerical portion gives the number of significant figures.

Example : 1.32×10^{-2} has three significant figures.

1.32×10^{4} has three significant figures.

Rounding Off

While rounding off measurements, we use the following rules by convention:

(1) If the digit to be dropped is less than 5, then the preceding digit is left unchanged.

Example : $x = 7.82$ is rounded off to 7.8,

again $x = 3.94$ is rounded off to 3.9.

(2) If the digit to be dropped is more than 5, then the preceding digit is raised by one.

Example : x = 6.87 is rounded off to 6.9,

again x = 12.78 is rounded off to 12.8.

(3) If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is raised by one.

Example : x = 16.351 is rounded off to 16.4,

again x = 6.758 is rounded off to 6.8.

(4) If digit to be dropped is 5 or 5 followed by zeros, then preceding digit is left unchanged, if it is even.

Example : x = 3.250 becomes 3.2 on rounding off,

again x = 12.650 becomes 12.6 on rounding off.

(5) If digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd.

Example : x = 3.750 is rounded off to 3.8,

again x = 16.150 is rounded off to 16.2.

Significant Figures in Calculation

In most of the experiments, the observations of various measurements are to be combined mathematically, *i.e.*, added, subtracted, multiplied or divided to achieve the final result. Since, all the observations in measurements do not have the same precision, it is natural that the final result cannot be more precise than the least precise measurement. The following two rules should be followed to obtain the proper number of significant figures in any calculation.

(1) The result of an addition or subtraction in the number having different precisions should be reported to the same number of decimal places as present in the number having the least number of decimal places. The rule is illustrated by the following examples :

(i)
33.3 ← (has only one decimal place)
3.11
+ 0.313
36.723 ← (answer should be reported to one decimal place)

Answer = 36.7

(ii)
3.1421
0.241
+ 0.09 ← (has 2 decimal places)
3.4731 ← (answer should be reported to 2 decimal places)

Answer = 3.47

(iii)
62.831 ← (has 3 decimal places)
− 24.5492
38.2818 ← (answer should be reported to 3 decimal places after rounding off)

Answer = 38.282

(2) The answer to a multiplication or division is rounded off to the same number of significant figures as possessed by the least precise term used in the calculation. The rule is illustrated by the following examples :

(i)
142.06
× 0.23 ← (two significant figures)
32.6738 ← (answer should have two significant figures)

Answer = 33

(ii)
51.028
× 1.31 ← (three significant figures)
66.84668

Answer = 66.8

(iii) $\frac{0.90}{4.26} = 0.2112676$

Answer = 0.21

Order of Magnitude

In scientific notation the numbers are expressed as, Number $= M \times 10^x$. Where M is a number lies between 1 and 10 and x is integer. Order of magnitude of quantity is the power of 10 required to represent the quantity. For determining this power, the value of the quantity has to be rounded off. While rounding off, we ignore the last digit which is less than 5. If the last digit is 5 or more than five, the preceding digit is increased by one. For example,

(1) Speed of light in vacuum

$= 3 \times 10^8 ms^{-1} \approx 10^8 m/s$ (ignoring 3 < 5)

(2) Mass of electron $= 9.1 \times 10^{-31} kg \approx 10^{-30} kg$ (as 9.1 > 5).

Errors of Measurement

The measuring process is essentially a process of comparison. Inspite of our best efforts, the measured value of a quantity is always somewhat different from its actual value, or true value. This difference in the true value and measured value of a quantity is called error of measurement.

(1) **Absolute error :** Absolute error in the measurement of a physical quantity is the magnitude of the difference between the true value and the measured value of the quantity.

Let a physical quantity be measured n times. Let the measured value be $a_1, a_2, a_3, \ldots\ldots a_n$. The arithmetic mean of these value is $a_m = \frac{a_1 + a_2 + \ldots\ldots + a_n}{n}$

Usually, a_m is taken as the true value of the quantity, if the same is unknown otherwise.

By definition, absolute errors in the measured values of the quantity are

$$\Delta a_1 = a_m - a_1$$

$$\Delta a_2 = a_m - a_2$$

....

$$\Delta a_n = a_m - a_n$$

The absolute errors may be positive in certain cases and negative in certain other cases.

(2) **Mean absolute error :** It is the arithmetic mean of the magnitudes of absolute errors in all the measurements of the quantity. It is represented by $\overline{\Delta a}$. Thus

$$\overline{\Delta a} = \frac{|\Delta a_1| + |\Delta a_2| + \ldots\ldots |\Delta a_n|}{n}$$

Hence the final result of measurement may be written as $a = a_m \pm \overline{\Delta a}$

This implies that any measurement of the quantity is likely to lie between $(a_m + \overline{\Delta a})$ and $(a_m - \overline{\Delta a})$.

(3) **Relative error or Fractional error :** The relative error or fractional error of measurement is defined as the ratio of mean absolute error to the mean value of the quantity measured. Thus

Relative error or Fractional error $= \frac{\text{Mean absolute error}}{\text{Mean value}} = \frac{\overline{\Delta a}}{a_m}$

(4) **Percentage error :** When the relative/fractional error is expressed in percentage, we call it percentage error. Thus

Percentage error $= \frac{\overline{\Delta a}}{a_m} \times 100\%$

Propagation of Errors

(1) **Error in sum of the quantities :** Suppose $x = a + b$

Let Δa = absolute error in measurement of a

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x

i.e. sum of a and b.

The maximum absolute error in x is $\Delta x = \pm(\Delta a + \Delta b)$

Percentage error in the value of $x = \frac{(\Delta a + \Delta b)}{a + b} \times 100\%$

(2) **Error in difference of the quantities :** Suppose $x = a - b$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* difference of a and b.

The maximum absolute error in x is $\Delta x = \pm(\Delta a + \Delta b)$

Percentage error in the value of $x = \frac{(\Delta a + \Delta b)}{a - b} \times 100\%$

(3) **Error in product of quantities :**

Suppose $x = a \times b$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* product of a and b.

The maximum fractional error in x is $\frac{\Delta x}{x} = \pm\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right)$

Percentage error in the value of x

= (% error in value of a) + (% error in value of b)

(4) **Error in division of quantities :** Suppose $x = \frac{a}{b}$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* division of a and b.

The maximum fractional error in x is $\frac{\Delta x}{x} = \pm\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right)$

Percentage error in the value of x

= (% error in value of a) + (% error in value of b)

(5) **Error in quantity raised to some power :** Suppose $x = \frac{a^n}{b^m}$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x

The maximum fractional error in x is $\frac{\Delta x}{x} = \pm\left(n\frac{\Delta a}{a} + m\frac{\Delta b}{b}\right)$

Percentage error in the value of x

= n (% error in value of a) + m (%error in value of b)

Tips & Tricks

✍ The standard of Weight and Measures Act was passed in India in 1976. It recommended the use of SI in all fields of science, technology, trade and industry.

✍ The dimensions of many physical quantities, especially those in heat, thermodynamics, electricity and magnetism in terms of mass, length and time alone become irrational. Therefore, SI is adopted which uses 7 basic units.

✍ The dimensions of a physical quantity are the powers to which basic units (not fundamental units alone) should be raised to represent the derived unit of that physical quantity.

- The dimensional formula is very helpful in writing the unit of a physical quantity in terms of the basic units.
- The dimensions of a physical quantity do not depend on the system of units.
- A physical quantity that does not have any unit must be dimensionless.
- The pure numbers are dimensionless.
- Generally, the symbols of those basic units, whose dimension (power) in the dimensional formula is zero, are omitted from the dimensional formula.
- It is wrong to say that the dimensions of force are MLT^{-2}. On the other hand we should say that the dimensional formula for force is MLT^{-2} and that the dimensions of force are 1 in mass, 1 in length and –2 in time.
- Physical quantities defined as the ratio of two similar quantities are dimensionless.
- The physical relation involving logarithm, exponential, trigonometric ratios, numerical factors etc. cannot be derived by the method of dimensional analysis.
- Physical relations involving addition or subtraction sign cannot be derived by the method of dimensional analysis.
- If units or dimensions of two physical quantities are same, these need not represent the same physical characteristics. For example torque and work have the same units and dimensions but their physical characteristics are different.
- The standard units must not change with space and time. That is why atomic standard of length and time have been defined. Attempts are being made to define the atomic standard for mass as well.
- The unit of time, the second, was initially defined in terms of the rotation of the earth around the sun as well as that about its own axis. This time standard is subjected to variation with time. Therefore, the atomic standard of time has been defined.
- Any repetitive phenomenon, such as an oscillating pendulum, spinning of earth about its axis, etc can be used to measure time.
- The product of numerical value of the physical quantity (n) and its unit (U) remains constant.

That is : nU = constant or $n_1U_1 = n_2U_2$.

- The product of numerical value (n) and unit (U) of a physical quantity is called magnitude of the physical quantity.

Thus : Magnitude = nU

- Poiseuille (unit of viscosity) = pascal (unit of pressure) × second. That is : $Pl : Pa\text{-}s$.
- The unit of power of lens (dioptre) gives the ability of the lens to converge or diverge the rays refracted through it.
- The order of magnitude of a quantity means its value (in suitable power of 10) nearest to the actual value of the quantity.
- Angle is exceptional physical quantity, which though is a ratio of two similar physical quantities (angle = arc / radius) but still requires a unit (degrees or radians) to specify it along with its numerical value.
- Solid angle subtended at a point inside the closed surface is 4π steradian.
- A measurement of a physical quantity is said to be accurate if the systematic error in its measurement is relatively very low. On the other hand, the measurement of a physical quantity is said to be precise if the random error is small.
- A measurement is most accurate if its observed value is very close to the true value.
- Errors are always additive in nature.
- For greater accuracy, the quantity with higher power should have least error.
- The absolute error in each measurement is equal to the least count of the measuring instrument.
- Percentage error = relative error × 100.
- The unit and dimensions of the absolute error are same as that of quantity itself.
- Absolute error is not dimensionless quantity.
- Relative error is dimensionless quantity.
- Least Count = $\dfrac{\text{value of 1 part on main scale}(s)}{\text{Number of parts on vernier scale}(n)}$
- Least count of vernier callipers

$$= \begin{Bmatrix}\text{value of 1 part of} \\ \text{main scale}(s)\end{Bmatrix} - \begin{Bmatrix}\text{value of 1 part of} \\ \text{vernier scale}(v)\end{Bmatrix}$$

$\Rightarrow$ Least count of vernier calliper = 1 MSD – 1 VSD

where MSD = Main Scale Division

VSD = Vernier Scale Division

- Least count of screw guaze = $\dfrac{\text{Pitch}(p)}{\text{No. of parts on circular scale}(n)}$
- Smaller the least count, higher is the accuracy of measurement.
- Larger the number of significant figures after the decimal in a measurement, higher is the accuracy of measurement.
- Significant figures do not change if we measure a physical quantity in different units.
- Significant figures retained after mathematical operation (like addition, subtraction, multiplication and division) should be equal to the minimum significant figures involved in any physical quantity in the given operation.
- Significant figures are the number of digits upto which we are sure about their accuracy.
- If a number is without a decimal and ends in one or more zeros, then all the zeros at the end of the number may not be significant. To make the number of significant figures clear, it is suggested that the number may be written in exponential form. For example 20300 may be expressed as 203.00×10^2, to suggest that all the zeros at the end of 20300 are significant.
- 1 $inch$ = 2.54 cm

1 $foot$ = 12 $inches$ = 30.48 cm = 0.3048 m

1 $mile$ = 5280 ft = 1.609 km

- 1 $yard$ = 0.9144 m

- 1 $slug = 14.59\ kg$
- 1 $barn = 10^{-28}\ m^2$
- 1 $liter = 10^3\ cm^3 = 10^{-3}\ m^3$
- 1 $km/h = \frac{5}{18}\ m/s$

  1 $m/s = 3.6\ km/h$
- 1 $g/cm^3 = 1000\ kg/m^3$
- 1 $atm. = 76\ cm$ of $Hg = 1.013 \times 10^5\ N/m^2$

  1 $N/m^2 = Pa\ (Pascal)$
- When we add or subtract two measured quantities, the absolute error in the final result is equal to the sum of the absolute errors in the measured quantities.
- When we multiply or divide two measured quantities, the relative error in the final result is equal to the sum of the relative errors in the measured quantities.

Ordinary Thinking

Objective Questions

Units

1. Light year is a unit of [MP PMT 1989; CPMT 1991; AFMC 1991,2005]
   (a) Time (b) Mass
   (c) Distance (d) Energy
2. The magnitude of any physical quantity
   (a) Depends on the method of measurement
   (b) Does not depend on the method of measurement
   (c) Is more in SI system than in CGS system
   (d) Directly proportional to the fundamental units of mass, length and time
3. Which of the following is not equal to *watt* [SCRA 1991; CPMT 1990]
   (a) *Joule/second* (b) *Ampere* × *volt*
   (c) $(Ampere)^2 \times ohm$ (d) *Ampere/volt*
4. Newton–*second* is the unit of [CPMT 1984, 85; MP PMT 1984]
   (a) Velocity (b) Angular momentum
   (c) Momentum (d) Energy
5. Which of the following is not represented in correct unit [NCERT 1984; MNR 1995]
   (a) $\frac{\text{Stress}}{\text{Strain}} = N/m^2$ (b) Surface tension $= N/m$
   (c) Energy $= kg\text{-}m/\sec$ (d) Pressure $= N/m^2$
6. One *second* is equal to [MNR 1986]
   (a) 1650763.73 time periods of Kr clock
   (b) 652189.63 time periods of Kr clock
   (c) 1650763.73 time periods of Cs clock
   (d) 9192631770 time periods of Cs clock
7. One nanometre is equal to [SCRA 1986; MNR 1986]
   (a) $10^9 mm$ (b) $10^{-6}\ cm$
   (c) $10^{-7} cm$ (d) $10^{-9} cm$
8. A *micron* is related to centimetre as
   (a) $1\,micron = 10^{-8} cm$ (b) $1\,micron = 10^{-6} cm$
   (c) $1\,micron = 10^{-5} cm$ (d) $1\,micron = 10^{-4}\ cm$
9. The unit of power is [CPMT 1985]
   (a) *Joule*
   (b) *Joule* per *second* only
   (c) *Joule* per *second* and *watt* both
   (d) Only *watt*
10. A suitable unit for gravitational constant is [MNR 1988]
    (a) $kg\text{-}m\sec^{-1}$ (b) $N\ m^{-1}\sec$
    (c) $N\ m^2\ kg^{-2}$ (d) $kg\,m\sec^{-1}$
11. SI unit of pressure is [EAMCET 1980; DPMT 1984; CBSE PMT 1988; NCERT 1976; AFMC 1991; USSR MEE 1991]
    (a) *Pascal* (b) $Dynes/cm^2$
    (c) cm of Hg (d) *Atmosphere*
12. The unit of angular acceleration in the SI system is [SCRA 1980; EAMCET 1981]
    (a) $N\,kg^{-1}$ (b) $m\,s^{-2}$
    (c) $rad\,s^{-2}$ (d) $m\,kg^{-1}K$
13. The unit of Stefan's constant σ is [AFMC 1986; MP PET 1992; MP PMT 1992; CBSE PMT 2002]
    (a) $W\,m^{-2}\,K^{-1}$ (b) $W\,m^2\,K^{-4}$
    (c) $W\,m^{-2}\,K^{-4}$ (d) $W\,m^{-2}\,K^4$
14. Which of the following is not a unit of energy [AIIMS 1985]
    (a) $W\text{-}s$ (b) $kg\text{-}m/\sec$
    (c) $N\text{-}m$ (d) *Joule*
15. In $S = a + bt + ct^2$. S is measured in metres and t in *seconds*. The unit of c is [MP PMT 1993]
    (a) None (b) m
    (c) ms^{-1} (d) ms^{-2}
16. *Joule-second* is the unit of [CPMT 1990; CBSE PMT 1993; BVP 2003]
    (a) Work (b) Momentum
    (c) Pressure (d) Angular momentum
17. Unit of energy in SI system is [CPMT 1971; NCERT 1976]
    (a) *Erg* (b) *Calorie*
    (c) *Joule* (d) Electron *volt*
18. A cube has numerically equal volume and surface area. The volume of such a cube is [CPMT 1971, 74]
    (a) 216 *units* (b) 1000 *units*
    (c) 2000 *units* (d) 3000 *units*
19. Wavelength of ray of light is $0.00006\,m$. It is equal to [CPMT 1977]
    (a) $6\ microns$ (b) $60\ microns$
    (c) $600\ microns$ (d) $0.6\ microns$
20. Electron *volt* is a unit of [MP PMT 1993]
    (a) Charge (b) Potential difference
    (c) Momentum (d) Energy
21. Temperature can be expressed as a derived quantity in terms of any of the following [MP PET 1993; UPSEAT 2001]
    (a) Length and mass
    (b) Mass and time
    (c) Length, mass and time
    (d) None of these
22. Unit of power is [NCERT 1972; CPMT 1971; DCE 1999]

(a) *Kilowatt* (b) *Kilowatt-hour*
(c) *Dyne* (d) *Joule*

23. Density of wood is $0.5 gm/cc$ in the CGS system of units. The corresponding value in MKS units is [CPMT 1983; NCERT 1973; JIPMER 1993]
(a) 500 (b) 5
(c) 0.5 (d) 5000

24. Unit of energy is [NCERT 1974; CPMT 1975]
(a) $J/\sec$ (b) $Watt-day$
(c) $Kilowatt$ (d) $gm\text{-}cm/\sec^2$

25. Which is the correct unit for measuring nuclear radii
(a) *Micron* (b) *Millimetre*
(c) *Angstrom* (d) *Fermi*

26. One Mach number is equal to
(a) Velocity of light
(b) Velocity of sound $(332\ m/\sec)$
(c) $1\ km/\sec$
(d) $1\ m/\sec$

27. The unit for nuclear dose given to a patient is
(a) *Fermi* (b) Rutherford
(c) Curie (d) Roentgen

28. *Volt/metre* is the unit of [AFMC 1991; CPMT 1984]
(a) Potential (b) Work
(c) Force (d) Electric intensity

29. $Newton/metre^2$ is the unit of [CPMT 1985; ISM Dhanbad 1994; AFMC 1995]
(a) Energy (b) Momentum
(c) Force (d) Pressure

30. The unit of surface tension in SI system is [MP PMT 1984; AFMC 1986; CPMT 1985, 87; CBSE PMT 1993; KCET 1999; DCE 2000, 01]
(a) $Dyne/cm^2$ (b) $Newton/m$
(c) $Dyne/cm$ (d) $Newton/m^2$

31. The unit of reduction factor of tangent galvanometer is [CPMT 1987; AFMC 2004]
(a) *Ampere* (b) *Gauss*
(c) *Radian* (d) None of these

32. The unit of self inductance of a coil is [MP PMT 1983, 92; SCRA 1986; CBSE PMT 1993; CPMT 1984, 85, 87]
(a) *Farad* (b) *Henry*
(c) *Weber* (d) *Tesla*

33. *Henry/ohm* can be expressed in [CPMT 1987]
(a) *Second* (b) *Coulomb*
(c) *Mho* (d) *Metre*

34. The SI unit of momentum is [SCRA 1986, 89; CPMT 1987]
(a) $\frac{kg}{m}$ (b) $\frac{kg.m}{\sec}$
(c) $\frac{kg.m^2}{\sec}$ (d) $kg \times Newton$

35. The velocity of a particle depends upon as $v = a + bt + ct^2$; if the velocity is in $m/\sec$, the unit of a will be [CPMT 1990]
(a) $m/\sec$ (b) $m/\sec^2$
(c) $m^2/\sec$ (b) $m/\sec^3$

36. One million electron *volt* $(1\ MeV)$ is equal to [JIPMER 1993, 97]
(a) $10^5 eV$ (b) $10^6 eV$
(c) $10^4 eV$ (d) $10^7 eV$

37. $Erg - m^{-1}$ can be the unit of measure for [DCE 1993]
(a) Force (b) Momentum
(c) Power (d) Acceleration

38. The unit of potential energy is [AFMC 1991]
(a) $g(cm/\sec^2)$ (b) $g(cm/\sec)^2$
(c) $g(cm^2/\sec)$ (d) $g(cm/\sec)$

39. Which of the following represents a *volt* [CPMT 1990; AFMC 1991]
(a) *Joule/second* (b) *Watt/Ampere*
(c) *Watt/Coulomb* (d) *Coulomb/Joule*

40. $Kilowatt-hour$ is a unit of [NCERT 1975; AFMC 1991]
(a) Electrical charge (b) Energy
(c) Power (d) Force

41. What is the SI unit of permeability [CBSE PMT 1993]
(a) *Henry* per *metre*
(b) Tesla *metre* per *ampere*
(c) *Weber* per *ampere metre*
(d) All the above units are correct

42. In which of the following systems of unit, $Weber$ is the unit of magnetic flux [SCRA 1991; CBSE PMT 1993; DPMT 2005]
(a) CGS (b) MKS
(c) SI (d) None of these

43. Tesla is a unit for measuring [CBSE PMT 1993]
(a) Magnetic moment (b) Magnetic induction
(c) Magnetic intensity (d) Magnetic pole strength

44. If the unit of length and force be increased four times, then the unit of energy is [Kerala PMT 2005]
(a) Increased 4 times (b) Increased 8 times
(c) Increased 16 times (d) Decreased 16 times

45. Oersted is a unit of [SCRA 1989]
(a) Dip (b) Magnetic intensity
(c) Magnetic moment (d) Pole strength

46. $Ampere - hour$ is a unit of [SCRA 1980, 89; ISM Dhanbad 1994]
(a) Quantity of electricity
(b) Strength of electric current
(c) Power
(d) Energy

47. The unit of specific resistance is [SCRA 1989; MP PET 1984; CPMT 1975]
(a) Ohm/cm^2 (b) Ohm/cm
(c) $Ohm\text{–}cm$ (d) $(Ohm\text{–}cm)^{-1}$

48. The binding energy of a nucleon in a nucleus is of the order of a few [SCRA 1979]

(a) eV (b) $Ergs$
(c) MeV (d) $Volts$

49. $Parsec$ is a unit of [SCRA 1986; BVP 2003; AIIMS 2005]
(a) Distance (b) Velocity
(c) Time (d) Angle

50. If u_1 and u_2 are the units selected in two systems of measurement and n_1 and n_2 their numerical values, then [SCRA 1986]
(a) $n_1u_1 = n_2u_2$ (b) $n_1u_1 + n_2u_2 = 0$
(c) $n_1n_2 = u_1u_2$ (d) $(n_1 + u_1) = (n_2 + u_2)$

51. $1\,eV$ is [SCRA 1986]
(a) Same as one *joule* (b) $1.6 \times 10^{-19}\,J$
(c) $1V$ (d) $1.6 \times 10^{-19}\,C$

52. $1kWh =$ [AFMC 1986; SCRA 1986, 91]
(a) $1000W$ (b) $36 \times 10^5\,J$
(c) $1000J$ (d) $3600\,J$

53. Universal time is based on [SCRA 1989]
(a) Rotation of the earth on its axis
(b) Earth's orbital motion around the earth
(c) Vibrations of cesium atom
(d) Oscillations of quartz crystal

54. The nuclear cross-section is measured in barn, it is equal to
(a) $10^{-20}\,m^2$ (b) $10^{-30}\,m^2$
(c) $10^{-28}\,m^2$ (d) $10^{-14}\,m^2$

55. Unit of moment of inertia in MKS system [MP PMT 1984]
(a) $kg \times cm^2$ (b) kg/cm^2
(c) $kg \times m^2$ (d) $Joule \times m$

56. Unit of stress is [MP PMT 1984]
(a) N/m (b) $N\text{–}m$
(c) N/m^2 (d) $N\text{–}m^2$

57. Unit of Stefan's constant is [MP PMT 1989]
(a) $J\,s^{-1}$ (b) $J\,m^{-2}s^{-1}K^{-4}$
(c) $J\,m^{-2}$ (d) $J\,s$

58. Unit of magnetic moment is [MP PET 1989]
(a) $Ampere\text{–}metre^2$ (b) $Ampere\text{–}metre$
(c) $Weber\text{–}metre^2$ (c) $Weber/metre$

59. Curie is a unit of [CBSE PMT 1992; CPMT 1992]
(a) Energy of γ-rays (b) Half life
(c) Radioactivity (d) Intensity of γ-rays

60. Hertz is the unit for [MNR 1983; SCRA 1983; RPMT 1999]
(a) Frequency (b) Force
(c) Electric charge (d) Magnetic flux

61. One pico *Farad* is equal to
(a) $10^{-24}\,F$ (b) $10^{-18}\,F$
(c) $10^{-12}\,F$ (d) $10^{-6}\,F$

62. In SI, *Henry* is the unit of [MP PET 1984; CBSE PMT 1993; DPMT 1984]
(a) Self inductance (b) Mutual inductance
(c) (a) and (b) both (d) None of the above

63. The unit of $e.m.f.$ is [CPMT 1986; AFMC 1986]
(a) *Joule* (b) *Joule-Coulomb*
(c) *Volt–Coulomb* (d) *Joule/Coulomb*

64. Which of the following is not the unit of time [CPMT 1991; NCERT 1990; DPMT 1987; AFMC 1996]
(a) Micro *second* (b) Leap year
(c) Lunar months (d) Parallactic *second*
(e) Solar day

65. Unit of self inductance is [MP PET 1982]
(a) $\dfrac{Newton\text{ - }second}{Coulomb \times Ampere}$ (b) $\dfrac{Joule/Coulomb \times Second}{Ampere}$
(c) $\dfrac{Volt \times metre}{Coulomb}$ (d) $\dfrac{Newton \times metre}{Ampere}$

66. To determine the Young's modulus of a wire, the formula is $Y = \dfrac{F}{A} \times \dfrac{L}{\Delta L}$; where L = length, A = area of cross-section of the wire, ΔL = change in length of the wire when stretched with a force F. The conversion factor to change it from CGS to MKS system is
(a) 1 (b) 10
(c) 0.1 (d) 0.01

67. Young's modulus of a material has the same units as [MP PMT 1994]
(a) Pressure (b) Strain
(c) Compressibility (d) Force

68. One yard in SI units is equal [MP PMT 1995]
(a) 1.9144 $metre$ (b) 0.9144 $metre$
(c) 0.09144 $kilometre$ (d) 1.0936 $kilometre$

69. Which of the following is smallest unit [AFMC 1996]
(a) *Millimetre* (b) *Angstrom*
(c) *Fermi* (d) *Metre*

70. Which one of the following pairs of quantities and their units is a proper match
(a) Electric field – $Coulomb/m$
(b) Magnetic flux – $Weber$
(c) Power – *Farad*
(d) Capacitance – *Henry*

71. The units of modulus of rigidity are [MP PMT 1997]
(a) $N\text{–}m$ (b) N/m
(c) $N\text{–}m^2$ (d) N/m^2

72. The unit of absolute permittivity is [CMEET Bihar 1995]
(a) Fm (*Farad*-meter) (b) Fm^{-1} (*Farad*/meter)
(c) Fm^{-2} (*Farad*/ $metre^2$) (d) F (*Farad*)
(e) None of these

73. Match List-I with List-II and select the correct answer using the codes given below the lists [SCRA 1994]

List-I	List-II
I. *Joule*	A. *Henry* × *Amp/sec*
II. *Watt*	B. *Farad* × *Volt*
III. *Volt*	C. *Coulomb* × *Volt*

IV. *Coulomb* D. *Oersted* × *cm*

E. *Amp* × *Gauss*

F. Amp^2 × *Ohm*

Codes:

(a) $I-A, II-F, III-E, IV-D$

(b) $I-C, II-F, III-A, IV-B$

(c) $I-C, II-F, III-A, IV-E$

(d) $I-B, II-F, III-A, IV-C$

74. Which relation is wrong [RPMT 1997]

(a) 1 *Calorie* = 4.18 *Joules*

(b) $1\text{Å} = 10^{-10}\, m$

(c) $1\ MeV = 1.6 \times 10^{-13}\ Joules$

(d) $1\ Newton = 10^{-5}\ Dynes$

75. If $x = at + bt^2$, where x is the distance travelled by the body in kilometres while t is the time in seconds, then the units of b are

(a) km/s (b) $km\text{–}s$

(c) km/s^2 (d) $km\text{–}s^2$

76. The equation $\left(P + \frac{a}{V^2}\right)$ $(V - b)$ constant. The units of a are

(a) $Dyne \times cm^5$ (b) $Dyne \times cm^4$

(c) $Dyne/cm^3$ (d) $Dyne/cm^2$

77. Which of the following quantity is expressed as force per unit area

(a) Work (b) Pressure

(c) Volume (d) Area

78. Match List-I with List-II and select the correct answer by using the codes given below the lists [NDA 1995]

List-I	List-II
(a) Distance between earth and stars	1. Microns
(b) Inter-atomic distance in a solid	2. Angstroms
(c) Size of the nucleus	3. Light years
(d) Wavelength of infrared laser	4. *Fermi*
	5. Kilometres

Codes

	a	b	c	d		a	b	c	d
(a)	5	4	2	1	(b)	3	2	4	1
(c)	5	2	4	3	(d)	3	4	1	2

79. Unit of impulse is [CPMT 1997]

(a) Newton (b) $kg\text{–}m$

(c) $kg\text{–}m/s$ (d) *Joule*

80. Which is not a unit of electric field [UPSEAT 1999]

(a) NC^{-1} (b) Vm^{-1}

(c) JC^{-1} (d) $JC^{-1}m^{-1}$

81. The correct value of $0^o C$ on the Kelvin scale is [UPSEAT 2000]

(a) $273.15 K$ (b) $272.85 K$

(c) $273 K$ (d) $273.2 K$

82. 'Torr' is the unit of [RPMT 1999, 2000]

(a) Pressure (b) Volume

(c) Density (d) Flux

83. Which of the following is a derived unit [BHU 2000]

(a) Unit of mass (b) Unit of length

(c) Unit of time (d) Unit of volume

84. *Dyne/cm* is not a unit of [RPET 2000]

(a) Pressure (b) Stress

(c) Strain (d) Young's modulus

85. The units of angular momentum are [MP PMT 2000]

(a) $kg\text{–}m^2/s^2$ (b) $Joule\text{–}s$

(c) $Joule/s$ (d) $kg\text{–}m\text{–}s^2$

86. Which of the following is not the unit of energy [MP PET 2000]

(a) *Calorie* (b) *Joule*

(c) Electron *volt* (d) *Watt*

87. Which of the following is not a unit of time [UPSEAT 2001] [CBSE PMT 1993]

(a) *Leap year* (b) *Micro second*

(c) *Lunar month* (d) *Light year*

88. The S.I. unit of gravitational potential is [AFMC 2001]

(a) J [MNR 1995; AFMC 1995] (b) $J\text{-}kg^{-1}$

(c) $J\text{-}kg$ (d) $J\text{-}kg^{-2}$

89. Which one of the following is not a unit of young's modulus [KCET 2005]

(a) Nm [AFMC 1995] (b) Nm^{-2}

(c) $Dyne\ cm^{-2}$ (d) Mega Pascal

90. In C.G.S. system the magnitutde of the force is 100 *dynes*. In another system where the fundamental physical quantities are kilogram, *metre* and minute, the magnitude of the force is

(a) 0.036 (b) 0.36

(c) 3.6 (d) 36

91. The unit of L/R is (where L = inductance and R = resistance)

(a) sec (b) $\sec^{-1}$

(c) *Volt* (d) *Ampere*

92. Which is different from others by units [Orissa JEE 2002]

(a) Phase difference (b) Mechanical equivalent

(c) Loudness of sound (d) Poisson's ratio

93. Length cannot be measured by [AIIMS 2002]

(a) *Fermi* (b) Debye

(c) *Micron* (d) *Light year*

94. The value of Planck's constant is [CBSE PMT 2002]

(a) 6.63×10^{-34} *J*-sec (b) 6.63×10^{34} *J*/sec

(c) $6.63 \times 10^{-34}\ kg\text{-}m^2$ (d) $6.63 \times 10^{34}\ kg$/sec

95. A physical quantity is measured and its value is found to be nu where $n =$ numerical value and $u =$ unit. Then which of the following relations is true [RPET 2003]

(a) $n \propto u^2$ (b) $n \propto u$

(c) $n \propto \sqrt{u}$ (d) $n \propto \frac{1}{u}$

96. *Faraday* is the unit of [AFMC 2003]

(a) Charge (b) emf
(c) Mass (d) Energy

97. *Candela* is the unit of [UPSEAT 1999; CPMT 2003]
(a) Electric intensity (b) Luminous intensity
(c) Sound intensity (d) None of these

98. The unit of reactance is [MP PET 2003]
(a) *Ohm* (b) *Volt*
(c) *Mho* (d) *Newton*

99. The unit of Planck's constant is [RPMT 1999; MP PET 2003; Pb. PMT 2004]
(a) *Joule* (b) *Joule*/s
(c) *Joule*/*m* (d) *Joule*-s

100. Number of base SI units is [MP PET 2003]
(a) 4 (b) 7
(c) 3 (d) 5

101. SI unit of permittivity is [KCET 2004]
(a) $C^2m^2N^{-1}$ (b) $C^{-1}m^2N^{-2}$
(c) $C^2m^2N^2$ (d) $C^2m^{-2}N^{-1}$

102. Which does not has the same unit as others [Orissa PMT 2004]
(a) *Watt-sec* (b) *Kilowatt-hour*
(c) *eV* (d) *J-sec*

103. Unit of surface tension is [Orissa PMT 2004]
(a) Nm^{-1} (b) Nm^{-2}
(c) N^2m^{-1} (d) Nm^{-3}

104. Which of the following system of units is not based on units of mass, length and time alone [Kerala PMT 2004]
(a) SI (b) MKS
(c) FPS (d) CGS

105. The unit of the coefficient of viscosity in S.I. system is [J & K CET 2004]
(a) $m/kg\text{-}s$ (b) $m\text{-}s/kg^2$
(c) $kg/m\text{-}s^2$ (d) $kg/m\text{-}s$

106. The unit of Young's modulus is [Pb. PET 2001]
(a) Nm^2 (b) Nm^{-2}
(c) Nm (d) Nm^{-1}

107. One femtometer is equivalent to [DCE 2004]
(a) $10^{15}\ m$ (b) $10^{-15}\ m$
(c) $10^{-12}\ m$ (d) $10^{12}\ m$

108. How many wavelength of Kr^{86} are there in one *metre* [MNR 1985; UPSEAT 2000; Pb. PET 2004]
(a) 1553164.13 (b) 1650763.73
(c) 652189.63 (d) 2348123.73

109. Which of the following pairs is wrong [AFMC 2003]
(a) Pressure-Baromter
(b) Relative density-Pyrometer
(c) Temperature-Thermometer
(d) Earthquake-Seismograph

Dimensions

1. Select the pair whose dimensions are same
(a) Pressure and stress
(b) Stress and strain
(c) Pressure and force
(d) Power and force

2. Dimensional formula $ML^{-1}T^{-2}$ does not represent the physical quantity [Manipal MEE 1995]
(a) Young's modulus of elasticity
(b) Stress
(c) Strain
(d) Pressure

3. Dimensional formula ML^2T^{-3} represents [EAMCET 1981; MP PMT 1996, 2001]
(a) Force (b) Power
(c) Energy (d) Work

4. The dimensions of *calorie* are [CPMT 1985]
(a) ML^2T^{-2} (b) MLT^{-2}
(c) ML^2T^{-1} (d) ML^2T^{-3}

5. Whose dimensions is ML^2T^{-1} [CPMT 1989]
(a) Torque (b) Angular momentum
(c) Power (d) Work

6. If L and R are respectively the inductance and resistance, then the dimensions of $\frac{L}{R}$ will be [CPMT 1986; CBSE PMT 1988; Roorkee 1995; MP PET/PMT 1998; DCE 2002]
(a) $M^0L^0T^{-1}$
(b) M^0LT^0
(c) M^0L^0T
(d) Cannot be represented in terms of M, L and T

7. Which pair has the same dimensions [EAMCET 1982; CPMT 1984, 85; Pb. PET 2002; MP PET 1985]
(a) Work and power
(b) Density and relative density
(c) Momentum and impulse
(d) Stress and strain

8. If C and R represent capacitance and resistance respectively, then the dimensions of RC are [CPMT 1981, 85; CBSE PMT 1992, 95; Pb. PMT 1999]
(a) $M^0L^0T^2$ (b) M^0L^0T
(c) ML^{-1} (d) None of the above

9. Dimensions of one or more pairs are same. Identify the pairs
(a) Torque and work
(b) Angular momentum and work
(c) Energy and Young's modulus
(d) Light year and wavelength

10. Dimensional formula for latent heat is [MNR 1987; CPMT 1978, 86; IIT 1983, 89; RPET 2002]
(a) $M^0L^2T^{-2}$ (b) MLT^{-2}

(c) ML^2T^{-2} (d) ML^2T^{-1}

11. Dimensional formula for volume elasticity is [MP PMT 1991, 2002; CPMT 1991; MNR 1986]

(a) $M^1L^{-2}T^{-2}$ (b) $M^1L^{-3}T^{-2}$

(c) $M^1L^2T^{-2}$ (d) $M^1L^{-1}T^{-2}$

12. The dimensions of universal gravitational constant are [MP PMT 1984, 87, 97, 2000; CBSE PMT 1988, 92; 2004 MP PET 1984, 96, 99; MNR 1992; DPMT 1984; CPMT 1978, 84, 89, 90, 92, 96; AFMC 1999; NCERT 1975; DPET 1993; AIIMS 2000; RPET 2001; Pb. PMT 2002, 03; UPSEAT 1999; BCECE 2003, 05;]

(a) $M^{-2}L^2T^{-2}$ (b) $M^{-1}L^3T^{-2}$

(c) $ML^{-1}T^{-2}$ (d) ML^2T^{-2}

13. The dimensional formula of angular velocity is [JIPMER 1993; AFMC 1996; AIIMS 1998]

(a) $M^0L^0T^{-1}$ (b) MLT^{-1}

(c) $M^0L^0T^1$ (d) ML^0T^{-2}

14. The dimensions of power are [CPMT 1974, 75; SCRA 1989]

(a) $M^1L^2T^{-3}$ (b) $M^2L^1T^{-2}$

(c) $M^1L^2T^{-1}$ (d) $M^1L^1T^{-2}$

15. The dimensions of couple are [CPMT 1972; JIPMER 1993]

(a) ML^2T^{-2} (b) MLT^{-2}

(c) $ML^{-1}T^{-3}$ (d) $ML^{-2}T^{-2}$

16. Dimensional formula for angular momentum is [CBSE PMT 1988, 92; EAMCET 1995; DPMT 1987; CMC Vellore 1982; CPMT 1973, 82, 86; MP PMT 1987; BHU 1995; IIT 1983; Pb. PET 2000]

(a) ML^2T^{-2} (b) ML^2T^{-1}

(c) MLT^{-1} (d) $M^0L^2T^{-2}$

17. The dimensional formula for impulse is [EAMCET 1981; CBSE PMT 1991; CPMT 1978; AFMC 1998; BCECE 2003]

(a) MLT^{-2} (b) MLT^{-1}

(c) ML^2T^{-1} (d) M^2LT^{-1}

18. The dimensional formula for the modulus of rigidity is [MNR 1984; IIT 1982; MP PET 2000]

(a) ML^2T^{-2} (b) $ML^{-1}T^{-3}$

(c) $ML^{-2}T^{-2}$ (d) $ML^{-1}T^{-2}$

19. The dimensional formula for $r.m.s.$ (root mean square) velocity is

(a) M^0LT^{-1} (b) $M^0L^0T^{-2}$

(c) $M^0L^0T^{-1}$ (d) MLT^{-3}

20. The dimensional formula for Planck's constant (h) is [DPMT 1987; MP PMT 1983, 96; IIT 1985; MP PET 1995; AFMC 2003; RPMT 1999; Kerala PMT 2002]

(a) $ML^{-2}T^{-3}$ (b) ML^2T^{-2}

(c) ML^2T^{-1} (d) $ML^{-2}T^{-2}$

21. Out of the following, the only pair that does not have identical dimensions is [MP PET/PMT 1998; BHU 1997]

(a) Angular momentum and Planck's constant
(b) Moment of inertia and moment of a force
(c) Work and torque
(d) Impulse and momentum

22. The dimensional formula for impulse is same as the dimensional formula for [CPMT 1982, 83; CBSE PMT 1993; UPSEAT 2001]

(a) Momentum
(b) Force
(c) Rate of change of momentum
(d) Torque

23. Which of the following is dimensionally correct

(a) Pressure = Energy per unit area
(b) Pressure = Energy per unit volume
(c) Pressure = Force per unit volume
(d) Pressure = Momentum per unit volume per unit time

24. Planck's constant has the dimensions (unit) of [CPMT 1983, 84, 85, 90, 91; AIIMS 1985; MP PMT 1987; EAMCET 1990; RPMT 1999; CBSE PMT 2001; MP PET 2002; KCET 2004]

(a) Energy (b) Linear momentum

(c) Work (d) Angular momentum

25. The equation of state of some gases can be expressed as $\left(P+\frac{a}{V^2}\right)(V-b)=RT$. Here P is the pressure, V is the volume, T is the absolute temperature and a, b, R are constants. The dimensions of $'a'$ are [CBSE PMT 1991, 96; NCERT 1984; MP PET 1992; CPMT 1974, 79, 87, 97; MP PMT 1992, 94; MNR 1995; AFMC 1995]

(a) ML^5T^{-2} (b) $ML^{-1}T^{-2}$

(c) $M^0L^3T^0$ (d) $M^0L^6T^0$

26. If V denotes the potential difference across the plates of a capacitor of capacitance C, the dimensions of CV^2 are [CPMT 1982]

(a) Not expressible in MLT (b) MLT^{-2}

(c) M^2LT^{-1} (d) ML^2T^{-2}

27. If L denotes the inductance of an inductor through which a current i is flowing, the dimensions of Li^2 are [CPMT 1982, 85, 87]

(a) ML^2T^{-2} (b) Not expressible in MLT

(c) MLT^{-2} (d) $M^2L^2T^{-2}$

28. Of the following quantities, which one has dimensions different from the remaining three [AIIMS 1987; CBSE PMT 1993]

(a) Energy per unit volume
(b) Force per unit area
(c) Product of voltage and charge per unit volume
(d) Angular momentum per unit mass

29. A spherical body of mass m and radius r is allowed to fall in a medium of viscosity η. The time in which the velocity of the body

increases from zero to 0.63 times the terminal velocity (v) is called time constant (τ). Dimensionally τ can be represented by

(a) $\frac{mr^2}{6\pi\eta}$ (b) $\sqrt{\left(\frac{6\pi mr\eta}{g^2}\right)}$

(c) $\frac{m}{6\pi\eta rv}$ (d) None of the above

30. The frequency of vibration f of a mass m suspended from a spring of spring constant K is given by a relation of this type $f = C m^x K^y$; where C is a dimensionless quantity. The value of x and y are [CBSE PMT 1990]

(a) $x = \frac{1}{2}, y = \frac{1}{2}$ (b) $x = -\frac{1}{2}, y = -\frac{1}{2}$

(c) $x = \frac{1}{2}, y = -\frac{1}{2}$ (d) $x = -\frac{1}{2}, y = \frac{1}{2}$

31. The quantities A and B are related by the relation, $m = A/B$, where m is the linear density and A is the force. The dimensions of B are of

(a) Pressure (b) Work

(c) Latent heat (d) None of the above

32. The velocity of water waves v may depend upon their wavelength λ, the density of water ρ and the acceleration due to gravity g. The method of dimensions gives the relation between these quantities as

[NCERT 1979; CET 1992; MP PET 2001; UPSEAT 2000]

(a) $v^2 \propto \lambda g^{-1}\rho^{-1}$ (b) $v^2 \propto g\lambda\rho$

(c) $v^2 \propto g\lambda$ (d) $v^2 \propto g^{-1}\lambda^{-3}$

33. The dimensions of *Farad* are [MP PET 1993]

(a) $M^{-1}L^{-2}T^2Q^2$ (b) $M^{-1}L^{-2}TQ$

(c) $M^{-1}L^{-2}T^{-2}Q$ (d) $M^{-1}L^{-2}TQ^2$

34. The dimensions of resistivity in terms of M, L, T and Q where Q stands for the dimensions of charge, is

[MP PET 1993]

(a) $ML^3T^{-1}Q^{-2}$ (b) $ML^3T^{-2}Q^{-1}$

(c) $ML^2T^{-1}Q^{-1}$ (d) $MLT^{-1}Q^{-1}$

35. The equation of a wave is given by

$$Y = A\sin\omega\left(\frac{x}{v} - k\right)$$

where ω is the angular velocity and v is the linear velocity. The dimension of k is [MP PMT 1993]

(a) LT (b) T

(c) T^{-1} (d) T^2

36. The dimensions of coefficient of thermal conductivity is

[MP PMT 1993]

(a) $ML^2T^{-2}K^{-1}$ (b) $MLT^{-3}K^{-1}$

(c) $MLT^{-2}K^{-1}$ (d) $MLT^{-3}K$

37. Dimensional formula of stress is [AIIMS 1987]

(a) M^0LT^{-2} (b) $M^0L^{-1}T^{-2}$

(c) $ML^{-1}T^{-2}$ (d) ML^2T^{-2}

38. Dimensional formula of velocity of sound is

(a) M^0LT^{-2} (b) LT^0

(c) M^0LT^{-1} (d) $M^0L^{-1}T^{-1}$

39. Dimensional formula of capacitance is

[CPMT 1978; MP PMT 1979; IIT 1983]

(a) $M^{-1}L^{-2}T^4A^2$ (b) $ML^2T^4A^{-2}$

(c) $MLT^{-4}A^2$ (d) $M^{-1}L^{-2}T^{-4}A^{-2}$

40. MLT^{-1} represents the dimensional formula of

[CPMT 1975]

(a) Power (b) Momentum

(c) Force (d) Couple

41. Dimensional formula of heat energy is

[CPMT 1976, 81, 86, 91]

(a) ML^2T^{-2} (b) MLT^{-1}

(c) $M^0L^0T^{-2}$ (d) None of these

42. If C and L denote capacitance and inductance respectively, then the dimensions of LC are

[CPMT 1981; MP PET 1997]

(a) $M^0L^0T^0$ (b) $M^0L^0T^2$

(c) $M^2L^0T^2$ (d) MLT^2

43. Which of the following quantities has the same dimensions as that of energy [AFMC 1991; CPMT 1976; DPMT 2001]

(a) Power (b) Force

(c) Momentum (d) Work

44. The dimensions of "time constant" $\frac{L}{R}$ during growth and decay of current in all inductive circuit is same as that of

[MP PET 1993; EAMCET 1994]

(a) Constant (b) Resistance

(c) Current (d) Time

45. The period of a body under SHM *i.e.* presented by $T = P^aD^bS^c$; where P is pressure, D is density and S is surface tension. The value of a, b and c are [CPMT 1981]

(a) $-\frac{3}{2}, \frac{1}{2}, 1$ (b) $-1, -2, 3$

(c) $\frac{1}{2}, -\frac{3}{2}, -\frac{1}{2}$ (d) $1, 2, \frac{1}{3}$

46. Which of the following pairs of physical quantities has the same dimensions [CPMT 1978; NCERT 1987]

(a) Work and power (b) Momentum and energy

(c) Force and power (d) Work and energy

47. The velocity of a freely falling body changes as g^ph^q where g is acceleration due to gravity and h is the height. The values of p and q are [NCERT 1983; EAMCET 1994]

(a) $1, \frac{1}{2}$ (b) $\frac{1}{2}, \frac{1}{2}$

(c) $\frac{1}{2}, 1$ (d) $1, 1$

48. Which one of the following does not have the same dimensions

(a) Work and energy

(b) Angle and strain

(c) Relative density and refractive index

(d) Planck constant and energy

49. Dimensions of frequency are [CPMT 1988]

(a) $M^0L^{-1}T^0$ (b) $M^0L^0T^{-1}$

(c) M^0L^0T (d) MT^{-2}

50. Which one has the dimensions different from the remaining three

(a) Power (b) Work

(c) Torque (d) Energy

51. A small steel ball of radius r is allowed to fall under gravity through a column of a viscous liquid of coefficient of viscosity η. After some time the velocity of the ball attains a constant value known as terminal velocity v_T. The terminal velocity depends on (i) the mass of the ball m, (ii) η, (iii) r and (iv) acceleration due to gravity g. Which of the following relations is dimensionally correct

[CPMT 1992; CBSE PMT 1992; NCERT 1983; MP PMT 2001]

(a) $v_T \propto \frac{mg}{\eta r}$ (b) $v_T \propto \frac{\eta r}{mg}$

(c) $v_T \propto \eta rmg$ (d) $v_T \propto \frac{mgr}{\eta}$

52. The quantity $X = \frac{\varepsilon_0 LV}{t}$: ε_0 is the permittivity of free space, L is length, V is potential difference and t is time. The dimensions of X are same as that of [IIT 2001]

(a) Resistance (b) Charge

(c) Voltage (d) Current

53. μ_0 and ε_0 denote the permeability and permittivity of free space, the dimensions of $\mu_0\varepsilon_0$ are

(a) LT^{-1} (b) $L^{-2}T^2$

(c) $M^{-1}L^{-3}Q^2T^2$ (d) $M^{-1}L^{-3}I^2T^2$

54. The expression $[ML^2T^{-2}]$ represents [JIPMER 1993, 97]

(a) Pressure (b) Kinetic energy

(c) Momentum (d) Power

55. The dimensions of physical quantity X in the equation Force $= \frac{X}{\text{Density}}$ is given by [DCE 1993]

(a) $M^1L^4T^{-2}$ (b) $M^2L^{-2}T^{-1}$

(c) $M^2L^{-2}T^{-2}$ (d) $M^1L^{-2}T^{-1}$

56. The dimensions of CV^2 matches with the dimensions of

[DCE 1993]

(a) L^2I (b) L^2I^2

(c) LI^2 (d) $\frac{1}{LI}$

57. The M[CPMT 1985]artians use force (F), acceleration (A) and time (T) as their fundamental physical quantities. The dimensions of length on Martians system are [DCE 1993]

(a) FT^2 (b) $F^{-1}T^2$

(c) $F^{-1}A^2T^{-1}$ (d) AT^2

58. The dimension of $\frac{1}{\sqrt{\varepsilon_0\mu_0}}$ is that of [SCRA 1986]

(a) Velocity (b) Time

(c) Ca[CBSE PMT 1988]pacitance (d) Distance

59. An athletic coach told his team that muscle times speed equals power. What dimensions does he view for muscle

(a) MLT^{-2} (b) ML^2T^{-2}

(c) MLT^2 (d) L

60. The foundations of dimensional analysis were laid down by

(a) Gallileo (b) Newton

(c) Fourier (d) Joule

61. The dimensional formula of wave number is

(a) $M^0L^0T^{-1}$ (b) $M^0L^{-1}T^0$

(c) $M^{-1}L^{-1}T^0$ (d) $M^0L^0T^0$

62. The dimensions of stress are equal to [MP PET 1991, 2003]

(a) Force (b) Pressure

(c) Work (d) $\frac{1}{\text{Pressure}}$

63. The dimensions of pressure are

[CPMT 1977; MP PMT 1994]

(a) MLT^{-2} (b) $ML^{-2}T^2$

(c) $ML^{-1}T^{-2}$ (d) MLT^2

64. Dimensions of permeability are

[CBSE PMT 1991; AIIMS 2003]

(a) $A^{-2}M^1L^1T^{-2}$ (b) MLT^{-2}

(c) ML^0T^{-1} (d) $A^{-1}MLT^2$

65. Dimensional formula of magnetic flux is

[DCE 1993; IIT 1982; CBSE PMT 1989, 99; DPMT 2001; Kerala PMT 2005]

(a) $ML^2T^{-2}A^{-1}$ (b) $ML^0T^{-2}A^{-2}$

(c) $M^0L^{-2}T^{-2}A^{-3}$ (d) $ML^2T^{-2}A^3$

66. If P represents radiation pressure, c represents speed of light and Q represents radiation energy striking a unit area per *second*, then non-zero integers x, y and z such that $P^xQ^yc^z$ is dimensionless, are

[AFMC 1991; CBSE PMT 1992; CPMT 1981, 92; MP PMT 1992]

(a) $x = 1,\ y = 1,\ z = -1$

(b) $x = 1, y = -1, z = 1$

(c) $x = -1, y = 1, z = 1$

(d) $x = 1, y = 1, z = 1$

67. Inductance L can be dimensionally represented as

[CBSE PMT 1989, 92; IIT 1983; CPMT 1992; DPMT 1999; KCET 2004; J&K CET 2005]

(a) $ML^2T^{-2}A^{-2}$ (b) $ML^2T^{-4}A^{-3}$

(c) $ML^{-2}T^{-2}A^{-2}$ (d) $ML^2T^4A^3$

68. Dimensions of strain are [MP PET 1984; SCRA 1986]

(a) MLT^{-1} (b) ML^2T^{-1}

(c) MLT^{-2} (d) $M^0L^0T^0$

69. Dimensions of time in power are [EAMCET 1982]

(a) T^{-1} (b) T^{-2}

(c) T^{-3} (d) T^0

70. Dimensions of kinetic energy are

[Bihar PET 1983; DPET 1993; AFMC 1991]

(a) ML^2T^{-2} (b) M^2LT^{-1}

(c) ML^2T^{-1} (d) ML^3T^{-1}

71. Dimensional formula for torque is

[DPMT 1984; IIT 1983; CBSE PMT 1990; MNR 1988; AIIMS 2002; BHU 1995, 2001; RPMT 1999; RPET 2003; DCE 1999, 2000; DCE 2004]

(a) L^2MT^{-2} (b) $L^{-1}MT^{-2}$

(c) L^2MT^{-3} (d) LMT^{-2}

72. Dimensions of coefficient of viscosity are

[AIIMS 1993; CPMT 1992; Bihar PET 1984; MP PMT 1987, 89, 91; AFMC 1986; CBSE PMT 1992; KCET 1994; DCE 1999; AIEEE 2004; DPMT 2004]

(a) ML^2T^{-2} (b) ML^2T^{-1}

(c) $ML^{-1}T^{-1}$ (d) MLT

73. The dimension of quantity (L/RCV) is [Roorkee 1994]

(a) $[A]$ (b) $[A^2]$

(c) $[A^{-1}]$ (d) None of these

74. The dimension of the ratio of angular to linear momentum is

(a) $M^0L^1T^0$ (b) $M^1L^1T^{-1}$

(c) $M^1L^2T^{-1}$ (d) $M^{-1}L^{-1}T^{-1}$

75. The pair having the same dimensions is

[MP PET 1994; CPMT 1996]

(a) Angular momentum, work
(b) Work, torque
(c) Potential energy, linear momentum
(d) Kinetic energy, velocity

76. The dimensions of surface tension are

[MP PMT 1994, 99; UPSEAT 1999]

(a) $ML^{-1}T^{-2}$ (b) MLT^{-2}

(c) $ML^{-1}T^{-1}$ (d) MT^{-2}

77. In the following list, the only pair which have different dimensions, is [Manipal MEE 1995]

(a) Linear momentum and moment of a force
(b) Planck's constant and angular momentum
(c) Pressure and modulus of elasticity
(d) Torque and potential energy

78. If R and L represent respectively resistance and self inductance, which of the following combinations has the dimensions of frequency

[MP PMT 1996, 2000, 02; MP PET 1999]

(a) $\frac{R}{L}$ (b) $\frac{L}{R}$

(c) $\sqrt{\frac{R}{L}}$ (d) $\sqrt{\frac{L}{R}}$

79. If velocity v, acceleration A and force F are chosen as fundamental quantities, then the dimensional formula of angular momentum in terms of v, A and F would be

(a) $FA^{-1}v$ (b) Fv^3A^{-2}

(c) Fv^2A^{-1} (d) $F^2v^2A^{-1}$

80. The dimensions of permittivity ε_0 are

[MP PET 1997; AIIMS-2004; DCE-2003]

(a) $A^2T^2M^{-1}L^{-3}$ (b) $A^2T^4M^{-1}L^{-3}$

(c) $A^{-2}T^{-4}ML^3$ (d) $A^2T^{-4}M^{-1}L^{-3}$

81. Dimensions of the following three quantities are the same

[MP PET 1997]

(a) Work, energy, force
(b) Velocity, momentum, impulse
(c) Potential energy, kinetic energy, momentum
(d) Pressure, stress, coefficient of elasticity

82. The dimensions of Planck's constant and angular momentum are respectively [CPMT 1999; BCECE 2004]

(a) ML^2T^{-1} and MLT^{-1} (b) ML^2T^{-1} and ML^2T^{-1}

(c) MLT^{-1} and ML^2T^{-1} (d) MLT^{-1} and ML^2T^{-2}

83. Let $[\varepsilon_0]$ denotes the dimensional formula of the permittivity of the vacuum and $[\mu_0]$ that of the permeability of the vacuum. If $M = \text{mass}$, $L = \text{length}$, $T = \text{Time}$ and $I = \text{electric current}$, then [IIT 1998]

(a) $[\varepsilon_0] = M^{-1}L^{-3}T^2I$ (b) $[\varepsilon_0] = M^{-1}L^{-3}T^4I^2$

(c) $[\mu_0] = MLT^{-2}I^{-2}$ (d) $[\mu_0] = ML^2T^{-1}I$

[MNR 1994]

84. Dimensions of CR are those of

[EAMCET (Engg.) 1995; AIIMS 1999]

(a) Frequency (b) Energy

(c) Time period (d) Current

85. The physical quantity that has no dimensions

[EAMCET (Engg.) 1995]

(a) Angular Velocity (b) Linear momentum

(c) Angular momentum (d) Strain

86. $ML^{-1}T^{-2}$ represents

[EAMCET (Med.) 1995; Pb. PMT 2001]

(a) Stress
(b) Young's Modulus
(c) Pressure
(d) All the above three quantities

87. Dimensions of magnetic field intensity is

[RPMT 1997; EAMCET (Med.) 2000; MP PET 2003]

(a) $[M^0L^{-1}T^0A^1]$ (b) $[MLT^{-1}A^{-1}]$

(c) $[ML^0T^{-2}A^{-1}]$ (d) $[MLT^{-2}A]$

88. The force F on a sphere of radius 'a' moving in a medium with velocity 'v' is given by $F = 6\pi\eta a v$. The dimensions of η are [CBSE PMT 1997; DPMT 2000]

(a) $ML^{-1}T^{-1}$ (b) MT^{-1}

(c) MLT^{-2} (d) ML^{-3}

89. Which physical quantities have the same dimension [CPMT 1997]

(a) Couple of force and work

(b) Force and power

(c) Latent heat and specific heat

(d) Work and power

90. Two quantities A and B have different dimensions. Which mathematical operation given below is physically meaningful

(a) A/B (b) $A+B$

(c) $A-B$ (d) None

91. Given that v is speed, r is the radius and g is the acceleration due to gravity. Which of the following is dimensionless

(a) v^2/rg (b) v^2r/g

(c) v^2g/r (d) v^2rg

92. The physical quantity which has the dimensional formula M^1T^{-3} is [CET 1998]

(a) Surface tension (b) Solar constant

(c) Density (d) Compressibility

93. A force F is given by $F = at + bt^2$, where t is time. What are the dimensions of a and b [AFMC 2001; BHU 1998, 2005]

(a) MLT^{-3} and ML^2T^{-4} (b) MLT^{-3} and MLT^{-4}

(c) MLT^{-1} and MLT^0 (d) MLT^{-4} and MLT^1

94. The dimensions of inter atomic force constant are [UPSEAT 1999]

(a) MT^{-2} (b) MLT^{-1}

(c) MLT^{-2} (d) $ML^{-1}T^{-1}$

95. If the speed of light (c), acceleration due to gravity (g) and pressure (p) are taken as the fundamental quantities, then the dimension of gravitational constant is [AMU (Med.) 1999]

(a) $c^2g^0p^{-2}$ (b) $c^0g^2p^{-1}$

(c) cg^3p^{-2} (d) $c^{-1}g^0p^{-1}$

96. If the time period (T) of vibration of a liquid drop depends on surface tension (S), radius (r) of the drop and density (ρ) of the liquid, then the expression of T is [AMU (Med.) 2000]

(a) $T = k\sqrt{\rho r^3/S}$ (b) $T = k\sqrt{\rho^{1/2}r^3/S}$

(c) $T = k\sqrt{\rho r^3/S^{1/2}}$ (d) None of these

97. $ML^3T^{-1}Q^{-2}$ is dimension of [RPET 2000]

(a) Resistivity (b) Conductivity

(c) Resistance (d) None of these

98. Dimension of electric current is [CBSE PMT 2000]

(a) $[M^0L^0T^{-1}Q]$ (b) $[ML^2T^{-1}Q]$

(c) $[M^2LT^{-1}Q]$ (d) $[M^2L^2T^{-1}Q]$

99. The fundamental physical quantities that have same dimensions in the dimensional formulae of torque and angular momentum are

(a) Mass, time (b) Time, length

(c) Mass, length (d) Time, mole

100. If pressure P, velocity V and time T are taken as fundamental physical quantities, the dimensional formula of force is

(a) PV^2T^2 (b) $P^{-1}V^2T^{-2}$

(c) PVT^2 (d) $P^{-1}VT^2$

101. The physical quantity which has dimensional formula as that of $\frac{\text{Energy}}{\text{Mass} \times \text{Length}}$ is [CPMT 1997] [EAMCET (Eng.) 2000]

(a) Force (b) Power

(c) Pressure (d) Acceleration

102. If energy (E), velocity (v) and force (F) be taken as fundamental quantity, then what are the dimensions of mass [CET 1998] [AMU 2000]

(a) Ev^2 (b) Ev^{-2}

(c) Fv^{-1} (d) Fv^{-2}

103. Dimensions of luminous flux are [UPSEAT 2001]

(a) ML^2T^{-2} (b) ML^2T^{-3}

(c) ML^2T^{-1} (d) MLT^{-2}

104. A physcial quantity x depends on quantities y and z as follows: $x = Ay + B\tan Cz$, where A, B and C are constants. Which of the following do not have the same dimensions

(a) x and B (b) C and z^{-1}

(c) y and B/A (d) x and A

105. Which of the following pair does not have similar dimensions

(a) Stress and pressure

(b) Angle and strain

(c) Tension and surface tension

(d) Planck's constant and angular momentum

106. Out of the following which pair of quantities do not have same dimensions [RPET 2001]

(a) Planck's constant and angular momentum

(b) Work and energy

(c) Pressure and Young's modulus

(d) Torque & moment of inertia

107. Identify the pair which has different dimensions [KCET 2001]

(a) Planck's constant and angular momentum

(b) Impulse and linear momentum

(c) Angular momentum and frequency

(d) Pressure and Young's modulus

108. The dimensional formula $M^0L^2T^{-2}$ stands for [KCET 2001]

(a) Torque

(b) Angular momentum

(c) Latent heat

(d) Coefficient of thermal conductivity

109. Which of the following represents the dimensions of *Farad*

[AMU (Med.) 2002]

(a) $M^{-1}L^{-2}T^4A^2$ (b) $ML^2T^2A^{-2}$

(c) $ML^2T^2A^{-1}$ (d) $MT^{-2}A^{-1}$

110. If L, C and R denote the inductance, capacitance and resistance respectively, the dimensional formula for C^2LR is [UPSEAT 2002]

(a) $[ML^{-2}T^{-1}I^0]$ (b) $[M^0L^0T^3I^0]$

(c) $[M^{-1}L^{-2}T^6I^2]$ (d) $[M^0L^0T^2I^0]$

111. If the velocity of light (c), gravitational constant (G) and Planck's constant (h) are chosen as fundamental units, then the dimensions of mass in new system is [UPSEAT 2002]

(a) $c^{1/2}G^{1/2}h^{1/2}$ (b) $c^{1/2}G^{1/2}h^{-1/2}$

(c) $c^{1/2}G^{-1/2}h^{1/2}$ (d) $c^{-1/2}G^{1/2}h^{1/2}$

112. Dimensions of charge are [DPMT 2002]
(a) $M^0L^0T^{-1}A^{-1}$ (b) $MLTA^{-1}$
(c) $T^{-1}A$ (d) TA

113. According to Newton, the viscous force acting between liquid layers of area A and velocity gradient $\Delta v / \Delta z$ is given by $F = -\eta A \frac{\Delta v}{\Delta z}$ where η is constant called coefficient of viscosity. The dimension of η are [JIPMER 2001, 02]
(a) $[ML^2T^{-2}]$ (b) $[ML^{-1}T^{-1}]$
(c) $[ML^{-2}T^{-2}]$ (d) $[M^0L^0T^0]$

114. Identify the pair whose dimensions are equal [AIEEE 2002]
(a) Torque and work (b) Stress and energy
(c) Force and stress (d) Force and work

115. The dimensions of pressure is equal to [AIEEE 2002]
(a) Force per unit volume
(b) Energy per unit volume
(c) Force
(d) Energy

116. Which of the two have same dimensions [AIEEE 2002]
(a) Force and strain
(b) Force and stress
(c) Angular velocity and frequency
(d) Energy and strain

117. An object is moving through the liquid. The viscous damping force acting on it is proportional to the velocity. Then dimension of constant of proportionality is [Orissa JEE 2002]
(a) $ML^{-1}T^{-1}$ (b) MLT^{-1}
(c) M^0LT^{-1} (d) ML^0T^{-1}

118. The dimensions of emf in MKS is [CPMT 2002]
(a) $ML^{-1}T^{-2}Q^{-2}$ (b) $ML^2T^{-2}Q^{-2}$
(c) $MLT^{-2}Q^{-1}$ (d) $ML^2T^{-2}Q^{-1}$

119. Which of the following quantities is dimensionless [MP PET 2002]
(a) Gravitational constant (b) Planck's constant
(c) Power of a convex lens (d) None

120. The dimensional formula for Boltzmann's constant is [MP PET 2002; Pb. PET 2001]
(a) $[ML^2T^{-2}\theta^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^0T^{-2}\theta^{-1}]$ (d) $[ML^{-2}T^{-1}\theta^{-1}]$

121. The dimensions of K in the equation $W = \frac{1}{2}Kx^2$ is [Orissa JEE 2003]
(a) $M^1L^0T^{-2}$ (b) $M^0L^1T^{-1}$
(c) $M^1L^1T^{-2}$ (d) $M^1L^0T^{-1}$

122. The physical quantities not having same dimensions are [AIEEE 2003]
(a) Speed and $(\mu_0\varepsilon_0)^{-1/2}$
(b) Torque and work
(c) Momentum and Planck's constant
(d) Stress and Young's modules

123. Dimension of R is [AFMC 2003; AIIMS 2005]
(a) ML^2T^{-1} (b) $ML^2T^{-3}A^{-2}$
(c) $ML^{-1}T^{-2}$ (d) None of these

124. The dimensional formula of relative density is [CPMT 2003]
(a) ML^{-3} (b) LT^{-1}
(c) MLT^{-2} (d) Dimensionless

125. The dimensional formula for young's modulus is [BHU 2003; CPMT 2004]
(a) $ML^{-1}T^{-2}$ (b) M^0LT^{-2}
(c) MLT^{-2} (d) ML^2T^{-2}

126. Frequency is the function of density (ρ), length (a) and surface tension (T). Then its value is [BHU 2003]
(a) $k\rho^{1/2}a^{3/2}/\sqrt{T}$ (b) $k\rho^{3/2}a^{3/2}/\sqrt{T}$
(c) $k\rho^{1/2}a^{3/2}/T^{3/4}$ (d) $k\rho^{1/2}a^{1/2}/T^{3/2}$

127. The dimensions of electric potential are [UPSEAT 2003]
(a) $[ML^2T^{-2}Q^{-1}]$ (b) $[MLT^{-2}Q^{-1}]$
(c) $[ML^2T^{-1}Q]$ (d) $[ML^2T^{-2}Q]$

128. Dimensions of potential energy are [MP PET 2003]
(a) MLT^{-1} (b) ML^2T^{-2}
(c) $ML^{-1}T^{-2}$ (d) $ML^{-1}T^{-1}$

129. The dimension of $\frac{R}{L}$ are [MP PET 2003]
(a) T^2 (b) T
(c) T^{-1} (d) T^{-2}

130. The dimensions of shear modulus are [MP PMT 2004]
(a) MLT^{-1} (b) ML^2T^{-2}
(c) $ML^{-1}T^{-2}$ (d) MLT^{-2}

131. Pressure gradient has the same dimension as that of [AFMC 2004]
(a) Velocity gradient (b) Potential gradient
(c) Energy gradient (d) None of these

132. If force (*F*), length (*L*) and time (*T*) are assumed to be fundamental units, then the dimensional formula of the mass will be
(a) $FL^{-1}T^2$ (b) $FL^{-1}T^{-2}$
(c) $FL^{-1}T^{-1}$ (d) FL^2T^2

133. The dimensions of universal gas constant is [Pb. PET 2003]
(a) $[ML^2T^{-2}\theta^{-1}]$ (b) $[M^2LT^{-2}\theta]$
(c) $[ML^3T^{-1}\theta^{-1}]$ (d) None of these

134. In the relation $y = a\cos(\omega t - kx)$, the dimensional formula for k is
(a) $[M^0L^{-1}T^{-1}]$ (b) $[M^0LT^{-1}]$
(c) $[M^0L^{-1}T^0]$ (d) $[M^0LT]$

135. Position of a body with acceleration '*a*' is given by $x = Ka^mt^n$, here t is time. Find dimension of m and n. [Orissa JEE 2005]
(a) $m = 1$, $n = 1$ (b) $m = 1, n = 2$
(c) $m = 2, n = 1$ (d) $m = 2, n = 2$

136. "Pascal-Second" has dimension of [AFMC 2005]
(a) Force (b) Energy
(c) Pressure (d) Coefficient of viscosity

137. In a system of units if force (*F*), acceleration (*A*) and time (*T*) are taken as fundamental units then the dimensional formula of energy is [BHU 2005]
(a) FA^2T (b) FAT^2

(c) F^2AT (d) FAT

138. Out of the following pair, which one does not have identical dimensions [AIEEE 2005]

(a) Moment of inertia and moment of force

(b) Work and torque

(c) Angular momentum and Planck's constant

(d) Impulse and momentum

139. The ratio of the dimension of Planck's constant and that of moment of inertia is the dimension of [CBSE PMT 2005]

(a) Frequency (b) Velocity

(c) Angular momentum (d) Time

140. Which of the following group have different dimension [IIT JEE 2005]

(a) Potential difference, EMF, voltage

(b) Pressure, stress, young's modulus

(c) Heat, energy, work-done

(d) Dipole moment, electric flux, electric field

141. Out of following four dimensional quantities, which one quantity is to be called a dimensional constant [KCET 2005]

(a) Acceleration due to gravity

(b) Surface tension of water

(c) Weight of a standard kilogram mass

(d) The velocity of light in vacuum

142. Density of a liquid in CGS system is 0.625 g/cm^3 . What is its magnitude in SI system [J&K CET 2005]

(a) 0.625 (b) 0.0625

(c) 0.00625 (d) 625

Errors of Measurement

1. The period of oscillation of a simple pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$ where l is about 100 *cm* and is known to have 1*mm* accuracy. The period is about 2*s*. The time of 100 oscillations is measured by a stop watch of least count 0.1 s. The percentage error in g is

(a) 0.1% (b) 1%

(c) 0.2% (d) 0.8%

2. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimation of the kinetic energy obtained by measuring mass and speed

(a) 11% (b) 8%

(c) 5% (d) 1%

3. The random error in the arithmetic mean of 100 observations is x; then random error in the arithmetic mean of 400 observations would be

(a) $4x$ (b) $\frac{1}{4}x$

(c) $2x$ (d) $\frac{1}{2}x$

4. What is the number of significant figures in 0.310×10^{3}

(a) 2 (b) 3

(c) 4 (d) 6

5. Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is [AFMC 2005]

(a) 1% (b) 3%

(c) 5% (d) 7%

6. The mean time period of *second*s pendulum is 2.00*s* and mean absolute error in the time period is 0.05*s*. To express maximum estimate of error, the time period should be written as

(a) (2.00 ± 0.01) *s* (b) $(2.00 + 0.025)$ *s*

(c) (2.00 ± 0.05) *s* (d) (2.00 ± 0.10) *s*

7. A body travels uniformly a distance of (13.8 ± 0.2) *m* in a time (4.0 ± 0.3) s. The velocity of the body within error limits is

(a) (3.45 ± 0.2) *ms* (b) (3.45 ± 0.3) *ms*

(c) (3.45 ± 0.4) *ms* (d) (3.45 ± 0.5) *ms*

8. The percentage error in the above problem is

(a) 7% (b) 5.95%

(c) 8.95% (d) 9.85%

9. The unit of percentage error is

(a) Same as that of physical quantity

(b) Different from that of physical quantity

(c) Percentage error is unit less

(d) Errors have got their own units which are different from that of physical quantity measured

10. The decimal equivalent of 1/20 upto three significant figures is

(a) 0.0500 (b) 0.05000

(c) 0.0050 (d) 5.0×10^{-2}

11. Accuracy of measurement is determined by

(a) Absolute error (b) Percentage error

(c) Both (d) None of these

12. The radius of a sphere is (5.3 ± 0.1) *cm*. The percentage error in its volume is

(a) $\frac{0.1}{5.3}\times100$ (b) $3\times\frac{0.1}{5.3}\times100$

(c) $\frac{0.1\times100}{3.53}$ (d) $3+\frac{0.1}{5.3}\times100$

13. A thin copper wire of length *l metre* increases in length by 2% when heated through 10°C. What is the percentage increase in area when a square copper sheet of length *l metre* is heated through 10°C

(a) 4% (b) 8%

(c) 16% (d) None of the above

14. In the context of accuracy of measurement and significant figures in expressing results of experiment, which of the following is/are correct

(1) Out of the two measurements 50.14 *cm* and 0.00025 *ampere*, the first one has greater accuracy

(2) If one travels 478 *km* by rail and 397 *m*. by road, the total distance travelled is 478 *km*.

(a) Only (1) is correct (b) Only (2) is correct

(c) Both are correct (d) None of them is correct.

15. A physical parameter a can be determined by measuring the parameters b, c, d and e using the relation $a = b^{\alpha}c^{\beta}/d^{\gamma}e^{\delta}$. If the maximum errors in the measurement of b, c, d and e are b_1 %, c_1 %, d_1 % and e_1 %, then the maximum error in the value of a determined by the experiment is

(a) $(b_1 + c_1 + d_1 + e_1)$%

(b) $(b_1 + c_1 - d_1 - e_1)$%

(c) $(\alpha b_1 + \beta c_1 - \gamma d_1 - \delta e_1)$%

(d) $(\alpha b_1 + \beta c_1 + \gamma d_1 + \delta e_1)\%$

16. The relative density of material of a body is found by weighing it first in air and then in water. If the weight in air is (5.00 ± 0.05) *Newton* and weight in water is (4.00 ± 0.05) *Newton*. Then the relative density along with the maximum permissible percentage error is

(a) $5.0 \pm 11\%$ (b) $5.0 \pm 1\%$

(c) $5.0 \pm 6\%$ (d) $1.25 \pm 5\%$

17. The resistance $R = \frac{V}{i}$ where $V = 100 \pm 5$ *volts* and $i = 10 \pm 0.2$ *amperes*. What is the total error in R

(a) 5% (b) 7%

(c) 5.2% (d) $\frac{5}{2}\%$

18. The period of oscillation of a simple pendulum in the experiment is recorded as 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s respectively. The average absolute error is

(a) 0.1 s (b) 0.11 s

(c) 0.01 s (d) 1.0 s

19. The length of a cylinder is measured with a meter rod having least count 0.1 *cm*. Its diameter is measured with vernier calipers having least count 0.01 *cm*. Given that length is 5.0 *cm*. and radius is 2.0 *cm*. The percentage error in the calculated value of the volume will be

(a) 1% (b) 2%

(c) 3% (d) 4%

20. In an experiment, the following observation's were recorded : L = 2.820 *m*, M = 3.00 *kg*, l = 0.087 *cm*, Diameter D = 0.041 *cm*

Taking g = 9.81 m/s^2 using the formula , $Y = \frac{4MgL}{\pi D^2 l}$, the maximum permissible error in Y is

(a) 7.96% (b) 4.56%

(c) 6.50% (d) 8.42%

21. According to *Joule*'s law of heating, heat produced $H = I^2 Rt$, where I is current, R is resistance and t is time. If the errors in the measurement of I, R and t are 3%, 4% and 6% respectively then error in the measurement of H is

(a) $\pm 17\%$ (b) $\pm 16\%$

(c) $\pm 19\%$ (d) $\pm 25\%$

22. If there is a positive error of 50% in the measurement of velocity of a body, then the error in the measurement of kinetic energy is

(a) 25% (b) 50%

(c) 100% (d) 125%

23. A physical quantity P is given by $P = \frac{A^3 B^{\frac{1}{2}}}{C^{-4} D^{\frac{3}{2}}}$. The quantity which brings in the maximum percentage error in P is

(a) A (b) B

(c) C (d) D

24. If $L = 2.331\,cm$, $B = 2.1\,cm$, then $L + B =$ **[DCE 2003]**

(a) 4.431 *cm* (b) 4.43 *cm*

(c) 4.4 *cm* (d) 4 *cm*

25. The number of significant figures in all the given numbers 25.12, 2009, 4.156 and 1.217×10^{-4} is **[Pb. PET 2003]**

(a) 1 (b) 2

(c) 3 (d) 4

26. If the length of rod A is 3.25 ± 0.01 *cm* and that of B is 4.19 ± 0.01 *cm* then the rod B is longer than rod A by **[J&K CET 2005]**

(a) 0.94 ± 0.00 *cm* (b) 0.94 ± 0.01 *cm*

(c) 0.94 ± 0.02 *cm* (d) 0.94 ± 0.005 *cm*

27. A physical quantity is given by $X = M^a L^b T^c$. The percentage error in measurement of M, L and T are α, β and γ respectively. Then maximum percentage error in the quantity X is

(a) $a\alpha + b\beta + c\gamma$ (b) $a\alpha + b\beta - c\gamma$

(c) $\frac{a}{\alpha} + \frac{b}{\beta} + \frac{c}{\gamma}$ (d) None of these

28. A physical quantity A is related to four observable a, b, c and d as follows, $A = \frac{a^2 b^3}{c\sqrt{d}}$, the percentage errors of measurement in a, b, c and d are 1%,3%,2% and 2% respectively. What is the percentage error in the quantity A **[Kerala PET 2005]**

(a) 12% (b) 7%

(c) 5% (d) 14%

Critical Thinking

Objective Questions

1. If the acceleration due to gravity is $10\,ms^{-2}$ and the units of length and time are changed in kilometer and hour respectively, the numerical value of the acceleration is **[Kerala PET 2002]**

(a) 360000 (b) 72,000

(c) 36,000 (d) 129600

2. If L, C and R represent inductance, capacitance and resistance respectively, then which of the following does not represent dimensions of frequency **[IIT 1984]**

(a) $\frac{1}{RC}$ (b) $\frac{R}{L}$

(c) $\frac{1}{\sqrt{LC}}$ (d) $\frac{C}{L}$

3. Number of particles is given by $n = -D\frac{n_2 - n_1}{x_2 - x_1}$ crossing a unit area perpendicular to X-axis in unit time, where n_1 and n_2 are number of particles per unit volume for the value of x meant to x_2 and x_1. Find dimensions of D called as diffusion constant

(a) $M^0 LT^2$ (b) $M^0 L^2 T^{-4}$

(c) $M^0 LT^{-3}$ (d) $M^0 L^2 T^{-1}$

4. With the usual notations, the following equation $S_t = u + \frac{1}{2}a(2t - 1)$ is

(a) Only numerically correct
(b) Only dimensionally correct
(c) Both numerically and dimensionally correct
(d) Neither numerically nor dimensionally correct

5. If the dimensions of length are expressed as $G^x c^y h^z$; where G, c and h are the universal gravitational constant, speed of light and Planck's constant respectively, then [IIT 1992]

(a) $x = \frac{1}{2}, y = \frac{1}{2}$ (b) $x = \frac{1}{2}, z = \frac{1}{2}$

(c) $y = \frac{1}{2}, z = \frac{3}{2}$ (d) $y = -\frac{3}{2}, z = \frac{1}{2}$

6. A highly rigid cubical block A of small mass M and side L is fixed rigidly onto another cubical block B of the same dimensions and of low modulus of rigidity η such that the lower face of A completely covers the upper face of B. The lower face of B is rigidly held on a horizontal surface. A small force F is applied perpendicular to one of the side faces of A. After the force is withdrawn block A executes small oscillations. The time period of which is given by [IIT 1992]

(a) $2\pi\sqrt{\frac{M\eta}{L}}$ (b) $2\pi\sqrt{\frac{L}{M\eta}}$

(c) $2\pi\sqrt{\frac{ML}{\eta}}$ (d) $2\pi\sqrt{\frac{M}{\eta L}}$

7. The pair(s) of physical quantities that have the same dimensions, is (are) [IIT 1995]

(a) Reynolds number and coefficient of friction
(b) Latent heat and gravitational potential
(c) Curie and frequency of a light wave
(d) Planck's constant and torque

8. The speed of light (c), gravitational constant (G) and Planck's constant (h) are taken as the fundamental units in a system. The dimension of time in this new system should be

(a) $G^{1/2}h^{1/2}c^{-5/2}$ (b) $G^{-1/2}h^{1/2}c^{1/2}$

(c) $G^{1/2}h^{1/2}c^{-3/2}$ (d) $G^{1/2}h^{1/2}c^{1/2}$

9. If the constant of gravitation (G), Planck's constant (h) and the velocity of light (c) be chosen as fundamental units. The dimension of the radius of gyration is [AMU (Eng.) 1999]

(a) $h^{1/2}c^{-3/2}G^{1/2}$ (b) $h^{1/2}c^{3/2}G^{1/2}$

(c) $h^{1/2}c^{-3/2}G^{-1/2}$ (d) $h^{-1/2}c^{-3/2}G^{1/2}$

10. $X = 3YZ^2$ find dimension of Y in (MKSA) system, if X and Z are the dimension of capacity and magnetic field respectively

(a) $M^{-3}L^{-2}T^{-4}A^{-1}$ (b) ML^{-2}

(c) $M^{-3}L^{-2}T^4A^4$ (d) $M^{-3}L^{-2}T^8A^4$

11. In the relation $P = \frac{\alpha}{\beta}e^{-\frac{\alpha Z}{k\theta}}$ P is pressure, Z is the distance, k is Boltzmann constant and θ is the temperature. The dimensional formula of β will be [IIT (Screening) 2004]

(a) $[M^0L^2T^0]$ (b) $[M^1L^2T^1]$

(c) $[M^1L^0T^{-1}]$ (d) $[M^0L^2T^{-1}]$

12. The frequency of vibration of string is given by $\nu = \frac{p}{2l}\left[\frac{F}{m}\right]^{1/2}$. Here p is number of segments in the string and l is the length. The dimensional formula for m will be [BHU 2004]

(a) $[M^0LT^{-1}]$ (b) $[ML^0T^{-1}]$

(c) $[ML^{-1}T^0]$ (d) $[M^0L^0T^0]$

13.

Column I	Column II
(i) Curie	(A) MLT^{-2}
(ii) Light year	(B) M
(iii) Dielectric strength	(C) Dimensionless
(iv) Atomic weight	(D) T
(v) Decibel	(E) ML^2T^{-2}
	(F) MT^{-3}
	(G) T^{-1}
	(H) L
	(I) $MLT^{-3}I^{-1}$
	(J) LT^{-1}

Choose the correct match [IIT 1992]

(a) (i) G, (ii) H, (iii) C, (iv) B, (v) C
(b) (i) D, (ii) H, (iii) I, (iv) B, (v) G
(c) (i) G, (ii) H, (iii) I, (iv) B, (v) G
(d) None of the above

14. A wire has a mass $0.3 \pm 0.003\,g$, radius $0.5 \pm 0.005\,mm$ and length $6 \pm 0.06\,cm$. The maximum percentage error in the measurement of its density is [IIT (Screening) 2004]

(a) 1 (b) 2

(c) 3 (d) 4

15. If 97.52 is divided by 2.54, the correct result in terms of significant figures is

(a) 38.4 (b) 38.3937

(c) 38.394 (d) 38.39

AR Assertion & Reason

For AIIMS Aspirants

Choose any one of the following four responses :

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : '*Light year*' and 'Wavelength' both measure distance. [MP PMT 2003]

Reason : Both have dimensions of time.

2. Assertion : Light year and year, both measure time.

Reason : Because light year is the time that light takes to reach the earth from the sun.

3. Assertion : Force cannot be added to pressure.

Reason : Because their dimensions are different.

4. Assertion : Linear mass density has the dimensions of $[ML^{-1}T^0]$.

Reason : Because density is always mass per unit volume.

5. Assertion : Rate of flow of a liquid represents velocity of flow.

Reason : The dimensions of rate of flow are $[M^0L^3T^{-1}]$.

6. Assertion : Units of Rydberg constant R are m^{-1}

Reason : It follows from Bohr's formula $\bar{\nu} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where the symbols have their usual meaning.

7. Assertion : Parallex method cannot be used for measuring distances of stars more than 100 light years away.

Reason : Because parallex angle reduces so much that it cannot be measured accurately.

8. Assertion : Number of significant figures in 0.005 is one and that in 0.500 is three.

Reason : This is because zeros are not significant.

9. Assertion : Out of three measurements *l* = 0.7 *m*; *l* = 0.70 *m* and *l* = 0.700 *m*, the last one is most accurate.

Reason : In every measurement, only the last significant digit is not accurately known.

10. Assertion : Mass, length and time are fundamental physical quantities.

Reason : They are independent of each other.

11. Assertion : Density is a derived physical quantity.

Reason : Density cannot be derived from the fundamental physical quantities.

12. Assertion : Now a days a standard *metre* is defined as in terms of the wavelength of light.

Reason : Light has no relation with length.

13. Assertion : Radar is used to detect an aeroplane in the sky

Reason : Radar works on the principle of reflection of waves.

14. Assertion : Surface tension and surface energy have the same dimensions.

Reason : Because both have the same S.I. unit

15. Assertion : In $y = A\sin(\omega t - kx)$, $(\omega t - kx)$ is dimensionless.

Reason : Because dimension of $\omega = [M^0 L^0 T]$.

16. Assertion : Radian is the unit of distance.

Reason : One radian is the angle subtended at the centre of a circle by an arc equal in length to the radius of the circle.

17. Assertion : A.U. is much bigger than Å.

Reason : A.U. stands for astronomical unit and Å stands from *Angstrom*.

18. Assertion : When we change the unit of measurement of a quantity, its numerical value changes.

Reason : Smaller the unit of measurement smaller is its numerical value.

19. Assertion : Dimensional constants are the quantities whose value are constant.

Reason : Dimensional constants are dimensionless.

20. Assertion : The time period of a pendulum is given by the formula, $T = 2\pi\sqrt{g/l}$.

Reason : According to the principle of homogeneity of dimensions, only that formula is correct in which the dimensions of L.H.S. is equal to dimensions of R.H.S.

21. Assertion : In the relation $f = \frac{1}{2l}\sqrt{\frac{T}{m}}$, where symbols have standard meaning, *m* represent linear mass density.

Reason : The frequency has the dimensions of inverse of time.

22. Assertion : The graph between *P* and *Q* is straight line, when *P/Q* is constant.

Reason : The straight line graph means that *P* proportional to *Q* or *P* is equal to constant multiplied by *Q*.

23. Assertion : Avogadro number is the number of atoms in one gram mole.

Reason : Avogadro number is a dimensionless constant.

24. Assertion : *L*/*R* and *CR* both have same dimensions.

Reason : *L/R* and *CR* both have dimension of time.

25. Assertion : The quantity $(1/\sqrt{\mu_0 \varepsilon_0})$ is dimensionally equal to velocity and numerically equal to velocity of light.

Reason : μ_0 is permeability of free space and ε_0 is the permittivity of free space.

Answers

Units

1	c	2	b	3	d	4	c	5	c
6	d	7	c	8	d	9	c	10	c
11	a	12	c	13	c	14	b	15	d
16	d	17	c	18	a	19	b	20	d
21	d	22	a	23	a	24	b	25	d
26	b	27	d	28	d	29	d	30	b
31	a	32	b	33	a	34	b	35	a
36	b	37	a	38	b	39	b	40	b
41	d	42	c	43	c, b	44	c	45	b
46	a	47	c	48	c	49	a	50	a
51	b	52	b	53	c	54	c	55	c
56	c	57	b	58	a	59	c	60	a
61	c	62	c	63	d	64	d	65	b
66	c	67	a	68	b	69	c	70	b
71	d	72	b	73	b	74	d	75	c
76	b	77	b	78	b	79	c	80	c
81	a	82	a	83	d	84	c	85	b
86	d	87	d	88	b	89	a	90	c
91	a	92	d	93	b	94	a	95	d
96	a	97	b	98	a	99	d	100	b
101	d	102	d	103	a	104	a	105	d
106	b	107	b	108	b	109	b		

Dimensions

1	a	2	c	3	b	4	a	5	b
6	c	7	c	8	b	9	ad	10	a
11	d	12	b	13	a	14	a	15	a
16	b	17	b	18	d	19	a	20	c
21	b	22	a	23	b	24	d	25	a
26	d	27	a	28	d	29	d	30	d
31	c	32	c	33	a	34	a	35	b
36	b	37	c	38	c	39	a	40	b
41	a	42	b	43	d	44	d	45	a

46	d	47	b	48	d	49	b	50	a
51	a	52	d	53	b	54	b	55	c
56	c	57	d	58	a	59	a	60	c
61	b	62	b	63	c	64	a	65	a
66	b	67	a	68	d	69	c	70	a
71	a	72	c	73	c	74	a	75	b
76	d	77	a	78	a	79	b	80	b
81	d	82	b	83	bc	84	c	85	d
86	d	87	c	88	a	89	a	90	a
91	a	92	b	93	b	94	a	95	b
96	a	97	a	98	a	99	c	100	a
101	d	102	b	103	b	104	d	105	c
106	d	107	c	108	c	109	a	110	b
111	c	112	d	113	b	114	a	115	b
116	c	117	d	118	d	119	d	120	a
121	a	122	c	123	b	124	d	125	a
126	a	127	a	128	b	129	c	130	c
131	d	132	a	133	a	134	c	135	b
136	d	137	b	138	a	139	a	140	d
141	d	142	d						

Errors of Measurement

1	c	2	b	3	b	4	b	5	b
6	c	7	b	8	c	9	c	10	a
11	b	12	b	13	a	14	c	15	d
16	a	17	b	18	b	19	c	20	c
21	b	22	d	23	c	24	c	25	d
26	c	27	a	28	d				

Critical Thinking Questions

1	d	2	d	3	d	4	c	5	bd
6	d	7	abc	8	a	9	a	10	d
11	a	12	c	13	a	14	d	15	a

Assertion and Reason

1	c	2	d	3	a	4	c	5	d
6	a	7	a	8	c	9	b	10	a
11	c	12	c	13	a	14	c	15	c
16	e	17	b	18	c	19	c	20	e
21	b	22	a	23	c	24	a	25	b

Answers and Solutions

Units

1. (c) Light year is a distance which light travels in one year.
2. (b) Because magnitude is absolute.
3. (d) *Watt=Joule/second* = *Ampere×volt* = *Ampere×Ohm*
4. (c) Impulse = change in momentum = $F\times t$
   So the unit of momentum will be equal to *Newton-sec.*
5. (c) Unit of energy will be $kg\text{-}m^2/\sec^2$
6. (d) It is by standard definition.
7. (c) $1\,nm = 10^{-9}\,m = 10^{-7}\,cm$
8. (d) $1\,micron = 10^{-6}\,m = 10^{-4}\,cm$
9. (c) *Watt* = *Joule/sec.*
10. (c) $F = \frac{Gm_1m_2}{d^2}$; $\therefore\ G = \frac{Fd^2}{m_1m_2} = Nm^2/kg^2$
11. (a)
12. (c) Angular acceleration $= \frac{\text{Angular velocity}}{\text{Time}} = \frac{rad}{\sec^2}$
13. (c) Stefan's law is $E = \sigma(T^4) \Rightarrow \sigma = \frac{E}{T^4}$
    where, $E = \frac{\text{Energy}}{\text{Area}\times\text{Time}} = \frac{\text{Watt}}{m^2}$
    $\sigma = \frac{\text{Watt-}m^{-2}}{K^4} = Watt\text{–}m^{-2}K^{-4}$
14. (b) *Kg-m/sec* is the unit of linear momentum
15. (d) ct^2 must have dimensions of L
    $\Rightarrow$ c must have dimensions of L/T^2 *i.e.* LT^{-2}.
16. (d) $\tau = \frac{dL}{dt} \Rightarrow dL = \tau\times dt = r\times F\times dt$
    i.e. the unit of angular momentum is *joule-second.*
17. (c)
18. (a) Volume of cube = a^3
    Surface area of cube = $6a^2$
    according to problem $a = 6a \Rightarrow a = 6$
    $\therefore V = a^3 = 216\,units.$
19. (b) $6\times10^{-5} = 60\times10^{-6} = 60\,microns$
20. (d)
21. (d) Because temperature is a fundamental quantity.
22. (a)
23. (a) 1 C.G.S unit of density = 1000 M.K.S. unit of density
    $\Rightarrow 0.5\ gm/cc = 500\,kg/m^3$
24. (b)
25. (d)
26. (b) Mach number $= \frac{\text{Velocity of object}}{\text{Velocity of sound}}$.
27. (d)
28. (d) $E = -\frac{dV}{dx}$
29. (d)
30. (b) Surface tension = $\frac{\text{Force}}{\text{Length}}$ = $Newtons/metre$
31. (a)
32. (b) $L = \frac{\phi}{I} = \frac{Wb}{A} = Henry$.
33. (a) $\frac{L}{R}$ is a time constant of *L-R* circuit so *Henry/ohm* can be expressed as *second.*
34. (b) $mv = kg\left(\frac{m}{\sec}\right)$
35. (a) Quantities of similar dimensions can be added or subtracted so unit of *a* will be same as that of velocity.
36. (b) $1\ MeV = 10^6\ eV$
37. (a) Energy $(E) = F\times d \Rightarrow F = \frac{E}{d}$ so *Erg/metre* can be the unit of force.
38. (b) Potential energy $= mgh = g\left(\frac{cm}{\sec^2}\right)cm = g\left(\frac{cm}{\sec}\right)^2$
39. (b) $\frac{watt}{ampere} = volt$
40. (b)
41. (d)
42. (c)
43. (b,c)
44. (c) Energy = force × distance, so if both are increased by 4 times then energy will increase by 16 times.
45. (b) 1 Oerstead = 1 Gauss = $10^{-4}\,Tesla$
46. (a) Charge = current × time
47. (c) $R = \rho\frac{L}{A} \Rightarrow \rho = \frac{RA}{L} = ohm\times cm$
48. (c)
49. (a) Astronomical unit of distance.
50. (a) Physical quantity (p) = Numerical value $(n)\times$ Unit (u)
    If physical quantity remains constant then $n \propto 1/u$ $\therefore\ n_1u_1 = n_2u_2$.
51. (b) $1eV = 1.6\times10^{-19}\,coulomb\times1\,volt = 1.6\times10^{-19}\,J$.
52. (b) $1\,kWh = 1\times10^3\times3600\,W\times\sec = 36\times10^5\,J$
53. (c) According to the definition.
54. (c)
55. (c) As $I = MR^2 = kg - m^2$
56. (c) $\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{N}{m^2}$
57. (b) $\frac{Q}{t} = \sigma AT^4 \Rightarrow \sigma = Jm^{-2}s^{-1}K^{-4}$
58. (a) M = Pole strength × length
    $= amp - metre\times metre = amp - metre^2$
59. (c) *Curie* = *disintegration/second*
60. (a)
61. (c) Pico prefix used for 10^{-12}

62. (c)

63. (d) Unit of $e.m.f.$ = *volt* = *joule/coulomb*

64. (d)

65. (b)

66. (c) $Y = \frac{F}{A}.\frac{L}{\Delta L} = \frac{dyne}{cm^2} = \frac{10^{-5}N}{10^{-4}m^2} = 0.1 N/m^2$

67. (a) $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{\text{Force/Area}}{\text{Dimensionless}} \Rightarrow Y \equiv \text{Pressure}.$

68. (b) $1\ yard = 36\ inches = 36 \times 2.54\ cm = 0.9144 m$.

69. (c) $1\ \text{fermi} = 10^{-15} metre$

70. (b)

71. (d)

72. (b)

73. (b)

74. (d) 1 *Newton* = 10^5 *Dyne*

75. (c) $[x] = [bt^2] \Rightarrow [b] = [x/t^2] = km/s^2$

76. (b) Units of *a* and PV^2 are same and equal to $dyne \times cm^4$.

77. (b)

78. (b)

79. (c) Impulse = Force × time $= (kg\text{-}m/s^2) \times s = kg\text{-}m/s$

80. (c)

81. (a) $K = C + 273.15$

82. (a)

83. (d)

84. (c)

85. (b)

86. (d) *Watt* is a unit of power

87. (d) $1\,\text{lightyear} = 9.46 \times 10^{15}\ meter$

88. (b) $V = \frac{W}{m}$ so, SI unit = $\frac{Joule}{kg}$

89. (a)

90. (c) $n_2 = n_1 \left(\frac{M_1}{M_2}\right)^1 \left(\frac{L_1}{L_2}\right)^1 \left(\frac{T}{T_2}\right)^{-2}$

$= 100 \left(\frac{gm}{kg}\right)^1 \left(\frac{cm}{m}\right)^1 \left(\frac{\sec}{min}\right)^{-2}$

$= 100 \left(\frac{gm}{10^3 gm}\right)^1 \left(\frac{cm}{10^2 cm}\right)^1 \left(\frac{\sec}{60 \sec}\right)^{-2}$

$n_2 = \frac{3600}{10^3} = 3.6$

91. (a) $[L/R]$ is a time constant so its unit is *Second*.

92. (d) Poission ratio is a unitless quantity.

93. (b)

94. (a)

95. (d) $P = nu \therefore n \propto \frac{1}{u}$

96. (a) 1 *Faraday* = 96500 *coulomb*.

97. (b)

98. (a)

99. (d)

100. (b)

101. (d) $F = \frac{1}{4\pi \in} \frac{q_1 q_2}{r^2} \Rightarrow \in = \frac{1}{4\pi} \frac{q_1 q_2}{Fr^2} = C^2 m^{-2} N^{-1}$

102. (d) *Joule-sec* is the unit of angular momentum where as other units are of energy.

103. (a) $T = \frac{F}{l} = Nm^{-1}$

104. (a) Because in S.I. system there are seven fundamental quantities.

105. (d) $[\eta] = ML^{-1}T^{-1}$ so its unit will be *kg/m-sec.*

106. (b)

107. (b)

108. (b) According to the definition.

109. (b) Pyrometer is used for measurement of temperature.

Dimensions

1. (a) Pressure $= \frac{\text{Force}}{\text{Area}} = ML^{-1}T^{-2}$

Stress $= \frac{\text{Restoring force}}{\text{Area}} = ML^{-1}T^{-2}$

2. (c) Strain $= \frac{\Delta L}{L} \Rightarrow$ dimensionless quantity

3. (b) Power $= \frac{\text{Work}}{\text{Time}} = \frac{ML^2T^{-2}}{T} = ML^2T^{-3}$

4. (a) *Calorie* is the unit of heat *i.e.*, energy.

So dimensions of energy $= ML^2T^{-2}$

5. (b) Angular momentum = $mvr = MLT^{-1} \times L = ML^2T^{-1}$

6. (c) $\frac{L}{R}$ = Time constant

7. (c) Impulse = change in momentum so dimensions of both quantities will be same and equal to MLT^{-1}

8. (b) $RC = T$

$\because\ [R] = [ML^2T^{-3}I^{-2}]$ and $[C] = [M^{-1}L^{-2}T^4I^2]$

9. (a,d) [Torque] = [work] = $[ML^2T^{-2}]$

[Light year] = [Wavelength] = $[L]$

10. (a) $Q = mL \Rightarrow L = \frac{Q}{m}$ (Heat is a form of energy)

$= \frac{ML^2T^{-2}}{M} = [M^0L^2T^{-2}]$

11. (d) Volume elasticity = $\frac{\text{Force/Area}}{\text{Volume strain}}$

Strain is dimensionless, so

$= \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

12. (b) $F = \frac{Gm_1m_2}{d^2} \Rightarrow G = \frac{Fd^2}{m_1m_2}$

$\therefore\ [G] = \frac{[MLT^{-2}][L^2]}{[M^2]} = [M^{-1}L^3T^{-2}]$

13. (a) Angular velocity = $\frac{\theta}{t}$, $[\omega] = \frac{[M^0L^0T^0]}{[T]} = [T^{-1}]$

14. (a) Power = $\frac{\text{Work done}}{\text{Time}} = \left[\frac{ML^2T^{-2}}{T}\right] = [ML^2T^{-3}]$

15. (a) Couple = Force × Arm length = $[MLT^{-2}][L] = [ML^2T^{-2}]$

16. (b) Angular momentum = mvr
$= [MLT^{-1}][L] = [ML^2T^{-1}]$

17. (b) Impulse = Force × Time = $[MLT^{-2}][T] = [MLT^{-1}]$

18. (d) Modulus of rigidity = $\frac{\text{Shear stress}}{\text{Shear strain}} = [ML^{-1}T^{-2}]$

19. (a)

20. (c) $E = h\nu \Rightarrow [ML^2T^{-2}] = [h][T^{-1}] \Rightarrow [h] = [ML^2T^{-1}]$

21. (b) $\text{Moment of inertia} = mr^2 = [M][L^2]$
Moment of Force = Force × Perpendicular distance
= $[MLT^{-2}][L] = [ML^2T^{-2}]$

22. (a) Momentum = $mv = [MLT^{-1}]$
Impulse = Force × Time = $[MLT^{-2}] \times [T] = [MLT^{-1}]$

23. (b) Pressure = $\frac{\text{Force}}{\text{Area}} = \frac{\text{Energy}}{\text{Volume}} = ML^{-1}T^{-2}$

24. (d) $[h] = [\text{Angular momentum}] = [ML^2T^{-1}]$

25. (a) By principle of dimensional homogenity $\left[\frac{a}{V^2}\right] = [P]$
$\therefore [a] = [P][V^2] = [ML^{-1}T^{-2}] \times [L^6] = [ML^5T^{-2}]$

26. (d) $\frac{1}{2}CV^2$ = Stored energy in a capacitor = $[ML^2T^{-2}]$

27. (a) $\frac{1}{2}Li^2$ = Stored energy in an inductor = $[ML^2T^{-2}]$

28. (d) Energy per unit volume = $\frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$
Force per unit area = $\frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$
Product of voltage and charge per unit volume
$= \frac{V \times Q}{\text{Volume}} = \frac{VIt}{\text{Volume}} = \frac{\text{Power} \times \text{Time}}{\text{Volume}}$
$\Rightarrow \frac{[ML^2T^{-3}][T]}{[L^3]} = [ML^{-1}T^{-2}]$
Angular momentum per unit mass = $\frac{[ML^2T^{-1}]}{[M]} = [L^2T^{-1}]$
So angular momentum per unit mass has different dimension.

29. (d) Time constant $\tau = [T]$ and Viscosity $\eta = [ML^{-1}T^{-1}]$
For options (a), (b) and (c) dimensions are not matching with time constant.

30. (d) By putting the dimensions of each quantity both the sides we get $[T^{-1}] = [M]^x[MT^{-2}]^y$
Now comparing the dimensions of quantities in both sides we get $x + y = 0$ and $2y = 1$ $\therefore$ $x = -\frac{1}{2}, y = \frac{1}{2}$

31. (c) m = linear density = mass per unit length = $\left[\frac{M}{L}\right]$
A= force $= [MLT^{-2}]$ $\therefore$ $[B] = \frac{[A]}{[m]} = \frac{[MLT^{-2}]}{[ML^{-1}]} = [L^2T^{-2}]$
This is same dimension as that of latent heat.

32. (c) Let $v^x = kg^y\lambda^z\rho^\delta$. Now by substituting the dimensions of each quantities and equating the powers of *M*, *L* and *T* we get $\delta = 0$ and $x = 2, y = 1, z = 1$.

33. (a) *Farad* is the unit of capacitance and $C = \frac{Q}{V} = \frac{[Q]}{[ML^2T^{-2}Q^{-1}]} = M^{-1}L^{-2}T^2Q^2$

34. (a) $\rho = \frac{RA}{l}$ *i.e.* dimension of resistivity is $[ML^3T^{-1}Q^{-2}]$

35. (b) From the principle of homogenity $\left(\frac{x}{v}\right)$ has dimensions of *T*.

36. (b) $\frac{dQ}{dt} = -KA\left(\frac{d\theta}{dx}\right)$
$\Rightarrow [K] = \frac{[ML^2T^{-2}]}{[T]} \times \frac{[L]}{[L^2][K]} = MLT^{-3}K^{-1}$

37. (c) Stress = $\frac{\text{Force}}{\text{Area}} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

38. (c)

39. (a) $[C] = \left(\frac{Q}{V}\right) = \left(\frac{Q^2}{W}\right) = \left[\frac{A^2T^2}{ML^2T^{-2}}\right] = [M^{-1}L^{-2}T^4A^2]$

40. (b) Momentum = mv = $[MLT^{-1}]$

41. (a) $Q = [ML^2T^{-2}]$ (All energies have same dimension)

42. (b) $f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow LC = \frac{1}{f^2} = [M^0L^0T^2]$

43. (d) Energy = Work done [Dimensionally]

44. (d) $\frac{L}{R}$ = Time constant.

45. (a) By substituting the dimension of each quantity we get $T = [ML^{-1}T^{-2}]^a[L^{-3}M]^b[MT^{-2}]^c$
By solving we get $a = -3/2$, $b = 1/2$ and $c = 1$

46. (d)

47. (b) $v \propto g^ph^q$ (given)
By substituting the dimension of each quantity and comparing the powers in both sides we get $[LT^{-1}] = [LT^{-2}]^p[L]^q$
$\Rightarrow p + q = 1, -2p = -1, \therefore p = \frac{1}{2}, q = \frac{1}{2}$

48. (d) [Planck constant] = $[ML^2T^{-1}]$ and
[Energy] = $[ML^2T^{-2}]$

49. (b) Frequency $= \frac{1}{T} = [M^0L^0T^{-1}]$

50. (a) Power = $\frac{\text{Energy}}{\text{Time}}$

51. (a) By substituting dimension of each quantity in R.H.S. of option (a) we get $\left[\frac{mg}{\eta r}\right]=\left[\frac{M\times LT^{-2}}{ML^{-1}T^{-1}\times L}\right]=[LT^{-1}]$.

This option gives the dimension of velocity.

52. (d) $[\varepsilon_0 L]$ = [C] $\therefore$ $X=\frac{\varepsilon_0 LV}{t}=\frac{C\times V}{t}=\frac{Q}{t}$ = current

53. (b) $C=\frac{1}{\sqrt{\mu_0\varepsilon_0}}\Rightarrow \mu_0\varepsilon_0=\left(\frac{1}{C^2}\right)$ (where C = velocity of light)

$\therefore$ $[\mu_0\varepsilon_0]=L^{-2}T^2$

54. (b)

55. (c) $[X]=[F]\times[\rho]=[MLT^{-2}]\times\left[\frac{M}{L^3}\right]=[M^2L^{-2}T^{-2}]$

56. (c) Both are the formula of energy. $\left(E=\frac{1}{2}CV^2=\frac{1}{2}LI^2\right)$

57. (d) Acceleration = $\frac{\text{distance}}{\text{time}^2}\Rightarrow A=LT^{-2}\Rightarrow L=AT^2$

58. (a) $\frac{1}{\sqrt{\varepsilon_0\mu_0}}=C=$ velocity of light

59. (a) According to problem muscle × speed = power

$\therefore$ muscle = $\frac{\text{power}}{\text{speed}}=\frac{ML^2T^{-3}}{LT^{-1}}=MLT^{-2}$

60. (c)

61. (b) Wave number = $\frac{1}{\lambda}$ $\therefore$ dimension is $[M^0L^{-1}T^0]$

62. (b) [Pressure] =[stress] = $[ML^{-1}T^{-2}]$

63. (c)

64. (a) $F=\frac{\mu_0}{4\pi}\frac{2I_1I_2l}{r}\Rightarrow \mu_0=[F][A]^{-2}=[MLT^{-2}A^{-2}]$

65. (a) $\phi=BA=\frac{F}{I\times L}A=\frac{[MLT^{-2}][L^2]}{[A][L]}=[ML^2T^{-2}A^{-1}]$

66. (b) By substituting the dimension of given quantities $[ML^{-1}T^{-2}]^x[MT^{-3}]^y[LT^{-1}]^z=[MLT]^0$

By comparing the power of M, L, T in both sides $x+y=0$

$-x+z=0$ .....(ii)

$-2x-3y-z=0$ ...(iii)

The only values of x,y,z satisfying (i), (ii) and (iii) corresponds to (b).

67. (a) $E=\frac{1}{2}Li^2$ hence $L=[ML^2T^{-2}A^{-2}]$

68. (d) Strain is dimensionless.

69. (c) Dimensions of power is $[ML^2T^{-3}]$

70. (a) Kinetic energy = $\frac{1}{2}mv^2=M[LT^{-1}]^2=[ML^2T^{-2}]$

71. (a) Torque = force × distance = $[ML^2T^{-2}]$

72. (c) $F=-\eta.A\frac{dv}{dx}\Rightarrow[\eta]=[ML^{-1}T^{-1}]$

73. (c) $\frac{L}{RCV}=\left[\frac{L}{R}\right]\frac{1}{CV}=\frac{T}{Q}=[A^{-1}]$

74. (a) $\frac{\text{Angular momentum}}{\text{Linear momentum}}=\frac{mvr}{mv}=r=[M^0L^1T^0]$

75. (b) Dimension of work and torque = $[ML^2T^{-2}]$

76. (d) Surface tension = $\frac{\text{Force}}{\text{Length}}=\frac{[MLT^{-2}]}{L}=[MT^{-2}]$

77. (a) Linear momentum = Mass × Velocity = $[MLT^{-1}]$

Moment of a force = Force × Distance = $[ML^2T^{-2}]$

78. (a) $\frac{R}{L}=\frac{V/I}{V\times T/I}=\frac{1}{T}$ = Frequency

79. (b) $L\propto v^xA^yF^z\Rightarrow L=kv^xA^yF^z$

Putting the dimensions in the above relation

$[ML^2T^{-1}]=k[LT^{-1}]^x[LT^{-2}]^y[MLT^{-2}]^z$

$\Rightarrow[ML^2T^{-1}]=k[M^zL^{x+y+z}T^{-x-2y-2z}]$

Comparing the powers of M, L and T

$z=1$ ...(i)

$x+y+z=2$ ...(ii)

$-x-2y-2z=-1$ ...(iii)

On solving (i), (ii) and (iii) $x=3, y=-2, z=1$

So dimension of L in terms of v, A and f

$[L]=[Fv^3A^{-2}]$

80. (b) $F=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$\Rightarrow\ \varepsilon_0=\frac{|q_1||q_2|}{[F][r^2]}=\frac{[A^2T^2]}{[MLT^{-2}][L^2]}=[A^2T^4M^{-1}L^{-3}]$

81. (d) [Pressure] = [Stress] = [coefficient of elasticity] = $[ML^{-1}T^{-2}]$

82. (b)

83. (b, c)

84. (c) Capacity × Resistance = $\frac{\text{Charge}}{\text{Potential}}\times\frac{\text{Volt}}{\text{amp}}$

$=\frac{\text{amp}\times\text{second}\times\text{Volt}}{\text{Volt}\times\text{amp}}=$ Second .....(i)

85. (d) Strain has no dimensions.

86. (d)

87. (c) $B=\frac{F}{IL}=\frac{[MLT^{-2}]}{[A][L]}=[MT^{-2}A^{-1}]$

88. (a) $\eta=\frac{F}{av}=\frac{[MLT^{-2}]}{[L][LT^{-1}]}=[ML^{-1}T^{-1}]$

89. (a) Couple of force = $|\vec{r}\times\vec{F}|=[ML^2T^{-2}]$

Work = $[\vec{F}.\vec{d}]=[ML^2T^{-2}]$

90. (a) Quantities having different dimensions can only be divided or multiplied but they cannot be added or subtracted.

91. (a) Angle of banking : $\tan\theta=\frac{v^2}{rg}$. *i.e.* $\frac{v^2}{rg}$ is dimensionless.

92. (b) Solar constant is energy received per unit area per unit time *i.e.* $\frac{[ML^2T^{-2}]}{[L^2][T]} = [M^1T^{-3}]$

93. (b) From the principle of dimensional homogenity $[a] = \left[\frac{F}{t}\right] = [MLT^{-3}]$ and $[b] = \left[\frac{F}{t^2}\right] = [MLT^{-4}]$

94. (a) $K = Y \times r_0 = [ML^{-1}T^{-2}] \times [L] = [MT^{-2}]$

Y = Young's modulus and r_0 = Interatomic distance

95. (b) Let $[G] \propto c^x g^y p^z$

by substituting the following dimensions :

$[G] = [M^{-1}L^3T^{-2}], [c] = [LT^{-1}], [g] = [LT^{-2}]$

$[p] = [ML^{-1}T^{-2}]$

and by comparing the powers of both sides

we can get $x = 0, y = 2, z = -1$

$\therefore\ [G] \propto c^0 g^2 p^{-1}$

96. (a) Let $T \propto S^x r^y \rho^z$

by substituting the dimension of $[T] = [T]$

$[S] = [MT^{-2}], [r] = [L], [\rho] = [ML^{-3}]$

and by comparing the power of both the sides

$x = -1/2, y = 3/2, z = 1/2$

so $T \propto \sqrt{\rho r^3 / S} \Rightarrow T = k\sqrt{\frac{\rho r^3}{S}}$

97. (a) Resistivity $[\rho] = \frac{[R].[A]}{[l]}$ where $[R] = [ML^2T^{-1}Q^{-2}]$

$\therefore\ [\rho] = [ML^3T^{-1}Q^{-2}]$

98. (a) $I = \frac{Q}{t} = \frac{[Q]}{[T]} = [M^0L^0T^{-1}Q]$

99. (c) Torque = $[ML^2T^{-2}]$, Angular momentum = $[ML^2T^{-1}]$ So mass and length have the same dimensions

100. (a) Let $F \propto P^x V^y T^z$

by substituting the following dimensions :

$[P] = [ML^{-1}T^{-2}]\ [V] = [LT^{-1}], [T] = [T]$

and comparing the dimension of both sides

$x = 1, y = 2, z = 2$, so $F = PV^2T^2$

101. (d) $\frac{\text{Energy}}{\text{mass} \times \text{length}} = \frac{[ML^2T^{-2}]}{[M][L]} = [LT^{-2}]$

102. (b) Let $m \propto E^x v^y F^z$

By substituting the following dimensions :

$[E] = [ML^2T^{-2}], [v] = [LT^{-1}], [F] = [MLT^{-2}]$

and by equating the both sides

$x = 1, y = -2, z = 0$. So $[m] = [Ev^{-2}]$

103. (b)

104. (d) $x = Ay + B\tan Cz$

From the dimensional homogenity

$[x] = [Ay] = [B] \Rightarrow \left[\frac{x}{A}\right] = [y] = \left[\frac{B}{A}\right]$

$[Cz] = [M^0L^0T^0] =$ Dimension less

x and B ; C and Z^{-1}; y and $\frac{B}{A}$ have the same dimension but x and A have the different dimensions.

105. (c) Tension = $[MLT^{-2}]$, Surface Tension = $[MT^{-2}]$

106. (d) Torque = $[ML^2T^{-2}]$, Moment of inertia = $[ML^2]$

107. (c) Angular momentum = $[ML^2T^{-1}]$, Frequency = $[T^{-1}]$

108. (c) Latent Heat $L = \frac{Q}{m} = \frac{\text{Energy}}{\text{mass}} = \frac{[ML^2T^{-2}]}{[M]} = [L^2T^{-2}]$

109. (a) $C = \frac{Q}{V} = \frac{[AT]}{[ML^2T^{-3}A^{-1}]} = [M^{-1}L^{-2}T^4A^2]$

110. (b) $C^2LR = [C^2L^2] \times \left[\frac{R}{L}\right] = [T^4] \times \left[\frac{1}{T}\right] = [T^3]$

As $\left[\frac{L}{R}\right] = T$ and $\sqrt{LC} = T$

111. (c) Let $m \propto C^x G^y h^z$

By substituting the following dimensions :

$[C] = LT^{-1}; [G] = [M^{-1}L^3T^{-2}]$ and $[h] = [ML^2T^{-1}]$

Now comparing both sides we will get

$x = 1/2; y = -1/2, z = +1/2$

So $m \propto c^{1/2}G^{-1/2}h^{1/2}$

112. (d) Charge = Current × Time $= [AT]$

113. (b) $F = -\eta A \frac{\Delta v}{\Delta z} \Rightarrow [\eta] = [ML^{-1}T^{-1}]$

As $F = [MLT^{-2}],\ A = [L^2], \frac{\Delta v}{\Delta z} = [T^{-1}]$

114. (a)

115. (b) $\frac{\text{Energy}}{\text{Volume}} = \frac{ML^2T^{-2}}{L^3} = [ML^{-1}T^{-2}]$ = Pressure

116. (c) $\omega = \frac{d\theta}{dt} = [T^{-1}]$ and frequency $[n] = [T^{-1}]$

117. (d) $F \propto v \Rightarrow F = kv \Rightarrow [k] = \left[\frac{F}{v}\right] = \left[\frac{MLT^{-2}}{LT^{-1}}\right] = [MT^{-1}]$

118. (d) $e = L\frac{di}{dt} \Rightarrow [e] = [ML^2T^{-2}A^{-2}]\left[\frac{A}{T}\right]$

$[e] = \left[\frac{ML^2T^{-2}}{AT}\right] = [ML^2T^{-2}Q^{-1}]$

119. (d) $[G] = [M^{-1}L^3T^{-2}]; [h] = [ML^2T^{-1}]$

Power = $\frac{1}{\text{focal length}} = [L^{-1}]$

All quantities have dimensions

120. (a) $k = \left[\frac{R}{N}\right] = [ML^2T^{-2}\theta^{-1}]$

121. (a) $W = \frac{1}{2}kx^2 \Rightarrow [k] = \frac{[W]}{[x^2]} = \left[\frac{ML^2T^{-2}}{L^2}\right] = [MT^{-2}]$

122. (c) Momentum $[MLT^{-1}]$, Planck's constant $[ML^2T^{-1}]$

123. (b) $R = \frac{V}{I} = \left[\frac{ML^2T^{-3}A^{-1}}{A}\right] = [ML^2T^{-3}A^{-2}]$

124. (d) Relative density = $\frac{\text{Density of substance}}{\text{density of water}} = [M^0L^0T^0]$

125. (a)

126. (a) Let $n = k\rho^a a^b T^c$ where $[\rho] = [ML^{-3}], [a] = [L]$ and $[T] = [MT^{-2}]$

Comparing both sides, we get

$a = \frac{1}{2}, b = \frac{3}{2}$ and $c = \frac{-1}{2}$ $\therefore \eta = \frac{k\rho^{1/2}a^{3/2}}{\sqrt{T}}$

127. (a) $V = \frac{W}{Q} = [ML^2T^{-2}Q^{-1}]$

128. (b)

129. (c) L/R is a time constant so $(R/L) = T^{-1}$

130. (c) Shear modulus = $\frac{\text{Shearing stress}}{\text{Shearing strain}} = \frac{F}{A\theta} = [ML^{-1}T^{-2}]$

131. (d) Velocity gradient $= \frac{v}{x} = \frac{[LT^{-1}]}{[L]} = [T^{-1}]$

Potential gradient $= \frac{V}{x} = \frac{[ML^2T^{-3}A^{-1}]}{[L]} = [MLT^{-3}A^{-1}]$

Energy gradient $= \frac{E}{x} = \frac{[ML^2T^2]}{[L]} = [MLT^{-2}]$

and pressure gradient $= \frac{P}{x} = \frac{[ML^{-1}T^{-2}]}{[L]} = [ML^{-2}T^{-2}]$

132. (a) Let $m = KF^aL^bT^c$

Substituting the dimension of

$[F] = [MLT^{-2}],\ [C] = [L]\ and\ [T] = [T]$

and comparing both sides, we get $m = FL^{-1}T^{-2}$

133. (a) $\because R = \frac{PV}{T} = \left[\frac{ML^{-1}T^{-2} \times L^3}{\theta}\right] = [ML^2T^{-2}\theta^{-1}]$

134. (c) $[Kx]$ = Dimension of ωt = (dimensionless) hence $K = \frac{1}{X} = \frac{1}{L} = [L^{-1}]$ $\therefore [K] = [L^{-1}]$

135. (b) As $x = Ka^m \times t^n$

$[M^0LT^0] = [LT^{-2}]^m[T]^n = [L^mT^{-2m+n}]$

$\therefore m = 1$ and $-2m + n = 0 \Rightarrow n = 2$.

136. (d) $NSm^{-2} = Nm^{-2} \times S =$ Pascal-second.

137. (b) $E = KF^aA^bT^c$

$[ML^2T^{-2}] = [MLT^{-2}]^a[LT^{-2}]^b[T]^c$

$[ML^2T^{-2}] = [M^aL^{a+b}T^{-2a-2b+c}]$

$\therefore a = 1,\ a + b = 2 \Rightarrow b = 1$

and $-2a - 2b + c = -2 \Rightarrow c = 2$

$\therefore E = KFAT^2$.

138. (a)

139. (a) $\frac{h}{I} = \left[\frac{ML^2T^{-1}}{ML^2}\right] = [T^{-1}]$

140. (d)

141. (d)

142. (d) CGS SI

$N_1U_1 = N_2U_2$

$N_1[M_1L_1^{-3}] = N_2[M_2L_2^{-3}]$

$\therefore N_2 = N_1\left[\frac{M_1}{M_2}\right] \times \left[\frac{L_1}{L_2}\right]^{-3} = 0.625\left[\frac{1g}{1kg}\right] \times \left[\frac{1cm}{1m}\right]^{-3}$

$= 0.625 \times 10^{-3} \times 10^6 = 625$

Errors of Measurement

1. (c) $T = 2\pi\sqrt{l/g} \Rightarrow T^2 = 4\pi^2 l/g \Rightarrow g = \frac{4\pi^2 l}{T^2}$

Here % error in l = $\frac{1mm}{100cm} \times 100 = \frac{0.1}{100} \times 100 = 0.1\%$

and % error in $T = \frac{0.1}{2 \times 100} \times 100 = 0.05\%$

$\therefore$ % error in g = % error in l + 2(% error in T)

$= 0.1 + 2 \times 0.05 = 0.2$ %

2. (b) $\therefore E = \frac{1}{2}mv^2$

$\therefore$ % Error in K.E.

= % error in mass + 2 × % error in velocity

= 2 + 2 × 3 = 8 %

3. (b)

4. (b) Number of significant figures are 3, because 10 is decimal multiplier.

5. (b) $\because V = \frac{4}{3}\pi r^3$

$\therefore$ % error is volume $= 3 \times \%$ error in radius

$= 3 \times 1 = 3\%$

6. (c) Mean time period T = 2.00 *sec*

& Mean absolute error = ΔT = 0.05 *sec.*

To express maximum estimate of error, the time period should be written as (2.00 ± 0.05) *sec*

7. (b) Here, $S = (13.8 \pm 0.2)\ m$

and $t = (4.0 \pm 0.3)$ *sec*

Expressing it in percentage error, we have,

$S = 13.8 \pm \frac{0.2}{13.8} \times 100\% = 13.8 \pm 1.4\%$

and $t = 4.0 \pm \frac{0.3}{4} \times 100\% = 4 \pm 7.5\%$

$\because V = \frac{s}{t} = \frac{13.8 \pm 1.4}{4 \pm 7.5} = (3.45 \pm 0.3)\ m/s.$

8. (c) % error in velocity = %error in L + %error in t

$= \frac{0.2}{13.8} \times 100 + \frac{0.3}{4} \times 100$

= 1.44 + 7.5 = 8.94 %

9. (c)

10. (a) $\frac{1}{20} = 0.05$

$\therefore$ Decimal equivalent upto 3 significant figures is 0.0500

11. (b)

12. (b) $\because V = \frac{4}{3}\pi r^3$

$\therefore$ % error in volume

$= 3 \times \%$ error in radius.

$= \frac{3 \times 0.1}{5.3} \times 100$

13. (a) Since percentage increase in length = 2 %

Hence, percentage increase in area of square sheet

$= 2 \times 2\%$ = 4%

14. (c) Since for 50.14 *cm*, significant number = 4 and for 0.00025, significant numbers = 2

15. (d) $a = b^\alpha c^\beta / d^\gamma e^\delta$

So maximum error in *a* is given by

$$\left(\frac{\Delta a}{a} \times 100\right)_{max} = \alpha . \frac{\Delta b}{b} \times 100 + \beta . \frac{\Delta c}{c} \times 100$$

$$+ \gamma . \frac{\Delta d}{d} \times 100 + \delta . \frac{\Delta e}{e} \times 100$$

$= (\alpha b_1 + \beta c_1 + \gamma d_1 + \delta e_1)\%$

16. (a) Weight in air $= (5.00 \pm 0.05) N$

Weight in water $= (4.00 \pm 0.05) N$

Loss of weight in water $= (1.00 \pm 0.1) N$

Now relative density $= \frac{\text{weight in air}}{\text{weight loss in water}}$

i.e. R . D $= \frac{5.00 \pm 0.05}{1.00 \pm 0.1}$

Now relative density with max permissible error

$= \frac{5.00}{1.00} \pm \left(\frac{0.05}{5.00} + \frac{0.1}{1.00}\right) \times 100 = 5.0 \pm (1 + 10)\%$

$= 5.0 \pm 11\%$

17. (b) $\therefore \left(\frac{\Delta R}{R} \times 100\right)_{max} = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$

$= \frac{5}{100} \times 100 + \frac{0.2}{10} \times 100 = (5 + 2)\%$ = 7%

18. (b) Average value $= \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5}$

$= 2.62$ sec

Now $|\Delta T_1| = 2.63 - 2.62 = 0.01$

$|\Delta T_2| = 2.62 - 2.56 = 0.06$

$|\Delta T_3| = 2.62 - 2.42 = 0.20$

$|\Delta T_4| = 2.71 - 2.62 = 0.09$

$|\Delta T_5| = 2.80 - 2.62 = 0.18$

Mean absolute error

$$\Delta T = \frac{|\Delta T_1| + |\Delta T_2| + |\Delta T_3| + |\Delta T_4| + |\Delta T_5|}{5}$$

$= \frac{0.54}{5} = 0.108 = 0.11 sec$

19. (c) Volume of cylinder $V = \pi r^2 l$

Percentage error in volume

$\frac{\Delta V}{V} \times 100 = \frac{2\Delta r}{r} \times 100 + \frac{\Delta l}{l} \times 100$

$= \left(2 \times \frac{0.01}{2.0} \times 100 + \frac{0.1}{5.0} \times 100\right) = (1 + 2)\% = 3\%$

20. (c) $Y = \frac{4MgL}{\pi D^2 l}$ so maximum permissible error in *Y*

$= \frac{\Delta Y}{Y} \times 100 = \left(\frac{\Delta M}{M} + \frac{\Delta g}{g} + \frac{\Delta L}{L} + \frac{2\Delta D}{D} + \frac{\Delta l}{l}\right) \times 100$

$= \left(\frac{1}{300} + \frac{1}{981} + \frac{1}{2820} + 2 \times \frac{1}{41} + \frac{1}{87}\right) \times 100$

$= 0.065 \times 100 = 6.5\%$

21. (b) $H = I^2 R t$

$\therefore \frac{\Delta H}{H} \times 100 = \left(\frac{2\Delta I}{I} + \frac{\Delta R}{R} + \frac{\Delta t}{t}\right) \times 100$

$= (2 \times 3 + 4 + 6)\% = 16\%$

22. (d) Kinetic energy $E = \frac{1}{2} m v^2$

$\therefore \frac{\Delta E}{E} \times 100 = \frac{v'^2 - v^2}{v^2} \times 100$

$= [(1.5)^2 - 1] \times 100$

$\therefore \frac{\Delta E}{E} \times 100 = 125\%$

23. (c) Quantity *C* has maximum power. So it brings maximum error in *P*.

24. (c) Given, $L = 2.331\ cm$

$= 2.33$ (correct upto two decimal places)

and $B = 2.1\ cm = 2.10\ cm$

$\therefore L + B = 2.33 + 2.10 = 4.43\ cm. = 4.4\ cm$

Since minimum significant figure is 2.

25. (d) The number of significant figures in all of the given number is 4.

26. (c)

27. (a) Percentage error in $X = a\alpha + b\beta + c\gamma$

28. (d) Percentage error in *A*

$= \left(2 \times 1 + 3 \times 3 + 1 \times 2 + \frac{1}{2} \times 2\right)\% = 14\%$

Critical Thinking Questions

1. (d) $n_2 = n_1 \left[\frac{L_1}{L_2}\right]^1 \left[\frac{T_1}{T_2}\right]^{-2} = 10 \left[\frac{meter}{km}\right]^1 \left[\frac{\sec}{hr}\right]^{-2}$

$n_2 = 10 \left[\frac{m}{10^3 m}\right]^1 \left[\frac{\sec}{3600 \sec}\right]^{-2} = 129600$

2. (d) $f = \frac{1}{2\pi\sqrt{LC}}$ $\therefore$ $\left(\frac{C}{L}\right)$ does not represent the dimension of frequency

3. (d) $[n]$ = Number of particles crossing a unit area in unit time = $[L^{-2}T^{-1}]$

$[n_2] = [n_1]$ = number of particles per unit volume = $[L^{-3}]$

$[x_2] = [x_1]$ = positions

$\therefore D = \frac{[n][x_2 - x_1]}{[n_2 - n_1]} = \frac{[L^{-2}T^{-1}] \times [L]}{[L^{-3}]} = [L^2T^{-1}]$

4. (c) We can derive this equation from equations of motion so it is numerically correct.

S_t = distance travelled in t second = $\frac{\text{Distance}}{\text{time}} = [LT^{-1}]$

u = velocity = $[LT^{-1}]$ and $\frac{1}{2}a(2t-1) = [LT^{-1}]$

As dimensions of each term in the given equation are same, hence equation is dimensionally correct also.

5. (b, d) Length $\propto Gch$

$L = [M^{-1}L^3T^{-2}]^x \; [LT^{-1}]^y [ML^2T^{-1}]^z$

By comparing the power of M, L and T in both sides we get $-x+z=0$, $3x+y+2z=1$ and $-2x-y-z=0$

By solving above three equations we get

$x = \frac{1}{2}, y = -\frac{3}{2}, z = \frac{1}{2}$

6. (d) By substituting the dimensions of mass [M], length [L] and coefficient of rigidity $[ML^{-1}T^{-2}]$ we get $T = 2\pi\sqrt{\frac{M}{\eta L}}$ is the right formula for time period of oscillations

7. (a, b, c) Reynolds number and coefficient of friction are dimensionless.

Latent heat and gravitational potential both have dimension $[L^2T^{-2}]$.

Curie and frequency of a light wave both have dimension $[T^{-1}]$. But dimensions of Planck's constant is $[ML^2T^{-1}]$ and torque is $[ML^2T^{-2}]$

8. (a) Time $\propto c^x G^y h^z \Rightarrow T = kc^x G^y h^z$

Putting the dimensions in the above relation

$\Rightarrow [M^0L^0T^1] = [LT^{-1}]^x [M^{-1}L^3T^{-2}]^y [ML^2T^{-1}]^z$

$\Rightarrow [M^0L^0T^1] = [M^{-y+z}L^{x+3y+2z}T^{-x-2y-z}]$

Comparing the powers of M, L and T

$-y+z=0$ ...(i)

$x+3y+2z=0$ ...(ii)

$-x-2y-z=1$ ...(iii)

On solving equations (i) and (ii) and (iii)

$x = \frac{-5}{2}, y = z = \frac{1}{2}$

Hence dimension of time are $[G^{1/2}h^{1/2}c^{-5/2}]$

9. (a) Let radius of gyration $[k] \propto [h]^x [c]^y [G]^z$

By substituting the dimension of $[k] = [L]$

$[h] = [ML^2T^{-1}], [c] = [LT^{-1}], [G] = [M^{-1}L^3T^{-2}]$

and by comparing the power of both sides

we can get $x = 1/2, y = -3/2, z = 1/2$

So dimension of radius of gyration are $[h]^{1/2}[c]^{-3/2}[G]^{1/2}$

10. (d) $Y = \frac{X}{3Z^2} = \frac{M^{-1}L^{-2}T^4A^2}{[MT^{-2}A^{-1}]^2} = [M^{-3}L^{-2}T^8A^4]$

11. (a) In given equation, $\frac{\alpha z}{k\theta}$ should be dimensionless

$\therefore \alpha = \frac{k\theta}{z} \Rightarrow [\alpha] = \frac{[ML^2T^{-2}K^{-1} \times K]}{[L]} = [MLT^{-2}]$

and $P = \frac{\alpha}{\beta} \Rightarrow [\beta] = \left[\frac{\alpha}{p}\right] = \frac{[MLT^{-2}]}{[ML^{-1}T^{-2}]} = [M^0L^2T^0]$.

12. (c) $v = \frac{P}{2l}\left[\frac{F}{m}\right]^{1/2} \Rightarrow v^2 = \frac{P^2}{4l^2}\left[\frac{F}{m}\right] \therefore m \propto \frac{F}{l^2v^2}$

$\Rightarrow [m] = \left[\frac{MLT^{-2}}{L^2T^{-2}}\right] = [ML^{-1}T^0]$

13. (a)

14. (d) $\because$ Density, $\rho = \frac{M}{V} = \frac{M}{\pi r^2 L}$

$\Rightarrow \frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 2\frac{\Delta r}{r} + \frac{\Delta L}{L}$

$= \frac{0.003}{0.3} + 2 \times \frac{0.005}{0.5} + \frac{0.06}{6}$

$= 0.01 + 0.02 + 0.01 = 0.04$

$\therefore$ Percentage error $= \frac{\Delta\rho}{\rho} \times 100 = 0.04 \times 100 = 4\%$

15. (a)

Assertion and Reason

1. (c) Light year and wavelength both represents the distance, so both has dimension of length not of time.

2. (d) Light year measures distance and year measures time. One light year is the distance traveled by light in one year.

3. (a) Addition and subtraction can be done between quantities having same dimension.

4. (c) Density is not always mass per unit volume.

5. (d) Rate of flow of liquid is expressed as the volume of liquid flowing per second and it has dimension $[L^3T^{-1}]$.

6. (a)

7. (a) As the distance of star increases, the parallax angle decreases, and great degree of accuracy is required for its measurement. Keeping in view the practical limitation in measuring the parallax angle, the maximum distance of a star we can measure is limited to 100 light year.

8. (c) Since zeros placed to the left of the number are never significant, but zeros placed to right of the number are significant.

9. (b) The last number is most accurate because it has greatest significant figure (3).

10. (a) As length, mass and time represent our basic scientific notations, therefore they are called fundamental quantities and they cannot be obtained from each other.

11. (c) Because density can be derived from fundamental quantities.

12. (c) Because representation of standard metre in terms of wavelength of light is most accurate.

13. (a) As radar is most accurate instrument used to detect aeroplane in sky based on principle of reflection of radio waves.

14. (c) As surface tension and surface energy both have different S.I. unit and same dimensional formula.

15. (c) As ω (angular velocity) has the dimension of $[T^{-1}]$ not $[T]$.

16. (e) Radian is the unit of plane angle.

17. (b) A.U. is used (Astronomical units) to measure the average distance of the centre of the sun from the centre of the earth, while angstrom is used for very short distances. 1 A.U. = $1.5\times10^{11}\,m;\;\; 1Å = 10^{-10}\,m.$

18. (c) We know that $Q = n_1u_1 = n_2u_2$ are the two units of measurement of the quantity Q and n, n are their respective numerical values. From relation $Q_1 = n_1u_1 = n_2u_2$, nu = constant $\Rightarrow n \propto 1/u$ *i.e.,* smaller the unit of measurement, greater is its numerical value.

19. (c) Dimensional constants are the quantities whose value are constant and they posses dimensions. For example, velocity of light in vacuum, universal gravitational constant, Boltzman constant, Planck's constant etc.

20. (e) Let us write the dimension of various quantities on two sides of the given relation.

L.H.S. $= T = [T]$, R.H.S. $= 2\pi\sqrt{g/l} = \sqrt{\frac{LT^{-2}}{L}} = [T^{-1}]$

($\because 2\pi$ has no dimension). As dimensions of L.H.S. is not equal to dimension of R.H.S. therefore according to principle of homogeneity the relation

$T = 2\pi\sqrt{g/l}$ is not valid.

21. (b) From, $f = \frac{1}{2l}\sqrt{\frac{T}{m}}$, $f^2 = \frac{T}{4l^2m}$

or, $m = \frac{T}{4l^2f^2} = \frac{[MLT^{-2}]}{L^2T^{-2}} = \frac{M}{L} = \frac{\text{Mass}}{\text{length}}$ = linear mass density.

22. (a) According to statement of reason, as the graph is a straight line, $P \propto Q$, or P = constant × Q

i.e. $\frac{P}{Q}$ = constant

23. (c) Avogadro number (N) represents the number of atoms in 1 gram mole of an element, i.e. it has the dimensions of mole.

24. (a) Unit of quantity (L/R) is Henry/ohm.

As Henry = ohm × sec, hence unit of L/R is sec i.e.

[L/R] = [T].

Similarly, unit of product CR is farad × ohm or,

$\frac{\text{Coulomb}}{\text{Volt}} \times \frac{\text{Volt}}{\text{Amp}}$ or, $\frac{\text{Sec}\times\text{Amp}}{\text{Amp}}$ or, *sec* i.e. [CR] = [T] therefore [L/R] and [CR] both have the same dimension.

25. (b) Both assertion and reason are true but reason is not the correct explanation of assertion.

$[\varepsilon_0] = [M^{-1}L^{-3}T^4I^2]$, $[\mu_0] = [MLT^{-2}I^{-2}]$

$$\Rightarrow \frac{1}{\sqrt{(\mu_0/4\pi)\times 4\pi E_0}} = \sqrt{\frac{9\times10^9}{10^{-7}}} = \sqrt{9\times10^{16}}$$

$= 3\times10^8\,m/s.$

Therefore $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ has dimension of velocity and numerically equal to velocity of light.

Units, Dimensions and Measurement

SET Self Evaluation Test - 1

1. The surface tension of a liquid is $70\ dyne/cm$. In MKS system its value is [CPMT 1973, 74; AFMC 1996; BHU 2002]
(a) $70\,N/m$ (b) $7\times10^{-2}\ N/m$
(c) $7\times10^{3}\ N/m$ (d) $7\times10^{2}\ N/m$

2. The SI unit of universal gas constant (R) is [MP Board 1988; JIPMER 1993; AFMC 1996; MP PMT 1987, 94; CPMT 1984, 87; UPSEAT 1999]
(a) $Watt K^{-1}mol^{-1}$
(b) $Newton\ K^{-1}mol^{-1}$
(c) $Joule\,K^{-1}\ mol^{-1}$
(d) $Erg\,K^{-1}\ mol^{-1}$

3. The unit of permittivity of free space ε_0 is [MP PET 1993; MP PMT 2003; CBSE PMT 2004]
(a) *Coulomb/Newton-metre*
(b) Newton-$metre^2/Coulomb^2$
(c) Coulomb$^2/(Newton\text{-}metre)^2$
(d) $Coulomb^2/Newton\text{-}metre^2$

4. The temperature of a body on Kelvin scale is found to be $X\ K$. When it is measured by a Fahrenheit thermometer, it is found to be X^0F. Then X is [UPSEAT 2000]
(a) 301.25
(b) 574.25
(c) 313
(d) 40

5. What are the units of $K=1/4\pi\varepsilon_0$ [AFMC 2004]
(a) $C^2N^{-1}m^{-2}$ (b) Nm^2C^{-2}
(c) Nm^2C^2 (d) Unitless

6. The SI unit of surface tension is [DCE 2003]
(a) *Dyne/cm* (b) *Newton/cm*
(c) *Newton/metre* (d) *Newton-metre*

7. E, m, l and G denote energy, mass, angular momentum and gravitational constant respectively, then the dimension of $\frac{El^2}{m^5G^2}$ are [AIIMS 1985]
(a) Angle (b) Length
(c) Mass (d) Time

8. From the equation $\tan\theta=\frac{rg}{v^2}$, one can obtain the angle of banking θ for a cyclist taking a curve (the symbols have their usual meanings). Then say, it is
(a) Both dimensionally and numerically correct
(b) Neither numerically nor dimensionally correct
(c) Dimensionally correct only
(d) Numerically correct only

9. A dimensionally consistent relation for the volume V of a liquid of coefficient of viscosity η flowing per *second* through a tube of radius r and length l and having a pressure difference p across its end, is
(a) $V=\frac{\pi pr^4}{8\eta l}$ (b) $V=\frac{\pi\eta l}{8pr^4}$
(c) $V=\frac{8p\eta l}{\pi r^4}$ (d) $V=\frac{\pi p\eta}{8lr^4}$

10. The velocity v (in $cm/\sec$) of a particle is given in terms of time t (in *sec*) by the relation $v=at+\frac{b}{t+c}$; the dimensions of a, b and c are [CPMT 1990]
(a) $a=L^2, b=T, c=LT^2$
(b) $a=LT^2, b=LT, c=L$
(c) $a=LT^{-2}, b=L, c=T$
(d) $a=L, b=LT, c=T^2$

11. From the dimensional consideration, which of the following equation is correct [CPMT 1983]
(a) $T=2\pi\sqrt{\frac{R^3}{GM}}$ (b) $T=2\pi\sqrt{\frac{GM}{R^3}}$
(c) $T=2\pi\sqrt{\frac{GM}{R^2}}$ (d) $T=2\pi\sqrt{\frac{R^2}{GM}}$

12. The position of a particle at time t is given by the relation $x(t)=\left(\frac{v_0}{\alpha}\right)(1-c^{-\alpha t})$, where v_0 is a constant and $\alpha>0$. The dimensions of v_0 and α are respectively [CBSE PMT 1995]
(a) $M^0L^1T^{-1}$ and T^{-1}
(b) $M^0L^1T^0$ and T^{-1}
(c) $M^0L^1T^{-1}$ and LT^{-2}
(d) $M^0L^1T^{-1}$ and T

13. The equation of state of some gases can be expressed as $\left(P + \frac{a}{V^2}\right) = \frac{R\theta}{V}$ Where P is the pressure, V the volume, θ the absolute temperature and a and b are constants. The dimensional formula of a is

[UPSEAT 2002; Orissa PMT 2004]

(a) $[ML^5T^{-2}]$ (b) $[M^{-1}L^5T^{-2}]$

(c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-5}T^{-2}]$

14. The dimensions of $\frac{a}{b}$ in the equation $P = \frac{a - t^2}{bx}$, where P is pressure, x is distance and t is time, are

[KCET 2003]

(a) MT^{-2} (b) M^2LT^{-3}

(c) ML^3T^{-1} (d) LT^{-3}

15. Dimensions of $\frac{1}{\mu_0\varepsilon_0}$, where symbols have their usual meaning, are [AIEEE 2003]

(a) $[LT^{-1}]$ (b) $[L^{-1}T]$

(c) $[L^{-2}T^2]$ (d) $[L^2T^{-2}]$

16. The dimensions of $e^2/4\pi\varepsilon_0 hc$, where e, ε_0, h and c are electronic charge, electric permittivity, Planck's constant and velocity of light in vacuum respectively [UPSEAT 2004]

(a) $[M^0L^0T^0]$ (b) $[M^1L^0T^0]$

(c) $[M^0L^1T^0]$ (d) $[M^0L^0T^1]$

17. If radius of the sphere is $(5.3 \pm 0.1)\, cm$. Then percentage error in its volume will be [Pb. PET 2000]

(a) $3 + 6.01 \times \frac{100}{5.3}$ (b) $\frac{1}{3} \times 0.01 \times \frac{100}{5.3}$

(c) $\left(\frac{3 \times 0.1}{5.3}\right) \times 100$ (d) $\frac{0.1}{5.3} \times 100$

18. The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate. If the maximum error in the measurement of force and length are respectively 4% and 2%, The maximum error in the measurement of pressure is

[CPMT 1993]

(a) 1% (b) 2%

(c) 6% (d) 8%

19. While measuring the acceleration due to gravity by a simple pendulum, a student makes a positive error of 1% in the length of the pendulum and a negative error of 3% in the value of time period. His percentage error in the measurement of g by the relation $g = 4\pi^2(l/T^2)$ will be

(a) 2% (b) 4%

(c) 7% (d) 10%

20. The length, breadth and thickness of a block are given by $l = 12\,cm, b = 6\,cm$ and $t = 2.45\,cm$

The volume of the block according to the idea of significant figures should be [CPMT 2004]

(a) $1 \times 10^2\ cm^3$ (b) $2 \times 10^2\ cm^3$

(c) $1.763 \times 10^2 cm^3$ (d) None of these

Answers and Solutions

(SET -1)

1. (b) 1 $dyne = 10^{-5}$ $Newton$, $1\,cm = 10^{-2}\,m$

$$70\frac{dyne}{cm} = \frac{70\times 10^{-5}}{10^{-2}}\frac{N}{m}$$

$= 7\times 10^{-2}\,N/m$.

2. (c) $PV = nRT \Rightarrow R = \frac{PV}{nT} = \frac{Joule}{mole\times Kelvin} = JK^{-1}mol^{-1}$

3. (d) $F = \frac{1}{4\pi\varepsilon_0}.\frac{Q_1Q_2}{r^2}$

$\Rightarrow \varepsilon_0 \propto \frac{Q^2}{F\times r^2}$

So ε_0 has units of $Coulomb^2/Newton\text{-}m^2$

4. (b) $\frac{F-32}{9} = \frac{K-273}{5} \Rightarrow \frac{x-32}{9} = \frac{x-273}{5} \Rightarrow x = 574.25$

5. (b) Unit of $\varepsilon_0 = C^2/N\text{-}m^2$ $\therefore$Unit of K = Nm^2C^{-2}

6. (c)

7. (a) $[E]=[ML^2T^{-2}]$, $[m]=[M]$, $[l]=[ML^2T^{-1}]$ and $[G]=[M^{-1}L^3T^{-2}]$ Substituting the dimension of above quantities in the given formula :

$$\frac{El^2}{m^5G^2}\ \frac{[ML^2T^{-2}][ML^2T^{-1}]^2}{[M^5][M^{-1}L^3T^{-2}]^2} = \frac{M^3L^6T^{-4}}{M^3L^6T^{-4}} = [M^0L^0T^0]$$

8. (c) Given equation is dimensionally correct because both sides are dimensionless but numerically wrong because the correct equation is $\tan\theta = \frac{v^2}{rg}$.

9. (a) Formula for viscosity $\eta = \frac{\pi pr^4}{8Vl} \Rightarrow V = \frac{\pi pr^4}{8\eta l}$

10. (c) From the principle of dimensional homogenity $[v]=[at] \Rightarrow [a]=[LT^{-2}]$. Similarly $[b]=[L]$ and $[c]=[T]$

11. (a) By substituting the dimensions in $T = 2\pi\sqrt{\frac{R^3}{GM}}$

we get $\sqrt{\frac{L^3}{M^{-1}L^3T^{-2}\times M}} = T$

12. (a) Dimension of αt = $[M^0L^0T^0]$ $\therefore$ $[\alpha]$ = $[T^{-1}]$

Again $\left[\frac{v_0}{\alpha}\right] = [L]$ so $[v_0] = [LT^{-1}]$

***

13. (a) By the principle of dimensional homogenity

$$[P] = \left[\frac{a}{V^2}\right] \Rightarrow [a] = [P]\times[V^2] = [ML^{-1}T^{-2}][L^6]$$

$= [ML^5T^{-2}]$

14. (a) $[a]=[T^2]$ and $[b] = \frac{[a-t^2]}{[P][x]} = \frac{T^2}{[ML^{-1}T^{-2}][L]}$

$\Rightarrow [b] = [M^{-1}T^4]$

So $\left[\frac{a}{b}\right] = \frac{[T^2]}{[M^{-1}T^4]} = [MT^{-2}]$

15. (d) $C = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow \frac{1}{\mu_0\varepsilon_0} = c^2 = [L^2T^{-2}]$

16. (a) $[e]=[AT]$, $\epsilon_0 = [M^{-1}L^{-3}T^4A^2]$, $[h]=[ML^2T^{-1}]$

and $[c]=[LT^{-1}]$

$$\therefore \left[\frac{e^2}{4\pi\epsilon_0\,hc}\right] = \left[\frac{A^2T^2}{M^{-1}L^{-3}T^4A^2\times ML^2T^{-1}\times LT^{-1}}\right]$$

$= [M^0L^0T^0]$

17. (c) Volume of sphere $(V) = \frac{4}{3}\pi r^3$

% error in volume $= 3\times\frac{\Delta r}{r}\times 100 = \left(3\times\frac{0.1}{5.3}\right)\times 100$

18. (d) $P = \frac{F}{A} = \frac{F}{l^2}$, so maximum error in pressure (P)

$$\left(\frac{\Delta P}{P}\times 100\right)_{max} = \frac{\Delta F}{F}\times 100 + 2\frac{\Delta l}{l}\times 100$$

=4%+2×2%=8%

19. (c) Percentage error in g = (%error in l) + 2(% error in T) = 1% + 2(3%) = 7%

20. (b) Volume $V = l\times b\times t$

$= 12\times 6\times 2.45 = 176.4\ cm^3$

$V = 1.764\times 10^2\ cm^3$

since, the minimum number of significant figure is one in breadth, hence volume will also contain only one significant figure. Hence, $V = 2\times 10^2\ cm^3$.

Chapter
2
Motion In One Dimension

Position

Any object is situated at point O and three observers from three different places are looking at same object, then all three observers will have different observations about the position of point O and no one will be wrong. Because they are observing the object from different positions.

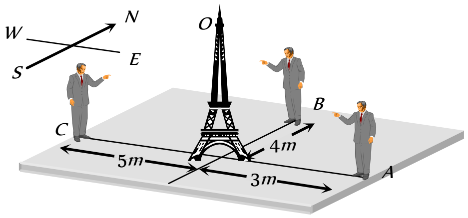


Fig. 2.1

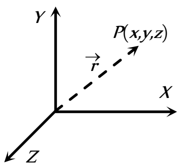
Observer 'A' says : Point O is 3 m away in west direction.

Observer 'B' says : Point O is 4 m away in south direction.

Observer 'C' says : Point O is 5 m away in east direction.

Therefore position of any point is completely expressed by two factors: Its distance from the observer and its direction with respect to observer.

That is why position is characterised by a vector known as position vector.



Consider a point P in xy plane and its coordinates are (x, y). Then position vector $(\vec{r})$ of point will be $x\hat{i} + y\hat{j}$ and if the point P is in space and its coordinates are (x, y, z) then position vector can be expressed as $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

Rest and Motion

If a body does not change its position as time passes with respect to frame of reference, it is said to be at rest.

And if a body changes its position as time passes with respect to frame of reference, it is said to be in motion.

Frame of Reference : It is a system to which a set of coordinates are attached and with reference to which observer describes any event.

A passenger standing on platform observes that a tree on a platform is at rest. But the same passenger passing away in a train through station, observes that tree is in motion. In both conditions observer is right. But observations are different because in first situation observer stands on a platform, which is reference frame at rest and in second situation observer moving in train, which is reference frame in motion.

So rest and motion are relative terms. It depends upon the frame of references.

Table 2.1 : Types of motion

One dimensional	Two dimensional	Three dimensional
Motion of a body in a straight line is called one dimensional motion.	Motion of body in a plane is called two dimensional motion.	Motion of body in a space is called three dimensional motion.
When only one coordinate of the position of a body changes with time then it is said to be moving one dimensionally.	When two coordinates of the position of a body changes with time then it is said to be moving two dimensionally.	When all three coordinates of the position of a body changes with time then it is said to be moving three dimensionally.
Ex. (i) Motion of car on a straight road. (ii) Motion of freely falling body.	*Ex.* (i) Motion of car on a circular turn. (ii) Motion of billiards ball.	*Ex.* (i) Motion of flying kite. (ii) Motion of flying insect.

Particle or Point Mass or Point object

The smallest part of matter with zero dimension which can be described by its mass and position is defined as a particle or point mass.

If the size of a body is negligible in comparison to its range of motion then that body is known as a particle.

A body (Group of particles) can be treated as a particle, depends upon types of motion. For example in a planetary motion around the sun the different planets can be presumed to be the particles.

In above consideration when we treat body as particle, all parts of the body undergo same displacement and have same velocity and acceleration.

Distance and Displacement

(1) **Distance :** It is the actual length of the path covered by a moving particle in a given interval of time.

(i) If a particle starts from A and reach to C through point B as shown in the figure.

Then distance travelled by particle

$= AB + BC = 7\ m$

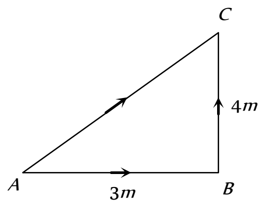


Fig. 2.2

(ii) Distance is a scalar quantity.

(iii) Dimension : $[M^0L^1T^0]$

(iv) Unit : metre (S.I.)

(2) **Displacement :** Displacement is the change in position vector i.e., A vector joining initial to final position.

(i) Displacement is a vector quantity

(ii) Dimension : $[M^0L^1T^0]$

(iii) Unit : metre (S.I.)

(iv) In the above figure the displacement of the particle $\overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC} \Rightarrow |\ AC|$

$= \sqrt{(AB)^2 + (BC)^2 + 2(AB)(BC)\cos 90^o} = 5\ m$

(v) If $\vec{S}_1, \vec{S}_2, \vec{S}_3$ .... $\vec{S}_n$ are the displacements of a body then the total (net) displacement is the vector sum of the individuals. $\vec{S} = \vec{S}_1 + \vec{S}_2 + \vec{S}_3 + ... + \vec{S}_n$

(3) **Comparison between distance and displacement :**

(i) The magnitude of displacement is equal to minimum possible distance between two positions.

So distance $\geq$ |Displacement|.

(ii) For a moving particle distance can never be negative or zero while displacement can be.

(zero displacement means that body after motion has came back to initial position)

i.e., Distance > 0 but Displacement > = or < 0

(iii) For motion between two points, displacement is single valued while distance depends on actual path and so can have many values.

(iv) For a moving particle distance can never decrease with time while displacement can. Decrease in displacement with time means body is moving towards the initial position.

(v) In general, magnitude of displacement is not equal to distance. However, it can be so if the motion is along a straight line without change in direction.

(vi) If $\vec{r}_A$ and $\vec{r}_B$ are the position vectors of particle initially and finally.

Then displacement of the particle $\vec{r}_{AB} = \vec{r}_B - \vec{r}_A$

and *s* is the distance travelled if the particle has gone through the path *APB*.

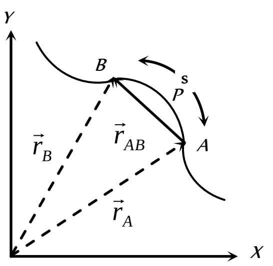


Fig. 2.3

Speed and Velocity

(1) **Speed :** The rate of distance covered with time is called speed.

(i) It is a scalar quantity having symbol υ .

(ii) Dimension : $[M^0L^1T^{-1}]$

(iii) Unit : *metre/second* (S.I.), *cm/second* (C.G.S.)

(iv) Types of speed :

(a) **Uniform speed :** When a particle covers equal distances in equal intervals of time, (no matter how small the intervals are) then it is said to be moving with uniform speed. In given illustration motorcyclist travels equal distance (= 5*m*) in each second. So we can say that particle is moving with uniform speed of 5 *m/s*.

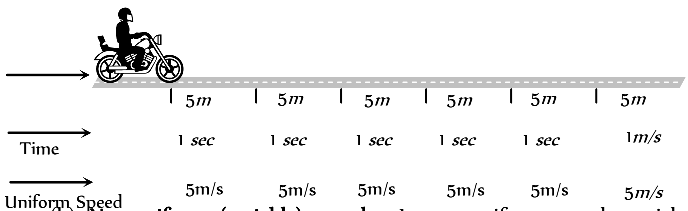


Fig. 2.4

(b) **Non-uniform (variable) speed :** In non-uniform speed particle covers unequal distances in equal intervals of time. In the given illustration motorcyclist travels 5*m* in 1st second, 8*m* in 2nd second, 10*m* in 3rd second, 4*m* in 4th second *etc.*

Therefore its speed is different for every time interval of one second. This means particle is moving with variable speed.

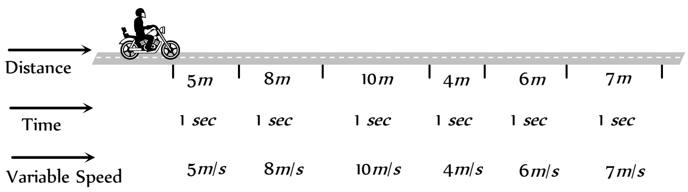


Fig. 2.5

(c) **Average speed :** The average speed of a particle for a given 'Interval of time' is defined as the ratio of total distance travelled to the time taken.

Average speed $= \dfrac{\text{Total distance travelled}}{\text{Time taken}}$; $v_{av} = \dfrac{\Delta s}{\Delta t}$

❑ Time average speed : When particle moves with different uniform speed υ_1, υ_2, υ_3 ... *etc* in different time intervals t_1, t_2, t_3, ... *etc* respectively, its average speed over the total time of journey is given as

$$v_{av} = \frac{\text{Total distance covered}}{\text{Total time elapsed}}$$

$$= \frac{d_1 + d_2 + d_3 + ...}{t_1 + t_2 + t_3 + ...} = \frac{\upsilon_1 t_1 + \upsilon_2 t_2 + \upsilon_3 t_3 + ...}{t_1 + t_2 + t_3 + ...}$$

❑ Distance averaged speed : When a particle describes different distances d_1, d_2, d_3, ... with different time intervals t_1, t_2, t_3, ... with speeds v_1, v_2, v_3...... respectively then the speed of particle averaged over the total distance can be given as

$$\upsilon_{av} = \frac{\text{Total distance covered}}{\text{Total time elapsed}} = \frac{d_1 + d_2 + d_3 + ...}{t_1 + t_2 + t_3 + ...}$$

$$= \frac{d_1 + d_2 + d_3 + ...}{\dfrac{d_1}{\upsilon_1} + \dfrac{d_2}{\upsilon_2} + \dfrac{d_3}{\upsilon_3} + ...}$$

❑ If speed is continuously changing with time then

$$v_{av} = \frac{\int v dt}{\int dt}$$

(d) **Instantaneous speed :** It is the speed of a particle at a particular instant of time. When we say "speed", it usually means instantaneous speed.

The instantaneous speed is average speed for infinitesimally small time interval (*i.e.*, $\Delta t \to 0$). Thus

Instantaneous speed $v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$

(2) **Velocity :** The rate of change of position *i.e.* rate of displacement with time is called velocity.

(i) It is a vector quantity having symbol $\vec{v}$.

(ii) Dimension : $[M^0LT^{-1}]$

(iii) Unit : *metre/second* (S.I.), *cm/second* (C.G.S.)

(iv) Types of velocity :

(a) **Uniform velocity :** A particle is said to have uniform velocity, if magnitudes as well as direction of its velocity remains same and this is possible only when the particles moves in same straight line without reversing its direction.

(b) **Non-uniform velocity :** A particle is said to have non-uniform velocity, if either of magnitude or direction of velocity changes or both of them change.

(c) **Average velocity** : It is defined as the ratio of displacement to time taken by the body

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time taken}}; \quad \vec{v}_{av} = \frac{\Delta \vec{r}}{\Delta t}$$

(d) **Instantaneous velocity :** Instantaneous velocity is defined as rate of change of position vector of particles with time at a certain instant of time.

Instantaneous velocity $\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta \vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$

(v) **Comparison between instantaneous speed and instantaneous velocity**

(a) instantaneous velocity is always tangential to the path followed by the particle.

When a stone is thrown from point O then at point of projection the instantaneous velocity of stone is $\vec{v}_1$, at point A the instantaneous velocity of stone is $\vec{v}_2$, similarly at point B and C are $\vec{v}_3$ and $\vec{v}_4$ respectively.

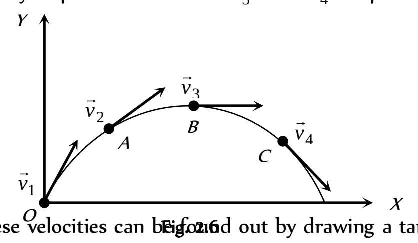


Fig. 2.6

Direction of these velocities can be found out by drawing a tangent on the trajectory at a given point.

(b) A particle may have constant instantaneous speed but variable instantaneous velocity.

Example : When a particle is performing uniform circular motion then for every instant of its circular motion its speed remains constant but velocity changes at every instant.

(c) The magnitude of instantaneous velocity is equal to the instantaneous speed.

(d) If a particle is moving with constant velocity then its average velocity and instantaneous velocity are always equal.

(e) If displacement is given as a function of time, then time derivative of displacement will give velocity.

Let displacement $\vec{x} = A_0 - A_1 t + A_2 t^2$

Instantaneous velocity $\vec{v} = \frac{d\vec{x}}{dt} = \frac{d}{dt}(A_0 - A_1 t + A_2 t^2)$

$\vec{v} = -A_1 + 2A_2 t$

For the given value of t, we can find out the instantaneous velocity.

e.g for $t = 0$, Instantaneous velocity $\vec{v} = -A_1$ and Instantaneous speed $|\vec{v}| = A_1$

(vi) **Comparison between average speed and average velocity**

(a) Average speed is a scalar while average velocity is a vector both having same units (m/s) and dimensions $[LT^{-1}]$.

(b) Average speed or velocity depends on time interval over which it is defined.

(c) For a given time interval average velocity is single valued while average speed can have many values depending on path followed.

(d) If after motion body comes back to its initial position then $\vec{v}_{av} = 0$ (as $\Delta \vec{r} = 0$) but $v_{av} > 0$ and finite as $(\Delta s > 0)$.

(e) For a moving body average speed can never be negative or zero (unless $t \to \infty$) while average velocity can be *i.e.* $v_{av} > 0$ while $\vec{v}_{av}$ = or < 0.

(f) As we know for a given time interval

Distance ≥ |displacement|

∴ Average speed ≥ |Average velocity|

Acceleration

The time rate of change of velocity of an object is called acceleration of the object.

(1) It is a vector quantity. It's direction is same as that of change in velocity (Not of the velocity)

Table 2.2 : Possible ways of velocity change

When only direction of velocity changes	When only magnitude of velocity changes	When both magnitude and direction of velocity changes
Acceleration perpendicular to velocity	Acceleration parallel or anti-parallel to velocity	Acceleration has two components one is perpendicular to velocity and another parallel or anti-parallel to velocity
Ex. Uniform circular motion	*Ex.* Motion under gravity	*Ex.* Projectile motion

(2) Dimension : $[M^0LT^{-2}]$

(3) Unit : *metre/second²* (S.I.); *cm/second²* (C.G.S.)

(4) Types of acceleration :

(i) **Uniform acceleration :** A body is said to have uniform acceleration if magnitude and direction of the acceleration remains constant during particle motion.

(ii) **Non-uniform acceleration :** A body is said to have non-uniform acceleration, if either magnitude or direction or both of them change during motion.

(iii) **Average acceleration :** $\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

The direction of average acceleration vector is the direction of the change in velocity vector as $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

(iv) **Instantaneous acceleration** = $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$

(v) For a moving body there is no relation between the direction of instantaneous velocity and direction of acceleration.

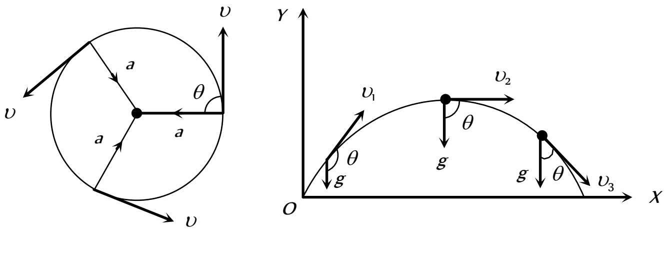


Fig. 2.7

Ex. (a) In uniform circular motion θ = 90° always

(b) In a projectile motion θ is variable for every point of trajectory.

(vi) If a force $\vec{F}$ acts on a particle of mass *m*, by Newton's 2nd law, acceleration $\vec{a} = \frac{\vec{F}}{m}$

(vii) By definition $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{x}}{dt^2}\left[\text{As } \vec{v} = \frac{d\vec{x}}{dt}\right]$

i.e., if *x* is given as a function of time, second time derivative of displacement gives acceleration

(viii) If velocity is given as a function of position, then by chain rule

$$a = \frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt} = v.\frac{d\upsilon}{dx}\left[\text{as } v = \frac{dx}{dt}\right]$$

(xi) Acceleration can be positive, zero or negative. Positive acceleration means velocity increasing with time, zero acceleration means velocity is uniform constant while negative acceleration (retardation) means velocity is decreasing with time.

(xii) For motion of a body under gravity, acceleration will be equal to "*g*", where g is the acceleration due to gravity. Its value is 9.8 m/s^2 or 980 cm/s^2 or 32 feet/s^2.

Position time Graph

During motion of the particle its parameters of kinematical analysis (*v*, *a*, *s*) changes with time. This can be represented on the graph.

Position time graph is plotted by taking time *t* along *x*-axis and position of the particle on *y*-axis.

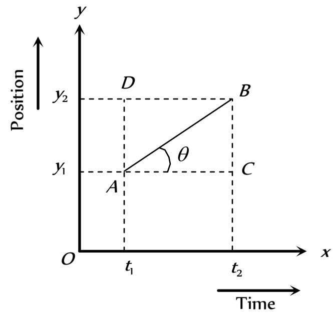


Fig. 2.8

Let *AB* is a position-time graph for any moving particle

As Velocity = $\frac{\text{Change in position}}{\text{Time taken}} = \frac{y_2 - y_1}{t_2 - t_1}$ ...(i)

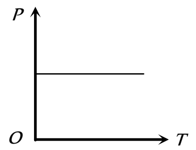
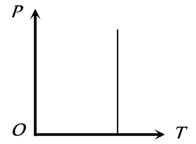
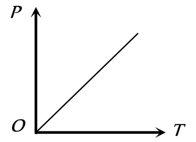
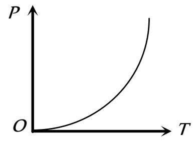
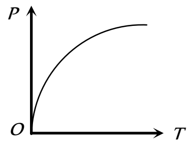
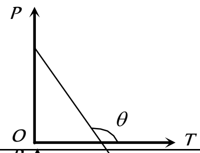
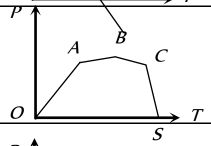
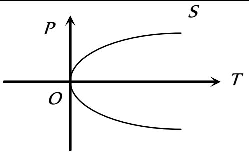
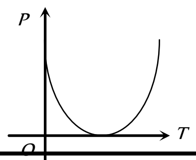
From triangle *ABC*, $\tan\theta = \frac{BC}{AC} = \frac{AD}{AC} = \frac{y_2 - y_1}{t_2 - t_1}$ ....(ii)

By comparing (i) and (ii) Velocity = $\tan\theta$

$v = \tan\theta$

It is clear that slope of tangent on position-time graph represents the velocity of the particle.

Table 2.3 : Various position -time graphs and their interpretation

	θ = 0° so $v = 0$ *i.e.*, line parallel to time axis represents that the particle is at rest.
	θ = 90° so $v = \infty$ i.e., line perpendicular to time axis represents that particle is changing its position but time does not changes it means the particle possesses infinite velocity. Practically this is not possible.
	θ = constant so v = constant, $a = 0$ i.e., line with constant slope represents uniform velocity of the particle.
	θ is increasing so v is increasing, a is positive. *i.e.*, line bending towards position axis represents increasing velocity of particle. It means the particle possesses acceleration.
	θ is decreasing so v is decreasing, a is negative *i.e.*, line bending towards time axis represents decreasing velocity of the particle. It means the particle possesses retardation.
	θ constant but > 90° so v will be constant but negative *i.e.*, line with negative slope represent that particle returns towards the point of reference. (negative displacement).
	Straight line segments of different slopes represent that velocity of the body changes after certain interval of time.
	This graph shows that at one instant the particle has two positions, which is not possible.
	The graph shows that particle coming towards origin initially and after that it is moving away from origin.

Note : ❑ If the graph is plotted between distance and time then it is always an increasing curve and it never comes back towards origin because distance never decrease with time. Hence such type of distance time graph is valid up to point A only, after point *A*, it is not valid as shown in the figure.

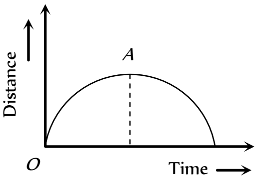


Fig. 2.9

Velocity-time Graph

The graph is plotted by taking time t along x-axis and velocity of the particle on y-axis.

Calculation of Distance and displacement : The area covered between the velocity time graph and time axis gives the displacement and distance travelled by the body for a given time interval.

Total distance $= |A_1| + |A_2| + |A_3|$

= Addition of modulus of different area. *i.e.* $s = \int |v|\, dt$

Total displacement $= A_1 + A_2 + A_3$

= Addition of different area considering their sign.

i.e. $r = \int \upsilon \, dt$

Area above time axis is taken as positive, while area below time axis is taken as negative

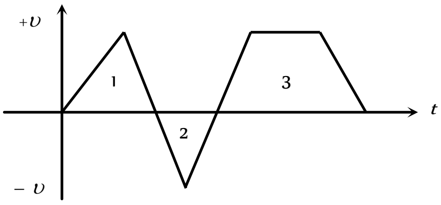


Fig. 2.10

here A_1 and A_2 are area of triangle 1 and 2 respectively and A_3 is the area of trapezium .

Calculation of Acceleration : Let *AB* is a velocity-time graph for any moving particle

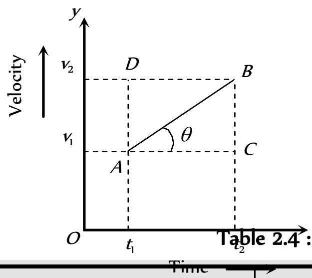


Fig. 2.11

As Acceleration = $\dfrac{\text{Change in velocity}}{\text{Time taken}}$

$$= \frac{v_2 - v_1}{t_2 - t_1} \quad \text{...(i)}$$

From triangle *ABC*, $\tan\theta = \dfrac{BC}{AC} = \dfrac{AD}{AC}$

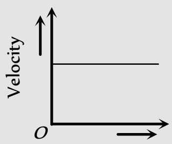
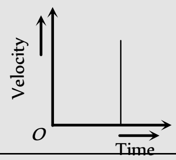
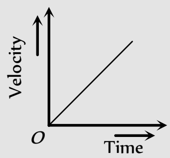
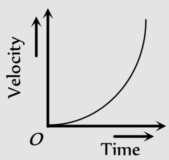
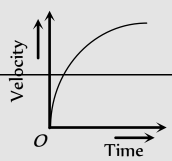
$$= \frac{v_2 - v_1}{t_2 - t_1} \quad \text{....(ii)}$$

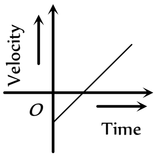
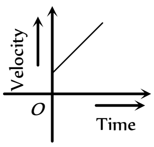
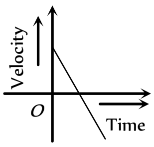
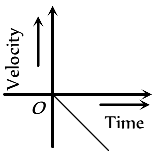
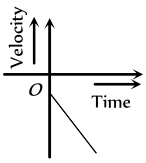
By comparing (i) and (ii)

Acceleration (a) = $\tan\theta$

It is clear that slope of tangent on velocity-time graph represents the acceleration of the particle.

Table 2.4 : Various velocity -time graphs and their interpretation

	$\theta = 0°$, $a = 0$, v = constant *i.e.*, line parallel to time axis represents that the particle is moving with constant velocity.
	$\theta = 90°$, $a = \infty$, v = increasing *i.e.*, line perpendicular to time axis represents that the particle is increasing its velocity, but time does not change. It means the particle possesses infinite acceleration. Practically it is not possible.
	θ = constant, so a = constant and v is increasing uniformly with time *i.e.*, line with constant slope represents uniform acceleration of the particle.
	θ increasing so acceleration increasing *i.e.*, line bending towards velocity axis represent the increasing acceleration in the body.
	θ decreasing so acceleration decreasing

	i.e. line bending towards time axis represents the decreasing acceleration in the body
	Positive constant acceleration because θ is constant and < 90° but initial velocity of the particle is negative.
	Positive constant acceleration because θ is constant and < 90° but initial velocity of particle is positive.
	Negative constant acceleration because θ is constant and > 90° but initial velocity of the particle is positive.
	Negative constant acceleration because θ is constant and > 90° but initial velocity of the particle is zero.
	Negative constant acceleration because θ is constant and > 90° but initial velocity of the particle is negative.

Equation of Kinematics

These are the various relations between *u, v, a, t* and *s* for the particle moving with uniform acceleration where the notations are used as :

u = Initial velocity of the particle at time *t* = 0 *sec*

v = Final velocity at time *t sec*

a = Acceleration of the particle

s = Distance travelled in time *t sec*

s_n = Distance travelled by the body in *n sec*

(1) **When particle moves with zero acceleration**

(i) It is a unidirectional motion with constant speed.

(ii) Magnitude of displacement is always equal to the distance travelled.

(iii) $v = u$, $s = u\,t$ [As $a = 0$]

(2) **When particle moves with constant acceleration**

(i) Acceleration is said to be constant when both the magnitude and direction of acceleration remain constant.

(ii) There will be one dimensional motion if initial velocity and acceleration are parallel or anti-parallel to each other.

(iii) Equations of motion (in scalar from)	Equation of motion (in vector from)
$v = u + at$	$\vec{v} = \vec{u} + \vec{a}t$
$s = ut + \frac{1}{2}at^2$	$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$
$v^2 = u^2 + 2as$	$\vec{v}.\vec{v} - \vec{u}.\vec{u} = 2\vec{a}.\vec{s}$
$s = \left(\frac{u+v}{2}\right)t$	$\vec{s} = \frac{1}{2}(\vec{u} + \vec{v})t$

$$s_n = u + \frac{a}{2}(2n-1) \qquad \vec{s}_n = \vec{u} + \frac{\vec{a}}{2}(2n-1)$$

Motion of Body Under Gravity (Free Fall)

The force of attraction of earth on bodies, is called force of gravity. Acceleration produced in the body by the force of gravity, is called acceleration due to gravity. It is represented by the symbol g.

In the absence of air resistance, it is found that all bodies (irrespective of the size, weight or composition) fall with the same acceleration near the surface of the earth. This motion of a body falling towards the earth from a small altitude ($h << R$) is called free fall.

An ideal example of one-dimensional motion is motion under gravity in which air resistance and the small changes in acceleration with height are neglected.

(1) **If a body is dropped from some height (initial velocity zero)**

(i) Equations of motion : Taking initial position as origin and direction of motion (*i.e.*, downward direction) as a positive, here we have

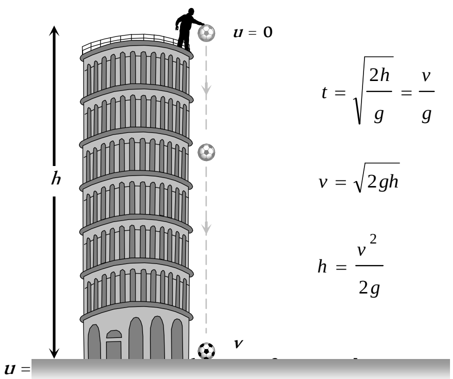


Fig. 2.12

$u = 0$

$a = +g$ [As acceleration is in the direction of motion]

$v = g\,t$ ...(i)

$h = \frac{1}{2}gt^2$ ...(ii)

$v^2 = 2gh$ ...(iii)

$h_n = \frac{g}{2}(2n-1)$ ...(iv)

(ii) Graph of distance, velocity and acceleration with respect to time :

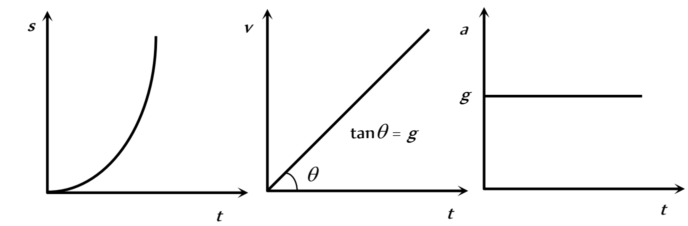


Fig. 2.13

(iii) As $h = (1/2)gt^2$, *i.e.*, $h \propto t^2$, distance covered in time t, $2t$, $3t$, *etc.*, will be in the ratio of $1^2 : 2^2 : 3^2$, *i.e.*, square of integers.

(iv) The distance covered in the *nth sec*, $h_n = \frac{1}{2}g(2n-1)$

So distance covered in 1st, 2nd, 3rd *sec*, *etc.*, will be in the ratio of 1 : 3 : 5, *i.e.*, odd integers only.

(2) **If a body is projected vertically downward with some initial velocity**

Equation of motion : $v = u + gt$

$$h = ut + \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2gh$$

$$h_n = u + \frac{g}{2}(2n-1)$$

(3) **If a body is projected vertically upward**

(i) Equation of motion : Taking initial position as origin and direction of motion (*i.e.*, vertically up) as positive

$a = -g$ [As acceleration is downwards while motion upwards]

So, if the body is projected with velocity u and after time t it reaches up to height h then

$$v = u - gt\,;\, h = ut - \frac{1}{2}gt^2\,;\, v^2 = u^2 - 2gh\,;\, h_n = u - \frac{g}{2}(2n-1)$$

(ii) For maximum height $v = 0$

So from above equation $u = gt$,

$$h = \frac{1}{2}gt^2$$

and $u^2 = 2gh$

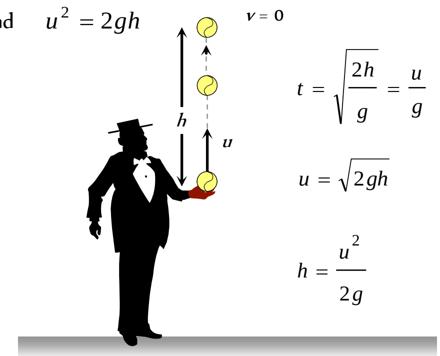


Fig. 2.14

(iii) Graph of displacement, velocity and acceleration with respect to time (for maximum height) :

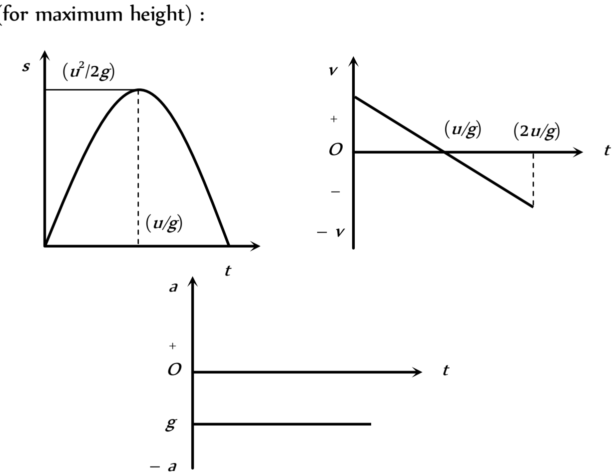


Fig. 2.15

It is clear that both quantities do not depend upon the mass of the body or we can say that in absence of air resistance, all bodies fall on the surface of the earth with the same rate.

(4) The motion is independent of the mass of the body, as in any equation of motion, mass is not involved. That is why a heavy and light body when released from the same height, reach the ground simultaneously and with same velocity *i.e.*, $t = \sqrt{(2h/g)}$ and $v = \sqrt{2gh}$.

(5) In case of motion under gravity, time taken to go up is equal to the time taken to fall down through the same distance. Time of descent (t_2) = time of ascent (t_1) = u/g

$\therefore$ Total time of flight $T = t_1 + t_2 = \dfrac{2u}{g}$

(6) In case of motion under gravity, the speed with which a body is projected up is equal to the speed with which it comes back to the point of projection.

As well as the magnitude of velocity at any point on the path is same whether the body is moving in upwards or downward direction.

(7) A body is thrown vertically upwards. If air resistance is to be taken into account, then the time of ascent is less than the time of descent. $t_2 > t_1$

Let u is the initial velocity of body then time of ascent $t_1 = \dfrac{u}{g+a}$

and $h = \dfrac{u^2}{2(g+a)}$

where g is acceleration due to gravity and a is retardation by air resistance and for upward motion both will work vertically downward.

For downward motion a and g will work in opposite direction because a always work in direction opposite to motion and g always work vertically downward.

So $h = \dfrac{1}{2}(g-a)t_2^2$

$$\Rightarrow \frac{u^2}{2(g+a)} = \frac{1}{2}(g-a)t_2^2$$

$$\Rightarrow t_2 = \frac{u}{\sqrt{(g+a)(g-a)}}$$

Comparing t_1 and t_2 we can say that $t_2 > t_1$

since $(g + a) > (g - a)$

Motion with Variable Acceleration

(i) If acceleration is a function of time

$a = f(t)$ then $v = u + \int_0^t f(t)\,dt$

and $s = ut + \int_0^t \left(\int f(t)\,dt\right)dt$

(ii) If acceleration is a function of distance

$a = f(x)$ then $v^2 = u^2 + 2\int_{x_0}^{x} f(x)\,dx$

(iii) If acceleration is a function of velocity

$a = f(v)$ then $t = \int_u^v \dfrac{dv}{f(v)}$ and $x = x_0 + \int_u^v \dfrac{v\,dv}{f(v)}$

Tips & Tricks

- During translational motion of the body, there is change in the location of the body.
- During rotational motion of the body, there is change in the orientation of the body, while there is no change in the location of the body from the axis of rotation.
- A point object is just a mathematical point. This concept is introduced to study the motion of a body in a simple manner.
- The choice of the origin is purely arbitrary.
- For one dimensional motion the angle between acceleration and velocity is either 0° or 180° and it does not change with time.
- For two dimensional motion, the angle between acceleration and velocity is other than 0° or 180° and also it may change with time.
- If the angle between $\vec{a}$ and $\vec{v}$ is 90°, the path of the particle is a circle.
- The particle speed up, that is the speed of the particle increases when the angle between $\vec{a}$ and $\vec{v}$ lies between –90° and +90°.
- The particle speeds down, that is the speed of the particle decreases, when the angle between $\vec{a}$ and $\vec{v}$ lies between +90° and 270°.
- The speed of the particle remains constant when the angle between $\vec{a}$ and $\vec{v}$ is equal to 90°.
- The distance covered by a particle never decreases with time, it always increases.
- Displacement of a particle is the unique path between the initial and final positions of the particle. It may or may not be the actually travelled path of the particle.
- Displacement of a particle gives no information regarding the nature of the path followed by the particle.
- Magnitude of displacement ≤ Distance covered.
- Since distance ≥ |Displacement|, so average speed of a body is equal or greater than the magnitude of the average velocity of the body.
- The average speed of a body is equal to its instantaneous speed if the body moves with a constant speed
- No force is required to move the body or an object with uniform velocity.
- Velocity of the body is positive, if it moves to the right side of the origin. Velocity is negative if the body moves to the left side of the origin.
- When a particle returns to the starting point, its displacement is zero but the distance covered is not zero.
- When a body reverses its direction of motion while moving along a straight line, then the distance travelled by the body is greater than the magnitude of the displacement of the body. In this case, average speed of

the body is greater than its average velocity.

✍ Speedometer measures the instantaneous speed of a vehicle.

✍ When particle moves with speed v_1 upto half time of its total motion and in rest time it is moving with speed v_2 then $v_{av} = \frac{v_1 + v_2}{2}$

✍ When particle moves the first half of a distance at a speed of v_1 and second half of the distance at speed v_2 then

$$v_{av} = \frac{2v_1v_2}{v_1 + v_2}$$

✍ When particle covers one-third distance at speed v_1, next one third at speed v_2 and last one third at speed v_3, then

$$v_{av} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

✍ For two particles having displacement time graph with slopes θ_1 and θ_2 possesses velocities v_1 and v_2 respectively then $\frac{\upsilon_1}{\upsilon_2} = \frac{\tan\theta_1}{\tan\theta_2}$

✍ Velocity of a particle having uniform motion = slope of displacement–time graph.

✍ Greater the slope of displacement-time graph, greater is the velocity and vice-versa.

✍ Area under $v - t$ graph = displacement of the particle.

✍ Slope of velocity-time graph = acceleration.

✍ If a particle is accelerated for a time t_1 with acceleration a_1 and for time t_2 with acceleration a_2 then average acceleration is $a_{av} = \frac{a_1t_1 + a_2t_2}{t_1 + t_2}$

✍ If same force is applied on two bodies of different masses m_1 and m_2 separately then it produces accelerations a_1 and a_2 respectively. Now these bodies are attached together and form a combined system and same force is applied on that system so that a be the acceleration of the combined system, then

$$a = \frac{a_1a_2}{a_1 + a_2}$$

✍ If a body starts from rest and moves with uniform acceleration then distance covered by the body in t *sec* is proportional to t (*i.e.* $s \propto t^2$).

So we can say that the ratio of distance covered in 1 *sec*, 2 *sec* and 3 *sec* is $1^2 : 2^2 : 3^2$ or 1 : 4 : 9.

✍ If a body starts from rest and moves with uniform acceleration then distance covered by the body in *n*th sec is proportional to $(2n-1)$ (*i.e.* $s_n \propto (2n-1)$)

So we can say that the ratio of distance covered in 1st, 2nd and 3rd is 1 : 3 : 5.

✍ A body moving with a velocity u is stopped by application of brakes after covering a distance s. If the same body moves with velocity nu and same braking force is applied on it then it will come to rest after covering a distance of n^2s.

As $\upsilon^2 = u^2 - 2as \Rightarrow 0 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a}$, $s \propto u^2$

[since a is constant]

So we can say that if u becomes n times then s becomes n^2 times that of previous value.

✍ A particle moving with uniform acceleration from A to B along a straight line has velocities υ_1 and υ_2 at A and B respectively. If C is the mid-point between A and B then velocity of the particle at C is equal to

$$\upsilon = \sqrt{\frac{\upsilon_1^2 + \upsilon_2^2}{2}}$$

✍ The body returns to its point of projection with the same magnitude of the velocity with which it was thrown vertically upward, provided air resistance is neglected.

✍ All bodies fall freely with the same acceleration.

✍ The acceleration of the falling bodies does not depend on the mass of the body.

✍ If two bodies are dropped from the same height, they reach the ground in the same time and with the same velocity.

✍ If a body is thrown upwards with velocity u from the top of a tower and another body is thrown downwards from the same point and with the same velocity, then both reach the ground with the same speed.

✍ When a particle returns to the starting point, its average velocity is zero but the average speed is not zero.

✍ If both the objects A and B move along parallel lines in the same direction, then the relative velocity of A w.r.t. B is given by $v_{AB} = v_A - v_B$

and the relative velocity of B w.r.t. A is given by $v_{BA} = v_B - v_A$

✍ If both the objects A and B move along parallel lines in the opposite direction, then the relative velocity of A w.r.t. B is given by $v_{AB} = v_A - (-v_B) = v_A + v_B$

and the relative velocity of B w.r.t. A is given by $v_{BA} = -v_B - v_A$

✍ Suppose a body is projected upwards from the ground and with the velocity u. It is assumed that the friction of the air is negligible. The characteristics of motion of such a body are as follows.

(i) The maximum height attained = $H = u/2g$.

(ii) Time taken to go up (ascent) = Time taken to come down (descent) = $t = u/g$.

(iii) Time of flight $T = 2t = 2u/g$.

(iv) The speed of the body on return to the ground = speed with which it was thrown upwards.

(v) When the height attained is not large, that is u is not large, the mass, the weight as well as the acceleration remain constant with time. But its speed, velocity, momentum, potential energy and kinetic energy change with time.

(vi) Let m be the mass of the body. Then in going from the ground to the highest point, following changes take place.

(a) Change in speed = u

(b) Change in velocity = u

(c) Change in momentum = $m\,u$

(d) Change in kinetic energy = Change in potential energy = (1/2) mu.

(vii) On return to the ground the changes in these quantities are as follows

(a) Change in speed = 0

(b) Change in velocity = $2u$

(c) Change in momentum = $2mu$

(d) Change in kinetic energy = Change in potential energy = 0

(viii) If, the friction of air be taken into account, then the motion of the object thrown upwards will have the following properties

(a) Time taken to go up (ascent) < time taken to come down (descent)

(b) The speed of the object on return to the ground is less than the initial speed. Same is true for velocity (magnitude), momentum (magnitude) and kinetic energy.

(c) Maximum height attained is less than $u/2g$.

(d) A part of the kinetic energy is used up in overcoming the friction.

✍ A ball is dropped from a building of height h and it reaches after t seconds on earth. From the same building if two balls are thrown (one upwards and other downwards) with the same velocity u and they reach the earth surface after t_1 and t_2 seconds respectively then

$$t = \sqrt{t_1 t_2}$$

✍ A particle is dropped vertically from rest from a height. The time taken by it to fall through successive distance of $1m$ each will then be in the ratio of the difference in the square roots of the integers *i.e.*

$$\sqrt{1},(\sqrt{2}-\sqrt{1}),(\sqrt{3}-\sqrt{2}).......(\sqrt{4}-\sqrt{3}),........$$

Ordinary Thinking

Objective Questions

Distance and Displacement

1. A Body moves 6 *m* north. 8 *m* east and 10*m* vertically upwards, what is its resultant displacement from initial position

(a) $10\sqrt{2}m$ (b) $10m$

(c) $\frac{10}{\sqrt{2}}m$ (d) $10 \times 2m$

2. A man goes 10*m* towards North, then 20*m* towards east then displacement is [KCET 1999; JIPMER 1999; AFMC 2003]

(a) 22.5*m* (b) 25*m*

(c) 25.5*m* (d) 30*m*

3. A person moves 30 *m* north and then 20 *m* towards east and finally $30\sqrt{2}$ *m* in south-west direction. The displacement of the person from the origin will be [J & K CET 2004]

(a) 10 *m* along north (b) 10 *m* long south

(c) 10 *m* along west (d) Zero

4. An aeroplane flies 400 *m* north and 300 *m* south and then flies 1200 *m* upwards then net displacement is [AFMC 2004]

(a) 1200 *m* (b) 1300 *m*

(c) 1400 *m* (d) 1500 *m*

5. An athlete completes one round of a circular track of radius *R* in 40 *sec*. What will be his displacement at the end of 2 min. 20 *sec* [NCERT 1990; Kerala PMT 2004]

(a) Zero (b) 2*R*

(c) $2\pi R$ (d) $7\pi R$

6. A wheel of radius 1 meter rolls forward half a revolution on a horizontal ground. The magnitude of the displacement of the point of the wheel initially in contact with the ground is [BCECE 2005]

(a) 2π (b) $\sqrt{2}\pi$

(c) $\sqrt{\pi^2+4}$ (d) π

Uniform Motion

1. A person travels along a straight road for half the distance with velocity v_1 and the remaining half distance with velocity v_2 The average velocity is given by [MP PMT 2001]

(a) $v_1 v_2$ (b) $\frac{v_2^2}{v_1^2}$

(c) $\frac{v_1+v_2}{2}$ (d) $\frac{2v_1v_2}{v_1+v_2}$

2. The displacement-time graph for two particles *A* and *B* are straight lines inclined at angles of 30^o and 60^o with the time axis. The ratio of velocities of $V_A : V_B$ is [CPMT 1990; MP PET 1999; MP PET 2001; Pb. PET 2003]

(a) $1:2$ (b) $1:\sqrt{3}$

(c) $\sqrt{3}:1$ (d) $1:3$

3. A car travels from *A* to *B* at a speed of $20\ km/hr$ and returns at a speed of $30\ km/hr$. The average speed of the car for the whole journey is [MP PET 1985]

(a) $25\ km/hr$ (b) $24\ km/hr$

(c) $50\ km/hr$ (d) $5\ km/hr$

4. A boy walks to his school at a distance of 6 *km* with constant speed of 2.5 *km/hour* and walks back with a constant speed of 4 *km/hr*. His average speed for round trip expressed in *km/hour*, is [DCE 2000]

(a) 24/13 (b) 40/13

(c) 3 (d) 1/2

5. A car travels the first half of a distance between two places at a speed of 30 *km/hr* and the second half of the distance at 50 *km/hr*. The average speed of the car for the whole journey is [Manipal MEE 1995; A

(a) 42.5 *km/hr* (b) 40.0 *km/hr*

(c) 37.5 *km/hr* (d) 35.0 *km/hr*

6. One car moving on a straight road covers one third of the distance with 20 *km/hr* and the rest with 60 *km/hr*. The average speed is [MP PMT 199

(a) 40 *km/hr* (b) 80 *km/hr*

(c) $46\frac{2}{3}$ *km/hr* (d) 36 *km/hr*

7. A car moves for half of its time at 80 *km/h* and for rest half of time at 40 *km/h*. Total distance covered is 60 *km*. What is the average speed of the car [RPET 1996]

(a) $60\ km/h$ (b) $80\ km/h$

(c) $120\ km/h$ (d) $180\ km/h$

8. A train has a speed of 60 *km/h*. for the first one hour and 40 *km/h* for the next half hour. Its average speed in *km/h* is [JIPMER 1999]

(a) 50 (b) 53.33

(c) 48 (d) 70

9. Which of the following is a one dimensional motion [BHU 2000; CBSE PMT 2001]

(a) Landing of an aircraft

(b) Earth revolving a round the sun

(c) Motion of wheels of a moving trains

(d) Train running on a straight track

10. A 150 *m* long train is moving with a uniform velocity of 45 *km/h*. The time taken by the train to cross a bridge of length 850 meters is [CBSE PMT 2001]

(a) 56 *sec* (b) 68 *sec*

(c) 80 *sec* (d) 92 *sec*

11. A particle is constrained to move on a straight line path. It returns to the starting point after 10 *sec*. The total distance covered by the particle during this time is 30 *m*. Which of the following statements about the motion of the particle is false [CBSE PMT 2000; AFMC 2001]

(a) Displacement of the particle is zero

(b) Average speed of the particle is 3 *m/s*

(c) Displacement of the particle is 30 *m*

(d) Both (a) and (b)

12. A particle moves along a semicircle of radius 10*m* in 5 seconds. The average velocity of the particle is [Kerala (Engg.) 2001]

(a) $2\pi\ ms^{-1}$ (b) $4\pi\ ms^{-1}$

(c) $2\ ms^{-1}$ (d) $4\ ms^{-1}$

13. A man walks on a straight road from his home to a market 2.5 *km* away with a speed of 5 *km/h*. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 *km/h*. The average speed of the man over the interval of time 0 to 40 *min.* is equal to

(a) 5 *km/h* (b) $\frac{25}{4}$ *km/h*

(c) $\frac{30}{4}$ *km/h* (d) $\frac{45}{8}$ *km/h*

14. The ratio of the numerical values of the average velocity and average speed of a body is always [MP PET 2002]

(a) Unity (b) Unity or less

(c) Unity or more (d) Less than unity

15. A person travels along a straight road for the first half time with a velocity v_1 and the next half time with a velocity v_2. The mean velocity V of the man is

[RPET 1999; BHU 2002]

(a) $\frac{2}{V}=\frac{1}{v_1}+\frac{1}{v_2}$ (b) $V=\frac{v_1+v_2}{2}$

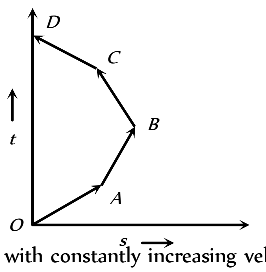
(c) $V=\sqrt{v_1 v_2}$ (d) $V=\sqrt{\frac{v_1}{v_2}}$

16. If a car covers 2/5 of the total distance with v_1 speed and 3/5 distance with v_2 then average speed is [MP PMT 2003]

(a) $\frac{1}{2}\sqrt{v_1 v_2}$ (b) $\frac{v_1+v_2}{2}$

(c) $\frac{2v_1 v_2}{v_1+v_2}$ (d) $\frac{5v_1 v_2}{3v_1+2v_2}$

17. Which of the following options is correct for the object having a straight line motion represented by the following graph



(a) The object moves with constantly increasing velocity from O to A and then it moves with constant velocity.

(b) Velocity of the object increases uniformly

(c) Average velocity is zero

(d) The graph shown is impossible

18. The numerical ratio of displacement to the distance covered is always [BHU 2004]

(a) Less than one

(b) Equal to one

(c) Equal to or less than one

(d) Equal to or greater than one

19. A 100 *m* long train is moving with a uniform velocity of 45 *km/hr.* The time taken by the train to cross a bridge of length 1 *km* is [AMU (Med) 2002]

(a) 58 *s* (b) 68 *s*

(c) 78 *s* (d) 88 *s*

20. A particle moves for 20 *seconds* with velocity 3 *m/s* and then velocity 4 *m/s* for another 20 *seconds* and finally moves with velocity 5 *m/s* for next 20 *seconds*. What is the average velocity of the particle [MH CET 2004]

(a) 3 *m/s* (b) 4 *m/s*

(c) 5 *m/s* (d) Zero

21. The correct statement from the following is [MP PET 1993]

(a) A body having zero velocity will not necessarily have zero acceleration

(b) A body having zero velocity will necessarily have zero acceleration

(c) A body having uniform speed can have only uniform acceleration

(d) A body having non-uniform velocity will have zero acceleration

22. A bullet fired into a fixed target loses half of its velocity after penetrating 3 *cm*. How much further it will penetrate before coming to rest assuming that it faces constant resistance to motion?

(a) 1.5 *cm* (b) 1.0 *cm*

(c) 3.0 *cm* (d) 2.0 *cm*

23. Two boys are standing at the ends A and B of a ground where $AB=a$. The boy at B starts running in a direction perpendicular to AB with velocity v_1. The boy at A starts running simultaneously with velocity v and catches the other boy in a time *t*, where *t* is

(a) $a/\sqrt{v^2+v_1^2}$ (b) $\sqrt{a^2/(v^2-v_1^2)}$

(c) $a/(v-v_1)$ (d) $a/(v+v_1)$

24. A car travels half the distance with constant velocity of 40 *kmph* and the remaining half with a constant velocity of 60 *kmph.* The average velocity of the car in *kmph* is

[DCE 2004] [Kerala PMT 2005]

(a) 40 (b) 45

(c) 48 (d) 50

Non-uniform Motion

1. A particle experiences a constant acceleration for 20 sec after starting from rest. If it travels a distance S_1 in the first 10 sec and a distance S_2 in the next 10 sec, then

[NCERT 1972; CPMT 1997; MP PMT 2002]

(a) $S_1=S_2$ (b) $S_1=S_2/3$

(c) $S_1=S_2/2$ (d) $S_1=S_2/4$

2. The displacement x of a particle along a straight line at time t is given by $x=a_0+a_1t+a_2t^2$. The acceleration of the particle is [NCERT 19

(a) a_0 (b) a_1

(c) $2a_2$ (d) a_2

3. The coordinates of a moving particle at any time are given by $x = at^2$ and $y = bt^2$. The speed of the particle at any moment is [DPMT 1984; CPMT 1997]

(a) $2t(a+b)$ (b) $2t\sqrt{(a^2-b^2)}$

(c) $t\sqrt{a^2+b^2}$ (d) $2t\sqrt{(a^2+b^2)}$

4. An electron starting from rest has a velocity that increases linearly with the time that is $v = kt$, where $k = 2m/\sec^2$. The distance travelled in the first 3 seconds will be [NCERT 1982]

(a) 9 m (b) 16 m

(c) 27 m (d) 36 m

5. The displacement of a body is given to be proportional to the cube of time elapsed. The magnitude of the acceleration of the body is

(a) Increasing with time (b) Decreasing with time

(c) Constant but not zero (d) Zero

6. The instantaneous velocity of a body can be measured

(a) Graphically (b) Vectorially

(c) By speedometer (d) None of these

7. A body is moving from rest under constant acceleration and let S_1 be the displacement in the first $(p-1)$ sec and S_2 be the displacement in the first p sec. The displacement in $(p^2-p+1)^{th}$ sec. will be

(a) S_1+S_2 (b) S_1S_2

(c) S_1-S_2 (d) S_1/S_2

8. A body under the action of several forces will have zero acceleration

(a) When the body is very light

(b) When the body is very heavy

(c) When the body is a point body

(d) When the vector sum of all the forces acting on it is zero

9. A body starts from the origin and moves along the X-axis such that the velocity at any instant is given by $(4t^3-2t)$, where t is in sec and velocity in m/s. What is the acceleration of the particle, when it is 2 m from the origin

(a) $28\ m/s^2$ (b) $22\ m/s^2$

(c) $12 m/s^2$ (d) $10\ m/s^2$

10. The relation between time and distance is $t = \alpha x^2 + \beta x$, where α and β are constants. The retardation is [NCERT 1982; AIEEE 2005]

(a) $2\alpha v^3$ (b) $2\beta v^3$

(c) $2\alpha\beta v^3$ (d) $2\beta^2 v^3$

11. A point moves with uniform acceleration and v_1, v_2 and v_3 denote the average velocities in the three successive intervals of time t_1, t_2 and t_3. Which of the following relations is correct

(a) $(v_1-v_2):(v_2-v_3)=(t_1-t_2):(t_2+t_3)$

(b) $(v_1-v_2):(v_2-v_3)=(t_1+t_2):(t_2+t_3)$

(c) $(v_1-v_2):(v_2-v_3)=(t_1-t_2):(t_1-t_3)$

(d) $(v_1-v_2):(v_2-v_3)=(t_1-t_2):(t_2-t_3)$

12. The acceleration of a moving body can be found from [DPMT 1981]

(a) Area under velocity-time graph

(b) Area under distance-time graph

(c) Slope of the velocity-time graph

(d) Slope of distance-time graph

13. The initial velocity of a particle is u (at $t=0$) and the acceleration f is given by at. Which of the following relation is valid [CPMT 1981; BHU 1995]

(a) $v = u + at^2$ [NCERT 1990] (b) $v = u + a\frac{t^2}{2}$

(c) $v = u + at$ (d) $v = u$

14. The initial velocity of the particle is $10\ m/\sec$ and its retardation is $2m/\sec^2$. The distance moved by the particle in $5th$ second of its motion is [CPMT 1976]

(a) 1 m (b) 19 m

(c) 50 m (d) 75 m

15. A motor car moving with a uniform speed of $20 m/\sec$ comes to stop on the application of brakes after travelling a distance of $10 m$ Its acceleration is [EAMCET 1979]

(a) $20 m/\sec^2$ (b) $-20m/\sec^2$

(c) $-40\ m/\sec^2$ (d) $+2m/\sec^2$

16. The velocity of a body moving with a uniform acceleration of $2\ m./\sec^2$ is $10\ m/\sec$. Its velocity after an interval of 4 *sec* is

(a) $12\ m/\sec$ (b) $14\ m/\sec$

(c) $16\ m/\sec$ (d) $18\ m/\sec$

17. A particle starting from rest travels a distance x in first 2 *seconds* and a distance y in next two *seconds*, then [EAMCET 1982]

(a) $y = x$ (b) $y = 2x$

(c) $y = 3x$ (d) $y = 4x$

18. The initial velocity of a body moving along a straight line is 7 m/s. It has a uniform acceleration of $4 m/s^2$. The distance covered by the body in the 5th second of its motion is

(a) 25 m (b) 35 m

(c) 50 m (d) 85 m

19. The velocity of a body depends on time according to the equation $v = 20 + 0.1t^2$. The body is undergoing [MNR 1995; UPSEAT 2000]

(a) Uniform acceleration

(b) Uniform retardation

(c) Non-uniform acceleration [NCERT 1982]

(d) Zero acceleration

20. Which of the following four statements is false [Manipal MEE 1995]

(a) A body can have zero velocity and still be accelerated

(b) A body can have a constant velocity and still have a varying speed

(c) A body can have a constant speed and still have a varying velocity

(d) The direction of the velocity of a body can change when its acceleration is constant

21. A particle moving with a uniform acceleration travels 24 *m* and 64 *m* in the first two consecutive intervals of 4 *sec* each. Its initial velocity is **[MP PET 1995]**

(a) 1 *m/sec* (b) $10\,m/\sec$

(c) 5 *m/sec* (d) 2 *m/sec*

22. The position of a particle moving in the *xy*-plane at any time t is given by $x=(3t^2-6t)$ *metres*, $y=(t^2-2t)$ *metres*. Select the correct statement about the moving particle from the following

(a) The acceleration of the particle is zero at $t=0$ second

(b) The velocity of the particle is zero at $t=0$ second

(c) The velocity of the particle is zero at $t=1$ second

(d) The velocity and acceleration of the particle are never zero

23. If body having initial velocity zero is moving with uniform acceleration $8\ m/\sec^2$ the distance travelled by it in fifth second will be **[MP PMT 1996; DPMT 2001]**

(a) 36 *metres* (b) 40 *metres*

(c) 100 *metres* (d) Zero

24. An alpha particle enters a hollow tube of 4 *m* length with an initial speed of 1 *km/s*. It is accelerated in the tube and comes out of it with a speed of 9 *km/s*. The time for which it remains inside the tube is

(a) $8\times10^{-3}\,s$ (b) $80\times10^{-3}\,s$

(c) $800\times10^{-3}\,s$ (d) $8\times10^{-4}\,s$

25. Two cars A and B are travelling in the same direction with velocities v_1 and v_2 $(v_1>v_2)$. When the car A is at a distance d ahead of the car B, the driver of the car A applied the brake producing a uniform retardation a There will be no collision when

(a) $d<\frac{(v_1-v_2)^2}{2a}$ (b) $d<\frac{v_1^2-v_2^2}{2a}$

(c) $d>\frac{(v_1-v_2)^2}{2a}$ (d) $d>\frac{v_1^2-v_2^2}{2a}$

26. A body of mass 10 *kg* is moving with a constant velocity of 10 *m/s*. When a constant force acts for 4 *seconds* on it, it moves with a velocity 2 *m/sec* in the opposite direction. The acceleration produced in it is **[MP PET 1997]**

(a) $3\,m/\sec^2$ (b) $-3m/\sec^2$

(c) $0.3\,m/\sec^2$ (d) $-0.3\,m/\sec^2$

27. A body starts from rest from the origin with an acceleration of $6\,m/s^2$ along the *x*-axis and $8\,m/s^2$ along the *y*-axis. Its distance from the origin after 4 seconds will be **[MP PMT 1999]**

(a) 56 *m* (b) 64 *m*

(c) 80 *m* (d) 128 *m*

28. A car moving with a velocity of 10 *m/s* can be stopped by the application of a constant force *F* in a distance of 20 *m*. If the velocity of the car is 30 *m/s*, it can be stopped by this force in

(a) $\frac{20}{3}\,m$ (b) 20 *m*

(c) 60 *m* (d) 180 *m*

29. The displacement of a particle is given by $y=a+bt+ct^2-dt^4$. The initial velocity and acceleration are respectively **[CPMT 1999, 2003]**

(a) $b,-4d$ (b) $-b,2c$

(c) $b,2c$ (d) $2c,-4d$

30. A car moving with a speed of 40 *km/h* can be stopped by applying brakes after atleast 2 *m*. If the same car is moving with a speed of 80 *km/h*, what is the minimum stopping distance **[MP PMT 1995][CBSE PMT 1998,1999; AFMC 2000; JIPMER 2001, 02]**

(a) 8 *m* (b) 2 *m*

(c) 4 *m* (d) 6 *m*

31. An elevator car, whose floor to ceiling distance is equal to 2.7 *m*, starts ascending with constant acceleration of 1.2 ms^{-2}. 2 *sec* after the start, a bolt begins fallings from the ceiling of the car. The free fall time of the bolt is **[KCET 1994]**

(a) $\sqrt{0.54}\ s$ (b) $\sqrt{6}\ s$

(c) 0.7 *s* (d) 1 *s*

32. The displacement is given by $x=2t^2+t+5$, the acceleration at $t=2s$ is **[EAMCET (Engg.) 1995]**

(a) $4\ m/s^2$ (b) $8\ m/s^2$

(c) $10\,m/s^2$ (d) $15\,m/s^2$

33. Two trains travelling on the same track are approaching each other with equal speeds of 40 *m/s*. The drivers of the trains begin to decelerate simultaneously when they are just 2.0 *km* apart. Assuming the decelerations to be uniform and equal, the value of the deceleration to barely avoid collision should be

(a) 11.8 m/s^2 (b) 11.0 m/s^2

(c) 2.1 m/s^2 (d) 0.8 m/s^2

34. A body moves from rest with a constant acceleration of $5\,m/s^2$. Its instantaneous speed (in m/s) at the end of 10 *sec* is **[Pb. PET 2004]**

(a) 50 (b) 5

(c) 2 (d) 0.5

35. A boggy of uniformly moving train is suddenly detached from train and stops after covering some distance. The distance covered by the boggy and distance covered by the train in the same time has relation **[RPET 1997]**

(a) Both will be equal

(b) First will be half of second

(c) First will be 1/4 of second

(d) No definite ratio

36. A body starts from rest. What is the ratio of the distance travelled by the body during the 4th and 3rd second **[CBSE PMT 1993]**

(a) $\frac{7}{5}$ (b) $\frac{5}{7}$

(c) $\frac{7}{3}$ (d) $\frac{3}{7}$

37. The acceleration 'a' in m/s^2 of a particle is given by $a = 3t^2 + 2t + 2$ where t is the time. If the particle starts out with a velocity $u = 2 m/s$ at $t = 0$, then the velocity at the end of 2 *second* is [MNR 1994; SCRA 1994]

(a) 12 *m/s* (b) 18 *m/s*
(c) 27 *m/s* (d) 36 *m/s*

38. A particle moves along a straight line such that its displacement at any time t is given by

$S = t^3 - 6t^2 + 3t + 4$ *metres*

The velocity when the acceleration is zero is [CBSE PMT 1994; JIPMER 2001, 02]

(a) $3ms^{-1}$ (b) $-12ms^{-1}$
(c) $42ms^{-1}$ (d) $-9ms^{-1}$

39. For a moving body at any instant of time [NTSE 1995]

(a) If the body is not moving, the acceleration is necessarily zero
(b) If the body is slowing, the retardation is negative
(c) If the body is slowing, the distance is negative
(d) If displacement, velocity and acceleration at that instant are known, we can find the displacement at any given time in future

40. The x and y coordinates of a particle at any time t are given by $x = 7t + 4t^2$ and $y = 5t$, where x and y are in metre and t in seconds. The acceleration of particle at $t = 5$ *s* is

(a) Zero (b) $8\ m/s^2$
(c) 20 m/s^2 (d) 40 m/s^2

41. The engine of a car produces acceleration $4 m/s^2$ in the car. If this car pulls another car of same mass, what will be the acceleration produced [RPET 1996]

(a) $8 m/s^2$ (b) $2 m/s^2$
(c) $4 m/s^2$ (d) $\frac{1}{2} m/s^2$

42. If a body starts from rest and travels 120 *cm* in the 6th second, then what is the acceleration [AFMC 1997]

(a) 0.20 m/s^2 (b) 0.027 m/s^2
(c) 0.218 m/s^2 (d) 0.03 m/s^2

43. If a car at rest accelerates uniformly to a speed of 144 *km/h* in 20 *s*. Then it covers a distance of [CBSE PMT 1997]

(a) 20 *m* (b) 400 *m*
(c) 1440 *m* (d) 2880 *m*

44. The position x of a particle varies with time t as $x = at^2 - bt^3$. The acceleration of the particle will be zero at time t equal to [CBSE PMT 1997; BHU 1999; DPMT 2000; KCET 2000]

(a) $\frac{a}{b}$ (b) $\frac{2a}{3b}$
(c) $\frac{a}{3b}$ (d) Zero

45. A truck and a car are moving with equal velocity. On applying the brakes both will stop after certain distance, then [CPMT 1997]

(a) Truck will cover less distance before rest
(b) Car will cover less distance before rest
(c) Both will cover equal distance
(d) None

46. If a train travelling at 72 *kmph* is to be brought to rest in a distance of 200 metres, then its retardation should be [SCRA 1998; MP PMT 2004]

(a) 20 ms^{-2} (b) 10 ms^{-2}
(c) 2 ms^{-2} (d) 1 ms^{-2}

47. The displacement of a particle starting from rest (at $t = 0$) is given by $s = 6t^2 - t^3$. The time in seconds at which the particle will attain zero velocity again, is [SCRA 1998]

(a) 2 (b) 4
(c) 6 (d) 8

48. What is the relation between displacement, time and acceleration in case of a body having uniform acceleration [DCE 1999]

(a) $S = ut + \frac{1}{2}ft^2$ (b) $S = (u + f)t$
(c) $S = v^2 - 2fs$ (d) None of these

49. Two cars A and B at rest at same point initially. If A starts with uniform velocity of 40 *m/sec* and B starts in the same direction with constant acceleration of $4 m/s^2$, then B will catch A after how much time [RPET 1999] [SCRA 1996]

(a) 10 *sec* (b) 20 *sec*
(c) 30 *sec* (d) 35 *sec*

50. The motion of a particle is described by the equation $x = a + bt^2$ where $a = 15$ *cm* and $b = 3$ *cm/s*. Its instantaneous velocity at time 3 *sec* will be [AMU (Med.) 2000]

(a) 36 *cm/sec* (b) 18 *cm/sec*
(c) 16 *cm/sec* (d) 32 *cm/sec*

51. A body travels for 15 *sec* starting from rest with constant acceleration. If it travels distances S_1, S_2 and S_3 in the first five seconds, second five seconds and next five seconds respectively the relation between S_1, S_2 and S_3 is [AMU (Engg.) 2000]

(a) $S_1 = S_2 = S_3$ (b) $5S_1 = 3S_2 = S_3$
(c) $S_1 = \frac{1}{3}S_2 = \frac{1}{5}S_3$ (d) $S_1 = \frac{1}{5}S_2 = \frac{1}{3}S_3$

52. A body is moving according to the equation $x = at + bt^2 - ct^3$ where $x =$ displacement and a, b and c are constants. The acceleration of the body is [BHU 2000]

(a) $a + 2bt$ (b) $2b + 6ct$
(c) $2b - 6ct$ (d) $3b - 6ct^2$

53. A particle travels 10*m* in first 5 *sec* and 10*m* in next 3 *sec*. Assuming constant acceleration what is the distance travelled in next 2 *sec*

(a) 8.3 *m* (b) 9.3 *m*
(c) 10.3 *m* (d) None of above

54. The distance travelled by a particle is proportional to the squares of time, then the particle travels with [RPET 1999; RPMT 2000]

(a) Uniform acceleration (b) Uniform velocity
(c) Increasing acceleration (d) Decreasing velocity

55. Acceleration of a particle changes when [RPMT 2000]
(a) Direction of velocity changes
(b) Magnitude of velocity changes
(c) Both of above
(d) Speed changes

56. The motion of a particle is described by the equation $u = at$. The distance travelled by the particle in the first 4 seconds
(a) $4a$ (b) $12a$
(c) $6a$ (d) $8a$

57. The relation $3t = \sqrt{3x} + 6$ describes the displacement of a particle in one direction where x is in *metres* and t in sec. The displacement, when velocity is zero, is [CPMT 2000]
(a) 24 *metres* (b) 12 *metres*
(c) 5 *metres* (d) Zero

58. A constant force acts on a body of mass 0.9 *kg* at rest for 10*s*. If the body moves a distance of 250 *m*, the magnitude of the force is
(a) $3N$ (b) $3.5N$
(c) $4.0N$ (d) $4.5N$

59. The average velocity of a body moving with uniform acceleration travelling a distance of 3.06 *m* is 0.34 *ms*. If the change in velocity of the body is 0.18ms^{-1} during this time, its uniform acceleration is [EAMCET (Med.) 2000]
(a) 0.01 ms^{-2} (b) 0.02 ms^{-2}
(c) 0.03 ms^{-2} (d) 0.04 ms^{-2}

60. Equation of displacement for any particle is $s = 3t^3 + 7t^2 + 14t + 8m$. Its acceleration at time $t = 1$ sec is [CBSE PMT 2000]
(a) 10 *m/s* (b) 16 *m/s*
(c) 25 *m/s* (d) 32 *m/s*

61. The position of a particle moving along the *x*-axis at certain times is given below :

t (*s*)	0	1	2	3
x (*m*)	–2	0	6	16

Which of the following describes the motion correctly [AMU (Engg.) 2001]
(a) Uniform, accelerated
(b) Uniform, decelerated
(c) Non-uniform, accelerated
(d) There is not enough data for generalization

62. Consider the acceleration, velocity and displacement of a tennis ball as it falls to the ground and bounces back. Directions of which of these changes in the process [AMU (Engg.) 2001]
(a) Velocity only
(b) Displacement and velocity
(c) Acceleration, velocity and displacement
(d) Displacement and acceleration

63. The displacement of a particle, moving in a straight line, is given by $s = 2t^2 + 2t + 4$ where s is in *metres* and t in seconds. The acceleration of the particle is [CPMT 2001]
(a) 2 *m/s* (b) 4 *m/s*
(c) 6 *m/s* (d) 8 *m/s*

64. A body *A* starts from rest with an acceleration a_1. After 2 seconds, another body *B* starts from rest with an acceleration a_2. If they travel equal distances in the 5th second, after the start of A, then the ratio $a_1 : a_2$ is equal to [AIIMS 2001]
(a) 5 : 9 (b) 5 : 7
(c) 9 : 5 (d) 9 : 7

65. The velocity of a bullet is reduced from 200*m/s* to 100*m/s* while travelling through a wooden block of thickness 10*cm*. The retardation, assuming it to be uniform, will be
[DCE 2000] [AIIMS 2001]
(a) 10×10^4 *m/s* (b) 12×10^4 *m/s*
(c) 13.5×10^4 *m/s* (d) 15×10^4 *m/s*

66. A body of 5 *kg* is moving with a velocity of 20 *m/s*. If a force of 100*N* is applied on it for 10*s* in the same direction as its velocity, what will now be the velocity of the body [MP PMT 2000; RPET 2001]
(a) 200 *m/s* (b) 220 *m/s*
(c) 240 *m/s* (d) 260 *m/s*
[EAMCET (Engg.) 2000]

67. A particle starts from rest, accelerates at 2 *m/s* for 10*s* and then goes for constant speed for 30*s* and then decelerates at 4 *m/s* till it stops. What is the distance travelled by it [DCE 2001; AIIMS 2002; DCE 2003]
(a) 750 *m* (b) 800 *m*
(c) 700 *m* (d) 850 *m*

68. The engine of a motorcycle can produce a maximum acceleration 5 *m/s*. Its brakes can produce a maximum retardation 10 *m/s*. What is the minimum time in which it can cover a distance of 1.5 *km*
(a) 30 *sec* (b) 15 *sec*
(c) 10 *sec* (d) 5 *sec*

69. The path of a particle moving under the influence of a force fixed in magnitude and direction is [MP PET 2002]
(a) Straight line (b) Circle
(c) Parabola (d) Ellipse

70. A car, moving with a speed of 50 *km/hr*, can be stopped by brakes after at least 6*m*. If the same car is moving at a speed of 100 *km/hr*, the minimum stopping distance is [AIEEE 2003]
(a) 6*m* (b) 12*m*
(c) 18*m* (d) 24*m*

71. A student is standing at a distance of 50metres from the bus. As soon as the bus begins its motion with an acceleration of 1ms^{-2}, the student starts running towards the bus with a uniform velocity u. Assuming the motion to be along a straight road, the minimum value of u, so that the student is able to catch the bus is [KCET 2003]
(a) 5 ms^{-1} (b) 8 ms^{-1}
(c) 10 ms^{-1} (d) 12 ms^{-1}

72. A body *A* moves with a uniform acceleration a and zero initial velocity. Another body *B*, starts from the same point moves in the same direction with a constant velocity v. The two bodies meet after a time t. The value of t is [MP PET 2003]
(a) $\frac{2v}{a}$ (b) $\frac{v}{a}$
(c) $\frac{v}{2a}$ (d) $\sqrt{\frac{v}{2a}}$

73. A particle moves along X-axis in such a way that its coordinate X varies with time t according to the equation $x = (2 - 5t + 6t^2)m$. The initial velocity of the particle is

[MNR 1987; MP PET 1996; Pb. PET 2004]

(a) $-5\,m/s$ (b) $6\,m/s$

(c) $-3\,m/s$ (d) $3\,m/s$

74. A car starts from rest and moves with uniform acceleration *a* on a straight road from time *t* = 0 to *t* = *T*. After that, a constant deceleration brings it to rest. In this process the average speed of the car is [MP PMT 2004]

(a) $\frac{aT}{4}$ (b) $\frac{3aT}{2}$

(c) $\frac{aT}{2}$ (d) aT

75. An object accelerates from rest to a velocity 27.5 *m/s* in 10 *sec* then find distance covered by object in next 10 *sec* [BCECE 2004]

(a) 550 *m* (b) 137.5 *m*

(c) 412.5 *m* (d) 275 *m*

76. If the velocity of a particle is given by $v=(180-16x)^{1/2}$ *m/s*, then its acceleration will be [J & K CET 2004]

(a) Zero (b) 8 *m/s*

(c) – 8 *m/s* (d) 4 *m/s*

77. The displacement of a particle is proportional to the cube of time elapsed. How does the acceleration of the particle depends on time obtained [Pb. PET 2001]

(a) $a\propto t^2$ (b) $a\propto 2t$

(c) $a\propto t^3$ (d) $a\propto t$

78. Starting from rest, acceleration of a particle is $a=2(t-1)$. The velocity of the particle at $t=5s$ is [RPET 2002]

(a) 15 *m/sec* (b) 25 *m/sec*

(c) 5 *m/sec* (d) None of these

79. A body is moving with uniform acceleration describes 40 *m* in the first 5 *sec* and 65 *m* in next 5 *sec*. Its initial velocity will be

(a) 4 *m/s* (b) 2.5 *m/s*

(c) 5.5 *m/s* (d) 11 *m/s*

80. Speed of two identical cars are u and $4u$ at a specific instant. The ratio of the respective distances in which the two cars are stopped from that instant is [AIEEE 2002]

(a) 1 : 1 (b) 1 : 4

(c) 1 : 8 (d) 1 : 16

81. The displacement x of a particle varies with time t, $x=ae^{-\alpha t}+be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will [CBSE PMT 2005]

(a) Go on decreasing with time

(b) Be independent of α and β

(c) Drop to zero when $\alpha=\beta$

(d) Go on increasing with time

82. A car, starting from rest, accelerates at the rate *f* through a distance *S*, then continues at constant speed for time *t* and then decelerates at the rate $\frac{f}{2}$ to come to rest. If the total distance traversed is 15 *S*, then [AIEEE 2005]

(a) $S=\frac{1}{2}ft^2$ (b) $S=\frac{1}{4}ft^2$

(c) $S=\frac{1}{72}ft^2$ (d) $S=\frac{1}{6}ft^2$

83. A man is 45 *m* behind the bus when the bus start accelerating from rest with acceleration 2.5 *m/s*. With what minimum velocity should the man start running to catch the bus ?

(a) 12 *m/s* (b) 14 *m/s*

(c) 15 *m/s* (d) 16 *m/s*

84. A particle moves along *x*-axis as

$x=4(t-2)+a(t-2)^2$

Which of the following is true ? [J&K CET 2005]

(a) The initial velocity of particle is 4

(b) The acceleration of particle is 2*a*

(c) The particle is at origin at *t* = 0

(d) None of these

85. A body starting from rest moves with constant acceleration. The ratio of distance covered by the body during the 5th *sec* to that covered in 5 *sec* is [Kerala PET 2005]

(a) 9/25 (b) 3/5

(c) 25/9 (d) 1/25

86. What determines the nature of the path followed by the particle

(a) Speed (b) Velocity

(c) Acceleration (d) None of these

Relative Motion

1. Two trains, each 50 *m* long are travelling in opposite direction with velocity 10 *m/s* and 15 *m/s*. The time of crossing is [CPMT 1999; JIPMER 2000;

(a) $2s$ (b) $4\,s$

(c) $2\sqrt{3}s$ (d) $4\sqrt{3}\,s$

2. A 120 *m* long train is moving in a direction with speed 20 *m/s*. A train *B* moving with 30 *m/s* in the opposite direction and 130 *m* long crosses the first train in a time

[CPMT 1996; Kerala PET 2002]

(a) 6 *s* (b) 36 *s*

[Pb. PET 2003]

(c) 38 *s* (d) None of these

3. A 210 meter long train is moving due North at a of 25 *m/s*. A small bird is flying due South a little above the train with speed 5 *m/s*. The time taken by the bird to cross the train is

[AMU (Med.) 2001]

(a) $6s$ (b) $7s$

(c) $9s$ (d) $10s$

4. A police jeep is chasing with, velocity of 45 *km/h* a thief in another jeep moving with velocity 153 *km/h*. Police fires a bullet with muzzle velocity of 180 *m/s*. The velocity it will strike the car of the thief is [BHU 2003

(a) 150 *m/s* (b) 27 *m/s*

(c) 450 *m/s* (d) 250 *m/s*

5. A boat is sent across a river with a velocity of 8 *km/hr*. If the resultant velocity of boat is 10 *km/hr*, then velocity of the river is :

(a) 10 *km/hr* (b) 8 *km/hr*

(c) 6 *km/hr* (d) 4 *km/hr*

6. A train of 150 *meter* length is going towards north direction at a speed of $10\,m/\sec$. A parrot flies at the speed of $5\,m/\sec$ towards south direction parallel to the railway track. The time taken by the parrot to cross the train is

[CBSE PMT 1992; BHU 1998]

(a) 12 *sec* (b) 8 *sec*

(c) 15 *sec* (d) 10 *sec*

7. A boat is moving with velocity of $3\hat{i}+4\hat{j}$ in river and water is moving with a velocity of $-3\hat{i}-4\hat{j}$ with respect to ground. Relative velocity of boat with respect to water is : [Pb. PET 2002]

(a) $-6\hat{i}-8\hat{j}$ (b) $6\hat{i}+8\hat{j}$

(c) $8\hat{i}$ (d) $6\hat{i}$

8. The distance between two particles is decreasing at the rate of 6 *m/sec*. If these particles travel with same speeds and in the same direction, then the separation increase at the rate of 4 *m/sec*. The particles have speeds as [RPET 1999]

(a) 5 *m/sec* ; 1 *m/sec* (b) 4 *m/sec* ; 1 *m/sec*

(c) 4 *m/sec* ; 2 *m/sec* (d) 5 *m/sec* ; 2 *m/sec*

9. A boat moves with a speed of 5 *km/h* relative to water in a river flowing with a speed of 3 *km/h* and having a width of 1 *km*. The minimum time taken around a round trip is [J&K CET 2005]

(a) 5 min (b) 60 min

(c) 20 min (d) 30 min

10. For a body moving with relativistic speed, if the velocity is doubled, then [Orissa JEE 2005]

(a) Its linear momentum is doubled

(b) Its linear momentum will be less than double

(c) Its linear momentum will be more than double

(d) Its linear momentum remains unchanged

11. A river is flowing from W to E with a speed of 5 *m/min*. A man can swim in still water with a velocity 10 *m/min*. In which direction should the man swim so as to take the shortest possible path to go to the south. [BHU 2005]

(a) 30° with downstream (b) 60° with downstream

(c) 120° with downstream (d) South

12. A train is moving towards east and a car is along north, both with same speed. The observed direction of car to the passenger in the train is [J & K CET 2004]

(a) East-north direction (b) West-north direction

(c) South-east direction (d) None of these

13. An express train is moving with a velocity v_1. Its driver finds another train is moving on the same track in the same direction with velocity v_2. To escape collision, driver applies a retardation a on the train. the minimum time of escaping collision will be

(a) $t=\frac{v_1-v_2}{a}$ (b) $t_1=\frac{v_1^2-v_2^2}{2}$

(c) None (d) Both

Motion Under Gravity

1. A stone falls from a balloon that is descending at a uniform rate of $12\ m/s$. The displacement of the stone from the point of release after 10 *sec* is

(a) 490 m (b) 510 m

(c) 610 m (d) 725 m

2. A ball is dropped on the floor from a height of 10 *m*. It rebounds to a height of 2.5 *m*. If the ball is in contact with the floor for 0.01 *sec*, the average acceleration during contact is

(a) 2100 $m/\sec^2$ downwards (b) 2100 $m/\sec^2$ upwards

(c) 1400 $m/\sec^2$ (d) 700 $m/\sec^2$

3. A body A is projected upwards with a velocity of $98\,m/s$. The second body B is projected upwards with the same initial velocity but after 4 *sec*. Both the bodies will meet after

(a) 6 sec (b) 8 sec

(c) 10 sec (d) 12 sec

4. Two bodies of different masses m_a and m_b are dropped from two different heights a and b. The ratio of the time taken by the two to cover these distances are [NCERT 1972; MP PMT 1993]

(a) $a:b$ (b) $b:a$

(c) $\sqrt{a}:\sqrt{b}$ (d) $a^2:b^2$

5. A body falls freely from rest. It covers as much distance in the last second of its motion as covered in the first three seconds. The body has fallen for a time of [MNR 1998]

(a) $3\ s$ (b) $5\ s$

(c) $7\ s$ (d) $9\ s$

6. A stone is dropped into water from a bridge $44.1\ m$ above the water. Another stone is thrown vertically downward 1 *sec* later. Both strike the water simultaneously. What was the initial speed of the second stone

(a) $12.25\ m/s$ (b) $14.75\ m/s$

(c) $16.23\ m/s$ (d) $17.15\ m/s$

7. An iron ball and a wooden ball of the same radius are released from the same height in vacuum. They take the same time to reach the ground. The reason for this is

(a) Acceleration due to gravity in vacuum is same irrespective of the size and mass of the body

(b) Acceleration due to gravity in vacuum depends upon the mass of the body

(c) There is no acceleration due to gravity in vacuum

(d) In vacuum there is a resistance offered to the motion of the body and this resistance depends upon the mass of the body

8. A body is thrown vertically upwards. If air resistance is to be taken into account, then the time during which the body rises is [RPET 2000; KCET 2001; DPMT 2001]

(a) Equal to the time of fall

(b) Less than the time of fall

(c) Greater than the time of fall [RPET 2002]

(d) Twice the time of fall

9. A ball P is dropped vertically and another ball Q is thrown horizontally with the same velocities from the same height and at the same time. If air resistance is neglected, then [MNR 1986; BHU 1994]

(a) Ball P reaches the ground first

(b) Ball Q reaches the ground first

(c) Both reach the ground at the same time

(d) The respective masses of the two balls will decide the time

10. A body is released from a great height and falls freely towards the earth. Another body is released from the same height exactly one second later. The separation between the two bodies, two seconds after the release of the second body is [CPMT 1983; Kerala PMT 20

(a) $4.9\,m$ (b) $9.8\,m$

[BHU 1997; CPMT 1997]

(c) $19.6\,m$ (d) $24.5\,m$

11. An object is projected upwards with a velocity of 100 m/s. It will strike the ground after (approximately) [NCERT 1981; AFMC 1995]

(a) 10 sec (b) 20 sec
(c) 15 sec (d) 5 sec

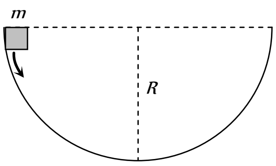
12. A stone dropped from the top of the tower touches the ground in 4 sec. The height of the tower is about [MP PET 1986; AFMC 1994; CPMT 1997; BHU 1998; DPMT 1999; RPET 1999; MH CET 2003]

(a) $80\, m$ (b) $40\, m$
(c) $20\ m$ (d) $160\ m$

13. A body is released from the top of a tower of height h. It takes t *sec* to reach the ground. Where will be the ball after time $t/2$ sec [NCERT 1981; MP PMT 2004]

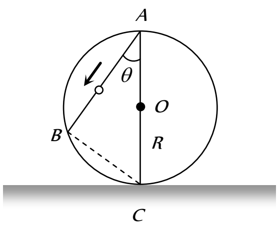
(a) At $h/2$ from the ground
(b) At $h/4$ from the ground
(c) Depends upon mass and volume of the body
(d) At $3h/4$ from the ground

14. A mass m slips along the wall of a semispherical surface of radius R. The velocity at the bottom of the surface is [MP PMT 1993]



(a) $\sqrt{Rg}$
(b) $\sqrt{2Rg}$
(c) $2\sqrt{\pi Rg}$
(d) $\sqrt{\pi Rg}$

15. A frictionless wire *AB* is fixed on a sphere of radius *R*. A very small spherical ball slips on this wire. The time taken by this ball to slip from *A* to *B* is



(a) $\dfrac{2\sqrt{gR}}{g\cos\theta}$
(b) $2\sqrt{gR}.\dfrac{\cos\theta}{g}$
(c) $2\sqrt{\dfrac{R}{g}}$
(d) $\dfrac{gR}{\sqrt{g\cos\theta}}$

16. A body is slipping from an inclined plane of height h and length l. If the angle of inclination is θ, the time taken by the body to come from the top to the bottom of this inclined plane is

(a) $\sqrt{\dfrac{2h}{g}}$ (b) $\sqrt{\dfrac{2l}{g}}$
(c) $\dfrac{1}{\sin\theta}\sqrt{\dfrac{2h}{g}}$ (d) $\sin\theta\sqrt{\dfrac{2h}{g}}$

17. A particle is projected up with an initial velocity of $80\, ft/\sec$. The ball will be at a height of $96\, ft$ from the ground after

(a) 2.0 and 3.0 *sec* (b) Only at 3.0 *sec*
(c) Only at 2.0 *sec* (d) After 1 and 2 *sec*

18. A body falls from rest, its velocity at the end of first second is $(g = 32\, ft/\sec)$ [AFMC 1980]

(a) $16\ ft/\sec$ (b) $32\ ft/\sec$
(c) $64\ ft/\sec$ (d) $24\ ft/\sec$

19. A stone thrown upward with a speed u from the top of the tower reaches the ground with a velocity $3u$. The height of the tower is [EAMCET 1983; RPET 2003]

(a) $3u^2/g$ (b) $4u^2/g$
(c) $6u^2/g$ (d) $9u^2/g$

20. Two stones of different masses are dropped simultaneously from the top of a building [EAMCET 1978]

(a) Smaller stone hit the ground earlier
(b) Larger stone hit the ground earlier
(c) Both stones reach the ground simultaneously
(d) Which of the stones reach the ground earlier depends on the composition of the stone

21. A body thrown with an initial speed of $96\, ft/\sec$ reaches the ground after $(g = 32\, ft/\sec^2)$ [EAMCET 1980]

(a) 3 *sec* (b) 6 *sec*
(c) 12 *sec* (d) 8 *sec*

22. A stone is dropped from a certain height which can reach the ground in 5 *second*. If the stone is stopped after 3 *second* of its fall and then allowed to fall again, then the time taken by the stone to reach the ground for the remaining distance is

(a) 2 *sec* (b) 3 *sec*
(c) 4 *sec* (d) None of these

23. A man in a balloon rising vertically with an acceleration of $4.9\, m/\sec^2$ releases a ball 2 *sec* after the balloon is let go from the ground. The greatest height above the ground reached by the ball is $(g = 9.8\, m/\sec^2)$ [MNR 1986]

(a) 14.7 *m* (b) 19.6 *m*
(c) 9.8 *m* (d) 24.5 *m*

24. A particle is dropped under gravity from rest from a height $h (g = 9.8\, m/\sec^2)$ and it travels a distance $9h/25$ in the last second, the height h is [MNR 1987]

(a) 100 *m* (b) 122.5 *m*
(c) 145 *m* (d) 167.5 *m*

25. A balloon is at a height of 81 *m* and is ascending upwards with a velocity of 12 *m/s*. A body of $2 kg$ weight is dropped from it. If $g = 10\, m/s^2$, the body will reach the surface of the earth in

(a) 1.5 *s* (b) 4.025 *s*
(c) 5.4 *s* (d) 6.75 *s*

26. An aeroplane is moving with a velocity u. It drops a packet from a height h. The time t taken by the packet in reaching the ground will be [MP PMT 1985]

(a) $\sqrt{\left(\dfrac{2g}{h}\right)}$ (b) $\sqrt{\left(\dfrac{2u}{g}\right)}$
(c) $\sqrt{\left(\dfrac{h}{2g}\right)}$ (d) $\sqrt{\left(\dfrac{2h}{g}\right)}$

27. Water drops fall at regular intervals from a tap which is $5\ m$ above the ground. The third drop is leaving the tap at the instant the first

drop touches the ground. How far above the ground is the second drop at that instant [CBSE PMT 1995]

(a) 2.50 *m* (b) 3.75 *m*
(c) 4.00 *m* (d) 1.25 *m*

28. A ball is thrown vertically upwards from the top of a tower at $4.9\ ms^{-1}$. It strikes the pond near the base of the tower after 3 *seconds*. The height of the tower is

[Manipal MEE 1995]

(a) 73.5 *m* (b) 44.1 *m*
(c) 29.4 *m* (d) None of these

29. An aeroplane is moving with horizontal velocity u at height h. The velocity of a packet dropped from it on the earth's surface will be (g is acceleration due to gravity)

[MP PET 1995]

(a) $\sqrt{u^2+2gh}$ (b) $\sqrt{2gh}$
(c) $2gh$ (d) $\sqrt{u^2-2gh}$

30. A rocket is fired upward from the earth's surface such that it creates an acceleration of 19.6 *m/sec*. If after 5 *sec* its engine is switched off, the maximum height of the rocket from earth's surface would be

(a) 245 *m* (b) 490 *m*
(c) 980 *m* (d) 735 *m*

31. A bullet is fired with a speed of $1000\ m/\sec$ in order to hit a target 100 *m* away. If $g = 10\ m/s^2$, the gun should be aimed

(a) Directly towards the target
(b) 5 *cm* above the target
(c) 10 *cm* above the target
(d) 15 *cm* above the target

32. A body starts to fall freely under gravity. The distances covered by it in first, second and third *second* are in ratio

[MP PET 1997; RPET 2001]

(a) $1:3:5$ (b) $1:2:3$
(c) $1:4:9$ (d) $1:5:6$

33. P, Q and R are three balloons ascending with velocities $U, 4U$ and $8U$ respectively. If stones of the same mass be dropped from each, when they are at the same height, then

(a) They reach the ground at the same time
(b) Stone from P reaches the ground first
(c) Stone from R reaches the ground first
(d) Stone from Q reaches the ground first

34. A body is projected up with a speed 'u' and the time taken by it is T to reach the maximum height H. Pick out the correct statement [EAMCET (Engg.) 1995]

(a) It reaches $H/2$ in $T/2$ *sec*
(b) It acquires velocity $u/2$ in $T/2\sec$
(c) Its velocity is $u/2$ at $H/2$
(d) Same velocity at $2T$

35. A body falling for 2 seconds covers a distance S equal to that covered in next second. Taking $g = 10\,m/s^2, S =$

[EAMCET (Engg.) 1995]

(a) 30 *m* (b) 10 *m*
(c) 60 *m* (d) 20 *m*

36. A body dropped from a height h with an initial speed zero, strikes the ground with a velocity $3\,km/h$. Another body of same mass is dropped from the same height h with an initial speed $-u' = 4km/h$. Find the final velocity of second body with which it strikes the ground [CBSE PMT 1996]

(a) 3 *km/h* (b) 4 *km/h*
(c) 5 *km/h* (d) 12 *km/h*

37. A ball of mass m_1 and another ball of mass m_2 are dropped from equal height. If time taken by the balls are t_1 and t_2 respectively, then [BHU 1997]

(a) $t_1 = \frac{t_2}{2}$ (b) $t_1 = t_2$
(c) $t_1 = 4t_2$ (d) $t_1 = \frac{t_2}{4}$

38. With what velocity a ball be projected vertically so that the distance covered by it in 5th second is twice the distance it covers in its 6th second $(g = 10\,m/s^2)$

[CPMT 1997; MH CET 2000]

(a) 58.8 *m/s* [MP PET 1995] (b) 49 *m/s*
(c) 65 *m/s* (d) 19.6 *m/s*

39. A body sliding on a smooth inclined plane requires 4 seconds to reach the bottom starting from rest at the top. How much time does it take to cover one-fourth distance starting from rest at the top

(a) 1 *s* (b) 2 *s*
(c) 4 *s* [MP PET 1996] (d) 16 *s*

40. A ball is dropped downwards. After 1 second another ball is dropped downwards from the same point. What is the distance between them after 3 seconds [BHU 1998]

(a) 25 *m* (b) 20 *m*
(c) 50 *m* (d) 9.8 *m*

41. A stone is thrown with an initial speed of 4.9 *m/s* from a bridge in vertically upward direction. It falls down in water after 2 *sec*. The height of the bridge is [AFMC 1999; Pb. PMT 2003]

(a) 4.9 *m* (b) 9.8 *m*
(c) 19.8 *m* (d) 24.7 *m*

42. A stone is shot straight upward with a speed of 20 *m/sec* from a tower 200 *m* high. The speed with which it strikes the ground is approximately [AMU (Engg.) 1999]

(a) 60 *m/sec* (b) 65 *m/sec*
(c) 70 *m/sec* [ISM Dhanbad 1994] (d) 75 *m/sec*

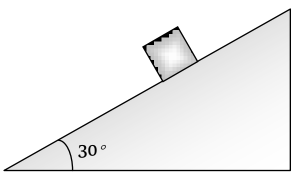
43. A body freely falling from the rest has a velocity '*v*' after it falls through a height '*h*'. The distance it has to fall down for its velocity to become double, is [BHU 1999]

(a) $2h$ (b) $4h$
(c) $6h$ (d) $8h$

44. The time taken by a block of wood (initially at rest) to slide down a smooth inclined plane 9.8 *m* long (angle of inclination is 30^o) is

[JIPMER 1999]

(a) $\frac{1}{2}\sec$
(b) 2 sec
(c) 4 sec
(d) 1 sec



45. Velocity of a body on reaching the point from which it was projected upwards, is [AIIMS 1999; Pb. PMT 1999]
(a) $v = 0$ (b) $v = 2u$
(c) $v = 0.5u$ (d) $v = u$

46. A body projected vertically upwards with a velocity u returns to the starting point in 4 seconds. If $g = 10$ *m/sec*, the value of u is [KCET 1999]
(a) 5 *m/sec* (b) 10 *m/sec*
(c) 15 *m/sec* (d) 20 *m/sec*

47. Time taken by an object falling from rest to cover the height of h_1 and h_2 is respectively t_1 and t_2 then the ratio of t_1 to t_2 is [RPMT 1996; RPET 2002]
(a) $h_1 : h_2$ (b) $\sqrt{h_1} : \sqrt{h_2}$
(c) $h_1 : 2h_2$ (d) $2h_1 : h_2$

48. A body is thrown vertically up from the ground. It reaches a maximum height of 100*m* in 5*sec*. After what time it will reach the ground from the maximum height position [Pb. PMT 2000]
(a) 1.2 *sec* (b) 5 *sec*
(c) 10 *sec* (d) 25 *sec*

49. A body thrown vertically upwards with an initial velocity u reaches maximum height in 6 seconds. The ratio of the distances travelled by the body in the first second and the seventh second is [EAMCET (Engg.) 2000]
(a) 1 : 1 (b) 11 : 1
(c) 1 : 2 (d) 1 : 11

50. A particle is thrown vertically upwards. If its velocity at half of the maximum height is 10 *m/s*, then maximum height attained by it is (Take $g = 10$ *m/s*) [CBSE PMT 2001, 2004]
(a) 8 *m* (b) 10 *m*
(c) 12 *m* (d) 16 *m*

51. A body, thrown upwards with some velocity, reaches the maximum height of 20*m*. Another body with double the mass thrown up, with double initial velocity will reach a maximum height of [KCET 2001]
(a) 200 *m* (b) 16 *m*
(c) 80 *m* (d) 40 *m*

52. A balloon starts rising from the ground with an acceleration of 1.25 *m/s* after 8s, a stone is released from the balloon. The stone will ($g = 10$ *m/s*) [KCET 2001]
(a) Reach the ground in 4 second
(b) Begin to move down after being released
(c) Have a displacement of 50 *m*
(d) Cover a distance of 40 *m* in reaching the ground

53. A body is thrown vertically upwards with a velocity u. Find the true statement from the following [Kerala 2001]
(a) Both velocity and acceleration are zero at its highest point
(b) Velocity is maximum and acceleration is zero at the highest point
(c) Velocity is maximum and acceleration is g downwards at its highest point
(d) Velocity is zero at the highest point and maximum height reached is $u^2/2g$

54. A man throws a ball vertically upward and it rises through 20 *m* and returns to his hands. What was the initial velocity (u) of the ball and for how much time (T) it remained in the air $[g = 10m/s^2]$ [MP PET 2001]
(a) u = 10 *m/s*, T = 2*s* (b) u = 10 *m/s*, T = 4*s*
(c) u = 20 *m/s*, T = 2*s* (d) u = 20 *m/s*, T = 4*s*

55. A particle when thrown, moves such that it passes from same height at 2 and 10*s*, the height is [UPSEAT 2001]
(a) g (b) $2g$
(c) $5g$ (d) $10g$

56. Three different objects of masses m_1, m_2 and m_3 are allowed to fall from rest and from the same point '*O*' along three different frictionless paths. The speeds of the three objects, on reaching the ground, will be in the ratio of [AIIMS 2002]
(a) $m_1 : m_2 : m_3$ (b) $m_1 : 2m_2 : 3m_3$
(c) 1 : 1 : 1 (d) $\frac{1}{m_1} : \frac{1}{m_2} : \frac{1}{m_3}$

57. From the top of a tower, a particle is thrown vertically downwards with a velocity of 10 *m/s*. The ratio of the distances, covered by it in the 3rd and 2nd seconds of the motion is (Take $g = 10m/s^2$) [AIIMS 2000; CBSE PMT 2002]
(a) 5 : 7 (b) 7 : 5
(c) 3 : 6 (d) 6 : 3

58. Two balls *A* and *B* of same masses are thrown from the top of the building. *A*, thrown upward with velocity *V* and *B*, thrown downward with velocity *V*, then [AIEEE 2002]
(a) Velocity of *A* is more than *B* at the ground
(b) Velocity of *B* is more than *A* at the ground
(c) Both *A* & *B* strike the ground with same velocity
(d) None of these

59. A ball is dropped from top of a tower of 100*m* height. Simultaneously another ball was thrown upward from bottom of the tower with a speed of 50 *m/s* ($g = 10m/s^2$). They will cross each other after [Orissa JEE 2002]
(a) 1*s* (b) 2*s*
(c) 3*s* (d) 4*s*

60. A cricket ball is thrown up with a speed of 19.6 *ms*⁻¹. The maximum height it can reach is [Kerala PMT 2002]
(a) 9.8 *m* (b) 19.6 *m*
(c) 29.4 *m* (d) 39.2 *m*

61. A very large number of balls are thrown vertically upwards in quick succession in such a way that the next ball is thrown when the previous one is at the maximum height. If the maximum height is 5*m*, the number of ball thrown per minute is (take $g = 10ms^{-2}$) [KCET 2002]
(a) 120 (b) 80
(c) 60 (d) 40

62. A body falling from a high Minaret travels 40 meters in the last 2 seconds of its fall to ground. Height of Minaret in meters is (take $g = 10m/s^2$) [MP PMT 2002]
(a) 60 (b) 45
(c) 80 (d) 50

63. A body falls from a height $h = 200m$ (at New Delhi). The ratio of distance travelled in each 2 *sec* during t = 0 to $t = 6$ second of the journey is [BHU 2003; CPMT 2004]
(a) 1 : 4 : 9 (b) 1 : 2 : 4
(c) 1 : 3 : 5 (d) 1 : 2 : 3

64. A man drops a ball downside from the roof of a tower of height 400 meters. At the same time another ball is thrown upside with a velocity 50 *meter/sec*. from the surface of the tower, then they will meet at which height from the surface of the tower

(a) 100 meters (b) 320 meters
(c) 80 meters (d) 240 meters

65. Two balls are dropped from heights h and $2h$ respectively from the earth surface. The ratio of time of these balls to reach the earth is [CPMT 2003]

(a) $1:\sqrt{2}$ (b) $\sqrt{2}:1$
(c) 2 : 1 (d) 1 : 4

66. The acceleration due to gravity on the planet *A* is 9 times the acceleration due to gravity on planet *B*. A man jumps to a height of $2m$ on the surface of *A*. What is the height of jump by the same person on the planet *B* [CBSE PMT 2003]

(a) $18m$ (b) $6m$
(c) $\frac{2}{3}m$ (d) $\frac{2}{9}m$

67. A body falls from rest in the gravitational field of the earth. The distance travelled in the fifth second of its motion is $(g = 10 m/s^2)$ [MP PET 2003]

(a) $25m$ (b) $45m$
(c) $90m$ (d) $125m$

68. If a body is thrown up with the velocity of 15 *m/s* then maximum height attained by the body is (*g* = 10 *m/s*) [MP PMT 2003]

(a) 11.25 *m* (b) 16.2 *m*
(c) 24.5 *m* (d) 7.62 *m*

69. A balloon is rising vertically up with a velocity of 29 ms^{-1}. A stone is dropped from it and it reaches the ground in 10 seconds. The height of the balloon when the stone was dropped from it is (*g* = 9.8 ms^{-2})

(a) 100 *m* (b) 200 *m*
(c) 400 *m* (d) 150 *m*

70. A ball is released from the top of a tower of height *h* meters. It takes *T* seconds to reach the ground. What is the position of the ball in *T*/3 seconds [AIEEE 2004]

(a) *h*/9 *meters* from the ground
(b) 7*h*/9 *meters* from the ground
(c) 8*h*/9 *meters* from the ground
(d) 17*h*/18 *meters* from the ground

71. Two balls of same size but the density of one is greater than that of the other are dropped from the same height, then which ball will reach the earth first (air resistance is negligible)

(a) Heavy ball
(b) Light ball
(c) Both simultaneously
(d) Will depend upon the density of the balls

72. A packet is dropped from a balloon which is going upwards with the velocity 12 *m/s*, the velocity of the packet after 2 seconds will be

(a) –12 *m/s* (b) 12 *m/s*
(c) –7.6 *m/s* (d) 7.6 *m/s*

73. If a freely falling body travels in the last second a distance equal to the distance travelled by it in the first three second, the time of the travel is [Pb. PMT 2004; MH CET 2003]

(a) 6 *sec* (b) 5 *sec*
(c) 4 *sec* (d) 3 *sec*

74. The effective acceleration of a body, when thrown upwards with acceleration *a* will be : [Pb. PMT 2004]

(a) $\sqrt{a-g^2}$ (b) $\sqrt{a^2+g^2}$
(c) $(a-g)$ (d) $(a+g)$

75. A body is thrown vertically upwards with velocity *u*. The distance travelled by it in the fifth and the sixth seconds are equal. The velocity *u* is given by (*g* = 9.8 *m/s*) [UPSEAT 2004]

(a) 24.5 *m/s* (b) 49.0 *m/s*
(c) 73.5 *m/s* (d) 98.0 *m/s*

76. A body, thrown upwards with some velocity reaches the maximum height of 20 *m*. Another body with double the mass thrown up with double the initial velocity will reach a maximum height of [CPMT 2003]

(a) 100 *m* (b) 200 *m*
(c) 300 *m* (d) 400 *m*

77. A parachutist after bailing out falls 50 *m* without friction. When parachute opens, it decelerates at 2 *m/s*. He reaches the ground with a speed of 3 *m/s*. At what height, did he bail out ?

(a) 293 *m* (b) 111 *m*
(c) 91 *m* (d) 182 *m*

78. Three particles *A, B* and *C* are thrown from the top of a tower with the same speed. *A* is thrown up, *B* is thrown down and *C* is horizontally. They hit the ground with speeds V_A, V_B and V_C respectively. [Orissa JEE 2005]

(a) $V_A = V_B = V_C$ (b) $V_A = V_B > V_C$
(c) $V_B > V_C > V_A$ (d) $V_A > V_B = V_C$

79. From the top of a tower two stones, whose masses are in the ratio 1 : 2 are thrown one straight up with an initial speed *u* and the second straight down with the same speed *u*. Then, neglecting air resistance [KCET 2005]

(a) The heavier stone hits the ground with a higher speed
(b) The lighter stone hits the ground with a higher speed
(c) Both the stones will have the same speed when they hit the ground.
(d) The speed can't be determined with the given data.

80. When a ball is thrown up vertically with velocity V_o, it reaches a maximum height of '*h*'. If one wishes to triple the maximum height then the ball should be thrown with velocity [KCET 2004]

(a) $\sqrt{3}V_o$ (b) $3V_o$
(c) $9V_o$ (d) $3/2V_o$

81. An object start sliding on a frictionless inclined plane and from same height another object start falling freely [RPET 2000]

(a) Both will reach with same speed
(b) Both will reach with same acceleration
(c) Both will reach in same time
(d) None of above [J & K CET 2004]

CT Critical Thinking

Objective Questions

[Pb. PMT 2004]

1. A particle moving in a straight line covers half the distance with speed of 3 *m/s*. The other half of the distance is covered in two equal time intervals with speed of 4.5 *m/s* and 7.5 *m/s* respectively. The average speed of the particle during this motion is

(a) 4.0 *m/s* (b) 5.0 *m/s*
(c) 5.5 *m/s* (d) 4.8 *m/s*

2. The acceleration of a particle is increasing linearly with time t as bt. The particle starts from the origin with an initial velocity v_0. The distance travelled by the particle in time t will be

(a) $v_0t + \frac{1}{3}bt^2$ (b) $v_0t + \frac{1}{3}bt^3$

(c) $v_0 t + \frac{1}{6} b t^3$ (d) $v_0 t + \frac{1}{2} b t^2$

3. The motion of a body is given by the equation $\frac{dv(t)}{dt} = 6.0 - 3v(t)$. where $v(t)$ is speed in m/s and t in $\sec$. If body was at rest at $t = 0$ [IIT-JEE 1995]

(a) The terminal speed is 2.0 m/s

(b) The speed varies with the time as $v(t) = 2(1 - e^{-3t}) m/s$

(c) The speed is $0.1 m/s$ when the acceleration is half the initial value

(d) The magnitude of the initial acceleration is $6.0 m/s^2$

4. A particle of mass m moves on the *x*-axis as follows : it starts from rest at $t = 0$ from the point $x = 0$ and comes to rest at $t = 1$ at the point $x = 1$. No other information is available about its motion at intermediate time $(0 < t < 1)$. If α denotes the instantaneous acceleration of the particle, then [IIT-JEE 1993]

(a) α cannot remain positive for all t in the interval $0 \le t \le 1$

(b) $|\alpha|$ cannot exceed 2 at any point in its path

(c) $|\alpha|$ must be ≥ 4 at some point or points in its path

(d) α must change sign during the motion but no other assertion can be made with the information given

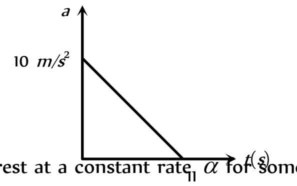
5. A particle starts from rest. Its acceleration (*a*) versus time (*t*) is as shown in the figure. The maximum speed of the particle will be [IIT-JEE (Screening) 2004]

(a) 110 *m/s*

(b) 55 *m/s*

(c) 550 *m/s*

(d) 660 *m/s*



6. A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β and comes to rest. If the total time elapsed is *t*, then the maximum velocity acquired by the car is [IIT 1978; CBSE PMT 1994]

(a) $\left(\frac{\alpha^2 + \beta^2}{\alpha\beta}\right) t$ (b) $\left(\frac{\alpha^2 - \beta^2}{\alpha\beta}\right) t$

(c) $\frac{(\alpha + \beta) t}{\alpha\beta}$ (d) $\frac{\alpha\beta t}{\alpha + \beta}$

7. A stone dropped from a building of height h and it reaches after t seconds on earth. From the same building if two stones are thrown (one upwards and other downwards) with the same velocity u and they reach the earth surface after t_1 and t_2 seconds respectively, then [CPMT 1997; UPSEAT 2002; KCET 2002]

(a) $t = t_1 - t_2$ (b) $t = \frac{t_1 + t_2}{2}$

(c) $t = \sqrt{t_1 t_2}$ (d) $t = t_1^2 t_2^2$

8. A ball is projected upwards from a height h above the surface of the earth with velocity v. The time at which the ball strikes the ground is

(a) $\frac{v}{g} + \frac{2hg}{\sqrt{2}}$ (b) $\frac{v}{g}\left[1 - \sqrt{1 + \frac{2h}{g}}\right]$

(c) $\frac{v}{g}\left[1 + \sqrt{1 + \frac{2gh}{v^2}}\right]$ (d) $\frac{v}{g}\left[1 + \sqrt{v^2 + \frac{2g}{h}}\right]$

9. A particle is dropped vertically from rest from a height. The time taken by it to fall through successive distances of 1 *m* each will then be [Kurukshetra CEE 1996]

(a) All equal, being equal to $\sqrt{2/g}$ second

(b) In the ratio of the square roots of the integers 1, 2, 3.....

(c) In the ratio of the difference in the square roots of the integers *i.e.* $\sqrt{1}, (\sqrt{2} - \sqrt{1}), (\sqrt{3} - \sqrt{2}), (\sqrt{4} - \sqrt{3})$....

(d) In the ratio of the reciprocal of the square roots of the integers *i.e.,* $\frac{1}{\sqrt{1}}, \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{4}}$

10. A man throws balls with the same speed vertically upwards one after the other at an interval of 2 seconds. What should be the speed of the throw so that more than two balls are in the sky at any time (Given $g = 9.8 m/s^2$) [CBSE PMT 2003]

(a) At least 0.8 *m/s*

(b) Any speed less than 19.6 *m/s*

(c) Only with speed 19.6 *m/s*

(d) More than 19.6 *m/s*

11. If a ball is thrown vertically upwards with speed u, the distance covered during the last t seconds of its ascent is [CBSE PMT 2003]

(a) $\frac{1}{2} g t^2$ (b) $ut - \frac{1}{2} g t^2$

(c) $(u - gt)t$ (d) ut d

12. A small block slides without friction down an inclined plane starting from rest. Let S_n be the distance travelled from time $t = n - 1$ to $t = n$. Then $\frac{S_n}{S_{n+1}}$ is [IIT-JEE (Screening) 2004]

(a) $\frac{2n - 1}{2n}$ (b) $\frac{2n + 1}{2n - 1}$

(c) $\frac{2n - 1}{2n + 1}$ (d) $\frac{2n}{2n + 1}$

Graphical Questions

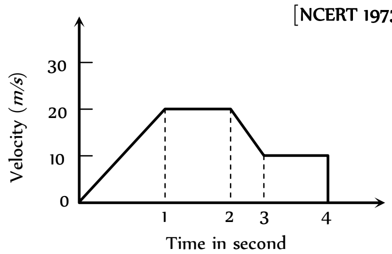
1. The variation of velocity of a particle with time moving along a straight line is illustrated in the following figure. The distance travelled by the particle in four seconds is [NCERT 1973]

(a) 60 m

(b) 55 m

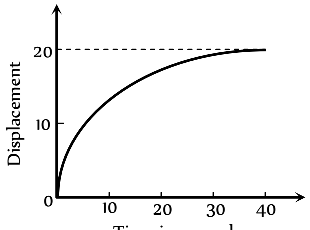
(c) 25 m

(d) 30 m



2. The displacement of a particle as a function of time is shown in the figure. The figure shows that

[CPMT 1970, 86]



(a) The particle starts with certain velocity but the motion is retarded and finally the particle stops

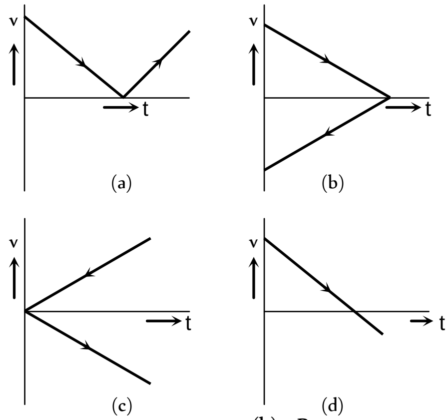
(b) The velocity of the particle is constant throughout

(c) The acceleration of the particle is constant throughout.

(d) The particle starts with constant velocity, then motion is accelerated and finally the particle moves with another constant velocity

3. A ball is thrown vertically upwards. Which of the following graph/graphs represent velocity-time graph of the ball during its flight (air resistance is neglected)

[CPMT 1993; AMU (Engg.) 2000]

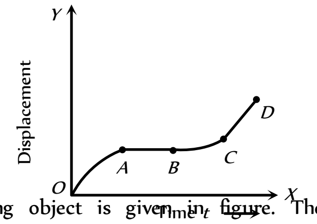


(a) A (b) B

(c) C (d) D

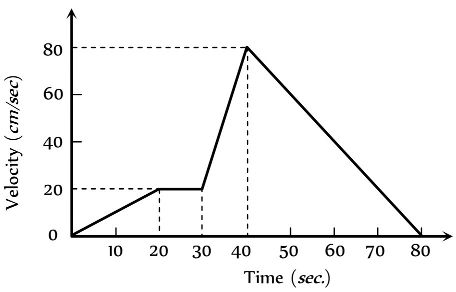
4. The graph between the displacement x and time t for a particle moving in a straight line is shown in figure. During the interval OA, AB, BC and CD, the acceleration of the particle is

	OA,	AB,	BC,	CD
(a)	+	0	+	+
(b)	–	0	+	0
(c)	+	0	–	+
(d)	–	0	–	0



5. The $v-t$ graph of a moving object is given in figure. The maximum acceleration is

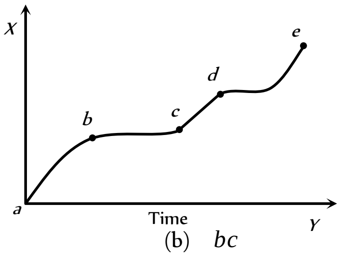
[NCERT 1972]



(a) $1 cm/sec^2$ (b) $2 cm/sec^2$

(c) $3\ cm/sec^2$ (d) $6\ cm/sec^2$

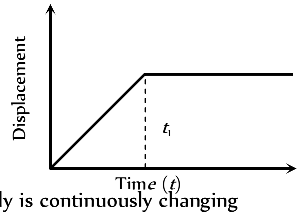
6. The displacement versus time graph for a body moving in a straight line is shown in figure. Which of the following regions represents the motion when no force is acting on the body



(a) ab (b) bc

(c) cd (d) de

7. The $x-t$ graph shown in figure represents [CPMT 1984]



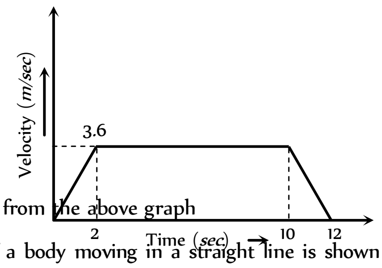
(a) Constant velocity

(b) Velocity of the body is continuously changing

(c) Instantaneous velocity

(d) The body travels with constant speed upto time t_1 and then stops

8. A lift is going up. The variation in the speed of the lift is as given in the graph. What is the height to which the lift takes the passengers



(a) 3.6 m

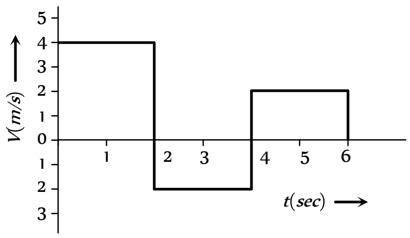
(b) 28.8 m

(c) 36.0 m

(d) Cannot be calculated from the above graph

[CPMT 1986]

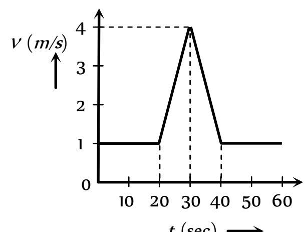
9. The velocity-time graph of a body moving in a straight line is shown in the figure. The displacement and distance travelled by the body in 6 *sec* are respectively [MP PET 1994]



(a) 8 m, 16 m (b) 16 m, 8 m

(c) 16 m, 16 m (d) 8 m, 8 m

10. Velocity-time (v-t) graph for a moving object is shown in the figure. Total displacement of the object during the time interval when there is non-zero acceleration and retardation is



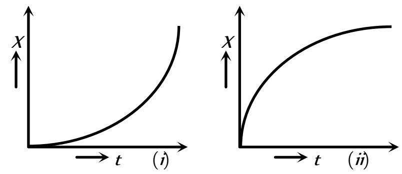
(a) 60 m

(b) 50 m

(c) 30 m

(d) 40 m

11. Figures (i) and (ii) below show the displacement-time graphs of two particles moving along the x-axis. We can say that



(a) Both the particles are having a uniformly accelerated motion

(b) Both the particles are having a uniformly retarded motion

(c) Particle (i) is having a uniformly accelerated motion while particle (ii) is having a uniformly retarded motion

(d) Particle (i) is having a uniformly retarded motion while particle (ii) is having a uniformly accelerated motion

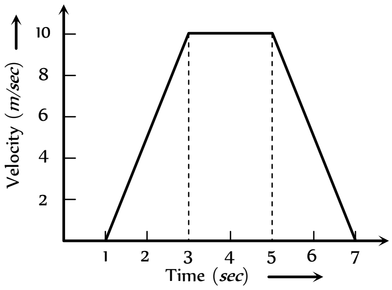
12. For the velocity-time graph shown in figure below the distance covered by the body in last two seconds of its motion is what fraction of the total distance covered by it in all the seven seconds [MP PMT/PET 1998; RPET 2001]

(a) $\frac{1}{2}$

(b) $\frac{1}{4}$

(c) $\frac{1}{3}$

(d) $\frac{2}{3}$



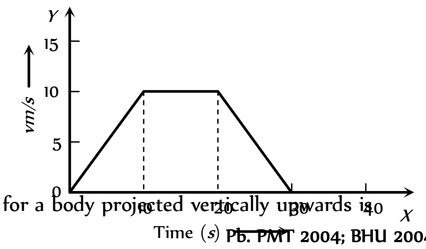
13. In the following graph, distance travelled by the body in metres is

(a) 200

(b) 250

(c) 300

(d) 400

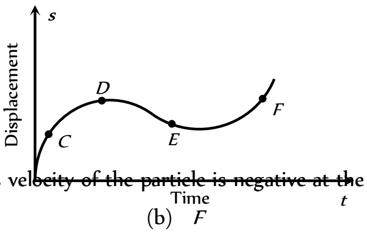


14. Velocity-time curve for a body projected vertically upwards is [EAMCET (Med.) 1995; AIIMS 1999; Pb. PMT 2004; BHU 2004]

(a) Parabola (b) Ellipse

(c) Hyperbola (d) Straight line

15. The displacement-time graph of moving particle is shown below



The instantaneous velocity of the particle is negative at the point [CBSE PMT 1994]

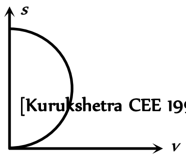
(a) D (b) F

(c) C (d) E

16. An object is moving with a uniform acceleration which is parallel to its instantaneous direction of motion. The displacement $(s)-$ velocity (v) graph of this object is

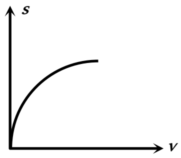
[SCRA 1998; DCE 2000; AIIMS 2003; Orissa PMT 2004]

(a)

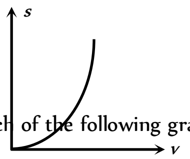


[Kurukshetra CEE 1996]

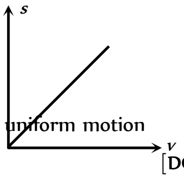
(b)



(c)

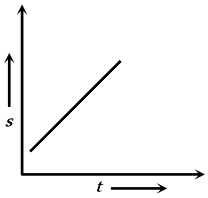


(d)

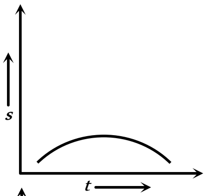


17. Which of the following graph represents uniform motion [DCE 1999]

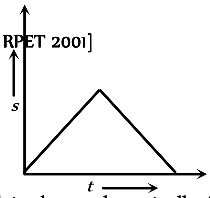
(a)



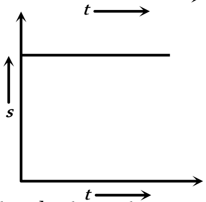
(b)



(c)

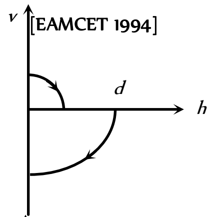


(d)

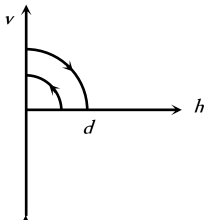


18. A ball is dropped vertically from a height d above the ground. It hits the ground and bounces up vertically to a height $d/2$. Neglecting subsequent motion and air resistance, its velocity v varies with the height h above the ground is [EAMCET 1994]

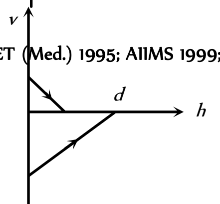
(a)



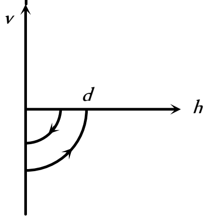
(b)



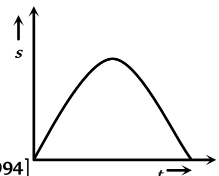
(c)



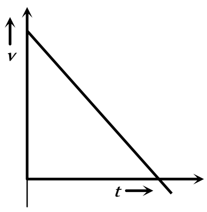
(d)

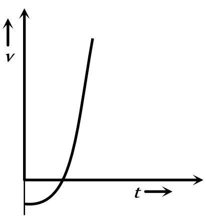


19. The graph of displacement v/s time is



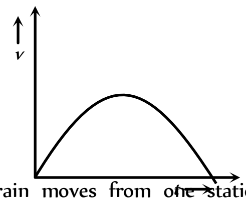
Its corresponding velocity-time graph will be [DCE 2001]



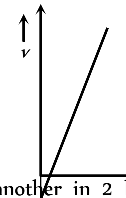


(a) (b)

(c)

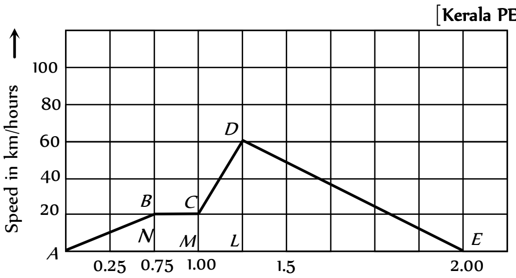


(d)



20. A train moves from one station to another in 2 hours time. Its speed-time graph during this motion is shown in the figure. The maximum acceleration during the journey is

[Kerala PET 2002]



(a) 140 $km\ h^{-1}$ (b) 160 $km\ h^{-1}$
(c) 100 $km\ h^{-1}$ (d) 120 $km\ h^{-1}$

21. The area under acceleration-time graph gives

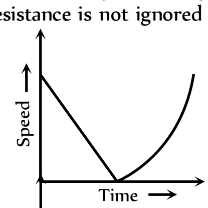
[Kerala PET 2005]

(a) Distance travelled (b) Change in acceleration
(c) Force acting (d) Change in velocity

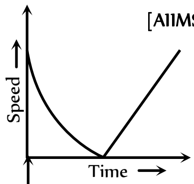
22. A ball is thrown vertically upwards. Which of the following plots represents the speed-time graph of the ball during its height if the air resistance is not ignored

[AIIMS 2003]

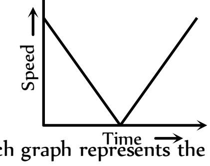
(a)



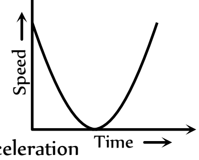
(b)



(c)



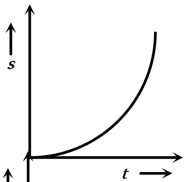
(d)



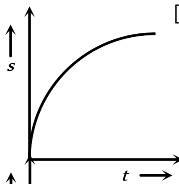
23. Which graph represents the uniform acceleration

[DCE 2003]

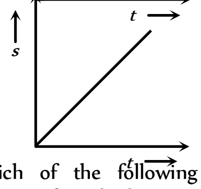
(a)



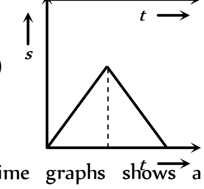
(b)



(c)



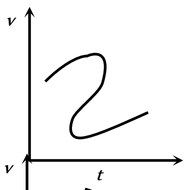
(d)



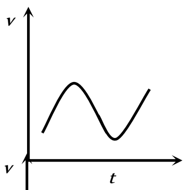
24. Which of the following velocity-time graphs shows a realistic situation for a body in motion

[AIIMS 2004]

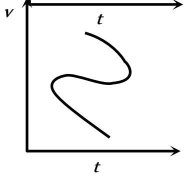
(a)



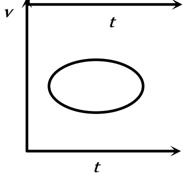
(b)



(c)



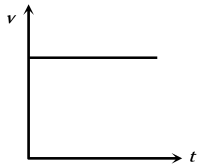
(d)



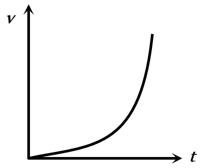
25. Which of the following velocity-time graphs represent uniform motion

[Kerala PMT 2004]

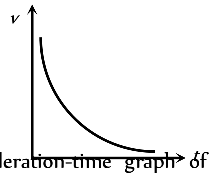
(a)



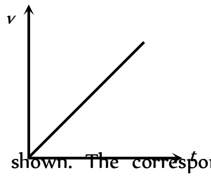
(b)



(c)

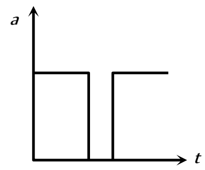


(d)

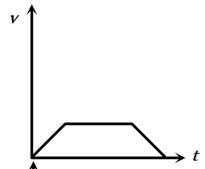


26. Acceleration-time graph of a body is shown. The corresponding velocity-time graph of the same body is

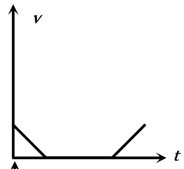
[DPMT 2004]



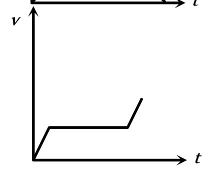
(a)



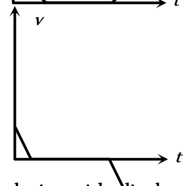
(b)



(c)

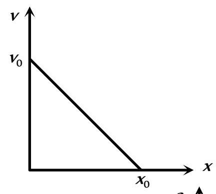


(d)

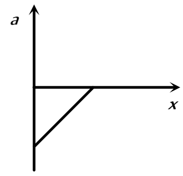


27. The given graph shows the variation of velocity with displacement. Which one of the graph given below correctly represents the variation of acceleration with displacement

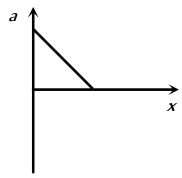
[IIT-JEE (Screening) 2005]



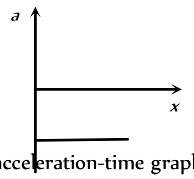
(a)



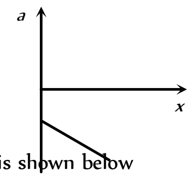
(b)



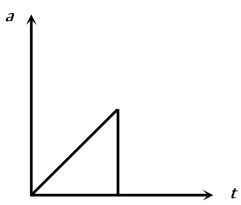
(c)



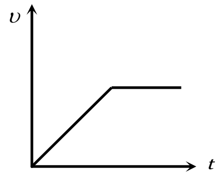
(d)

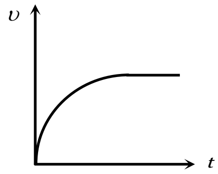


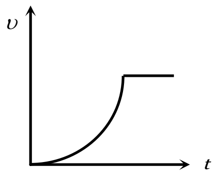
28. The acceleration-time graph of a body is shown below

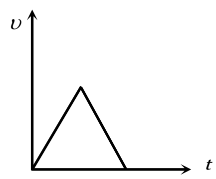


The most probable velocity-time graph of the body is

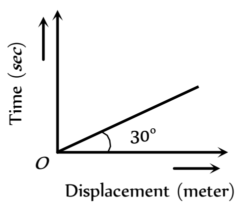
(a) 

(b) 

(c) 

(d) 

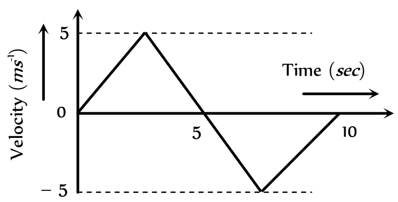
29. From the following displacement-time graph find out the velocity of a moving body



(a) $\frac{1}{\sqrt{3}}$ *m/s* (b) 3 *m/s*

(c) $\sqrt{3}$ *m/s* (d) $\frac{1}{3}$

30. The $\upsilon - t$ plot of a moving object is shown in the figure. The average velocity of the object during the first 10 seconds is



(a) 0 (b) 2.5 *ms*

(c) 5 *ms* (d) 2 *ms*

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : A body can have acceleration even if its velocity is zero at a given instant of time.

Reason : A body is momentarily at rest when it reverses its direction of motion.

2. Assertion : Two balls of different masses are thrown vertically upward with same speed. They will pass through their point of projection in the downward direction with the same speed.

Reason : The maximum height and downward velocity attained at the point of projection are independent of the mass of the ball.

3. Assertion : If the displacement of the body is zero, the distance covered by it may not be zero.

Reason : Displacement is a vector quantity and distance is a scalar quantity.

4. Assertion : The average velocity of the object over an interval of time is either smaller than or equal to the average speed of the object over the same interval.

Reason : Velocity is a vector quantity and speed is a scalar quantity.

5. Assertion : An object can have constant speed but variable velocity.

Reason : Speed is a scalar but velocity is a vector quantity.

6. Assertion : The speed of a body can be negative.

Reason : If the body is moving in the opposite direction of positive motion, then its speed is negative.

7. Assertion : The position-time graph of a uniform motion in one dimension of a body can have negative slope.

Reason : When the speed of body decreases with time, the position-time graph of the moving body has negative slope.

8. Assertion : A positive acceleration of a body can be associated with a '*slowing down*' of the body.

Reason : Acceleration is a vector quantity.

9. Assertion : A negative acceleration of a body can be associated with a '*speeding up*' of the body.

Reason : Increase in speed of a moving body is independent of its direction of motion.

10. Assertion : When a body is subjected to a uniform acceleration, it always move in a straight line.

Reason : Straight line motion is the natural tendency of the body.

11. Assertion : Rocket in flight is not an illustration of projectile.

Reason : Rocket takes flight due to combustion of fuel and does not move under the gravity effect alone.

12. Assertion : The average speed of a body over a given interval of time is equal to the average velocity of the body in the same interval of time if a body moves in a straight line in one direction.

Reason : Because in this case distance travelled by a body is equal to the displacement of the body.

13. Assertion : Position-time graph of a stationary object is a straight line parallel to time axis.

Reason : For a stationary object, position does not change with time.

14. Assertion : The slope of displacement-time graph of a body moving with high velocity is steeper than the slope of displacement-time graph of a body with low velocity.

Reason : Slope of displacement-time graph = Velocity of the body.

15. Assertion : Distance-time graph of the motion of a body having uniformly accelerated motion is a straight line inclined to the time axis.

Reason : Distance travelled by a body having uniformly accelerated motion is directly proportional to the square of the time taken.

16. Assertion : A body having non-zero acceleration can have a constant velocity.

Reason : Acceleration is the rate of change of velocity.

17. Assertion : A body, whatever its motion is always at rest in a frame of reference which is fixed to the body itself.

Reason : The relative velocity of a body with respect to itself is zero.

18. Assertion : Displacement of a body may be zero when distance travelled by it is not zero.

Reason : The displacement is the longest distance between initial and final position.

19. Assertion : The equation of motion can be applied only if acceleration is along the direction of velocity and is constant.

Reason : If the acceleration of a body is constant then its motion is known as uniform motion.

20. Assertion : A bus moving due north takes a turn and starts moving towards east with same speed. There will be no change in the velocity of bus.

Reason : Velocity is a vector-quantity.

21. Assertion : The relative velocity between any two bodies moving in opposite direction is equal to sum of the velocities of two bodies.

Reason : Sometimes relative velocity between two bodies is equal to difference in velocities of the two.

22. Assertion : The displacement-time graph of a body moving with uniform acceleration is a straight line.

Reason : The displacement is proportional to time for uniformly accelerated motion.

23. Assertion : Velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to the time axis.

Reason : In uniform motion of an object velocity increases as the square of time elapsed.

24. Assertion : A body may be accelerated even when it is moving uniformly.

Reason : When direction of motion of the body is changing then body may have acceleration.

25. Assertion : A body falling freely may do so with constant velocity.

Reason : The body falls freely, when acceleration of a body is equal to acceleration due to gravity.

26. Assertion : Displacement of a body is vector sum of the area under velocity-time graph.

Reason : Displacement is a vector quantity.

27. Assertion : The position-time graph of a body moving uniformly is a straight line parallel to position-axis.

Reason : The slope of position-time graph in a uniform motion gives the velocity of an object.

28. Assertion : The average speed of an object may be equal to arithmetic mean of individual speed.

Reason : Average speed is equal to total distance travelled per total time taken.

29. Assertion : The average and instantaneous velocities have same value in a uniform motion.

Reason : In uniform motion, the velocity of an object increases uniformly.

30. Assertion : The speedometer of an automobile measure the average speed of the automobile.

Reason : Average velocity is equal to total displacement per total time taken.

Answers

Distance and Displacement

1	a	2	a	3	c	4	a	5	b
6	c								

Uniform Motion

1	d	2	d	3	b	4	b	5	c
6	d	7	a	8	b	9	d	10	c
11	c	12	d	13	d	14	b	15	b
16	d	17	c	18	c	19	d	20	b
21	a	22	b	23	b	24	c		

Non-uniform Motion

1	b	2	c	3	d	4	a	5	a
6	ac	7	a	8	d	9	b	10	a
11	b	12	c	13	b	14	a	15	b
16	d	17	c	18	a	19	c	20	b
21	a	22	c	23	a	24	d	25	c
26	b	27	c	28	d	29	c	30	a
31	c	32	a	33	d	34	a	35	b
36	a	37	b	38	d	39	d	40	b
41	b	42	c	43	b	44	c	45	b
46	d	47	b	48	a	49	b	50	b

51	c	52	c	53	a	54	a	55	c
56	d	57	d	58	d	59	b	60	d
61	c	62	b	63	b	64	a	65	d
66	b	67	a	68	a	69	a	70	d
71	c	72	a	73	a	74	c	75	c
76	c	77	d	78	a	79	c	80	d
81	d	82	c	83	c	84	b	85	a
86	d								

Relative Motion

1	b	2	d	3	b	4	a	5	c
6	d	7	b	8	a	9	d	10	c
11	c	12	b	13	a				

Motion Under Gravity

1	c	2	b	3	d	4	c	5	b
6	a	7	a	8	b	9	c	10	d
11	b	12	a	13	d	14	b	15	c
16	c	17	a	18	b	19	b	20	c
21	b	22	c	23	a	24	b	25	c
26	d	27	b	28	c	29	a	30	d
31	b	32	a	33	b	34	b	35	a
36	c	37	b	38	c	39	b	40	a
41	b	42	b	43	b	44	b	45	d
46	d	47	b	48	b	49	b	50	b
51	c	52	a	53	d	54	d	55	d
56	c	57	b	58	c	59	b	60	b
61	c	62	b	63	c	64	c	65	a
66	a	67	b	68	a	69	b	70	c
71	c	72	c	73	b	74	c	75	b
76	b	77	a	78	a	79	c	80	a
81	a								

Critical Thinking Questions

1	a	2	c	3	abd	4	ad	5	b
6	d	7	c	8	c	9	c	10	d
11	a	12	c						

Graphical Questions

1	b	2	a	3	d	4	b	5	d
6	c	7	d	8	c	9	a	10	b
11	c	12	b	13	a	14	d	15	d
16	c	17	a	18	a	19	a	20	b
21	d	22	c	23	a	24	b	25	a
26	c	27	a	28	c	29	c	30	a

Assertion and Reason

1	a	2	a	3	a	4	a	5	a
6	d	7	c	8	b	9	b	10	e
11	a	12	a	13	a	14	a	15	e
16	e	17	a	18	c	19	d	20	e
21	b	22	d	23	c	24	e	25	e
26	a	27	e	28	b	29	c	30	e

Answers and Solutions

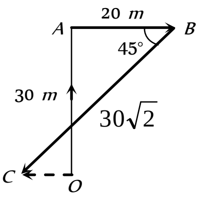
Distance and Displacement

1. (a) $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k} \quad \therefore r = \sqrt{x^2 + y^2 + z^2}$

$r = \sqrt{6^2 + 8^2 + 10^2} = 10\sqrt{2}\ m$

2. (a) $\vec{r} = 20\hat{i} + 10\hat{j} \quad \therefore \quad r = \sqrt{20^2 + 10^2} = 22.5\ m$

3. (c) From figure, $\overrightarrow{OA} = 0\ \hat{i} + 30\ \hat{j}$, $\overrightarrow{AB} = 20\ \hat{i} + 0\ \hat{j}$



$\overrightarrow{BC} = -30\sqrt{2}\ cos45^o\hat{i} - 30\sqrt{2}\ \sin 45^o\hat{j} = -30\ \hat{i} - 30\ \hat{j}$

$\therefore$ Net displacement, $\overrightarrow{OC} = \overrightarrow{OA} + \overrightarrow{AB} + \overrightarrow{BC} = -10\ \hat{i} + 0\ \hat{j}$

$|\overrightarrow{OC}| = 10\ m.$

4. (a) An aeroplane flies 400 *m* north and 300 *m* south so the net displacement is 100 *m* towards north.

Then it flies 1200 *m* upward so $r = \sqrt{(100)^2 + (1200)^2}$

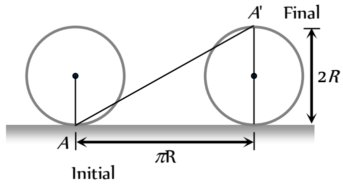
$= 1204\,m \simeq 1200\,m$

The option should be 1204 *m*, because this value mislead one into thinking that net displacement is in upward direction only.

5. (b) Total time of motion is 2 *min* 20 *sec* = 140 *sec.*

As time period of circular motion is 40 *sec* so in 140 *sec.* athlete will complete 3.5 revolution *i.e.,* He will be at diametrically opposite point *i.e.,* Displacement = 2*R.*

6. (c) Horizontal distance covered by the wheel in half revolution = πR.



So the displacement of the point which was initially in contact with ground = $AA' = \sqrt{(\pi R)^2 + (2R)^2}$

$= R\sqrt{\pi^2 + 4} = \sqrt{\pi^2 + 4} \qquad (As\ R = 1m)$

Uniform Motion

1. (d) As the total distance is divided into two equal parts therefore distance averaged speed $= \dfrac{2v_1v_2}{v_1 + v_2}$

2. (d) $\dfrac{v_A}{v_B} = \dfrac{\tan\theta_A}{\tan\theta_B} = \dfrac{\tan 30°}{\tan 60°} = \dfrac{1/\sqrt{3}}{\sqrt{3}} = \dfrac{1}{3}$

3. (b) Distance average speed $= \dfrac{2v_1v_2}{v_1 + v_2} = \dfrac{2 \times 20 \times 30}{20 + 30}$

$= \dfrac{120}{5} = 24\ km/hr$

4. (b) Distance average speed $= \dfrac{2v_1v_2}{v_1 + v_2} = \dfrac{2 \times 2.5 \times 4}{2.5 + 4}$

$= \dfrac{200}{65} = \dfrac{40}{13} km/hr$

5. (c) Distance average speed $= \dfrac{2v_1v_2}{v_1 + v_2} = \dfrac{2 \times 30 \times 50}{30 + 50}$

$= \dfrac{75}{2} = 37.5\ km/hr$

6. (d) Average speed $= \dfrac{\text{Total distance}}{\text{Total time}} = \dfrac{x}{t_1 + t_2}$

$= \dfrac{x}{\dfrac{x/3}{v_1} + \dfrac{2x/3}{v_2}} = \dfrac{1}{\dfrac{1}{3 \times 20} + \dfrac{2}{3 \times 60}} = 36\ km/hr$

7. (a) Time average speed $= \dfrac{v_1 + v_2}{2} = \dfrac{80 + 40}{2} = 60 km/hr$.

8. (b) Distance travelled by train in first 1 *hour* is 60 *km* and distance in next 1/2 *hour* is 20 *km.*

So Average speed $= \dfrac{\text{Total distance}}{\text{Total time}} = \dfrac{60 + 20}{3/2}$

$= 53.33\ km/hour$

9. (d)

10. (c) Total distance to be covered for crossing the bridge

= length of train + length of bridge

$= 150m + 850m = 1000m$

$\text{Time} = \dfrac{\text{Distance}}{\text{Velocity}} = \dfrac{1000}{45 \times \dfrac{5}{18}} = 80\ sec$

11. (c) Displacement of the particle will be zero because it comes back to its starting point

$\text{Average speed} = \dfrac{\text{Total distance}}{\text{Total time}} = \dfrac{30m}{10\ sec} = 3\ m/s$

12. (d) Velocity of particle $= \dfrac{\text{Total diplacement}}{\text{Total time}}$

$= \dfrac{\text{Diameter of circle}}{5} = \dfrac{2 \times 10}{5} = 4\ m/s$

13. (d) A man walks from his home to market with a speed of $5\ km/h$. Distance $= 2.5\ km$ and time $= \dfrac{d}{v} = \dfrac{2.5}{5} = \dfrac{1}{2} hr$.

and he returns back with speed of $7.5\ km/h$ in rest of time of 10 *minutes*.

Distance $= 7.5 \times \frac{10}{60} = 1.25\ km$

So, Average speed $= \frac{\text{Total distance}}{\text{Total time}}$

$= \frac{(2.5+1.25)km}{(40/60)hr} = \frac{45}{8} km/hr$.

14. (b) $\frac{|\text{Average velocity}|}{|\text{Average speed}|} = \frac{|\text{displacement}|}{|\text{distance}|} \le 1$

because displacement will either be equal or less than distance. It can never be greater than distance.

15. (b)

16. (d) Average speed $= \frac{\text{Total distance travelled}}{\text{Total time taken}}$

$= \frac{x}{\frac{2x/5}{v_1} + \frac{3x/5}{v_2}} = \frac{5v_1v_2}{3v_1 + 2v_2}$

17. (c) From given figure, it is clear that the net displacement is zero. So average velocity will be zero.

18. (c) Since displacement is always less than or equal to distance, but never greater than distance. Hence numerical ratio of displacement to the distance covered is always equal to or less than one.

19. (d) Length of train = 100 *m*

Velocity of train $= 45\ km/hr = 45 \times \frac{5}{18} = 12.5\ m/s$

Length of bridge = 1 *km* = 1000 *m*

$\therefore$ Total length covered by train = 1100 *m*

Time taken by train to cross the bridge $= \frac{1100}{12.5}$ = 88 *sec*

20. (b) Time average velocity $= \frac{v_1 + v_2 + v_3}{3} = \frac{3+4+5}{3} = 4 m/s$

21. (a) When the body is projected vertically upward then at the highest point its velocity is zero but acceleration is not equal to zero $(g = 9.8 m/s^2)$.

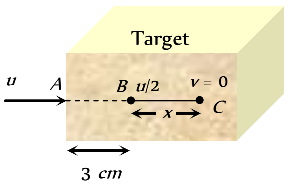
22. (b) Let initial velocity of the bullet = *u*

After penetrating 3 *cm* its velocity becomes $\frac{u}{2}$

From $v^2 = u^2 - 2as$

$\left(\frac{u}{2}\right)^2 = u^2 - 2a(3)$

$\Rightarrow 6a = \frac{3u^2}{4} \Rightarrow a = \frac{u^2}{8}$

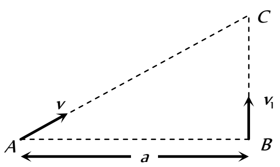


Let further it will penetrate through distance *x* and stops at point *C*.

For distance *BC*, $v = 0, u = u/2, s = x, a = u^2/8$

From $v^2 = u^2 - 2as \Rightarrow 0 = \left(\frac{u}{2}\right)^2 - 2\left(\frac{u^2}{8}\right).x \Rightarrow x = 1$ *cm.*

23. (b) Let two boys meet at point *C* after time '*t*' from the starting. Then $AC = vt$, $BC = v_1 t$



$(AC)^2 = (AB)^2 + (BC)^2 \Rightarrow v^2t^2 = a^2 + v_1^2t^2$

By solving we get $t = \sqrt{\frac{a^2}{v^2 - v_1^2}}$

24. (c) $v_{av} = \frac{2v_1v_2}{v_1 + v_2} = \frac{2 \times 40 \times 60}{100} = 48 kmph.$

Non-uniform Motion

1. (b) As $S = ut + \frac{1}{2}at^2 \therefore S_1 = \frac{1}{2}a(10)^2 = 50a$ .....(i)

As $v = u + at \therefore$ velocity acquired by particle in 10 *sec* $v = a \times 10$

For next 10 *sec*, $S_2 = (10a) \times 10 + \frac{1}{2}(a) \times (10)^2$

$S_2 = 150a$ .....(ii)

From (i) and (ii) $S_1 = S_2/3$

2. (c) Acceleration $= \frac{d^2x}{dt^2} = 2a_2$

3. (d) Velocity along *X*-axis $v_x = \frac{dx}{dt} = 2at$

Velocity along *Y*-axis $v_y = \frac{dy}{dt} = 2bt$

Magnitude of velocity of the particle,

$v = \sqrt{v_x^2 + v_y^2} = 2t\sqrt{a^2 + b^2}$

4. (a) $S = \int_0^3 v\,dt = \int_0^3 kt\,dt = \left[\frac{1}{2}kt^2\right]_0^3 = \frac{1}{2} \times 2 \times 9 = 9m$

5. (a) $S = kt^3 \therefore a = \frac{d^2S}{dt^2} = 6kt$ *i.e.* $a \propto t$

6. (a,c)

7. (a) From $S = ut + \frac{1}{2}a\,t^2$

$S_1 = \frac{1}{2}a(P-1)^2$ and $S_2 = \frac{1}{2}a\,P^2$ $[As\ u = 0]$

From $S_n = u + \frac{a}{2}(2n-1)$

$S_{(P^2-P+1)^{th}} = \frac{a}{2}\left[2(P^2 - P + 1) - 1\right] = \frac{a}{2}\left[2P^2 - 2P + 1\right]$

It is clear that $S_{(P^2-P+1)^{th}} = S_1 + S_2$

8. (d) $\vec{a} = \frac{\vec{F}}{m}$. If $\vec{F} = 0$ then $\vec{a} = 0$.

9. (b) $v = 4t^3 - 2t$ (given) $\therefore a = \frac{dv}{dt} = 12t^2 - 2$

and $x = \int_0^t v\,dt = \int_0^t (4t^3 - 2t)\,dt = t^4 - t^2$

When particle is at 2*m* from the origin $t^4 - t^2 = 2$

$\Rightarrow\ t^4 - t^2 - 2 = 0 \quad (t^2-2)(t^2+1) = 0 \ \Rightarrow\ t = \sqrt{2}$ sec

Acceleration at $t = \sqrt{2}$ sec given by,

$a = 12t^2 - 2 = 12 \times 2 - 2 = 22\ m/s^2$

10. (a) $\frac{dt}{dx} = 2\alpha x + \beta \Rightarrow v = \frac{1}{2\alpha x + \beta}$

$\because\ a = \frac{dv}{dt} = \frac{dv}{dx}.\frac{dx}{dt}$

$a = v\frac{dv}{dx} = \frac{-v.2\alpha}{(2\alpha x+\beta)^2} = -2\alpha.v.v^2 = -2\alpha v^3$

$\therefore$ Retardation $= 2\alpha v^3$

11. (b) Let u_1, u_2, u_3 and u_4 be velocities at time $t = 0, t_1, (t_1+t_2)$ and $(t_1+t_2+t_3)$ respectively and acceleration is a then

$v_1 = \frac{u_1+u_2}{2}, v_2 = \frac{u_2+u_3}{2}$ and $v_3 = \frac{u_3+u_4}{2}$

Also $u_2 = u_1 + at_1$, $u_3 = u_1 + a(t_1+t_2)$

and $u_4 = u_1 + a(t_1+t_2+t_3)$

By solving, we get $\frac{v_1 - v_2}{v_2 - v_3} = \frac{(t_1+t_2)}{(t_2+t_3)}$

12. (c) Acceleration $a = \tan\theta$, where θ is the angle of tangent drawn on the graph with the time axis.

13. (b) If acceleration is variable (depends on time) then

$v = u + \int (f)\,dt = u + \int (a\,t)\,dt = u + \frac{a\,t^2}{2}$

14. (a) $S_n = u - \frac{a}{2}(2n-1) = 10 - \frac{2}{2}(2\times 5 - 1) = 1\ meter$

15. (b) From $v^2 = u^2 + 2aS \ \Rightarrow\ 0 = u^2 + 2aS$

$\Rightarrow\ a = \frac{-u^2}{2S} = \frac{-(20)^2}{2\times 10} = -20 m/s^2$

16. (d) $v = u + at = 10 + 2\times 4 = 18\ m/\text{sec}$

17. (c) If particle starts from rest and moves with constant acceleration then in successive equal interval of time the ratio of distance covered by it will be

$1:3:5:7$ ..... $(2n-1)$

i.e. ratio of *x* and *y* will be $1:3$ *i.e.* $\frac{x}{y} = \frac{1}{3} \ \Rightarrow\ y = 3x$

18. (a) $S_n = u + \frac{a}{2}[2n-1]$

$S_{5^{th}} = 7 + \frac{4}{2}[2\times 5 - 1] = 7 + 18 = 25m$.

19. (c) Acceleration $a = \frac{dv}{dt} = 0.1\times 2t = 0.2t$

Which is time dependent *i.e.* non-uniform acceleration.

20. (b) Constant velocity means constant speed as well as same direction throughout.

21. (a) Distance travelled in 4 *sec*

$24 = 4u + \frac{1}{2}a\times 16$ ...(i)

Distance travelled in total 8 *sec*

$88 = 8u + \frac{1}{2}a\times 64$ ...(ii)

After solving (i) and (ii), we get $u = 1$ *m/s*.

22. (c) $v_x = \frac{dx}{dt} = \frac{d}{dt}(3t^2 - 6t) = 6t - 6$. At $t = 1, v_x = 0$

$v_y = \frac{dy}{dt} = \frac{d}{dt}(t^2 - 2t) = 2t - 2$. At $t = 1, v_y = 0$

Hence $v = \sqrt{v_x^2 + v_y^2} = 0$

23. (a) Distance travelled in n^{th} second $= u + \frac{a}{2}(2n-1)$

Distance travelled in 5^{th} second $= 0 + \frac{8}{2}(2\times 5 - 1) = 36m$

24. (d) $v^2 = u^2 + 2as \Rightarrow (9000)^2 - (1000)^2 = 2\times a\times 4$

$\Rightarrow a = 10^7 m/s^2$ Now $t = \frac{v-u}{a}$

$\Rightarrow t = \frac{9000-1000}{10^7} = 8\times 10^{-4}\ sec$

25. (c) Initial relative velocity $= v_1 - v_2$, Final relative velocity $= 0$

From $v^2 = u^2 - 2as \Rightarrow 0 = (v_1 - v_2)^2 - 2\times a\times s$

$\Rightarrow\ s = \frac{(v_1 - v_2)^2}{2a}$

If the distance between two cars is '*s*' then collision will take place. To avoid collision $d > s \ \therefore\ d > \frac{(v_1 - v_2)^2}{2a}$

where $d =$ actual initial distance between two cars.

26. (b) $v = u + at \Rightarrow -2 = 10 + a\times 4 \Rightarrow a = -3m/sec^2$

27. (c) $S_x = u_x t + \frac{1}{2}a_x t^2 \Rightarrow S_x = \frac{1}{2}\times 6\times 16 = 48\ m$

$S_y = u_y t + \frac{1}{2}a_y t^2 \Rightarrow S_y = \frac{1}{2}\times 8\times 16 = 64\ m$

$S = \sqrt{S_x^2 + S_y^2} = 80m$

28. (d) $S \propto u^2$. If *u* becomes 3 times then *S* will become 9 times *i.e.* $9\times 20 = 180m$

29. (c) $y = a + bt + ct^2 - dt^4$

$\therefore v = \frac{dy}{dt} = b + 2ct - 4dt^3$ and $a = \frac{dv}{dt} = 2c - 12dt^2$

Hence, at $t = 0$, $v_{initial} = b$ and $a_{initial} = 2c$.

30. (a) $S \propto u^2 \ \therefore\ \frac{S_1}{S_2} = \left(\frac{u_1}{u_2}\right)^2 \Rightarrow \frac{2}{S_2} = \frac{1}{4} \Rightarrow S_2 = 8\ m$

31. (c) $t = \sqrt{\frac{2h}{(g+a)}} = \sqrt{\frac{2\times 2.7}{(9.8+1.2)}} = \sqrt{\frac{5.4}{11}} = \sqrt{0.49} = 0.7\,\text{sec}$

As $u = 0$ and lift is moving upward with acceleration

32. (a) Displacement $x = 2t^2 + t + 5$

Velocity $= \frac{dx}{dt} = 4t + 1$

Acceleration $= \frac{d^2x}{dt^2} = 4$ *i.e.* independent of time

Hence acceleration $= 4\ m/s^2$

33. (d) Both trains will travel a distance of 1 *km* before to come in rest. In this case by using $v^2 = u^2 + 2as$

$\Rightarrow 0 = (40)^2 + 2a \times 1000 \Rightarrow a = -0.8\ m/s^2$

34. (a) $v = u + at \Rightarrow v = 0 + 5 \times 10 = 50\ m/s$

35. (b) Let '*a*' *be* the retardation of boggy then distance covered by it be *S*. If *u* is the initial velocity of boggy after detaching from train (*i.e.* uniform speed of train)

$v^2 = u^2 + 2as \Rightarrow 0 = u^2 - 2as \Rightarrow s_b = \dfrac{u^2}{2a}$

Time taken by boggy to stop

$v = u + at \Rightarrow 0 = u - at \Rightarrow t = \dfrac{u}{a}$

In this time *t* distance travelled by train $= s_t = ut = \dfrac{u^2}{a}$

Hence ratio $\dfrac{s_b}{s_t} = \dfrac{1}{2}$

36. (a) $S_n = u + \dfrac{a}{2}(2n-1) = \dfrac{a}{2}(2n-1)$ because $u = 0$

Hence $\dfrac{S_4}{S_3} = \dfrac{7}{5}$

37. (b) $v = u + \int a dt = u + \int (3t^2 + 2t + 2)dt$

$= u + \dfrac{3t^3}{3} + \dfrac{2t^2}{2} + 2t = u + t^3 + t^2 + 2t$

$= 2 + 8 + 4 + 4 = 18\ m/s$ (As $t = 2$ *sec*)

38. (d) $v = \dfrac{ds}{dt} = 3t^2 - 12t + 3$ and $a = \dfrac{dv}{dt} = 6t - 12$

For $a = 0$, we have $t = 2$ and at $t = 2, v = -9\ ms^{-1}$

39. (d)

40. (b) $a = \sqrt{a_x^2 + a_y^2} = \left[\left(\dfrac{d^2x}{dt^2}\right)^2 + \left(\dfrac{d^2y}{dt^2}\right)^2\right]^{\frac{1}{2}}$

Here $\dfrac{d^2y}{dt^2} = 0$. Hence $a = \dfrac{d^2x}{dt^2} = 8m/s^2$

41. (b) $F = m \times a$, If force is constant then $a \propto \dfrac{1}{m}$. So If mass is doubled then acceleration becomes half.

42. (c) $S_n = u + \dfrac{a}{2}(2n-1) \Rightarrow 1.2 = 0 + \dfrac{a}{2}(2 \times 6 - 1)$

$\Rightarrow a = \dfrac{1.2 \times 2}{11} = 0.218\ m/s^2$

43. (b) Here $v = 144\ km/h = 40m/s$

$v = u + at \Rightarrow 40 = 0 + 20 \times a \Rightarrow a = 2\ m/s^2$

$\therefore s = \dfrac{1}{2}at^2 = \dfrac{1}{2} \times 2 \times (20)^2 = 400\ m$

44. (c) $\dfrac{dx}{dt} = 2at - 3bt^2 \Rightarrow \dfrac{d^2x}{dt^2} = 2a - 6bt = 0 \Rightarrow t = \dfrac{a}{3b}$

45. (b) Stopping distance $= \dfrac{\text{Kineticenergy}}{\text{Retardins force}} = \dfrac{\frac{1}{2}mu^2}{F}$

If retarding force (*F*) and velocity (*v*) are equal then stopping distance $\propto m$ (mass of vehicle)

As $m_{car} < m_{truck}$ therefore car will cover less distance before coming to rest.

46. (d) $u = 72\ kmph = 20m/s,\ v = 0$

By using $v^2 = u^2 - 2as \Rightarrow a = \dfrac{u^2}{2s} = \dfrac{(20)^2}{2 \times 200} = 1\ m/s^2$

47. (b) $v = \dfrac{ds}{dt} = 12t - 3t^2$

Velocity is zero for $t = 0$ and $t = 4$ sec

48. (a)

49. (b) Let *A* and *B* will meet after time *t sec*. it means the distance travelled by both will be equal.

$S_A = ut = 40t$ and $S_B = \dfrac{1}{2}at^2 = \dfrac{1}{2} \times 4 \times t^2$

$S_A = S_B \Rightarrow 40t = \dfrac{1}{2}4t^2 \Rightarrow t = 20$ *sec*

50. (b) $x = a + bt^2, v = \dfrac{dx}{dt} = 2bt$

Instantaneous velocity $v = 2 \times 3 \times 3 = 18\ cm/\text{sec}$

51. (c) If the body starts from rest and moves with constant acceleration then the ratio of distances in consecutive equal time interval $S_1 : S_2 : S_3 = 1 : 3 : 5$

52. (c) $x = at + bt^2 - ct^3,\ a = \dfrac{d^2x}{dt^2} = 2b - 6ct$

53. (a) Let initial $(t = 0)$ velocity of particle $= u$

For first 5 *sec* motion $s_5 = 10$ *metre*

$s = ut + \dfrac{1}{2}at^2 \Rightarrow 10 = 5u + \dfrac{1}{2}a(5)^2$

$2u + 5a = 4$ ....(i)

For first 8 *sec* of motion $s_8 = 20$ *metre*

$20 = 8u + \dfrac{1}{2}a(8)^2 \Rightarrow 2u + 8a = 5$ ....(ii)

By solving $u = \dfrac{7}{6}m/s$ and $a = \dfrac{1}{3}m/s^2$

Now distance travelled by particle in Total 10 *sec.*

$s_{10} = u \times 10 + \dfrac{1}{2}a(10)^2$

By substituting the value of *u* and *a* we will get $s_{10} = 28.3\ m$

so the distance in last 2 sec $= s_{10} - s_8$

$= 28.3 - 20 = 8.3m$

54. (a) $s \propto t^2$ (given) $\therefore\ s = Kt^2$

Acceleration $a = \dfrac{d^2s}{dt^2} = 2k$ (constant)

It means the particle travels with uniform acceleration.

55. (c) Because acceleration is a vector quantity

56. (d) $u = at,\ x = \int u\ dt = \int at\ dt = \dfrac{at^2}{2}$

For $t = 4$ sec, $x = 8a$

57. (d) $3t = \sqrt{3x} + 6 \Rightarrow 3x = (3t - 6)^2$

$\Rightarrow x = 3t^2 - 12t + 12$

$v = \frac{dx}{dt} = 6t - 12$, for $v = 0, t = 2\sec$

$x = 3(2)^2 - 12 \times 2 + 12 = 0$

58. (d) $u = 0, S = 250m, t = 10\sec$

$S = ut + \frac{1}{2}at^2 \Rightarrow 250 = \frac{1}{2}a[10]^2 \Rightarrow a = 5m/s^2$

So, $F = ma = 0.9 \times 5 = 4.5N$

59. (b) $\text{Time} = \frac{\text{Distance}}{\text{Average velocity}} = \frac{3.06}{0.34} = 9$ sec

$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time}} = \frac{0.18}{9} = 0.02\, m/s^2$

60. (d) $s = 3t^3 + 7t^2 + 14t + 8\ m$

$a = \frac{d^2s}{dt^2} = 18t + 14$ at $t = 1$ sec $\Rightarrow a = 32m/s^2$

61. (c) Instantaneous velocity $v = \frac{\Delta x}{\Delta t}$

By using the data from the table

$v_1 = \frac{0-(-2)}{1} = 2m/s, \quad v_2 = \frac{6-0}{1} = 6\ m/s$

$v_3 = \frac{16-6}{1} = 10\ m/s$

So, motion is non-uniform but accelerated.

62. (b) Only direction of displacement and velocity gets changed, acceleration is always directed vertically downward.

63. (b) $s = 2t^2 + 2t + 4, a = \frac{d^2s}{dt^2} = 4\,m/s^2$

64. (a) According to problem

Distance travelled by body A in 5^{th} *sec* and distance travelled by body B in 3^{rd} *sec.* of its motion are equal.

$0 + \frac{a_1}{2}(2 \times 5 - 1) = 0 + \frac{a_2}{2}[2 \times 3 - 1]$

$9a_1 = 5a_2 \Rightarrow \frac{a_1}{a_2} = \frac{5}{9}$

65. (d) $u = 200\ m/s, v = 100\ m/s, s = 0.1\ m$

$a = \frac{u^2 - v^2}{2s} = \frac{(200)^2 - (100)^2}{2 \times 0.1} = 15 \times 10^4\, m/s^2$

66. (b) $v = u + at = u + \left(\frac{F}{m}\right)t = 20 + \left(\frac{100}{5}\right) \times 10 = 220\ m/s$

67. (a) Velocity acquired by body in 10*sec*

$v = 0 + 2 \times 10 = 20m/s$

and distance travelled by it in 10 *sec*

$S_1 = \frac{1}{2} \times 2 \times (10)^2 = 100\ m$

then it moves with constant velocity (20 *m/s*) for 30 sec

$S_2 = 20 \times 30 = 600\ m$

After that due to retardation $(4m/s^2)$ it stops

$S_3 = \frac{v^2}{2a} = \frac{(20)^2}{2 \times 4} = 50m$

Total distance travelled $S_1 + S_2 + S_3 = 750m$

68. (a) If a body starts from rest with acceleration α and then retards with retardation β and comes to rest. The total time taken for this journey is t and distance covered is S

then $S = \frac{1}{2}\frac{\alpha\beta t^2}{(\alpha + \beta)} = \frac{1}{2}\frac{5 \times 10}{(5 + 10)} \times t^2$

$\Rightarrow \quad 1500 = \frac{1}{2}\frac{5 \times 10}{(5+10)} \times t^2 \quad \Rightarrow t = 30\sec$.

69. (a)

70. (d) $S \propto u^2$. Now speed is two times so distance will be four times $S = 4 \times 6 = 24m$

71. (c) Let student will catch the bus after t *sec.* So it will cover distance *ut.*

Similarly distance travelled by the bus will be $\frac{1}{2}at^2$ for the given condition

$ut = 50 + \frac{1}{2}at^2 = 50 + \frac{t^2}{2} \qquad [a = 1\,m/s^2]$

$\Rightarrow u = \frac{50}{t} + \frac{t}{2}$

To find the minimum value of u

$\frac{du}{dt} = 0$, so we get $t = 10\sec$, then $u = 10\ m/s$

72. (a) $\frac{1}{2}at^2 = vt \Rightarrow t = \frac{2v}{a}$

73. (a) The velocity of the particle is

$\frac{dx}{dt} = \frac{d}{dt}(2 - 5t + 6t^2) = (0 - 5 + 12t)$

For initial velocity $t = 0$, hence $v = -5\ m/s$.

74. (c) For First part,

$u = 0$, $t = T$ and acceleration $= a$

$\therefore v = 0 + aT = aT$ and $S_1 = 0 + \frac{1}{2}aT^2 = \frac{1}{2}aT^2$

For Second part,

$u = aT$, retardation$=a_1$, $v = 0$ and time taken $= T_1$ (let)

$\therefore\ 0 = u - a_1T_1 \Rightarrow aT = a_1T_1$

and from $v^2 = u^2 - 2aS_2 \ \Rightarrow S_2 = \frac{u^2}{2a_1} = \frac{1}{2}\frac{a^2T^2}{a_1}$

$S_2 = \frac{1}{2}aT \times T_1 \qquad \left(\text{As } a_1 = \frac{aT}{T_1}\right)$

$\therefore\ v_{av} = \frac{S_1 + S_2}{T + T_1} = \frac{\frac{1}{2}aT^2 + \frac{1}{2}aT \times T_1}{T + T_1}$

$= \frac{\frac{1}{2}aT\,(T + T_1)}{T + T_1} = \frac{1}{2}aT$

75. (c) $u = 0$, $v = 27.5\ m/s$ and $t = 10$ *sec*

$\therefore a = \frac{27.5 - 0}{10} = 2.75\ m/s^2$

Now, the distance traveled in next 10 *sec*,

$S = ut + \frac{1}{2}at^2 = 27.5 \times 10 + \frac{1}{2} \times 2.75 \times 100$

$= 275 + 137.5 = 412.5\ m$

76. (c) $v = (180 - 16x)^{1/2}$

As $a = \frac{dv}{dt} = \frac{dv}{dx}.\frac{dx}{dt}$

$\therefore a = \frac{1}{2}(180-16x)^{-1/2} \times (-16)\left(\frac{dx}{dt}\right)$

$= -8\,(180-16x)^{-1/2} \times v$

$= -8\,(180-16x)^{-1/2} \times (180-16x)^{1/2} = -8\ m/s^2$

77. (d) $x \propto t^3 \ \therefore\ x = Kt^3$

$\Rightarrow v = \frac{dx}{dt} = 3\ Kt^2$ and $a = \frac{dv}{dt} = 6\ Kt$

i.e. $a \propto t$

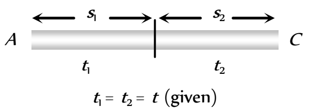
78. (a) $\because a = \frac{dv}{dt} = 2(t-1) \Rightarrow dv = 2(t-1)\,dt$

$\Rightarrow v = \int_0^5 2\,(t-1)dt = 2\left[\frac{t^2}{2} - t\right]_0^5 = 2\left[\frac{25}{2} - 5\right] = 15\ m/s$

79. (c) $\because S_1 = ut + \frac{1}{2}at^2$ .....(i)

and velocity after first t *sec*

$v = u + at$



Now, $S_2 = vt + \frac{1}{2}at^2$

$= (u+at)t + \frac{1}{2}at^2$ ..... (ii)

Equation (ii) – (i) $\Rightarrow S_2 - S_1 = at^2$

$\Rightarrow a = \frac{S_2 - S_1}{t^2} = \frac{65-40}{(5)^2} = 1\ m/s^2$

From equation (i), we get,

$S_1 = ut + \frac{1}{2}at^2 \Rightarrow 40 = 5u + \frac{1}{2} \times 1 \times 25$

$\Rightarrow 5u = 27.5 \ \therefore\ u = 5.5\ m/s$

80. (d) $S \propto u^2 \Rightarrow \frac{S_1}{S_2} = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

81. (d) $x = ae^{-\alpha t} + be^{\beta t}$

Velocity $v = \frac{dx}{dt} = \frac{d}{dt}(ae^{-\alpha t} + be^{\beta t})$

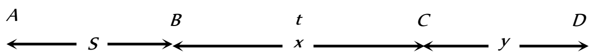
$= a.e^{-\alpha t}(-\alpha) + be^{\beta t}.\beta) = -a\alpha e^{-\alpha t} + b\beta e^{\beta t}$

Acceleration $= -a\alpha e^{-\alpha t}(-\alpha) + b\beta e^{bt}.\beta$

$= a\alpha^2 e^{-\alpha t} + b\beta^2 e^{\beta t}$

Acceleration is positive so velocity goes on increasing with time.

82. (c) Let car starts from point A from rest and moves up to point B with acceleration f



Velocity of car at point B, $v = \sqrt{2fS}$

[As $v^2 = u^2 + 2as$]

Car moves distance BC with this constant velocity in time t

$x = \sqrt{2fS}.t$ ......(i) [As $s = ut$]

So the velocity of car at point C also will be $\sqrt{2fs}$ and finally car stops after covering distance y.

Distance $CD \Rightarrow y = \frac{(\sqrt{2fS})^2}{2(f/2)} = \frac{2fS}{f} = 2S$ ....(ii)

[As $v^2 = u^2 - 2as \Rightarrow s = u^2/2a$]

So, the total distance $AD = AB + BC + CD = 15S$ (given)

$\Rightarrow \quad S + x + 2S = 15S \ \Rightarrow\ x = 12S$

Substituting the value of x in equation (i) we get

$x = \sqrt{2fS}.t \Rightarrow 12S = \sqrt{2fS}.t \ \Rightarrow\ 144S^2 = 2fS.t^2$

$\Rightarrow S = \frac{1}{72}ft^2$.

83. (c) Let man will catch the bus after 't' *sec* . So he will cover distance ut.

Similarly distance travelled by the bus will be $\frac{1}{2}at^2$. For the given condition

$u\,t = 45 + \frac{1}{2}a\,t^2 = 45 + 1.25\,t^2$ [As $a = 2.5m/s^2$]

$\Rightarrow u = \frac{45}{t} + 1.25\,t$

To find the minimum value of u

$\frac{du}{dt} = 0$ so we get $t = 6$ sec then,

$u = \frac{45}{6} + 1.25 \times 6 = 7.5 + 7.5 = 15m/s$

84. (b) $x = 4(t-2) + a(t-2)^2$

At $t = 0, x = -8 + 4a = 4a - 8$

$v = \frac{dx}{dt} = 4 + 2a(t-2)$

At $t = 0,\ v = 4 - 4a = 4(1-a)$

But acceleration, $a = \frac{d^2x}{dt^2} = 2a$

85. (a) Distance covered in 5th second,

$S_{5^{th}} = u + \frac{a}{2}(2n-1) = 0 + \frac{a}{2}(2 \times 5 - 1) = \frac{9a}{2}$

and distance covered in 5 second,

$S_5 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times a \times 25 = \frac{25a}{2}$

$\therefore \frac{S_{5^{th}}}{S_5} = \frac{9}{25}$

86. (d) The nature of the path is decided by the direction of velocity, and the direction of acceleration. The trajectory can be a straight line, circle or a parabola depending on these factors.

Relative Motion

1. (b) Time $= \dfrac{\text{Total length}}{\text{Relative velocity}} = \dfrac{50+50}{10+15} = \dfrac{100}{25} = 4\ sec$

2. (d) Total distance $= 130 + 120 = 250\ m$

Relative velocity $= 30 - (-20) = 50\ m/s$

Hence $t = 250/50 = 5s$

3. (b) Relative velocity of bird *w.r.t* train $= 25 + 5 = 30\ m/s$

time taken by the bird to cross the train $t = \dfrac{210}{30} = 7\ sec$

4. (a) Effective speed of the bullet

= speed of bullet + speed of police jeep

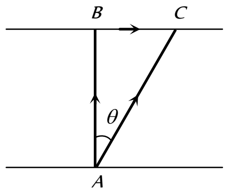
$= 180\ m/s + 45\ km/h = (180 + 12.5)\ m/s = 192.5\ m/s$

Speed of thief's jeep $= 153 km/h = 42.5 m/s$

Velocity of bullet *w.r.t* thief's car $= 192.5 - 42.5 = 150 m/s$

5. (c) Given $\overrightarrow{AB}$ = Velocity of boat = 8 *km/hr*

$\overrightarrow{AC}$ = Resultant velocity of boat = 10 *km/hr*



$\overrightarrow{BC}$ = Velocity of river $= \sqrt{AC^2 - AB^2}$

$= \sqrt{(10)^2 - (8)^2} = 6\ km/hr$

6. (d) Relative velocity

$= 10 + 5 = 15\ m/sec$

$\therefore\ t = \dfrac{150}{15} = 10\ sec$

7. (b) The relative velocity of boat *w.r.t.* water

$= v_{\text{boat}} - v_{\text{water}} = (3\hat{i} + 4\hat{j}) - (-3\hat{i} - 4\hat{j}) = 6\hat{i} + 8\hat{j}$

8. (a) When two particles moves towards each other then $v_1 + v_2 = 6$ ...(i)

When these particles moves in the same direction then $v_1 - v_2 = 4$ ...(ii)

By solving $v_1 = 5$ and $v_2 = 1\ m/s$

9. (d) For the round trip he should cross perpendicular to the river

$\therefore$ Time for trip to that side $= \dfrac{1 km}{4 km/hr} = 0.25 hr$

To come back, again he take 0.25 *hr* to cross the river.

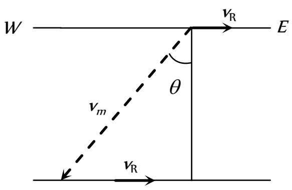
Total time is 30 min, he goes to the other bank and come back at the same point.

10. (c) Relativistic momentum $= \dfrac{m_0 v}{\sqrt{1 - v^2/c^2}}$

If velocity is doubled then the relativistic mass also increases. Thus value of linear momentum will be more than double.

11. (c) For shortest possible path man should swim with an angle $(90+\theta)$ with downstream.

From the fig,

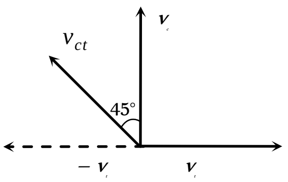


$\sin\theta = \dfrac{v_r}{v_m} = \dfrac{5}{10} = \dfrac{1}{2}$

$\Rightarrow\ \therefore\ \theta = 30°$

So angle with downstream $= 90° + 30° = 120°$

12. (b) $\overrightarrow{v_{ct}} = \overrightarrow{v_c} - \overrightarrow{v_t}$



$\overrightarrow{v_{ct}} = \overrightarrow{v_c} + (-\overrightarrow{v_t})$

Velocity of car *w.r.t.* train (v_{ct}) is towards West – North

13. (a) As the trains are moving in the same direction. So the initial relative speed $(v_1 - v_2)$ and by applying retardation final relative speed becomes zero.

From $v = u - at \Rightarrow 0 = (v_1 - v_2) - at \Rightarrow t = \dfrac{v_1 - v_2}{a}$

Motion Under Gravity

1. (c) $u = 12\ m/s,\ g = 9.8\ m/\sec^2,\ t = 10$ sec

Displacement $= ut + \frac{1}{2}gt^2$

$= 12 \times 10 + \frac{1}{2} \times 9.8 \times 100 = 610 m$

2. (b) Velocity at the time of striking the floor,

$u = \sqrt{2gh_1} = \sqrt{2 \times 9.8 \times 10} = 14 m/s$

Velocity with which it rebounds.

$v = \sqrt{2gh_2} = \sqrt{2 \times 9.8 \times 2.5} = 7\ m/s$

$\therefore$ Change in velocity $\Delta v = 7 - (-14) = 21 m/s$

$\therefore$ Acceleration $= \dfrac{\Delta v}{\Delta t} = \dfrac{21}{0.01} = 2100\ m/s^2$ (upwards)

3. (d) Let t be the time of flight of the first body after meeting, then $(t-4)$ *sec* will be the time of flight of the second body. Since $h_1 = h_2$

$\therefore\ 98t - \frac{1}{2}gt^2 = 98(t-4) - \frac{1}{2}g(t-4)^2$

On solving, we get $t = 12$ *seconds*

4. (c) $h = \frac{1}{2}gt^2 \Rightarrow t = \sqrt{2h/g}$

$t_a = \sqrt{\dfrac{2a}{g}}$ and $t_b = \sqrt{\dfrac{2b}{g}} \Rightarrow \dfrac{t_a}{t_b} = \sqrt{\dfrac{a}{b}}$

5. (b) $\frac{1}{2}g(3)^2 = \frac{g}{2}(2n-1) \Rightarrow n = 5\ s$

6. (a) Time taken by first stone to reach the water surface from the bridge be t, then

$h = ut + \frac{1}{2}gt^2 \Rightarrow 44.1 = 0 \times t + \frac{1}{2} \times 9.8 t^2$

$t = \sqrt{\dfrac{2 \times 44.1}{9.8}} = 3\ sec$

Second stone is thrown 1 *sec* later and both strikes simultaneously. This means that the time left for second stone $= 3 - 1 = 2\ sec$

Hence $44.1 = u \times 2 + \frac{1}{2}9.8(2)^2$

$\Rightarrow 44.1 - 19.6 = 2u \Rightarrow u = 12.25\ m/s$

7. (a)

8. (b) Let the initial velocity of ball be u

Time of rise $t_1 = \dfrac{u}{g+a}$ and height reached $= \dfrac{u^2}{2(g+a)}$

Time of fall t_2 is given by

$\frac{1}{2}(g-a)t_2^2 = \frac{u^2}{2(g+a)}$

$\Rightarrow t_2 = \frac{u}{\sqrt{(g+a)(g-a)}} = \frac{u}{(g+a)}\sqrt{\frac{g+a}{g-a}}$

$\therefore t_2 > t_1$ because $\frac{1}{g+a} < \frac{1}{g-a}$

9. (c) Vertical component of velocities of both the balls are same and equal to zero. So $t = \sqrt{\frac{2h}{g}}$

10. (d) The separation between the two bodies, two seconds after the release of second body

$= \frac{1}{2} \times 9.8[(3)^2 - (2)^2] = 24.5\ m$

11. (b) Time of flight $= \frac{2u}{g} = \frac{2 \times 100}{10} = 20\ sec$

12. (a) $h = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times (4)^2 = 80\ m$

13. (d) Let the body after time $t/2$ be at x from the top, then

$x = \frac{1}{2}g\frac{t^2}{4} = \frac{gt^2}{8}$ ...(i)

$h = \frac{1}{2}gt^2$ ...(ii)

Eliminate t from (i) and (ii), we get $x = \frac{h}{4}$

$\therefore$ Height of the body from the ground $= h - \frac{h}{4} = \frac{3h}{4}$

14. (b) By applying law of conservation of energy

$mgR = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2Rg}$

15. (c) Acceleration of body along AB is $g\cos\theta$

Distance travelled in time t sec $= AB = \frac{1}{2}(g\cos\theta)t^2$

From ΔABC, $AB = 2R\cos\theta$; $2R\cos\theta = \frac{1}{2}g\cos\theta t^2$

$\Rightarrow t^2 = \frac{4R}{g}$ or $t = 2\sqrt{\frac{R}{g}}$

16. (c) Force down the plane $= mg\sin\theta$

$\therefore$ Acceleration down the plane $= g\sin\theta$

Since $l = 0 + \frac{1}{2}g\sin\theta t^2$

$\therefore t^2 = \frac{2l}{g\sin\theta} = \frac{2h}{g\sin^2\theta} \Rightarrow t = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$

17. (a) $h = ut - \frac{1}{2}gt^2 \Rightarrow 96 = 80t - \frac{32}{2}t^2$

$\Rightarrow t^2 - 5t + 6 = 0 \Rightarrow t = 2$ sec or 3 sec

18. (b) $v = g \times t = 32 \times 1 = 32\ ft/\sec$

19. (b) $v^2 = u^2 + 2gh \Rightarrow (3u)^2 = (-u)^2 + 2gh \Rightarrow h = \frac{4u^2}{g}$

20. (c) $t = \sqrt{\frac{2h}{g}}$ and h and g are same.

21. (b) Time of flight $= \frac{2u}{g} = \frac{2 \times 96}{32} = 6\ sec$

22. (c) Total distance $= \frac{1}{2}gt^2 = \frac{25}{2}g$

Distance moved in 3 *sec* $= \frac{9}{2}g$

Remaining distance $= \frac{16}{2}g$

If t is the time taken by the stone to reach the ground for the remaining distance then

$\Rightarrow \frac{16}{2}g = \frac{1}{2}gt^2 \Rightarrow t = 4$ sec

23. (a) Height travelled by ball (with balloon) in 2 *sec*

$h_1 = \frac{1}{2}a\,t^2 = \frac{1}{2} \times 4.9 \times 2^2 = 9.8\ m$

Velocity of the balloon after 2 sec

$v = a\,t = 4.9 \times 2 = 9.8\ m/s$

Now if the ball is released from the balloon then it acquire same velocity in upward direction.

Let it move up to maximum height h_2

$v^2 = u^2 - 2gh_2 \Rightarrow 0 = (9.8)^2 - 2 \times (9.8) \times h_2 \therefore h_2 = 4.9m$

Greatest height above the ground reached by the ball $= h_1 + h_2 = 9.8 + 4.9 = 14.7\ m$

24. (b) Let h distance is covered in n *sec*

$\Rightarrow h = \frac{1}{2}gn^2$ ...(i)

Distance covered in n^{th} *sec* $= \frac{1}{2}g(2n-1)$

$\Rightarrow \frac{9h}{25} = \frac{g}{2}(2n-1)$ ...(ii)

From (i) and (ii), $h = 122.5\ m$

25. (c) $h = ut + \frac{1}{2}gt^2 \Rightarrow 81 = -12t + \frac{1}{2} \times 10 \times t^2 \Rightarrow t = 5.4\ sec$

26. (d) The initial velocity of aeroplane is horizontal, then the vertical component of velocity of packet will be zero.

So $t = \sqrt{\frac{2h}{g}}$

27. (b) Time taken by first drop to reach the ground $t = \sqrt{\frac{2h}{g}}$

$\Rightarrow t = \sqrt{\frac{2 \times 5}{10}} = 1$ sec

As the water drops fall at regular intervals from a tap therefore time difference between any two drops $= \frac{1}{2}$ sec

In this given time, distance of second drop from the tap $= \frac{1}{2}g\left(\frac{1}{2}\right)^2 = \frac{5}{5} = 1.25\,m$

Its distance from the ground $= 5 - 1.25 = 3.75\ m$

28. (c) $h = ut + \frac{1}{2}gt^2$, $t = 3$ sec, $u = -4.9\ m/s$

$\Rightarrow h = -4.9 \times 3 + 4.9 \times 9 = 29.4\ m$

29. (a) Horizontal velocity of dropped packet $= u$

Vertical velocity $= \sqrt{2gh}$

$\therefore$ Resultant velocity at earth $= \sqrt{u^2 + 2gh}$

30. (d) Given $a = 19.6\ m/s^2 = 2g$

Resultant velocity of the rocket after 5 *sec*

$v = 2g \times 5 = 10g\ m/s$

Height achieved after 5 *sec*, $h_1 = \frac{1}{2} \times 2g \times 25 = 245m$

On switching off the engine it goes up to height h_2 where its velocity becomes zero.

$0 = (10g)^2 - 2gh_2 \Rightarrow h_2 = 490m$

$\therefore$ Total height of rocket $= 245 + 490 = 735\ m$

31. (b) Bullet will take $\frac{100}{1000} = 0.1$ *sec* to reach target.

During this period vertical distance (downward) travelled by the bullet $= \frac{1}{2}gt^2$

$= \frac{1}{2} \times 10 \times (0.1)^2 m = 5\ cm$

So the gun should be aimed 5 *cm* above the target.

32. (a) $S_n = u + \frac{g}{2}(2n-1)$; when $u = 0$, $S_1 : S_2 : S_3 = 1 : 3 : 5$

33. (b) It has lesser initial upward velocity.

34. (b) At maximum height velocity $v = 0$

We know that $v = u + at$, hence

$0 = u - gT \Rightarrow u = gT$

When $v = \frac{u}{2}$, then

$\frac{u}{2} = u - gt \Rightarrow gt = \frac{u}{2} \Rightarrow gt = \frac{gT}{2} \Rightarrow t = \frac{T}{2}$

Hence at $t = \frac{T}{2}$, it acquires velocity $\frac{u}{2}$

35. (a) If u is the initial velocity then distance covered by it in 2 *sec*

$S = ut + \frac{1}{2}at^2 = u \times 2 + \frac{1}{2} \times 10 \times 4 = 2u + 20$ ...(i)

Now distance covered by it in 3 *sec*

$S_{3^{rd}} = u + \frac{g}{2}(2 \times 3 - 1)10 = u + 25$ ...(ii)

From(i) and (ii), $2u + 20 = u + 25 \Rightarrow u = 5$

$\therefore S = 2 \times 5 + 20 = 30\ m$

36. (c) For first case $v^2 - 0^2 = 2gh \Rightarrow (3)^2 = 2gh$

For second case $v^2 = (-u)^2 + 2gh = 4^2 + 3^2 \therefore v = 5$ *km/h*

37. (b) The time of fall is independent of the mass.

38. (c) $h_{n^{th}} = u - \frac{g}{2}(2n-1)$

$h_{5^{th}} = u - \frac{10}{2}(2 \times 5 - 1) = u - 45$

$h_{6^{th}} = u - \frac{10}{2}(2 \times 6 - 1) = u - 55$

Given $h_{5^{th}} = 2 \times h_{6^{th}}$. By solving we get $u = 65\ m/s$

39. (b) $S = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2$

Hence $t \propto \sqrt{S}$ *i.e.*, if S becomes one-fourth then t will become half *i.e.*, 2 *sec*

40. (a) Distance between the balls = Distance travelled by first ball in 3 seconds –Distance travelled by second ball in 2 seconds

$= \frac{1}{2}g\,(3)^2 - \frac{1}{2}g\,(2)^2 = 45 - 20 = 25\ m$

41. (b) Speed of stone in a vertically upward direction is 4.9 *m/s*. So for vertical downward motion we will consider $u = -4.9\ m/s$

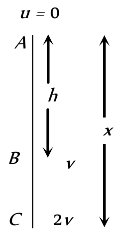
$h = ut + \frac{1}{2}gt^2 = -4.9 \times 2 + \frac{1}{2} \times 9.8 \times (2)^2 = 9.8\ m$

42. (b) Speed of stone in a vertically upward direction is 20 *m/s*. So for vertical downward motion we will consider $u = -20\ m/s$

$v^2 = u^2 + 2gh = (-20)^2 + 2 \times 9.8 \times 200 = 4320\ m/s$

$\therefore v \simeq 65\,m/s$.

43. (b) Let at point A initial velocity of body is equal to zero



for path AB: $v^2 = 0 + 2gh$ ...(i)

for path AC: $(2v)^2 = 0 + 2gx$

$4v^2 = 2gx$ ...(ii)

Solving (i) and (ii) $x = 4h$

44. (b) For one dimensional motion along a plane

$S = ut + \frac{1}{2}at^2 \Rightarrow 9.8 = 0 + \frac{1}{2}\ g \sin 30^o\, t^2 \Rightarrow t = 2\sec$

45. (d) Body reaches the point of projection with same velocity.

46. (d) Time of flight $T = \frac{2u}{g} = 4\ \sec \Rightarrow u = 20\ m/s$

47. (b) $t = \sqrt{\frac{2h}{g}} \Rightarrow \frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}}$

48. (b) Time of ascent = Time of descent = 5 *sec*

49. (b) Time of ascent $= \frac{u}{g} = 6\ \sec \Rightarrow u = 60\ m/s$

Distance in first second $h_{\text{first}} = 60 - \frac{g}{2}(2 \times 1 - 1) = 55\ m$

Distance in seventh second will be equal to the distance in first second of vertical downward motion

$h_{\text{seventh}} = \frac{g}{2}(2 \times 1 - 1) = 5\ m \Rightarrow h_{\text{first}} / h_{\text{seventh}} = 11 : 1$

50. (b) Let particle thrown with velocity u and its maximum height is H then $H = \frac{u^2}{2g}$

When particle is at a height $H/2$, then its speed is 10 *m/s*

From equation $v^2 = u^2 - 2gh$

$(10)^2 = u^2 - 2g\left(\frac{H}{2}\right) = u^2 - 2g\frac{u^2}{4g} \Rightarrow u^2 = 200$

Maximum height $\Rightarrow H = \frac{u^2}{2g} = \frac{200}{2 \times 10} = 10\ m$

51. (c) Mass does not affect on maximum height.

$H = \frac{u^2}{2g} \Rightarrow H \propto u^2$, So if velocity is doubled then height will become four times. *i.e.* $H = 20 \times 4 = 80m$

52. (a) When the stone is released from the balloon. Its height $h = \frac{1}{2}at^2 = \frac{1}{2} \times 1.25 \times (8)^2 = 40\ m$ and velocity

$v = at = 1.25 \times 8 = 10\ m/s$

Time taken by the stone to reach the ground

$$t = \frac{v}{g}\left[1 + \sqrt{1 + \frac{2gh}{v^2}}\right] = \frac{10}{10}\left[1 + \sqrt{1 + \frac{2 \times 10 \times 40}{(10)^2}}\right] = 4\ sec$$

53. (d) At highest point $v = 0$ and $H_{max} = \frac{u^2}{2g}$

54. (d) $u = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20\ m/s$

and $T = \frac{2u}{g} = \frac{2 \times 20}{10} = 4\ sec$

55. (d) If t_1 and t_2 are the time, when body is at the same height then, $h = \frac{1}{2}g\,t_1 t_2 = \frac{1}{2} \times g \times 2 \times 10 = 10\ g$

56. (c) Speed of the object at reaching the ground $v = \sqrt{2gh}$

If heights are equal then velocity will also be equal.

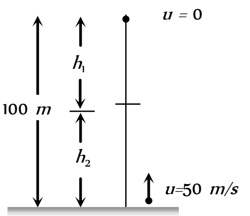
57. (b) $S_{3^{rd}} = 10 + \frac{10}{2}(2 \times 3 - 1) = 35\ m$

$S_{2^{nd}} = 10 + \frac{10}{2}(2 \times 2 - 1) = 25m \Rightarrow \frac{S_{3^{rd}}}{S_{2^{nd}}} = \frac{7}{5}$

58. (c) $v^2 = u^2 + 2gh \Rightarrow v = \sqrt{u^2 + 2gh}$

so for both the cases velocity will be equal.

59. (b) $h_1 = \frac{1}{2}gt^2$, $h_2 = 50t - \frac{1}{2}gt^2$



Given $h_1 + h_2 = 100m \Rightarrow 50t = 100 \Rightarrow t = 2$ sec

60. (b) $H_{max} = \frac{u^2}{2g} = \frac{19.6 \times 19.6}{2 \times 9.8} = 19.6\ m$

61. (c) Maximum height of ball = 5 *m*

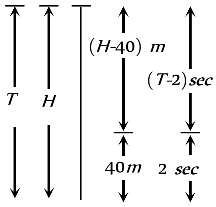
So velocity of projection $\Rightarrow u = \sqrt{2gh} = 10\ m/s$

Time interval between two balls (time of ascent)

$= \frac{u}{g} = 1\ sec = \frac{1}{60} min$.

So number of ball thrown per min. = 60

62. (b) Let height of minaret is *H* and body take time *T* to fall from top to bottom.



$H = \frac{1}{2}gT^2$ ...(i)

In last 2 *sec.* body travels distance of 40 *meter* so in $(T-2)$ *sec* distance travelled $= (H - 40)\ m$.

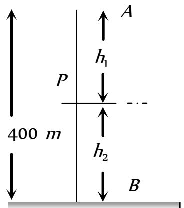
$(H - 40) = \frac{1}{2}g(T - 2)^2$ ...(ii)

By solving (i) and (ii) $T = 3$ *sec* and $H = 45\ m$.

63. (c) $S_n \propto (2n - 1)$. In equal time interval of 2 *seconds*

Ratio of distance $= 1 : 3 : 5$

64. (c) Let both balls meet at point *P* after time *t*.



The distance travelled by ball *A*, $h_1 = \frac{1}{2}gt^2$

The distance travelled by ball *B*, $h_2 = ut - \frac{1}{2}gt^2$

$h_1 + h_2 = 400\ m \Rightarrow ut = 400,\ t = 400/50 = 8\ sec$

$\therefore\ h_1 = 320\ m$ and $h_2 = 80\ m$

65. (a) $t = \sqrt{\frac{2h}{g}} \Rightarrow \frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}} = \sqrt{\frac{1}{2}} = \frac{1}{\sqrt{2}}$

66. (a) $H_{max} = \frac{u^2}{2g} \Rightarrow H_{max} \propto \frac{1}{g}$

On planet *B* value of *g* is $1/9$ times to that of *A*. So value of H_{max} will become 9 times *i.e.* $2 \times 9 = 18\ metre$

67. (b) $h_n = \frac{g}{2}(2n - 1) \Rightarrow h_{5^{th}} = \frac{10}{2}(2 \times 5 - 1) = 45\ m$.

68. (a) $h_{max} = \frac{u^2}{2g} = \frac{(15)^2}{2 \times 10} = 11.25\ m$.

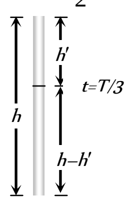
69. (b) For stone to be dropped from rising balloon of velocity 29 *m/s*.

$u = -29\ m/s$, $t = 10$ *sec.*

$\therefore h = -29 \times 10 + \frac{1}{2} \times 9.8 \times 100$

$= -290 + 490 = 200$ *m.*

70. (c) $\because\ h = ut + \frac{1}{2}gt^2 \Rightarrow h = \frac{1}{2}gT^2$



After $\frac{T}{3}$ seconds, the position of ball,

$$h' = 0 + \frac{1}{2}g\left(\frac{T}{3}\right)^2 = \frac{1}{2}\times\frac{g}{9}\times T^2$$

$$h' = \frac{1}{2}\times\frac{g}{9}\times T^2 = \frac{h}{9}m \text{ from top}$$

$\therefore$ Position of ball from ground $= h - \frac{h}{9} = \frac{8h}{9}m$.

71. (c) Since acceleration due to gravity is independent of mass, hence time is also independent of mass (or density) of object.

72. (c) When packet is released from the balloon, it acquires the velocity of balloon of value 12 *m/s*. Hence velocity of packet after 2 *sec*, will be

$v = u + gt = 12 - 9.8\times 2 = -7.6$ *m/s*.

73. (b) The distance traveled in last second.

$$S_{Last} = u + \frac{g}{2}(2t-1) = \frac{1}{2}\times 9.8(2t-1) = 4.9(2t-1)$$

and distance traveled in first three second,

$$S_{Three} = 0 + \frac{1}{2}\times 9.8\times 9 = 44.1\ m$$

According to problem $S_{Last} = S_{Three}$

$\Rightarrow 4.9(2t-1) = 44.1 \Rightarrow 2t - 1 = 9 \Rightarrow t = 5$ *sec*.

74. (c) Net acceleration of a body when thrown upward

= acceleration of body – acceleration due to gravity

$= a - g$

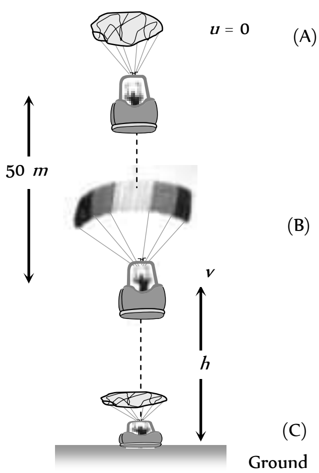
75. (b) The given condition is possible only when body is at its highest position after 5 seconds

It means time of ascent = 5 *sec*

and time of flight $T = \frac{2u}{g} = 10 \Rightarrow u = 50\ m/s$

76. (b) $H_{max} \propto u^2$, It body projected with double velocity then maximum height will become four times *i.e.* 200 *m*.

77. (a) After bailing out from point *A* parachutist falls freely under gravity. The velocity acquired by it will '*v*'



From $v^2 = u^2 + 2as = 0 + 2\times 9.8\times 50 = 980$

[As $u = 0$, $a = 9.8 m/s^2$, $s = 50\ m$]

At point *B*, parachute opens and it moves with retardation of $2\ m/s^2$ and reach at ground (Point *C*) with velocity of $3m/s$

For the part '*BC*' by applying the equation $v^2 = u^2 + 2as$

$v = 3m/s$, $u = \sqrt{980}\,m/s$, $a = -2m/s^2$, $s = h$

$\Rightarrow (3)^2 = (\sqrt{980})^2 + 2\times(-2)\times h \Rightarrow 9 = 980 - 4h$

$$\Rightarrow h = \frac{980 - 9}{4} = \frac{971}{4} = 242.7 \cong 243\ m.$$

So, the total height by which parachutist bail out $= 50 + 243 = 293\ m$.

78. (a)

79. (c)

80. (a) $H_{max} \propto u^2 \ \therefore u \propto \sqrt{H_{max}}$

i.e. to triple the maximum height, ball should be thrown with velocity $\sqrt{3}\,u$.

81. (a)

Critical Thinking Questions

1. (a) If t_1 and $2t_2$ are the time taken by particle to cover first and second half distance respectively.

$t_1 = \frac{x/2}{3} = \frac{x}{6}$ ...(i)

$x_1 = 4.5\ t_2$ and $x_2 = 7.5\ t_2$

So, $x_1 + x_2 = \frac{x}{2} \Rightarrow 4.5t_2 + 7.5t_2 = \frac{x}{2}$

$t_2 = \frac{x}{24}$ ...(ii)

Total time $t = t_1 + 2t_2 = \frac{x}{6} + \frac{x}{12} = \frac{x}{4}$

So, average speed $= 4\ m/sec$.

2. (c) $\frac{dv}{dt} = bt \Rightarrow dv = bt\,dt \Rightarrow v = \frac{bt^2}{2} + K_1$

At $t = 0, v = v_0 \Rightarrow K_1 = v_0$

We get $v = \frac{1}{2}bt^2 + v_0$

Again $\frac{dx}{dt} = \frac{1}{2}bt^2 + v_0 \Rightarrow x = \frac{1}{2}\frac{bt^2}{3} + v_0 t + K_2$

At $t = 0, x = 0 \Rightarrow K_2 = 0$

$\therefore x = \frac{1}{6}bt^3 + v_0 t$

3. (a,b,d) $\frac{dv}{dt} = 6 - 3v \Rightarrow \frac{dv}{6-3v} = dt$

Integrating both sides, $\int \frac{dv}{6-3v} = \int dt$

$\Rightarrow \frac{\log_e(6-3v)}{-3} = t + K_1$

$\Rightarrow \log_e(6-3v) = -3t + K_2$ ...(i)

At $t=0, v=0 \therefore \log_e 6 = K_2$

Substituting the value of K_2 in equation (i)

$\log_e(6-3v) = -3t + \log_e 6$

$\Rightarrow \log_e\left(\frac{6-3v}{6}\right) = -3t \Rightarrow e^{-3t} = \frac{6-3v}{6}$

$\Rightarrow 6-3v = 6e^{-3t} \Rightarrow 3v = 6(1-e^{-3t})$

$\Rightarrow v = 2(1-e^{-3t})$

$\therefore v_{\text{trminal}} = 2\ m/s$ (When $t=\infty$)

Acceleration $a = \frac{dv}{dt} = \frac{d}{dt}\left[2\left(1-e^{-3t}\right)\right] = 6e^{-3t}$

Initial acceleration = $6\ m/s^2$.

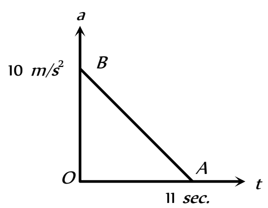
4. (a,d) The body starts from rest at $x=0$ and then again comes to rest at $x=1$. It means initially acceleration is positive and then negative.

So we can conclude that α can not remains positive for all t in the interval $0 \le t \le 1$ *i.e.* α must change sign during the motion.

5. (b) The area under acceleration time graph gives change in velocity. As acceleration is zero at the end of 11 *sec*

i.e. $v_{\max}$ = Area of ΔOAB

$= \frac{1}{2} \times 11 \times 10 = 55\ m/s$



6. (d) Let the car accelerate at rate α for time t_1 then maximum velocity attained, $v = 0 + \alpha t_1 = \alpha t_1$

Now, the car decelerates at a rate β for time $(t-t_1)$ and finally comes to rest. Then,

$0 = v - \beta(t-t_1) \Rightarrow 0 = \alpha t_1 - \beta t + \beta t_1$

$\Rightarrow t_1 = \frac{\beta}{\alpha+\beta} t$

$\therefore v = \frac{\alpha\beta}{\alpha+\beta} t$

7. (c) If a stone is dropped from height h

then $h = \frac{1}{2} g t^2$ ...(i)

If a stone is thrown upward with velocity u then

$h = -u\, t_1 + \frac{1}{2} g\, t_1^2$ ...(ii)

If a stone is thrown downward with velocity u then

$h = ut_2 + \frac{1}{2} g t_2^2$ ...(iii)

From (i) (ii) and (iii) we get

$-ut_1 + \frac{1}{2} g t_1^2 = \frac{1}{2} g t^2$ ...(iv)

$ut_2 + \frac{1}{2} g t_2^2 = \frac{1}{2} g t^2$ ...(v)

Dividing (iv) and (v) we get

$\therefore \frac{-ut_1}{ut_2} = \frac{\frac{1}{2} g(t^2 - t_1^2)}{\frac{1}{2} g(t^2 - t_2^2)}$

or $-\frac{t_1}{t_2} = \frac{t^2 - t_1^2}{t^2 - t_2^2}$

By solving $t = \sqrt{t_1 t_2}$

8. (c) Since direction of v is opposite to the direction of g and h so from equation of motion

$h = -vt + \frac{1}{2} g t^2$

$\Rightarrow gt^2 - 2vt - 2h = 0$

$\Rightarrow t = \frac{2v \pm \sqrt{4v^2 + 8gh}}{2g}$

$\Rightarrow t = \frac{v}{g}\left[1 + \sqrt{1 + \frac{2gh}{v^2}}\right]$

9. (c) $h = ut + \frac{1}{2} gt^2 \Rightarrow 1 = 0 \times t_1 + \frac{1}{2} g t_1^2 \Rightarrow t_1 = \sqrt{2/g}$

Velocity after travelling 1m distance

$v^2 = u^2 + 2gh \Rightarrow v^2 = (0)^2 + 2g \times 1 \Rightarrow v = \sqrt{2g}$

For second 1 meter distance

$1 = \sqrt{2g} \times t_2 + \frac{1}{2} g t_2^2 \Rightarrow g t_2^2 + 2\sqrt{2g}\, t_2 - 2 = 0$

$t_2 = \frac{-2\sqrt{2g} \pm \sqrt{8g + 8g}}{2g} = \frac{-\sqrt{2} \pm 2}{\sqrt{g}}$

Taking +ve sign $t_2 = (2 - \sqrt{2})/\sqrt{g}$

$\therefore \frac{t_1}{t_2} = \frac{\sqrt{2/g}}{(2-\sqrt{2})/\sqrt{g}} = \frac{1}{\sqrt{2}-1}$ and so on.

10. (d) Interval of ball throw = 2 *sec.*

If we want that minimum three (more than two) ball remain in air then time of flight of first ball must be greater than 4 *sec.*

$T > 4\ sec$

$\frac{2u}{g} > 4\ sec \Rightarrow u > 19.6\ m/s$

for u =19.6. First ball will just strike the ground(in sky)

Second ball will be at highest point (in sky)

Third ball will be at point of projection or at ground (not in sky)

11. (a) The distance covered by the ball during the last t seconds of its upward motion = Distance covered by it in first t seconds of its downward motion

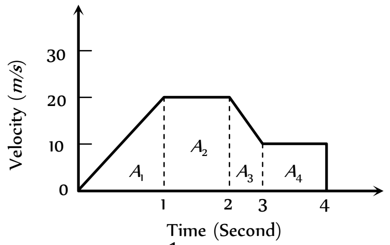
From $h = ut + \frac{1}{2} g t^2$

$h = \frac{1}{2} g t^2$ [As u = 0 for it downward motion]

12. (c)

Graphical Questions

1. (b) Distance = Area under $v - t$ graph $= A_1 + A_2 + A_3 + A_4$



$= \frac{1}{2} \times 1 \times 20 + (20 \times 1) + \frac{1}{2}(20 + 10) \times 1 + (10 \times 1)$

$= 10 + 20 + 15 + 10 = 55\ m$

2. (a) The slope of displacement-time graph goes on decreasing, it means the velocity is decreasing *i.e.* It's motion is retarded and finally slope becomes zero *i.e.* particle stops.

3. (d) In the positive region the velocity decreases linearly (during rise) and in the negative region velocity increases linearly (during fall) and the direction is opposite to each other during rise and fall, hence fall is shown in the negative region.

4. (b) Region *OA* shows that graph bending toward time axis *i.e.* acceleration is negative.

Region *AB* shows that graph is parallel to time axis *i.e.* velocity is zero. Hence acceleration is zero.

Region *BC* shows that graph is bending towards displacement axis *i.e.* acceleration is positive.

Region *CD* shows that graph having constant slope *i.e.* velocity is constant. Hence acceleration is zero.

5. (d) Maximum acceleration means maximum change in velocity in minimum time interval.

In time interval $t = 30$ to $t = 40$ sec

$a = \frac{\Delta v}{\Delta t} = \frac{80 - 20}{40 - 30} = \frac{60}{10} = 6\ cm/\sec^2$

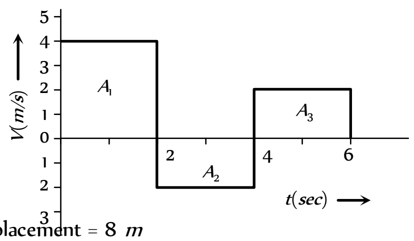
6. (c) In part *cd* displacement-time graph shows constant slope *i.e.* velocity is constant. It means no acceleration or no force is acting on the body.

7. (d) Up to time t_1 slope of the graph is constant and after t_1 slope is zero *i.e.* the body travel with constant speed up to time t_1 and then stops.

8. (c) Area of trapezium $= \frac{1}{2} \times 3.6 \times (12 + 8) = 36.0\ m$

9. (a) Displacement = Summation of all the area with sign

$= (A_1) + (-A_2) + (A_3) = (2 \times 4) + (-2 \times 2) + (2 \times 2)$



$\therefore$ Displacement = 8 *m*

Distance =Summation of all the areas without sign

$= |A_1| + |-A_2| + |A_3| = |8| + |-4| + |4| = 8 + 4 + 4$

$\therefore$ Distance = 16 *m*.

10. (b) Between time interval 20 *sec* to 40 *sec*, there is non-zero acceleration and retardation. Hence distance travelled during this interval

= Area between time interval 20 *sec* to 40 *sec*

$= \frac{1}{2} \times 20 \times 3 + 20 \times 1$ = 30 + 20 = 50 *m*.

11. (c)

12. (b) $\frac{(S)_{(last\ 2s)}}{(S)_{7s}} = \frac{\frac{1}{2} \times 2 \times 10}{\frac{1}{2} \times 2 \times 10 + 2 \times 10 + \frac{1}{2} \times 2 \times 10} = \frac{1}{4}$

13. (a) Distance = Area covered between graph and displacement axis $= \frac{1}{2}(30 + 10)10 = 200\ meter$.

14. (d) Because acceleration due to gravity is constant so the slope of line will be constant *i.e.* velocity time curve for a body projected vertically upwards is straight line.

15. (d) Slope of displacement time graph is negative only at point *E*.

16. (c) $v^2 = u^2 + 2aS$, If $u = 0$ then $v^2 \propto S$

i.e. graph should be parabola symmetric to displacement axis.

17. (a) This graph shows uniform motion because line having a constant slope.

18. (a) For the given condition initial height $h = d$ and velocity of the ball is zero. When the ball moves downward its velocity increases and it will be maximum when the ball hits the ground & just after the collision it becomes half and in opposite direction. As the ball moves upward its velocity again decreases and becomes zero at height $d/2$. This explanation match with graph (*A*).

19. (a) We know that the velocity of body is given by the slope of displacement – time graph. So it is clear that initially slope of the graph is positive and after some time it becomes zero (corresponding to the peak of graph) and then it will becomes negative.

20. (b) Maximum acceleration will be represented by *CD* part of the graph

Acceleration $= \frac{dv}{dt} = \frac{(60 - 20)}{0.25} = 160\ km/h^2$

21. (d)

22. (c) For upward motion

Effective acceleration $= -(g + a)$

and for downward motion

Effective acceleration $= (g - a)$

But both are constants. So the slope of speed-time graph will be constant.

23. (a) Since slope of graph remains constant for velocity-time graph.

24. (b) Other graph shows more than one velocity of the particle at single instant of time which is not practically possible.

25. (a) Slope of velocity-time graph measures acceleration. For graph (a) slope is zero. Hence $a = 0$ *i.e.* motion is uniform.

26. (c) From acceleration time graph, acceleration is constant for first part of motion so, for this part velocity of body increases uniformly with time and as $a = 0$ then the velocity becomes constant. Then again increased because of constant acceleration.

27. (a) Given line have positive intercept but negative slope. So its equation can be written as

$$v = -mx + v_0 \quad .....(i) \qquad [\text{where } m = \tan\theta = \frac{v_0}{x_0}]$$

By differentiating with respect to time we get

$$\frac{dv}{dt} = -m\frac{dx}{dt} = -mv$$

Now substituting the value of v from eq. (i) we get

$$\frac{dv}{dt} = -m[-mx + v_0] = m^2x - mv_0 \quad \therefore \quad a = m^2x - mv_0$$

i.e. the graph between a and x should have positive slope but negative intercept on a-axis. So graph (a) is correct.

28. (c) From given $a - t$ graph it is clear that acceleration is increasing at constant rate

$$\therefore \frac{da}{dt} = k \text{ (constant)} \Rightarrow a = kt \text{ (by integration)}$$

$$\Rightarrow \frac{dv}{dt} = kt \Rightarrow dv = ktdt$$

$$\Rightarrow \int dv = k\int tdt \Rightarrow v = \frac{kt^2}{2}$$

i.e. v is dependent on time parabolically and parabola is symmetric about v-axis.

and suddenly acceleration becomes zero. *i.e.* velocity becomes constant.

Hence (c) is most probable graph.

29. (c) In first instant you will apply $\upsilon = \tan\theta$ and say, $\upsilon = \tan 30^o = \frac{1}{\sqrt{3}}$ *m/s.*

But it is wrong because formula $\upsilon = \tan\theta$ is valid when angle is measured with time axis.

Here angle is taken from displacement axis. So angle from time axis $= 90^o - 30^o = 60^o$

Now $\upsilon = \tan 60^o = \sqrt{3}$

30. (a) Since total displacement is zero, hence average velocity is also zero.

Assertion and Reason

1. (a) When body going vertically upwards, reaches at the highest point, then it is momentarily at rest and it then reverses its direction. At the highest point of motion, its velocity is zero but its acceleration is equal to acceleration due to gravity.

2. (a) As motion is governed by force of gravity and acceleration due to gravity (g) is independent of mass of object.

3. (a) As distance being a scalar quantity is always positive but displacement being a vector may be positive, zero and negative depending on situation.

4. (a) As displacement is either smaller or equal to distance but never be greater than distance.

5. (a) Since velocity is a vector quantity, hence as its direction changes keeping magnitude constant, velocity is said to be changed. But for constant speed in equal time interval distance travelled should be equal.

6. (d) Speed can never be negative because it is a scalar quantity.

7. (c) Negative slope of position time graph represents that the body is moving towards the negative direction and if the slope of the graph decrease with time then it represents the decrease in speed *i.e.* retardation in motion.

8. (b) A body having positive acceleration can be associated with slowing down, as time rate of change of velocity decreases, but velocity increases with time, from graph it is clear that slope with time axis decreases, but velocity increases with time.

9. (b) A body having negative acceleration can be associated with a speeding up, if object moves along negative X-direction with increasing speed.

10. (e) It is not necessary that an object moving under uniform acceleration have straight path. *eg.* projectile motion.

11. (a) Motion of rocket is based on action reaction phenomena and is governed by rate of fuel burning causing the change in momentum of ejected gas.

12. (a) When a body moves on a straight path in one direction value of distance & displacement remains same so that average speed equals the average velocity for a given time interval.

13. (a) Position-time graph for a stationary object is a straight line parallel to time axis showing that no change in position with time.

14. (a) Since slope of displacement-time graph measures velocity of an object.

15. (e) For distance-time graph, a straight line inclined to time axis measures uniform speed for which acceleration is zero and for uniformly accelerated motion $S \propto t^2$.

16. (e) As per definition, acceleration is the rate of change of velocity, *i.e.* $\vec{a} = \frac{d\vec{v}}{dt}$.

If velocity is constant $d\vec{v}/dt = 0, \ \therefore \vec{a} = 0$.

Therefore, if a body has constant velocity it cannot have non zero acceleration.

17. (a) A body has no relative motion with respect to itself. Hence if a frame of reference of the body is fixed, then the body will be always at relative rest in this frame of reference.

18. (c) The displacement is the shortest distance between initial and final position. When final position of a body coincides with its initial position, displacement is zero, but the distance travelled is not zero.

19. (d) Equation of motion can be applied if the acceleration is in opposite direction to that of velocity and uniform motion mean the acceleration is zero.

20. (e) As velocity is a vector quantity, its value changes with change in direction. Therefore when a bus takes a turn from north to east its velocity will also change.

21. (b) When two bodies are moving in opposite direction, relative velocity between them is equal to sum of the velocity of bodies. But if the bodies are moving in same direction their relative velocity is equal to difference in velocity of the bodies.

22. (d) The displacement of a body moving in straight line is given by, $s = ut + \frac{1}{2}at^2$. This is a equation of a parabola, not straight line. Therefore the displacement-time graph is a parabola. The displacement time graph will be straight line, if acceleration of body is zero or body moving with uniform velocity.

23. (c) In uniform motion the object moves with uniform velocity, the magnitude of its velocity at different instant *i.e.* at $t = 0$, $t = 1 sec$, $t = 2 sec$,.... will always be constant. Thus velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to time axis.

24. (e) The uniform motion of a body means that the body is moving with constant velocity, but if the direction of motion is changing (such as in uniform circular motion), its velocity changes and thus acceleration is produced in uniform motion.

25. (e) When a body falling freely, only gravitational force acts on it in vertically downward direction. Due to this downward acceleration the velocity of a body increases and will be maximum when the body touches the ground.

26. (a) According to definition,displacement = velocity × time Since displacement is a vector quantity so its value is equal to the vector sum of the area under velocity-time graph.

27. (e) If the position-time graph of a body moving uniformly in a straight line parallel to position axis, it means that the position of body is changing at constant time. The statement is abrupt and shows that the velocity of body is infinite.

28. (b) Average speed = Total distance /Total time

Time average speed $= \dfrac{v_1 + v_2 + v_3 + ...}{n}$

29. (c) An object is said to be in uniform motion if it undergoes equal displacement in equal intervals of time.

$$\therefore v_{av} = \frac{s_1 + s_2 + s_3 + ...}{t_1 + t_2 + t_3 + ...} = \frac{s + s + s + ...}{t + t + t + ...} = \frac{ns}{nt} = \frac{s}{t}$$

and $v_{ins} = \dfrac{s}{t}$.

Thus, in uniform motion average and instantaneous velocities have same value and body moves with constant velocity.

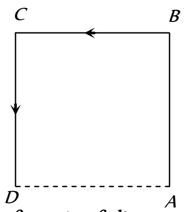
30. (e) Speedometer measures instantaneous speed of automobile.

Motion In One Dimension

SET Self Evaluation Test - 2

1. A car travels a distance S on a straight road in two hours and then returns to the starting point in the next three hours. Its average velocity is
   (a) $S/5$ (b) $2S/5$
   (c) $S/2+S/3$ (d) None of the above

2. A particle moves along the sides *AB, BC, CD* of a square of side 25 *m* with a velocity of 15 ms^{-1}. Its average velocity is



   (a) 15 ms^{-1}
   (b) 10 ms^{-1}
   (c) 7.5 ms^{-1}
   (d) 5 ms^{-1}

3. A body has speed *V*, 2*V* and 3*V* in first 1/3 of distance *S*, seconds 1/3 of *S* and third 1/3 of *S* respectively. Its average speed will be
   (a) V (b) $2V$
   (c) $\frac{18}{11}V$ (d) $\frac{11}{18}V$

4. If the body covers one-third distance at speed v, next one third at speed v and last one third at speed v, then average speed will be
   (a) $\frac{\upsilon_1\upsilon_2+\upsilon_2\upsilon_3+\upsilon_3\upsilon_1}{\upsilon_1+\upsilon_2+\upsilon_3}$ (b) $\frac{\upsilon_1+\upsilon_2+\upsilon_3}{3}$
   (c) $\frac{\upsilon_1\upsilon_2\upsilon_3}{\upsilon_1\upsilon_2+\upsilon_2\upsilon_3+\upsilon_3\upsilon_1}$ (d) $\frac{3\upsilon_1\upsilon_2\upsilon_3}{\upsilon_1\upsilon_2+\upsilon_2\upsilon_3+\upsilon_3\upsilon_1}$

5. The displacement of the particle varies with time according to the relation $x=\frac{k}{b}[1-e^{-bt}]$. Then the velocity of the particle is
   (a) $k(e^{-bt})$ (b) $\frac{k}{b^2e^{-bt}}$
   (c) $k\,b\,e^{-bt}$ (d) None of these

6. The acceleration of a particle starting from rest, varies with time according to the relation $A=-a\omega\sin\omega t$. The displacement of this particle at a time *t* will be
   (a) $-\frac{1}{2}(a\omega^2\sin\omega t)t^2$ (b) $a\omega\sin\omega t$
   (c) $a\omega\cos\omega t$ (d) $a\sin\omega t$

7. If the velocity of a particle is $(10+2t)$ *m/s*, then the average acceleration of the particle between $2s$ and $5s$ is
   (a) 2 m/s^2 (b) 4 m/s^2
   (c) 12 m/s^2 (d) 14 m/s^2

8. A bullet moving with a velocity of 200 *cm/s* penetrates a wooden block and comes to rest after traversing 4 *cm* inside it. What velocity is needed for travelling distance of 9 *cm* in same block
   (a) 100 *cm/s* (b) 136.2 cm/s
   (c) 300 cm/s (d) 250 *cm/s*

9. A thief is running away on a straight road in jeep moving with a speed of 9 ms^{-1}. A police man chases him on a motor cycle moving at a speed of 10 ms^{-1}. If the instantaneous separation of the jeep from the motorcycle is 100 *m*, how long will it take for the police to catch the thief
   (a) 1 *s* (b) 19 *s*
   (c) 90 *s* (d) 100 *s*

10. A car *A* is travelling on a straight level road with a uniform speed of 60 km/h. It is followed by another car *B* which is moving with a speed of 70 km/h. When the distance between them is 2.5 *km*, the car *B* is given a deceleration of 20 km/h^2. After how much time will *B* catch up with *A*
    (a) 1 *hr* (b) 1/2 *hr*
    (c) 1/4 *hr* (d) 1/8 *hr*

11. The speed of a body moving with uniform acceleration is *u*. This speed is doubled while covering a distance *S*. When it covers an additional distance *S*, its speed would become
    (a) $\sqrt{3}\,u$ (b) $\sqrt{5}\,u$
    (c) $\sqrt{11}\,u$ (d) $\sqrt{7}\,u$

12. Two trains one of length 100 *m* and another of length 125 *m*, are moving in mutually opposite directions along parallel lines, meet each other, each with speed 10 m/s. If their acceleration are 0.3 m/s^2 and 0.2 m/s^2 respectively, then the time they take to pass each other will be
    (a) 5 *s* (b) 10 *s*
    (c) 15 *s* (d) 20 *s*

13. A body starts from rest with uniform acceleration. If its velocity after *n* second is υ, then its displacement in the last two seconds is
    (a) $\frac{2\upsilon(n+1)}{n}$ (b) $\frac{\upsilon(n+1)}{n}$
    (c) $\frac{\upsilon(n-1)}{n}$ (d) $\frac{2\upsilon(n-1)}{n}$

14. A point starts moving in a straight line with a certain acceleration. At a time t after beginning of motion the acceleration suddenly becomes retardation of the same value. The time in which the point returns to the initial point is
    (a) $\sqrt{2t}$
    (b) $(2+\sqrt{2})\,t$
    (c) $\frac{t}{\sqrt{2}}$

(d) Cannot be predicted unless acceleration is given

15. A particle is moving in a straight line and passes through a point O with a velocity of $6\ ms^{-1}$. The particle moves with a constant retardation of $2\ ms^{-2}$ for 4 s and there after moves with constant velocity. How long after leaving O does the particle return to O

(a) $3s$ (b) $8s$

(c) Never (d) $4s$

16. A bird flies for 4 s with a velocity of $|t-2|\ m/s$ in a straight line, where t is time in seconds. It covers a distance of

(a) $2\ m$ (b) $4\ m$

(c) $6\ m$ (d) $8\ m$

17. A particle is projected with velocity υ_0 along $x-axis$. The deceleration on the particle is proportional to the square of the distance from the origin i.e., $a=\alpha x^2$. The distance at which the particle stops is

(a) $\sqrt{\frac{3\upsilon_0}{2\alpha}}$ (b) $\left(\frac{3v_o}{2\alpha}\right)^{\frac{1}{3}}$

(c) $\sqrt{\frac{3\upsilon_0^2}{2\alpha}}$ (d) $\left(\frac{3\upsilon_0^2}{2\alpha}\right)^{\frac{1}{3}}$

18. A body is projected vertically up with a velocity v and after some time it returns to the point from which it was projected. The average velocity and average speed of the body for the total time of flight are

(a) $\vec{v}/2$ and $v/2$ (b) 0 and $v/2$

(c) 0 and 0 (d) $\vec{v}/2$ and 0

19. A stone is dropped from a height h. Simultaneously, another stone is thrown up from the ground which reaches a height 4 h. The two stones cross each other after time

(a) $\sqrt{\frac{h}{8g}}$ (b) $\sqrt{8gh}$

(c) $\sqrt{2gh}$ (d) $\sqrt{\frac{h}{2g}}$

20. Four marbles are dropped from the top of a tower one after the other with an interval of one second. The first one reaches the ground after 4 *seconds*. When the first one reaches the ground the distances between the first and second, the second and third and the third and forth will be respectively

(a) 35, 25 and 15 m (b) 30, 20 and 10 m

(c) 20, 10 and 5 m (d) 40, 30 and 20 m

21. A balloon rises from rest with a constant acceleration $g/8$. A stone is released from it when it has risen to height h. The time taken by the stone to reach the ground is

(a) $4\sqrt{\frac{h}{g}}$ (b) $2\sqrt{\frac{h}{g}}$

(c) $\sqrt{\frac{2h}{g}}$ (d) $\sqrt{\frac{g}{h}}$

22. Two bodies are thrown simultaneously from a tower with same initial velocity v_0 : one vertically upwards, the other vertically downwards. The distance between the two bodies after time t is

(a) $2v_0t+\frac{1}{2}gt^2$ (b) $2v_0t$

(c) $v_0t+\frac{1}{2}gt^2$ (d) v_0t

23. A body falls freely from the top of a tower. It covers 36% of the total height in the last second before striking the ground level. The height of the tower is

(a) 50 m (b) 75 m

(c) 100 m (d) 125 m

24. A particle is projected upwards. The times corresponding to height h while ascending and while descending are t_1 and t_2 respectively. The velocity of projection will be

(a) gt_1 (b) gt_2

(c) $g(t_1+t_2)$ (d) $\frac{g(t_1+t_2)}{2}$

25. A projectile is fired vertically upwards with an initial velocity u. After an interval of T seconds a second projectile is fired vertically upwards, also with initial velocity u.

(a) They meet at time $t=\frac{u}{g}$ and at a height $\frac{u^2}{2g}+\frac{gT^2}{8}$

(b) They meet at time $t=\frac{u}{g}+\frac{T}{2}$ and at a height $\frac{u^2}{2g}+\frac{gT^2}{8}$

(c) They meet at time $t=\frac{u}{g}+\frac{T}{2}$ and at a height $\frac{u^2}{2g}-\frac{gT^2}{8}$

(d) They never meet

Answers and Solutions

(SET -2)

1. (d) Average velocity $=\frac{\text{Total displacement}}{\text{Time}}=\frac{0}{2+3}=0$

2. (d) Average velocity = $\frac{\text{Total displacement}}{\text{Time taken}}=\frac{25}{75/15}$ =5m/s

3. (c) $v_{av}=\frac{\text{Total distance}}{\text{Time taken}}=\frac{x}{\frac{x/3}{v}+\frac{x/3}{2v}+\frac{x/3}{3v}}=\frac{18}{11}v$

4. (d) $v_{av}=\frac{x}{\frac{x/3}{v_1}+\frac{x/3}{v_2}+\frac{x/3}{v_3}}=\frac{3v_1v_2v_3}{v_1v_2+v_2v_3+v_1v_3}$

5. (a) $v = \frac{dx}{dt} = \frac{d}{dt}\left[\frac{k}{b}\left(1 - e^{-bt}\right)\right] = \frac{k}{b}\left[0 - (-b)e^{-bt}\right] = ke^{-bt}$.

6. (d) Velocity $v = \int A\,dt = \int(-a\omega^2 \sin\omega t)\,dt = a\omega\cos\omega t$

Displacement $x = \int v\,dt = \int a\omega\cos\omega t\,dt = a\sin\omega t$

7. (d) Average acceleration $= \frac{\text{Change in velocity}}{\text{Time taken}} = \frac{v_2 - v_1}{t_2 - t_1}$

$= \frac{\left[10 + 2(5)^2\right] - \left[10 + 2(2)^2\right]}{3} = \frac{60 - 18}{3} = 14\ m/s^2$.

8. (c) As $v^2 = u^2 - 2as \Rightarrow u^2 = 2as \quad (\because v = 0)$

$\Rightarrow u^2 \propto s \;\Rightarrow \frac{u_2}{u_1} = \left(\frac{s_2}{s_1}\right)^{1/2}$

$\Rightarrow u_2 = \left(\frac{9}{4}\right)^{1/2} u_1 = \frac{3}{2}u_1 = 300 cm/s$.

9. (d) The relative velocity of policeman *w.r.t.* thief $= 10 - 9 = 1 m/s$.

$\therefore$ Time taken by police to catch the thief $= \frac{100}{1}$ =100 *sec*

10. (b) Let car *B* catches, car A after '*t*' sec, then

$60t + 2.5 = 70t - \frac{1}{2} \times 20 \times t^2$

$\Rightarrow 10t^2 - 10t + 2.5 = 0 \Rightarrow t^2 - t + 0.25 = 0$

$\therefore\; t = \frac{1 \pm \sqrt{1 - 4 \times (0.25)}}{2} = \frac{1}{2} hr$

11. (d) As $v^2 = u^2 + 2as \Rightarrow (2u)^2 = u^2 + 2as \Rightarrow 2as = 3u^2$

Now, after covering an additional distance *s*, if velocity becomes *v*, then,

$v^2 = u^2 + 2a(2s) = u^2 + 4as = u^2 + 6u^2 = 7u^2$

$\therefore\; v = \sqrt{7}u$.

12. (b) Relative velocity of one train *w.r.t.* other

=10+10=20 *m/s*.

Relative acceleration =0.3+0.2=0.5 *m/s*

If trains cross each other then from $s = ut + \frac{1}{2}at^2$

$As,\ s = s_1 + s_2 = 100 + 125 = 225$

$\Rightarrow 225 = 20t + \frac{1}{2} \times 0.5 \times t^2 \Rightarrow 0.5t^2 + 40t - 450 = 0$

$\Rightarrow t = -\frac{40 \pm \sqrt{1600 + 4.(005) \times 450}}{1} = -40 \pm 50$

$\therefore\; t = 10\,\text{sec}$ (Taking +ve value).

13. (d) $\because v = 0 + na \Rightarrow a = v/n$

Now, distance travelled in *n sec.* $\Rightarrow S_n = \frac{1}{2}an^2$ and distance travelled in $(n-2)\sec \Rightarrow S_{n-2} = \frac{1}{2}a(n-2)^2$

$\therefore$ Distance travelled in last two seconds,

$= S_n - S_{n-2} = \frac{1}{2}an^2 - \frac{1}{2}a(n-2)^2$

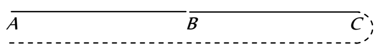
$= \frac{a}{2}\left[n^2 - (n-2)^2\right] = \frac{a}{2}[n + (n-2)][n - (n-2)]$

$= a(2n - 2) = \frac{v}{n}(2n - 2) = \frac{2v(n-1)}{n}$

14. (b) In this problem point starts moving with uniform acceleration *a* and after time *t* (Position *B*) the direction of acceleration get reversed *i.e.* the retardation of same value works on the point. Due to this velocity of points goes on decreasing and at position *C* its velocity becomes zero. Now the direction of motion of point reversed and it moves from *C* to *A* under the effect of acceleration *a*.

We have to calculate the total time in this motion. Starting velocity at position *A* is equal to zero.

Velocity at position $B \Rightarrow v = at$ [As $u = 0$]



Distance between *A* and *B*, $S_{AB} = \frac{1}{2}at^2$

As same amount of retardation works on a point and it comes to rest therefore $S_{BC} = S_{AB} = \frac{1}{2}a\,t^2$

$\therefore\; S_{AC} = S_{AB} + S_{BC} = a\,t^2$ and time required to cover this distance is also equal to *t*.

$\therefore$ Total time taken for motion between *A* and *C* = 2*t*

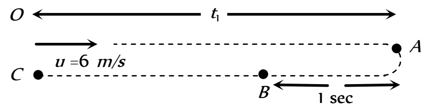
Now for the return journey from *C* to *A* $\left(S_{AC} = a\,t^2\right)$

$S_{AC} = u\,t + \frac{1}{2}at^2 \Rightarrow a\,t^2 = 0 + \frac{1}{2}a\,t_1^2 \Rightarrow t_1 = \sqrt{2}\,t$

Hence total time in which point returns to initial point

$T = 2t + \sqrt{2}\,t = (2 + \sqrt{2})t$

15. (b) Let the particle moves toward right with velocity 6 *m/s*. Due to retardation after time t_1 its velocity becomes zero.



From $v = u - a\,t \Rightarrow 0 = 6 - 2 \times t_1 \Rightarrow t_1 = 3\,\text{sec}$

But retardation works on it for 4 *sec*. It means after reaching point *A* direction of motion get reversed and acceleration works on the particle for next one second.

$$S_{OA} = u t_1 - \frac{1}{2} a t_1^2 = 6 \times 3 - \frac{1}{2}(2)(3)^2 = 18 - 9 = 9m$$

$$S_{AB} = \frac{1}{2} \times 2 \times (1)^2 = 1m$$

$$\therefore \; S_{BC} = S_{0A} - S_{AB} = 9 - 1 = 8m$$

Now velocity of the particle at point B in return journey

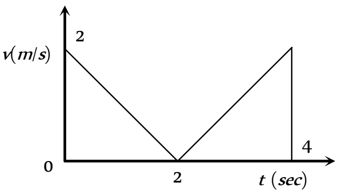
$$v = 0 + 2 \times 1 = 2m/s$$

In return journey from B to C, particle moves with constant velocity 2 *m/s* to cover the distance 8*m*.

Time taken $= \frac{\text{Distance}}{\text{Velocity}} = \frac{8}{2} = 4 \text{ sec}$

Total time taken by particle to return at point O is $\Rightarrow T = t_{0A} + t_{AB} + t_{BC} = 3 + 1 + 4 = 8 \text{ sec}$.

16. (b) The velocity time graph for given problem is shown in the figure.



Distance travelled S = Area under curve= 2+2=4*m*

17. (d) $a = \frac{dv}{dt} = \frac{dv}{dx}\frac{dx}{dt} = v\frac{dv}{dx} = -\alpha x^2$ (given)

$$\Rightarrow \int_{v_0}^{0} v dv = -\alpha \int_0^S x^2 dx \Rightarrow \left[\frac{v^2}{2}\right]_{v_0}^{0} = -\alpha \left[\frac{x^3}{3}\right]_0^S$$

$$\Rightarrow \frac{v_0^2}{2} = \frac{\alpha S^3}{3} \Rightarrow S = \left(\frac{3v_0^2}{2\alpha}\right)^{\frac{1}{3}}$$

18. (b) Average velocity =0 because net displacement of the body is zero.

Average speed $= \frac{\text{Total distance covered}}{\text{Time of flight}} = \frac{2H_{\max}}{2u/g}$

$$\Rightarrow v_{av} = \frac{2u^2/2g}{2u/g} \Rightarrow v_{av} = u/2$$

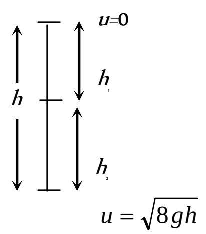
Velocity of projection = v (given)

$$\therefore \; v_{\text{av}} = v/2$$

19. (a) For first stone $u = 0$ and

For second stone $\frac{u^2}{2g} = 4h \Rightarrow u^2 = 8gh$

$$\therefore \; u = \sqrt{8gh}$$



Now, $h_1 = \frac{1}{2}gt^2$

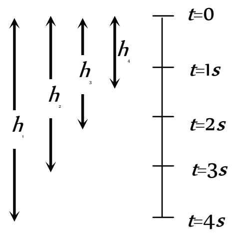
$$h_2 = \sqrt{8gh}t - \frac{1}{2}gt^2$$

where, t =time to cross each other.

$$\because h_1 + h_2 = h$$

$$\Rightarrow \frac{1}{2}gt^2 + \sqrt{8gh}t - \frac{1}{2}gt^2 = h \Rightarrow t = \frac{h}{\sqrt{8gh}} = \sqrt{\frac{h}{8g}}$$

20. (a) For first marble, $h_1 = \frac{1}{2}g \times 16 = 8g$



For Second marble, $h_2 = \frac{1}{2}g \times 9 = 4.5g$

For third marble, $h_3 = \frac{1}{2}g \times 4 = 2g$

For fourth marble, $h_4 = \frac{1}{2}g \times 1 = 0.5g$

$\therefore \; h_1 - h_2 = 8g - 4.5g = 3.5g$ = 35*m*.

$h_2 - h_3 = 4.5g - 2g = 2.5g = 25m$ and

$h_3 - h_4 = 2g - 0.5g = 1.5g = 15m$.

21. (b) The velocity of balloon at height h, $v = \sqrt{2\left(\frac{g}{8}\right)h}$

When the stone released from this balloon, it will go upward with velocity $v = \frac{\sqrt{gh}}{2}$ (Same as that of balloon). In this condition time taken by stone to reach the ground

$$t = \frac{v}{g}\left[1 + \sqrt{1 + \frac{2gh}{v^2}}\right] = \frac{\sqrt{gh}/2}{g}\left[1 + \sqrt{1 + \frac{2gh}{gh/4}}\right]$$

$$= \frac{2\sqrt{gh}}{g} = 2\sqrt{\frac{h}{g}}$$

22. (b) For vertically upward motion, $h_1 = v_0 t - \frac{1}{2}g t^2$ and for vertically down ward motion, $h_2 = v_0 t + \frac{1}{2}g t^2$

$\therefore$ Total distance covered in t sec $h = h_1 + h_2 = 2v_o t$.

23. (d) Let height of tower is h and body takes t time to reach to ground when it fall freely.

$$\therefore \; h = \frac{1}{2}g t^2 \quad \text{...(i)}$$

In last second *i.e.* t^{th} *sec* body travels = 0.36 h

It means in rest of the time *i.e.* in $(t-1)$ *sec* it travels

$$= h - 0.36\,h = 0.64\,h$$

Now applying equation of motion for $(t-1)$ *sec*

$$0.64\,h = \frac{1}{2}g(t-1)^2 \quad \text{...(ii)}$$

From (i) and (ii) we get, $t = 5\sec$ and $h = 125m$

***

24. (d) If t_1 and t_2 are time of ascent and descent respectively then

time of flight $T = t_1 + t_2 = \frac{2u}{g}$

$\Rightarrow u = \frac{g(t_1 + t_2)}{2}$

25. (c) For first projectile, $h_1 = ut - \frac{1}{2}gt^2$

For second projectile, $h_2 = u(t-T) - \frac{1}{2}g(t-T)^2$

When both meet *i.e.* $h_1 = h_2$

$ut - \frac{1}{2}gt^2 = u(t-T) - \frac{1}{2}g(t-T)^2$

$\Rightarrow uT + \frac{1}{2}gT^2 = gtT$

$\Rightarrow t = \frac{u}{g} + \frac{T}{2}$

and $h_1 = u\left(\frac{u}{g} + \frac{T}{2}\right) - \frac{1}{2}g\left(\frac{u}{2} + \frac{T}{2}\right)^2$

$= \frac{u^2}{2g} - \frac{gT^2}{8}.$

Chapter

3

Motion In Two Dimension

The motion of an object is called two dimensional, if two of the three co-ordinates required to specify the position of the object in space, change *w.r.t* time.

In such a motion, the object moves in a plane. For example, a billiard ball moving over the billiard table, an insect crawling over the floor of a room, earth revolving around the sun *etc*.

Two special cases of motion in two dimension are

1. Projectile motion 2. Circular motion

Introduction of Projectile Motion

A hunter aims his gun and fires a bullet directly towards a monkey sitting on a distant tree. If the monkey remains in his position, he will be safe but at the instant the bullet leaves the barrel of gun, if the monkey drops from the tree, the bullet will hit the monkey because the bullet will not follow the linear path.

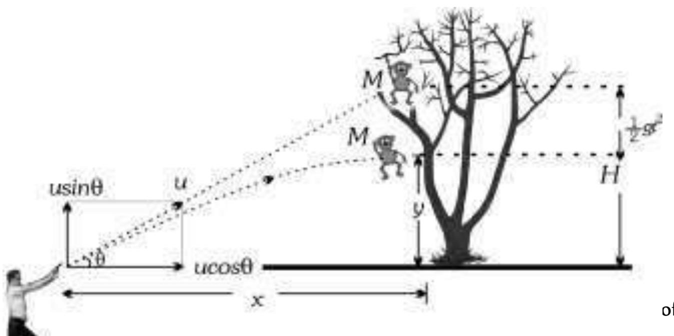


Fig : 3.1

If the force acting on a particle is oblique with initial velocity then the motion of particle is called projectile motion.

Projectile

A body which is in flight through the atmosphere under the effect of gravity alone and is not being propelled by any fuel is called projectile.

Example:

(i) A bomb released from an aeroplane in level flight

(ii) A bullet fired from a gun

(iii) An arrow released from bow

(iv) A Javelin thrown by an athlete

Assumptions of Projectile Motion

(1) There is no resistance due to air.

(2) The effect due to curvature of earth is negligible.

(3) The effect due to rotation of earth is negligible.

(4) For all points of the trajectory, the acceleration due to gravity 'g' is constant in magnitude and direction.

Principle of Physical Independence of Motions

(1) The motion of a projectile is a two-dimensional motion. So, it can be discussed in two parts. Horizontal motion and vertical motion. These two motions take place independent of each other. This is called the principle of physical independence of motions.

(2) The velocity of the particle can be resolved into two mutually perpendicular components. Horizontal component and vertical component.

(3) The horizontal component remains unchanged throughout the flight. The force of gravity continuously affects the vertical component.

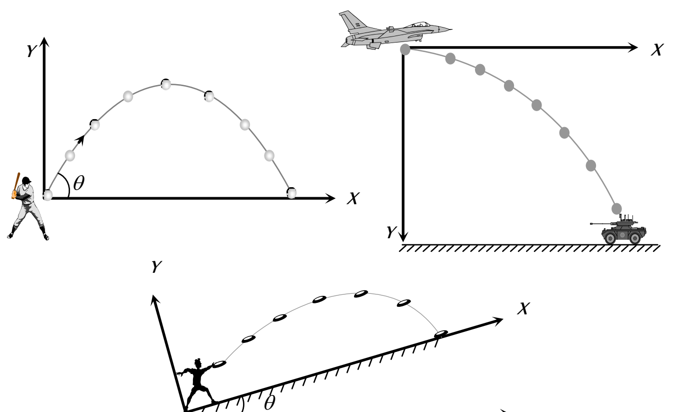
(4) The horizontal motion is a uniform motion and the vertical motion is a uniformly accelerated or retarded motion.

Types of Projectile Motion

(1) Oblique projectile motion

(2) Horizontal projectile motion

(3) Projectile motion on an inclined plane



Oblique Projectile

In projectile motion, horizontal component of velocity (u cosθ), acceleration (g) and mechanical energy remains constant while, speed, velocity, vertical component of velocity (u sin θ), momentum, kinetic energy and potential energy all changes. Velocity, and KE are maximum at the point of projection while minimum (but not zero) at highest point.

(1) **Equation of trajectory :** A projectile is thrown with velocity u at an angle θ with the horizontal. The velocity u can be resolved into two rectangular components.

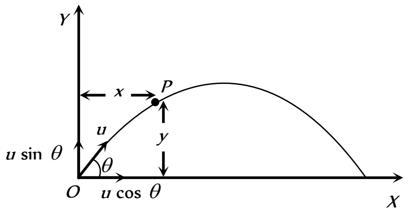


Fig : 3.3

v cos θ component along X–axis and u sin θ component along Y–axis.

For horizontal motion $x = u \cos\theta \times t \Rightarrow t = \dfrac{x}{u\cos\theta}$ ... (i)

For vertical motion $y = (u\sin\theta)t - \dfrac{1}{2}gt^2$ ...(ii)

From equation (i) and (ii)

$$y = u\sin\theta\left(\frac{x}{u\cos\theta}\right) - \frac{1}{2}g\left(\frac{x^2}{u^2\cos^2\theta}\right)$$

$$y = x\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$$

This equation shows that the trajectory of projectile is parabolic because it is similar to equation of parabola

$y = ax - bx$

Note : ❑ Equation of oblique projectile also can be written as

$$y = x\tan\theta\left[1 - \frac{x}{R}\right] \text{ (where } R = \text{horizontal range} = \frac{u^2\sin 2\theta}{g}\text{)}$$

(2) **Displacement of projectile ($\vec{r}$) :** Let the particle acquires a position P having the coordinates (x, y) just after time t from the instant of projection. The corresponding position vector of the particle at time t is $\vec{r}$ as shown in the figure.

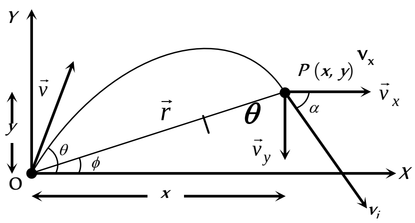


Fig : 3.4

$\vec{r} = x\hat{i} + y\hat{j}$ ...(i)

The horizontal distance covered during time t is given as

$x = v_x t \Rightarrow x = u\cos\theta\ t$ ...(ii)

The vertical velocity of the particle at time t is given as

$v_y = (v_0)_y - gt,$ ...(iii)

Now the vertical displacement y is given as

$y = u\sin\theta t - 1/2\, gt^2$ ...(iv)

Putting the values of x and y from equation (ii) and equation (iv) in equation (i) we obtain the position vector at any time t as

$$\vec{r} = (u\cos\theta)t\hat{i} + \left((u\sin\theta)t - \frac{1}{2}gt^2\right)\hat{j}$$

$$\Rightarrow r = \sqrt{(ut\cos\theta)^2 + \left((ut\sin\theta) - \frac{1}{2}gt^2\right)^2}$$

$$r = ut\sqrt{1 + \left(\frac{gt}{2u}\right)^2 - \frac{gt\sin\theta}{u}} \text{ and } \phi = \tan^{-1}(y/x)$$

$$= \tan^{-1}\left(\frac{ut\sin\theta - \frac{1}{2}gt^2}{(ut\cos\theta)}\right) \text{ or } \phi = \tan^{-1}\left(\frac{2u\sin\theta - gt}{2u\cos\theta}\right)$$

Note : ❑ The angle of elevation ϕ of the highest point of the projectile and the angle of projection θ are related to each other as

$$\tan\phi = \frac{1}{2}\tan\theta$$

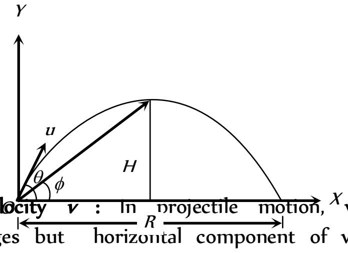


Fig : 3.5

(3) **Instantaneous velocity v :** In projectile motion, vertical component of velocity changes but horizontal component of velocity remains always constant.

Example : When a man jumps over the hurdle leaving behind its skateboard then vertical component of his velocity is changing, but not the horizontal component which matches with the skateboard velocity.

As a result, the skateboard stays underneath him, allowing him to land on it.

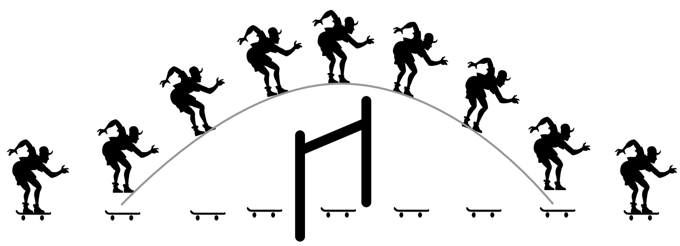


Fig : 3.6

Let v_i be the instantaneous velocity of projectile at time t, direction of this velocity is along the tangent to the trajectory at point P.

$$\vec{v}_i = v_x i + v_y\hat{j} \Rightarrow v_i = \sqrt{v_x^2 + v_y^2}$$

$= \sqrt{u^2 \cos^2 \theta + (u \sin\theta - gt)^2}$

$v_i = \sqrt{u^2 + g^2 t^2 - 2u\, gt \sin\theta}$

Direction of instantaneous velocity $\tan\alpha = \frac{v_y}{v_x} = \frac{u\sin\theta - gt}{u\cos\theta}$

or $\alpha = \tan^{-1}\left[\tan\theta - \frac{gt}{u}\sec\theta\right]$

(4) **Change in velocity :** Initial velocity (at projection point) $\vec{u}_i = u\cos\theta\,\hat{i} + u\sin\theta\,\hat{j}$

Final velocity (at highest point) $\vec{u}_f = u\cos\theta\,\hat{i} + 0\,\hat{j}$

(i) Change in velocity (Between projection point and highest point) $\Delta\vec{u} = \vec{u}_f - \vec{u}_i = -u\sin\theta\,\hat{j}$

When body reaches the ground after completing its motion then final velocity $\vec{u}_f = u\cos\theta\,\hat{i} - u\sin\theta\,\hat{j}$

(ii) Change in velocity (Between complete projectile motion) $\Delta\vec{u} = u_f - u_i = -2u\sin\theta\,\hat{i}$

(5) **Change in momentum :** Simply by the multiplication of mass in the above expression of velocity (Article-4).

(i) Change in momentum (Between projection point and highest point) $\Delta\vec{p} = \vec{p}_f - \vec{p}_i = -mu\sin\theta\,\hat{j}$

(ii) Change in momentum (For the complete projectile motion) $\Delta\vec{p} = \vec{p}_f - \vec{p}_i = -2mu\sin\theta\,\hat{j}$

(6) **Angular momentum :** Angular momentum of projectile at highest point of trajectory about the point of projection is given by

$L = mvr$ $\left[\text{Here } r = H = \frac{u^2\sin^2\theta}{2g}\right]$

$\therefore \quad L = m\,u\cos\theta \frac{u^2\sin^2\theta}{2g} = \frac{m\,u^3\cos\theta\sin^2\theta}{2g}$

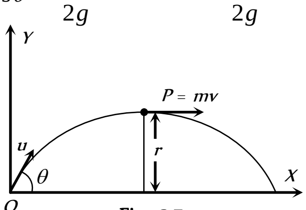


Fig : 3.7

(7) **Time of flight :** The total time taken by the projectile to go up and come down to the same level from which it was projected is called time of flight.

For vertical upward motion $0 = u\sin\theta - gt$

$\Rightarrow t = (u\sin\theta/g)$

Now as time taken to go up is equal to the time taken to come down so

Time of flight $T = 2t = \frac{2u\sin\theta}{g}$

(i) Time of flight can also be expressed as : $T = \frac{2.u_y}{g}$ (where u_y is the vertical component of initial velocity).

(ii) For complementary angles of projection θ and $90° - \theta$

(a) Ratio of time of flight $= \frac{T_1}{T_2} = \frac{2u\sin\theta/g}{2u\sin(90-\theta)/g}$

$= \tan\theta \Rightarrow \frac{T_1}{T_2} = \tan\theta$

(b) Multiplication of time of flight $= T_1 T_2 = \frac{2u\sin\theta}{g}\frac{2u\cos\theta}{g}$

$\Rightarrow T_1 T_2 = \frac{2R}{g}$

(iii) If t_1 is the time taken by projectile to rise upto point p and t_2 is the time taken in falling from point p to ground level then

$t_1 + t_2 = \frac{2u\sin\theta}{g}$ = time of flight or $u\sin\theta = \frac{g(t_1+t_2)}{2}$

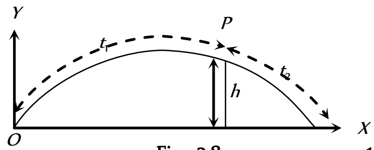


Fig : 3.8

and height of the point p is given by $h = u\sin\theta\, t_1 - \frac{1}{2}gt_1^2$

$h = g\frac{(t_1+t_2)}{2}t_1 - \frac{1}{2}gt_1^2$

by solving $h = \frac{g\,t_1 t_2}{2}$

(iv) If B and C are at the same level on trajectory and the time difference between these two points is t_1 similarly A and D are also at the same level and the time difference between these two positions is t_2 then

$t_2^2 - t_1^2 = \frac{8h}{g}$

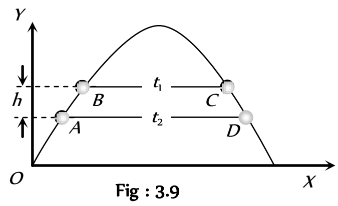


Fig : 3.9

(8) **Horizontal range :** It is the horizontal distance travelled by a body during the time of flight.

So by using second equation of motion in x-direction

$R = u\cos\theta \times T$

$= u\cos\theta \times (2u\sin\theta/g)$

$= \frac{u^2\sin 2\theta}{g}$

$R = \frac{u^2\sin 2\theta}{g}$

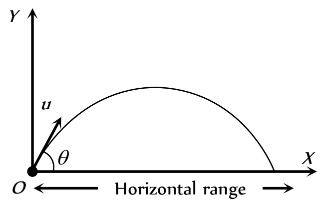


Fig : 3.10

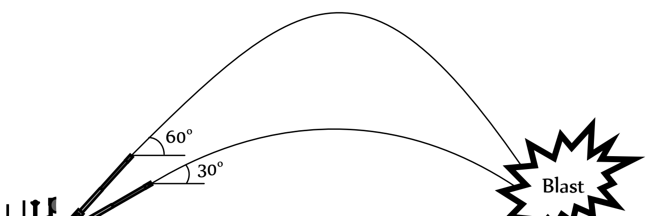
(i) Range of projectile can also be expressed as :

$R = u\cos\theta \times T = u\cos\theta\frac{2u\sin\theta}{g}$

$= \frac{2u\cos\theta\; u\sin\theta}{g} = \frac{2u_x u_y}{g}$

$\therefore R = \frac{2u_x u_y}{g}$ (where u_x and u_y are the horizontal and vertical component of initial velocity)

(ii) If angle of projection is changed from θ to $\theta' = (90 - \theta)$ then range remains unchanged.



$$R' = \frac{u^2 \sin 2\theta'}{g} = \frac{u^2 \sin[2(90^o - \theta)]}{g} = \frac{u^2 \sin 2\theta}{g} = R$$

So a projectile has same range at angles of projection θ and $(90 - \theta)$, though time of flight, maximum height and trajectories are different.

These angles θ and $90° - \theta$ are called complementary angles of projection and for complementary angles of projection, ratio of range

$$\frac{R_1}{R_2} = \frac{u^2 \sin 2\theta / g}{u^2 \sin[2(90^o - \theta)]/g} = 1 \Rightarrow \frac{R_1}{R_2} = 1$$

(iii) For angle of projection $\theta_1 = (45 - \alpha)$ and $\theta_2 = (45 + \alpha)$, range will be same and equal to $u^2 \cos 2\alpha/g$.

θ_1 and θ_2 are also the complementary angles.

(iv) Maximum range : For range to be maximum

$$\frac{dR}{d\theta} = 0 \Rightarrow \frac{d}{d\theta}\left[\frac{u^2 \sin 2\theta}{g}\right] = 0$$

$\Rightarrow$ $\cos 2\theta = 0$ *i.e.* $2\theta = 90° \Rightarrow \theta = 45°$

and $R_{max} = (u^2/g)$

i.e., a projectile will have maximum range when it is projected at an angle of $45°$ to the horizontal and the maximum range will be (u^2/g).

When the range is maximum, the height H reached by the projectile

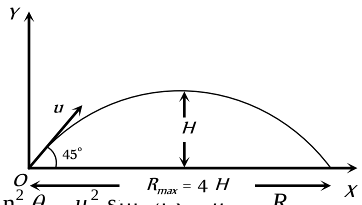


Fig : 3.12

$$H = \frac{u^2 \sin^2 \theta}{2g} = \frac{u^2 \sin^2 45}{2g} = \frac{u^2}{4g} = \frac{R_{max}}{4}$$

i.e., if a person can throw a projectile to a maximum distance R_{max}, The maximum height during the flight to which it will rise is $\left(\frac{R_{max}}{4}\right)$.

(v) Relation between horizontal range and maximum height : $R = \frac{u^2 \sin 2\theta}{g}$ and $H = \frac{u^2 \sin^2 \theta}{2g}$

$$\therefore \frac{R}{H} = \frac{u^2 \sin 2\theta / g}{u^2 \sin^2 \theta / 2g} = 4 \cot\theta \Rightarrow R = 4H \cot\theta$$

(vi) If in case of projectile motion range R is n times the maximum height H

i.e. $R = nH \Rightarrow \frac{u^2 \sin 2\theta}{g} = n \frac{u^2 \sin^2 \theta}{2g}$

$\Rightarrow \tan\theta = [4/n]$ or $\theta = \tan^{-1}[4/n]$

The angle of projection is given by $\theta = \tan^{-1}[4/n]$

Note : ❑ If $R = H$ then $\theta = \tan^{-1}(4)$ or $\theta = 76^o$.

If $R = 4H$ then $\theta = \tan^{-1}(1)$ or $\theta = 45^o$.

(9) **Maximum height :** It is the maximum height from the point of projection, a projectile can reach.

So, by using $v^2 = u^2 + 2as$

$$0 = (u \sin\theta)^2 - 2gH$$

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

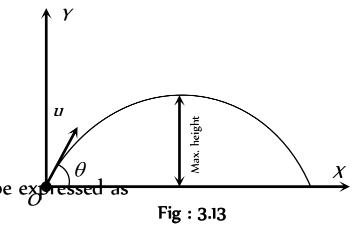


Fig : 3.13

(i) Maximum height can also be expressed as

$H = \frac{u_y^2}{2g}$ (where u_y is the vertical component of initial velocity).

(ii) $H_{max} = \frac{u^2}{2g}$ (when $\sin\theta = \max = 1$ *i.e.,* $\theta = 90°$)

i.e., for maximum height body should be projected vertically upward. So it falls back to the point of projection after reaching the maximum height.

(iii) For complementary angles of projection θ and $90° - \theta$

Ratio of maximum height

$$= \frac{H_1}{H_2} = \frac{u^2 \sin^2 \theta / 2g}{u^2 \sin^2 (90^o - \theta)/2g} = \frac{\sin^2 \theta}{\cos^2 \theta} = \tan^2 \theta$$

$$\therefore \frac{H_1}{H_2} = \tan^2 \theta$$

(10) **Projectile passing through two different points on same height at time t_1 and t_2 :** If the particle passes two points situated at equal height y at $t = t_1$ and $t = t_2$, then

(i) **Height (y):** $y = (u \sin\theta) t_1 - \frac{1}{2} g t_1^2$ ...(i)

and $y = (u \sin\theta) t_2 - \frac{1}{2} g t_2^2$ ...(ii)

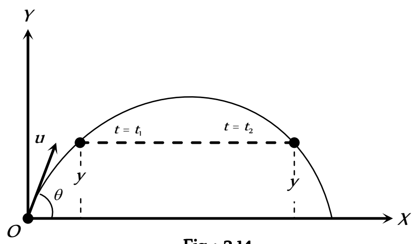


Fig : 3.14

Comparing equation (i) with equation (ii)

$$u \sin\theta = \frac{g(t_1 + t_2)}{2}$$

Substituting this value in equation (i)

$$y = g\left(\frac{t_1 + t_2}{2}\right) t_1 - \frac{1}{2} g t_1^2 \Rightarrow y = \frac{g t_1 t_2}{2}$$

(ii) **Time (t_1 and t_2):** $y = u \sin\theta\, t - \frac{1}{2} g t^2$

$$t^2 - \frac{2u\sin\theta}{g}t + \frac{2y}{g} = 0 \Rightarrow \quad t = \frac{u\sin\theta}{g}\left[1 \pm \sqrt{1 - \left(\frac{\sqrt{2gy}}{u\sin\theta}\right)^2}\right]$$

$$t_1 = \frac{u\sin\theta}{g}\left[1 + \sqrt{1 - \left(\frac{\sqrt{2gy}}{u\sin\theta}\right)^2}\right]$$

and $t_2 = \dfrac{u\sin\theta}{g}\left[1 - \sqrt{1 - \left(\dfrac{\sqrt{2gy}}{u\sin\theta}\right)^2}\right]$

(11) **Motion of a projectile as observed from another projectile :** Suppose two balls A and B are projected simultaneously from the origin, with initial velocities u_1 and u_2 at angle θ_1 and θ_2, respectively with the horizontal.

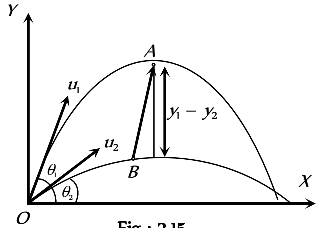


Fig : 3.15

The instantaneous positions of the two balls are given by

Ball A : $x_1 = (u_1 \cos\theta_1)t$, $y_1 = (u_1 \sin\theta_1)t - \frac{1}{2}gt^2$

Ball B : $x_2 = (u_2 \cos\theta_2)t$, $y_2 = (u_2 \sin\theta_2)t - \frac{1}{2}gt^2$

The position of the ball A with respect to ball B is given by

$$x = x_1 - x_2 = (u_1\cos\theta_1 - u_2\cos\theta_2)t$$

$$y = y_1 - y_2 = (u_1\sin\theta_1 - u_2\sin\theta_2)t$$

Now $\dfrac{y}{x} = \left(\dfrac{u_1\sin\theta_1 - u_2\sin\theta_2}{u_1\cos\theta_1 - u_2\cos\theta_2}\right) =$ constant

Thus motion of a projectile relative to another projectile is a straight line.

(12) **Energy of projectile :** When a projectile moves upward its kinetic energy decreases, potential energy increases but the total energy always remain constant.

If a body is projected with initial kinetic energy $K(=1/2\ mu^2)$, with angle of projection θ with the horizontal then at the highest point of trajectory

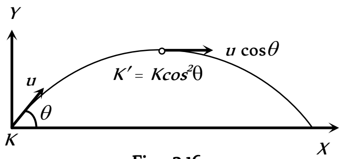


Fig : 3.16

(i) **Kinetic energy**

$$= \frac{1}{2}m(u\cos\theta)^2 = \frac{1}{2}mu^2\cos^2\theta$$

$$\therefore \quad K' = K\cos^2\theta$$

(ii) **Potential energy** $= mgH \quad = \quad mg\dfrac{u^2\sin^2\theta}{2g}$

$= \dfrac{1}{2}mu^2\sin^2\theta \qquad \left(\text{As } H = \dfrac{u^2\sin^2\theta}{2g}\right)$

$= K\sin^2\theta$

(iii) **Total energy** = Kinetic energy + Potential energy

$$= \frac{1}{2}mu^2\cos^2\theta + \frac{1}{2}mu^2\sin^2\theta$$

$= \dfrac{1}{2}mu^2$ = Energy at the point of projection.

This is in accordance with the law of conservation of energy.

Horizontal Projectile

When a body is projected horizontally from a certain height 'y' vertically above the ground with initial velocity u. If friction is considered to be absent, then there is no other horizontal force which can affect the horizontal motion. The horizontal velocity therefore remains constant and so the object covers equal distance in horizontal direction in equal intervals of time.

The horizontal velocity therefore remains constant and so the object covers equal distance in horizontal direction in equal intervals of time.

(1) **Trajectory of horizontal projectile :** The horizontal displacement x is governed by the equation

$x = ut \Rightarrow t = \dfrac{x}{u}$ .... (i)

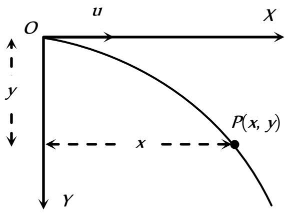


Fig : 3.17

The vertical displacement y is governed by

$y = \dfrac{1}{2}gt^2$ .... (ii)

(since initial vertical velocity is zero)

By substituting the value of t in equation (ii) $y = \dfrac{1}{2}\dfrac{gx^2}{u^2}$

(2) **Displacement of Projectile** $(\vec{r})$: After time t, horizontal displacement $x = ut$ and vertical displacement $y = \frac{1}{2}gt^2$.

So, the position vector $\vec{r} = ut\,\hat{i} + \frac{1}{2}gt^2\,\hat{j}$

Therefore $\quad r = ut\sqrt{1 + \left(\dfrac{gt}{2u}\right)^2} \qquad$ and $\quad \alpha = \tan^{-1}\left(\dfrac{gt}{2u}\right)$

$$\alpha = \tan^{-1}\left(\sqrt{\frac{gy}{2}}\Big/u\right) \qquad \left(\text{as } t = \sqrt{\frac{2y}{g}}\right)$$

(3) **Instantaneous velocity :** Throughout the motion, the horizontal component of the velocity is $v_x = u$.

The vertical component of velocity increases with time and is given by

$v_y = 0 + g\,t = g\,t \qquad$ (From $v = u + g\,t$)

So, $\vec{v} = v_x\hat{i} + v_y\hat{j} \;=\; u\,\hat{i} + g\,t\,\hat{j}$

i.e. $v = \sqrt{u^2 + (gt)^2} \quad = u\sqrt{1 + \left(\frac{gt}{u}\right)^2}$

Again $\vec{v} = u\hat{i} + \sqrt{2gy}\,\hat{j}$

i.e. $v = \sqrt{u^2 + 2gy}$

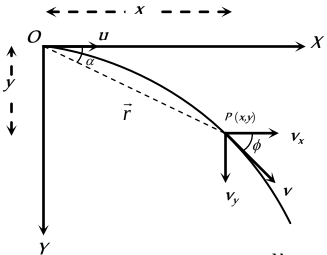


Fig : 3.18

Direction of instantaneous velocity : $\tan\phi = \frac{v_y}{v_x}$

$\Rightarrow \quad \phi = \tan^{-1}\left(\frac{v_y}{v_x}\right) \quad = \tan^{-1}\left(\frac{\sqrt{2gy}}{u}\right)$ or $\phi = \tan^{-1}\left(\frac{gt}{u}\right)$

Where ϕ is the angle of instantaneous velocity from the horizontal.

(4) **Time of flight :** If a body is projected horizontally from a height h with velocity u and time taken by the body to reach the ground is T, then

$h = 0 + \frac{1}{2}gT^2$ (for vertical motion)

$T = \sqrt{\frac{2h}{g}}$

(5) **Horizontal range :** Let R is the horizontal distance travelled by the body

$R = uT + \frac{1}{2}\,0\,T^2$ (for horizontal motion)

$R = u\sqrt{\frac{2h}{g}}$

(6) If projectiles A and B are projected horizontally with different initial velocity from same height and third particle C is dropped from same point then

(i) All three particles will take equal time to reach the ground.

(ii) Their net velocity would be different but all three particle possess same vertical component of velocity.

(iii) The trajectory of projectiles A and B will be straight line *w.r.t.* particle C.

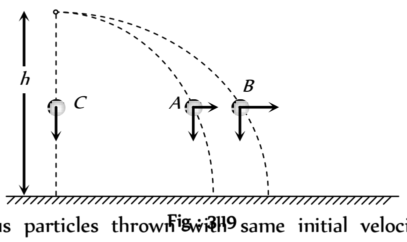


Fig : 3.19

(7) If various particles thrown with same initial velocity but in different direction then

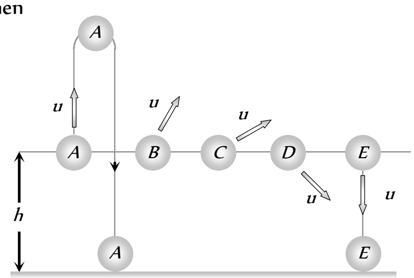


Fig : 3.20

(i) They strike the ground with same speed at different times irrespective of their initial direction of velocities.

(ii) Time would be least for particle E which was thrown vertically downward.

(iii) Time would be maximum for particle A which was thrown vertically upward.

Projectile Motion on An Inclined Plane

Let a particle be projected up with a speed u from an inclined plane which makes an angle α with the horizontal and velocity of projection makes an angle θ with the inclined plane.

We have taken reference *x*-axis in the direction of plane.

Hence the component of initial velocity parallel and perpendicular to the plane are equal to $u\cos\theta$ and $u\sin\theta$ respectively *i.e.* $u_{\parallel} = u\cos\theta$ and $u_{\perp} = u\sin\theta$.

The component of g along the plane is $g\sin\alpha$ and perpendicular to the plane is $g\cos\alpha$ as shown in the figure *i.e.* $a_{\parallel} = -g\sin\alpha$ and $a_{\perp} = g\cos\alpha$.

Therefore the particle decelerates at a rate of $g\sin\alpha$ as it moves from O to P.

(1) **Time of flight :** We know for oblique projectile motion $T = \frac{2u\sin\theta}{g}$ or we can say $T = \frac{2u_{\perp}}{a_{\perp}}$

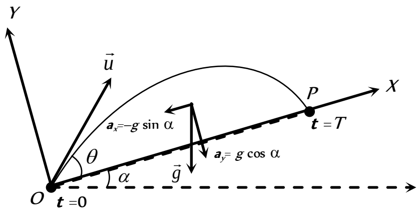


Fig : 3.21

$\therefore$ Time of flight on an inclined plane $T = \frac{2u\sin\theta}{g\cos\alpha}$

(2) **Maximum height :** We know for oblique projectile motion $H = \frac{u^2\sin^2\theta}{2g}$ or we can say $H = \frac{u_{\perp}^2}{2a_{\perp}}$

$\therefore$ Maximum height on an inclined plane $H = \frac{u^2\sin^2\theta}{2g\cos\alpha}$

(3) **Horizontal range :** For one dimensional motion $s = ut + \frac{1}{2}at^2$

Horizontal range on an inclined plane $R = u_{\parallel}\,T + \frac{1}{2}a_{\parallel}\,T^2$

$$R = u\cos\theta\,T - \frac{1}{2}g\sin\alpha\,T^2$$

$$R = u\cos\theta\left(\frac{2u\sin\theta}{g\cos\alpha}\right) - \frac{1}{2}g\sin\alpha\left(\frac{2u\sin\theta}{g\cos\alpha}\right)^2$$

By solving $\quad R = \frac{2u^2}{g}\,\frac{\sin\theta\cos(\theta+\alpha)}{\cos^2\alpha}$

(i) Maximum range occurs when $\theta = \frac{\pi}{4} - \frac{\alpha}{2}$

(ii) The maximum range along the inclined plane when the projectile is thrown upwards is given by

$$R_{\max} = \frac{u^2}{g(1+\sin\alpha)}$$

(iii) The maximum range along the inclined plane when the projectile is thrown downwards is given by

$$R_{\max} = \frac{u^2}{g(1-\sin\alpha)}$$

Circular Motion

Circular motion is another example of motion in two dimensions. To create circular motion in a body it must be given some initial velocity and a force must then act on the body which is always directed at right angles to instantaneous velocity.

Since this force is always at right angles to the displacement therefore no work is done by the force on the particle. Hence, its kinetic energy and thus speed is unaffected. But due to simultaneous action of the force and the velocity the particle follows resultant path, which in this case is a circle. Circular motion can be classified into two types – Uniform circular motion and non-uniform circular motion.

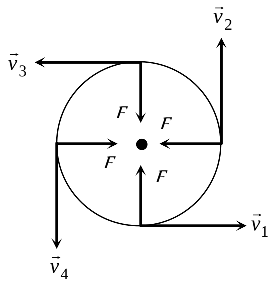


Fig : 3.22

Variables of Circular Motion

(1) **Displacement and distance :** When particle moves in a circular path describing an angle θ during time t (as shown in the figure) from the position A to the position B, we see that the magnitude of the position vector $\vec{r}$ (that is equal to the radius of the circle) remains constant. *i.e.,* $|\vec{r}_1| = |\vec{r}_2| = r$ and the direction of the position vector changes from time to time.

(i) Displacement : The change of position vector or the displacement $\Delta\vec{r}$ of the particle from position A to the position B is given by referring the figure.

$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1 \Rightarrow \Delta r = |\Delta\vec{r}| = |\vec{r}_2 - \vec{r}_1|$$

$$\Delta r = \sqrt{r_1^2 + r_2^2 - 2r_1r_2\cos\theta}$$

Putting $r_1 = r_2 = r$ we obtain

$$\Delta r = \sqrt{r^2 + r^2 - 2r.r\cos\theta}$$

$$\Rightarrow \Delta r = \sqrt{2r^2(1-\cos\theta)}$$

$$= \sqrt{2r^2\left(2\sin^2\frac{\theta}{2}\right)}$$

$$\Delta r = 2r\sin\frac{\theta}{2}$$

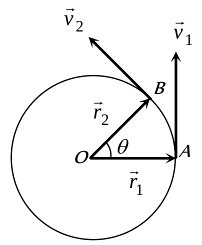


Fig : 3.23

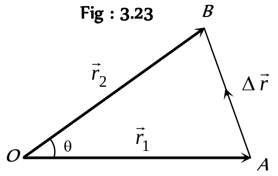


Fig : 3.24

(ii) Distance : The distanced covered by the particle during the time t is given as

d = length of the arc AB = $r\,\theta$

(iii) Ratio of distance and displacement : $\frac{d}{\Delta r} = \frac{r\theta}{2r\sin\theta/2}$

$$= \frac{\theta}{2}\,\text{cosec}(\theta/2)$$

(2) **Angular displacement (θ) :** The angle turned by a body moving in a circle from some reference line is called angular displacement.

(i) Dimension = $[M^0L^0T^0]$ (as θ = arc/radius).

(ii) Units = Radian or Degree. It is some time also specified in terms of fraction or multiple of revolution.

(iii) $2\pi\,\text{rad} = 360^o = 1\,\text{Revolution}$

(iv) Angular displacement is a axial vector quantity.

Its direction depends upon the sense of rotation of the object and can be given by Right Hand Rule; which states that if the curvature of the fingers of right hand represents the sense of rotation of the object, then the thumb, held perpendicular to the curvature of the fingers, represents the direction of angular displacement vector.

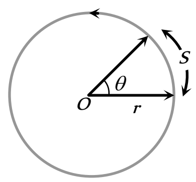


Fig : 3.25

(v) Relation between linear displacement and angular displacement $\vec{s} = \vec{\theta} \times \vec{r}$

or $s = r\theta$

(3) **Angular velocity (ω) :** Angular velocity of an object in circular motion is defined as the time rate of change of its angular displacement.

(i) Angular velocity $\omega = \frac{\text{angle traced}}{\text{time taken}} = \underset{\Delta t \to 0}{Lt}\frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$

$$\therefore\ \omega = \frac{d\theta}{dt}$$

(ii) Dimension : $[M^0L^0T^{-1}]$

(iii) Units : Radians per second ($rad.s^{-1}$) or Degree per second.

(iv) Angular velocity is an axial vector.

Its direction is the same as that of $\Delta\theta$. For anticlockwise rotation of the point object on the circular path, the direction of ω, according to Right hand rule is along the axis of circular path directed upwards. For clockwise rotation of the point object on the circular path, the direction of ω is along the axis of circular path directed downwards.

(v) Relation between angular velocity and linear velocity $\vec{v} = \vec{\omega} \times \vec{r}$

(vi) For uniform circular motion ω remains constant where as for non-uniform motion ω varies with respect to time.

Note : It is important to note that nothing actually moves in the direction of the angular velocity vector $\vec{\omega}$. The direction of $\vec{\omega}$ simply represents that the circular motion is taking place in a plane perpendicular to it.

(4) **Change in velocity :** We want to know the magnitude and direction of the change in velocity of the particle which is performing uniform circular motion as it moves from A to B during time t as shown in figure. The change in velocity vector is given as

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$

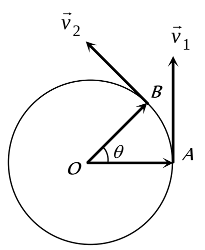


Fig : 3.26

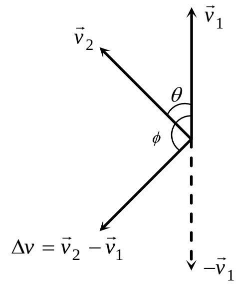


Fig : 3.27

or $|\Delta\vec{v}| = |\vec{v}_2 - \vec{v}_1| \Rightarrow \Delta v = \sqrt{v_1^2 + v_2^2 - 2v_1v_2\cos\theta}$

For uniform circular motion $v_1 = v_2 = v$

So $\Delta v = \sqrt{2v^2(1-\cos\theta)} = 2v\sin\dfrac{\theta}{2}$

The direction of $\Delta\vec{v}$ is shown in figure that can be given as

$$\phi = \frac{180^o - \theta}{2} = (90^o - \theta/2)$$

(5) **Time period (T) :** In circular motion, the time period is defined as the time taken by the object to complete one revolution on its circular path.

(i) Units : second.

(ii) Dimension : $[M^0L^0T]$

(iii) Time period of second's hand of watch = 60 *second.*

(iv) Time period of minute's hand of watch = 60 *minute*

(v) Time period of hour's hand of watch = 12 *hour*

(6) **Frequency (n) :** In circular motion, the frequency is defined as the number of revolutions completed by the object on its circular path in a unit time.

(i) Units : s^{-1} or hertz (Hz).

(ii) Dimension : $[M^0L^0T^{-1}]$

Note : ❑ Relation between time period and frequency : If n is the frequency of revolution of an object in circular motion, then the object completes n revolutions in 1 second. Therefore, the object will complete one revolution in $1/n$ second.

$\therefore T = 1/n$

❑ Relation between angular velocity, frequency and time period : Consider a point object describing a uniform circular motion with frequency n and time period T. When the object completes one revolution, the angle traced at its axis of circular motion is 2π radians. It means, when time $t = T$, $\theta = 2\pi$ radians. Hence, angular velocity $\omega = \dfrac{\theta}{t} = \dfrac{2\pi}{T} = 2\pi n$ $(\because T = 1/n)$

$$\omega = \frac{2\pi}{T} = 2\pi n$$

❑ If two particles are moving on same circle or different coplanar concentric circles in same direction with different uniform angular speeds ω_A and ω_B respectively, the angular velocity of B relative to A will be

$$\omega_{\text{rel}} = \omega_B - \omega_A$$

So the time taken by one to complete one revolution around O with respect to the other (i.e., time in which B complete one revolution around O with respect to the other (*i.e.*, time in which B completes one more or less revolution around O than A)

$$T = \frac{2\pi}{\omega_{\text{rel}}} = \frac{2\pi}{\omega_2 - \omega_1} = \frac{T_1T_2}{T_1 - T_2} \qquad \left[\text{as } T = \frac{2\pi}{\omega}\right]$$

Special case : If $\omega_B = \omega_A, \omega_{\text{rel}} = 0$ and so $T = \infty$., particles will maintain their position relative to each other. This is what actually happens in case of geostationary satellite $(\omega_1 = \omega_2 = \text{constant})$

(7) **Angular acceleration (α) :** Angular acceleration of an object in circular motion is defined as the time rate of change of its angular velocity.

(i) If $\Delta\omega$ be the change in angular velocity of the object in time interval Δt, while moving on a circular path, then angular acceleration of the object will be

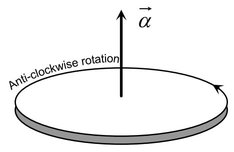


Fig : 3.28

$$\alpha = \underset{\Delta t \to 0}{Lt} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

(ii) Units : *rad.* s^{-2}

(iii) Dimension : $[M^0L^0T^{-2}]$

(iv) Relation between linear acceleration and angular acceleration $\vec{a} = \vec{\alpha} \times \vec{r}$

(v) For uniform circular motion since ω is constant so $\alpha = \dfrac{d\omega}{dt} = 0$

(vi) For non-uniform circular motion $\alpha \neq 0$

Centripetal Acceleration

(1) Acceleration acting on the object undergoing uniform circular motion is called centripetal acceleration.

(2) It always acts on the object along the radius towards the centre of the circular path.

(3) Magnitude of centripetal acceleration,

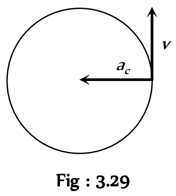


Fig : 3.29

$$a = \frac{v^2}{r} = \omega^2 r = 4\pi^2 n^2 r = \frac{4\pi^2}{T^2} r$$

(4) Direction of centripetal acceleration : It is always the same as that of $\Delta\vec{\upsilon}$. When Δt decreases, $\Delta\theta$ also decreases. Due to which $\Delta\vec{\upsilon}$ becomes more and more perpendicular to $\vec{\upsilon}$. When $\Delta t \to 0$, $\Delta\vec{\upsilon}$ becomes perpendicular to the velocity vector. As the velocity vector of the particle at an instant acts along the tangent to the circular path, therefore $\Delta\vec{\upsilon}$ and hence the centripetal acceleration vector acts along the radius of the circular path at that point and is directed towards the centre of the circular path.

Centripetal force

According to Newton's first law of motion, whenever a body moves in a straight line with uniform velocity, no force is required to maintain this velocity. But when a body moves along a circular path with uniform speed, its direction changes continuously *i.e.* velocity keeps on changing on account of a change in direction. According to Newton's second law of motion, a change in the direction of motion of the body can take place only if some external force acts on the body.

Due to inertia, at every point of the circular path; the body tends to move along the tangent to the circular path at that point (in figure). Since every body has directional inertia, a velocity cannot change by itself and as such we have to apply a force. But this force should be such that it changes the direction of velocity and not its magnitude. This is possible only if the force acts perpendicular to the direction of velocity. Because the velocity is along the tangent, this force must be along the radius (because the radius of a circle at any point is perpendicular to the tangent at that point). Further, as this force is to move the body in a circular path, it must acts towards the centre. This centre-seeking force is called the centripetal force.

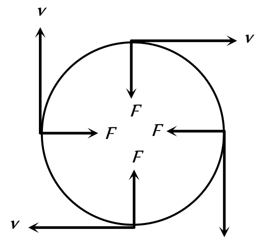


Fig : 3.30

Hence, centripetal force is that force which is required to move a body in a circular path with uniform speed. The force acts on the body along the radius and towards centre.

Formulae for centripetal force :

$$F = \frac{mv^2}{r} = m\omega^2 r = m\,4\pi^2 n^2 r = \frac{m4\pi^2 r}{T^2}$$

Table 3.1 : Centripetal force in different situation

Situation	Centripetal Force
A particle tied to a string and whirled in a horizontal circle	Tension in the string
Vehicle taking a turn on a level road	Frictional force exerted by the road on the tyres
A vehicle on a speed breaker	Weight of the body or a component of weight
Revolution of earth around the sun	Gravitational force exerted by the sun
Electron revolving around the nucleus in an atom	Coulomb attraction exerted by the protons in the nucleus
A charged particle describing a circular path in a magnetic field	Magnetic force exerted by the agent that sets up the magnetic field

Centrifugal Force

It is an imaginary force due to incorporated effects of inertia. When a body is rotating in a circular path and the centripetal force vanishes, the body would leave the circular path. To an observer *A* who is not sharing the motion along the circular path, the body appears to fly off tangentially at the point of release. To another observer *B*, who is sharing the motion along the circular path (*i.e.*, the observer *B* is also rotating with the body with the same velocity), the body appears to be stationary before it is released. When the body is released, it appears to *B*, as if it has been thrown off along the radius away from the centre by some force. In reality no force is actually seen to act on the body. In absence of any real force the body tends to continue its motion in a straight line due to its inertia. The observer *A* easily relates this events to be due to inertia but since the inertia of both the observer *B* and the body is same, the observer *B* can not relate the above happening to inertia. When the centripetal force ceases to act on the body, the body leaves its circular path and continues to move in its straight-line motion but to observer *B* it appears that a real force has actually acted on the body and is responsible for throwing the body radially out-wards. This imaginary force is given a name to explain the effects of inertia to the observer who is sharing the circular motion of the body. This inertial force is called centrifugal force. Thus centrifugal force is a fictitious force which has significance only in a rotating frame of reference.

Work Done by Centripetal Force

The work done by centripetal force is always zero as it is perpendicular to velocity and hence instantaneous displacement.

Work done = Increment in kinetic energy of revolving body

Work done = 0

Also $W = \vec{F}.\vec{S} = F \cdot S\cos\theta = FS\cos 90^\circ = 0$

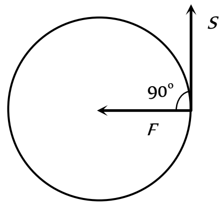


Fig : 3.31

Example : (i) When an electron revolves around the nucleus in hydrogen atom in a particular orbit, it neither absorb nor emit any energy means its energy remains constant.

(ii) When a satellite established once in a orbit around the earth and it starts revolving with particular speed, then no fuel is required for its circular motion.

Skidding of Vehicle on A Level Road

When a vehicle takes a turn on a circular path it requires centripetal force.

If friction provides this centripetal force then vehicle can move in circular path safely if

Friction force ≥ Required centripetal force

$$\mu mg \geq \frac{mv^2}{r}$$

$$\therefore\ v_{safe} \leq \sqrt{\mu rg}$$

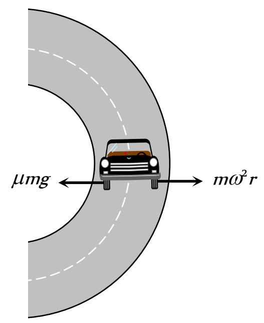


Fig : 3.32

This is the maximum speed by which vehicle can take a turn on a circular path of radius *r*, where coefficient of friction between the road and tyre is μ.

Skidding of Object on A Rotating Platform

On a rotating platform, to avoid the skidding of an object (mass *m*) placed at a distance *r* from axis of rotation, the centripetal force should be provided by force of friction.

Centripetal force ≤ Force of friction

$m\omega r \leq \mu mg$

$$\therefore\ \omega_{\max} = \sqrt{(\mu g / r)},$$

Hence maximum angular velocity of rotation of the platform is $\sqrt{(\mu g / r)}$, so that object will not skid on it.

Bending of A Cyclist

A cyclist provides himself the necessary centripetal force by leaning inward on a horizontal track, while going round a curve. Consider a cyclist of weight mg taking a turn of radius r with velocity v. In order to provide the necessary centripetal force, the cyclist leans through angle θ inwards as shown in figure.

The cyclist is under the action of the following forces :

The weight mg acting vertically downward at the centre of gravity of cycle and the cyclist.

The reaction R of the ground on cyclist. It will act along a line-making angle θ with the vertical.

The vertical component $R\cos\theta$ of the normal reaction R will balance the weight of the cyclist, while the horizontal component $R\sin\theta$ will provide the necessary centripetal force to the cyclist.

$$R\sin\theta = \frac{mv^2}{r} \quad \text{...(i)}$$

and $R\cos\theta = mg$ ...(ii)

Dividing equation (i) by (ii), we have

$$\frac{R\sin\theta}{R\cos\theta} = \frac{mv^2/r}{mg}$$

or $$\tan\theta = \frac{v^2}{rg} \quad \text{...(iii)}$$

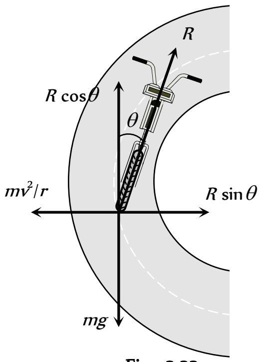


Fig : 3.33

Therefore, the cyclist should bend through an angle $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$

It follows that the angle through which cyclist should bend will be greater, if

(i) The radius of the curve is small *i.e.* the curve is sharper

(ii) The velocity of the cyclist is large.

Note : ❑ For the same reasons, an ice skater or an aeroplane has to bend inwards, while taking a turn.

Banking of A Road

For getting a centripetal force, cyclist bend towards the centre of circular path but it is not possible in case of four wheelers.

Therefore, outer bed of the road is raised so that a vehicle moving on it gets automatically inclined towards the centre.

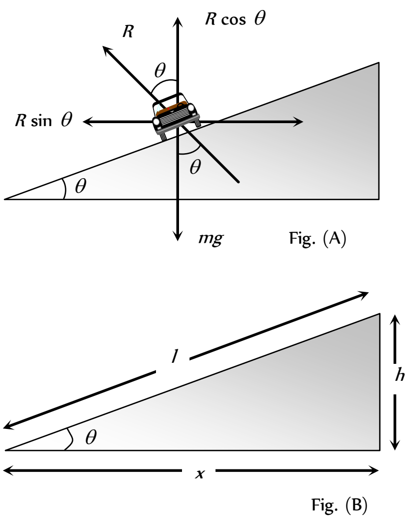


Fig : 3.34

In the figure (A) shown reaction R is resolved into two components, the component $R\cos\theta$ balances weight of vehicle

$$\therefore \; R\cos\theta = mg \quad \text{...(i)}$$

and the horizontal component $R\sin\theta$ provides necessary centripetal force as it is directed towards centre of desired circle

Thus $$R\sin\theta = \frac{mv^2}{r} \quad \text{...(ii)}$$

Dividing (ii) by (i), we have

$$\tan\theta = \frac{v^2}{rg} \quad \text{...(iii)}$$

or $$\tan\theta = \frac{\omega^2 r}{g} = \frac{v\omega}{g} \quad \text{...(iv)} \quad [\text{As } v = r\omega]$$

If l = width of the road, h = height of the outer edge from the ground level then from the figure (B)

$$\tan\theta = \frac{h}{x} = \frac{h}{l} \quad \text{...(v)} \qquad [\text{since } \theta \text{ is very small}]$$

From equation (iii), (iv) and (v)

$$\tan\theta = \frac{v^2}{rg} = \frac{\omega^2 r}{g} = \frac{v\omega}{g} = \frac{h}{l}$$

Note : ❑ If friction is also present between the tyres and road then $\frac{v^2}{rg} = \frac{\mu + \tan\theta}{1 - \mu\tan\theta}$

❑ Maximum safe speed on a banked frictional road $v = \sqrt{\frac{rg(\mu + \tan\theta)}{1 - \mu\tan\theta}}$

Overturning of Vehicle

When a car moves in a circular path with speed more than a certain maximum speed then it overturns even if friction is sufficient to avoid skidding and its inner wheel leaves the ground first

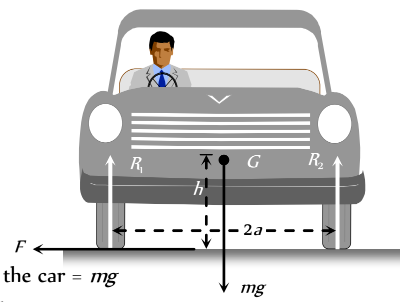


Fig : 3.35

Weight of the car = mg

Speed of the car = v

Radius of the circular path = r

Distance between the centre of wheels of the car = $2a$

Height of the centre of gravity (G) of the car from the road level = h

Reaction on the inner wheel of the car by the ground = R_1

Reaction on the outer wheel of the car by the ground = R_2

When a car move in a circular path, horizontal friction force F provides the required centripetal force *i.e.*, $F = \frac{mv^2}{R}$ ...(i)

For rotational equilibrium, by taking the moment of forces R_1, R_2 and F about G

$$Fh + R_1 a = R_2 a \quad ...(ii)$$

As there is no vertical motion so $R_1 + R_2 = mg$ ...(iii)

By solving (i), (ii) and (iii)

$$R_1 = \frac{1}{2}M\left[g - \frac{v^2 h}{ra}\right] \quad ...(iv)$$

and $$R_2 = \frac{1}{2}M\left[g + \frac{v^2 h}{ra}\right] \quad ...(v)$$

It is clear from equation (iv) that if v increases value of R_1 decreases and for $R_1 = 0$

$$\frac{v^2 h}{ra} = g \text{ or } v = \sqrt{\frac{gra}{h}}$$

i.e. the maximum speed of a car without overturning on a flat road is given by $v = \sqrt{\frac{gra}{h}}$

Motion of Charged Particle In Magnetic Field

When a charged particle having mass m, charge q enters perpendicularly in a magnetic field B with velocity v then it describes a circular path.

Because magnetic force (qvB) works in the perpendicular direction of v and it provides required centripetal force

Magnetic force = Centripetal force

$$qvB = \frac{mv^2}{r}$$

$\therefore$ radius of the circular path

$$r = \frac{mv}{qB}$$

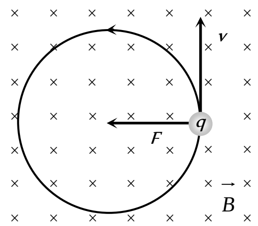


Fig : 3.36

Reaction of Road On Car

(1) When car moves on a concave bridge then

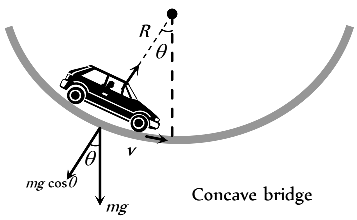


Fig : 3.37

Centripetal force = $R - mg\cos\theta = \frac{mv^2}{r}$

and reaction $R = mg\cos\theta + \frac{mv^2}{r}$

(2) When car moves on a convex bridge

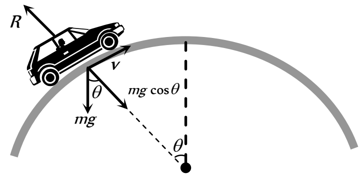


Fig : 3.38

Centripetal force = $mg\cos\theta - R = \frac{mv^2}{r}$

and reaction $R = mg\cos\theta - \frac{mv^2}{r}$

Non-Uniform Circular Motion

If the speed of the particle in a horizontal circular motion changes with respect to time, then its motion is said to be non-uniform circular motion.

Consider a particle describing a circular path of radius r with centre at O. Let at an instant the particle be at P and $\vec{\upsilon}$ be its linear velocity and $\vec{\omega}$ be its angular velocity.

Then, $\vec{\upsilon} = \vec{\omega} \times \vec{r}$ ...(i)

Differentiating both sides of *w.r.t.* time t we have

$$\frac{d\vec{\upsilon}}{dt} = \frac{d\vec{\omega}}{dt} \times \vec{r} + \vec{\omega} \times \frac{d\vec{r}}{dt} \quad ...(ii)$$

Here, $\frac{d\vec{v}}{dt} = \vec{a}$, (Resultant acceleration)

$$\vec{a} = \vec{\alpha} \times \vec{r} + \vec{\omega} \times \vec{\upsilon}$$

$\frac{d\vec{\omega}}{dt} = \vec{\alpha}$ (Angular acceleration)

$$\vec{a} = \vec{a}_t + \vec{a}_c \quad ...(iii)$$

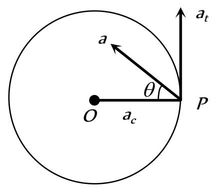


Fig : 3.39

$\frac{d\vec{r}}{dt} = \vec{\upsilon}$ (Linear velocity)

Thus the resultant acceleration of the particle at P has two component accelerations

(1) **Tangential acceleration :** $\vec{a}_t = \vec{\alpha} \times \vec{r}$

It acts along the tangent to the circular path at P in the plane of circular path.

According to right hand rule since $\vec{\alpha}$ and $\vec{r}$ are perpendicular to each other, therefore, the magnitude of tangential acceleration is given by

$$|\vec{a}_t| = |\vec{\alpha} \times \vec{r}| = \alpha r \sin 90^o = \alpha r.$$

(2) **Centripetal (Radial) acceleration :** $\vec{a}_c = \vec{\omega} \times \vec{v}$

It is also called centripetal acceleration of the particle at P.

It acts along the radius of the particle at P.

According to right hand rule since $\vec{\omega}$ and $\vec{\upsilon}$ are perpendicular to each other, therefore, the magnitude of centripetal acceleration is given by

$$|\vec{a}_c| = |\vec{\omega} \times \vec{\upsilon}| = \omega\upsilon \sin 90^o = \omega\upsilon = \omega(\omega r) = \omega^2 r = \upsilon^2 / r$$

Table 3.2 : Tangential and centripetal acceleration

Centripetal acceleration	Tangential acceleration	Net acceleration	Type of motion
$a_c = 0$	$a_t = 0$	$a = 0$	Uniform

			translatory motion
$a_c = 0$	$a_t \neq 0$	$a = a_t$	Accelerated translatory motion
$a_c \neq 0$	$a_t = 0$	$a = a_c$	Uniform circular motion
$a_c \neq 0$	$a_t \neq 0$	$a = \sqrt{a_c^2 + a_t^2}$	Non-uniform circular motion

Note : ❑ Here a_t governs the magnitude of $\vec{v}$ while $\vec{a}_c$ its direction of motion.

(3) **Force :** In non-uniform circular motion the particle simultaneously possesses two forces

Centripetal force : $F_c = ma_c = \frac{mv^2}{r} = mr\omega^2$

Tangential force : $F_t = ma_t$

Net force : $F_{net} = ma = m\sqrt{a_c^2 + a_t^2}$

Note : ❑ In non-uniform circular motion work done by centripetal force will be zero since $\vec{F}_c \perp \vec{v}$

❑ In non uniform circular motion work done by tangential force will not be zero since $F_t \neq 0$

❑ Rate of work done by net force in non-uniform circular motion = rate of work done by tangential force

i.e. $P = \frac{dW}{dt} = \vec{F}_t . \vec{v}$

Equations of Circular Motion

For accelerated motion	For retarded motion
$\omega_2 = \omega_1 + \alpha t$	$\omega_2 = \omega_1 - \alpha t$
$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$	$\theta = \omega_1 t - \frac{1}{2}\alpha t^2$
$\omega_2^2 = \omega_1^2 + 2\alpha\theta$	$\omega_2^2 = \omega_1^2 - 2\alpha\theta$
$\theta_n = \omega_1 + \frac{\alpha}{2}(2n-1)$	$\theta_n = \omega_1 - \frac{\alpha}{2}(2n-1)$

Where

ω_1 = Initial angular velocity of particle

ω_2 = Final angular velocity of particle

α = Angular acceleration of particle

θ = Angle covered by the particle in time t

θ_n = Angle covered by the particle in n^{th} second

Motion in vertical circle

This is an example of non-uniform circular motion. In this motion body is under the influence of gravity of earth. When body moves from lowest point to highest point. Its speed decrease and becomes minimum at highest point. Total mechanical energy of the body remains conserved and *KE* converts into *PE* and vice versa.

(1) **Velocity at any point on vertical loop :** If u is the initial velocity imparted to body at lowest point then velocity of body at height h is given by

$$v = \sqrt{u^2 - 2gh} = \sqrt{u^2 - 2gl(1-\cos\theta)}$$

[As $h = l - l\cos\theta = l(1 - \cos\theta)$]

where l is the length of the string

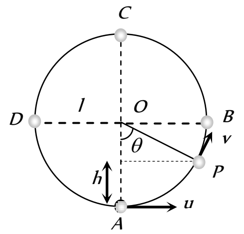


Fig : 3.40

(2) **Tension at any point on vertical loop** : Tension at general point *P*, According to Newton's second law of motion.

Net force towards centre = centripetal force

$T - mg\cos\theta = \frac{mv^2}{l}$

or $T = mg\cos\theta + \frac{mv^2}{l}$

$T = \frac{m}{l}[u^2 - gl(2 - 3\cos\theta)]$

[As $v = \sqrt{u^2 - 2gl(1-\cos\theta)}$]

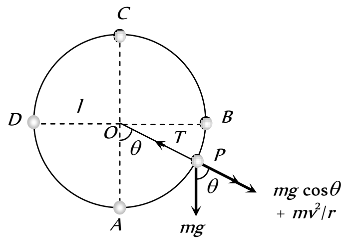


Fig : 3.41

Table 3.3 : Velocity and tension in a vertical loop

Position	Angle	Velocity	Tension
A	0°	u	$\frac{mu^2}{l} + mg$
B	90°	$\sqrt{u^2 - 2gl}$	$\frac{mu^2}{l} - 2mg$
C	180°	$\sqrt{u^2 - 4gl}$	$\frac{mu^2}{l} - 5mg$
D	270°	$\sqrt{u^2 - 2gl}$	$\frac{mu^2}{l} - 2mg$

It is clear from the table that : $T_A > T_B > T_C$ and $T_B = T_D$

$T_A - T_B = 3mg,$

$T_A - T_C = 6mg$

and $T_B - T_C = 3mg$

Table 3.4 : Various conditions for vertical motion

Velocity at lowest point	Condition
$u_A > \sqrt{5gl}$	Tension in the string will not be zero at any of the point and body will continue the circular motion.
$u_A = \sqrt{5gl},$	Tension at highest point C will be zero and body will just complete the circle.
$\sqrt{2gl} < u_A < \sqrt{5gl},$	Particle will not follow circular motion. Tension in string become zero somewhere between points B and C whereas velocity remain positive. Particle leaves circular path and follow parabolic trajectory.

$u_A = \sqrt{2gl}$	Both velocity and tension in the string becomes zero at *B* and particle will oscillate along semi-circular path.
$u_A < \sqrt{2gl}$	velocity of particle becomes zero between *A* and *B* but tension will not be zero and the particle will oscillate about the point *A*.

Note : ❑ *K.E.* of a body moving in horizontal circle is same throughout the path but the *K.E.* of the body moving in vertical circle is different at different places.

❑ If body of mass *m* is tied to a string of length *l* and is projected with a horizontal velocity *u* then :

Height at which the velocity vanishes is $h = \frac{u^2}{2g}$

Height at which the tension vanishes is $h = \frac{u^2 + gl}{3g}$

(3) **Critical condition for vertical looping :** If the tension at *C* is zero, then body will just complete revolution in the vertical circle. This state of body is known as critical state. The speed of body in critical state is called as critical speed.

From the above table 3.3 $T_c = \frac{mu^2}{l} - 5mg = 0$

$\Rightarrow u = \sqrt{5gl}$

It means to complete the vertical circle the body must be projected with minimum velocity of $\sqrt{5gl}$ at the lowest point.

Table 3.5 : Different variables in vertical loop

Quantity	Point *A*	Point *B*	Point *C*	Point *D*	Point *P*
Linear velocity (*v*)	$\sqrt{5gl}$	$\sqrt{3gl}$	$\sqrt{gl}$	$\sqrt{3gl}$	$\sqrt{gl(3+2\cos\theta)}$
Angular velocity (ω)	$\sqrt{\frac{5g}{l}}$	$\sqrt{\frac{3g}{l}}$	$\sqrt{\frac{g}{l}}$	$\sqrt{\frac{3g}{l}}$	$\sqrt{\frac{g}{l}(3+2\cos\theta)}$
Tension in String (*T*)	6 *mg*	3 *mg*	0	3 *mg*	$3mg(1+\cos\theta)$
Kinetic Energy (*KE*)	$\frac{5}{2}mgl$	$\frac{3}{2}mgl$	$\frac{1}{2}mgl$	$\frac{3}{2}mgl$	$\frac{mu^2}{l} - 5mg = 0$
Potential Energy (*PE*)	0	*mgl*	2 *mgl*	*mgl*	$mgl(1-\cos\theta)$
Total Energy (*TE*)	$\frac{5}{2}mgl$	$\frac{5}{2}mgl$	$\frac{5}{2}mgl$	$\frac{5}{2}mgl$	$\frac{5}{2}mgl$

(4) **Motion of a block on frictionless hemisphere :** A small block of mass *m* slides down from the top of a frictionless hemisphere of radius *r*. The component of the force of gravity ($mg\cos\theta$) provides required centripetal force but at point *B* it's circular motion ceases and the block lose contact with the surface of the sphere.

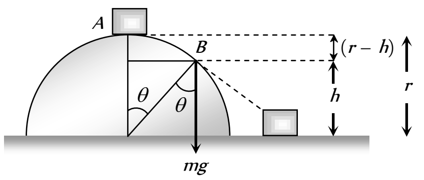


Fig : 3.42

For point *B*, by equating the forces,

$$mg\cos\theta = \frac{mv^2}{r} \quad ...(i)$$

For point *A* and *B*, by law of conservation of energy

Total energy at point *A* = Total energy at point *B*

$K.E._A + P.E._A = K.E._B + P.E._B$

$$0 + mgr = \frac{1}{2}mv^2 + mgh \Rightarrow v = \sqrt{2g(r-h)} \quad ...(ii)$$

and from the given figure $h = r\cos\theta$ ...(iii)

By substituting the value of *v* and *h* from *eq* (ii) and (iii) in *eq* (i)

$$mg\left(\frac{h}{r}\right) = \frac{m}{r}\left(\sqrt{2g(r-h)}\right)^2 \Rightarrow h = 2(r-h) \Rightarrow h = \frac{2}{3}r$$

i.e. the block lose contact at the height of $\frac{2}{3}r$ from the ground.

and angle from the vertical can be given by $\cos\theta = \frac{h}{r} = \frac{2}{3}$

$\therefore \theta = \cos^{-1}\frac{2}{3}$.

Conical Pendulum

This is the example of uniform circular motion in horizontal plane.

A bob of mass *m* attached to a light and in-extensible string rotates in a horizontal circle of radius *r* with constant angular speed ω about the vertical. The string makes angle θ with vertical and appears tracing the surface of a cone. So this arrangement is called conical pendulum.

The force acting on the bob are tension and weight of the bob.

From the figure $T\sin\theta = \frac{mv^2}{r}$ ....(i)

and $T\cos\theta = mg$ ....(ii)

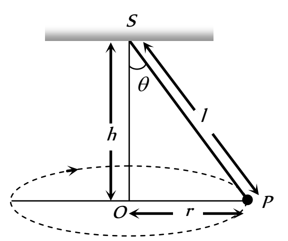


Fig : 3.43

(1) Tension in the string : $T = mg\sqrt{1+\left(\frac{v^2}{rg}\right)^2}$

$$T = \frac{mg}{\cos\theta} = \frac{mgl}{\sqrt{l^2-r^2}} \qquad \left[\text{As } \cos\theta = \frac{h}{l} = \frac{\sqrt{l^2-r^2}}{l}\right]$$

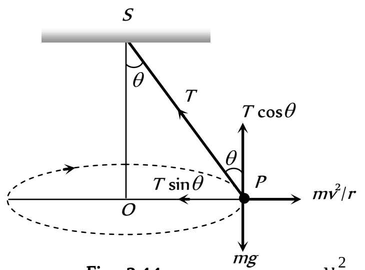


Fig : 3.44

(2) Angle of string from the vertical : $\tan\theta = \frac{v^2}{rg}$

(3) Linear velocity of the bob : $v = \sqrt{gr\tan\theta}$

(4) Angular velocity of the bob :

$$\omega = \sqrt{\frac{g}{r}\tan\theta} = \sqrt{\frac{g}{h}} = \sqrt{\frac{g}{l\cos\theta}}$$

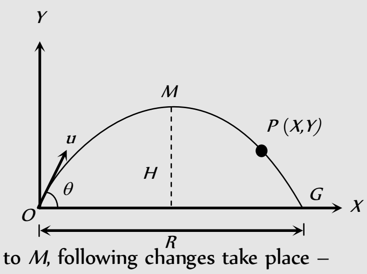
(5) Time period of revolution :

$$T_P = 2\pi\sqrt{\frac{l\cos\theta}{g}} = 2\pi\sqrt{\frac{h}{g}}$$

$$= 2\pi\sqrt{\frac{l^2-r^2}{g}} = 2\pi\sqrt{\frac{r}{g\tan\theta}}$$

Tips & Tricks

✍ Consider a projectile of mass m thrown with velocity u making angle θ with the horizontal. It is projected from the point O and returns to the ground at G. Also M is the highest point attained by it. (See figure).



(i) In going from O to M, following changes take place –

(a) Change in velocity $= u\sin\theta$

(b) Change in speed $= u(1-\cos\theta) = 2u\cos^2(\theta/2)$

(c) Change in momentum $= mu\sin\theta$

(d) Change (loss) in kinetic energy $= 1/2\, mu^2\sin^2\theta$

(e) Change (gain) in potential energy $= 1/2\, mu^2\sin^2\theta$

(f) Change in the direction of motion $= \angle\theta$

(ii) On return to the ground, that is in going from O to G, the following changes take place

(a) Change in speed = zero

(b) Change in velocity = $2u\sin\theta$

(c) Change in momentum = $2mu\sin\theta$

(d) Change in kinetic energy = zero

(e) Change in potential energy = zero

(f) Change in the direction of motion = $\angle 2\theta$

✍ (i) At highest point, the horizontal component of velocity is $v_x = u\cos\theta$ and vertical component of velocity v_y is zero.

(ii) At highest point, linear momentum of a particle

$m\,v_x = mu\cos\theta$.

(iii) Kinetic energy of the particle at the highest point = $\frac{1}{2}mv_x^2$

$= \frac{1}{2}mu^2\cos^2\theta$.

✍ At highest point, acceleration due to gravity acting vertically downward makes an angle of 90° with the horizontal component of the velocity of the projectile.

✍ At the highest point, momentum of the projectile thrown at an angle θ with horizontal is $p\cos\theta$ and K.E. = (K.E.) $\cos^2\theta$.

✍ In projectile motion, horizontal component $u\cos\theta$ of velocity u remains constant throughout, whereas vertical component $u\sin\theta$ changes and becomes zero at the highest point.

✍ The trajectory of a projectile is parabolic.

✍ For a projectile, time of flight and maximum height depend on the vertical component of the velocity of projection.

✍ The range of the projectile is maximum for the angle of projection $\theta = 45°$.

✍ The maximum range of the projectile is :

$$R_{max} = \frac{u^2}{g}$$

✍ When the range is maximum, the height attained by the projectile is :

$$H = \frac{u^2}{4g} = \frac{R_{max}}{4}$$

✍ When the range of the projectile is maximum, the time of flight is :

$$T = 2t = \frac{\sqrt{2}u}{g}$$

✍ The height attained by a projectile is maximum, when $\theta = 90°$.

$$H_{max} = \frac{u^2}{2g}$$

It is twice that of height attained, when the range is maximum.

✍ The time of flight of the projectile is also largest for $\theta = 90°$.

$$T_{max} = \frac{2u}{g}$$

✍ The trajectory of the projectile is a symmetric parabola only when g is constant through out the motion and θ is not equal to 0°, 90° or 180°.

✍ If velocity of projection is made n times, the maximum height attained and the range become n times and the time of flight becomes n times the initial value.

✍ If the force acting on a particle is always perpendicular to the velocity of the particle, then the path of the particle is a circle. The centripetal force is always perpendicular to the velocity of the particle.

✍ If circular motion of the object is uniform, the object will possess only centripetal acceleration.

✍ If circular motion of the object is non-uniform, the object will possess both centripetal and transverse acceleration.

✍ When the particle moves along the circular path with constant speed, the angular velocity is also constant. But linear velocity, momentum as well as centripetal acceleration change in direction, although their magnitude remains unchanged.

✍ For circular motion of rigid bodies with uniform speed, the angular speed is same for all particles, but linear speed varies directly as the radius of the circular path described by the particle $(v \propto r)$.

✍ When a body rotates, all its particles describe circular paths about a line, called axis of rotation.

✍ The centre of the circle describe by the different particles of the rotating body lie on the axis of rotation.

✍ Centripetal force $F_r = ma_r$, $m\omega^2 r$ where m = mass of the body.

✍ Centripetal force is always directed towards the centre of the circular path.

✍ When a body rotates with uniform velocity, its different particles have centripetal acceleration directly proportional to the radius $(a_c \propto r)$.

✍ There can be no circular motion without centripetal force.

✍ Centripetal force can be mechanical, electrical or magnetic force.

✍ Planets go round the earth in circular orbits due to the centripetal force provided by gravitational force of the sun.

✍ Gravitational pull of earth provides centripetal force for the orbital motion of the moon and artificial satellites.

✍ Centripetal force cannot change the kinetic energy of the body.

✍ In uniform circular motion the magnitude of the centripetal acceleration remains constant whereas its direction changes continuously but always directed towards the centre.

✍ A pseudo force, that is equal and opposite to the centripetal force is called centrifugal force.

✍ The $\vec{\theta}$, $\vec{\omega}$ and $\vec{\alpha}$ are directed along the axis of the circular path. Their sense of direction is given by the right hand fist rule as follows : 'If we catch axis of rotation in right hand fist such that the fingers point in the direction of rotation, then the outstretched thumb gives the direction of $\vec{\theta}$, $\vec{\omega}$ and $\vec{\alpha}$

✍ $\vec{\theta}$, $\vec{\omega}$ and $\vec{\alpha}$ are called pseudo vectors or axial vectors.

✍ For circular motion we have –

(i) $\vec{r} \perp \vec{v}$ (ii) $\vec{r}$ antiparallel to $\vec{a}_c$

(iii) $\vec{a}_c \perp \vec{v}$ (iv) $\vec{a}_c \perp \vec{a}_t$

(v) $\vec{\theta}$, $\vec{\omega}$, $\vec{\alpha}$ are perpendicular to $\vec{r}, \vec{a}_c, \vec{a}_t, \vec{v}$

(vi) $\vec{r}, \vec{a}_c, \vec{a}_t$ and $\vec{v}$ lie in the same plane

Ordinary Thinking

Objective Questions

Uniform Circular Motion

1. If the body is moving in a circle of radius r with a constant speed v, its angular velocity is [CPMT 1975; RPET 1999]
   (a) v^2/r (b) vr
   (c) v/r (d) r/v
2. Two racing cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2 respectively. Their speeds are such that each makes a complete circle in the same duration of time t. The ratio of the angular speed of the first to the second car is
   CBSE PMT 1999; UPSEAT 2000]
   (a) $m_1 : m_2$ (b) $r_1 : r_2$
   (c) 1 : 1 (d) $m_1r_1 : m_2r_2$
3. A cyclist turns around a curve at 15 miles/hour. If he turns at double the speed, the tendency to overturn is
   [CPMT 1974; AFMC 2003]
   (a) Doubled (b) Quadrupled
   (c) Halved (d) Unchanged
4. A body of mass m is moving in a circle of radius r with a constant speed v. The force on the body is $\frac{mv^2}{r}$ and is directed towards the centre. What is the work done by this force in moving the body over half the circumference of the circle
   (a) $\frac{mv^2}{r} \times \pi r$ (b) Zero
   (c) $\frac{mv^2}{r^2}$ (d) $\frac{\pi r^2}{mv^2}$
5. If a particle moves in a circle describing equal angles in equal times, its velocity vector
   [CPMT 1972, 74; JIPMER 1997]
   (a) Remains constant
   (b) Changes in magnitude
   (c) Changes in direction
   (d) Changes both in magnitude and direction
6. A stone of mass m is tied to a string of length l and rotated in a circle with a constant speed v. If the string is released, the stone flies [NCERT 1977]
   (a) Radially outward
   (b) Radially inward
   (c) Tangentially outward
   (d) With an acceleration $\frac{mv^2}{l}$
7. A body is moving in a circular path with a constant speed. It has
   (a) A constant velocity
   (b) A constant acceleration
   (c) An acceleration of constant magnitude
   (d) An acceleration which varies with time
8. A motor cyclist going round in a circular track at constant speed has
   (a) Constant linear velocity (b) Constant acceleration
   (c) Constant angular velocity (d) Constant force
9. A particle P is moving in a circle of radius 'a' with a uniform speed v. C is the centre of the circle and AB is a diameter. When passing through B the angular velocity of P about A and C are in the ratio [NCERT 1982]
   (a) 1 : 1 (b) 1 : 2
   (c) 2 : 1 (d) 4 : 1
10. A car moving on a horizontal road may be thrown out of the road in taking a turn [NCERT 1983]
    (a) By the gravitational force
    (b) Due to lack of sufficient centripetal force
    (c) Due to rolling frictional force between tyre and road
    (d) Due to the reaction of the ground
11. Two particles of equal masses are revolving in circular paths of radii r_1 and r_2 respectively with the same speed. The ratio of their centripetal forces is [NCERT 1980; MNR 1995; [NCERT 1984]
    (a) $\frac{r_2}{r_1}$ (b) $\sqrt{\frac{r_2}{r_1}}$
    (c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\left(\frac{r_2}{r_1}\right)^2$
12. A particle moves with constant angular velocity in a circle. During the motion its
    (a) Energy is conserved
    (b) Momentum is conserved
    (c) Energy and momentum both are conserved
    (d) None of the above is conserved
13. A stone tied to a string is rotated in a circle. If the string is cut, the stone flies away from the circle because [NCERT 1977; RPET 1999]
    (a) A centrifugal force acts on the stone
    (b) A centripetal force acts on the stone
    (c) Of its inertia
    (d) Reaction of the centripetal force
14. A body is revolving with a constant speed along a circle. If its direction of motion is reversed but the speed remains the same, then which of the following statement is true
    (a) The centripetal force will not suffer any change in magnitude
    (b) The centripetal force will have its direction reversed
    (c) The centripetal force will not suffer any change in direction
    (d) The centripetal force would be doubled
15. When a body moves with a constant speed along a circle
    [CBSE PMT 1994; Orissa PMT 2004]
    (a) No work is done on it
    (b) No acceleration is produced in the body
    (c) No force acts on the body
    (d) Its velocity remains constant
16. A body of mass m moves in a circular path with uniform angular velocity. The motion of the body has constant
    [MP PET 2003]
    (a) Acceleration [CPMT 1972] (b) Velocity
    (c) Momentum (d) Kinetic energy
17. On a railway curve, the outside rail is laid higher than the inside one so that resultant force exerted on the wheels of the rail car by the tops of the rails will [NCERT 1975]
    (a) Have a horizontal inward component

(b) Be vertical

(c) Equilibriate the centripetal force

(d) Be decreased

18. If the overbridge is concave instead of being convex, the thrust on the road at the lowest position will be

(a) $mg+\frac{mv^2}{r}$ (b) $mg-\frac{mv^2}{r}$

(c) $\frac{m^2v^2g}{r}$ (d) $\frac{v^2g}{r}$

19. A cyclist taking turn bends inwards while a car passenger taking same turn is thrown outwards. The reason is [NCERT 1972; CPMT 1974]

(a) Car is heavier than cycle

(b) Car has four wheels while cycle has only two

(c) Difference in the speed of the two

(d) Cyclist has to counteract the centrifugal force while in the case of car only the passenger is thrown by this force

20. A car sometimes overturns while taking a turn. When it overturns, it is [AFMC 1988; MP PMT 2003]

(a) The inner wheel which leaves the ground first

(b) The outer wheel which leaves the ground first

(c) Both the wheels leave the ground simultaneously

(d) Either wheel leaves the ground first

21. A tachometer is a device to measure [DPMT 1999]

(a) Gravitational pull (b) Speed of rotation

(c) Surface tension (d) Tension in a spring

22. Two bodies of mass 10 kg and 5 kg moving in concentric orbits of radii R and r such that their periods are the same. Then the ratio between their centripetal acceleration is [CBSE PMT 2001]

(a) R/r (b) r/R

(c) R^2/r^2 (d) r^2/R^2

23. The ratio of angular speeds of minute hand and hour hand of a watch is [MH CET 2002]

(a) 1 : 12 (b) 6 : 1

(c) 12 : 1 (d) 1 : 6

24. A car travels north with a uniform velocity. It goes over a piece of mud which sticks to the tyre. The particles of the mud, as it leaves the ground are thrown

(a) Vertically upwards (b) Vertically inwards

(c) Towards north (d) Towards south

25. An aircraft executes a horizontal loop with a speed of 150 *m/s* with its, wings banked at an angle of 12^o. The radius of the loop is $(g=10\ m/s^2)$ [Pb. PET 2001]

(a) 10.6 *km* (b) 9.6 *km*

(c) 7.4 *km* (d) 5.8 *km*

26. A particle is moving in a horizontal circle with constant speed. It has constant [MP PMT 1987; AFMC 1993; CPMT 1997; MP PET 2000]

(a) Velocity (b) Acceleration

(c) Kinetic energy (d) Displacement

27. A motor cyclist moving with a velocity of 72 *km/hour* on a flat road takes a turn on the road at a point where the radius of curvature of the road is 20 *meters*. The acceleration due to gravity is 10 *m/sec*. In order to avoid skidding, he must not bend with respect to the vertical plane by an angle greater than

(a) $\theta=\tan^{-1}6$ (b) $\theta=\tan^{-1}2$

(c) $\theta=\tan^{-1}25.92$ (d) $\theta=\tan^{-1}4$

28. A train is moving towards north. At one place it turns towards north-east, here we observe that [AIIMS 1980]

(a) The radius of curvature of outer rail will be greater than that of the inner rail

(b) The radius of the inner rail will be greater than that of the outer rail

(c) The radius of curvature of one of the rails will be greater

(d) The radius of curvature of the outer and inner rails will be the same

29. The angular speed of a fly wheel making 120 *revolutions/minute* is [CBSE P

(a) $2\pi\ rad/s$ (b) $4\pi^2\ rad/s$

(c) $\pi\ rad/s$ (d) $4\pi\ rad/s$

30. A particle is moving on a circular path with constant speed, then its acceleration will be [RPET 2003]

(a) Zero

(b) External radial acceleration

(c) Internal radial acceleration

(d) Constant acceleration

31. A car is moving on a circular path and takes a turn. If R_1 and R_2 be the reactions on the inner and outer wheels respectively, then

(a) $R_1=R_2$ (b) $R_1<R_2$

(c) $R_1>R_2$ (d) $R_1\geq R_2$

32. A mass of 100 *gm* is tied to one end of a string 2 *m* long. The body is revolving in a horizontal circle making a maximum of 200 revolutions per min. The other end of the string is fixed at the centre of the circle of revolution. The maximum tension that the string can bear is (approximately) [MP PET 1993]

(a) 8.76 *N* (b) 8.94 *N*

(c) 89.42 *N* (d) 87.64 *N*

33. A road is 10 *m* wide. Its radius of curvature is 50 *m*. The outer edge is above the lower edge by a distance of 1.5 *m*. This road is most suited for the velocity

(a) 2.5 *m/sec* (b) 4.5 *m/sec*

(c) 6.5 *m/sec* (d) 8.5 *m/sec*

34. Certain neutron stars are believed to be rotating at about $1 rev/\sec$. If such a star has a radius of 20 *km*, the acceleration of an object on the equator of the star will be [NCERT 1982]

(a) $20\times10^8 m/\sec^2$ (b) $8\times10^5 m/\sec^2$

(c) $120\times10^5 m/\sec^2$ (d) $4\times10^8 m/\sec^2$

35. A particle revolves round a circular path. The acceleration of the particle is [MNR 1986; UPSEAT 1999]

(a) Along the circumference of the circle

(b) Along the tangent

(c) Along the radius

(d) Zero

36. The length of second's hand in a watch is 1 *cm*. The change in velocity of its tip in 15 seconds is [MP PMT 1987, 2003]

(a) Zero (b) $\frac{\pi}{30\sqrt{2}} cm/\sec$

(c) $\frac{\pi}{30} cm/\sec$ (d) $\frac{\pi\sqrt{2}}{30} cm/\sec$

37. A particle moves in a circle of radius 25 *cm* at two revolutions per second. The acceleration of the particle in m/s^2 is [MNR 1991; UPSEAT 2000; DPMT 1999; RPET 2003; Pb. PET 2004]

(a) π^2 (b) $8\pi^2$

(c) $4\pi^2$ (d) $2\pi^2$

38. An electric fan has blades of length 30 *cm* as measured from the axis of rotation. If the fan is rotating at 1200 *r.p.m.* The acceleration of a point on the tip of the blade is about [CBSE PMT 1990]

(a) 1600 $m/\sec^2$ (b) 4740 $m/\sec^2$

(c) 2370 $m/\sec^2$ (d) 5055 $m/\sec^2$

39. The force required to keep a body in uniform circular motion is [EAMCET 1982; AFMC 2003]

(a) Centripetal force (b) Centrifugal force

(c) Resistance (d) None of the above

40. Cream gets separated out of milk when it is churned, it is due to

(a) Gravitational force (b) Centripetal force

(c) Centrifugal force (d) Frictional force

41. A particle of mass m is executing uniform circular motion on a path of radius r. If p is the magnitude of its linear momentum. The radial force acting on the particle is [MP PET 1994]

(a) pmr (b) $\frac{rm}{p}$

(c) $\frac{mp^2}{r}$ (d) $\frac{p^2}{rm}$

42. A particle moves in a circular orbit under the action of a central attractive force inversely proportional to the distance 'r'. The speed of the particle is [CBSE PMT 1995]

(a) Proportional to r^2 (b) Independent of r

(c) Proportional to r (d) Proportional to $1/r$

43. Two masses M and m are attached to a vertical axis by weightless threads of combined length l. They are set in rotational motion in a horizontal plane about this axis with constant angular velocity ω. If the tensions in the threads are the same during motion, the distance of M from the axis is [MP PET 1995]

(a) $\frac{Ml}{M+m}$ (b) $\frac{ml}{M+m}$

(c) $\frac{M+m}{M}l$ (d) $\frac{M+m}{m}l$

44. A boy on a cycle pedals around a circle of 20 *metres* radius at a speed of $20 metres/\sec$. The combined mass of the boy and the cycle is 90 *kg*. The angle that the cycle makes with the vertical so that it may not fall is $(g = 9.8\, m/\sec^2)$ [MP PMT 1995]

(a) 60.25^o (b) 63.90^o

(c) 26.12^o (d) 30.00^o

45. The average acceleration vector for a particle having a uniform circular motion is [Kurukshetra CEE 1996]

(a) A constant vector of magnitude $\frac{v^2}{r}$

(b) A vector of magnitude $\frac{v^2}{r}$ directed normal to the plane of the given uniform circular motion

(c) Equal to the instantaneous acceleration vector at the start of the motion

(d) A null vector

46. Radius of the curved road on national highway is R. Width of the road is b. The outer edge of the road is raised by h with respect to inner edge so that a car with velocity v can pass safe over it. The value of h is [MP PMT 1996]

(a) $\frac{v^2b}{Rg}$ [EAMCET 1981] (b) $\frac{v}{Rgb}$

(c) $\frac{v^2R}{g}$ (d) $\frac{v^2b}{R}$

47. When a particle moves in a uniform circular motion. It has

(a) Radial velocity and radial acceleration

(b) Tangential velocity and radial acceleration

(c) Tangential velocity and tangential acceleration

(d) Radial velocity and tangential acceleration

48. A motorcycle is going on an overbridge of radius R. The driver maintains a constant speed. As the motorcycle is ascending on the overbridge, the normal force on it [MP PET 1997]

(a) Increases (b) Decreases

(c) Remains the same (d) Fluctuates

49. A mass of 2 *kg is* whirled in a horizontal circle by means of a string at an initial speed of 5 *revolutions per minute*. Keeping the radius constant the tension in the string is doubled. The new speed is nearly [MP PMT/PET 1998; JIPMER 2000]

(a) 14 *rpm* (b) 10 *rpm*

(c) 2.25 *rpm* (d) 7 *rpm*

50. The magnitude of the centripetal force acting on a body of mass m executing uniform motion in a circle of radius r with speed v is [AFMC 1998

(a) mvr (b) mv^2/r

(c) v/r^2m (d) v/rm

51. A string breaks if its tension exceeds 10 *newtons*. A stone of mass 250 *gm* tied to this string of length 10 *cm* is rotated in a horizontal circle. The maximum angular velocity of rotation can be

(a) 20 *rad/s* (b) 40 *rad/s*

(c) 100 *rad/s* (d) 200 *rad/s*

52. A 500 *kg* car takes a round turn of radius 50 *m* with a velocity of 36 *km/hr*. The centripetal force is [KCET 2001; CBSE PMT 1999;

[JIPMER 2001, 02]

(a) 250 *N* (b) 750 *N*

(c) 1000 *N* (d) 1200 *N*

53. A ball of mass 0.25 *kg* attached to the end of a string of length 1.96 *m* is moving in a horizontal circle. The string will break if the tension is more than 25 *N*. What is the maximum speed with which the ball can be moved

[CBSE PMT 1998]

(a) 14 *m/s* (b) 3 *m/s*

(c) 3.92 *m/s* (d) 5 *m/s*

54. A body of mass 5 *kg* is moving in a circle of radius $1m$ with an angular velocity of 2 *radian/sec*. The centripetal force is

[AIIMS 1998]

(a) 10 *N* (b) 20 *N*

(c) 30 *N* (d) 40 *N*

55. If a particle of mass m is moving in a horizontal circle of radius r with a centripetal force $(-k/r^2)$, the total energy is [EAMCET (Med.) 1995; AMU (Engg.) 2001]

(a) $-\frac{k}{2r}$ (b) $-\frac{k}{r}$

(c) $-\frac{2k}{r}$ (d) $-\frac{4k}{r}$

56. A stone of mass of 16 *kg* is attached to a string 144 *m* long and is whirled in a horizontal circle. The maximum tension the string can withstand is 16 *Newton*. The maximum velocity of revolution that can be given to the stone without breaking it, will be

(a) 20 ms^{-1} (b) 16 ms^{-1}

(c) 14 ms^{-1} (d) 12 ms^{-1}

57. A circular road of radius 1000 *m* has banking angle 45^o. The maximum safe speed of a car having mass 2000 *kg* will be, if the coefficient of friction between tyre and road is 0.5

[RPET 1997]

(a) 172 *m/s* (b) 124 *m/s*

(c) 99 *m/s* (d) 86 *m/s*

58. The second's hand of a watch has length 6 *cm*. Speed of end point and magnitude of difference of velocities at two perpendicular positions will be [RPET 1997]

(a) 6.28 and 0 *mm/s* (b) 8.88 and 4.44 *mm/s*

(c) 8.88 and 6.28 *mm/s* (d) 6.28 and 8.88 *mm/s*

59. A sphere of mass m is tied to end of a string of length l and rotated through the other end along a horizontal circular path with speed v. The work done in full horizontal circle is

[CPMT 1993; JIPMER 2000]

(a) 0 (b) $\left(\frac{mv^2}{l}\right).2\pi l$

(c) $mg.2\pi l$ (d) $\left(\frac{mv^2}{l}\right).(l)$

60. A body is whirled in a horizontal circle of radius 20 *cm*. It has angular velocity of 10 *rad/s*. What is its linear velocity at any point on circular path [CBSE PMT 1996]

(a) 10 *m/s* (b) 2 *m/s*

(c) 20 *m/s* (d) $\sqrt{2}$ *m/s*

61. Find the maximum velocity for skidding for a car moved on a circular track of radius 100 *m*. The coefficient of friction between the road and tyre is 0.2

[CPMT 1996; Pb. PMT 2001]

(a) 0.14 *m/s* (b) 140 *m/s*

(c) 1.4 *km/s* (d) 14 *m/s*

62. A car when passes through a convex bridge exerts a force on it which is equal to [AFMC 1997]

(a) $Mg+\frac{Mv^2}{r}$ (b) $\frac{Mv^2}{r}$

(c) Mg (d) None of these

63. The angular speed of seconds needle in a mechanical watch is

[RPMT 1999; CPMT 1997; MH CET 2000, 01; BHU 2000]

(a) $\frac{\pi}{30}$ *rad/s* (b) 2π *rad/s*

(c) π *rad/s* (d) $\frac{60}{\pi}$ *rad/s*

64. The angular velocity of a particle rotating in a circular orbit 100 times per minute is [SCRA 1998; DPMT 2000]

(a) 1.66 *rad/s* (b) 10.47 *rad/s*

(c) 10.47 *deg/s* (d) 60 *deg/s*

65. A body of mass 100 *g* is rotating in a circular path of radius *r* with constant velocity. The work done in one complete revolution is

[SCRA 1994]

(a) 100*rJ* (b) $(r/100)J$

(c) $(100/r)J$ (d) Zero

66. A particle comes round a circle of radius 1 *m* once. The time taken by it is 10 *sec*. The average velocity of motion is

[JIPMER 1999]

(a) 0.2 $\pi m/s$ (b) 2 $\pi m/s$

(c) 2 m/s (d) Zero

67. An unbanked curve has a radius of $60m$. The maximum speed at which a car can make a turn if the coefficient of static friction is 0.75, is [JIPMER 1999]

(a) 2.1 m/s (b) 14 m/s

(c) 21 m/s (d) 7 m/s

68. A wheel completes 2000 revolutions to cover the 9.5 *km*. distance. then the diameter of the wheel is [RPMT 1999]

(a) 1.5 *m* (b) 1.5 *cm*

(c) 7.5 *cm* (d) 7.5 *m*

69. A cycle wheel of radius 0.4 *m* completes one revolution in one *second* then the acceleration of a point on the cycle wheel will be

(a) 0.8 *m/s* (b) 0.4 *m/s*

(c) $1.6\pi^2 m/s^2$ (d) $0.4\pi^2 m/s^2$

70. The centripetal acceleration is given by [RPET 1999]

(a) *v/r* (b) *vr*

(c) *vr* (d) *v/r*

71. A cylindrical vessel partially filled with water is rotated about its vertical central axis. It's surface will [RPET 2000]

(a) Rise equally (b) Rise from the sides

(c) Rise from the middle (d) Lowered equally

72. If a particle covers half the circle of radius R with constant speed then [RPMT 2000]
(a) Momentum change is mvr
(b) Change in $K.E.$ is 1/2 mv
(c) Change in $K.E.$ is mv
(d) Change in $K.E.$ is zero

73. An aeroplane is flying with a uniform speed of 100 m/s along a circular path of radius 100 m. the angular speed of the aeroplane will be [KCET 2000]
(a) 1 rad/sec (b) 2 rad/sec
(c) 3 rad/sec (d) 4 rad/sec

74. A body moves with constant angular velocity on a circle. Magnitude of angular acceleration [RPMT 2000]
(a) $r\omega$ (b) Constant
(c) Zero (d) None of the above

75. What is the value of linear velocity, if $\vec{\omega} = 3\hat{i} - 4\hat{j} + \hat{k}$ and $\vec{r} = 5\hat{i} - 6\hat{j} + 6\hat{k}$ [Pb. PMT 2000]
(a) $6\hat{i} + 2\hat{j} - 3\hat{k}$ (b) $-18\hat{i} - 13\hat{j} + 2\hat{k}$
(c) $4\hat{i} - 13\hat{j} + 6\hat{k}$ (d) $6\hat{i} - 2\hat{j} + 8\hat{k}$

76. A stone is tied to one end of a string 50 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 10 revolutions in 20 s, what is the magnitude of acceleration of the stone [Pb. PMT 2000]
(a) 493 cm/s (b) 720 cm/s
(c) 860 cm/s (d) 990 cm/s

77. A 100 kg car is moving with a maximum velocity of 9 m/s across a circular track of radius 30 m. The maximum force of friction between the road and the car is [Pb. PMT 2000]
(a) 1000 N (b) 706 N
(c) 270 N (d) 200 N

78. The maximum speed of a car on a road–turn of radius 30 m, if the coefficient of friction between the tyres and the road is 0.4, will be
(a) 10.84 m/sec (b) 9.84 m/sec
(c) 8.84 m/sec (d) 6.84 m/sec

79. The angular velocity of a wheel is 70 rad/sec. If the radius of the wheel is 0.5 m, then linear velocity of the wheel is [MH CET 2000]
(a) 70 m/s (b) 35 m/s
(c) 30 m/s (d) 20 m/s

80. A cyclist goes round a circular path of circumference 34.3 m in $\sqrt{22}$ sec. the angle made by him, with the vertical, will be
(a) 45° (b) 40°
(c) 42° (d) 48°

81. A particle of mass M is moving in a horizontal circle of radius R with uniform speed V. When it moves from one point to a diametrically opposite point, its [CBSE PMT 1992]
(a) Kinetic energy changes by $MV^2/4$
(b) Momentum does not change
(c) Momentum changes by $2MV$
(d) Kinetic energy changes by MV^2

82. A ball of mass 0.1 Kg. is whirled in a horizontal circle of radius 1 m. by means of a string at an initial speed of 10 $R.P.M.$ Keeping the radius constant, the tension in the string is reduced to one quarter of its initial value. The new speed is
(a) 5 $r.p.m.$ (b) 10 $r.p.m.$
(c) 20 $r.p.m.$ (d) 14 $r.p.m.$

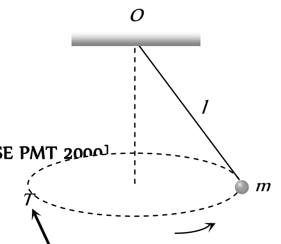
83. A cyclist riding the bicycle at a speed of $14\sqrt{3}$ ms takes a turn around a circular road of radius $20\sqrt{3}$ m without skidding. Given g = 9.8 ms, what is his inclination to the vertical
(a) 30° (b) 90°
(c) 45° (d) 60°

84. If a cycle wheel of radius 4 m completes one revolution in two seconds. Then acceleration of a point on the cycle wheel will be
(a) $\pi^2 m/s^2$ (b) $2\pi^2 m/s^2$
(c) $4\pi^2 m/s^2$ (d) $8\pi m/s^2$

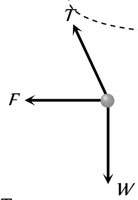
85. A bob of mass 10 kg is attached to wire 0.3 m long. Its breaking stress is 4.8 × 10 N/m. The area of cross section of the wire is 10 m. The maximum angular velocity with which it can be rotated in a horizontal circle [Pb. PMT 2001]
(a) 8 rad/sec (b) 4 rad/sec
(c) 2 rad/sec (d) 1 rad/sec

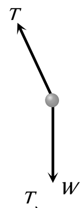
86. In uniform circular motion, the velocity vector and acceleration vector are [DCE 2000, 01, 03]
(a) Perpendicular to each other
(b) Same direction
(c) Opposite direction
(d) Not related to each other

87. A point mass m is suspended from a light thread of length l, fixed at O, is whirled in a horizontal circle at constant speed as shown. From your point of view, stationary with respect to the mass, the forces on the mass are [AMU (Med.) 2001]

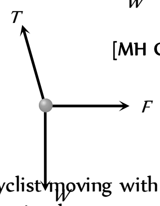


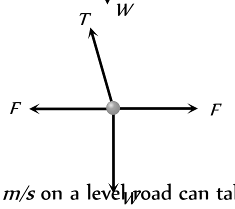
[CBSE PMT 2000]

(a) 

(b) 

[MH CET 2000]

(c) 

(d) 

88. If a cyclist moving with a speed of 4.9 m/s on a level road can take a sharp circular turn of radius 4 m, then coefficient of friction between the cycle tyres and road is [AIIMS 1999; AFMC 2001]
(a) 0.41 (b) 0.51
(c) 0.61 (d) 0.71

89. A car moves on a circular road. It describes equal angles about the centre in equal intervals of time. Which of the following statement about the velocity of the car is true [BHU 2001]

[MP PMT 2001]

(a) Magnitude of velocity is not constant
(b) Both magnitude and direction of velocity change
(c) Velocity is directed towards the centre of the circle
(d) Magnitude of velocity is constant but direction changes

90. A scooter is going round a circular road of radius 100 *m* at a speed of 10 *m/s*. The angular speed of the scooter will be [Pb. PMT 2002]

(a) 0.01 *rad/s* (b) 0.1 *rad/s*
(c) 1 *rad/s* (d) 10 *rad/s*

91. A particle of mass *M* moves with constant speed along a circular path of radius *r* under the action of a force *F*. Its speed is

(a) $\sqrt{\frac{rF}{m}}$ (b) $\sqrt{\frac{F}{r}}$
(c) $\sqrt{Fmr}$ (d) $\sqrt{\frac{F}{mr}}$

92. In an atom for the electron to revolve around the nucleus, the necessary centripetal force is obtained from the following force exerted by the nucleus on the electron [MP PET 2002]

(a) Nuclear force (b) Gravitational force
(c) Magnetic force (d) Electrostatic force

93. A particle moves with constant speed *v* along a circular path of radius *r* and completes the circle in time *T*. The acceleration of the particle is [Orissa JEE 2002]

(a) $2\pi v/T$ (b) $2\pi r/T$
(c) $2\pi r^2/T$ (d) $2\pi v^2/T$

94. The maximum velocity (in ms^{-1}) with which a car driver must traverse a flat curve of radius 150 *m* and coefficient of friction 0.6 to avoid skidding is [AIEEE 2002]

(a) 60 (b) 30
(c) 15 (d) 25

95. A car is moving with high velocity when it has a turn. A force acts on it outwardly because of [AFMC 2002]

(a) Centripetal force (b) Centrifugal force
(c) Gravitational force (d) All the above

96. A motor cycle driver doubles its velocity when he is having a turn. The force exerted outwardly will be [AFMC 2002]

(a) Double (b) Half
(c) 4 times (d) $\frac{1}{4}$ times

97. The coefficient of friction between the tyres and the road is 0.25. The maximum speed with which a car can be driven round a curve of radius 40 *m* without skidding is (assume $g = 10\ ms^{-2}$)

(a) 40 ms^{-1} (b) 20 ms^{-1}
(c) 15 ms^{-1} (d) 10 ms^{-1}

98. An athlete completes one round of a circular track of radius 10 *m* in 40 *sec*. The distance covered by him in 2 *min* 20 *sec* is

(a) 70 *m* (b) 140 *m*
(c) 110 *m* (d) 220 *m*

99. A proton of mass 1.6×10^{-27} *kg* goes round in a circular orbit of radius 0.10 *m* under a centripetal force of 4×10^{-13} *N*. then the frequency of revolution of the proton is about [Kerala (Med.) 2002]

(a) 0.08×10^{8} *cycles per sec*
(b) 4×10^{8} *cycles per sec*
(c) 8×10^{8} *cycles per sec*
(d) 12×10^{8} *cycles per sec*

100. A particle is moving in a circle with uniform speed *v*. In moving from a point to another diametrically opposite point [Orissa JEE 2003]

(a) The momentum changes by *mv*
(b) The momentum changes by 2*mv*
(c) The kinetic energy changes by (1/2)*mv*
(d) The kinetic energy changes by *mv*

101. In uniform circular motion [MP PMT 2002] [MP PMT 1994]

(a) Both the angular velocity and the angular momentum vary
(b) The angular velocity varies but the angular momentum remains constant
(c) Both the angular velocity and the angular momentum stay constant
(d) The angular momentum varies but the angular velocity remains constant

102. When a body moves in a circular path, no work is done by the force since, [KCET 2004]

(a) There is no displacement
(b) There is no net force
(c) Force and displacement are perpendicular to each other
(d) The force is always away from the centre

103. Which of the following statements is false for a particle moving in a circle with a constant angular speed [AIEEE 2004]

(a) The velocity vector is tangent to the circle
(b) The acceleration vector is tangent to the circle
(c) The acceleration vector points to the centre of the circle
(d) The velocity and acceleration vectors are perpendicular to each other

104. If a_r and a_t represent radial and tangential accelerations, the motion of a particle will be uniformly circular if [CPMT 2004]

(a) $a_r = 0$ and $a_t = 0$ (b) $a_r = 0$ but $a_t \neq 0$
(c) $a_r \neq 0$ but $a_t = 0$ (d) $a_r \neq 0$ and $a_t \neq 0$

105. A person with his hands in his pockets is skating on ice at the velocity of 10 *m/s* and describes a circle of radius 50 *m*. What is his inclination with vertical [Pb. PET 2000]

(a) $\tan^{-1}\left(\frac{1}{10}\right)$ [Kerala (Med.) 2002] (b) $\tan^{-1}\left(\frac{3}{5}\right)$
(c) $\tan^{-1}(1)$ (d) $\tan^{-1}\left(\frac{1}{5}\right)$

106. If the radius of curvature of the path of two particles of same masses are in the ratio 1 : 2, then in order to have constant centripetal force, their velocity, should be in the ratio of [Kerala (Med.) 2002] [Pb. PET 2000]

(a) 1 : 4 (b) 4 : 1
(c) $\sqrt{2} : 1$ (d) $1 : \sqrt{2}$

107. An object is moving in a circle of radius 100 *m* with a constant speed of 31.4 *m/s*. What is its average speed for one complete revolution [DCE 2004]

(a) Zero (b) 31.4 *m/s*
(c) 3.14 *m/s* (d) $\sqrt{2} \times 31.4\ m/s$

108. A body of mass 1 *kg* tied to one end of string is revolved in a horizontal circle of radius 0.1 *m* with a speed of 3 *revolution/sec*,

assuming the effect of gravity is negligible, then linear velocity, acceleration and tension in the string will be

(a) $1.88\ m/s,\ 35.5\ m/s^2,\ 35.5\ N$

(b) $2.88\ m/s,\ 45.5\ m/s^2,\ 45.5\ N$

(c) $3.88\ m/s,\ 55.5\ m/s^2,\ 55.5\ N$

(d) None of these

109. The acceleration of a train travelling with speed of 400 *m/s* as it goes round a curve of radius 160 *m*, is **[Pb. PET 2003]**

(a) $1\ km/s^2$ (b) $100\ m/s^2$

(c) $10\ m/s^2$ (d) $1\ m/s^2$

110. A car of mass 800 *kg* moves on a circular track of radius 40 *m*. If the coefficient of friction is 0.5, then maximum velocity with which the car can move is **[MH CET 2004]**

(a) 7 *m/s* (b) 14 *m/s*

(c) 8 *m/s* (d) 12 *m/s*

111. A 500 *kg* crane takes a turn of radius 50 *m* with velocity of 36 *km/hr*. The centripetal force is **[Pb. PMT 2003]**

(a) 1200 *N* (b) 1000 *N*

(c) 750 *N* (d) 250 *N*

112. Two bodies of equal masses revolve in circular orbits of radii R_1 and R_2 with the same period. Their centripetal forces are in the ratio **[Kerala PMT 2004]**

(a) $\left(\frac{R_2}{R_1}\right)^2$ (b) $\frac{R_1}{R_2}$

(c) $\left(\frac{R_1}{R_2}\right)^2$ (d) $\sqrt{R_1R_2}$

113. In case of uniform circular motion which of the following physical quantity do not remain constant **[Kerala PMT 2004]**

(a) Speed (b) Momentum

(c) Kinetic energy (d) Mass

114. What happens to the centripetal acceleration of a revolving body if you double the orbital speed v and half the angular velocity ω

(a) The centripetal acceleration remains unchanged

(b) The centripetal acceleration is halved

(c) The centripetal acceleration is doubled

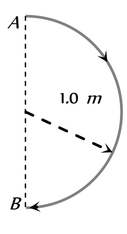
(d) The centripetal acceleration is quadrupled

115. A mass is supported on a frictionless horizontal surface. It is attached to a string and rotates about a fixed centre at an angular velocity ω_0. If the length of the string and angular velocity are doubled, the tension in the string which was initially T_0 is now

(a) T_0 (b) $T_0/2$

(c) $4T_0$ (d) $8T_0$

116. In 1.0 *s*, a particle goes from point *A* to point *B*, moving in a semicircle of radius 1.0 *m* (see figure). The magnitude of the average velocity is **[IIT-JEE 1999]**

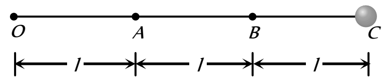


[DPMT 2003]

(a) $3.14 m/s$ (b) $2.0\ m/s$

(c) $1.0\ m/s$ (d) Zero

117. Three identical particles are joined together by a thread as shown in figure. All the three particles are moving in a horizontal plane. If the velocity of the outermost particle is *v*, then the ratio of tensions in the three sections of the string is



(a) 3 : 5 : 7 (b) 3 : 4 : 5

(c) 7 : 11 : 6 (d) 3 : 5 : 6

118. A particle is moving in a circle of radius *R* with constant speed *v*, if radius is double then its centripetal force to keep the same speed should be **[BCECE 2005]**

(a) Doubled

(b) Halved

(c) Quadrupled

(d) Unchanged

119. A stone ties to the end of a string $1m$ long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolution in 44 seconds, what is the magnitude and direction of acceleration of the stone **[CBSE PMT 2005]**

(a) $\frac{\pi^2}{4} ms^{-2}$ and direction along the radius towards the centre

(b) $\pi^2 ms^{-2}$ and direction along the radius away from the centre

(c) $\pi^2 ms^{-2}$ and direction along the radius towards the centre

(d) $\pi^2 ms^{-2}$ and direction along the tangent to the circle

120. A particle describes a horizontal circle in a conical funnel whose inner surface is smooth with speed of 0.5 *m/s*. What is the height of the plane of circle from vertex of the funnel ? **[J&K CET 2005]**

(a) 0.25 *cm* (b) 2 *cm*

(c) 4 *cm* (d) 2.5 *cm*

121. What is the angular velocity of earth **[Orissa JEE 2005]**

(a) $\frac{2\pi}{86400} rad/\sec$ (b) $\frac{2\pi}{3600} rad/\sec$

(c) $\frac{2\pi}{24} rad/\sec$ **[AIIMS 1985]** (d) $\frac{2\pi}{6400} rad/\sec$

122. If the length of the second's hand in a stop clock is 3 *cm* the angular velocity and linear velocity of the tip is **[Kerala PET 2005]**

(a) 0.2047 *rad/sec.*, 0.0314 *m/sec*

(b) 0.2547 *rad/sec.*, 0.314 *m/sec*

(c) 0.1472 *rad/sec.*, 0.06314 *m/sec*

(d) 0.1047 *rad/sec.*, 0.00314 *m/sec*

Non-uniform Circular Motion

1. In a circus stuntman rides a motorbike in a circular track of radius R in the vertical plane. The minimum speed at highest point of track will be

[CPMT 1979; JIPMER 1997; RPET 1999]

(a) $\sqrt{2gR}$ (b) $2gR$

(c) $\sqrt{3gR}$ (d) $\sqrt{gR}$

2. A block of mass m at the end of a string is whirled round in a vertical circle of radius R. The critical speed of the block at the top of its swing below which the string would slacken before the block reaches the top is [DCE 1999, 2001]

(a) Rg (b) $(Rg)^2$

(c) R/g (d) $\sqrt{Rg}$

3. A sphere is suspended by a thread of length l. What minimum horizontal velocity has to be imparted the ball for it to reach the height of the suspension

[ISM Dhanbad 1994]

(a) gl (b) $2gl$

(c) $\sqrt{gl}$ (d) $\sqrt{2gl}$

4. A bottle of sodawater is grasped by the neck and swing briskly in a vertical circle. Near which portion of the bottle do the bubbles collect

(a) Near the bottom

(b) In the middle of the bottle

(c) Near the neck

(d) Uniformly distributed in the bottle

5. A bucket tied at the end of a 1.6 m long string is whirled in a vertical circle with constant speed. What should be the minimum speed so that the water from the bucket does not spill, when the bucket is at the highest position (Take $g = 10 m/\sec^2$)

(a) 4 *m/sec* (b) 6.25 *m/sec*

(c) 16 *m/sec* (d) None of the above

6. A wheel is subjected to uniform angular acceleration about its axis. Initially its angular velocity is zero. In the first 2 *sec*, it rotates through an angle θ_1. In the next 2 *sec*, it rotates through an additional angle θ_2. The ratio of θ_2/θ_1 is

[AIIMS 1985]

(a) 1 (b) 2

(c) 3 (d) 5

7. A 1 *kg* stone at the end of 1 *m* long string is whirled in a vertical circle at constant speed of 4 *m/sec*. The tension in the string is 6 *N*, when the stone is at (g = 10 *m/sec*)

[AIIMS 1982]

(a) Top of the circle (b) Bottom of the circle

(c) Half way down (d) None of the above

8. A cane filled with water is revolved in a vertical circle of radius 4 *meter* and the water just does not fall down. The time period of revolution will be [CPMT 1985;

RPET 1995; UPSEAT 2002; MH CET 2002]

(a) 1 *sec* (b) 10 *sec*

(c) 8 *sec* (d) 4 *sec*

9. A 2 *kg* stone at the end of a string 1 *m* long is whirled in a vertical circle at a constant speed. The speed of the stone is 4 *m/sec*. The tension in the string will be 52 *N*, when the stone is

(a) At the top of the circle

(b) At the bottom of the circle

(c) Halfway down

(d) None of the above

10. A body slides down a frictionless track which ends in a circular loop of diameter D, then the minimum height h of the body in term of D so that it may just complete the loop, is

(a) $h = \frac{5D}{2}$ (b) $h = \frac{5D}{4}$

(c) $h = \frac{3D}{4}$ (d) $h = \frac{D}{4}$

11. A car is moving with speed 30 $m/\sec$ on a circular path of radius 500 *m*. Its speed is increasing at the rate of $2m/\sec^2$, What is the acceleration of the car

[MP PMT 2003; Roorkee 1982; RPET 1996; MH CET 2002]

(a) $2m/\sec^2$ (b) $2.7m/\sec^2$

(c) $1.8m/\sec^2$ (d) $9.8\,m/\sec^2$

12. The string of pendulum of length l is displaced through 90^o from the vertical and released. Then the minimum strength of the string in order to withstand the tension, as the pendulum passes through the mean position is

[MP PMT 1986]

(a) mg (b) $3mg$

[AIIMS 1987]

(c) $5\,mg$ (d) $6\,mg$

13. A weightless thread can support tension upto 30 *N*. A stone of mass 0.5 *kg* is tied to it and is revolved in a circular path of radius 2 *m* in a vertical plane. If $g = 10m/s^2$, then the maximum angular velocity of the stone will be

[MP PMT 1994]

(a) $5\ rad/s$ (b) $\sqrt{30}\ rad/s$

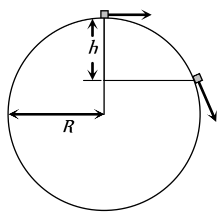
(c) $\sqrt{60}\ rad/s$ (d) $10\,rad/s$

14. A particle originally at rest at the highest point of a smooth vertical circle is slightly displaced. It will leave the circle at a vertical distance h below the highest point such that

(a) $h = R$

(b) $h = \frac{R}{3}$

(c) $h = \frac{R}{2}$



(d) $h = \frac{2R}{3}$

15. A heavy mass is attached to a thin wire and is whirled in a vertical circle. The wire is most likely to break

[MP PET 1997]

(a) When the mass is at the highest point of the circle

(b) When the mass is at the lowest point of the circle

(c) When the wire is horizontal

(d) At an angle of $\cos^{-1}(1/3)$ from the upward vertical

16. A weightless thread can bear tension upto 3.7 *kg wt*. A stone of mass 500 *gms* is tied to it and revolved in a circular path of radius 4 *m* in a vertical plane. If $g = 10\, ms^{-2}$, then the maximum angular velocity of the stone will be

[MP PMT/PET 1998]

(a) 4 *radians/sec* (b) 16 *radians/sec*

(c) $\sqrt{21}$ *radians/sec* (d) 2 *radians/sec*

17. The maximum velocity at the lowest point, so that the string just slack at the highest point in a vertical circle of radius l

[CPMT 1999; MH CET 2004]

(a) $\sqrt{gl}$ (b) $\sqrt{3gl}$

(c) $\sqrt{5gl}$ (d) $\sqrt{7gl}$

18. If the equation for the displacement of a particle moving on a circular path is given by $(\theta) = 2t^3 + 0.5$, where θ is in radians and t in seconds, then the angular velocity of the particle after 2 *sec* from its start is [AIIMS 1998]

(a) 8 *rad/sec* (b) 12 *rad/sec*

(c) 24 *rad/sec* (d) 36 *rad/sec*

19. A body of mass m hangs at one end of a string of length *l*, the other end of which is fixed. It is given a horizontal velocity so that the string would just reach where it makes an angle of 60^o with the vertical. The tension in the string at mean position is

(a) $2mg$ (b) mg

(c) $3mg$ (d) $\sqrt{3}mg$

20. In a vertical circle of radius *r*, at what point in its path a particle has tension equal to zero if it is just able to complete the vertical circle

(a) Highest point

(b) Lowest point

(c) Any point

(d) At a point horizontally from the centre of circle of radius *r*

21. The tension in the string revolving in a vertical circle with a mass m at the end which is at the lowest position

[EAMCET (Engg.) 1995; AIIMS 2001]

(a) $\frac{mv^2}{r}$ (b) $\frac{mv^2}{r} - mg$

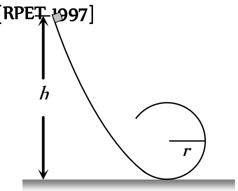
(c) $\frac{mv^2}{r} + mg$ (d) mg

22. A hollow sphere has radius 6.4 *m*. Minimum velocity required by a motor cyclist at bottom to complete the circle will be

(a) 17.7 *m/s* (b) 10.2 *m/s*

(c) 12.4 *m/s* (d) 16.0 *m/s*

23. A block follows the path as shown in the figure from height h. If radius of circular path is r, then relation that holds good to complete full circle is [RPET 1997]



(a) $h < 5r/2$

(b) $h > 5r/2$

(c) $h = 5r/2$

(d) $h \geq 5r/2$

24. A pendulum bob on a 2 *m* string is displaced 60° from the vertical and then released. What is the speed of the bob as it passes through the lowest point in its path [JIPMER 1999]

(a) $\sqrt{2}\ m/s$ (b) $\sqrt{9.8}\ m/s$

(c) 4.43 *m/s* (d) $1/\sqrt{2}\ m/s$

25. A fan is making 600 revolutions per *minute*. If after some time it makes 1200 revolutions per *minute*, then increase in its angular velocity is [BHU 1999]

(a) $10\pi\, rad/\sec$ (b) $20\pi\, rad/\sec$

(c) $40\pi\, rad/\sec$ (d) $60\pi\, rad/\sec$

26. A particle is tied to 20*cm* long string. It performs circular motion in vertical plane. What is the angular velocity of string when the tension in the string at the top is zero

[RPMT 1999]

(a) $5\, rad/sec$ (b) $2\, rad/sec$

(c) $7.5\, rad/sec$ (d) $7\, rad/sec$

27. A stone tied with a string, is rotated in a vertical circle. The minimum speed with which the string has to be rotated

[CBSE PMT 1999]

(a) Is independent of the mass of the stone

(b) Is independent of the length of the string

(c) Decreases with increasing mass of the stone

(d) Decreases with increasing in length of the string

28. For a particle in a non-uniform accelerated circular motion

[ISM Dhanbad 1994] [AMU (Med.) 2000]

(a) Velocity is radial and acceleration is transverse only

(b) Velocity is transverse and acceleration is radial only

(c) Velocity is radial and acceleration has both radial and transverse components

(d) Velocity is transverse and acceleration has both radial and transverse components [EAMCET 1994]

29. A fighter plane is moving in a vertical circle of radius '*r*'. Its minimum velocity at the highest point of the circle will be

[MP PET 2000]

(a) $\sqrt{3gr}$ (b) $\sqrt{2gr}$

(c) $\sqrt{gr}$ (d) $\sqrt{gr/2}$

30. A ball is moving to and fro about the lowest point *A* of a smooth hemispherical bowl. If it is able to rise up to a height of 20 *cm* on either side of *A*, its speed at *A* must be (Take = 10 *m/s*, mass of the body 5 *g*) [JIPMER 2000]

(a) 0.2 *m/s* (b) 2 *m/s*

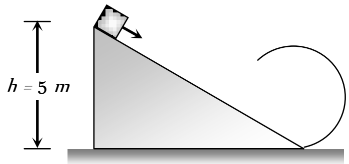
(c) 4 *m/s* (d) 4.5 *ms*

31. A stone of mass *m* is tied to a string and is moved in a vertical circle of radius *r* making *n* revolutions per *minute*. The total tension in the string when the stone is at its lowest point is [RPET 1997]

(a) *mg* (b) $m(g + \pi n r^2)$

(c) $m(g+\pi n r)$ (d) $m\{g+(\pi^2 n^2 r)/900\}$

32. As per given figure to complete the circular loop what should be the radius if initial height is 5 *m* **[RPET 2001]**



(a) 4 *m*
(b) 3 *m*
(c) 2.5 *m*
(d) 2 *m*

33. A coin, placed on a rotating turn-table slips, when it is placed at a distance of 9 *cm* from the centre. If the angular velocity of the turn-table is trippled, it will just slip, if its distance from the centre is **[CPMT 2001]**

(a) 27 *cm* (b) 9 *cm*
(c) 3 *cm* (d) 1 *cm*

34. When a ceiling fan is switched off its angular velocity reduces to 50% while it makes 36 rotations. How many more rotation will it make before coming to rest (Assume uniform angular retardation)

(a) 18 (b) 12
(c) 36 (d) 48

35. A body crosses the topmost point of a vertical circle with critical speed. Its centripetal acceleration, when the string is horizontal will be **[MH CET 2002]**

(a) 6 *g* (b) 3 *g*
(c) 2 *g* (d) *g*

36. A simple pendulum oscillates in a vertical plane. When it passes through the mean position, the tension in the string is 3 times the weight of the pendulum bob. What is the maximum displacement of the pendulum of the string with respect to the vertical

(a) 30° (b) 45°
(c) 60° (d) 90°

37. A particle is moving in a vertical circle. The tensions in the string when passing through two positions at angles 30° and 60° from vertical (lowest position) are T_1 and T_2 respectively. then

(a) $T_1 = T_2$
(b) $T_2 > T_1$
(c) $T_1 > T_2$
(d) Tension in the string always remains the same

38. A particle is kept at rest at the top of a sphere of diameter 42 *m*. When disturbed slightly, it slides down. At what height '*h*' from the bottom, the particle will leave the sphere **[BHU 2003]**

(a) 14 *m* (b) 28 *m*
(c) 35 *m* (d) 7 *m*

39. The coordinates of a moving particle at any time '*t*' are given by $x = \alpha t$ and $y = \beta t$. The speed of the particle at time '*t*' is given by

(a) $\sqrt{\alpha^2+\beta^2}$ (b) $3t\sqrt{\alpha^2+\beta^2}$
(c) $3t^2\sqrt{\alpha^2+\beta^2}$ (d) $t^2\sqrt{\alpha^2+\beta^2}$

40. A small disc is on the top of a hemisphere of radius R. What is the smallest horizontal velocity *v* that should be given to the disc for it to leave the hemisphere and not slide down it ? [There is no friction] **[CPMT 1991]**

(a) $v=\sqrt{2gR}$ (b) $v=\sqrt{gR}$
(c) $v=\dfrac{g}{R}$ (d) $v=\sqrt{g^2R}$

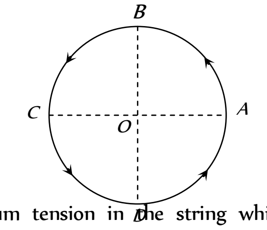
41. A body of mass 0.4 *kg* is whirled in a vertical circle making 2 *rev/sec*. If the radius of the circle is 2 *m*, then tension in the string when the body is at the top of the circle, is **[CBSE PMT 1999]**

(a) 41.56 *N* (b) 89.86 *N*
(c) 109.86 *N* (d) 115.86 *N*

42. A bucket full of water is revolved in vertical circle of radius 2*m*. What should be the maximum time-period of revolution so that the water doesn't fall off the bucket **[AFMC 2004]**

(a) 1 *sec* (b) 2 *sec*
(c) 3 *sec* (d) 4 *sec*

43. Figure shows a body of mass *m* moving with a uniform speed *v* along a circle of radius *r*. The change in velocity in going from *A* to *B* is **[DPMT 2004]**



(a) $v\sqrt{2}$
(b) $v/\sqrt{2}$ **[KCET 2001]**
(c) *v*
(d) zero

44. The maximum and minimum tension in the string whirling in a circle of radius 2.5 *m* with constant velocity are in the ratio 5 : 3 then its velocity is **[Pb. PET 2003]**

(a) $\sqrt{98}\ m/s$ (b) $7\ m/s$
(c) $\sqrt{490}\ m/s$ (d) $\sqrt{4.9}$

45. For a particle in circular motion the centripetal acceleration is **[Orissa JEE 2002]**

(a) Less than its tangential acceleration
(b) Equal to its tangential acceleration
(c) More than its tangential acceleration
(d) May be more or less than its tangential acceleration

46. A particle moves in a circular path with decreasing speed. Choose the correct statement. **[Orissa JEE 2002]** **[IIT JEE 2005]**

(a) Angular momentum remains constant
(b) Acceleration ($\vec{a}$) is towards the center
(c) Particle moves in a spiral path with decreasing radius
(d) The direction of angular momentum remains constant

47. A body of mass 1 *kg* is moving in a vertical circular path of radius 1*m*. The difference between the kinetic energies at its highest and lowest position is

(a) 20*J* (b) 10*J*
(c) $4\sqrt{5}J$ **[AIEEE 2003]** (d) $10(\sqrt{5}-1)J$

48. The angle turned by a body undergoing circular motion depends on time as $\theta=\theta_0+\theta_1 t+\theta_2 t^2$. Then the angular acceleration of the body is **[Orissa JEE 2005]**

(a) θ_1 (b) θ_2
(c) $2\theta_1$ (d) $2\theta_2$

Horizontal Projectile Motion

1. The maximum range of a gun on horizontal terrain is 16 *km*. If $g=10 m/s^2$. What must be the muzzle velocity of the shell

(a) 200 *m/s* (b) 400 *m/s*

(c) 100 *m/s* (d) 50 *m/s*

2. A stone is just released from the window of a train moving along a horizontal straight track. The stone will hit the ground following [NCERT 1972; AFMC 1996; BHU 2000]

(a) Straight path (b) Circular path

(c) Parabolic path (d) Hyperbolic path

3. A bullet is dropped from the same height when another bullet is fired horizontally. They will hit the ground

(a) One after the other (b) Simultaneously

(c) Depends on the observer (d) None of the above

4. An aeroplane is flying at a constant horizontal velocity of 600 *km/hr* at an elevation of 6 *km* towards a point directly above the target on the earth's surface. At an appropriate time, the pilot releases a ball so that it strikes the target at the earth. The ball will appear to be falling [MP PET 1993]

(a) On a parabolic path as seen by pilot in the plane

(b) Vertically along a straight path as seen by an observer on the ground near the target

(c) On a parabolic path as seen by an observer on the ground near the target

(d) On a zig-zag path as seen by pilot in the plane

5. A bomb is dropped from an aeroplane moving horizontally at constant speed. When air resistance is taken into consideration, the bomb

[EAMCET (Med.) 1995; AFMC 1999]

(a) Falls to earth exactly below the aeroplane

(b) Fall to earth behind the aeroplane

(c) Falls to earth ahead of the aeroplane

(d) Flies with the aeroplane

6. A man projects a coin upwards from the gate of a uniformly moving train. The path of coin for the man will be

[RPET 1997]

(a) Parabolic (b) Inclined straight line

(c) Vertical straight line (d) Horizontal straight line

7. An aeroplane is flying horizontally with a velocity of 600 *km/h* at a height of 1960 *m*. When it is vertically at a point A on the ground, a bomb is released from it. The bomb strikes the ground at point *B*. The distance *AB* is

[CPMT 1996; JIPMER 2001, 02]

(a) 1200 *m* (b) 0.33 *km*

(c) 3.33 *km* (d) 33 *km*

8. A ball is rolled off the edge of a horizontal table at a speed of 4 *m/second*. It hits the ground after 0.4 *second*. Which statement given below is true [AMU (Med.) 1999]

(a) It hits the ground at a horizontal distance 1.6 *m* from the edge of the table

(b) The speed with which it hits the ground is 4.0 *m/second*

(c) Height of the table is 0.8 *m*

(d) It hits the ground at an angle of 60° to the horizontal

9. An aeroplane flying 490 *m* above ground level at 100 *m/s*, releases a block. How far on ground will it strike

[RPMT 2000]

(a) 0.1 *km* (b) 1 *km*

(c) 2 *km* (d) None

10. A body is thrown horizontally from the top of a tower of height 5 *m*. It touches the ground at a distance of 10 *m* from the foot of the tower. The initial velocity of the body is ($g = 10\ ms^{-2}$)

(a) 2.5 ms^{-1} (b) 5 ms^{-1}

(c) 10 ms^{-1} (d) 20 ms^{-1}

11. An aeroplane moving horizontally with a speed of 720 *km/h* drops a food pocket, while flying at a height of 396.9 *m*. the time taken by a food pocket to reach the ground and its horizontal range is (Take $g = 9.8\ m/sec^2$) [AFMC 2001]

(a) 3 *sec* and 2000 *m* (b) 5 *sec* and 500 *m*

(c) 8 *sec* and 1500 *m* (d) 9 *sec* and 1800 *m*

12. A particle (*A*) is dropped from a height and another particle (*B*) is thrown in horizontal direction with speed of 5 *m/sec* from the same height. The correct statement is

[CBSE PMT 2002; Orissa JEE 2003]

(a) Both particles will reach at ground simultaneously

(b) Both particles will reach at ground with same speed

(c) Particle (*A*) will reach at ground first with respect to particle (*B*)

(d) Particle (*B*) will reach at ground first with respect to particle (*A*)

13. A particle moves in a plane with constant acceleration in a direction different from the initial velocity. The path of the particle will be [MP PMT 200

(a) A straight line (b) An arc of a circle

(c) A parabola (d) An ellipse

14. At the height 80 *m*, an aeroplane is moving with 150 *m/s*. A bomb is dropped from it so as to hit a target. At what distance from the target should the bomb be dropped (given $g = 10\ m/s^2$)

(a) 605.3 *m* (b) 600 *m*

(c) 80 *m* (d) 230 *m*

15. A bomber plane moves horizontally with a speed of 500 *m/s* and a bomb released from it, strikes the ground in 10 sec. Angle at which it strikes the ground will be $(g = 10\ m/s^2)$

[MH CET 2003]

(a) $\tan^{-1}\left(\frac{1}{5}\right)$ (b) $\tan\left(\frac{1}{5}\right)$

(c) $\tan^{-1}(1)$ (d) $\tan^{-1}(5)$

16. A large number of bullets are fired in all directions with same speed v. What is the maximum area on the ground on which these bullets will spread

(a) $\pi \frac{v^2}{g}$ (b) $\pi \frac{v^4}{g^2}$

(c) $\pi^2 \frac{v^4}{g^2}$ (d) $\pi^2 \frac{v^2}{g^2}$

Oblique Projectile Motion

1. A projectile fired with initial velocity u at some angle θ has a range R. If the initial velocity be doubled at the same angle of projection, then the range will be
(a) $2R$ (b) $R/2$
(c) R (d) $4R$

2. If the initial velocity of a projectile be doubled, keeping the angle of projection same, the maximum height reached by it will
(a) Remain the same (b) Be doubled
(c) Be quadrupled (d) Be halved

3. In the motion of a projectile freely under gravity, its
(a) Total energy is conserved
(b) Momentum is conserved
(c) Energy and momentum both are conserved
(d) None is conserved

4. The range of a projectile for a given initial velocity is maximum when the angle of projection is 45^o. The range will be minimum, if the angle of projection is
(a) 90^o (b) 180^o
(c) 60^o (d) 75^o

5. The angle of projection at which the horizontal range and maximum height of projectile are equal is
[Kurukshetra CEE 1996; BCECE 2003; Pb. PET 2001]
(a) 45^o (b) $\theta = \tan^{-1}(0.25)$
(c) $\theta = \tan^{-1} 4$ or $(\theta = 76°)$ (d) 60^o

6. A ball is thrown upwards and it returns to ground describing a parabolic path. Which of the following remains constant
[BHU 1999; DPMT 2001; AMU (Engg.) 2000]
(a) Kinetic energy of the ball
(b) Speed of the ball
(c) Horizontal component of velocity
(d) Vertical component of velocity

7. At the top of the trajectory of a projectile, the directions of its velocity and acceleration are
(a) Perpendicular to each other
(b) Parallel to each other
(c) Inclined to each other at an angle of 45^o
(d) Antiparallel to each other

8. An object is thrown along a direction inclined at an angle of 45^o with the horizontal direction. The horizontal range of the particle is equal to [MP PMT 1985]
(a) Vertical height
(b) Twice the vertical height
(c) Thrice the vertical height
(d) Four times the vertical height

9. The height y and the distance x along the horizontal plane of a projectile on a certain planet (with no surrounding atmosphere) are given by $y = (8t - 5t^2)$ *meter* and $x = 6t$ *meter*, where t is in second. The velocity with which the projectile is projected is[CPMT 1981; MP PET
(a) 8 *m/sec*
(b) 6 *m/sec*
(c) 10 *m/sec*
(d) Not obtainable from the data

10. Referring to above question, the angle with the horizontal at which the projectile was projected is [CPMT 1981]
(a) $\tan^{-1}(3/4)$
(b) $\tan^{-1}(4/3)$
(c) $\sin^{-1}(3/4)$
(d) Not obtainable from the given data

11. Referring to the above two questions, the acceleration due to gravity is given by [CPMT 1981]
(a) $10\, m/\sec^2$ (b) $5m/\sec^2$
(c) $20\ m/\sec^2$ (d) $2.5\ m/\sec^2$

12. The range of a particle when launched at an angle of 15^o with the horizontal is 1.5 *km*. What is the range of the projectile when launched at an angle of 45^o to the horizontal
(a) 1.5 *km* (b) 3.0 *km*
(c) 6.0 *km* (d) 0.75 *km*

13. A cricketer hits a ball with a velocity $25\ m/s$ at 60^o above the horizontal. How far above the ground it passes over a fielder 50 m from the bat (assume the ball is struck very close to the ground)
(a) 8.2 m (b) 9.0 m
(c) 11.6 m (d) 12.7 m

14. A stone is projected from the ground with velocity $25\, m/s$. Two seconds later, it just clears a wall 5 m high. The angle of projection of the stone is $(g = 10 m/\sec^2)$
(a) 30^o (b) 45^o
(c) 50.2^o (d) 60^o

15. Galileo writes that for angles of projection of a projectile at angles $(45+\theta)$ and $(45-\theta)$, the horizontal ranges described by the projectile are in the ratio of (if $\theta \le 45$)
[MP PET 1993]
(a) 2 : 1 (b) 1 : 2
(c) 1 : 1 (d) 2 : 3

16. A projectile thrown with a speed v at an angle θ has a range R on the surface of earth. For same v and θ, its range on the surface of moon will be
(a) $R/6$ (b) $6R$
(c) $R/36$ (d) $36R$

17. The greatest height to which a man can throw a stone is h. The greatest distance to which he can throw it, will be

(a) $\frac{h}{2}$ (b) h

(c) $2h$ (d) $3h$

18. The horizontal range is four times the maximum height attained by a projectile. The angle of projection is

[MP PET 1994; CBSE PMT 2000; RPET 2001]

(a) 90^o (b) 60^o

(c) 45^o (d) 30^o

19. A ball is projected with kinetic energy E at an angle of 45^o to the horizontal. At the highest point during its flight, its kinetic energy will be

[MP PMT 1994; CBSE PMT 1997, 2001; AIEEE 2002; Pb. PMT 2004; Orissa PMT 2004]

(a) Zero (b) $\frac{E}{2}$

(c) $\frac{E}{\sqrt{2}}$ (d) E

20. A particle of mass m is projected with velocity v making an angle of 45^o with the horizontal. The magnitude of the angular momentum of the particle about the point of projection when the particle is at its maximum height is (where $g =$ acceleration due to gravity)

[MP PMT 1994; MP PET 2001; Pb. PET 2004]

(a) Zero (b) $mv^3/(4\sqrt{2}g)$

(c) $mv^3/(\sqrt{2}g)$ (d) $mv^2/2g$

21. A particle reaches its highest point when it has covered exactly one half of its horizontal range. The corresponding point on the displacement time graph is characterised by

[AIIMS 1995]

(a) Negative slope and zero curvature

(b) Zero slope and negative curvature

(c) Zero slope and positive curvature

(d) Positive slope and zero curvature

22. At the top of the trajectory of a projectile, the acceleration is

(a) Maximum (b) Minimum

(c) Zero (d) g

23. When a body is thrown with a velocity u making an angle θ with the horizontal plane, the maximum distance covered by it in horizontal direction is [MP PMT 1996; RPET 2001]

(a) $\frac{u^2 \sin\theta}{g}$ (b) $\frac{u^2 \sin 2\theta}{2g}$

(c) $\frac{u^2 \sin 2\theta}{g}$ (d) $\frac{u^2 \cos 2\theta}{g}$

24. A football player throws a ball with a velocity of 50 *metre/sec* at an angle 30 degrees from the horizontal. The ball remains in the air for $(g = 10\, m/s^2)$

(a) 2.5 *sec* (b) 1.25 *sec*

(c) 5 *sec* (d) 0.625 *sec*

25. A body of mass 0.5 *kg* is projected under gravity with a speed of 98 *m/s* at an angle of 30^o with the horizontal. The change in momentum (in magnitude) of the body is

[MP PET 1997]

(a) $24.5\, N-s$ (b) $49.0\, N-s$

(c) $98.0\, N-s$ (d) $50.0\, N-s$

26. A body is projected at such an angle that the horizontal range is three times the greatest height. The angle of projection is [AIIM

(a) $25^o 8'$ (b) $33^o 7'$

(c) $42^o 8'$ (d) $53^o 8'$

27. A gun is aimed at a target in a line of its barrel. The target is released and allowed to fall under gravity at the same instant the gun is fired. The bullet will [EAMCET 1994]

(a) Pass above the target (b) Pass below the target

(c) Hit the target (d) Certainly miss the target

28. Two bodies are projected with the same velocity. If one is projected at an angle of 30^o and the other at an angle of 60^o to the horizontal, the ratio of the maximum heights reached is

[AIIMS 2001; EAMCET (Med.) 1995; Pb. PMT 2000]

(a) 3 : 1 (b) 1 : 3

(c) 1 : 2 (d) 2 : 1

29. If the range of a gun which fires a shell with muzzle speed V is R, then the angle of elevation of the gun is [AMU 1995]

(a) $\cos^{-1}\left(\frac{V^2}{Rg}\right)$ (b) $\cos^{-1}\left(\frac{gR}{V^2}\right)$

(c) $\frac{1}{2}\left(\frac{V^2}{Rg}\right)$ (d) $\frac{1}{2}\sin^{-1}\left(\frac{gR}{V^2}\right)$

30. If time of flight of a projectile is 10 seconds. Range is 500 *meters*. The maximum height attained by it will be

[RPMT 1997]

(a) 125 *m* (b) 50 *m*

(c) 100 *m* (d) 150 *m*

31. If a body *A* of mass *M* is thrown with velocity *V* at an angle of 30^o to the horizontal and another body *B* of the same mass is thrown with the same speed at an angle of 60^o to the horizontal. The ratio of horizontal range of *A* to *B* will be

[CBSE PMT 1992]

(a) 1 : 3 [Manipal MEE 1995] (b) 1 : 1

(c) $1:\sqrt{3}$ (d) $\sqrt{3}:1$

32. A bullet is fired from a cannon with velocity 500 *m/s*. If the angle of projection is 15^o and $g = 10 m/s^2$. Then the range is

(a) $25 \times 10^3 m$ (b) $12.5 \times 10^3 m$

(c) $50 \times 10^2 m$ (d) $25 \times 10^2 m$

33. A ball thrown by a boy is caught by another after 2 *sec*. some distance away in the same level. If the angle of projection is 30◦, the velocity of projection is [JIPMER 1999]

(a) 19.6 *m/s* (b) 9.8 *m/s*

(c) 14.7 *m/s* (d) None of these

34. A particle covers 50 *m* distance when projected with an initial speed. On the same surface it will cover a distance, when projected with double the initial speed [RPMT 2000]

(a) 100 *m* (b) 150 *m*

(c) 200 *m* (d) 250 *m*

35. A ball is thrown upwards at an angle of 60◦ to the horizontal. It falls on the ground at a distance of 90 *m*. If the ball is thrown with the same initial velocity at an angle 30°, it will fall on the ground at a distance of [BHU 2000]

(a) 30 *m* (b) 60 *m*
(c) 90 *m* (d) 120 *m*

36. Four bodies *P, Q, R* and *S* are projected with equal velocities having angles of projection 15°, 30°, 45° and 60° with the horizontal respectively. The body having shortest range is

(a) *P* (b) *Q*
(c) *R* (d) *S*

37. For a projectile, the ratio of maximum height reached to the square of flight time is (g = 10 ms^{-2}) [EAMCET (Med.) 2000]

(a) 5 : 4 (b) 5 : 2
(c) 5 : 1 (d) 10 : 1

38. A stone projected with a velocity u at an angle θ with the horizontal reaches maximum height H_1. When it is projected with velocity u at an angle $\left(\frac{\pi}{2}-\theta\right)$ with the horizontal, it reaches maximum height H_2. The relation between the horizontal range R of the projectile, H_1 and H_2 is

(a) $R = 4\sqrt{H_1 H_2}$ (b) $R = 4(H_1 - H_2)$
(c) $R = 4(H_1 + H_2)$ (d) $R = \frac{H_1^2}{H_2^2}$

39. An object is projected with a velocity of 20 *m/s* making an angle of 45° with horizontal. The equation for the trajectory is $h = Ax - Bx^2$ where h is height, x is horizontal distance, A and B are constants. The ratio $A : B$ is (g = 10 ms^{-2}) [EAMCET 2001]

(a) 1 : 5 (b) 5 : 1
(c) 1 : 40 (d) 40 : 1

40. Which of the following sets of factors will affect the horizontal distance covered by an athlete in a long–jump event

(a) Speed before he jumps and his weight
(b) The direction in which he leaps and the initial speed
(c) The force with which he pushes the ground and his speed
(d) None of these

41. A ball thrown by one player reaches the other in 2 *sec*. the maximum height attained by the ball above the point of projection will be about [Pb. PMT 2002]

(a) 10 *m* (b) 7.5 *m*
(c) 5 *m* (d) 2.5 *m*

42. In a projectile motion, velocity at maximum height is [AIEEE 2002]

(a) $\frac{u\cos\theta}{2}$ (b) $u\cos\theta$
(c) $\frac{u\sin\theta}{2}$ (d) None of these

43. If two bodies are projected at 30° and 60° respectively, with the same velocity, then [JIPMER 2002; CBSE PMT 2000]

(a) Their ranges are same
(b) Their heights are same
(c) Their times of flight are same
(d) All of these

44. A body is thrown with a velocity of 9.8 *m/s* making an angle of 30° with the horizontal. It will hit the ground after a time [JIPMER 2001, 2002; KCET 2001]

(a) 1.5 *s* (b) 1 *s*
(c) 3 *s* (d) 2 *s*

45. The equation of motion of a projectile are given by $x = 36\ t$ *metre* and $2y = 96\ t - 9.8\ t^2$ *metre*. The angle of projection is [EAMCET (Engg.) 2000]

(a) $\sin^{-1}\left(\frac{4}{5}\right)$ (b) $\sin^{-1}\left(\frac{3}{5}\right)$
(c) $\sin^{-1}\left(\frac{4}{3}\right)$ (d) $\sin^{-1}\left(\frac{3}{4}\right)$

46. For a given velocity, a projectile has the same range R for two angles of projection if t_1 and t_2 are the times of flight in the two cases then [KCET 2003;

(a) $t_1 t_2 \propto R^2$ (b) $t_1 t_2 \propto R$
(c) $t_1 t_2 \propto \frac{1}{R}$ (d) $t_1 t_2 \propto \frac{1}{R^2}$

47. A body of mass m is thrown upwards at an angle θ with the horizontal with velocity v. While rising up the velocity of the mass after *t seconds* will be [AMU (Engg.) 1999] [EAMCET 2000]

(a) $\sqrt{(v\cos\theta)^2 + (v\sin\theta)^2}$
(b) $\sqrt{(v\cos\theta - v\sin\theta)^2 - gt}$
(c) $\sqrt{v^2 + g^2t^2 - (2v\sin\theta)gt}$
(d) $\sqrt{v^2 + g^2t^2 - (2v\cos\theta)gt}$

48. A cricketer can throw a ball to a maximum horizontal distance of 100 *m*. With the same effort, he throws the ball vertically upwards. The maximum height attained by the ball is

(a) 100 *m* (b) 80 *m*
(c) 60 *m* (d) 50 *m*

49. A cricketer can throw a ball to a maximum horizontal distance of 100 *m*. The speed with which he throws the ball is (to the nearest integer) [Kerala (Med.) 2002] [AMU (Engg.) 2001]

(a) 30 ms^{-1} (b) 42 ms^{-1}
(c) 32 ms^{-1} (d) 35 ms^{-1}

50. A ball is projected with velocity V_o at an angle of elevation 30°. Mark the correct statement [MP PMT 2004]

(a) Kinetic energy will be zero at the highest point of the trajectory
(b) Vertical component of momentum will be conserved
(c) Horizontal component of momentum will be conserved
(d) Gravitational potential energy will be minimum at the highest point of the trajectory

51. Neglecting the air resistance, the time of flight of a projectile is determined by [J & K CET 2004]

(a) $U_{vertical}$
(b) $U_{horizontal}$
(c) $U = U^2{}_{vertical} + U^2{}_{horizontal}$
(d) $U = U(U^2{}_{vertical} + U^2{}_{horizontal})^{1/2}$

52. A ball is thrown from a point with a speed v_o at an angle of projection θ. From the same point and at the same instant a person starts running with a constant speed $v_o/2$ to catch the ball. Will the person be able to catch the ball? If yes, what should be the angle of projection [AIEEE 2004]

(a) Yes, 60^o (b) Yes, 30^o
(c) No (d) Yes, 45^o

53. A stone is thrown at an angle θ to the horizontal reaches a maximum height *H*. Then the time of flight of stone will be [BCECE 2004]

(a) $\sqrt{\frac{2H}{g}}$ (b) $2\sqrt{\frac{2H}{g}}$

(c) $\frac{2\sqrt{2H\sin\theta}}{g}$ (d) $\frac{\sqrt{2H\sin\theta}}{g}$

54. The horizontal range of a projectile is $4\sqrt{3}$ times its maximum height. Its angle of projection will be [J & K CET 2004; DPMT 2003]

(a) 45^o (b) 60^o

(c) 90^o (d) 30^o

55. A ball is projected upwards from the top of tower with a velocity $50\ ms^{-1}$ making an angle 30^o with the horizontal. The height of tower is 70 *m*. After how many seconds from the instant of throwing will the ball reach the ground [DPMT 2004]

(a) 2 *s* (b) 5 *s*

(c) 7 *s* (d) 9 *s*

56. Two bodies are thrown up at angles of 45° and 60°, respectively, with the horizontal. If both bodies attain same vertical height, then the ratio of velocities with which these are thrown is

(a) $\sqrt{\frac{2}{3}}$ (b) $\frac{2}{\sqrt{3}}$

(c) $\sqrt{\frac{3}{2}}$ (d) $\frac{\sqrt{3}}{2}$

57. At what point of a projectile motion acceleration and velocity are perpendicular to each other [Orissa JEE 2005]

(a) At the point of projection

(b) At the point of drop

(c) At the topmost point

(d) Any where in between the point of projection and topmost point

58. An object is projected at an angle of 45° with the horizontal. The horizontal range and the maximum height reached will be in the ratio. [Kerala PET 2005]

(a) 1 : 2 (b) 2 : 1

(c) 1 : 4 (d) 4 : 1

59. The maximum horizontal range of a projectile is 400 *m*. The maximum value of height attained by it will be [AFMC 2005]

(a) 100 *m* (b) 200 *m*

(c) 400 *m* (d) 800 *m*

Critical Thinking

Objective Questions

1. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. It follows that

(a) Velocity is constant

(b) Acceleration is constant

(c) Kinetic energy is constant

(d) It moves in a circular path

2. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. The force exerted by the liquid at the other end is [IIT 1992]

(a) $\frac{ML\omega^2}{2}$ (b) $ML\omega^2$

(c) $\frac{ML\omega^2}{4}$ (d) $\frac{ML^2\omega^2}{2}$

3. The kinetic energy k of a particle moving along a circle of radius R depends on the distance covered s as $k = as^2$ where a is a constant. The force acting on the particle is [MNR 1992; JIPMER 2001, 02; AMU (Engg.) 1999]

(a) $2a\frac{s^2}{R}$ (b) $2as\left(1+\frac{s^2}{R^2}\right)^{1/2}$

(c) $2as$ [DPMT 2005] (d) $2a\frac{R^2}{s}$

4. A car is moving in a circular horizontal track of radius 10 *m* with a constant speed of 10 *m/sec*. A plumb bob is suspended from the roof of the car by a light rigid rod of length 1.00 *m*. The angle made by the rod with track is [IIT 1992]

(a) Zero (b) 30^o

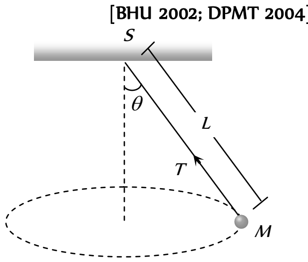
(c) 45^o (d) 60^o

5. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_c is varying with time *t* as, $a_c = k^2rt^2$, The power delivered to the particle by the forces acting on it is [IIT 1994]

(a) $2\pi mk^2r^2t$ (b) mk^2r^2t

(c) $\frac{mk^4r^2t^5}{3}$ (d) Zero

6. A string of length *L* is fixed at one end and carries a mass *M* at the other end. The string makes $2/\pi$ revolutions per *second* around the vertical axis through the fixed end as shown in the figure, then tension in the string is [BHU 2002; DPMT 2004]



(a) *ML*

(b) 2 *ML*

(c) 4 *ML*

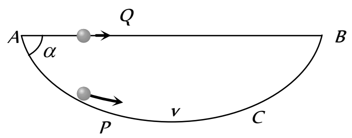
(d) 16 *ML*

7. A stone of mass 1 *kg* tied to a light inextensible string of length $L = \frac{10}{3}m$ is whirling in a circular path of radius L in a vertical plane. [IIT 1987] The ratio of the maximum tension in the string to the minimum tension in the string is 4 and if g is taken to be $10 m/\sec^2$, the speed of the stone at the highest point of the circle is [CBSE PMT 1990]

(a) $20 m/\sec$ (b) $10\sqrt{3} m/\sec$

(c) $5\sqrt{2}\ m/\sec$ (d) $10 m/\sec$

8. A particle P is sliding down a frictionless hemispherical bowl. It passes the point A at $t = 0$. At this instant of time, the horizontal component of its velocity is v. A bead Q of the same mass as P is ejected from A at $t = 0$ along the horizontal string AB (see figure) with the speed v. Friction between the bead and the string may be neglected. Let t_P and t_Q be the respective time taken by P and Q to reach the point B. Then



(a) $t_P < t_Q$

(b) $t_P = t_Q$

(c) $t_P > t_Q$

(d) All of these

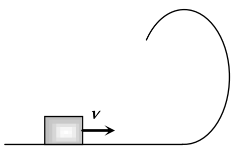
9. A long horizontal rod has a bead which can slide along its length, and initially placed at a distance L from one end A of the rod. The rod is set in angular motion about A with constant angular acceleration α. If the coefficient of friction between the rod and the bead is μ, and gravity is neglected, then the time after which the bead starts slipping is

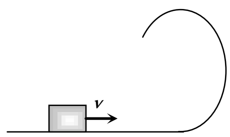
[IIT-JEE Screening 2000]

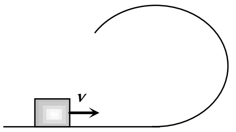
(a) $\sqrt{\frac{\mu}{\alpha}}$ (b) $\frac{\mu}{\sqrt{\alpha}}$

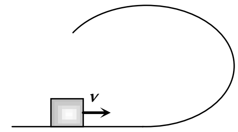
(c) $\frac{1}{\sqrt{\mu\alpha}}$ (d) Infinitesimal

10. A small block is shot into each of the four tracks as shown below. Each of the tracks rises to the same height. The speed with which the block enters the track is the same in all cases. At the highest point of the track, the normal reaction is maximum in

(a)


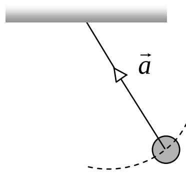
(b)


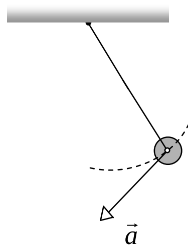
(c)


(d)


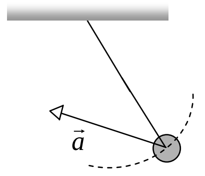
11. A simple pendulum is oscillating without damping. When the displacement of the bob is less than maximum, its acceleration vector $\vec{a}$ is correctly shown in

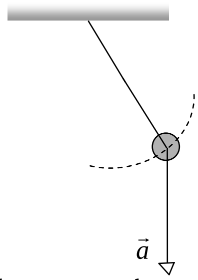
[IIT-JEE Screening 2002]





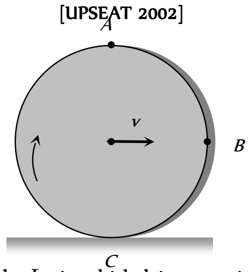
(a) (b)

(c)


(d)


[IIT 1993]

12. A solid disc rolls clockwise without slipping over a horizontal path with a constant speed υ. Then the magnitude of the velocities of points A, B and C (see figure) with respect to a standing observer are respectively [UPSEAT 2002]



(a) υ, υ and υ

(b) $2\upsilon, \sqrt{2}\upsilon$ and zero

(c) $2\upsilon, 2\upsilon$ and zero

(d) $2\upsilon, \sqrt{2}\upsilon$ and $\sqrt{2}\upsilon$

13. A stone tied to a string of length L is whirled in a vertical circle with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of the change in its velocity as it reaches a position where the string is horizontal is

[IIT 1998; CBSE PMT 2004]

(a) $\sqrt{u^2 - 2gL}$ (b) $\sqrt{2gL}$

(c) $\sqrt{u^2 - gl}$ (d) $\sqrt{2(u^2 - gL)}$

14. The driver of a car travelling at velocity v suddenly see a broad wall in front of him at a distance d. He should

[IIT 1977]

[IIT-JEE Screening 2001]

(a) Brake sharply (b) Turn sharply

(c) (a) and (b) both (d) None of the above

15. Four persons K, L, M and N are initially at the corners of a square of side of length d. If every person starts moving, such that K is always headed towards L, L towards M, M is headed directly towards N and N towards K, then the four persons will meet after [IIT 1984]

(a) $\frac{d}{v}$ *sec* (b) $\frac{\sqrt{2}d}{v}$ *sec*

(c) $\frac{d}{\sqrt{2}v}$ *sec* (d) $\frac{d}{2v}$ *sec*

16. The coordinates of a particle moving in a plane are given by $x(t) = a\cos(pt)$ and $y(t) = b\sin(pt)$ where $a, b (< a)$ and p are positive constants of appropriate dimensions. Then

[IIT-JEE 1999]

(a) The path of the particle is an ellipse

(b) The velocity and acceleration of the particle are normal to each other at $t = \pi/(2p)$

(c) The acceleration of the particle is always directed towards a focus

(d) The distance travelled by the particle in time interval $t = 0$ to $t = \pi/(2p)$ is a

17. A particle is moving eastwards with velocity of 5 *m/s*. In 10 *sec* the velocity changes to 5 *m/s* northwards. The average acceleration in this time is

[IIT 1982; AFMC 1999; Pb PET 2000; JIPMER 2001, 02]

(a) Zero

(b) $\frac{1}{\sqrt{2}}\ m/s^2$ toward north-west

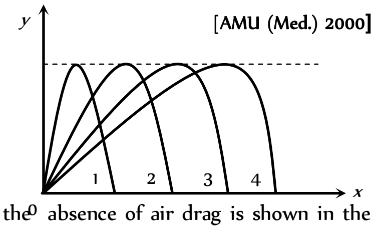
(c) $\frac{1}{\sqrt{2}}\ m/s^2$ toward north-east

(d) $\frac{1}{2}\ m/s^2$ toward north-west

Graphical Questions

1. Figure shows four paths for a kicked football. Ignoring the effects of air on the flight, rank the paths according to initial horizontal velocity component, highest first

[AMU (Med.) 2000]



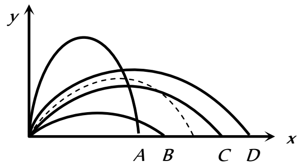
(a) 1, 2, 3, 4

(b) 2, 3, 4, 1

(c) 3, 4, 1, 2

(d) 4, 3, 2, 1

2. The path of a projectile in the absence of air drag is shown in the figure by dotted line. If the air resistance is not ignored then which one of the path shown in the figure is appropriate for the projectile



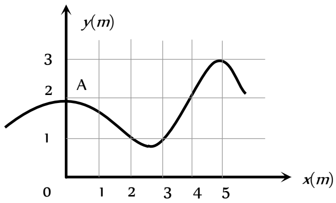
(a) B

(b) A

(c) D

(d) C

3. The trajectory of a particle moving in vast maidan is as shown in the figure. The coordinates of a position *A* are (0,2). The coordinates of another point at which the instantaneous velocity is same as the average velocity between the points are



(a) (1, 4)

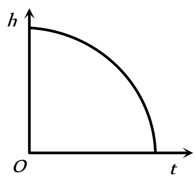
(b) (5, 3)

(c) (3, 4)

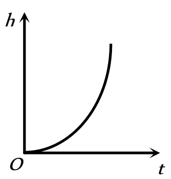
(d) (4, 1)

4. Which of the following is the graph between the height (h) of a projectile and time (t), when it is projected from the ground

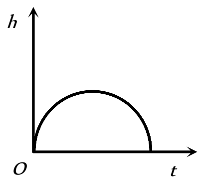
(a)



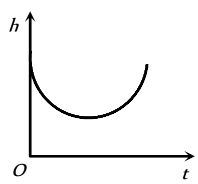
(b)



(c)

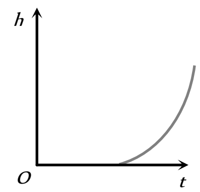


(d)

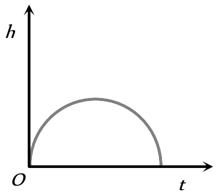


5. Which of the following is the altitude-time graph for a projectile thrown horizontally from the top of the tower

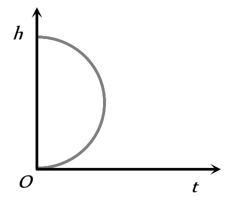
(a)



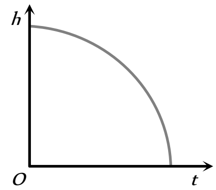
(b)



(c)



(d)



Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : In projectile motion, the angle between the instantaneous velocity and acceleration at the highest point is 180°.

Reason : At the highest point, velocity of projectile will be in horizontal direction only.

2. Assertion : Two particles of different mass, projected with same velocity at same angles. The maximum height attained by both the particle will be same.

Reason : The maximum height of projectile is independent of particle mass.

3. Assertion : The maximum horizontal range of projectile is proportional to square of velocity.

Reason : The maximum horizontal range of projectile is equal to maximum height attained by projectile.

4. Assertion : Horizontal range is same for angle of projection θ and (90 – θ).

Reason : Horizontal range is independent of angle of projection.

5. Assertion : For projection angle $\tan^{-1}(4)$, the horizontal range and the maximum height of a projectile are equal.

Reason : The maximum range of projectile is directly proportional to square of velocity and inversely proportional to acceleration due to gravity.

6. Assertion : The trajectory of projectile is quadratic in y and linear in x.

Reason : y component of trajectory is independent of x-component.

7. Assertion : In javelin throw, the athlete throws the projectile at an angle slightly more than 45°.

Reason : The maximum range does not depends upon angle of projection.

8. Assertion : When a body is dropped or thrown horizontally from the same height, it would reach the ground at the same time.

Reason : Horizontal velocity has no effect on the vertical direction.

9. Assertion : When the velocity of projection of a body is made n times, its time of flight becomes n times.

Reason : Range of projectile does not depend on the initial velocity of a body.

10. Assertion : The height attained by a projectile is twenty five percent of range, when projected for maximum range.

Reason : The height is independent of initial velocity of projectile.

11. Assertion : When range of a projectile is maximum, its angle of projection may be 45° or 135°.

Reason : Whether θ is 45° or 135°, value of range remains the same, only the sign changes.

12. Assertion : In order to hit a target, a man should point his rifle in the same direction as target.

Reason : The horizontal range of the bullet is dependent on the angle of projectile with horizontal direction.

13. Assertion : When a particle moves in a circle with a uniform speed, its velocity and acceleration both changes.

Reason : The centripetal acceleration in circular motion is dependent on angular velocity of the body.

14. Assertion : During a turn, the value of centripetal force should be less than the limiting frictional force.

Reason : The centripetal force is provided by the frictional force between the tyres and the road.

15. Assertion : When a vehicle takes a turn on the road, it travels along a nearly circular path.

Reason : In circular motion, velocity of vehicle remains same.

16. Assertion : As the frictional force increases, the safe velocity limit for taking a turn on an unbanked road also increases.

Reason : Banking of roads will increase the value of limiting velocity.

17. Assertion : If the speed of a body is constant, the body cannot have a path other than a circular or straight line path.

Reason : It is not possible for a body to have a constant speed in an accelerated motion.

18. Assertion : In circular motion, work done by centripetal force is zero.

Reason : In circular motion centripetal force is perpendicular to the displacement.

19. Assertion : In circular motion, the centripetal and centrifugal force acting in opposite direction balance each other.

Reason : Centripetal and centrifugal forces don't act at the same time.

20. Assertion : If both the speed of a body and radius of its circular path are doubled, then centripetal force also gets doubled.

Reason : Centripetal force is directly proportional to both speed of a body and radius of circular path.

21. Assertion : When an automobile while going too fast around a curve overturns, its inner wheels leave the ground first.

Reason : For a safe turn the velocity of automobile should be less than the value of safe limit velocity.

22. Assertion : A safe turn by a cyclist should neither be fast nor sharp.

Reason : The bending angle from the vertical would decrease with increase in velocity.

23. Assertion : Improper banking of roads causes wear and tear of tyres.

Reason : The necessary centripetal force is provided by the force of friction between the tyres and the road.

24. Assertion : Cream gets separated out of milk when it is churned, it is due to gravitational force.

Reason : In circular motion gravitational force is equal to centripetal force.

25. Assertion : Two similar trains are moving along the equatorial line with the same speed but in opposite direction. They will exert equal pressure on the rails.

Reason : In uniform circular motion the magnitude of acceleration remains constant but the direction continuously changes.

26. Assertion : A coin is placed on phonogram turn table. The motor is started, coin moves along the moving table.

Reason : The rotating table is providing necessary centripetal force to the coin.

Answers

Uniform Circular Motion

1	c	2	c	3	b	4	b	5	c
6	c	7	c	8	c	9	b	10	b
11	a	12	a	13	c	14	ac	15	a
16	d	17	a	18	a	19	d	20	a
21	b	22	a	23	c	24	d	25	a
26	c	27	b	28	a	29	d	30	c
31	b	32	d	33	d	34	b	35	c
36	d	37	c	38	b	39	a	40	c
41	d	42	b	43	b	44	b	45	d
46	a	47	b	48	a	49	d	50	b

51	a	52	c	53	a	54	b	55	a
56	d	57	a	58	d	59	a	60	b
61	d	62	d	63	a	64	b	65	d
66	d	67	c	68	a	69	c	70	a
71	b	72	d	73	a	74	c	75	b
76	a	77	c	78	a	79	b	80	a
81	c	82	a	83	d	84	c	85	b
86	a	87	c	88	c	89	d	90	b
91	a	92	d	93	a	94	b	95	b
96	c	97	d	98	d	99	a	100	b
101	c	102	c	103	b	104	c	105	d
106	d	107	b	108	a	109	a	110	b
111	b	112	b	113	b	114	a	115	d
116	b	117	d	118	b	119	c	120	d
121	a	122	d						

Non-uniform Circular Motion

1	d	2	d	3	d	4	c	5	a
6	c	7	a	8	d	9	b	10	b
11	b	12	b	13	a	14	b	15	b
16	a	17	c	18	c	19	a	20	a
21	c	22	a	23	d	24	c	25	b
26	d	27	a	28	d	29	c	30	b
31	d	32	d	33	d	34	b	35	b
36	d	37	c	38	c	39	c	40	b
41	d	42	c	43	a	44	a	45	d
46	d	47	a	48	d				

Horizontal Projectile Motion

1	b	2	c	3	b	4	c	5	b
6	c	7	c	8	ac	9	b	10	c
11	d	12	a	13	c	14	a	15	a
16	b								

Oblique Projectile Motion

1	d	2	c	3	a	4	a	5	c
6	c	7	a	8	d	9	c	10	b
11	a	12	b	13	a	14	a	15	c
16	b	17	c	18	c	19	b	20	b
21	b	22	d	23	c	24	c	25	b
26	d	27	c	28	b	29	d	30	a
31	b	32	b	33	a	34	c	35	c
36	a	37	a	38	a	39	d	40	b
41	c	42	b	43	a	44	b	45	a
46	b	47	c	48	d	49	c	50	c
51	a	52	a	53	b	54	d	55	c
56	c	57	c	58	d	59	b		

Critical Thinking Questions

1	cd	2	a	3	b	4	c	5	b
6	d	7	d	8	a	9	a	10	a
11	c	12	b	13	d	14	a	15	a
16	ab	17	b						

Graphical Questions

1	d	2	a	3	b	4	c	5	d

Assertion and Reason

1	e	2	a	3	c	4	c	5	b
6	d	7	d	8	a	9	c	10	c
11	a	12	e	13	b	14	a	15	c
16	b	17	d	18	a	19	d	20	c
21	b	22	c	23	a	24	d	25	e
26	d								

Answers and Solutions

Uniform Circular Motion

1. (c) $v = r\omega \Rightarrow \omega = \dfrac{v}{r}$ = constant [As v and r are constant]

2. (c) As time periods are equal therefore ratio of angular speeds will be same. $\omega = \dfrac{2\pi}{T}$

3. (b) $F = \dfrac{mv^2}{r} \Rightarrow F \propto v^2$. If v becomes double then F (tendency to overturn) will become four times.

4. (b) Work done by centripetal force is always zero.

5. (c) It is always directed in a direction of tangent to circle.

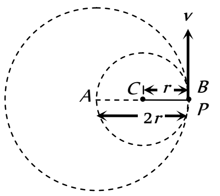
6. (c) Stone flies in the direction of instantaneous velocity due to inertia

7. (c) Centripetal acceleration $= \dfrac{v^2}{r} =$ constant. Direction keeps changing.

8. (c) Linear velocity, acceleration and force varies in direction.

9. (b) Angular velocity of particle P about point A,

$$\omega_A = \frac{v}{r_{AB}} = \frac{v}{2r}$$



Angular velocity of particle P about point C,

$$\omega_C = \frac{v}{r_{BC}} = \frac{v}{r}$$

Ratio $\dfrac{\omega_A}{\omega_C} = \dfrac{v/2r}{v/r} = \dfrac{1}{2}$.

10. (b)

11. (a) $F = \dfrac{mv^2}{r}$. If m and v are constants then $F \propto \dfrac{1}{r}$

$$\therefore \frac{F_1}{F_2} = \left(\frac{r_2}{r_1}\right)$$

12. (a) In uniform circular motion (constant angular velocity) kinetic energy remains constant but due to change in velocity of particle its momentum varies.

13. (c)

14. (a,c) Centripetal force $= \dfrac{mv^2}{r}$ and is directed always towards the centre of circle. Sense of rotation does not affect magnitude and direction of this centripetal force.

15. (a) When speed is constant in circular motion, it means work done by centripetal force is zero.

16. (d)

17. (a) This horizontal inward component provides required centripetal force.

18. (a) Thrust at the lowest point of concave bridge

$$= mg + \frac{mv^2}{r}$$

19. (d)

20. (a) Because the reaction on inner wheel decreases and becomes zero. So it leaves the ground first.

21. (b)

22. (a) $\dfrac{a_R}{a_r} = \dfrac{\omega_R^2 \times R}{\omega_r^2 \times r} = \dfrac{T_r^2}{T_R^2} \times \dfrac{R}{r} = \dfrac{R}{r}$ [As $T_r = T_R$]

23. (c) $\omega_{\min} = \dfrac{2\pi}{60}\dfrac{Rad}{min}$ and $\omega_{hr} = \dfrac{2\pi}{12 \times 60}\dfrac{Rad}{min}$

$$\therefore \frac{\omega_{\min}}{\omega_{hr}} = \frac{2\pi/60}{2\pi/12 \times 60}$$

24. (d) The particle performing circular motion flies off tangentially.

25. (a) The angle of banking, $\tan\theta = \dfrac{v^2}{rg}$

$$\Rightarrow \tan 12^\circ = \frac{(150)^2}{r \times 10} \Rightarrow r = 10.6 \times 10^3\, m = 10.6\, km$$

26. (c) K.E. $= \dfrac{1}{2}mv^2$. Which is scalar, so it remains constant.

27. (b) $v = 72\, km/hour = 20\, m/\sec$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{20 \times 20}{20 \times 10}\right) = \tan^{-1}(2)$$

28. (a)

29. (d) $120\, rev/\min = 120 \times \dfrac{2\pi}{60} rad/\sec = 4\pi\, rad/\sec$

30. (c) In uniform circular motion, acceleration causes due to change in direction and is directed radially towards centre.

31. (b) Reaction on inner wheel $R_1 = \dfrac{1}{2}M\left[g - \dfrac{v^2h}{ra}\right]$

Reaction on outer wheel $R_2 = \dfrac{1}{2}M\left[g + \dfrac{v^2h}{ra}\right]$

where, r = radius of circular path, $2a$ = distance between two wheels and h = height of centre of gravity of car.

32. (d) Maximum tension $= m\omega^2 r = m \times 4\pi^2 \times n^2 \times r$

By substituting the values we get $T_{max} = 87.64\, N$

33. (d) $\dfrac{v^2}{rg} = \dfrac{h}{l} \Rightarrow v = \sqrt{\dfrac{rgh}{l}} = \sqrt{\dfrac{50 \times 1.5 \times 9.8}{10}} = 8.57\, m/s$

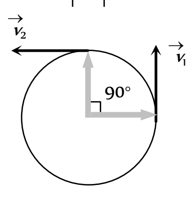
34. (b) $a = \omega^2 r = 4\pi^2 n^2 r = 4\pi^2 \times 1^2 \times 20 \times 10^3$

$\therefore$ a $= 8 \times 10^5\ m/\sec^2$

35. (c)

36. (d) In 15 second's hand rotate through 90°.

Change in velocity $\left|\Delta\vec{v}\right| = 2v\sin(\theta/2)$



$= 2(r\omega)\sin(90°/2) = 2\times 1\times \frac{2\pi}{T}\times\frac{1}{\sqrt{2}}$

$= \frac{4\pi}{60\sqrt{2}} = \frac{\pi\sqrt{2}}{30}\frac{cm}{\sec}$ [As T = 60 sec]

37. (c) Since $n = 2$, $\omega = 2\pi\times 2 = 4\pi\, rad/s^2$

So acceleration $= \omega^2 r = (4\pi)^2\times\frac{25}{100} m/s^2 = 4\pi^2$

38. (b) $\omega^2 r = 4\pi^2 n^2 r = 4\pi^2\left(\frac{1200}{60}\right)^3\times 30 = 4740\, m/s^2$

39. (a)

40. (c) Particles of cream are lighter so they get deposited near the centre of circular path.

41. (d) Radial force $= \frac{mv^2}{r} = \frac{m}{r}\left(\frac{p}{m}\right)^2 = \frac{p^2}{mr}$ [As $p = mv$]

42. (b) $\frac{mv^2}{r}\propto\frac{K}{r} \Rightarrow v\propto r^o$

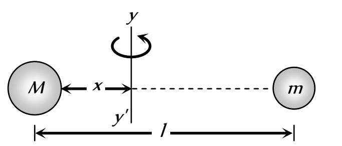
i.e. speed of the particle is independent of r.

43. (b) If the both mass are revolving about the axis yy' and tension in both the threads are equal then

$M\omega^2 x = m\omega^2(l-x)$

$\Rightarrow Mx = m(l-x)$

$\Rightarrow x = \frac{ml}{M+m}$



44. (b) $\tan\theta = \frac{v^2}{rg} = \frac{400}{20\times 9.8} \Rightarrow \theta = 63.9°$

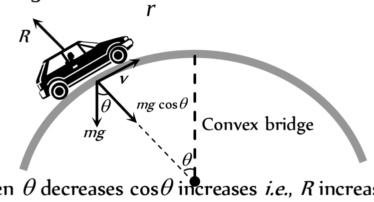
45. (d) In complete revolution change in velocity becomes zero so average acceleration will be zero.

46. (a) We know that $\tan\theta = \frac{v^2}{Rg}$ and $\tan\theta = \frac{h}{b}$

Hence $\frac{h}{b} = \frac{v^2}{Rg} \Rightarrow h = \frac{v^2 b}{Rg}$

47. (b)

48. (a) $R = mg\cos\theta - \frac{mv^2}{r}$



when θ decreases $\cos\theta$ increases *i.e.*, R increases.

49. (d) Tension in the string $T = m\omega^2 r = 4\pi^2 n^2 mr$

$\therefore T\propto n^2 \Rightarrow \frac{n_2}{n_1} = \sqrt{\frac{T_2}{T_1}} \Rightarrow n_2 = 5\sqrt{\frac{2T}{T}} = 7\, rpm$

50. (b)

51. (a) $T = m\omega^2 r \Rightarrow 10 = 0.25\times\omega^2\times 0.1 \Rightarrow \omega = 20\, rad/s$

52. (c) $v = 36\frac{km}{h} = 10\frac{m}{s}\ \therefore\ F = \frac{mv^2}{r} = \frac{500\times 100}{50} = 1000N.$

53. (a) $T = \frac{mv^2}{r} \Rightarrow 25 = \frac{0.25\times v^2}{1.96} \Rightarrow v = 14\, m/s$

54. (b) Centripetal force $= mr\omega^2 = 5\times 1\times(2)^2 = 20\, N$

55. (a) $\frac{mv^2}{r} = \frac{k}{r^2} \Rightarrow mv^2 = \frac{k}{r}\ \therefore$ K.E.$= \frac{1}{2}mv^2 = \frac{k}{2r}$

P.E. $= \int F\,dr = \int\frac{k}{r^2}dr = -\frac{k}{r}$

$\therefore$ Total energy = K.E. + P.E. $= \frac{k}{2r} - \frac{k}{r} = -\frac{k}{2r}$

56. (d) Maximum tension $= \frac{mv^2}{r} = 16N$

$\Rightarrow \frac{16\times v^2}{144} = 16 \Rightarrow v = 12\ m/s$

57. (a) The maximum velocity for a banked road with friction,

$v^2 = gr\left(\frac{\mu+\tan\theta}{1-\mu\tan\theta}\right)$

$\Rightarrow v^2 = 9.8\times 1000\times\left(\frac{0.5+1}{1-0.5\times 1}\right) \Rightarrow v = 172\, m/s$

58. (d) $v = r\omega = \frac{r\times 2\pi}{T} = \frac{0.06\times 2\pi}{60} = 6.28\, mm/s$

Magnitude of change in velocity $= |\vec{v}_2 - \vec{v}_1|$

$= \sqrt{v_1^2 + v_2^2} = 8.88\, mm/s$ $(\text{As } v_1 = v_2 = 6.28 mm/s)$

59. (a) Work done by centripetal force in uniform circular motion is always equal to zero.

60. (b) $v = r\omega = 20\times 10\, cm/s = 2\, m/s$

61. (d) $v_{max} = \sqrt{\mu rg} = \sqrt{0.2\times 100\times 9.8} = 14 m/s$

62. (d) $F = mg - \frac{mv^2}{r}$

63. (a) $\omega = \frac{2\pi}{T} = \frac{2\pi}{60} = \frac{\pi}{30} rad/s$

64. (b) $\omega = 2\pi n = \frac{2\pi\times 100}{60} = 10.47\, rad/s$

65. (d) Work done in circular motion is always zero.

66. (d) In complete revolution total displacement is zero so average velocity is zero

67. (c) $v_{max} = \sqrt{\mu rg} = \sqrt{0.75\times 60\times 9.8} = 21\, m/s$

68. (a) Distance covered in 'n' revolution $= n\,2\pi r = n\pi D$

$\Rightarrow 2000\pi D = 9500$ [As n = 2000, distance = 9500 m]

$\Rightarrow D = \frac{9500}{2000\times\pi} = 1.5\, m$

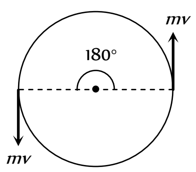
69. (c) Centripetal acceleration $= 4\pi n r = 4\pi\times(1)\times 0.4 = 1.6\pi$

70. (a)

71. (b) Due to centrifugal force.

72. (d) As momentum is vector quantity

$\therefore$ change in momentum



$\Delta P = 2mv\sin(\theta/2)$

$= 2mv\sin(90) = 2mv$

But kinetic energy remains always constant so change in kinetic energy is zero.

73. (a) $\omega = \frac{v}{r} = \frac{100}{100} = 1\,rad/s$

74. (c) $\alpha = \frac{d\omega}{dt} = 0$ (As ω = constant)

75. (b) $\vec{v} = \vec{\omega}\times\vec{r} = \begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & -4 & 1\\ 5 & -6 & 6\end{vmatrix} = -18\hat{i} - 13\hat{j} + 2\hat{k}$

76. (a) $a = 4\pi^2 n^2 r = 4\pi^2\left(\frac{1}{2}\right)^2 \times 50 = 493\,cm/s^2$

77. (c) Maximum force of friction = centripetal force

$\frac{mv^2}{r} = \frac{100\times(9)^2}{30} = 270\,N$

78. (a) $v = \sqrt{\mu rg} = \sqrt{0.4\times 30\times 9.8} = 10.84\,m/s$

79. (b) $v = r\omega = 0.5\times 70 = 35\,m/s$

80. (a) $2\pi r = 34.3 \Rightarrow r = \frac{34.3}{2\pi}$ and $v = \frac{2\pi r}{T} = \frac{2\pi r}{\sqrt{22}}$

Angle of binding $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = 45°$

81. (c)

82. (a) $T = m\omega^2 r \Rightarrow \omega \propto \sqrt{T}\ \therefore \frac{\omega_2}{\omega_1} = \sqrt{\frac{1}{4}} \Rightarrow \omega_2 = \frac{\omega_1}{2} = 5\,rpm$

83. (d) $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left[\frac{(14\sqrt{3})^2}{20\sqrt{3}\times 9.8}\right] = \tan^{-1}[\sqrt{3}] = 60°$

84. (c) Centripetal acceleration $= 4\pi^2 n^2 r = 4\pi^2\left(\frac{1}{2}\right)^2 \times 4 = 4\pi^2$

85. (b) Centripetal force = breaking force

$\Rightarrow m\omega^2 r =$ breaking stress × cross sectional area

$\Rightarrow m\omega^2 r = p\times A \Rightarrow \omega = \sqrt{\frac{p\times A}{mr}} = \sqrt{\frac{4.8\times 10^7\times 10^{-6}}{10\times 0.3}}$

$\therefore\ \omega = 4\,rad/\sec$

86. (a) Because velocity is always tangential and centripetal acceleration is radial.

87. (c) *T* = tension, *W* = weight and *F* = centrifugal force.

88. (c) $\mu = \frac{v^2}{rg} = \frac{(4.9)^2}{4\times 9.8} = 0.61$

89. (d) As body covers equal angle in equal time intervals. its angular velocity and hence magnitude of linear velocity is constant.

90. (b) $\omega = \frac{v}{r} = \frac{10}{100} = 0.1\,rad/s$

91. (a) $F = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{rF}{m}}$

92. (d) Electrostatic force provides necessary centripetal force for circular motion of electron.

93. (a) Acceleration $= \omega^2 r = \frac{v^2}{r} = \omega v = \frac{2\pi}{T}v$

94. (b) $v = \sqrt{\mu rg} = \sqrt{0.6\times 150\times 10} = 30\,m/s$

95. (b)

96. (c) $F = \frac{mv^2}{r} \Rightarrow F \propto v^2$ *i.e.* force will become 4 times.

97. (d) $v = \sqrt{\mu rg} = \sqrt{0.25\times 40\times 10} = 10\,m/s$

98. (d) Time period = 40 *sec*

No. of revolution $= \frac{\text{Total time}}{\text{Time period}} = \frac{140\text{ sec}}{40\text{ sec}} = 3.5\,Rev$.

So, distance $= 3.5\times 2\pi R = 3.5\times 2\pi\times 10 = 220\,m$.

99. (a) $m4\pi^2 n^2 r = 4\times 10^{-13} \Rightarrow n = 0.08\times 10^8\ cycles/\sec$.

100. (b) Momentum changes by $2mv$ but kinetic energy remains same.

101. (c) $L = I\omega$. In U.C.M. ω=constant ∴ *L* = constant.

102. (c) $\because\ W = FS\cos\theta\ \therefore\ \theta = 90°$

103. (b)

104. (c) In uniform circular motion tangential acceleration remains zero but magnitude of radial acceleration remains constant.

105. (d) The inclination of person from vertical is given by,

$\tan\theta = \frac{v^2}{rg} = \frac{(10)^2}{50\times 10} = \frac{1}{5}\ \therefore\ \theta = \tan^{-1}(1/5)$

106. (d) The centripetal force, $F = \frac{mv^2}{r} \Rightarrow r = \frac{mv^2}{F}$

$\therefore\ r \propto v^2$ or $v \propto \sqrt{r}$ (If *m* and *F* are constant),

$\Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{r_1}{r_2}} = \sqrt{\frac{1}{2}}$

107. (b) As the speed is constant throughout the circular motion therefore its average speed is equal to instantaneous speed.

108. (a) Linear velocity,

$v = \omega r = 2\pi nr = 2\times 3.14\times 3\times 0.1 = 1.88\,m/s$

Acceleration, $a = \omega^2 r = (6\pi)^2\times 0.1 = 35.5\,m/s^2$

Tension in string, $T = m\omega^2 r = 1\times(6\pi)^2\times 0.1 = 35.5\,N$

109. (a) $a = \frac{v^2}{r} = \frac{(400)^2}{160} = 10^3\,m/s^2 = 1\,km/s^2$

110. (b) $v_{max.} = \sqrt{\mu rg} = \sqrt{0.5\times 40\times 9.8} = 14\,m/s$

111. (b) $F = \frac{mv^2}{r} = \frac{500\times 100}{50} = 10^3\,N$

112. (b) $F = m\left(\frac{4\pi^2}{T^2}\right)R$. If masses and time periods are same then

$F \propto R \;\therefore\; F_1/F_2 = R_1/R_2$

113. (b) It is a vector quantity.

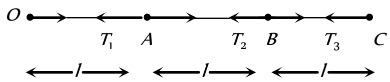
114. (a) $a = \frac{v^2}{r} = v\omega \Rightarrow a' = (2v)\left(\frac{\omega}{2}\right) = a$ *i.e.* remains constant.

115. (d) Tension in the string $T_0 = mR\omega_0^2$

In the second case $T = m(2R)(4\omega_0^2) = 8mR\omega_0^2 = 8T_0$

116. (b) Average velocity $= \frac{\text{Total displacement}}{\text{Total time}} = \frac{2m}{1s} = 2ms^{-1}$

117. (d) Let ω is the angular speed of revolution



$T_3 = m\omega^2 3l$

$T_2 - T_3 = m\omega^2 2l \Rightarrow T_2 = m\omega^2 5l$

$T_1 - T_2 = m\omega^2 l \Rightarrow T_1 = m\omega^2 6l$

$T_3 : T_2 : T_1 = 3:5:6$

118. (b) $F = \frac{mv^2}{r}$. For same mass and same speed if radius is doubled then force should be halved.

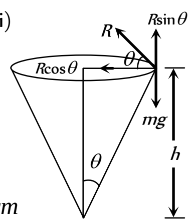
119. (c) $a = \frac{v^2}{r} = \omega^2 r = 4\pi^2 n^2 r = 4\pi^2\left(\frac{22}{44}\right)^2 \times 1 = \pi^2\ m/s^2$

and its direction is always along the radius and towards the centre.

120. (d) The particle is moving in circular path

From the figure, $mg = R\sin\theta$ ...(i)

$\frac{mv^2}{r} = R\cos\theta$ ...(ii)



From equation (i) and (ii) we get

$\tan\theta = \frac{rg}{v^2}$ but $\tan\theta = \frac{r}{h}$

$\therefore h = \frac{v^2}{g} = \frac{(0.5)^2}{10} = 0.025m = 2.5\,cm$

121. (a) Angular velocity $= \frac{2\pi}{T} = \frac{2\pi}{24} rad/hr = \frac{2\pi}{86400} rad/s$

122. (d) $\omega = \frac{2\pi}{T} = \frac{2\pi}{60} = 0.1047\ rad/s$

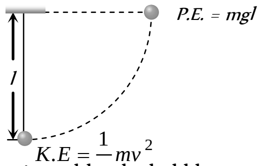
and $v = \omega r = 0.1047 \times 3 \times 10^{-2} = 0.00314\ m/s$

Non-uniform Circular Motion

1. (d) Minimum speed at the highest point of vertical circular path $v = \sqrt{gR}$

2. (d) At highest point $\frac{mv^2}{R} = mg \Rightarrow v = \sqrt{gR}$

3. (d) Kinetic energy given to a sphere at lowest point = potential energy at the height of suspension



$\Rightarrow \frac{1}{2}mv^2 = mgl$

$\therefore v = \sqrt{2gl}$

4. (c) Due to less centrifugal force experienced by the bubbles.

5. (a) Critical velocity at highest point $= \sqrt{gR} = \sqrt{10 \times 1.6} = 4\,m/s$

6. (c) Using relation $\theta = \omega_0 t + \frac{1}{2}at^2$

$\theta_1 = \frac{1}{2}(\alpha)(2)^2 = 2\alpha$ ...(i) (As $\omega_0 = 0, t = 2$ sec)

Now using same equation for $t = 4$ sec, $\omega = 0$

$\theta_1 + \theta_2 = \frac{1}{2}\alpha(4)^2 = 8\alpha$ ...(ii)

From (i) and (ii), $\theta_1 = 2\alpha$ and $\theta_2 = 6\alpha \therefore \frac{\theta_2}{\theta_1} = 3$

7. (a) $mg = 1 \times 10 = 10N$, $\frac{mv^2}{r} = \frac{1 \times (4)^2}{1} = 16$

Tension at the top of circle $= \frac{mv^2}{r} - mg = 6N$

Tension at the bottom of circle $= \frac{mv^2}{r} + mg = 26N$

8. (d) For critical condition at the highest point $\omega = \sqrt{g/R}$

$\Rightarrow T = \frac{2\pi}{\omega} = 2\pi\sqrt{R/g} = 2 \times 3.14\sqrt{4/9.8} = 4$ sec.

9. (b) $mg = 20N$ and $\frac{mv^2}{r} = \frac{2 \times (4)^2}{1} = 32N$

It is clear that 52 N tension will be at the bottom of the circle. Because we know that $T_{\text{Bottom}} = mg + \frac{mv^2}{r}$

10. (b) $h = \frac{5}{2}R = \frac{5}{2}\left(\frac{D}{2}\right) = \frac{5D}{4}$

11. (b) Net acceleration in nonuniform circular motion,

$a = \sqrt{a_t^2 + a_c^2} = \sqrt{(2)^2 + \left(\frac{900}{500}\right)^2} = 2.7\,m/s^2$

a_t = tangential acceleration

a_c = centripetal acceleration $= \frac{v^2}{r}$

12. (b) $T = mg + \frac{mv^2}{l} = mg + 2mg = 3mg$

where $v=\sqrt{2gl}$ from $\frac{1}{2}mv^2=mgl$

13. (a) $T_{max}=m\omega_{max}^2 r+mg \Rightarrow \frac{T_{max}}{m}=\omega^2 r+g$

$\Rightarrow \frac{30}{0.5}-10=\omega^2{}_{max}r \Rightarrow \omega_{max}=\sqrt{\frac{50}{r}}=\sqrt{\frac{50}{2}}=5\,rad/s$

14. (b)

15. (b) Because here tension is maximum.

16. (a) Max. tension that string can bear = 3.7 *kgwt* = 37*N*

Tension at lowest point of vertical $\text{loop}=mg+m\omega^2 r$

=

$0.5\times10+0.5\times\omega^2\times4=5+2\omega^2$

$\therefore$ 37 = 5 + 2$\omega \Rightarrow \omega$ = 4 rad/s.

17. (c)

18. (c) $\omega=\frac{d\theta}{dt}=\frac{d}{dt}(2t^3+0.5)=6t^2$

at t =2 *s*, $\omega=6\times(2)^2=24 rad/s$

19. (a) When body is released from the position *p* (inclined at angle θ from vertical) then velocity at mean position

$v=\sqrt{2gl(1-\cos\theta)}$

$\therefore$ Tension at the lowest point = $mg+\frac{mv^2}{l}$

$=mg+\frac{m}{l}[2gl(1-\cos 60)]=mg+mg=2mg$

20. (a)

21. (c) Tension = Centrifugal force + weight $=\frac{mv^2}{r}+mg$

22. (a) $v_{min}=\sqrt{5\,gr}=17.7\,m/\sec$

23. (d)

24. (c) $v=\sqrt{2gl(1-\cos\theta)}=\sqrt{2\times9.8\times2(1-\cos60°)}=4.43\,m/s$

25. (b) Increment in angular velocity $\omega=2\pi(n_2-n_1)$

$\omega=2\pi(1200-600)\frac{rad}{min}=\frac{2\pi\times600}{60}\frac{rad}{s}=20\pi\frac{rad}{s}$

26. (d) $\omega=\sqrt{\frac{g}{r}}=\sqrt{\frac{9.8}{0.2}}=7\,rad/s$

27. (a)

28. (d) In non-uniform circular motion particle possess both centripetal as well as tangential acceleration.

29. (c)

30. (b) $v=\sqrt{2gh}=\sqrt{2\times10\times0.2}=2\,m/s$

31. (d) $T=mg+m\omega^2 r=m\{g+4\pi^2 n^2 r\}$

$=m\left\{g+\left(4\pi^2\left(\frac{n}{60}\right)^2 r\right)\right\}=m\left\{g+\left(\frac{\pi^2 n^2 r}{900}\right)\right\}$

32. (d) $h=\frac{5}{2}r \Rightarrow r=\frac{2}{5}\times h=\frac{2}{5}\times5=2\,metre$

33. (d) In the given condition friction provides the required centripetal force and that is constant. *i.e.* $m\omega r$=constant

$\Rightarrow r\propto\frac{1}{\omega^2}$ $\therefore$ $r_2=r_1\left(\frac{\omega_1}{\omega_2}\right)^2=9\left(\frac{1}{3}\right)^2=1\,cm$

34. (b) By using equation $\omega^2=\omega_0^2-2\alpha\theta$

$\left(\frac{\omega_0}{2}\right)^2=\omega_0^2-2\alpha(2\pi n)\Rightarrow\alpha=\frac{3}{4}\frac{\omega_0^2}{4\pi\times36}$, ($n$ = 36) ..(i)

Now let fan completes total *n*′ revolution from the starting to come to rest

$0=\omega_0^2-2\alpha(2\pi n') \Rightarrow n'=\frac{\omega_0^2}{4\alpha\pi}$

substituting the value of α from equation (i)

$n'=\frac{\omega_0^2}{4\pi}\frac{4\times4\pi\times36}{3\omega_0^2}=48$ revolution

Number of rotation = 48 – 36 = 12

35. (b) $v=\sqrt{3gr}$ and $a=\frac{v^2}{r}=\frac{3gr}{r}=3g$

36. (d) Tension at mean position, $mg+\frac{mv^2}{r}=3mg$

$v=\sqrt{2gl}$ ...(i)

and if the body displaces by angle θ with the vertical then $v=\sqrt{2gl(1-\cos\theta)}$ ...(ii)

Comparing (i) and (ii), $\cos\theta=0 \Rightarrow \theta=90°$

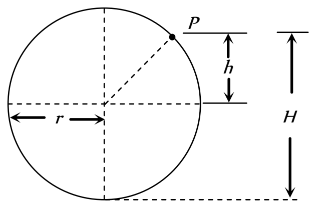
37. (c) Tension, $T=\frac{mv^2}{r}+mg\cos\theta$

For, $\theta=30°, T_1=\frac{mv^2}{r}+mg\cos30°$

$\theta=60°, T_2=\frac{mv^2}{r}+mg\cos60° \therefore T_1>T_2$

38. (c) As we know for hemisphere the particle will leave the sphere at height $h=2r/3$

$h=\frac{2}{3}\times21=14\,m$



but from the bottom

$H=h+r=14+21=35\,metre$

39. (c) $x=\alpha t^3$ and $y=\beta t^3$ (given)

$v_x=\frac{dx}{dt}=3\alpha t^2$ and $v_y=\frac{dy}{dt}=3\beta t^2$

Resultant velocity $=v=\sqrt{v_x^2+v_y^2}=3t^2\sqrt{\alpha^2+\beta^2}$

40. (b)

41. (d) Tension at the top of the circle, $T=m\omega^2 r-mg$

$T = 0.4 \times 4\pi^2 n^2 \times 2 - 0.4 \times 9.8 = 115.86\,N$

42. (c) Minimum angular velocity $\omega_{min} = \sqrt{g/R}$

$\therefore T_{max} = \frac{2\pi}{\omega_{min}} = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{\frac{2}{10}} = 2\sqrt{2} \cong 3s$

43. (a) $|\overrightarrow{\Delta v}| = 2v\sin(\theta/2) = 2v\sin\left(\frac{90}{2}\right) = 2v\sin 45 = v\sqrt{2}$

44. (a) In this problem it is assumed that particle although moving in a vertical loop but its speed remain constant.

Tension at lowest point $T_{max} = \frac{mv^2}{r} + mg$

Tension at highest point $T_{min} = \frac{mv^2}{r} - mg$

$\frac{T_{max}}{T_{min}} = \frac{\frac{mv^2}{r} + mg}{\frac{mv^2}{r} - mg} = \frac{5}{3}$

by solving we get, $v = \sqrt{4gr} = \sqrt{4 \times 9.8 \times 2.5} = \sqrt{98}\ m/s$

45. (d) There is no relation between centripetal and tangential acceleration. Centripetal acceleration is must for circular motion but tangential acceleration may be zero.

46. (d) Angular momentum is a axial vector. It is directed always in a fix direction (perpendicular to the plane of rotation either outward or inward), if the sense of rotation remain same.

47. (a) Difference in kinetic energy = $2mgr = 2 \times 1 \times 10 \times 1 = 20J$

48. (d) Angular acceleration = $\frac{d^2\theta}{dt^2} = 2\theta$

Horizontal Projectile Motion

1. (b) $R_{max} = \frac{u^2}{g} = 16 \times 10^3 \Rightarrow u = 400\,m/s$

2. (c) Due to constant velocity along horizontal and vertical downward force of gravity stone will hit the ground following parabolic path.

3. (b) Because the vertical components of velocities of both the bullets are same and equal to zero and $t = \sqrt{\frac{2h}{g}}$.

4. (c) The pilot will see the ball falling in straight line because the reference frame is moving with the same horizontal velocity but the observer at rest will see the ball falling in parabolic path.

5. (b) Due to air resistance, it's horizontal velocity will decrease so it will fall behind the aeroplane.

6. (c) Because horizontal velocity is same for coin and the observer. So relative horizontal displacement will be zero.

7. (c) Horizontal displacement of the bomb

AB = Horizontal velocity × time available

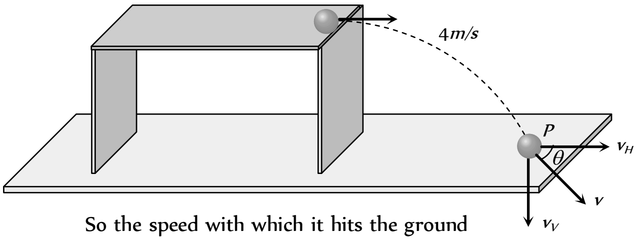
$AB = u \times \sqrt{\frac{2h}{g}} = 600 \times \frac{5}{18} \times \sqrt{\frac{2 \times 1960}{9.8}} = 3.33\,Km.$

8. (a,c) Vertical component of velocity of ball at point P

$v_V = 0 + gt = 10 \times 0.4 = 4\,m/s$

Horizontal component of velocity = initial velocity

$\Rightarrow v_H = 4\,m/s$



So the speed with which it hits the ground

$v = \sqrt{v_H^2 + v_V^2} = 4\sqrt{2}\,m/s$

and $\tan\theta = \frac{v_V}{v_H} = \frac{4}{4} = 1 \Rightarrow \theta = 45°$

It means the ball hits the ground at an angle of $45°$ to the horizontal.

Height of the table $h = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times (0.4)^2 = 0.8\,m$

Horizontal distance travelled by the ball from the edge of table $h = ut = 4 \times 0.4 = 1.6\,m$

9. (b) $S = u \times \sqrt{\frac{2h}{g}} = 100 \times \sqrt{\frac{2 \times 490}{9.8}} = 1000\,m = 1\,km$

10. (c) $S = u \times \sqrt{\frac{2h}{g}} \Rightarrow 10 = u\sqrt{2 \times \frac{5}{10}} \Rightarrow u = 10\,m/s$

11. (d) $t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 396.9}{9.8}} \simeq 9\sec$ and $u = 720\,km/hr = 200\,m/s$

$\therefore R = u \times t = 200 \times 9 = 1800\,m$

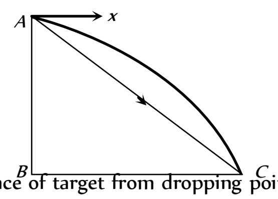
12. (a) For both cases $t = \sqrt{\frac{2h}{g}}$ = constant.

Because vertical downward component of velocity will be zero for both the particles.

13. (c)

14. (a) The horizontal distance covered by bomb,

$BC = v_H \times \sqrt{\frac{2h}{g}} = 150\sqrt{\frac{2 \times 80}{10}} = 660m$

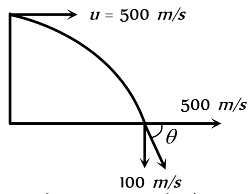


$\therefore$ The distance of target from dropping point of bomb,

$AC = \sqrt{AB^2 + BC^2} = \sqrt{(80)^2 + (600)^2} = 605.3\,m$

15. (a) Horizontal component of velocity $v = 500\ m/s$

and vertical components of velocity while striking the ground.



$v_y = 0 + 10 \times 10 = 100 m/s$

$\therefore$ Angle with which it strikes the ground.

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{100}{500}\right) = \tan^{-1}\left(\frac{1}{5}\right)$$

16. (b) Area in which bullet will spread = πr^2

For maximum area, $r = R_{\max} = \frac{v^2}{g}$[when $\theta = 45°$]

Maximum area $\pi R_{\max}^2 = \pi\left(\frac{v^2}{g}\right)^2 = \frac{\pi v^4}{g^2}$

Oblique Projectile Motion

1. (d) $R = \frac{u^2 \sin 2\theta}{g}$ $\therefore R \propto u^2$. If initial velocity be doubled then range will become four times.

2. (c) $H = \frac{u^2 \sin^2\theta}{2g}$ $\therefore H \propto u^2$. If initial velocity be doubled then maximum height reached by the projectile will quadrupled.

3. (a) An external force by gravity is present throughout the motion so momentum will not be conserved.

4. (a) Range $= \frac{u^2 \sin 2\theta}{g}$; when $\theta = 90°$, $R = 0$ *i.e.* the body will fall at the point of projection after completing one dimensional motion under gravity.

5. (c) $R = 4H\cot\theta$.

When $R = H$ then $\cot\theta = 1/4 \Rightarrow \theta = \tan^{-1}(4)$

6. (c) Because there is no accelerating or retarding force available in horizontal motion.

7. (a) Direction of velocity is always tangent to the path so at the top of trajectory, it is in horizontal direction and acceleration due to gravity is always in vertically downward direction. It means angle between $\vec{v}$ and $\vec{g}$ are perpendicular to each other.

8. (d) $R = 4H\cot\theta$ if $\theta = 45°$ then $R = 4H\cot(45°) = 4H$

9. (c) $v_y = \frac{dy}{dt} = 8 - 10t$, $v_x = \frac{dx}{dt} = 6$

at the time of projection *i.e.* $v_y = \frac{dy}{dt} = 8$ and $v_x = 6$

$\therefore v = \sqrt{v_x^2 + v_y^2} = \sqrt{6^2 + 8^2} = 10\ m/s$

10. (b) The angle of projection is given by $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{4}{3}\right)$

11. (a) $a_x = \frac{d}{dt}(v_x) = 0$, $a_y = \frac{d}{dt}(v_y) = -10\ m/s^2$

$\therefore$ Net acceleration $a = \sqrt{a_x^2 + a_y^2} = \sqrt{0^2 + 10^2} = 10 m/s$

12. (b) $R_{15°} = \frac{u^2 \sin(2 \times 15°)}{g} = \frac{u^2}{2g} = 1.5\,km$

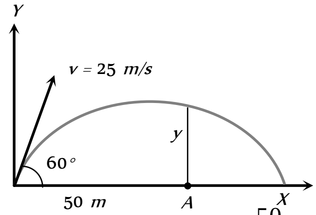
$R_{45°} = \frac{u^2 \sin(2 \times 45°)}{g} = \frac{u^2}{g} = 1.5 \times 2 = 3\,km$

13. (a) Horizontal component of velocity

$v_x = 25\cos 60° = 12.5\,m/s$

Vertical component of velocity

$v_y = 25\sin 60° = 12.5\sqrt{3}\,m/s$



Time to cover 50 m distance $t = \frac{50}{12.5} = 4$ sec

The vertical height y is given by

$$y = v_y t - \frac{1}{2}gt^2 = 12.5\sqrt{3} \times 4 - \frac{1}{2} \times 9.8 \times 16 = 8.2\,m$$

14. (a) For vertical upward motion $h = ut - \frac{1}{2}gt^2$

$5 = (25\sin\theta) \times 2 - \frac{1}{2} \times 10 \times (2)^2$

$\Rightarrow 25 = 50 \sin\theta \Rightarrow \sin\theta = \frac{1}{2} \Rightarrow \theta = 30°$

15. (c) For angle $(45° - \theta)$, $R = \frac{u^2 \sin(90° - 2\theta)}{g} = \frac{u^2 \cos 2\theta}{g}$

For angle $(45° + \theta)$, $R = \frac{u^2 \sin(90° + 2\theta)}{g} = \frac{u^2 \cos 2\theta}{g}$

16. (b) Range is given by $R = \frac{u^2 \sin 2\theta}{g}$

On moon $g_m = \frac{g}{6}$. Hence $R_m = 6R$

17. (c) For greatest height $\theta = 90°$

$H_{\max} = \frac{u^2 \sin^2(90°)}{2g} = \frac{u^2}{2g} = h$ (given)

$R_{\max} = \frac{u^2 \sin^2 2(45°)}{g} = \frac{u^2}{g} = 2h$

18. (c) $R = 4H\cot\theta$, if $R = 4H$ then $\cot\theta = 1 \Rightarrow \theta = 45°$

19. (b) $E' = E\cos^2\theta = E\cos^2(45°) = \frac{E}{2}$

20. (b)

21. (b)

22. (d) Acceleration through out the projectile motion remains constant and equal to *g*.

23. (c)

24. (c) Time of flight $= \frac{2u\sin\theta}{g} = \frac{2 \times 50 \times \sin 30}{10} = 5s$

25. (b) Change in momentum = $2mu\sin\theta$

$= 2\times 0.5\times 98\times \sin 30 = 45 N\text{-}s$

26. (d) $R = 4H\cot\theta$, if $R = 3H$ then $\cot\theta = \frac{3}{4} \Rightarrow \theta = 53°8'$

27. (c) Became vertical downward displacement of both (barrel and bullet) will be equal.

28. (b) As $H = \frac{u^2\sin^2\theta}{2g}$ $\therefore$ $\frac{H_1}{H_2} = \frac{\sin^2\theta_1}{\sin\theta_2} = \frac{\sin^2 30°}{\sin^2 60} = \frac{1/4}{3/4} = \frac{1}{3}$

29. (d) $R = \frac{v^2\sin 2\theta}{g} \Rightarrow \theta = \frac{1}{2}\sin^{-1}\left(\frac{gR}{v^2}\right)$

30. (a) $T = \frac{2u\sin\theta}{g} = 10\sec \Rightarrow u\sin\theta = 50\ m/s$

$\therefore\ H = \frac{u^2\sin^2\theta}{2g} = \frac{(u\sin\theta)^2}{2g} = \frac{50\times 50}{2\times 10} = 125 m$

31. (b) For complementary angles range will be equal.

32. (b) $R = \frac{u^2\sin 2\theta}{g} = \frac{(500)^2\times\sin 30°}{10} = 12.5\times 10^3\ m$

33. (a) $T = \frac{2u\sin\theta}{g} \Rightarrow u = \frac{T\times g}{2\sin\theta} = \frac{2\times 9.8}{2\times\sin 30} = 19.6\ m/s$

34. (c) $R = \frac{u^2\sin 2\theta}{g} = R\propto u^2$. So if the speed of projection doubled, the range will becomes four times,

i.e., $4\times 50 = 200\,m$

35. (c) Range will be equal for complementary angles.

36. (a) When the angle of projection is very far from 45° then range will be minimum.

37. (a) $H = \frac{u^2\sin^2\theta}{2g}$ and $T = \frac{2u\sin\theta}{g}$

So $\frac{H}{T^2} = \frac{u^2\sin^2\theta/2g}{4u^2\sin^2\theta/g^2} = \frac{g}{8} = \frac{5}{4}$

38. (a) $H_1 = \frac{u^2\sin^2\theta}{2g}$ and $H_2 = \frac{u^2\sin^2(90-\theta)}{2g} = \frac{u^2\cos^2\theta}{2g}$

$H_1H_2 = \frac{u^2\sin^2\theta}{2g}\times\frac{u^2\cos^2\theta}{2g} = \frac{(u^2\sin 2\theta)^2}{16g^2} = \frac{R^2}{16}$

$\therefore R = 4\sqrt{H_1H_2}$

39. (d) Standard equation of projectile motion

$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$

Comparing with given equation

$A = \tan\theta$ and $B = \frac{g}{2u^2\cos^2\theta}$

So $\frac{A}{B} = \frac{\tan\theta\times 2u^2\cos^2\theta}{g} = 40$

(As $\theta = 45°, u = 20\ m/s, g = 10\ m/s^2$)

40. (b) Range $= \frac{u^2\sin 2\theta}{g}$. It is clear that range is proportional to the direction (angle) and the initial speed.

41. (c) $\frac{2u\sin\theta}{g} = 2\sec \Rightarrow u\sin\theta = 10$

$\therefore\ H = \frac{u^2\sin^2\theta}{2g} = \frac{100}{2g} = 5m$

42. (b) Only horizontal component of velocity $(u\cos\theta)$.

43. (a) For complementary angles range is same.

44. (b) $T = \frac{2u\sin\theta}{g} = \frac{2\times 9.8\times\sin 30}{9.8} = 1\,s$

45. (a) $x = 36t$ $\therefore$ $v_x = \frac{dx}{dt} = 36\,m/s$

$y = 48t - 4.9t^2$ $\therefore$ $v_y = 48 - 9.8t$

at $t = 0$ $v_x = 36$ and $v_y = 48\,m/s$

So, angle of projection $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{4}{3}\right)$

Or $\theta = \sin^{-1}(4/5)$

46. (b) For same range angle of projection should be θ and $90-\theta$

So, time of flights $t_1 = \frac{2u\sin\theta}{g}$ and

$t_2 = \frac{2u\sin(90-\theta)}{g} = \frac{2u\cos\theta}{g}$

By multiplying $= t_1t_2 = \frac{4u^2\sin\theta\cos\theta}{g^2}$

$t_1t_2 = \frac{2}{g}\frac{(u^2\sin 2\theta)}{g} = \frac{2R}{g} \Rightarrow t_1t_2\propto R$

47. (c) Instantaneous velocity of rising mass after t sec will be $v_t = \sqrt{v_x^2 + v_y^2}$

where $v_x = v\cos\theta =$ Horizontal component of velocity

$v_y = v\sin\theta - gt =$ Vertical component of velocity

$v_t = \sqrt{(v\cos\theta)^2 + (v\sin\theta - gt)^2}$

$v_t = \sqrt{v^2 + g^2t^2 - 2v\sin\theta\, gt}$

48. (d) Maximum range $= \frac{u^2}{g} = 100\,m$

Maximum height $= \frac{u^2}{2g} = \frac{100}{2} = 50\,m$

49. (c) $R_{\max} = \frac{u^2}{g} = 100 \Rightarrow u = 10\sqrt{10} = 32\,m/s$

50. (c) Since horizontal component of velocity is constant, hence momentum is constant.

51. (a) Time of flight $= \frac{2u\sin\theta}{g} = \frac{2u_y}{g} = \frac{2\times u_{\text{vertical}}}{g}$

52. (a) Person will catch the ball if its velocity will be equal to horizontal component of velocity of the ball.

$\frac{v_0}{2} = v_0\cos\theta \Rightarrow \cos\theta = \frac{1}{2} \Rightarrow \theta = 60°$

53. (b) $H = \frac{u^2\sin^2\theta}{2g}$ and $T = \frac{2u\sin\theta}{g} \Rightarrow T^2 = \frac{4u^2\sin^2\theta}{g^2}$

$\therefore \ \dfrac{T^2}{H} = \dfrac{8}{g} \Rightarrow T = \sqrt{\dfrac{8H}{g}} = 2\sqrt{\dfrac{2H}{g}}$

54. (d) $R = 4H\cot\theta$, if $R = 4\sqrt{3}H$ then $\cot\theta = \sqrt{3} \Rightarrow \theta = 30°$

55. (c) The vertical component of velocity of projection $= -50\sin 30° = -25\, m/s$

If t be the time taken to reach the ground,

$h = ut + \dfrac{1}{2}gt^2 \Rightarrow 70 = -25t + \dfrac{1}{2}\times 10t^2$

$\Rightarrow 70 = -25t + 5t^2 \Rightarrow t^2 - 5t - 14 = 0 \Rightarrow t = -2s$ and $7s$

Since, $t = -2\ s$ is not valid $\therefore\ t = 7\ s$

56. (c) $H_{\_} = \dfrac{u^2\sin^2\theta}{2g}$

According to problem $\dfrac{u_1^{\ 2}\sin^2 45°}{2g} = \dfrac{u_2^{\ 2}\sin^2 60°}{2g}$

$\Rightarrow \dfrac{u_1^{\ 2}}{u_2^{\ 2}} = \dfrac{\sin^2 60°}{\sin^2 45°} \Rightarrow \dfrac{u_1}{u_2} = \dfrac{\sqrt{3}/2}{1/\sqrt{2}} = \sqrt{\dfrac{3}{2}}.$

57. (c)

58. (d) $R = 4H\cot\theta$, if $\theta = 45°$ then $R = 4H \Rightarrow \dfrac{R}{H} = \dfrac{4}{1}$

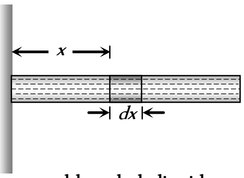
59. (b) $R_{\max} = \dfrac{u^2}{g} = 400m$ (For $\theta = 45°$)

$H_{\max} = \dfrac{u^2}{2g} = \dfrac{400}{2} = 200m$ (For $\theta = 90°$)

Critical Thinking Questions

1. (c,d) In the given condition, the particle undergoes uniform circular motion and for uniform circular motion the velocity and acceleration vector changes continuously but kinetic energy is constant for every point.

2. (a) $dM = \left(\dfrac{M}{L}\right)dx$



force on 'dM mass is

$dF = (dM)\omega^2 x$

By integration we can get the force exerted by whole liquid

$\Rightarrow F = \int_0^L \dfrac{M}{L}\omega^2 x\, dx = \dfrac{1}{2}M\omega^2 L$

3. (b) According to given problem $\dfrac{1}{2}mv^2 = as^2 \Rightarrow v = s\sqrt{\dfrac{2a}{m}}$

So $a_R = \dfrac{v^2}{R} = \dfrac{2as^2}{mR}$ ...(i)

Further more as $a_t = \dfrac{dv}{dt} = \dfrac{dv}{ds}\cdot\dfrac{ds}{dt} = v\dfrac{dv}{ds}$ ...(ii)

(By chain rule)

Which in light of equation (i) *i.e.* $v = s\sqrt{\dfrac{2a}{m}}$ yields

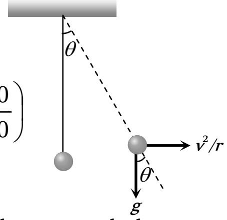
$a_t = \left[s\sqrt{\dfrac{2a}{m}}\right]\left[\sqrt{\dfrac{2a}{m}}\right] = \dfrac{2as}{m}$ ...(iii)

So that $a = \sqrt{a_R^2 + a_t^2} = \sqrt{\left[\dfrac{2as^2}{mR}\right]^2 + \left[\dfrac{2as}{m}\right]^2}$

Hence $a = \dfrac{2as}{m}\sqrt{1 + [s/R]^2}$

$\therefore\ F = ma = 2as\sqrt{1+[s/R]^2}$

4. (c) $\tan\theta = \dfrac{v^2/r}{g} = \dfrac{v^2}{rg}$



$\therefore\ \theta = \tan^{-1}\left(\dfrac{v^2}{rg}\right) = \tan^{-1}\left(\dfrac{10\times 10}{10\times 10}\right)$

$\therefore\ \theta = \tan^{-1}(1) = 45°$

5. (b) Here the tangential acceleration also exits which requires power.

Given that $a_C = k^2rt^2$ and $a_C = \dfrac{v^2}{r}$ $\therefore\ \dfrac{v^2}{r} = k^2rt^2$

or $v^2 = k^2r^2t^2$ or $v = krt$

Tangential acceleration $a = \dfrac{dv}{dt} = kr$

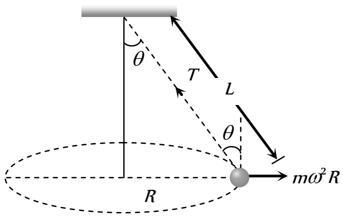
Now force $F = m\times a = mkr$

So power $P = F\times v = mkr\times krt = mk^2r^2t$

6. (d) $T\sin\theta = M\omega^2 R$ ...(i)

$T\sin\theta = M\omega^2 L\sin\theta$ ...(ii)

From (i) and (ii)



$T = M\omega^2 L$

$= M\,4\pi^2 n^2 L$

$= M\,4\pi^2\left(\dfrac{2}{\pi}\right)^2 L$

$= 16\, ML$

7. (d) Since the maximum tension T_B in the string moving in the vertical circle is at the bottom and minimum tension T_T is at the top.

$\therefore\ T_B = \dfrac{mv_B^2}{L} + mg$ and $T_T = \dfrac{mv_T^2}{L} - mg$

$\therefore\ \dfrac{T_B}{T_T} = \dfrac{\dfrac{mv_B^2}{L}+mg}{\dfrac{mv_T^2}{L}-mg} = \dfrac{4}{1}$ or $\dfrac{v_B^2+gL}{v_T^2-gL} = \dfrac{4}{1}$

or $v_B^2 + gL = 4v_T^2 - 4gL$ but $v_B^2 = v_T^2 + 4gL$

$\therefore\ v_T^2 + 4gL + gL = 4v_T^2 - 4gL \Rightarrow 3v_T^2 = 9gL$

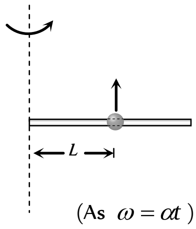
$\therefore\ v_T^2 = 3\times g\times L = 3\times 10\times \frac{10}{3}$ or $v_T = 10\, m/\sec$

8. (a) For particle P, motion between A and C will be an accelerated one while between C and B a retarded one. But in any case horizontal component of it's velocity will be greater than or equal to v on the other hand in case of particle Q, it is always equal to v. horizontal displacement of both the particles are equal, so $t_P < t_Q$.

9. (a) Let the bead starts slipping after time t

For critical condition

Frictional force provides the centripetal force



$m\omega^2 L = \mu R = \mu m \times a_t = \mu L m\alpha$

$\Rightarrow m(\alpha t)^2 L = \mu m L\alpha \Rightarrow t = \sqrt{\frac{\mu}{\alpha}}$ (As $\omega = \alpha t$)

10. (a) Normal reaction at the highest point

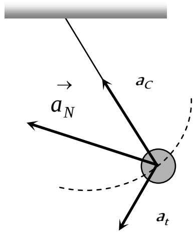
$$R = \frac{mv^2}{r} - mg$$

Reaction is inversely proportional to the radius of the curvature of path and radius is minimum for path depicted in (a).

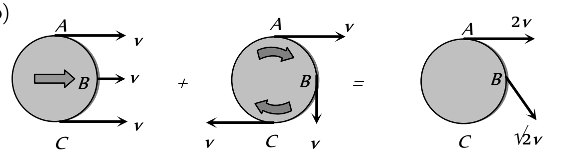
11. (c) a_c = centripetal acceleration

a_t = tangential acceleration

a_N = net acceleration = Resultant of a_c and a_t



12. (b)



Pure translation + Pure Rotation = Rolling without Slipping

13. (d) $\frac{1}{2}mu^2 - \frac{1}{2}mv^2 = mgL$

$\Rightarrow v = \sqrt{u^2 - 2gL}$

$|\vec{v} - \vec{u}| = \sqrt{u^2 + v^2} = \sqrt{u^2 + u^2 - 2gL} = \sqrt{2(u^2 - gL)}$

14. (a) When driver applies brakes and the car covers distance x before coming to rest, under the effect of retarding force F

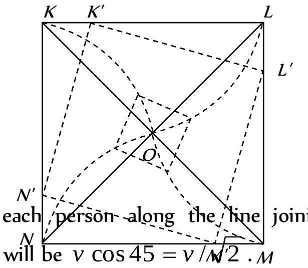
then $\frac{1}{2}mv^2 = Fx \Rightarrow x = \frac{mv^2}{2F}$

But when he takes turn then $\frac{mv^2}{r} = F \Rightarrow r = \frac{mv^2}{F}$

It is clear that $x = r/2$

i.e. by the same retarding force the car can be stopped in a less distance if the driver apply breaks. This retarding force is actually a friction force.

15. (a) It is obvious from considerations of symmetry that at any moment of time all of the persons will be at the corners of square whose side gradually decreases (see fig.) and so they will finally meet at the centre of the square O.



The speed of each person along the line joining his initial position and O will be $v\cos 45 = v/\sqrt{2}$.

As each person has displacement $d\cos 45 = d/\sqrt{2}$ to reach the centre, the four persons will meet at the centre of the square O after time.

$$\therefore\ t = \frac{d/\sqrt{2}}{v/\sqrt{2}} = \frac{d}{v}$$

16. (a,b) $x = a\cos(pt)$ and $y = b\sin(pt)$ (given)

$\therefore\ \cos pt = \frac{x}{a}$ and $\sin pt = \frac{y}{b}$

By squaring and adding

$$\cos^2(pt) + \sin^2(pt) = \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Hence path of the particle is ellipse.

Now differentiating x and y *w.r.t.* time

$$v_x = \frac{dx}{dt} = \frac{d}{dt}(a\cos(pt)) = -ap\sin(pt)$$

$$v_y = \frac{dy}{dt} = \frac{d}{dt}(b\sin(pt)) = bp\cos(pt)$$

$$\therefore\ \vec{v} = v_x\hat{i} + v_y\hat{j} = -ap\sin(pt)\hat{i} + bp\cos(pt)\hat{j}$$

Acceleration $\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}[-ap\sin(pt)\hat{i} + bp\cos(pt)\hat{j}]$

$$\vec{a} = -ap^2\cos(pt)\,\hat{i} - bp^2\sin(pt)\hat{j}$$

Velocity at $t = \frac{\pi}{2p}$

$$\vec{v} = -ap\sin p\left(\frac{\pi}{2p}\right)\hat{i} + bp\cos p\left(\frac{\pi}{2p}\right)\hat{j} = -ap\,\hat{i}$$

Acceleration at $t = \frac{\pi}{2p}$

$$\vec{a} = ap^2\cos p\left(\frac{\pi}{2p}\right)\hat{i} - bp^2\sin p\left(\frac{\pi}{2p}\right)\hat{j} = -bp^2\hat{j}$$

As $\vec{v}\,.\,\vec{a} = 0$

Hence velocity and acceleration are perpendicular to each other at $t = \frac{\pi}{2p}$.

17. (b) $\Delta\vec{\upsilon} = \vec{\upsilon}_2 - \vec{\upsilon}_1 = \sqrt{\upsilon_1^2 + \upsilon_2^2 - 2\upsilon_1\upsilon_2\cos 90^o} = \sqrt{5^2 + 5^2} = 5\sqrt{2}$

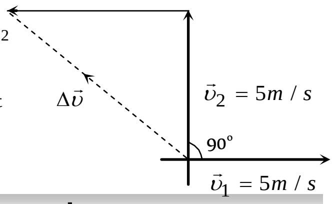
$-\vec{v}_1$

Average acceleration

$= \frac{\Delta v}{\Delta t} = \frac{5\sqrt{2}}{10} = \frac{1}{\sqrt{2}}$ m/s^2

Directed toward north-west

(As clear from the figure).



Graphical Questions

1. (d) $R = \frac{u^2 \sin 2\theta}{g} = \frac{2u_x v_y}{g}$

$\therefore$ Range $\propto$ horizontal initial velocity (u)

In path 4 range is maximum so football possess maximum horizontal velocity in this path.

2. (a) If air resistance is taken into consideration then range and maximum height, both will decrease.

3. (b)

4. (c)

5. (d)

Assertion and Reason

1. (e) At the highest point, vertical component of velocity becomes zero so there will be only horizontal velocity and it is perpendicular to the acceleration due to gravity.

2. (a) $H = \frac{u^2 \sin^2\theta}{2g}$ *i.e.* it is independent of mass of projectile.

3. (c) $R = \frac{u^2 \sin 2\theta}{g}$ $\therefore R_{max} = \frac{u^2}{g}$ when $\theta = 45°$ $\therefore R_{max} \propto u^2$

Height $H = \frac{u^2 \sin^2\theta}{2g} \Rightarrow H_{max} = \frac{u^2}{2g}$ when $\theta = 90°$

It is clear that $H_{max} = \frac{R_{max}}{2}$

4. (c) Horizontal range depends upon angle of projection and it is same for complementary angles *i.e.* θ and $(90 - \theta)$.

5. (b) We know $R = 4H\cot\theta$

if $R = H$ then $\cot\theta = \left(\frac{1}{4}\right)$ or tan $\theta = (4)$

and $R = \frac{u^2 \sin 2\theta}{g}$ $\therefore$ $R \propto \frac{u^2}{g}$

6. (d) $y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$

7. (d) If a body is projected from a place above the surface of earth, then for the maximum range, the angle of projection should be slightly less than 45^o.

8. (a) Both body will take same time to reach the earth because vertical downward component of velocity for both the bodies will be zero and time of descent $t = \sqrt{\frac{2h}{g}}$. Horizontal velocity has no effect on the vertical direction.

9. (c) $T \propto u$ and $R \propto u^2$

When velocity of projection of a body is made n times, then its time of flight becomes n times and range becomes n times.

10. (c) Range will be maximum when $\theta = 45°$ and in this condition $R = 4H \Rightarrow H = R/4$ (always)

because $R = 4H\cot\theta$ and $\theta = 45°$

So maximum height is 25% of maximum range.

It does not depends upon the velocity of projection.

11. (a) Range, $R = \frac{u^2 \sin 2\theta}{g}$

when $\theta = 45^o$, $R_{max} = \frac{u^2}{g}\sin 90^o = \frac{u^2}{g}$

when $\theta = 135^o$, $R_{max} = \frac{u^2}{g}\sin 270^o = \frac{-u^2}{g}$

Negative sign shows opposite direction.

12. (e) The man should point his rifle at a point higher than the target since the bullet suffers a vertically downward deflection $\left(y = \frac{1}{2}gt^2\right)$ due to gravity.

13. (b) In uniform circular motion, the magnitude of velocity and acceleration remains same, but due to change in direction of motion, the direction of velocity and acceleration changes. Also the centripetal acceleration is given by $a = \omega^2 r$.

14. (a) The body is able to move in a circular path due to centripetal force. The centripetal force in case of vehicle is provided by frictional force. Thus if the value of frictional force μmg is less than centripetal force, then it is not possible for a vehicle to take a turn and the body would overturn.

Thus condition for safe turning of vehicle is, $\mu mg \geq \frac{mv^2}{r}$.

15. (c) In circular motion the frictional force acting towards the centre of the horizontal circular path provides the centripetal force and avoid overturning of vehicle. Due to the change in direction of motion, velocity changes in circular motion.

16. (b) On an unbanked road, friction provides the necessary centripetal force $\frac{mv^2}{r} = \mu mg$ $\therefore v = \sqrt{\mu rg}$.

Thus with increase in friction, safe velocity limit also increases.

When the road is banked with angle of θ then its limiting velocity is given by $v = \sqrt{\frac{rg(\tan\theta + \mu)}{1 - \mu\tan\theta}}$.

Thus limiting velocity increase with banking of road.

17. (d) If the speed of a body is constant, all curved paths are possible.

In uniform circular motion a body has constant speed, but its direction keeps on changing, due to which it has non-zero acceleration.

18. (a) We know that $W = Fs\cos\theta$

in the circular motion if $\theta = 90^o$ then $W = 0$

19. (d) While moving along a circle, the body has a constant tendency to regain its natural straight line path.

This tendency gives rise to a force called centrifugal force. The centrifugal force does not act on the body in motion, the only force acting on the body in motion is centripetal force. The centrifugal force acts on the source of centripetal force to displace it radially outward from centre of the path.

20. (c) Centripetal force is defined from formula

$$F = \frac{mv^2}{r} \Rightarrow F \propto \frac{v^2}{r}$$

If v and r both are doubled then F also gets doubled.

21. (b) When automobile moves in circular path then reaction on inner wheel and outer wheel will be different.

$$R_{\text{inner}} = \frac{M}{2}\left[g - \frac{v^2h}{ra}\right] \text{ and } R_{\text{outer}} = \frac{M}{2}\left[g + \frac{v^2h}{ra}\right]$$

In critical condition $v_{\text{safe}} = \sqrt{\frac{gra}{h}}$

If v is equal or more that thus critical value then reaction on inner wheel becomes zero. So it leaves the ground first.

22. (c) For safe turn $\tan\theta \geq \frac{v^2}{rg}$.

It is clear that for safe turn v should be small and r should be large. Also bending angle from the vertical would increase with increase in velocity.

23. (a) When roads are not properly banked, force of friction between tyres and road provides partially the necessary centripetal force. This cause wear and tear of tyres.

24. (d) When the milk is churned centrifugal force acts on it outward and due to which cream in milk is separated from it.

25. (e) Due to earth's axial rotation, the speed of the trains relative to earth will be different and hence the centripetal forces on them will be different. Thus their effective weights $mg - \frac{mv^2}{r}$ and $mg + \frac{mv^2}{r}$ will be different. So they exert different pressure on the rails.

26. (d) Within a certain speed of the turn table the frictional force between the coin and the turn table supplies the necessary centripetal force required for circular motion. On further increase of speed, the frictional force cannot supply the necessary centripetal force. Therefore the coin flies off tangentially.

Motion In Two Dimension

SET Self Evaluation Test -3

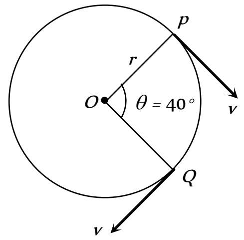
1. Roads are banked on curves so that
   (a) The speeding vehicles may not fall outwards
   (b) The frictional force between the road and vehicle may be decreased
   (c) The wear and tear of tyres may be avoided
   (d) The weight of the vehicle may be decreased

2. In uniform circular motion
   (a) Both velocity and acceleration are constant
   (b) Acceleration and speed are constant but velocity changes
   (c) Both acceleration and velocity changes
   (d) Both acceleration and speed are constant

3. For a body moving in a circular path, a condition for no skidding if μ is the coefficient of friction, is
   (a) $\frac{mv^2}{r} \le \mu mg$ (b) $\frac{mv^2}{r} \ge \mu mg$
   (c) $\frac{v}{r} = \mu g$ (d) $\frac{mv^2}{r} = \mu mg$

4. A car is moving with a uniform speed on a level road. Inside the car there is a balloon filled with helium and attached to a piece of string tied to the floor. The string is observed to be vertical. The car now takes a left turn maintaining the speed on the level road. The balloon in the car will
   (a) Continue to remain vertical
   (b) Burst while taking the curve
   (c) Be thrown to the right side
   (d) Be thrown to the left side

5. A particle is moving on a circular path of radius r with uniform velocity v. The change in velocity when the particle moves from P to Q is $(\angle POQ = 40^o)$



   (a) $2v\cos 40^o$
   (b) $2v\sin 40^o$
   (c) $2v\sin 20^o$
   (d) $2v\cos 20^o$

6. A body is revolving with a uniform speed v in a circle of radius r. The tangential acceleration is
   (a) $\frac{v}{r}$ (b) $\frac{v^2}{r}$
   (c) Zero (d) $\frac{v}{r^2}$

7. A particle does uniform circular motion in a horizontal plane. The radius of the circle is 20 *cm*. The centripetal force acting on the particle is 10 *N*. It's kinetic energy is
   (a) 0.1 *J* (b) 0.2 *J*
   (c) 2.0 *J* (d) 1.0 *J*

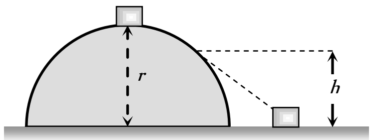
8. A body of mass m is suspended from a string of length l. What is minimum horizontal velocity that should be given to the body in its lowest position so that it may complete one full revolution in the vertical plane with the point of suspension as the centre of the circle
   (a) $v = \sqrt{2lg}$ (b) $v = \sqrt{3lg}$
   (c) $v = \sqrt{4lg}$ (d) $v = \sqrt{5lg}$

9. A particle moves with constant angular velocity in circular path of certain radius and is acted upon by a certain centripetal force F. If the angular velocity is doubled, keeping radius the same, the new force will be
   (a) $2F$ (b) F^2
   (c) $4F$ (d) $F/2$

10. In the above question, if the angular velocity is kept same but the radius of the path is halved, the new force will be
   (a) $2F$ (b) F^2
   (c) $F/2$ (d) $F/4$

11. In above question, if the centripetal force F is kept constant but the angular velocity is doubled, the new radius of the path (original radius R) will be
   (a) $2R$ (b) $R/2$
   (c) $R/4$ (d) $4R$

12. A small body of mass m slides down from the top of a hemisphere of radius r. The surface of block and hemisphere are frictionless. The height at which the body lose contact with the surface of the sphere is



   (a) $\frac{3}{2}r$ (b) $\frac{2}{3}r$
   (c) $\frac{1}{2}gt^2$ (d) $\frac{v^2}{2g}$

13. A body of mass m kg is rotating in a vertical circle at the end of a string of length r metre. The difference in the kinetic energy at the top and the bottom of the circle is
   (a) $\frac{mg}{r}$ (b) $\frac{2mg}{r}$
   (c) $2mgr$ (d) mgr

14. A car is travelling with linear velocity v on a circular road of radius r. If it is increasing its speed at the rate of 'a' $meter/\sec^2$, then the resultant acceleration will be

(a) $\sqrt{\left\{\frac{v^2}{r^2}-a^2\right\}}$ (b) $\sqrt{\left\{\frac{v^4}{r^2}+a^2\right\}}$

(c) $\sqrt{\left\{\frac{v^4}{r^2}-a^2\right\}}$ (d) $\sqrt{\left\{\frac{v^2}{r^2}+a^2\right\}}$

15. A ball of mass 0.1 *kg* is suspended by a string. It is displaced through an angle of 60^o and left. When the ball passes through the mean position, the tension in the string is

(a) 19.6 *N* (b) 1.96 *N*

(c) 9.8 *N* (d) Zero

16. An aeroplane moving horizontally at a speed of 200 *m/s* and at a height of $8.0\times10^3\ m$ is to drop a bomb on a target. At what horizontal distance from the target should the bomb be released

(a) 7.234 *km* (b) 8.081 *km*

(c) 8.714 *km* (d) 9.124 *km*

17. A body is projected horizontally from a height with speed 20 *metres/sec*. What will be its speed after 5 *seconds* $(g=10\ metres/\sec^2)$

(a) 54 *metres/sec* (b) 20 *metres/sec*

(c) 50 *metres/sec* (d) 70 *metres/sec*

18. A man standing on the roof of a house of height h throws one particle vertically downwards and another particle horizontally with the same velocity u. The ratio of their velocities when they reach the earth's surface will be

(a) $\sqrt{2gh+u^2}:u$ (b) $1:2$

(c) $1:1$ (d) $\sqrt{2gh+u^2}:\sqrt{2gh}$

19. (A projectile projected at an angle 30^o from the horizontal has a range R. If the angle of projection at the same initial velocity be 60^o, then the range will be

(a) R (b) $2R$

(c) $R/2$ (d) R^2

20. At the highest point of the path of a projectile, its

(a) Kinetic energy is maximum

(b) Potential energy is minimum

(c) Kinetic energy is minimum

(d) Total energy is maximum

21. A cricket ball is hit at 30^o with the horizontal with kinetic energy K. The kinetic energy at the highest point is

(a) Zero (b) $K/4$

(c) $K/2$ (d) $3K/4$

22. A cannon on a level plane is aimed at an angle θ above the horizontal and a shell is fired with a muzzle velocity v_0 towards a vertical cliff a distance D away. Then the height from the bottom at which the shell strikes the side walls of the cliff is

(a) $D\sin\theta-\frac{gD^2}{2v_0^2\sin^2\theta}$ (b) $D\cos\theta-\frac{gD^2}{2v_0^2\cos^2\theta}$

(c) $D\tan\theta-\frac{gD^2}{2v_0^2\cos^2\theta}$ (d) $D\tan\theta-\frac{gD^2}{2v_0^2\sin^2\theta}$

23. A stone is projected from the ground with velocity 50 *m/s* at an angle of 30^o. It crosses a wall after 3 *sec*. How far beyond the wall the stone will strike the ground $(g=10\,m/\sec^2)$

(a) 90.2 *m* (b) 89.6 *m*

(c) 86.6 *m* (d) 70.2 *m*

24. A body of mass m is projected at an angle of 45^o with the horizontal. If air resistance is negligible, then total change in momentum when it strikes the ground is

(a) $2mv$ (b) $\sqrt{2}\,mv$

(c) mv (d) $mv/\sqrt{2}$

25. A ball of mass m is thrown vertically upwards. Another ball of mass $2m$ is thrown at an angle θ with the vertical. Both of them stay in air for same period of time. The heights attained by the two balls are in the ratio of

(a) 2 : 1 (b) $1:\cos\theta$

(c) 1 : 1 (d) $\cos\theta:1$

26. A particle is projected with a velocity *v* such that its range on the horizontal plane is twice the greatest height attained by it. The range of the projectile is (where g is acceleration due to gravity)

(a) $\frac{4v^2}{5g}$ (b) $\frac{4g}{5v^2}$

(c) $\frac{v^2}{g}$ (d) $\frac{4v^2}{\sqrt{5}g}$

Answers and Solutions

(SET -3)

1. (a) By doing so component of weight of vehicle provides centripetal force.

2. (c) Both changes in direction although their magnitudes remains constant.

3. (a) The value of frictional force should be equal or more than required centripetal force. *i.e.* $\mu mg\ge\frac{mv^2}{r}$

4. (d) Air outside the balloon is heavier so it will have more tendency to move towards right and will keep the balloon towards left side (Here in this question car is supposed to be air tight).

5. (c) Change in velocity = $2v\sin(\theta/2) = 2v\sin 20°$

6. (c) In uniform circular motion only centripetal acceleration works.

7. (d) $\frac{mv^2}{r} = 10 \Rightarrow \frac{1}{2}mv^2 = 10 \times \frac{r}{2} = 1\,J$

8. (d) For looping the loop minimum velocity at the lowest point should be $\sqrt{5gl}$.

9. (c) $F = m\omega^2 R \;\therefore\; F \propto \omega^2$ (m and R are constant)
If angular velocity is doubled force will becomes four times.

10. (c) $F = m\omega^2 R \;\therefore\; F \propto R$ (m and ω are constant)
If radius of the path is halved, then force will also become half.

11. (c) $F = m\omega^2 R \;\therefore\; R \propto \frac{1}{\omega^2}$ (m and F are constant)
If ω is doubled then radius will become 1/4 times *i.e.* $R/4$

12. (b)

13. (c) Difference in K.E. = Difference in P.E. = $2mgr$

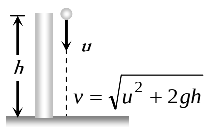
14. (b) $a_{resultant} = \sqrt{a^2_{radial} + a^2_{tangential}} = \sqrt{\frac{v^4}{r^2} + a^2}$

15. (b) $T = mg + \frac{mv^2}{l} = mg + \frac{m}{l}[2gl(1-\cos\theta)]$
$= mg + 2mg(1-\cos 60°) = 2mg = 2 \times 0.1 \times 9.8 = 1.96\,N$

16. (b) Horizontal distance travelled by the bomb $S = u \times t$
$= 200 \times \sqrt{\frac{2h}{g}} = 200 \times \sqrt{\frac{2 \times 8 \times 10^3}{9.8}} = 8.081\,km$

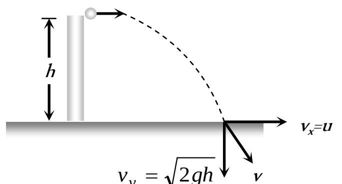
17. (a) Horizontal velocity $v_x = 20\,m/s$
Vertical velocity $v_y = u + gt = 0 + 10 \times 5 = 50\,m/\text{sec}$
Net velocity $v = \sqrt{v_x^2 + v_y^2} = \sqrt{(20)^2 + (50)^2} = 54\ m/s.$

18. (c) When particle thrown in vertical downward direction with velocity u then final velocity at the ground level



$v^2 = u^2 + 2gh \;\therefore\; v = \sqrt{u^2 + 2gh}$

Another particle is thrown horizontally with same velocity then*** at the surface of earth.



Horizontal component of velocity $v_x = u$

$\therefore$ Resultant velocity, $v = \sqrt{u^2 + 2gh}$

For both the particle final velocities when they reach the earth's surface are equal.

19. (a) For complementary angles of projection horizontal range is same.

20. (c) At the highest point of the path. Potential energy is maximum, so the kinetic energy will be minimum.

21. (d) Kinetic energy at the highest point

$$K' = K\cos^2\theta = K\cos^2 30 = K\left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3K}{4}$$

22. (c) Equation of trajectory for oblique projectile motion

$$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$

Substituting $x = D$ and $u = v_0$

$$h = D\tan\theta - \frac{gD^2}{2u_0^2\cos^2\theta}.$$

23. (c) Total time of flight $= \frac{2u\sin\theta}{g} = \frac{2 \times 50 \times 1}{2 \times 10} = 5\,s$
Time to cross the wall = 3 *sec* (given)
Time in air after crossing the wall = (5 − 3) = 2 *sec*
$\therefore$ Distance travelled beyond the wall $= (u\cos\theta)t$
$= 50 \times \frac{\sqrt{3}}{2} \times 2 = 86.6\,m$

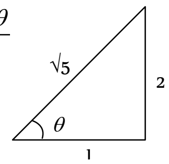
24. (b) Change in momentum $= 2mv\sin\theta = 2mv\sin\frac{\pi}{4} = \sqrt{2}mv$

25. (c) The vertical components of velocity of both the balls will be same if they stay in air for the same period of time. Hence vertical height attained will be same.

26. (a) $R = 2H$ given
We know $R = 4H\cot\theta \Rightarrow \cot\theta = \frac{1}{2}$
From triangle we can say that $\sin\theta = \frac{2}{\sqrt{5}}$, $\cos\theta = \frac{1}{\sqrt{5}}$

$\therefore$ Range of projectile $R = \frac{2v^2\sin\theta\cos\theta}{g}$

$= \frac{2v^2}{g} \times \frac{2}{\sqrt{5}} \times \frac{1}{\sqrt{5}} = \frac{4v^2}{5g}.$



Chapter 4

Newton's Laws of Motion

Point Mass

(1) An object can be considered as a point object if during motion in a given time, it covers distance much greater than its own size.

(2) Object with zero dimension considered as a point mass.

(3) Point mass is a mathematical concept to simplify the problems.

Inertia

(1) Inherent property of all the bodies by virtue of which they cannot change their state of rest or uniform motion along a straight line by their own is called inertia.

(2) Inertia is not a physical quantity, it is only a property of the body which depends on mass of the body.

(3) Inertia has no units and no dimensions

(4) Two bodies of equal mass, one in motion and another is at rest, possess same inertia because it is a factor of mass only and does not depend upon the velocity.

Linear Momentum

(1) Linear momentum of a body is the quantity of motion contained in the body.

(2) It is measured in terms of the force required to stop the body in unit time.

(3) It is also measured as the product of the mass of the body and its velocity *i.e.*, Momentum = mass × velocity.

If a body of mass m is moving with velocity $\vec{v}$ then its linear momentum $\vec{p}$ is given by $\vec{p} = m\vec{v}$

(4) It is a vector quantity and it's direction is the same as the direction of velocity of the body.

(5) Units : *kg-m/sec* [S.I.], *g-cm/sec* [C.G.S.]

(6) Dimension : $[MLT^{-1}]$

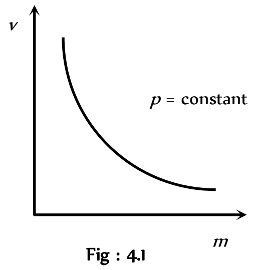


Fig : 4.1

(7) If two objects of different masses have same momentum, the lighter body possesses greater velocity.

$$p = m_1 v_1 = m_2 v_2 = \text{constant} \qquad \therefore \qquad \frac{v_1}{v_2} = \frac{m_2}{m_1}$$

i.e. $v \propto \frac{1}{m}$

[As p is constant]

(8) For a given body $p \propto v$

(9) For different bodies moving with same velocities $p \propto m$

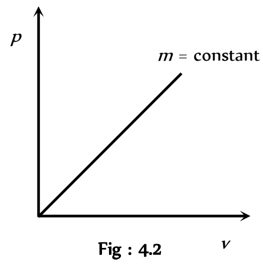


Fig : 4.2

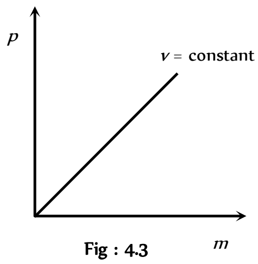


Fig : 4.3

Newton's First Law

A body continue to be in its state of rest or of uniform motion along a straight line, unless it is acted upon by some external force to change the state.

(1) If no net force acts on a body, then the velocity of the body cannot change *i.e.* the body cannot accelerate.

(2) Newton's first law defines inertia and is rightly called the law of inertia. Inertia are of three types :

Inertia of rest, Inertia of motion and Inertia of direction.

(3) **Inertia of rest :** It is the inability of a body to change by itself, its state of rest. This means a body at rest remains at rest and cannot start moving by its own.

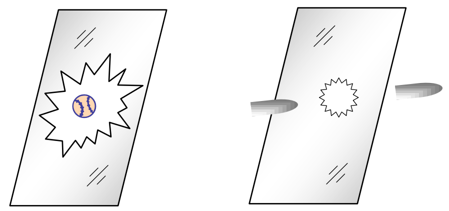
Example : (i) A person who is standing freely in bus, thrown backward, when bus starts suddenly.

When a bus suddenly starts, the force responsible for bringing bus in motion is also transmitted to lower part of body, so this part of the body comes in motion along with the bus. While the upper half of body (say above the waist) receives no force to overcome inertia of rest and so it stays in its original position. Thus there is a relative displacement between the two parts of the body and it appears as if the upper part of the body has been thrown backward.

Note : ❑ (i) If the motion of the bus is slow, the inertia of motion will be transmitted to the body of the person uniformly and so the entire body of the person will come in motion with the bus and the person will not experience any jerk.

(ii) When a horse starts suddenly, the rider tends to fall backward on account of inertia of rest of upper part of the body as explained above.

(iii) A bullet fired on a window pane makes a clean hole through it, while a ball breaks the whole window. The bullet has a speed much greater than the ball. So its time of contact with glass is small. So in case of bullet the motion is transmitted only to a small portion of the glass in that small time. Hence a clear hole is created in the glass window, while in case of ball, the time and the area of contact is large. During this time the motion is transmitted to the entire window, thus creating the cracks in the entire window.



Cracks by the ball   Hole by the bullet

Fig : 4.4

(iv) In the arrangement shown in the figure :

(a) If the string B is pulled with a sudden jerk then it will experience tension while due to inertia of rest of mass M this force will not be transmitted to the string A and so the string B will break.

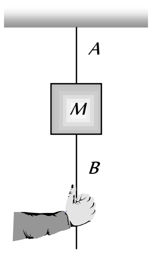


Fig : 4.5

(b) If the string B is pulled steadily the force applied to it will be transmitted from string B to A through the mass M and as tension in A will be greater than in B by Mg (weight of mass M), the string A will break.

(v) If we place a coin on smooth piece of card board covering a glass and strike the card board piece suddenly with a finger. The cardboard slips away and the coin falls into the glass due to inertia of rest.

(vi) The dust particles in a carpet falls off when it is beaten with a stick. This is because the beating sets the carpet in motion whereas the dust particles tend to remain at rest and hence separate.

(4) **Inertia of motion :** It is the inability of a body to change by itself its state of uniform motion *i.e.,* a body in uniform motion can neither accelerate nor retard by its own.

Example : (i) When a bus or train stops suddenly, a passenger sitting inside tends to fall forward. This is because the lower part of his body comes to rest with the bus or train but the upper part tends to continue its motion due to inertia of motion.

(ii) A person jumping out of a moving train may fall forward.

(iii) An athlete runs a certain distance before taking a long jump. This is because velocity acquired by running is added to velocity of the athlete at the time of jump. Hence he can jump over a longer distance.

(5) **Inertia of direction :** It is the inability of a body to change by itself it's direction of motion.

Example : (i) When a stone tied to one end of a string is whirled and the string breaks suddenly, the stone flies off along the tangent to the circle. This is because the pull in the string was forcing the stone to move in a circle. As soon as the string breaks, the pull vanishes. The stone in a bid to move along the straight line flies off tangentially.

(ii) The rotating wheel of any vehicle throw out mud, if any, tangentially, due to directional inertia.

(iii) When a car goes round a curve suddenly, the person sitting inside is thrown outwards.

Newton’s Second Law

(1) The rate of change of linear momentum of a body is directly proportional to the external force applied on the body and this change takes place always in the direction of the applied force.

(2) If a body of mass m, moves with velocity $\vec{v}$ then its linear momentum can be given by $\vec{p} = m\vec{v}$ and if force $\vec{F}$ is applied on a body, then

$$\vec{F} \propto \frac{d\vec{p}}{dt} \Rightarrow F = K\frac{d\vec{p}}{dt}$$

or $\vec{F} = \frac{d\vec{p}}{dt}$ ($K = 1$ in C.G.S. and S.I. units)

or $\vec{F} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}$

(As $a = \frac{d\vec{v}}{dt} =$ acceleration produced in the body)

$$\therefore \vec{F} = m\vec{a}$$

Force = mass × acceleration

Force

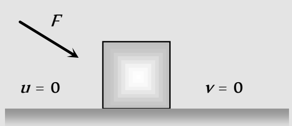
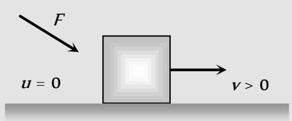
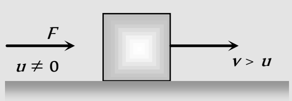
(1) Force is an external effect in the form of a push or pull which

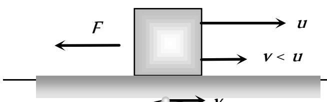
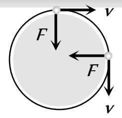
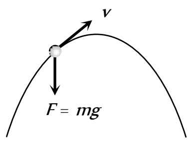
(i) Produces or tries to produce motion in a body at rest.

(ii) Stops or tries to stop a moving body.

(iii) Changes or tries to change the direction of motion of the body.

Table 4.1 : Various condition of force application

	Body remains at rest. Here force is trying to change the state of rest.
	Body starts moving. Here force changes the state of rest.
	In a small interval of time, force increases the magnitude of speed and direction of motion remains same.

	In a small interval of time, force decreases the magnitude of speed and direction of motion remains same.
	In uniform circular motion only direction of velocity changes, speed remains constant. Force is always perpendicular to velocity.
	In non-uniform circular motion, elliptical, parabolic or hyperbolic motion force acts at an angle to the direction of motion. In all these motions. Both magnitude and direction of velocity changes.

(2) Dimension : Force = mass × acceleration

$$[F]=[M][LT^{-2}]=[MLT^{-2}]$$

(3) Units : Absolute units : (i) *Newton* (S.I.) (ii) *Dyne* (C.G.S)

Gravitational units : (i) Kilogram-force (M.K.S.) (ii) Gram-force (C.G.S)

Newton : One Newton is that force which produces an acceleration of $1m/s^2$ in a body of mass 1 *Kilogram*.

$\therefore 1\ Newton = 1kg-m/s^2$

Dyne : One dyne is that force which produces an acceleration of $1cm/s^2$ in a body of mass 1 *gram*.

$\therefore$ 1 $Dyne = 1gm\,cm/\sec^2$

Relation between absolute units of force 1 *Newton* $= 10^5$ *Dyne*

Kilogram-force : It is that force which produces an acceleration of $9.8m/s^2$ in a body of mass 1 *kg*.

$\therefore$ 1 *kg-f* = 9.80 *Newton*

Gram-force : It is that force which produces an acceleration of $980cm/s^2$ in a body of mass 1*gm*.

$\therefore$ 1 *gm-f* = 980 *Dyne*

(4) $\vec{F}=m\vec{a}$ formula is valid only if force is changing the state of rest or motion and the mass of the body is constant and finite.

(5) If *m* is not constant $\vec{F}=\frac{d}{dt}(m\vec{v})=m\frac{d\vec{v}}{dt}+\vec{v}\frac{dm}{dt}$

(6) If force and acceleration have three component along *x*, *y* and *z* axis, then

$\vec{F}=F_x\hat{i}+F_y\hat{j}+F_z\hat{k}$ and $\vec{a}=a_x\hat{i}+a_y\hat{j}+a_z\hat{k}$

From above it is clear that $F_x=ma_x,\ F_y=ma_y, F_z=ma_z$

(7) No force is required to move a body uniformly along a straight line with constant speed.

$\vec{F}=m\vec{a}$ $\qquad \therefore \vec{F}=0$ (As $\vec{a}=0$)

(8) When force is written without direction then positive force means repulsive while negative force means attractive.

Example : *Positive force* – Force between two similar charges

Negative force – Force between two opposite charges

(9) Out of so many natural forces, for distance 10^{-15} *metre*, nuclear force is strongest while gravitational force weakest. $F_{\text{nuclear}} > F_{\text{electromagnetic}} > F_{\text{gravitational}}$

(10) Ratio of electric force and gravitational force between two electron's $F_e/F_g = 10^{43}$ $\quad \therefore F_e >> F_g$

(11) Constant force : If the direction and magnitude of a force is constant. It is said to be a constant force.

(12) Variable or dependent force :

(i) *Time dependent force* : In case of impulse or motion of a charged particle in an alternating electric field force is time dependent.

(ii) *Position dependent force* : Gravitational force between two bodies $\frac{Gm_1m_2}{r^2}$

or Force between two charged particles $=\frac{q_1q_2}{4\pi\varepsilon_0 r^2}$.

(iii) *Velocity dependent force* : Viscous force $(6\pi\eta rv)$

Force on charged particle in a magnetic field $(qvB\sin\theta)$

(13) Central force : If a position dependent force is directed towards or away from a fixed point it is said to be central otherwise non-central.

Example : Motion of Earth around the Sun. Motion of electron in an atom. Scattering of α-particles from a nucleus.

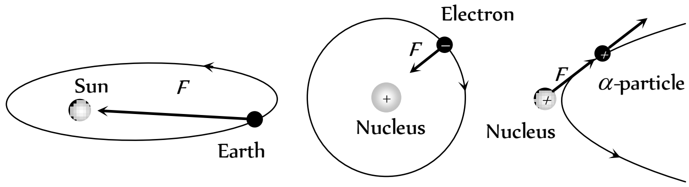


Fig : 4.6

(14) Conservative or non conservative force : If under the action of a force the work done in a round trip is zero or the work is path independent, the force is said to be conservative otherwise non conservative.

Example : Conservative force : Gravitational force, electric force, elastic force.

Non conservative force : Frictional force, viscous force.

(15) Common forces in mechanics :

(i) *Weight* : Weight of an object is the force with which earth attracts it. It is also called the force of gravity or the gravitational force.

(ii) *Reaction or Normal force :* When a body is placed on a rigid surface, the body experiences a force which is perpendicular to the surfaces in contact. Then force is called 'Normal force' or 'Reaction'.

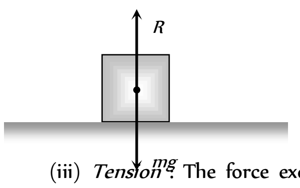


Fig : 4.7

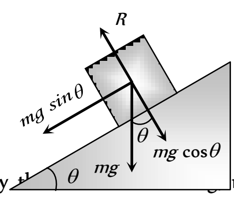


Fig : 4.8

(iii) *Tension* : The force exerted by [illegible] rope or chain against pulling (applied) force is called the tension. The direction of tension is so as to pull the body.

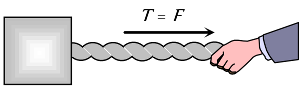


Fig : 4.9

(iv) *Spring force :* Every spring resists any attempt to change its length. This resistive force increases with change in length. Spring force is given by $F = -Kx$; where x is the change in length and K is the spring constant (unit N/m).

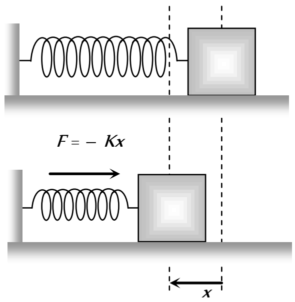


Fig : 4.10

Equilibrium of Concurrent Force

(1) If all the forces working on a body are acting on the same point, then they are said to be concurrent.

(2) A body, under the action of concurrent forces, is said to be in equilibrium, when there is no change in the state of rest or of uniform motion along a straight line.

(3) The necessary condition for the equilibrium of a body under the action of concurrent forces is that the vector sum of all the forces acting on the body must be zero.

(4) Mathematically for equilibrium $\sum \vec{F}_{\text{net}} = 0$ or $\sum F_x = 0$; $\sum F_y = 0$; , $\sum F_z = 0$

(5) Three concurrent forces will be in equilibrium, if they can be represented completely by three sides of a triangle taken in order.

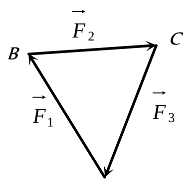


Fig : 4.11

(6) Lami's Theorem : For three concurrent forces in equilibrium $\dfrac{F_1}{\sin\alpha} = \dfrac{F_2}{\sin\beta} = \dfrac{F_3}{\sin\gamma}$

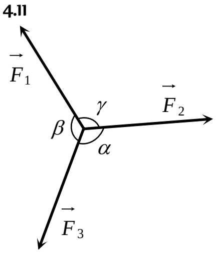


Fig : 4.12

Newton's Third Law

To every action, there is always an equal (in magnitude) and opposite (in direction) reaction.

(1) When a body exerts a force on any other body, the second body also exerts an equal and opposite force on the first.

(2) Forces in nature always occurs in pairs. A single isolated force is not possible.

(3) Any agent, applying a force also experiences a force of equal magnitude but in opposite direction. The force applied by the agent is called '*Action*' and the counter force experienced by it is called '*Reaction*'.

(4) Action and reaction never act on the same body. If it were so, the total force on a body would have always been zero *i.e.* the body will always remain in equilibrium.

(5) If $\vec{F}_{AB}$ = force exerted on body A by body B (Action) and $\vec{F}_{BA}$ = force exerted on body B by body A (Reaction)

Then according to Newton's third law of motion $\vec{F}_{AB} = -\vec{F}_{BA}$

(6) Example : (i) A book lying on a table exerts a force on the table which is equal to the weight of the book. This is the force of action.

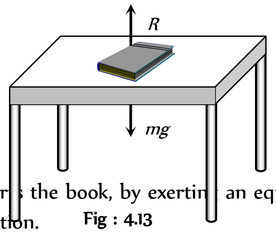


Fig : 4.13

The table supports the book, by exerting an equal force on the book. This is the force of reaction.

As the system is at rest, net force on it is zero. Therefore force of action and reaction must be equal and opposite.

(ii) Swimming is possible due to third law of motion.

(iii) When a gun is fired, the bullet moves forward (action). The gun recoils backward (reaction)

(iv) Rebounding of rubber ball takes place due to third law of motion.

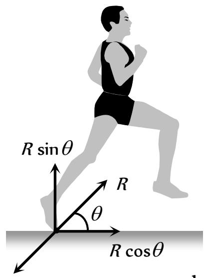


Fig : 4.14

(v) While walking a person presses the ground in the backward direction (action) by his feet. The ground pushes the person in forward direction with an equal force (reaction). The component of reaction in horizontal direction makes the person move forward.

(vi) It is difficult to walk on sand or ice.

(vii) Driving a nail into a wooden block without holding the block is difficult.

Frame of Reference

(1) A frame in which an observer is situated and makes his observations is known as his 'Frame of reference'.

(2) The reference frame is associated with a co-ordinate system and a clock to measure the position and time of events happening in space. We can describe all the physical quantities like position, velocity, acceleration etc. of an object in this coordinate system.

(3) Frame of reference are of two types : (i) Inertial frame of reference (ii) Non-inertial frame of reference.

(i) **Inertial frame of reference :**

(a) A frame of reference which is at rest or which is moving with a uniform velocity along a straight line is called an inertial frame of reference.

(b) In inertial frame of reference Newton's laws of motion holds good.

(c) Inertial frame of reference are also called unaccelerated frame of reference or Newtonian or Galilean frame of reference.

(d) Ideally no inertial frame exist in universe. For practical purpose a frame of reference may be considered as inertial if it's acceleration is negligible with respect to the acceleration of the object to be observed.

(e) To measure the acceleration of a falling apple, earth can be considered as an inertial frame.

(f) To observe the motion of planets, earth can not be considered as an inertial frame but for this purpose the sun may be assumed to be an inertial frame.

Example : The lift at rest, lift moving (up or down) with constant velocity, car moving with constant velocity on a straight road.

(ii) **Non-inertial frame of reference**

(a) Accelerated frame of references are called non-inertial frame of reference.

(b) Newton's laws of motion are not applicable in non-inertial frame of reference.

Example : Car moving in uniform circular motion, lift which is moving upward or downward with some acceleration, plane which is taking off.

Impulse

(1) When a large force works on a body for very small time interval, it is called impulsive force.

An impulsive force does not remain constant, but changes first from zero to maximum and then from maximum to zero. In such case we measure the total effect of force.

(2) Impulse of a force is a measure of total effect of force.

(3) $\vec{I} = \int_{t_1}^{t_2} \vec{F}\, dt$.

(4) Impulse is a vector quantity and its direction is same as that of force.

(5) Dimension : $[MLT^{-1}]$

(6) Units : *Newton-second* or $Kg\text{-}m\text{-}s^{-1}$ (S.I.)

Dyne-second or $gm\text{-}cm\text{-}s^{-1}$ (C.G.S.)

(7) Force-time graph : Impulse is equal to the area under *F-t* curve.

If we plot a graph between force and time, the area under the curve and time axis gives the value of impulse.

$I =$ Area between curve and time axis

$= \frac{1}{2} \times$ Base $\times$ Height

$= \frac{1}{2} F\, t$

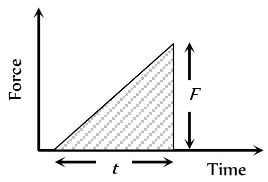


Fig : 4.15

(8) If F_{av} is the average magnitude of the force then

$$I = \int_{t_1}^{t_2} F\, dt = F_{av} \int_{t_1}^{t_2} dt = F_{av} \Delta t$$

(9) From Newton's second law

$$\vec{F} = \frac{d\vec{p}}{dt}$$

or $\int_{t_1}^{t_2} \vec{F}\, dt = \int_{p_1}^{p_2} d\vec{p}$

$\Rightarrow \vec{I} = \vec{p}_2 - \vec{p}_1 = \overrightarrow{\Delta p}$

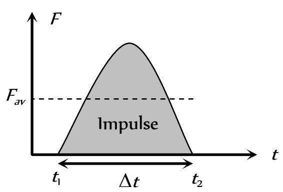


Fig : 4.16

i.e. The impulse of a force is equal to the change in momentum.

This statement is known as *Impulse momentum theorem*.

Examples : Hitting, kicking, catching, jumping, diving, collision *etc*.

In all these cases an impulse acts.

$$I = \int F\, dt = F_{av} . \Delta t = \Delta p = \text{constant}$$

So if time of contact Δt is increased, average force is decreased (or diluted) and vice-versa.

(i) In hitting or kicking a ball we decrease the time of contact so that large force acts on the ball producing greater acceleration.

(ii) In catching a ball a player by drawing his hands backwards increases the time of contact and so, lesser force acts on his hands and his hands are saved from getting hurt.

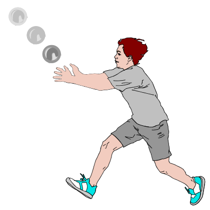


Fig : 4.17

(iii) In jumping on sand (or water) the time of contact is increased due to yielding of sand or water so force is decreased and we are not injured. However if we jump on cemented floor the motion stops in a very short interval of time resulting in a large force due to which we are seriously injured.

(iv) An athlete is advised to come to stop slowly after finishing a fast race, so that time of stop increases and hence force experienced by him decreases.

(v) China wares are wrapped in straw or paper before packing.

Law of Conservation of Linear Momentum

If no external force acts on a system (called isolated) of constant mass, the total momentum of the system remains constant with time.

(1) According to this law for a system of particles $\vec{F} = \frac{d\vec{p}}{dt}$

In the absence of external force $\vec{F} = 0$ then $\vec{p} =$ constant

i.e., $\vec{p} = \vec{p}_1 + \vec{p}_2 + \vec{p}_3 + ... =$ constant.

or $m_1 \vec{v}_1 + m_2 \vec{v}_2 + m_3 \vec{v}_3 + ... =$ constant

This equation shows that in absence of external force for a closed system the linear momentum of individual particles may change but their sum remains unchanged with time.

(2) Law of conservation of linear momentum is independent of frame of reference, though linear momentum depends on frame of reference.

(3) Conservation of linear momentum is equivalent to Newton's third law of motion.

For a system of two particles in absence of external force, by law of conservation of linear momentum.

$\vec{p}_1 + \vec{p}_2 =$ constant.

$\therefore\ m_1 \vec{v}_1 + m_2 \vec{v}_2 =$ constant.

Differentiating above with respect to time

$$m_1 \frac{d\vec{v}_1}{dt} + m_2 \frac{d\vec{v}_2}{dt} = 0 \Rightarrow m_1 \vec{a}_1 + m_2 \vec{a}_2 = 0 \ \Rightarrow \vec{F}_1 + \vec{F}_2 = 0$$

$\therefore\ \vec{F}_2 = -\vec{F}_1$

i.e. for every action there is an equal and opposite reaction which is Newton's third law of motion.

(4) Practical applications of the law of conservation of linear momentum

(i) When a man jumps out of a boat on the shore, the boat is pushed slightly away from the shore.

(ii) A person left on a frictionless surface can get away from it by blowing air out of his mouth or by throwing some object in a direction opposite to the direction in which he wants to move.

(iii) **Recoiling of a gun :** For bullet and gun system, the force exerted by trigger will be internal so the momentum of the system remains unaffected.

Fig : 4.18

Let $m_G =$ mass of gun, $m_B =$ mass of bullet,

$v_G =$ velocity of gun, $v_B =$ velocity of bullet

Initial momentum of system = 0

Final momentum of system $= m_G\vec{v}_G + m_B\vec{v}_B$

By the law of conservation of linear momentum

$$m_G\vec{v}_G + m_B\vec{v}_B = 0$$

So recoil velocity $\vec{v}_G = -\frac{m_B}{m_G}\vec{v}_B$

(a) Here negative sign indicates that the velocity of recoil $\vec{v}_G$ is opposite to the velocity of the bullet.

(b) $v_G \propto \frac{1}{m_G}$ *i.e.* higher the mass of gun, lesser the velocity of recoil of gun.

(c) While firing the gun must be held tightly to the shoulder, this would save hurting the shoulder because in this condition the body of the shooter and the gun behave as one body. Total mass become large and recoil velocity becomes too small.

$$v_G \propto \frac{1}{m_G + m_{\text{man}}}$$

(iv) **Rocket propulsion :** The initial momentum of the rocket on its launching pad is zero. When it is fired from the launching pad, the exhaust gases rush downward at a high speed and to conserve momentum, the rocket moves upwards.

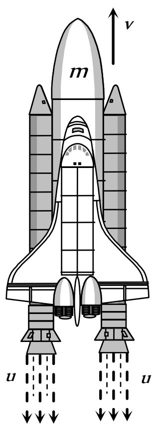


Fig : 4.19

Let $m_0 =$ initial mass of rocket,

m = mass of rocket at any instant 't' (instantaneous mass)

$m_r =$ residual mass of empty container of the rocket

u = velocity of exhaust gases,

v = velocity of rocket at any instant 't' (instantaneous velocity)

$\frac{dm}{dt} =$ rate of change of mass of rocket = rate of fuel consumption

= rate of ejection of the fuel.

(a) Thrust on the rocket : $F = -u\frac{dm}{dt} - mg$

Here negative sign indicates that direction of thrust is opposite to the direction of escaping gases.

$F = -u\frac{dm}{dt}$ (if effect of gravity is neglected)

(b) Acceleration of the rocket : $a = \frac{u}{m}\frac{dm}{dt} - g$

and if effect of gravity is neglected $a = \frac{u}{m}\frac{dm}{dt}$

(c) Instantaneous velocity of the rocket :

$$v = u\log_e\left(\frac{m_0}{m}\right) - gt$$

and if effect of gravity is neglected $v = u\log_e\left(\frac{m_0}{m}\right)$

$= 2.303u\log_{10}\left(\frac{m_0}{m}\right)$

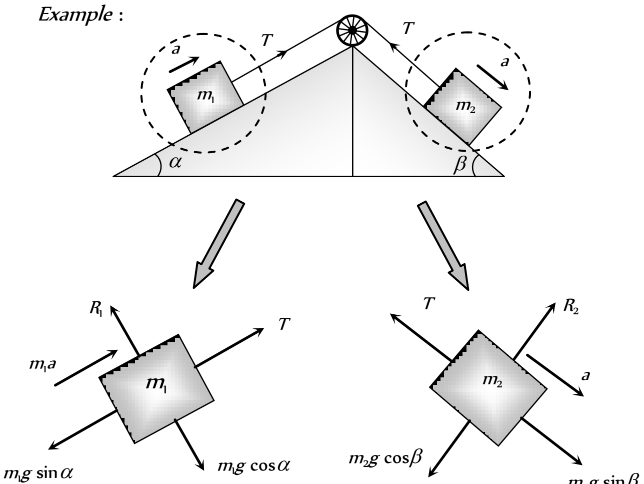
(d) Burnt out speed of the rocket : $v_b = v_{\max} = u\log_e\left(\frac{m_0}{m_r}\right)$

The speed attained by the rocket when the complete fuel gets burnt is called burnt out speed of the rocket. It is the maximum speed acquired by the rocket.

Free Body Diagram

In this diagram the object of interest is isolated from its surroundings and the interactions between the object and the surroundings are represented in terms of forces.

Example :



Free body diagram of

Free body diagram of

Apparent Weight of a Body in a Lift

When a body of mass m is placed on a weighing machine which is placed in a lift, then actual weight of the body is mg.

This acts on a weighing machine which offers a reaction R given by the reading of weighing machine. This reaction exerted by the surface of contact on the body is the *apparent weight* of the body.

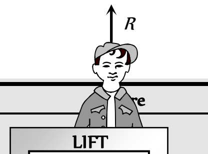
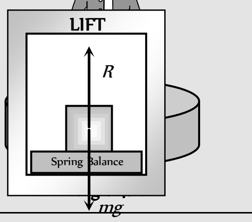
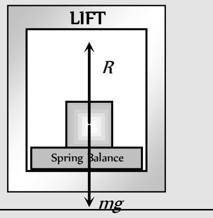
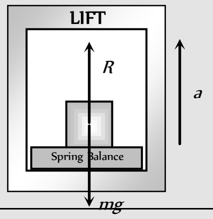
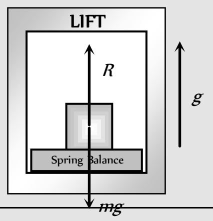
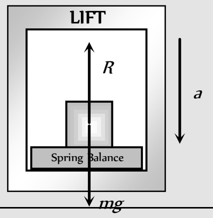
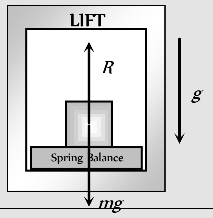
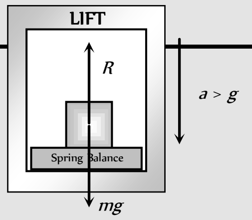


Table 4.2 : Apparent weight in a lift

Condition	re	Velocity	Acceleration	Reaction	Conclusion
Lift is at rest		$v = 0$	$a = 0$	$R - mg = 0$ $\therefore\ R = mg$	Apparent weight = Actual weight
Lift moving upward or downward with constant velocity		v = constant	$a = 0$	$R - mg = 0$ $\therefore\ R = mg$	Apparent weight = Actual weight
Lift accelerating upward at the rate of 'a'		v = variable	$a < g$	$R - mg = ma$ $\therefore R = m(g + a)$	Apparent weight > Actual weight
Lift accelerating upward at the rate of 'g'		v = variable	$a = g$	$R - mg = mg$ $R = 2mg$	Apparent weight = 2 Actual weight
Lift accelerating downward at the rate of 'a'		v = variable	$a < g$	$mg - R = ma$ $\therefore\ R = m(g - a)$	Apparent weight < Actual weight
Lift accelerating downward at the rate of 'g'		v = variable	$a = g$	$mg - R = mg$ $R = 0$	Apparent weight = Zero (weightlessness)
Lift accelerating downward at the rate		v = variable	$a > g$	$mg - R = ma$ $R = mg - ma$	Apparent weight negative means the body will rise

of a(>g)				$R = -$ *ve*	from the floor of the lift and stick to the ceiling of the lift.

Acceleration of Block on Horizontal Smooth Surface

(1) **When a pull is horizontal**

$R = mg$

and $F = ma$

$\therefore\ a = F/m$

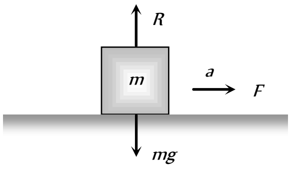


Fig : 4.22

(2) **When a pull is acting at an angle (θ) to the horizontal (upward)**

$R + F\sin\theta = mg$

$\Rightarrow R = mg - F\sin\theta$

and $F\cos\theta = ma$

$\therefore\ a = \dfrac{F\cos\theta}{m}$

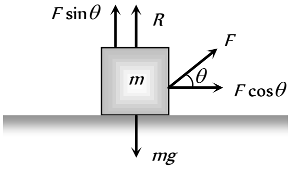


Fig : 4.23

(3) **When a push is acting at an angle (θ) to the horizontal (downward)**

$R = mg + F\sin\theta$

and $F\cos\theta = ma$

$a = \dfrac{F\cos\theta}{m}$

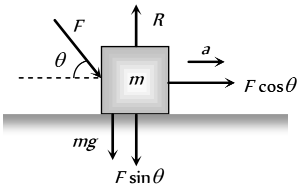


Fig : 4.24

Acceleration of Block on Smooth Inclined Plane

(1) **When inclined plane is at rest**

Normal reaction $R = mg\cos\theta$

Force along a inclined plane

$F = mg\sin\theta$; $ma = mg\ \sin\theta$

$\therefore a = g\sin\theta$

(2) **When a inclined plane given a horizontal acceleration '*b*'**

Since the body lies in an accelerating frame, an inertial force (mb) acts on it in the opposite direction.

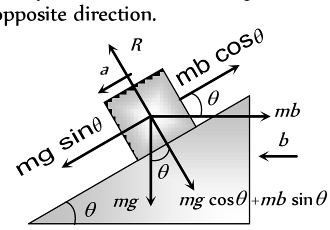


Fig : 4.25

Normal reaction $R = mg\cos\theta + mb\sin\theta$

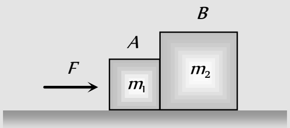
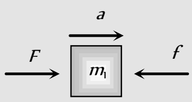
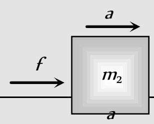
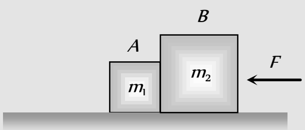
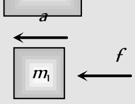
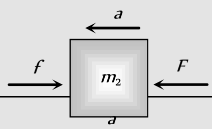
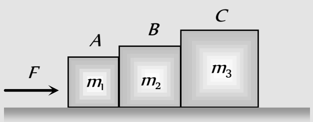
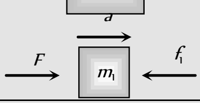
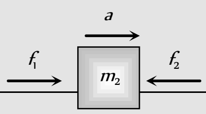
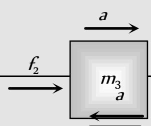
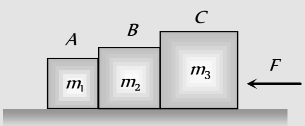
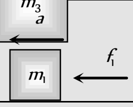
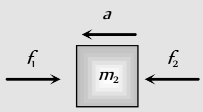
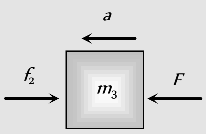
and $ma = mg\ \sin\theta - mb\cos\theta$

$\therefore\quad a = g\sin\theta - b\cos\theta$

Note : ❑ The condition for the body to be at rest relative to the inclined plane : $a = g\sin\theta - b\cos\theta = 0$

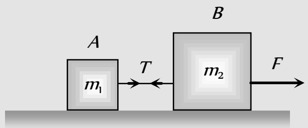
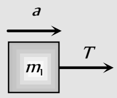
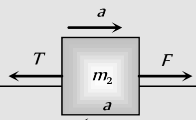
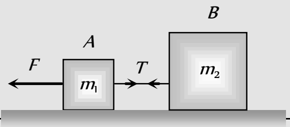
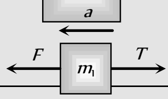
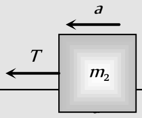
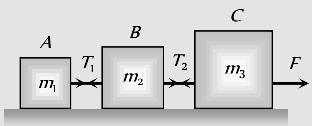
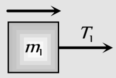
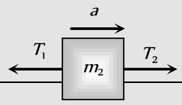
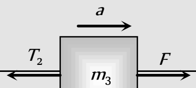
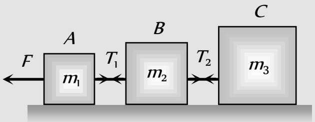
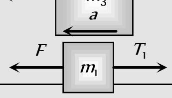
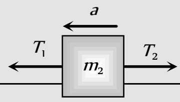
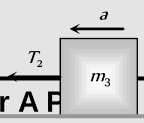
$\therefore\ b = g\tan\theta$

Motion of Blocks In Contact

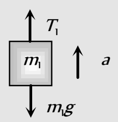
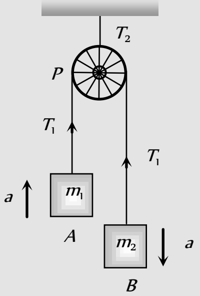
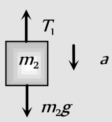
Condition	Free body diagram	Equation	Force and acceleration
		$F - f = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$f = m_2 a$	$f = \dfrac{m_2 F}{m_1 + m_2}$
		$f = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$F - f = m_2 a$	$f = \dfrac{m_1 F}{m_1 + m_2}$
		$F - f_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$f_1 - f_2 = m_2 a$	$f_1 = \dfrac{(m_2 + m_3)F}{m_1 + m_2 + m_3}$
		$f_2 = m_3 a$	$f_2 = \dfrac{m_3 F}{m_1 + m_2 + m_3}$
		$f_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$f_2 - f_1 = m_2 a$	$f_1 = \dfrac{m_1 F}{m_1 + m_2 + m_3}$
			

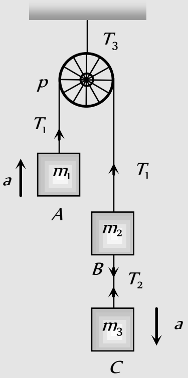
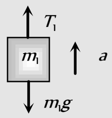
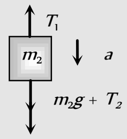
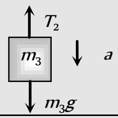
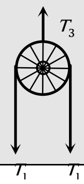
		$F - f_2 = m_3 a$	$f_2 = \dfrac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$

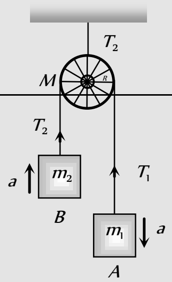
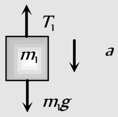
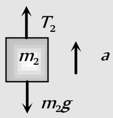
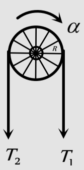
Motion of Blocks Connected by Mass Less String

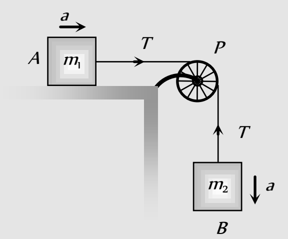
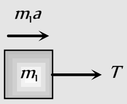
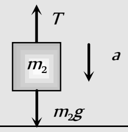
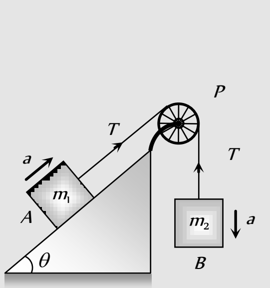
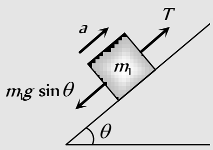
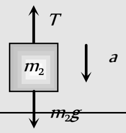
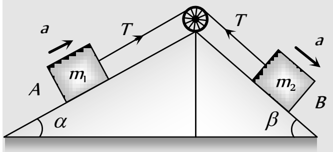
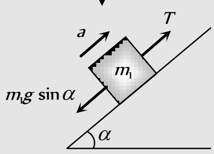
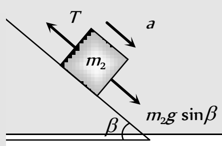
Condition	Free body diagram	Equation	Tension and acceleration
		$T = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$F - T = m_2 a$	$T = \dfrac{m_1 F}{m_1 + m_2}$
		$F - T = m_1 a$	$a = \dfrac{F}{m_1 + m_2}$
		$T = m_2 a$	$T = \dfrac{m_2 F}{m_1 + m_2}$
		$T_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$T_2 - T_1 = m_2 a$	$T_1 = \dfrac{m_1 F}{m_1 + m_2 + m_3}$
		$F - T_2 = m_3 a$	$T_2 = \dfrac{(m_1 + m_2)F}{m_1 + m_2 + m_3}$
		$F - T_1 = m_1 a$	$a = \dfrac{F}{m_1 + m_2 + m_3}$
		$T_1 - T_2 = m_2 a$	$T_1 = \dfrac{(m_2 + m_3)F}{m_1 + m_2 + m_3}$
		$T_2 = m_3 a$	$T_2 = \dfrac{m_3 F}{m_1 + m_2 + m_3}$

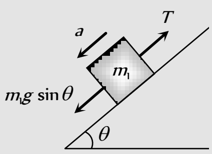
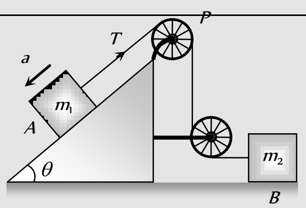
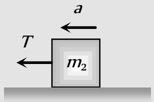
Motion of Connected Block Over A F

Condition	Free body diagram	Equation	Tension and acceleration
		$m_1 a = T_1 - m_1 g$	$T_1 = \dfrac{2m_1 m_2}{m_1 + m_2} g$
			
			

		$m_2a = m_2g - T_1$	$T_2 = \frac{4m_1m_2}{m_1+m_2}g$
		$T_2 = 2T_1$	$a = \left[\frac{m_2-m_1}{m_1+m_2}\right]g$
		$m_1a = T_1 - m_1g$	$T_1 = \frac{2m_1[m_2+m_3]}{m_1+m_2+m_3}g$
		$m_2a = m_2g + T_2 - T_1$	$T_2 = \frac{2m_1m_3}{m_1+m_2+m_3}g$
		$m_3a = m_3g - T_2$	$T_3 = \frac{4m_1[m_2+m_3]}{m_1+m_2+m_3}g$
		$T_3 = 2T_1$	$a = \frac{[(m_2+m_3)-m_1]g}{m_1+m_2+m_3}$

Condition	Free body diagram	Equation	Tension and acceleration
When pulley have a finite mass M and radius R then tension in two segments of string are different 		$m_1a = m_1g - T_1$	$a = \frac{m_1-m_2}{m_1+m_2+\frac{M}{2}}$
		$m_2a = T_2 - m_2g$	$T_1 = \frac{m_1\left[2m_2+\frac{M}{2}\right]}{m_1+m_2+\frac{M}{2}}g$
			

		Torque $=(T_1-T_2)R=I\alpha$ $(T_1-T_2)R=I\dfrac{a}{R}$ $(T_1-T_2)R=\dfrac{1}{2}MR^2\dfrac{a}{R}$ $T_1-T_2=\dfrac{Ma}{2}$	$T_2=\dfrac{m_2\left[2m_1+\dfrac{M}{2}\right]}{m_1+m_2+\dfrac{M}{2}}g$
		$T=m_1a$	$a=\dfrac{m_2}{m_1+m_2}g$
		$m_2a=m_2g-T$	$T=\dfrac{m_1m_2}{m_1+m_2}g$
		$m_1a=T-m_1g\sin\theta$	$a=\left[\dfrac{m_2-m_1\sin\theta}{m_1+m_2}\right]g$
		$m_2a=m_2g-T$	$T=\dfrac{m_1m_2(1+\sin\theta)}{m_1+m_2}g$
		$T-m_1g\sin\alpha=m_1a$	$a=\dfrac{(m_2\sin\beta-m_1\sin\alpha)}{m_1+m_2}g$
		$m_2a=m_2g\sin\beta-T$	$T=\dfrac{m_1m_2(\sin\alpha+\sin\beta)}{m_1+m_2}g$

Condition	Free body diagram	Equation	Tension and acceleration
		$m_1g\sin\theta-T=m_1a$	$a=\dfrac{m_1g\sin\theta}{m_1+m_2}$
			

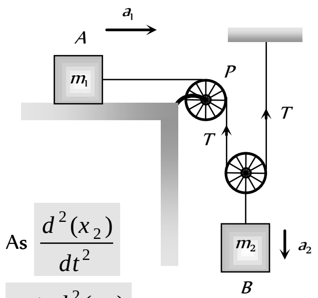
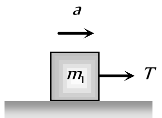
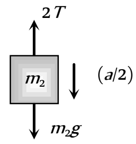
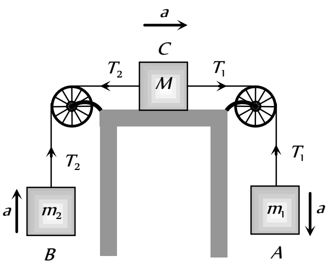
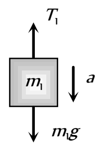
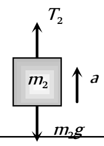
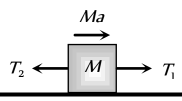
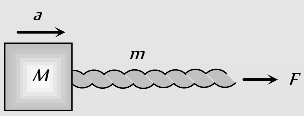
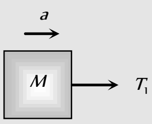
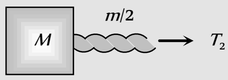
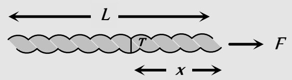
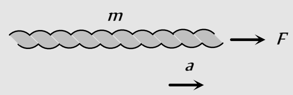
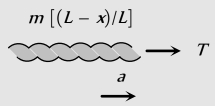
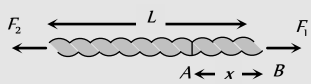
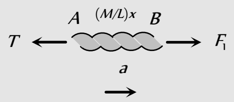
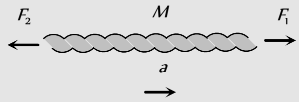
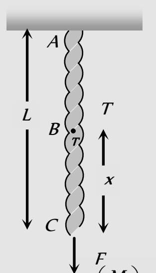
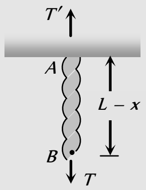
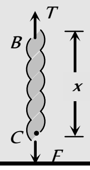
		$T = m_2 a$	$T = \frac{2m_1 m_2}{4m_1 + m_2} g$
 As $\frac{d^2(x_2)}{dt^2}$ $= \frac{1}{2}\frac{d^2(x_1)}{dt^2}$ $\therefore a_2 = \frac{a_1}{2}$ a_1 = acceleration of block *A* a_2 = acceleration of block *B*		$T = m_1 a$	$a_1 = a = \frac{2m_2 g}{4m_1 + m_2}$ $a_2 = \frac{m_2 g}{4m_1 + m_2}$ $T = \frac{2m_1 m_2 g}{4m_1 + m_2}$
		$m_2 \frac{a}{2} = m_2 g - 2T$	
		$m_1 a = m_1 g - T_1$	$a = \frac{(m_1 - m_2)}{[m_1 + m_2 + M]} g$
		$m_2 a = T_2 - m_2 g$	$T_1 = \frac{m_1(2m_2 + M)}{[m_1 + m_2 + M]} g$
		$T_1 - T_2 = Ma$	$T_2 = \frac{m_2(2m_2 + M)}{[m_1 + m_2 + M]} g$

Table 4.3 : Motion of massive string

Condition	Free body diagram	Equation	Tension and acceleration
	 T_1 = force applied by the string on the block 	$F = (M + m)a$ $T_1 = Ma$	$a = \frac{F}{M + m}$ $T_1 = M\frac{F}{(M + m)}$

	T_2 = Tension at mid point of the rope	$T_2 = \left(M + \frac{m}{2}\right)a$	$T_2 = \frac{(2M+m)}{2(M+m)}F$
		$F = ma$	$a = F/m$
m = Mass of string T = Tension in string at a distance x from the end where the force is applied		$T = m\left(\frac{L-x}{L}\right)a$	$T = \left(\frac{L-x}{L}\right)F$
		$F_1 - T = \frac{Mxa}{L}$	$a = \frac{F_1 - F_2}{M}$
M = Mass of uniform string L = Length of string		$F_1 - F_2 = Ma$	$T = F_1\left(1 - \frac{x}{L}\right) + F_2\left(\frac{x}{L}\right)$
 Mass of segment $BC = \left(\frac{M}{L}\right)x$	 	$T' = \frac{M}{L}(L-x)g + T$ $T = F + \frac{M}{L}xg$	$T' = F + Mg$ $T = F + \frac{M}{L}xg$

Spring Balance and Physical Balance

(1) **Spring balance :** When its upper end is fixed with rigid support and body of mass m hung from its lower end. Spring is stretched and the weight of the body can be measured by the reading of spring balance $R = W = mg$

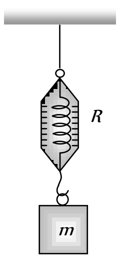


Fig : 4.26

The mechanism of weighing machine is same as that of spring balance.

Effect of frame of reference : In inertial frame of reference the reading of spring balance shows the actual weight of the body but in non-inertial frame of reference reading of spring balance increases or decreases in accordance with the direction of acceleration

(2) **Physical balance :** In physical balance actually we compare the mass of body in both the pans. Here we does not calculate the absolute weight of the body.

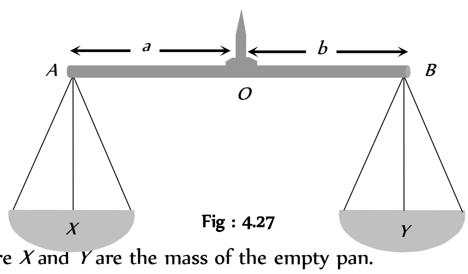


Fig : 4.27

Here X and Y are the mass of the empty pan.

(i) Perfect physical balance :

Weight of the pan should be equal *i.e.* $X = Y$

and the needle must in middle of the beam *i.e.* $a = b$.

Effect of frame of reference : If the physical balance is perfect then there will be no effect of frame of reference (either inertial or non-inertial) on the measurement. It is always errorless.

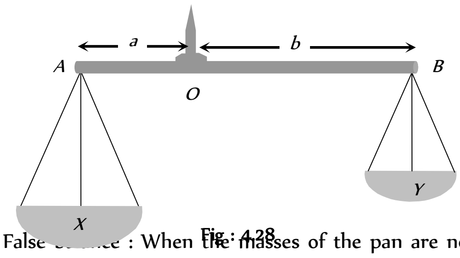


Fig : 4.28

(ii) False balance : When the masses of the pan are not equal then balance shows the error in measurement. False balance may be of two types

(a) If the beam of physical balance is horizontal (when the pans are empty) but the arms are not equal

$X > Y$ and $a < b$

For rotational equilibrium about point '*O*'

$Xa = Yb$ ...(i)

In this physical balance if a body of weight *W* is placed in pan *X* then to balance it we have to put a weight W_1 in pan *Y*.

For rotational equilibrium about point '*O*'

$(X + W)a = (Y + W_1)b$ ...(ii)

Now if the pans are changed then to balance the body we have to put a weight W_2 in pan *X*.

For rotational equilibrium about point '*O*'

$(X + W_2)a = (Y + W)b$ ...(iii)

From (i), (ii) and (iii)

True weight $W = \sqrt{W_1 W_2}$

(b) If the beam of physical balance is not horizontal (when the pans are empty) and the arms are equal

i.e. $X > Y$ and $a = b$

In this physical balance if a body of weight *W* is placed in *X* Pan then to balance it.

We have to put a weight W_1 in *Y* Pan

For equilibrium $X + W = Y + W_1$ ...(i)

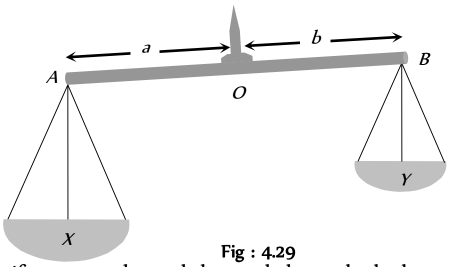


Fig : 4.29

Now if pans are changed then to balance the body we have to put a weight W_2 in X Pan.

For equilibrium $X + W_2 = Y + W$ ...(ii)

From (i) and (ii)

True weight $W = \dfrac{W_1 + W_2}{2}$

Modification of Newton's Laws of motion

According to Newton, time and space are absolute. The velocity of observer has no effect on it. But, according to special theory of relativity Newton's laws are true, as long as we are dealing with velocities which are small compare to velocity of light. Hence the time and space measured by two observers in relative motion are not same. Some conclusions drawn by the special theory of relativity about mass, time and distance which are as follows :

(1) Let the length of a rod at rest with respect to an observer is L_0. If the rod moves with velocity *v* w.r.t. observer and its length is *L*, then

$L = L_0\sqrt{1 - v^2/c^2}$

where, *c* is the velocity of light.

Now, as *v* increases *L* decreases, hence the length will appear shrinking.

(2) Let a clock reads T_0 for an observer at rest. If the clock moves with velocity *v* and clock reads *T* with respect to observer, then

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Hence, the clock in motion will appear slow.

(3) Let the mass of a body is m_0 at rest with respect to an observer. Now, the body moves with velocity *v* with respect to observer and its mass is *m*, then $m = \dfrac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

m_0 is called the rest mass.

Hence, the mass increases with the increases of velocity.

Note : ❑ If $v << c$, *i.e.*, velocity of the body is very small *w.r.t.* velocity of light, then $m = m_0$. *i.e.*, in the practice there will be no change in the mass.

❑ If *v* is comparable to c, then $m > m_0$ *i.e.*, mass will increase.

❑ If $v = c$, then $m = \dfrac{m_0}{\sqrt{1 - \frac{v^2}{v^2}}}$ or $m = \dfrac{m_0}{0} = \infty$. Hence, the mass becomes infinite, which is not possible, thus the speed cannot be equal to the velocity of light.

❑ The velocity of particles can be accelerated up to a certain limit. Even in cyclotron the speed of charged particles cannot be increased beyond a certain limit.

Tips & Tricks

- Inertia is proportional to mass of the body.
- Force cause acceleration.
- In the absence of the force, a body moves along a straight line path.
- A system or a body is said to be in equilibrium, when the net force acting on it is zero.
- If a number of forces $\vec{F}_1, \vec{F}_2, \vec{F}_3, \ldots\ldots$ act on the body, then it is in equilibrium when $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots = \vec{0}$

✍ A body in equilibrium cannot change the direction of motion.

✍ Four types of forces exist in nature. They are – gravitation (F_g), electromagnetic (F_{em}), weak force (F_w) and nuclear force (F_n).

$(F_g):(F_w):(F_{em}):(F_n) : : 1 : 10^{25} : 10^{36} : 10^{38}$

✍ If a body moves along a curved path, then it is certainly acted upon by a force.

✍ A single isolated force cannot exist.

✍ Forces in nature always occur in pairs.

✍ Newton's first law of the motion defines the force.

✍ Absolute units of force remains the same throughout the universe while gravitational units of force varies from place to place as they depend upon the value of 'g'.

✍ Newton's second law of motion gives the measure of force i.e. $F = ma$.

✍ Force is a vector quantity.

✍ Absolute units of force are dyne in CGS system and newton (N) in *SI*.

✍ $1\ N = 10^5$ *dyne.*

✍ Gravitational units of force are *gf* (or *gwt*) in *CGS* system and *kgf* (or *kgwt*) in *SI*.

✍ 1 *gf* = 980 *dyne* and 1 *kgf* = 9.8 *N*

✍ The beam balance compares masses.

✍ Acceleration of a horse-cart system is

$$a = \frac{H - F}{M + m}$$

where H = Horizontal component of reaction; F = force of friction; M = mass of horse; m = mass of cart.

✍ The weight of the body measured by the spring balance in a lift is equal to the apparent weight.

✍ Apparent weight of a freely falling body = ZERO, (state of weightlessness).

✍ If the person climbs up along the rope with acceleration a, then tension in the rope will be $m(g+a)$

✍ If the person climbs down along the rope with acceleration, then tension in the rope will be $m(g - a)$

✍ When the person climbs up or down with uniform speed, tension in the string will be mg.

✍ A body starting from rest moves along a smooth inclined plane of length l, height h and having angle of inclination θ.

(i) Its acceleration down the plane is $g \sin\theta$.

(ii) Its velocity at the bottom of the inclined plane will be $\sqrt{2gh} = \sqrt{2gl\sin\theta}$.

(iii) Time taken to reach the bottom will be

$$t = \sqrt{\frac{2l}{g\sin\theta}} = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}}$$

(iv) If the angle of inclination is changed keeping the height constant then

$$\frac{t_1}{t_2} = \frac{\sin\theta_2}{\sin\theta_1}$$

✍ For an isolated system (on which no external force acts), the total momentum remains conserved (Law of conservation of momentum).

✍ The change in momentum of a body depends on the magnitude and direction of the applied force and the period of time over which it is applied *i.e.* it depends on its impulse.

✍ Guns recoil when fired, because of the law of conservation of momentum. The positive momentum gained by the bullet is equal to negative recoil momentum of the gun and so the total momentum before and after the firing of the gun is zero.

✍ Recoil velocity of the gun is $\vec{V} = \frac{-m}{M}\vec{v}$

✍ where m = mass of bullet, M = mass of gun and $\vec{v}$ = muzzle velocity of bullet.

✍ The rocket pushes itself forwards by pushing the jet of exhaust gases backwards.

✍ Upthrust on the rocket = $u \times \frac{dm}{dt}$.

where u = velocity of escaping gases relative to rocket and $\frac{dm}{dt}$ = rate of consumption of fuel.

✍ Initial thrust on rocket = $m(g + a)$, where a is the acceleration of the rocket.

✍ Upward acceleration of rocket = $\frac{u}{m} \times \frac{dm}{dt}$.

✍ Impulse, $\vec{I} = \vec{F} \times \Delta t =$ change in momentum

✍ Unit of impulse is N-s.

✍ Action and reaction forces never act on the same body. They act on different bodies. If they act on the same body, the resultant force on the body will be zero i.e., the body will be in equilibrium.

✍ Action and reaction forces are equal in magnitude but opposite in direction.

✍ Action and reaction forces act along the line joining the centres of two bodies.

✍ Newton's third law is applicable whether the bodies are at rest or in motion.

✍ The non-inertial character of the earth is evident from the fact that a falling object does not fall straight down but slightly deflects to the east.

Ordinary Thinking

Objective Questions

First law of motion

1. A rider on horse back falls when horse starts running all of a sudden because [MP PMT 1982]
   (a) Rider is taken back
   (b) Rider is suddenly afraid of falling
   (c) Inertia of rest keeps the upper part of body at rest whereas lower part of the body moves forward with the horse
   (d) None of the above
2. When a train stops suddenly, passengers in the running train feel an instant jerk in the forward direction because [MP PMT 1982]
   (a) The back of seat suddenly pushes the passengers forward
   (b) Inertia of rest stops the train and takes the body forward
   (c) Upper part of the body continues to be in the state of motion whereas the lower part of the body in contact with seat remains at rest
   (d) Nothing can be said due to insufficient data
3. Inertia is that property of a body by virtue of which the body is [MGIMS Wardha 1982]
   (a) Unable to change by itself the state of rest
   (b) Unable to change by itself the state of uniform motion
   (c) Unable to change by itself the direction of motion
   (d) Unable to change by itself the state of rest and of uniform linear motion
4. A man getting down a running bus falls forward because [CPMT 1981]
   (a) Due to inertia of rest, road is left behind and man reaches forward
   (b) Due to inertia of motion upper part of body continues to be in motion in forward direction while feet come to rest as soon as they touch the road
   (c) He leans forward as a matter of habit
   (d) Of the combined effect of all the three factors stated in (*a*), (*b*) and (*c*)
5. A boy sitting on the topmost berth in the compartment of a train which is just going to stop on a railway station, drops an apple aiming at the open hand of his brother sitting vertically below his hands at a distance of about 2 *meter*. The apple will fall [CPMT 1986]
   (a) Precisely on the hand of his brother
   (b) Slightly away from the hand of his brother in the direction of motion of the train
   (c) Slightly away from the hand of his brother in the direction opposite to the direction of motion of the train
   (d) None of the above

6. Newton's first law of motion describes the following [MP PMT 1996]

(a) Energy (b) Work

(c) Inertia (d) Moment of inertia

7. A person sitting in an open car moving at constant velocity throws a ball vertically up into air. The ball falls [EAMCET (Med.) 1995; MH CET 2003;BCECE 2004]

(a) Outside the car

(b) In the car ahead of the person

(c) In the car to the side of the person

(d) Exactly in the hand which threw it up

8. A bird weighs 2 kg and is inside a closed cage of 1 kg. If it starts flying, then what is the weight of the bird and cage assembly

(a) 1.5 kg (b) 2.5 kg

(c) 3 kg (d) 4 kg

9. A particle is moving with a constant speed along a straight line path. A force is not required to [AFMC 2001]

(a) Increase its speed

(b) Decrease the momentum

(c) Change the direction

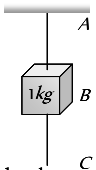
(d) Keep it moving with uniform velocity

10. When a bus suddenly takes a turn, the passengers are thrown outwards because of [AFMC 1999; CPMT 2000, 2001]

(a) Inertia of motion (b) Acceleration of motion

(c) Speed of motion (d) Both (b) and (c)

11. A mass of 1 kg is suspended by a string A. Another string C is connected to its lower end (see figure). If a sudden jerk is given to C, then



(a) The portion AB of the string will break

(b) The portion BC of the string will break

(c) None of the strings will break

(d) The mass will start rotating

12. In the above Question, if the string C is stretched slowly, then

(a) The portion AB of the string will break

(b) The portion BC of the string will break

(c) None of the strings will break

(d) None of the above

Second Law of Motion

1. If a bullet of mass 5 gm moving with velocity 100 m/sec, penetrates the wooden block upto 6 cm. Then the average force imposed by the bullet on the block is [MP PMT 2003]

(a) 8300 N (b) 417 N

(c) 830 N (d) Zero

2. Newton's second law gives the measure of [CPMT 1982]

(a) Acceleration (b) Force

(c) Momentum (d) Angular momentum

3. A force of 100 dynes acts on mass of 5 gm for 10 sec. The velocity produced is [MNR 1987]

(a) 2 cm/sec (b) 20 cm/sec

(c) 200 cm/sec (d) 2000 cm/sec

4. An object will continue moving uniformly until [CPMT 1975]

(a) The resultant force acting on it begins to decrease

(b) The resultant force on it is zero

(c) The resultant force is at right angle to its rotation

(d) The resultant force on it is increased continuously

5. A diwali rocket is ejecting 0.05 kg of gases per second at a velocity of 400 m/sec. The accelerating force on the rocket is [NCERT 1979; DPMT 2001; MP PMT 2004]

(a) 20 $dynes$ (b) 20 N

(c) 22 $dynes$ (d) 1000 N

6. A body of mass 2 kg moving on a horizontal surface with an initial velocity of 4 m/sec comes to rest after 2 sec. If one wants to keep this body moving on the same surface with a velocity of 4 m/sec, the force required is [NCERT 1977] [AFMC 1997]

(a) 8 N (b) 4 N

(c) Zero (d) 2 N

7. A body of mass 2 kg is hung on a spring balance mounted vertically in a lift. If the lift descends with an acceleration equal to the acceleration due to gravity 'g', the reading on the spring balance will be [NCERT 1977]

(a) 2 kg (b) $(4 \times g) kg$

(c) $(2 \times g) kg$ (d) Zero

8. In the above problem, if the lift moves up with a constant velocity of 2 m/sec, the reading on the balance will be [NCERT 1977]

(a) 2 kg (b) 4 kg

(c) Zero (d) 1 kg

9. In the above problem if the lift moves up with an acceleration equal to the acceleration due to gravity, the reading on the spring balance will be [NCERT 1977]

(a) 2 kg (b) $(2 \times g) kg$

(c) $(4 \times g) kg$ (d) 4 kg

10. A coin is dropped in a lift. It takes time t_1 to reach the floor when lift is stationary. It takes time t_2 when lift is moving up with constant acceleration. Then

(a) $t_1 > t_2$ (b) $t_2 > t_1$

(c) $t_1 = t_2$ (d) $t_1 >> t_2$

11. If the tension in the cable of 1000 kg elevator is 1000 kg weight, the elevator [NCERT 1971]

(a) Is accelerating upwards

(b) Is accelerating downwards

(c) May be at rest or accelerating

(d) May be at rest or in uniform motion

12. A man weighing 80 kg is standing in a trolley weighing 320 kg. The trolley is resting on frictionless horizontal rails. If the man starts walking on the trolley with a speed of 1 m/s, then after 4 sec his displacement relative to the ground will be

(a) 5 m (b) 4.8 m

(c) 3.2 m (d) 3.0 m

13. In doubling the mass and acceleration of the mass, the force acting on the mass with respect to the previous value

(a) Decreases to half (b) Remains unchanged

(c) Increases two times (d) Increases four times

14. A force of 5 *N* acts on a body of weight 9.8 *N*. What is the acceleration produced in $m/\sec^2$ [NCERT 1990]

(a) 49.00 (b) 5.00

(c) 1.46 (d) 0.51

15. A body of mass 40 *gm* is moving with a constant velocity of 2 *cm/sec* on a horizontal frictionless table. The force on the table is

(a) 39200 *dyne* (b) 160 *dyne*

(c) 80 *dyne* (d) Zero *dyne*

16. When 1 *N* force acts on 1 *kg* body that is able to move freely, the body receives [CPMT 1971]

(a) A speed of 1 *m/sec*

(b) An acceleration of $1\,m/\sec^2$

(c) An acceleration of $980\,cm/\sec^2$

(d) An acceleration of $1\,cm/\sec^2$

17. An object with a mass 10 *kg* moves at a constant velocity of 10 *m/sec*. A constant force then acts for 4 second on the object and gives it a speed of 2 *m/sec* in opposite direction. The acceleration produced in it, is [CPMT 1971]

(a) $3\,m/\sec^2$ (b) $-3\,m/\sec^2$

(c) $0.3\,m/\sec^2$ (d) $-0.3\,m/\sec^2$

18. In the above question, the force acting on the object is [CPMT 1971]

(a) 30 *N* (b) – 30 *N*

(c) 3 *N* (d) – 3 *N*

19. In the above question, the impulse acting on the object is [CPMT 1971]

(a) $120\ newton \times \sec$ (b) $-120\ newtont \sec$

(c) $30\ newton \times \sec$ (d) $-30\ newton \times \sec$

20. A machine gun is mounted on a 2000 *kg* car on a horizontal frictionless surface. At some instant the gun fires bullets of mass 10 *gm* with a velocity of 500 *m/sec* with respect to the car. The number of bullets fired per second is ten. The average thrust on the system is [CPMT 1971]

(a) 550 *N* (b) 50 *N*

(c) 250 *N* (d) 250 *dyne*

21. In the above question, the acceleration of the car will be [CPMT 1971]

(a) $0.25\,m/\sec^2$ (b) $2.5\,m/\sec^2$

(c) $5.0\,m/\sec^2$ (d) $0.025\,m/\sec^2$

22. A person is standing in an elevator. In which situation he finds his weight less than actual when [AIIMS 2005]

(a) The elevator moves upward with constant acceleration

(b) The elevator moves downward with constant acceleration.

(c) The elevator moves upward with uniform velocity

(d) The elevator moves downward with uniform velocity

23. A particle of mass 0.3 *kg* is subjected to a force $F = -kx$ with $k = 15\,N/m$. What will be its initial acceleration if it is released from a point 20 *cm* away from the origin [AIEEE 2005]

(a) 5 *m/s* (b) 10 *m/s*

(c) 3 *m/s* (d) 15 *m/s*

24. A block of metal weighing 2 *kg* is resting on a frictionless plane. It is struck by a jet releasing water at a rate of 1 *kg/sec* and at a speed of 5 *m/sec*. The initial acceleration of the block will be [NCERT 1978]

(a) $2.5\,m/\sec^2$ (b) $5.0\,m/\sec^2$

(c) $10\,m/\sec^2$ (d) None of the above

25. Gravels are dropped on a conveyor belt at the rate of 0.5 *kg/sec*. The extra force required in *newtons* to keep the belt moving at 2 *m/sec* is [EAMCET 1988]

(a) 1 (b) 2

(c) 4 (d) 0.5

26. A parachutist of weight '*w*' strikes the ground with his legs fixed and comes to rest with an upward acceleration of magnitude 3 *g*. Force exerted on him by ground during landing is

(a) w (b) $2w$

(c) $3w$ (d) $4w$

27. At a place where the acceleration due to gravity is $10\,m\sec^{-2}$ a force of 5 *kg-wt* acts on a body of mass 10 *kg* initially at rest. The velocity of the body after 4 *second* is [EAMCET 1981]

(a) $5\,m\sec^{-1}$ (b) $10\,m\sec^{-1}$

(c) $20\,m\sec^{-1}$ (d) $50\,m\sec^{-1}$

28. In a rocket of mass 1000 *kg* fuel is consumed at a rate of 40 *kg/s*. The velocity of the gases ejected from the rocket is $5 \times 10^4\,m/s$. The thrust on the rocket is [MP PMT 1994]

(a) $2 \times 10^3\,N$ (b) $5 \times 10^4\,N$

(c) $2 \times 10^6\,N$ (d) $2 \times 10^9\,N$

29. A man is standing on a weighing machine placed in a lift. When stationary his weight is recorded as 40 *kg*. If the lift is accelerated upwards with an acceleration of $2\,m/s^2$, then the weight recorded in the machine will be $(g = 10\,m/s^2)$ [MP PMT 1994]

(a) 32 *kg* (b) 40 *kg*

(c) 42 *kg* (d) 48 *kg*

30. A body of mass 4 *kg* weighs 4.8 *kg* when suspended in a moving lift. The acceleration of the lift is [Manipal MEE 1995]

(a) $9.80\,ms^{-2}$ downwards (b) $9.80\,ms^{-2}$ upwards

(c) $1.96\,ms^{-2}$ downwards (d) $1.96\,ms^{-2}$ upwards

31. An elevator weighing 6000 *kg* is pulled upward by a cable with an acceleration of $5\,ms^{-2}$. Taking *g* to be $10\,ms^{-2}$, then the tension in the cable is [Manipal MEE 1995]

(a) 6000 *N* (b) 9000 *N*

(c) 60000 *N* (d) 90000 *N*

32. A ball of mass 0.2 *kg* moves with a velocity of 20 *m/sec* and it stops in 0.1 *sec*; then the force on the ball is [BHU 1995]

(a) 40 *N* (b) 20 *N*
(c) 4 *N* (d) 2 *N*

33. A vehicle of 100 *kg* is moving with a velocity of 5 *m/sec*. To stop it in $\frac{1}{10}\sec$, the required force in opposite direction is [MP PET 1995]

(a) 5000 *N* (b) 500 *N*
(c) 50 *N* (d) 1000 *N*

34. A boy having a mass equal to 40 *kilograms* is standing in an elevator. The force felt by the feet of the boy will be greatest when the elevator

$(g = 9.8\, metres/\sec^2)$ [MP PMT 1995; BVP 2003]

(a) Stands still
(b) Moves downward at a constant velocity of 4 *metres/sec*
(c) Accelerates downward with an acceleration equal to $4\, metres/\sec^2$
(d) Accelerates upward with an acceleration equal to $4\, metres/\sec^2$

35. A rocket has an initial mass of $20\times10^3\, kg$. If it is to blast off with an initial acceleration of $4\, ms^{-2}$, the initial thrust needed is $(g \cong 10\, ms^{-2})$ [Kurukshetra CEE 1996]

(a) $6\times10^4\, N$ (b) $28\times10^4\, N$
(c) $20\times10^4\, N$ (d) $12\times10^4\, N$

36. The ratio of the weight of a man in a stationary lift and when it is moving downward with uniform acceleration '*a*' is 3 : 2. The value of '*a*' is (*g*-Acceleration due to gravity of the earth) [MP PET 1997]

(a) $\frac{3}{2}g$ (b) $\frac{g}{3}$
(c) $\frac{2}{3}g$ (d) g

37. The mass of a lift is 500 *kg*. When it ascends with an acceleration of $2\, m/s^2$, the tension in the cable will be $[g = 10\, m/s^2]$ [MP PMT 1999, 2000]

(a) 6000 *N* (b) 5000 *N*
(c) 4000 *N* (d) 50 *N*

38. If force on a rocket having exhaust velocity of 300 *m/sec* is 210 *N*, then rate of combustion of the fuel is [CBSE PMT 1999; MH CET 2003; Pb. PMT 2004]

(a) 0.7 *kg/s* (b) 1.4 *kg/s*
(c) 0.07 *kg/s* (d) 10.7 *kg/s*

39. In an elevator moving vertically up with an acceleration *g*, the force exerted on the floor by a passenger of mass *M* is [CPMT 1999]

(a) *Mg* (b) $\frac{1}{2}Mg$
(c) Zero (d) 2 *Mg*

40. A mass 1 *kg* is suspended by a thread. It is

(i) lifted up with an acceleration $4.9\, m/s^2$

(ii) lowered with an acceleration $4.9\, m/s^2$.

The ratio of the tensions is [CBSE PMT 1998]

(a) 3 : 1 (b) 1 : 3
(c) 1 : 2 (d) 2 : 1

41. A 5000 *kg* rocket is set for vertical firing. The exhaust speed is $800\, ms^{-1}$. To give an initial upward acceleration of $20\, ms^{-2}$, the amount of gas ejected per second to supply the needed thrust will be $(g = 10\, ms^{-2})$ [CBSE PMT 1998]

(a) $127.5\, kg\, s^{-1}$ (b) $187.5\, kg\, s^{-1}$
(c) $185.5\, kg\, s^{-1}$ (d) $137.5\, kg\, s^{-1}$

42. If a person with a spring balance and a body hanging from it goes up and up in an aeroplane, then the reading of the weight of the body as indicated by the spring balance will [AIIMS 1998; JIPMER 2000]

(a) Go on increasing
(b) Go on decreasing
(c) First increase and then decrease
(d) Remain the same

43. The time period of a simple pendulum measured inside a stationary lift is found to be *T*. If the lift starts accelerating upwards with an acceleration *g*/3, the time period is [EAMCET 1994; CMEET Bihar 1995; RPMT 2000]

(a) $T\sqrt{3}$ (b) $T\sqrt{3}/2$
(c) $T/\sqrt{3}$ (d) $T/3$

44. A cork is submerged in water by a spring attached to the bottom of a pail. When the pail is kept in a elevator moving with an acceleration downwards, the spring length [EAMCET (Engg.) 1995]

(a) Increases (b) Decreases
(c) Remains unchanged (d) Data insufficient

45. Two trolleys of mass *m* and 3*m* are connected by a spring. They were compressed and released once, they move off in opposite direction and comes to rest after covering distances S_1 and S_2 respectively. Assuming the coefficient of friction to be uniform, the ratio of distances $S_1 : S_2$ is [EAMCET (Engg.) 1995]

(a) 1 : 9 (b) 1 : 3
(c) 3 : 1 (d) 9 : 1

46. A boy of 50 *kg* is in a lift moving down with an acceleration $9.8\, ms^{-2}$. The apparent weight of the body is $(g = 9.8\, ms^{-2})$ [EAMCET (Med KCET 2000]

(a) $50\times9.8\, N$ (b) Zero
(c) 50 *N* (d) $\frac{50}{9.8}N$

47. A body is imparted motion from rest to move in a straight line. If it is then obstructed by an opposite force, then [NTSE 1995]

(a) The body may necessarily change direction

(b) The body is sure to slow down

(c) The body will necessarily continue to move in the same direction at the same speed

(d) None of these

48. A mass of 10 *gm* is suspended by a string and the entire system is falling with a uniform acceleration of $400\,cm/\sec^2$. The tension in the string will be $(g = 980\,cm/\sec^2)$

(a) 5,800 *dyne* (b) 9,800 *dyne*

(c) 11,800 *dyne* (d) 13,800 *dyne*

49. A second's pendulum is mounted in a rocket. Its period of oscillation decreases when the rocket [CBSE PMT 1994]

(a) Comes down with uniform acceleration

(b) Moves round the earth in a geostationary orbit

(c) Moves up with a uniform velocity

(d) Moves up with uniform acceleration

50. Two balls of masses m_1 and m_2 are separated from each other by a powder charge placed between them. The whole system is at rest on the ground. Suddenly the powder charge explodes and masses are pushed apart. The mass m_1 travels a distance s_1 and stops. If the coefficients of friction between the balls and ground are same, the mass m_2 stops after travelling the distance

(a) $s_2 = \frac{m_1}{m_2} s_1$ (b) $s_2 = \frac{m_2}{m_1} s_1$

(c) $s_2 = \frac{m_1^2}{m_2^2} s_1$ (d) $s_2 = \frac{m_2^2}{m_1^2} s_1$

51. A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates with $1\,m/s^2$. What will be the mass of the body [CBSE PMT 1996]

(a) $10\sqrt{2}\,kg$ (b) $2\sqrt{10}\,kg$

(c) 10 *kg* (d) 20 *kg*

52. A cart of mass *M* is tied by one end of a massless rope of length 10 *m*. The other end of the rope is in the hands of a man of mass *M*. The entire system is on a smooth horizontal surface. The man is at $x = 0$ and the cart at $x = 10$ *m*. If the man pulls the cart by the rope, the man and the cart will meet at the point

(a) $x = 0$ (b) $x = 5\,m$

(c) $x = 10\,m$ (d) They will never meet

53. A cricket ball of mass 250 *g* collides with a bat with velocity 10 *m/s* and returns with the same velocity within 0.01 second. The force acted on bat is [CPMT 1997]

(a) 25 *N* (b) 50 *N*

(c) 250 *N* (d) 500 *N*

54. A pendulum bob of mass 50 *gm* is suspended from the ceiling of an elevator. The tension in the string if the elevator goes up with uniform velocity is approximately

[AMU (Med.) 1999]

(a) 0.30 *N* (b) 0.40 *N*

(c) 0.42 *N* (d) 0.50 *N*

55. A train is moving with velocity 20 *m/sec.* on this dust is falling at the rate of 50 *kg/minute*. The extra force required to move this train with constant velocity will be [RPET 1999]

(a) 16.66 *N* (b) 1000 *N*

(c) 166.6 *N* (d) 1200 *N*

56. The average force necessary to stop a bullet of mass 20 *g* moving with a speed of 250 *m/s*, as it penetrates into the wood for a distance of 12 *cm* is

[SCRA 1994]

[CBSE PMT 2000; DPMT 2003]

(a) $2.2 \times 10^3\,N$ (b) $3.2 \times 10^3\,N$

(c) $4.2 \times 10^3\,N$ (d) $5.2 \times 10^3\,N$

57. The average resisting force that must act on a 5 *kg* mass to reduce its speed from 65 *cm/s* to 15 *cm/s* in 0.2*s* is

[RPET 2000]

(a) 12.5 *N* (b) 25 *N*

(c) 50 *N* (d) 100 *N*

58. A mass is hanging on a spring balance which is kept in a lift. The lift ascends. The spring balance will show in its reading

[DCE 2000]

(a) Increase

(b) Decrease

(c) No change

(d) Change depending upon velocity

[BHU 1994]

59. An army vehicle of mass 1000 *kg* is moving with a velocity of 10 *m/s* and is acted upon by a forward force of 1000 *N* due to the engine and a retarding force of 500 *N* due to friction. What will be its velocity after 10 *s* [Pb. PMT 2000]

(a) 5 *m/s* (b) 10 *m/s*

(c) 15 *m/s* (d) 20 *m/s*

60. A body of mass 2 *kg* is moving with a velocity 8 *m/s* on a smooth surface. If it is to be brought to rest in 4 seconds, then the force to be applied is [Pb. PMT 2000]

(a) 8 *N* (b) 4 *N*

(c) 2 *N* (d) 1 *N*

61. The apparent weight of the body, when it is travelling upwards with an acceleration of $2\,m/s^2$ and mass is 10 *kg*, will be

(a) 198 *N* (b) 164 *N*

(c) 140 *N* (d) 118 *N*

62. A man measures time period of a pendulum (T) in stationary lift. If the lift moves upward with acceleration $\frac{g}{4}$, then new time period will be [BHU 2001]

[CBSE PMT 1997]

(a) $\frac{2T}{\sqrt{5}}$ (b) $\frac{\sqrt{5}T}{2}$

(c) $\frac{\sqrt{5}}{2T}$ (d) $\frac{2}{\sqrt{5}T}$

63. A 30 *gm* bullet initially travelling at 120 *m/s* penetrates 12 *cm* into a wooden block. The average resistance exerted by the wooden block is [AFMC 1999; CPMT 2001]

(a) 2850*N* (b) 2200 *N*

(c) 2000*N* (d) 1800 *N*

64. A force of 10 Newton acts on a body of mass 20*kg* for 10 seconds. Change in its momentum is [MP PET 2002]

(a) $5\ kg\,m/s$ (b) $100 kg\,m/s$

(c) $200 kg\,m/s$ (d) $1000\ kg\,m/s$

65. A body of mass 1.0*kg* is falling with an acceleration of 10 m/sec^2. Its apparent weight will be $(g = 10 m/\sec^2)$ [MP PET 2002]

(a) $1.0 kg\,wt$ (b) $2.0 kg\,wt$

(c) $0.5 kg\,wt$ (d) Zero

66. A player caught a cricket ball of mass 150 *gm* moving at the rate of 20 *m/sec.* if the catching process be completed in 0.1 *sec* the force of the blow exerted by the ball on the hands of player is

(a) 0.3 *N* (b) 30 *N*

(c) 300 *N* (d) 3000 *N*

67. If rope of lift breaks suddenly, the tension exerted by the surface of lift [AFMC 2002]

(*a* = acceleration of lift)

(a) mg (b) $m(g+a)$

(c) $m(g-a)$ (d) 0

68. A boy whose mass is 50*kg* stands on a spring balance inside a lift. The lift starts to ascent with an acceleration of $2 ms^{-2}$. The reading of the machine or balance $(g = 10 ms^{-2})$ is [Kerala PET 2002]

(a) $50 kg$ (b) Zero

(c) $49 kg$ (d) $60 kg$

69. A rocket is ejecting $50 g$ of gases per sec at a speed of $500 m/s$. The accelerating force on the rocket will be [Pb. PMT 2002]

(a) $125 N$ (b) $25 N$

(c) $5 N$ (d) Zero

70. A block of mass $5 kg$ is moving horizontally at a speed of 1.5 *m/s*. A perpendicular force of 5*N* acts on it for 4 sec. What will be the distance of the block from the point where the force started acting

(a) 10 *m* (b) 8 *m*

(c) 6 *m* (d) 2 *m*

71. A lift of mass 1000 *kg* is moving with an acceleration of 1 m/s^2 in upward direction. Tension developed in the string, which is connected to the lift, is [CBSE PMT 2002]

(a) 9,800 *N* (b) 10,000 *N*

(c) 10,800 *N* (d) 11,000 *N*

72. A lift accelerated downward with acceleration '*a*'. A man in the lift throws a ball upward with acceleration $a_0 (a_0 < a)$. Then acceleration of ball observed by observer, which is on earth, is

(a) $(a + a_0)$ upward (b) $(a - a_0)$ upward

(c) $(a + a_0)$ downward (d) $(a - a_0)$ downward

73. A lift is moving down with acceleration *a*. A man in the lift drops a ball inside the lift. The acceleration of the ball as observed by the man in the lift and a man standing stationary on the ground are respectively [AIEEE 2002]

(a) g, g (b) $g-a, g-a$

(c) $g-a, g$ (d) a, g

74. A man weighs $80 kg$. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of $5 m/s^2$. What would be the reading on the scale. $(g = 10 m/s^2)$

(a) 400 *N* (b) 800 *N*

(c) 1200 *N* (d) Zero

75. A monkey of mass 20*kg* is holding a vertical rope. The rope will not break when a mass of 25 *kg* is suspended from it but will break if the mass exceeds 25 *kg*. What is the maximum acceleration with which the monkey can climb up along the rope $(g = 10 m/s^2)$ [Kerala PET 2005]

(a) $10 m/s^2$ (b) $25 m/s^2$

(c) $2.5 m/s^2$ (d) $5 m/s^2$

76. If in a stationary lift, a man is standing with a bucket full of water, having a hole at its bottom. The rate of flow of water through this hole is R_0. If the lift starts to move up and down with same acceleration and then that rates of flow of water are R_u and R_d, then [UPSEAT 2003]

(a) $R_0 > R_u > R_d$ (b) $R_u > R_0 > R_d$

(c) $R_d > R_0 > R_u$ (d) $R_u > R_d > R_0$

77. A rocket with a lift- off mass $3.5 \times 10^4\ kg$ is blasted upwards with an initial acceleration of $10 m/s^2$. Then the initial thrust of the blast is [AIEEE 2003]

(a) $1.75 \times 10^5 N$ (b) $3.5 \times 10^5 N$

(c) $7.0 \times 10^5 N$ (d) $14.0 \times 10^5 N$

78. A spring balance is attached to the ceiling of a lift. A man hangs his bag on the spring and the spring reads 49 *N*, when the lift is stationary. If the lift moves downward with an acceleration of $5 m/s^2$, the reading of the spring balance will be [Pb. PMT 2002]

(a) 49 *N* (b) 24 *N*

(c) 74 *N* (d) 15 *N*

79. A plumb line is suspended from a ceiling of a car moving with horizontal acceleration of *a*. What will be the angle of inclination with vertical [Orissa JEE 2003]

(a) $\tan^{-1}(a/g)$ (b) $\tan^{-1}(g/a)$

(c) $\cos^{-1}(a/g)$ (d) $\cos^{-1}(g/a)$

80. Mass of a person sitting in a lift is 50 *kg*. If lift is coming down with a constant acceleration of 10 m/sec^2. Then the reading of spring balance will be $(g = 10 m/sec^2)$ [AIEEE 2002] [RPET 2003; Kerala PMT 2005]

(a) 0 (b) 1000*N*

(c) 100 *N* (d) 10 *N*

81. A body of mass 2 *kg* has an initial velocity of 3 *meters* per second along *OE* and it is subjected to a force of 4 *N* in a direction perpendicular to *OE*. The distance of the body from *O* after 4 seconds will be [CPMT 1976]

(a) 12 *m* (b) 20 *m*

(c) 8 *m* (d) 48 *m*

82. A block of mass *m* is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block (*g* is acceleration due to gravity) will be

(a) $mg\cos\theta$ (b) $mg\sin\theta$

(c) mg (d) $mg/\cos\theta$

83. A machine gun fires a bullet of mass 40 *g* with a velocity $1200\ ms^{-1}$. The man holding it can exert a maximum force of 144 *N* on the gun. How many bullets can he fire per second at the most [AIEEE 2004]

(a) One (b) Four

(c) Two (d) Three

84. An automobile travelling with a speed of $60\ km/h$, can brake to stop within a distance of 20 *m*. If the car is going twice as fast, *i.e.* 120 *km/h*, the stopping distance will be

[AIEEE 2004]

(a) 20 *m* (b) 40 *m*

(c) 60 *m* (d) 80 *m*

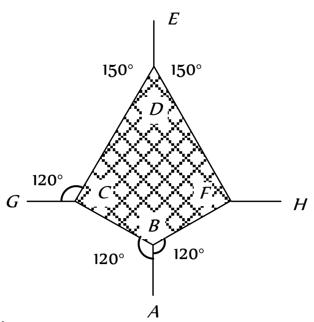
85. A man of weight 75 *kg* is standing in an elevator which is moving with an acceleration of $5\,m/s^2$ in upward direction the apparent weight of the man will be $(g = 10\ m/s^2)$

[Pb. PMT 2004]

(a) 1425 *N* (b) 1375 *N*

(c) 1250 *N* (d) 1125 *N*

86. The adjacent figure is the part of a horizontally stretched net. section *AB* is stretched with a force of 10 *N*. The tensions in the sections *BC* and *BF* are [KCET 2005]



(a) 10 *N*, 11 *N*

(b) 10 *N*, 6 *N*

(c) 10 *N*, 10 *N*

(d) Can't calculate due to insufficient data

87. The linear momentum *p* of a body moving in one dimension varies with time according to the equation $p = a + bt^2$ where *a* and *b* are positive constants. The net force acting on the body is

(a) A constant

(b) Proportional to t^2

(c) Inversely proportional to *t*

(d) Proportional to *t*

88. The spring balance inside a lift suspends an object. As the lift begins to ascent, the reading indicated by the spring balance will

(a) Increase [CBSE PMT 2004]

(b) Decrease

(c) Remain unchanged

(d) Depend on the speed of ascend

89. There is a simple pendulum hanging from the ceiling of a lift. When the lift is stand still, the time period of the pendulum is *T*. If the resultant acceleration becomes $g/4$, then the new time period of the pendulum is [DCE 2004]

(a) 0.8 *T* (b) 0.25 *T*

(c) 2 *T* (d) 4 *T*

90. A man of weight 80 *kg* is standing in an elevator which is moving with an acceleration of $6\ m/s^2$ in upward direction. The apparent weight of the man will be $(g = 10\,m/s^2)$

(a) 1480 *N* (b) 1280 *N*

(c) 1380 *N* (d) None of these

91. A force of 100 dynes acts on a mass of 5 *gram* for 10 *sec*. The velocity produced is [Pb. PET 2004]

(a) $2000\ cm/\sec$ (b) $200\ cm/\sec$

(c) $20\ cm/\sec$ (d) $2\ cm/\sec$

92. When the speed of a moving body is doubled

[UPSEAT 2004]

(a) Its acceleration is doubled

(b) Its momentum is doubled

(c) Its kinetic energy is doubled

(d) Its potential energy is doubled

93. A body of mass *m* collides against a wall with a velocity *v* and rebounds with the same speed. Its change of momentum is

(a) 2 *mv* (b) *mv*

(c) – *mv* (d) Zero

94. A thief stole a box full of valuable articles of weight *W* and while carrying it on his back, he jumped down a wall of height '*h*' from the ground. Before he reached the ground he experienced a load of

(a) 2*W* (b) *W*

(c) *W*/2 (d) Zero

95. *N* bullets each of mass *m kg* are fired with a velocity $v\,ms^{-1}$ at the rate of *n* bullets per second upon a wall. The reaction offered by the wall to the bullets is given by

(a) nmv (b) $\frac{Nmv}{n}$

(c) $n\frac{Nm}{v}$ (d) $n\frac{Nv}{m}$

96. If a body of mass m is carried by a lift moving with an upward acceleration a, then the forces acting on the body are (i) the reaction R on the floor of the lift upwards (ii) the weight mg of the body acting vertically downwards. The equation of motion will be given by [MNR 1998]

(a) $R = mg - ma$ (b) $R = mg + ma$

(c) $R = ma - mg$ (d) $R = mg \times ma$

97. With what minimum acceleration can a fireman slides down a rope while breaking strength of the rope is $\frac{2}{3}$ of his weight

(a) $\frac{2}{3}g$ (b) g

(c) $\frac{1}{3}g$ (d) Zero

98. A ball of mass m moves with speed v and it strikes normally with a wall and reflected back normally, if its time of contact with wall is t then find force exerted by ball on wall

[BCECE 2005]

(a) $\frac{2mv}{t}$ (b) $\frac{mv}{t}$

(c) mvt (d) $\frac{mv}{2t}$

99. The velocity of a body at time $t = 0$ is $10\sqrt{2}$ *m/s* in the north-east direction and it is moving with an acceleration of 2 *m/s* directed towards the south. The magnitude and direction of the velocity of the body after 5 *sec* will be

[AMU (Engg.) 1999]

(a) 10 *m/s*, towards east

(b) 10 *m/s*, towards north

(c) 10 *m/s*, towards south

(d) 10 *m/s*, towards north-east

100. A body of mass 5 *kg* starts from the origin with an initial velocity $\vec{u} = 30\hat{i} + 40\hat{j}\, ms^{-1}$. If a constant force $\vec{F} = -(\hat{i} + 5\hat{j})N$ acts on the body, the time in which the *y*–component of the velocity becomes zero is

[EAMCET (Med.) 2000]

(a) 5 *seconds* (b) 20 *seconds*

(c) 40 *seconds* (d) 80 *seconds*

101. A body of mass 8*kg* is moved by a force $F = 3x\,N$, where x is the distance covered. Initial position is $x = 2m$ and the final position is $x = 10$ *m*. The initial speed is $0.0 m/s$. The final speed is [Orissa JEE 2002]

(a) 6 *m*/*s* (b) 12 *m*/*s*

(c) 18 *m*/*s* (d) 14 *m*/*s*

102. The linear momentum p of a body moving in one dimension varies with time according to the equation $p = a + bt^2$, where a and b are positive constants. The net force acting on the body is

(a) Proportional to t^2

(b) A constant

(c) Proportional to t

(d) Inversely proportional to t

103. A ball of mass 0.5 *kg* moving with a velocity of 2 *m*/*sec* strikes a wall normally and bounces back with the same speed. If the time of contact between the ball and the wall is one millisecond, the average force exerted by the wall on the ball is

(a) 2000 *N* (b) 1000 *N*

(c) 5000 *N* (d) 125 *N*

[CPMT 1979]

104. A particle moves in the *xy*-plane under the action of a force **F** such that the components of its linear momentum **p** at any time t are $p_x = 2\cos t$, $p_y = 2\sin t$. The angle between **F** and **p** at time t is

[MP PET 1996; UPSEAT 2000]

(a) 90° (b) 0°

(c) 180° (d) 30°

105. n small balls each of mass m impinge elastically each second on a surface with velocity u. The force experienced by the surface will be

RPET 2001; BHU 2001; MP PMT 2003]

(a) mnu (b) 2 mnu

(c) 4 mnu (d) $\frac{1}{2}mnu$

106. A ball of mass 400 *gm* is dropped from a height of 5*m*. A boy on the ground hits the ball vertically upwards with a bat with an average force of 100 *newton* so that it attains a vertical height of 20 *m*. The time for which the ball remains in contact with the bat is $[g = 10\,m/s^2]$ [MP PMT 1999]

(a) 0.12*s* (b) 0.08 *s*

(c) 0.04 *s* (d) 12 *s*

107. The time in which a force of 2 *N* produces a change of momentum of $0.4\,kg - ms^{-1}$ in the body is

[CMEET Bihar 1995]

(a) 0.2 *s* (b) 0.02 *s*

(c) 0.5 *s* (d) 0.05 *s*

108. A gun of mass $10kg$ fires 4 bullets per second. The mass of each bullet is 20 *g* and the velocity of the bullet when it leaves the gun is $300\,ms^{-1}$. The force required to hold the gun while firing is

[EAMCET (Med.) 2000]

(a) 6 *N* (b) 8 *N*

(c) 24 *N* (d) 240 *N*

109. A gardner waters the plants by a pipe of diameter 1mm. The water comes out at the rate or 10 *cm*/*sec*. The reactionary force exerted on the hand of the gardner is

[KCET 2000]

(a) Zero (b) $1.27 \times 10^{-2}\,N$

(c) $1.27 \times 10^{-4}\,N$ (d) $0.127N$

110. A solid disc of mass M is just held in air horizontally by throwing 40 stones per sec vertically upwards to strike the disc each with a velocity 6 ms^{-1}. If the mass of each stone is $0.05kg$ what is the mass of the disc $(g = 10ms^{-2})$ [MP PMT 1993]

[Kerala (Engg.) 2001]

(a) $1.2kg$ (b) $0.5kg$

(c) $20kg$ (d) $3kg$

111. A ladder rests against a frictionless vertical wall, with its upper end $6m$ above the ground and the lower end $4m$ away from the wall. The weight of the ladder is 500 N and its C. G. at 1/3rd distance from the lower end. Wall's reaction will be, (in *Newton*)

(a) 111 (b) 333

(c) 222 (d) 129

112. A satellite in force-free space sweeps stationary interplanetary dust at a rate $dM/dt = \alpha v$ where M is the mass, v is the velocity of the satellite and α is a constant. What is the deacceleration of the satellite [CBSE PMT 1994]

(a) $-2\alpha v^2/M$ (b) $-\alpha v^2/M$

(c) $+\alpha v^2/M$ (d) $-\alpha v^2$

113. 10,000 small balls, each weighing 1 *gm*, strike one square *cm* of area per second with a velocity 100 *m/s* in a normal direction and rebound with the same velocity. The value of pressure on the surface will be [MP PMT 1994]

(a) $2 \times 10^3\ N/m^2$ (b) $2 \times 10^5\ N/m^2$

(c) $10^7\ N/m^2$ (d) $2 \times 10^7\ N/m^2$

Third Law of Motion

1. Swimming is possible on account of [AFMC 1998, 2003]

(a) First law of motion

(b) Second law of motion

(c) Third law of motion

(d) Newton's law of gravitation

2. When we jump out of a boat standing in water it moves

(a) Forward (b) Backward

(c) Sideways (d) None of the above

3. You are on a frictionless horizontal plane. How can you get off if no horizontal force is exerted by pushing against the surface

(a) By jumping

(b) By spitting or sneezing

(c) By rolling your body on the surface

(d) By running on the plane

4. On a stationary sail-boat, air is blown at the sails from a fan attached to the boat. The boat will

(a) Remain stationary

(b) Spin around

(c) Move in a direction opposite to that in which air is blown

(d) Move in the direction in which the air is blown

5. A man is at rest in the middle of a pond on perfectly smooth ice. He can get himself to the shore by making use of Newton's

(a) First law (b) Second law

(c) Third law (d) All the laws

6. A cannon after firing recoils due to [EAMCET 1980]

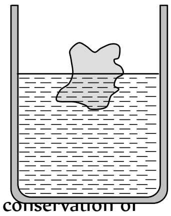
(a) Conservation of energy

(b) Backward thrust of gases produced

(c) Newton's third law of motion

(d) Newton's first law of motion

7. A body floats in a liquid contained in a beaker. If the whole system as shown in figure falls freely under gravity, then the upthrust on the body due to liquid is [Manipal MEE 1995]



(a) Zero [AMU (Med.) 2000]

(b) Equal to the weight of liquid displaced

(c) Equal to the weight of the body in air

(d) None of these

8. Newton's third law of motion leads to the law of conservation of

(a) Angular momentum (b) Energy

(c) Mass (d) Momentum

9. A man is carrying a block of a certain substance (of density 1000 kgm^{-3}) weighing 1 *kg* in his left hand and a bucket filled with water and weighing 10 *kg* in his right hand. He drops the block into the bucket. How much load does he carry in his right hand now

(a) 9 *kg* (b) 10 *kg*

(c) 11 *kg* (d) 12 *kg*

10. A man is standing on a balance and his weight is measured. If he takes a step in the left side, then weight [AFMC 1996]

(a) Will decrease

(b) Will increase

(c) Remains same

(d) First decreases then increases

11. A man is standing at a spring platform. Reading of spring balance is 60 *kg wt*. If man jumps outside platform, then reading of spring balance

[AFMC 1996; AIIMS 2000; Pb. PET 2000]

(a) First increases then decreases to zero

(b) Decreases

(c) Increases

(d) Remains same

12. A cold soft drink is kept on the balance. When the cap is open, then the weight [AFMC 1996]

(a) Increases

(b) Decreases

(c) First increases then decreases

(d) Remains same

13. Action and reaction forces act on

(a) The same body (b) The different bodies

(c) The horizontal surface (d) Nothing can be said

14. A bird is sitting in a large closed cage which is placed on a spring balance. It records a weight of 25 *N*. The bird (mass m = 0.5 *kg*) flies upward in the cage with an acceleration of $2\,m/s^2$. The spring balance will now record a weight of

[MP PMT 1999]

(a) 24 *N* (b) 25 *N*

(c) 26 [CPMT 1981] (d) 27 *N*

15. A light spring balance hangs from the hook of the other light spring balance and a block of mass *M kg* hangs from the former one. Then the true statement about the scale reading is

[AIEEE 2003]

(a) Both the scales read *M*/2 *kg* each

(b) Both the scales read *M kg* each

(c) The scale of the lower one reads M *kg* and of the upper one zero

(d) The reading of the two scales can be anything but the sum of the reading will be M *kg*

16. A machine gun fires 20 bullets per second into a target. Each bullet weighs 150 *gms* and has a speed of 800 *m/sec*. Find the force necessary to hold the gun in position [EAMCET 1994]

(a) 800 *N* (b) 1000 *N*

(c) 1200 *N* (d) 2400 *N*

17. The tension in the spring is [AMU (Engg.) 2001]

(a) Zero (b) $2.5\,N$

(c) $5\,N$ (d) $10\,N$

18. A book is lying on the table. What is the angle between the action of the book on the table and the reaction of the table on the book

(a) 0° (b) 30°

(c) 45° (d) 180°

19. When a horse pulls a wagon, the force that causes the horse to move forward is the force [Pb. PET 2004]

(a) The ground exerts on it (b) It exerts on the ground

(c) The wagon exerts on it (d) It exerts on the wagon

20. A student attempts to pull himself up by tugging on his hair. He will not succeed [KCET 2005]

(a) As the force exerted is small

(b) The frictional force while gripping, is small.

(c) Newton's law of inertia is not applicable to living beings.

(d) As the force applied is internal to the system.

21. A man is standing at the centre of frictionless pond of ice. How can he get himself to the shore [J&K CET 2005]

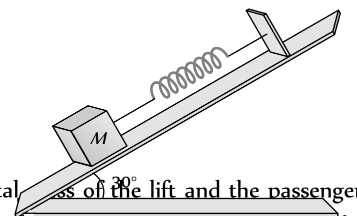
(a) By throwing his shirt in vertically upward direction

(b) By spitting horizontally

(c) He will wait for the ice to melt in pond

(d) Unable to get at the shore

22. A body of mass 5*kg* is suspended by a spring balance on an inclined plane as shown in figure. The spring balance measure



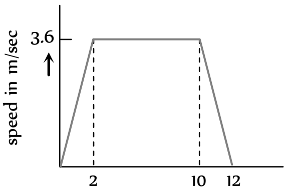
(a) 50 *N*

(b) 25 *N*

(c) 500 *N*

(d) 10 *N*

23. A lift is going up. The total mass of the lift and the passenger is 1500 *kg*. The variation in the speed of the lift is as given in the graph. The tension in the rope pulling the lift at t = 11th *sec* will be



(a) 17400 *N*

(b) 14700 *N*

(c) 12000 *N*

(d) Zero

24. In the above ques., the height to which the lift takes the passenger is

(a) 3.6 *meters* (b) 8 *meters*

(c) 1.8 *meters* (d) 36 *meters*

Conservation of Linear Momentum and Impulse

1. A jet plane flies in the air because [NCERT 1971]

(a) The gravity does not act on bodies moving with high speeds

(b) The thrust of the jet compensates for the force of gravity

(c) The flow of air around the wings causes an upward force, which compensates for the force of gravity

(d) The weight of air whose volume is equal to the volume of the plane is more than the weight of the plane

2. A player caught a cricket ball of mass 150 *gm* moving at a rate of 20 *m/s*. If the catching process be completed in 0.1 *s*, then the force of the blow exerted by the ball on the hands of the player is[AFMC 1993; CBSE PMT [Kerala PMT 2005]

(a) 0.3 *N* (b) 30 *N*

(c) 300 *N* (d) 3000 *N*

3. A rocket has a mass of 100 *kg*. 90% of this is fuel. It ejects fuel vapours at the rate of 1 *kg/sec* with a velocity of 500 *m/sec* relative to the rocket. It is supposed that the rocket is outside the gravitational field. The initial upthrust on the rocket when it just starts moving upwards is [NCERT 1978]

(a) Zero (b) 500 *N*

(c) 1000 *N* (d) 2000 *N*

4. In which of the following cases forces may not be required to keep the [AIIMS 1983]

(a) Particle going in a circle

(b) Particle going along a straight line

(c) The momentum of the particle constant

(d) Acceleration of the particle constant

5. A wagon weighing 1000 *kg* is moving with a velocity 50*km/h* on smooth horizontal rails. A mass of 250 *kg* is dropped into it. The velocity with which it moves now is [MP PMT 1994]

(a) 2.5 *km/hour* (b) 20 *km/hour*

(c) 40 *km/hour* (d) 50 *km/hour*

6. If a force of 250 *N* act on body, the momentum acquired is 125 *kg-m/s*. What is the period for which force acts on the body

(a) 0.5 *sec* (b) 0.2 *sec*

(c) 0.4 *sec* (d) 0.25 *sec*

7. A 100 *g* iron ball having velocity 10 *m/s* collides with a wall at an angle 30° and rebounds with the same angle. If the period of contact between the ball and wall is 0.1 *second*, then the force experienced by the wall is [CPMT 1997]

(a) 10 *N* (b) 100 *N*

(c) 1.0 *N* (d) 0.1 *N*

8. A ball of mass 150g starts moving with an acceleration of $20 m/s^2$. When hit by a force, which acts on it for 0.1 sec. The impulsive force is [AFMC 1999; Pb. PMT 2003]
(a) 0.5 *N-s* (b) 0.1 *N-s*
(c) 0.3 *N-s* (d) 1.2 *N-s*

9. A body, whose momentum is constant, must have constant [AIIMS 2000]
(a) Force (b) Velocity
(c) Acceleration (d) All of these

10. The motion of a rocket is based on the principle of conservation of
(a) Mass (b) Kinetic energy
(c) Linear momentum (d) Angular momentum

11. A rope of length 5m is kept on frictionless surface and a force of 5N is applied to one of its end. Find tension in the rope at 1m from this end [RPET 2000]
(a) 1 N (b) 3 N
(c) 4 N (d) 5 N

12. An aircraft is moving with a velocity of $300 ms^{-1}$. If all the forces acting on it are balanced, then [Kerala PMT 2004]
(a) It still moves with the same velocity
(b) It will be just floating at the same point in space
(c) It will fall down instantaneously
(d) It will lose its velocity gradually
(e) It will explode

13. A rocket of mass 1000 *kg* exhausts gases at a rate of 4 *kg/sec* with a velocity 3000 *m/s*. The thrust developed on the rocket is
(a) 12000 N (b) 120 N
(c) 800 N (d) 200 N

14. The momentum is most closely related to [DCE 2001]
(a) Force (b) Impulse
(c) Power (d) K.E.

15. Rocket engines lift a rocket from the earth surface because hot gas with high velocity [AIIMS 1998; JIPMER 2001, 02]
(a) Push against the earth
(b) Push against the air
(c) React against the rocket and push it up
(d) Heat up the air which lifts the rocket

16. A man fires a bullet of mass 200 g at a speed of 5 *m/s*. The gun is of one *kg* mass. by what velocity the gun rebounds backwards[CBSE PMT 1996; JIPMER 2000]
(a) 0.1 *m/s* (b) 10 *m/s*
(c) 1 *m/s* (d) 0.01 *m/s*

17. A bullet of mass 5 g is shot from a gun of mass 5 *kg*. The muzzle velocity of the bullet is 500 *m/s*. The recoil velocity of the gun is
(a) 0.5 *m/s* (b) 0.25 *m/s*
(c) 1 *m/s* (d) Data is insufficient

18. A force of 50 *dynes* is acted on a body of mass 5 g which is at rest for an interval of 3 seconds, then impulse is [AFMC 1998]
(a) 0.15×10^{-3} *Ns* (b) 0.98×10^{-3} *Ns*
(c) 1.5×10^{-3} *Ns* (d) 2.5×10^{-3} *Ns*

19. A body of mass M at rest explodes into three pieces, two of which of mass $M/4$ each are thrown off in perpendicular directions with velocities of 3 *m/s* and 4 *m/s* respectively. The third piece will be thrown off with a velocity of [CPMT 1990]
(a) 1.5 *m/s* (b) 2.0 *m/s*
(c) 2.5 *m/s* (d) 3.0 *m/s*

20. The momentum of a system is conserved [CPMT 1982]
(a) Always
(b) Never
(c) In the absence of an external force on the system
(d) None of the above [AFMC 2000]

21. A body of mass 0.25 *kg* is projected with muzzle velocity $100 ms^{-1}$ from a tank of mass 100 *kg*. What is the recoil velocity of the tank
(a) $5 ms^{-1}$ (b) $25 ms^{-1}$
(c) $0.5 ms^{-1}$ (d) $0.25 ms^{-1}$

22. A bullet is fired from a gun. The force on the bullet is given by $F = 600 - 2\times 10^5 t$, where F is in *newtons* and t in seconds. The force on the bullet becomes zero as soon as it leaves the barrel. What is the average impulse imparted to the bullet
(a) 9 *Ns* (b) Zero
(c) 0.9 *Ns* (d) 1.8 *Ns*

23. A bullet of mass 0.1 *kg* is fired with a speed of 100 *m/sec*, the mass of gun is 50 *kg*. The velocity of recoil is [AFMC 1995; JIPMER 2000; Pb.PMT 2002]
(a) 0.2 *m/sec* (b) 0.1 *m/sec*
(c) 0.5 *m/sec* [Orissa JEE 2005] (d) 0.05 *m/sec*

24. A bullet mass 10 *gm* is fired from a gun of mass 1*kg*. If the recoil velocity is 5 m/s, the velocity of the muzzle is [Orissa JEE 2002]
(a) 0.05 *m/s* (b) 5 *m/s*
(c) 50 *m/s* (d) 500 *m/s*

25. A rocket can go vertically upwards in earth's atmosphere because
(a) It is lighter than air
(b) Of gravitational pull of the sun
(c) It has a fan which displaces more air per unit time than the weight of the rocket
(d) Of the force exerted on the rocket by gases ejected by it

26. At a certain instant of time the mass of a rocket going up vertically is 100 kg. If it is ejecting 5 kg of gas per second at a speed of 400 m/s, the acceleration of the rocket would be (taking $g = 10 m/s^2$)
(a) $20 m/s^2$ (b) $10 m/s^2$
(c) $2 m/s^2$ [DCE 2004] (d) $1 m/s^2$

27. A jet engine works on the principle of [CPMT 1973; MP PMT 1996]
(a) Conservation of mass
(b) Conservation of energy
(c) Conservation of linear momentum
(d) Conservation of angular momentum

Equilibrium of Forces

1. The weight of an aeroplane flying in the air is balanced by [NCERT 1974]

(a) Vertical component of the thrust created by air currents striking the lower surface of the wings
(b) Force due to reaction of gases ejected by the revolving propeller
(c) Upthrust of the air which will be equal to the weight of the air having the same volume as the plane
(d) Force due to the pressure difference between the upper and lower surfaces of the wings created by different air speeds on the surfaces

2. When a body is stationary [NCERT 1978]

(a) There is no force acting on it
(b) The force acting on it is not in contact with it
(c) The combination of forces acting on it balances each other
(d) The body is in vacuum

3. Two forces of magnitude *F* have a resultant of the same magnitude *F*. The angle between the two forces is [CBSE PMT 1990]

(a) 45° (b) 120°
(c) 150° (d) 60°

4. Two forces with equal magnitudes *F* act on a body and the magnitude of the resultant force is *F*/3. The angle between the two forces is [MP PMT 1999]

(a) $\cos^{-1}\left(-\frac{17}{18}\right)$ (b) $\cos^{-1}\left(-\frac{1}{3}\right)$
(c) $\cos^{-1}\left(\frac{2}{3}\right)$ (d) $\cos^{-1}\left(\frac{8}{9}\right)$

5. An object is subjected to a force in the north-east direction. To balance this force, a second force should be applied in the direction

(a) North-East (b) South
(c) South-West (d) West

6. The resultant force of 5 *N* and 10 *N* can not be [RPET 2000]

(a) 12 *N* (b) 8 *N*
(c) 4 *N* (d) 5 *N*

7. The resultant of two forces $3P$ and $2P$ is *R*. If the first force is doubled then the resultant is also doubled. The angle between the two forces is [KCET 2001]

(a) 60^o (b) 120^o
(c) 70^o (d) 180^o

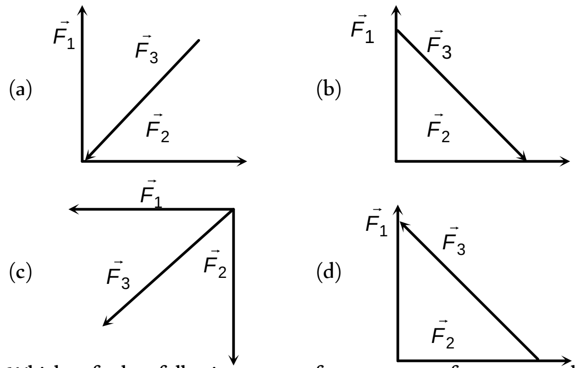
8. The resultant of two forces, one double the other in magnitude, is perpendicular to the smaller of the two forces. The angle between the two forces is [KCET 2002]

(a) 60^0 (b) 120^0
(c) 150^0 (d) 90^0

9. Two forces are such that the sum of their magnitudes is 18 *N* and their resultant is perpendicular to the smaller force and magnitude of resultant is 12 N. Then the magnitudes of the forces are

(a) 12 *N*, 6 *N* (b) 13 *N*, 5*N*
(c) 10 *N*, 8 *N* (d) 16 *N*, 2 *N*

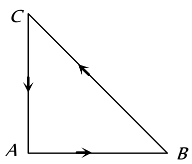
10. Which of the four arrangements in the figure correctly shows the vector addition of two forces $\vec{F_1}$ and $\vec{F_2}$ to yield the third force $\vec{F_3}$ [Orissa JEE 2003]



11. Which of the following sets of concurrent forces may be in equilibrium [KCET 2003]

(a) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 9N$
(b) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 1N$
(c) $F_1 = 3N, F_2 = 5N, F_3 = 15N$
(d) $F_1 = 3N,\ F_2 = 5N,\ F_3 = 6N$

12. Three forces starts acting simultaneously on a particle moving with velocity $\vec{v}$. These forces are represented in magnitude and direction by the three sides of a triangle *ABC* (as shown). The particle will now move with velocity [AIEEE 2003]

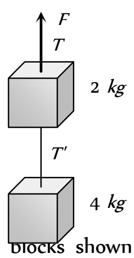


(a) $\vec{v}$ remaining unchanged
(b) Less than $\vec{v}$ [KCET 1994]
(c) Greater than $\vec{v}$
(d) $\vec{v}$ in the direction of the largest force *BC*

13. Which of the following groups of forces could be in equilibrium

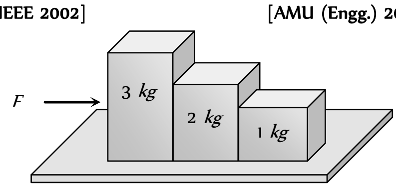
(a) 3 *N*, 4 *N*, 5 *N* (b) 4*N*, 5 *N*, 10 *N*
(c) 30*N*, 40 *N*, 80 *N* (d) 1*N*, 3 *N*, 5 *N*

14. Two blocks are connected by a string as shown in the diagram. The upper block is hung by another string. A force *F* applied on the upper string produces an acceleration of $2m/s^2$ in the upward direction in both the blocks. If *T* and T' be the tensions in the two parts of the string, then [AMU (Engg.) 2000]



(a) $T = 70.8N$ and $T' = 47.2N$
(b) $T = 58.8N$ and $T' = 47.2N$
(c) $T = 70.8N$ and $T' = 58.8N$
(d) $T = 70.8N$ and $T' = 0$

15. Consider the following statements about the blocks shown in the diagram that are being pushed by a constant force on a frictionless table [AIEEE 2002] [AMU (Engg.) 2001]



A. All blocks move with the same acceleration

B. The net force on each block is the same Which of these statements are/is correct

(a) A only (b) B only

(c) Both A and B (d) Neither A nor B

16. If two forces of 5 N each are acting along X and Y axes, then the magnitude and direction of resultant is

[DCE 2004]

(a) $5\sqrt{2}, \pi/3$ (b) $5\sqrt{2}, \pi/4$

(c) $-5\sqrt{2}, \pi/3$ (d) $-5\sqrt{2}, \pi/4$

17. Which of the following is the correct order of forces

[AIEEE 2002]

(a) Weak < gravitational forces < strong forces (nuclear) < electrostatic

(b) Gravitational < weak < (electrostatic) < strong force

(c) Gravitational < electrostatic < weak < strong force

(d) Weak < gravitational < electrostatic < strong forces

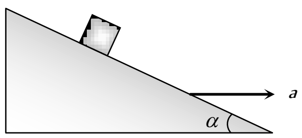
18. A block is kept on a frictionless inclined surface with angle of inclination 'α'. The incline is given an acceleration 'a' to keep the block stationary. Then a is equal to [AIEEE 2005]

(a) g

(b) $g \tan \alpha$

(c) $g / \tan \alpha$

(d) g cosec α



Motion of Connected Bodies

1. A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block will be

[CBSE PMT 1993; CPMT 1972, 75, 82;

MP PMT 1996; AIEEE 2003]

(a) P (b) $\frac{Pm}{M+m}$

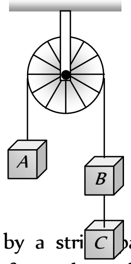
(c) $\frac{PM}{M+m}$ (d) $\frac{Pm}{M-m}$

2. A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from the end where the force is applied [MP PET 1996, 97, 2000]

(a) $\frac{FL}{x}$ (b) $\frac{F(L-x)}{L}$

(c) $\frac{FL}{L-x}$ (d) $\frac{Fx}{L-x}$

3. Three equal weights A, B and C of mass 2 kg each are hanging on a string passing over a fixed frictionless pulley as shown in the figure The tension in the string connecting weights B and C is[MP PET 1985; SCRA 1996]



(a) Zero

(b) 13 N

(c) 3.3 N

(d) 19.6 N

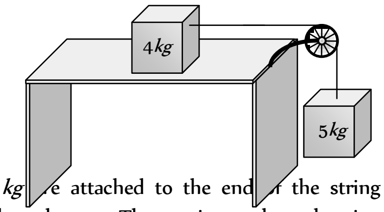
4. Two masses of 4 kg and 5 kg are connected by a string passing through a frictionless pulley and are kept on a frictionless table as shown in the figure. The acceleration of 5 kg mass is

(a) $49\, m/s^2$

(b) $5.44\, m/s^2$

(c) $19.5\, m/s^2$

(d) $2.72\, m/s^2$



5. Two masses 2 kg and 3 kg are attached to the end of the string passed over a pulley fixed at the top. The tension and acceleration are

(a) $\frac{7g}{8}; \frac{g}{8}$ (b) $\frac{21g}{8}; \frac{g}{8}$

(c) $\frac{21g}{8}; \frac{g}{5}$ (d) $\frac{12g}{5}; \frac{g}{5}$

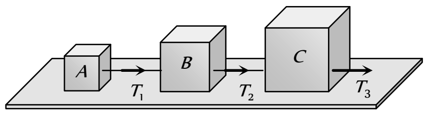
6. Three blocks A, B and C weighing 1, 8 and 27 kg respectively are connected as shown in the figure with an inextensible string and are moving on a smooth surface. T_3 is equal to 36 N. Then T_2 is

(a) 18 N

(b) 9 N

(c) 3.375 N

(d) 1.25 N



7. Two bodies of mass 3 kg and 4 kg are suspended at the ends of massless string passing over a frictionless pulley. The acceleration of the system is $(g = 9.8\, m/s^2)$

[MP PET 1994; CBSE PMT 2001]

(a) $4.9\, m/s^2$ (b) $2.45\, m/s^2$

(c) $1.4\, m/s^2$ (d) $9.5\, m/s^2$

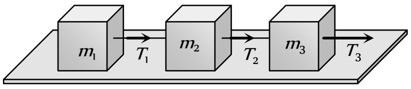
8. Three solids of masses m_1, m_2 and m_3 are connected with weightless string in succession and are placed on a frictionless table. If the mass m_3 is dragged with a force T, the tension in the string between m_2 and m_3 is

[MP PET 1995]

(a) $\frac{m_2}{m_1+m_2+m_3}T$ (b) $\frac{m_3}{m_1+m_2+m_3}T$

(c) $\frac{m_1+m_2}{m_1+m_2+m_3}T$ (d) $\frac{m_2+m_3}{m_1+m_2+m_3}T$

9. Three blocks of masses m_1, m_2 and m_3 are connected by massless strings as shown on a frictionless table. They are pulled with a force $T_3 = 40\, N$. If $m_1 = 10\, kg, m_2 = 6\, kg$ and $m_3 = 4\, kg$, the tension T_2 will be [MP PMT/PET 1998]



(a) 20 N (b) 40 N

(c) 10 N (d) 32 N

10. A block of mass m_1 rests on a horizontal table. A string tied to the block is passed on a frictionless pulley fixed at the end of the table and to the other end of string is hung another block of mass m_2. The acceleration of the system is

[EAMCET (Med.) 1995; DPMT 2000]

(a) $\frac{m_2 g}{(m_1 + m_2)}$ (b) $\frac{m_1 g}{(m_1 + m_2)}$

(c) g (d) $\frac{m_2 g}{m_1}$

11. A 2 kg block is lying on a smooth table which is connected by a body of mass 1 kg by a string which passes through a pulley. The 1 kg mass is hanging vertically. The acceleration of block and tension in the string will be [RPMT 1997]

(a) $3.27\, m/s^2, 6.54\, N$ (b) $4.38\, m/s^2, 6.54\, N$

(c) $3.27\, m/s^2, 9.86\, N$ (d) $4.38\, m/s^2, 9.86\, N$

12. A light string passes over a frictionless pulley. To one of its ends a mass of 6 kg is attached. To its other end a mass of 10 kg is attached. The tension in the thread will be

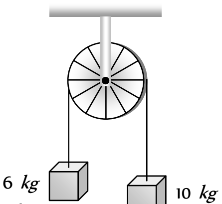
[RPET 1996; JIPMER 2001, 02]

(a) 24.5 N

(b) 2.45 N

(c) 79 N

(d) 73.5 N



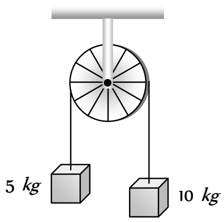
13. USS 150) Two masses of $5 kg$ and $10 kg$ are connected to a pulley as shown. What will be the acceleration of the system (g = acceleration due to gravity) [CBSE PMT 2000]

(a) g

(b) $\frac{g}{2}$

(c) $\frac{g}{3}$

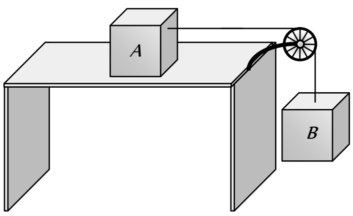
(d) $\frac{g}{4}$



14. A block A of mass 7 kg is placed on a frictionless table. A thread tied to it passes over a frictionless pulley and carries a body B of mass 3 kg at the other end. The acceleration of the system is (given $g = 10\, ms^{-2}$) [Kerala (Engg.) 2000]

(a) $100\, ms^{-2}$

(b) $3 ms^{-2}$



(c) $10 ms^{-2}$

(d) $30 ms^{-2}$

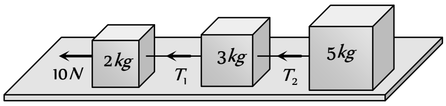
15. Three blocks of masses 2 kg, 3 kg and 5 kg are connected to each other with light string and are then placed on a frictionless surface as shown in the figure. The system is pulled by a force $F = 10 N$, then tension $T_1 =$ [Orissa JEE 2002]

(a) 1N

(b) 5 N

(c) 8 N

(d) 10 N



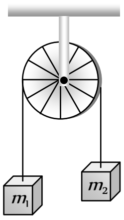
16. Two masses m_1 and m_2 are attached to a string which passes over a frictionless smooth pulley. When $m_1 = 10 kg$, $m_2 = 6 kg$, the acceleration of masses is [Orissa JEE 2002]

(a) 20 m/s^2

(b) $5 m/s^2$

(c) 2.5 m/s^2

(d) $10 m/s^2$



17. A body of weight $2 kg$ is suspended as shown in the figure. The tension T_1 in the horizontal string (in kg wt) is

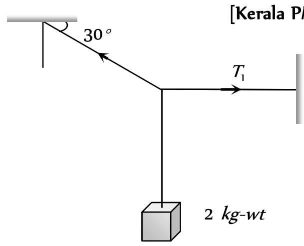
[Kerala PMT 2002]

(a) $2/\sqrt{3}$

(b) $\sqrt{3}/2$

(c) $2\sqrt{3}$

(d) 2



18. One end of a massless rope, which passes over a massless and frictionless pulley P is tied to a hook C while the other end is free. Maximum tension that the rope can bear is 360 N. with what value of minimum safe acceleration (in ms^{-2}) can a monkey of $60 kg$ move down on the rope

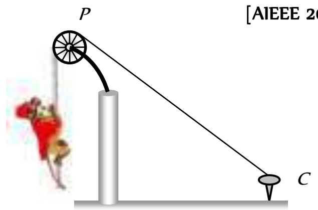
[AIEEE 2002]

(a) 16

(b) 6

(c) 4

(d) 8



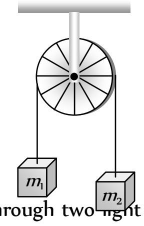
19. A light string passing over a smooth light pulley connects two blocks of masses m_1 and m_2 (vertically). If the acceleration of the system is $g/8$ then the ratio of the masses is

[AIEEE 2002]

(a) 8 : 1 (b) 9 : 7

(c) 4 : 3 (d) 5 : 3

20. Two masses $m_1 = 5\,kg$ and $m_2 = 4.8\,kg$ tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses when they are free to move $(g = 9.8\ m/s^2)$



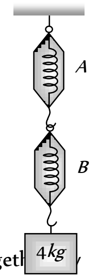
(a) $0.2\ m/s^2$

(b) $9.8\ m/s^2$

(c) $5\ m/s^2$

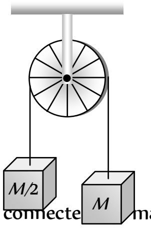
(d) $4.8\ m/s^2$

21. A block of mass 4 *kg* is suspended through two light spring balances *A* and *B*. Then *A* and *B* will read respectively [AIIMS 1995]



(a) 4 *kg* and zero *kg*
(b) Zero *kg* and 4 *kg*
(c) 4 *kg* and 4 *kg*
(d) 2 *kg* and 2 *kg*

22. Two masses *M* and *M*/2 are joint together by means of a light inextensible string passes over a frictionless pulley as shown in figure. When bigger mass is released the small one will ascend with an acceleration of [Kerala PET 2005]



(a) *g*/3
(b) 3*g*/2
(c) *g*/2
(d) *g*

23. Two masses m_1 and m_2 $(m_1 > m_2)$ are connected by massless flexible and inextensible string passed over massless and frictionless pulley. The acceleration of centre of mass is

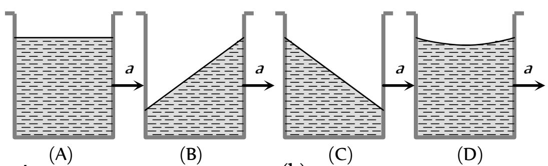
(a) $\left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g$ (b) $\frac{m_1 - m_2}{m_1 + m_2} g$

(c) $\frac{m_1 + m_2}{m_1 - m_2} g$ (d) Zero

Critical Thinking

Objective Questions

1. A vessel containing water is given a constant acceleration *a* towards the right, along a straight horizontal path. Which of the following diagram represents the surface of the liquid [IIT 1981]



(a) A   (b) B

(c) C   (d) D

2. A closed compartment containing gas is moving with some acceleration in horizontal direction. Neglect effect of gravity. Then the pressure in the compartment is [IIT-JEE 1999]

[AIEEE 2004]

(a) Same everywhere   (b) Lower in front side

(c) Lower in rear side   (d) Lower in upper side

3. A ship of mass $3 \times 10^7\ kg$ initially at rest is pulled by a force of $5 \times 10^4\ N$ through a distance of 3 *m*. Assume that the resistance due to water is negligible, the speed of the ship is [IIT 1980; MP PMT 2000]

(a) 1.5 *m*/*s*   (b) 60 *m*/*s*

(c) 0.1 *m*/*s*   (d) 5 *m*/*s*

4. The mass of a body measured by a physical balance in a lift at rest is found to be *m*. If the lift is going up with an acceleration *a*, its mass will be measured as [MP PET 1994]

(a) $m\left(1 - \frac{a}{g}\right)$ (b) $m\left(1 + \frac{a}{g}\right)$

(c) m (d) Zero

5. Three weights *W*, 2*W* and 3*W* are connected to identical springs suspended from a rigid horizontal rod. The assembly of the rod and the weights fall freely. The positions of the weights from the rod are such that [Roorkee 1999]

(a) 3*W* will be farthest
(b) *W* will be farthest
(c) All will be at the same distance
(d) 2*W* will be farthest

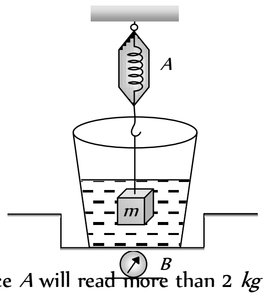
6. When forces F_1, F_2, F_3 are acting on a particle of mass *m* such that F_2 and F_3 are mutually perpendicular, then the particle remains stationary. If the force F_1 is now removed then the acceleration of the particle is [AIEEE 2002]

(a) F_1/m (b) F_2F_3/mF_1

[J&K CET 2005]

(c) $(F_2 - F_3)/m$ (d) F_2/m

7. The spring balance *A* reads 2 *kg* with a block *m* suspended from it. A balance *B* reads 5 *kg* when a beaker filled with liquid is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid as shown in figure. In this situation



(a) The balance *A* will read more than 2 *kg*

(b) The balance *B* will read more than 5 *kg*

(c) The balance *A* will read less than 2 *kg* and *B* will read more than 5 *kg*

(d) The balances *A* and *B* will read 2 *kg* and 5 *kg* respectively

8. A rocket is propelled by a gas which is initially at a temperature of 4000 *K*. The temperature of the gas falls to 1000 *K* as it leaves the exhaust nozzle. The gas which will acquire the largest momentum while leaving the nozzle, is

[SCRA 1994]

(a) Hydrogen (b) Helium

(c) Nitrogen (d) Argon

9. Consider the following statement: When jumping from some height, you should bend your knees as you come to rest, instead of keeping your legs stiff. Which of the following relations can be useful in explaining the statement

[AMU (Engg.) 2001]

(a) $\Delta\overrightarrow{P_1} = -\Delta\overrightarrow{P_2}$

(b) $\Delta E = -\Delta(PE + KE) = 0$

(c) $\vec{F}\Delta t = m\Delta\vec{v}$

(d) $\Delta\vec{x} \propto \Delta\vec{F}$

Where symbols have their usual meaning

10. A false balance has equal arms. An object weigh X when placed in one pan and Y when placed in other pan, then the weight W of the object is equal to [AFMC 1994]

(a) $\sqrt{XY}$

(b) $\frac{X+Y}{2}$

(c) $\frac{X^2+Y^2}{2}$

(d) $\frac{2}{\sqrt{X^2+Y^2}}$

11. The vector sum of two forces is perpendicular to their vector differences. In that case, the force [CBSE PMT 2003]

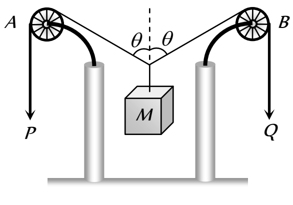
(a) Are equal to each other in magnitude

(b) Are not equal to each other in magnitude

(c) Cannot be predicted

(d) Are equal to each other

12. In the arrangement shown in figure the ends P and Q of an unstretchable string move downwards with uniform speed U. Pulleys A and B are fixed. Mass M moves upwards with a speed



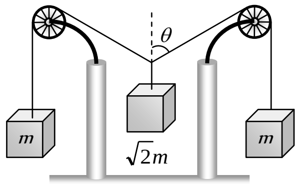
(a) $2U\cos\theta$

(b) $U\cos\theta$

(c) $\frac{2U}{\cos\theta}$

(d) $\frac{U}{\cos\theta}$

13. The pulleys and strings shown in the figure are smooth and of negligible mass. For the system to remain in equilibrium, the angle θ should be [IIT-JEE 2001]



(a) 0^o

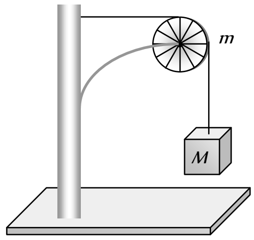
(b) 30^o

(c) 45^o

(d) 60^o

14. A string of negligible mass going over a clamped pulley of mass m supports a block of mass M as shown in the figure. The force on the pulley by the clamp is given by

[IIT-JEE 2001]



(a) $\sqrt{2}Mg$

(b) $\sqrt{2}mg$

(c) $\sqrt{(M+m)^2 + m^2}\,g$

(d) $\sqrt{(M+m)^2 + M^2}\,g$

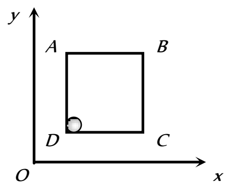
15. A pulley fixed to the ceilling carries a string with blocks of mass m and 3 m attached to its ends. The masses of string and pulley are negligible. When the system is released, its centre of mass moves with what acceleration

[UPSEAT 2002]

(a) 0 (b) $g/4$

(c) $g/2$ (d) $-g/2$

16. A solid sphere of mass 2 kg is resting inside a cube as shown in the figure. The cube is moving with a velocity $v = (5t\hat{i} + 2t\hat{j})m/s$. Here t is the time in second. All surface are smooth. The sphere is at rest with respect to the cube. What is the total force exerted by the sphere on the cube. (Take g = 10 m/s)



(a) $\sqrt{29}N$ (b) 29 N

(c) 26 N (d) $\sqrt{89}$ N

17. A stick of 1 m is moving with velocity of $2.7\times10^8 ms^{-1}$. What is the apparent length of the stick $(c = 3\times10^8 ms^{-1})$ [IIT 1982]

[BHU 1995]

(a) 10 m (b) 0.22 m

(c) 0.44 m (d) 2.4 m

18. One day on a spacecraft corresponds to 2 days on the earth. The speed of the spacecraft relative to the earth is

[CBSE PMT 1993]

(a) $1.5\times10^8 ms^{-1}$ (b) $2.1\times10^8 ms^{-1}$

(c) $2.6\times10^8 ms^{-1}$ (d) $5.2\times10^8 ms^{-1}$

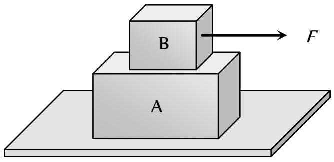
19. A flat plate moves normally with a speed v_1 towards a horizontal jet of water of uniform area of cross-section. The jet discharges water at the rate of volume V per second at a speed of v_2. The density of water is ρ. Assume that water splashes along the surface of the plate at right angles to the original motion. The magnitude of the force acting on the plate due to the jet of water is

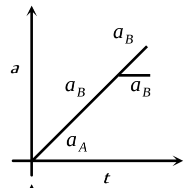
(a) $\rho V v_1$ (b) $\rho V(v_1 + v_2)$

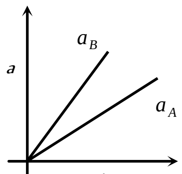
(c) $\frac{\rho V}{v_1 + v_2} v_1^2$ (d) $\rho\left[\frac{V}{v_2}\right](v_1 + v_2)^2$

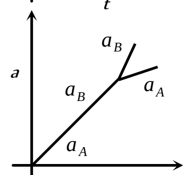
GQ Graphical Questions

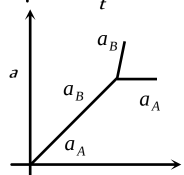
1. A block B is placed on block A. The mass of block B is less than the mass of block A. Friction exists between the blocks, whereas the ground on which the block A is placed is taken to be smooth. A horizontal force F, increasing linearly with time begins to act on B. The acceleration a_A and a_B of blocks A and B respectively are plotted against t. The correctly plotted graph is



(a)


(b)


(c)


(d)


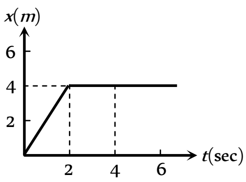
2. In the figure given below, the position-time graph of a particle of mass 0.1 Kg is shown. The impulse at $t = 2\sec$ is

(a) $0.2\ kg\ m\ sec^{-1}$

(b) $-0.2 kg\ m\ sec^{-1}$

(c) $0.1 kg\ m\ sec^{-1}$

(d) $-0.4 kg\ m\ sec^{-1}$



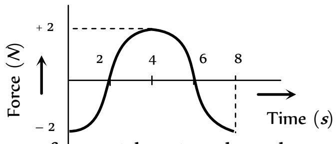
3. The force-time $(F - t)$ curve of a particle executing linear motion is as shown in the figure. The momentum acquired by the particle in time interval from zero to 8 *second* will be [CPMT 1989]

(a) – 2 *N-s*

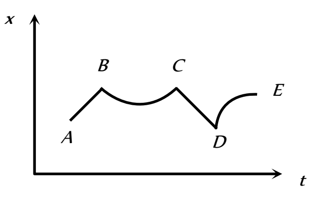
(b) + 4 *N-s*

(c) 6 *N-s*

(d) Zero



4. Figure shows the displacement of a particle going along the X-axis as a function of time. The force acting on the particle is zero in the region



(a) AB

(b) BC

(c) CD

(d) DE

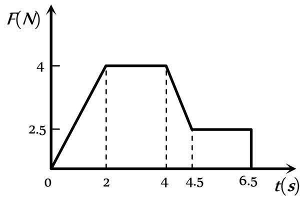
5. A body of 2 kg has an initial speed $5 ms$. A force acts on it for some time in the direction of motion. The force time graph is shown in figure. The final speed of the body. [IIT 1995]

(a) $9.25\ ms^{-1}$

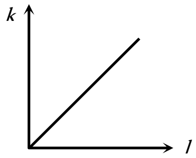
(b) $5\ ms^{-1}$

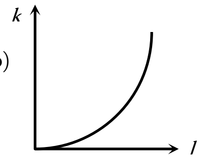
(c) $14.25\ ms$

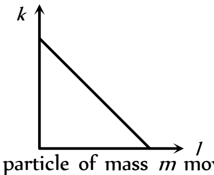
(d) $4.25\ ms$

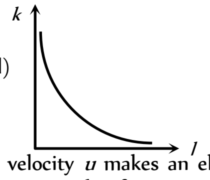


6. Which of the following graph depicts spring constant k versus length l of the spring correctly

(a)


(b)


(c)


(d)


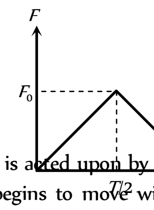
7. A particle of mass m moving with velocity u makes an elastic one dimensional collision with a stationary particle of mass m. They are in contact for a very short time T. Their force of interaction increases from zero to F linearly in time $T/2$, and decreases linearly to zero in further time $T/2$. The magnitude of F is

(a) mu / T

(b) $2mu / T$

(c) $mu / 2T$

(d) None of these



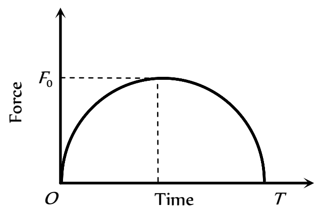
8. A particle of mass m, initially at rest, is acted upon by a variable force F for a brief interval of time T. It begins to move with a velocity u after the force stops acting. F is shown in the graph as a function of time. The curve is a semicircle. [AIIMS 2005]

(a) $u = \frac{\pi F_0^2}{2m}$

(b) $u = \frac{\pi T^2}{8m}$

(c) $u = \frac{\pi F_0 T}{4m}$

(d) $u = \frac{F_0 T}{2m}$



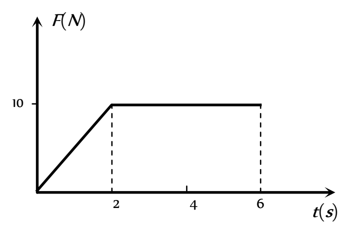
9. A body of mass 3kg is acted on by a force which varies as shown in the graph below. The momentum acquired is given by

(a) Zero

(b) 5 *N-s*

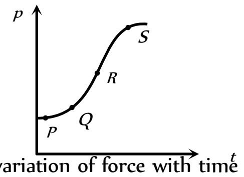
(c) 30 *N-s*

(d) 50 *N-s*

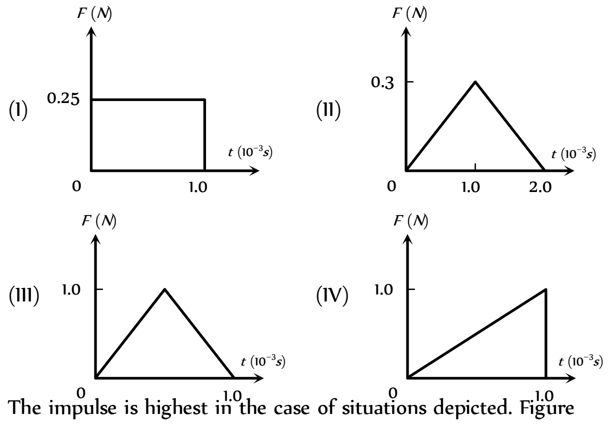


10. The variation of momentum with time of one of the body in a two body collision is shown in fig. The instantaneous force is maximum corresponding to point

(a) P
(b) Q
(c) R
(d) S



11. Figures I, II, III and IV depict variation of force with time



The impulse is highest in the case of situations depicted. Figure

(a) I and II
(b) III and I
(c) III and IV
(d) IV only

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Inertia is the property by virtue of which the body is unable to change by itself the state of rest only.
Reason : The bodies do not change their state unless acted upon by an unbalanced external force.

2. Assertion : If the net external force on the body is zero, then its acceleration is zero.
Reason : Acceleration does not depend on force.

3. Assertion : Newton's second law of motion gives the measurement of force.
Reason : According to Newton's second law of motion, force is directly proportional to the rate of change of momentum.

4. Assertion : Force is required to move a body uniformly along a circle.
Reason : When the motion is uniform, acceleration is zero.

5. Assertion : If two objects of different masses have same momentum, the lighter body possess greater velocity.
Reason : For all bodies momentum always remains same.

6. Assertion : Aeroplanes always fly at low altitudes.
Reason : According to Newton's third law of motion, for every action there is an equal and opposite reaction.

7. Assertion : No force is required by the body to remain in any state.
Reason : In uniform linear motion, acceleration has a finite value.

8. Assertion : Mass is a measure of inertia of the body in linear motion.
Reason : Greater the mass, greater is the force required to change its state of rest or of uniform motion.

9. Assertion : The slope of momentum versus time curve give us the acceleration.
Reason : Acceleration is given by the rate of change of momentum.

10. Assertion : A cyclist always bends inwards while negotiating a curve.
Reason : By bending, cyclist lowers his centre of gravity.

11. Assertion : The work done in bringing a body down from the top to the base along a frictionless incline plane is the same as the work done in bringing it down the vertical side.
Reason : The gravitational force on the body along the inclined plane is the same as that along the vertical side.

12. Assertion : Linear momentum of a body changes even when it is moving uniformly in a circle.
Reason : Force required to move a body uniformly along a straight line is zero.

13. Assertion : A bullet is fired from a rifle. If the rifle recoils freely, the kinetic energy of rifle is more than that of the bullet.
Reason : In the case of rifle bullet system the law of conservation of momentum violates.

14. Assertion : A rocket works on the principle of conservation of linear momentum.
Reason : Whenever there is a change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

15. Assertion : The apparent weight of a body in an elevator moving with some downward acceleration is less than the actual weight of body.
Reason : The part of the weight is spent in producing downward acceleration, when body is in elevator.

16. Assertion : When the lift moves with uniform velocity the man in the lift will feel weightlessness.
Reason : In downward accelerated motion of lift, apparent weight of a body decreases.

17. Assertion : In the case of free fall of the lift, the man will feel weightlessness.
Reason : In free fall, acceleration of lift is equal to acceleration due to gravity.

18. Assertion : A player lowers his hands while catching a cricket ball and suffers less reaction force.
Reason : The time of catch increases when cricketer lowers its hand while catching a ball.

19. Assertion : The acceleration produced by a force in the motion of a body depends only upon its mass.

Reason : Larger is the mass of the body, lesser will be the acceleration produced.

20. Assertion : Linear momentum of a body changes even when it is moving uniformly in a circle.

Reason : In uniform circular motion velocity remain constant.

21. Assertion : Newton's third law of motion is applicable only when bodies are in motion.

Reason : Newton's third law applies to all types of forces, *e.g.* gravitational, electric or magnetic forces etc.

22. Assertion : A reference frame attached to earth is an inertial frame of reference.

Reason : The reference frame which has zero acceleration is called a non inertial frame of reference.

23. Assertion : A table cloth can be pulled from a table without dislodging the dishes.

Reason : To every action there is an equal and opposite reaction.

24. Assertion : A body subjected to three concurrent forces cannot be in equilibrium.

Reason : If large number of concurrent forces acting on the same point, then the point will be in equilibrium, if sum of all the forces is equal to zero.

25. Assertion : Impulse and momentum have different dimensions.

Reason : From Newton's second law of motion, impulse is equal to change in momentum.

Answers

First Law of Motion

1	c	2	c	3	d	4	b	5	b
6	c	7	d	8	c	9	d	10	a
11	b	12	a						

Second Law of Motion

1	b	2	b	3	c	4	b	5	b
6	b	7	d	8	a	9	d	10	a
11	d	12	c	13	d	14	b	15	a
16	b	17	b	18	b	19	b	20	b
21	d	22	b	23	b	24	a	25	a
26	d	27	c	28	c	29	d	30	d
31	d	32	a	33	a	34	d	35	b
36	b	37	a	38	a	39	d	40	a
41	b	42	c	43	b	44	b	45	d
46	b	47	b	48	a	49	d	50	c
51	a	52	b	53	d	54	d	55	a
56	d	57	a	58	d	59	c	60	b
61	d	62	a	63	d	64	b	65	d
66	b	67	d	68	d	69	b	70	a
71	c	72	d	73	c	74	c	75	c
76	b	77	c	78	b	79	a	80	a
81	b	82	d	83	d	84	d	85	d
86	c	87	d	88	a	89	c	90	b
91	b	92	b	93	a	94	d	95	a
96	b	97	c	98	a	99	a	100	c
101	a	102	c	103	a	104	a	105	b
106	a	107	a	108	c	109	d	110	a
111	a	112	c	113	d				

Third Law of Motion

1	c	2	b	3	b	4	a	5	c
6	c	7	a	8	d	9	c	10	c
11	a	12	c	13	b	14	b	15	b
16	d	17	c	18	d	19	a	20	d
21	b	22	b	23	c	24	d		

Conservation of Linear Momentum Impulse

1	b	2	b	3	b	4	c	5	c
6	a	7	a	8	c	9	b	10	c
11	c	12	a	13	a	14	b	15	c
16	c	17	a	18	c	19	c	20	c
21	d	22	c	23	a	24	d	25	d
26	b	27	c						

Equilibrium of Forces

1	d	2	c	3	b	4	a	5	c
6	c	7	b	8	b	9	b	10	c
11	d	12	a	13	a	14	a	15	a
16	b	17	b	18	b				

Motion of Connected Bodies

1	c	2	b	3	b	4	b	5	d
6	b	7	c	8	c	9	d	10	a
11	a	12	d	13	c	14	b	15	c
16	c	17	c	18	c	19	b	20	a
21	c	22	a	23	a				

Critical Thinking Questions

1	c	2	b	3	c	4	c	5	c
6	a	7	bc	8	d	9	c	10	b
11	a	12	d	13	c	14	d	15	b
16	c	17	c	18	c	19	d		

Graphical Questions

1	d	2	b	3	d	4	ac	5	c
6	d	7	b	8	c	9	d	10	c
11	c								

Assertion & Reason

1	e	2	c	3	a	4	b	5	c
6	a	7	c	8	a	9	d	10	c
11	c	12	b	13	d	14	a	15	c
16	e	17	a	18	a	19	b	20	c
21	e	22	d	23	b	24	e	25	e

Answers and Solutions

First Law of Motion

1. (c)
2. (c)
3. (d)
4. (b)
5. (b) Horizontal velocity of apple will remain same but due to retardation of train, velocity of train and hence velocity of boy *w.r.t.* ground decreases, so apple falls away from the hand of boy in the direction of motion of the train.
6. (c) Newton's first law of motion defines the inertia of body. It states that every body has a tendency to remain in its state (either rest or motion) due to its inerta.
7. (d) Horizontal velocity of ball and person are same so both will cover equal horizontal distance in a given interval of time and after following the parabolic path the ball falls exactly in the hand which threw it up.
8. (c) When the bird flies, it pushes air down to balance its weight. So the weight of the bird and closed cage assembly remains unchanged.
9. (d) Particle will move with uniform velocity due to inertia.
10. (a)
11. (b) When a sudden jerk is given to C, an impulsive tension exceeding the breaking tension develops in C first, which breaks before this impulse can reach A as a wave through block.
12. (a) When the spring C is stretched slowly, the tension in A is greater than that of C, because of the weight mg and the former reaches breaking point earlier.

Second Law of Motion

1. (b) $u = 100\ m/s,\ v = 0,\ s = 0.06\ m$

Retardation $= a = \dfrac{u^2}{2s} = \dfrac{(100)^2}{2\times 0.06} = \dfrac{1\times 10^6}{12}$

$\therefore$ Force $= ma = \dfrac{5\times 10^{-3}\times 1\times 10^6}{12} = \dfrac{5000}{12} = 417\ N$

2. (b) $\vec{F} = m\vec{a}$
3. (c) Acceleration $a = \dfrac{F}{m} = \dfrac{100}{5} = 20\ cm/s^2$

Now $v = at = 20\times 10 = 200\ cm/s$

4. (b)
5. (b) $F = u\left(\dfrac{dm}{dt}\right) = 400\times 0.05 = 20\ N$
6. (b) $u = 4\ m/s,\ v = 0,\ t = 2\sec$

$v = u + at \Rightarrow 0 = 4 + 2a \Rightarrow a = -2\ m/s^2$

$\therefore$ Retarding force $= ma = 2\times 2 = 4\ N$

This force opposes the motion. If the same amount of force is applied in forward direction, then the body will move with constant velocity.

7. (d) Reading on the spring balance $= m\,(g-a)$

and since $a = g$ $\therefore$ Force = 0

8. (a) The lift is not accelerated, hence the reading of the balance will be equal to the true weight.

$R = mg = 2g\ Newton$ or $2\ kg$

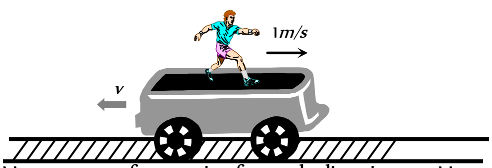
9. (d) When lift moves upward then reading of the spring balance, $R = m(g+a) = 2(g+g) = 4g\ N = 4\ kg$ [As $a = g$]

10. (a) For stationary lift $t_1 = \sqrt{\frac{2h}{g}}$

and when the lift is moving up with constant acceleration $t_2 = \sqrt{\frac{2h}{g+a}}$ $\therefore\ t_1 > t_2$

11. (d) Since $T = mg$, it implies that elevator may be at rest or in uniform motion.

12. (c) If the man starts walking on the trolley in the forward direction then whole system will move in backward direction with same momentum.



Momentum of man in forward direction = Momentum of system (man + trolley) in backward direction

$\Rightarrow 80 \times 1 = (80 + 320) \times v \Rightarrow v = 0.2\ m/s$

So the velocity of man *w.r.t.* ground $1.0 - 0.2 = 0.8\ m/s$

$\therefore$ Displacement of man *w.r.t.* ground $= 0.8 \times 4 = 3.2\ m$

13. (d) Force = Mass × Acceleration. If mass and acceleration both are doubled then force will become four times.

14. (b) As weight = 9.8 N $\therefore$ Mass = 1 kg

Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{5}{1} = 5\ m/s^2$

15. (a) Force on the table $= mg = 40 \times 980 = 39200\ dyne$

16. (b) $a = \frac{F}{m} = \frac{1\ N}{1\ kg} = 1\ m/s^2$

17. (b) $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t} = \frac{(-2)-(+10)}{4} = \frac{-12}{4} = -3\ m/s^2$

18. (b) $F = ma = 10 \times (-3) = -30\ N$

19. (b) Impulse = Force × Time = $-30 \times 4 = -120$ *N-s*

20. (b) u = velocity of bullet

$\frac{dm}{dt}$ = Mass thrown per second by the machine gun

= Mass of bullet × Number of bullet fired per second

$= 10\ g \times 10\ bullet/\text{sec} = 100\ g/\text{sec} = 0.1\ kg/\text{sec}$

$\therefore$ Thrust $= \frac{udm}{dt} = 500 \times 0.1 = 50\ N$

21. (d) Acceleration of the car $= \frac{\text{Thrust on the car}}{\text{Mass of the car}}$

$= \frac{50}{2000} = \frac{1}{40} = 0.025\ m/s^2$

22. (b)

23. (b) Force on particle at 20 cm away $F = kx$

$F = 15 \times 0.2 = 3\ N$ $[\text{As } k = 15\ N/m]$

$\therefore$ Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{3}{0.3} = 10\ m/s^2$

24. (a) Force on the block $F = u\left(\frac{dm}{dt}\right) = 5 \times 1 = 5\ N$

$\therefore$ Acceleration of block $a = \frac{F}{m} = \frac{5}{2} = 2.5\ m/s^2$

25. (a) Opposing force $F = u\left(\frac{dm}{dt}\right) = 2 \times 0.5 = 1\ N$

So same amount of force is required to keep the belt moving at 2 *m/s*

26. (d) Resultant force is $w + 3w = 4w$

27. (c) Acceleration $= \frac{\text{Force}}{\text{Mass}} = \frac{50\ N}{10\ kg} = 5\ m/s^2$

From $v = u + at = 0 + 5 \times 4 = 20\ m/s$

28. (c) Thrust $F = u\left(\frac{dm}{dt}\right) = 5 \times 10^4 \times 40 = 2 \times 10^6\ N$

29. (d) In stationary lift man weighs 40 kg *i.e.* 400 N.

When lift accelerates upward it's apparent weight $= m(g+a) = 40(10+2) = 480\ N$ *i.e.* 48 kg

For the clarity of concepts in this problem *kg-wt* can be used in place of *kg*.

30. (d) As the apparent weight increase therefore we can say that acceleration of the lift is in upward direction.

$R = m(g+a) \Rightarrow 4.8\ g = 4(g+a)$

$\Rightarrow a = 0.2g = 1.96\ m/s^2$

31. (d) $T = m\,(g+a) = 6000\,(10+5) = 90000\ N$

32. (a) $F = ma = \frac{m\Delta v}{\Delta t} = \frac{0.2 \times 20}{0.1} = 40\ N$

33. (a) $F = m\left(\frac{dv}{dt}\right) = \frac{100 \times 5}{0.1} = 5000\ N$

34. (d)

35. (b) $F = m\,(g+a) = 20 \times 10^3 \times (10+4) = 28 \times 10^4\ N$

36. (b) $\frac{mg}{m(g-a)} = \frac{3}{2} \Rightarrow a = g/3$

37. (a) $T = m\,(g+a) = 500(10+2) = 6000\,N$

38. (a) $F = u\left(\frac{dm}{dt}\right) \Rightarrow \frac{dm}{dt} = \frac{F}{u} = \frac{210}{300} = 0.7\ kg/s$

39. (d) $R = m\,(g+a) = m\,(g+g) = 2mg$

40. (a) $T_1 = m\,(g+a) = 1 \times \left(g + \frac{g}{2}\right) = \frac{3g}{2}$

$T_2 = m(g-a) = 1 \times \left(g - \frac{g}{2}\right) = \frac{g}{2}$ $\therefore$ $\frac{T_1}{T_2} = \frac{3}{1}$

41. (b) $F = \frac{udm}{dt} = m(g+a)$

$\Rightarrow \frac{dm}{dt} = \frac{m(g+a)}{u} = \frac{5000 \times (10+20)}{800} = 187.5\ kg/s$

42. (c) Initially due to upward acceleration apparent weight of the body increases but then it decreases due to decrease in gravity.

43. (b) $T = 2\pi\sqrt{\frac{l}{g}}$ and $T' = 2\pi\sqrt{\frac{l}{4g/3}}$

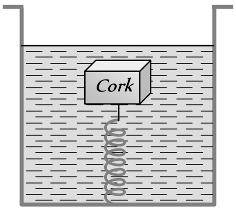
$[As\ g' = g + a = g + \frac{g}{3} = \frac{4g}{3}]$

$\therefore T' = \frac{\sqrt{3}}{2}T$

44. (b) Density of cork = d, Density of water = ρ

Resultant upward force on cork $= V(\rho - d)g$

This causes elongation in the spring. When the lift moves down with acceleration a, the resultant upward force on cork $= V(\rho - d)(g-a)$ which is less than the previous value. So the elongation decreases.



45. (d) When trolley are released then they posses same linear momentum but in opposite direction. Kinetic energy acquired by any trolley will dissipate against friction.

$\therefore \mu mg\, s = \frac{p^2}{2m} \Rightarrow s \propto \frac{1}{m^2}$ [As P and u are constants]

$\Rightarrow \frac{s_1}{s_2} = \left(\frac{m_2}{m_1}\right)^2 = \left(\frac{3}{1}\right)^2 = \frac{9}{1}$

46. (b) Apparent weight $= m(g-a) = 50(9.8 - 9.8) = 0$

47. (b) Opposite force causes retardation.

48. (a) $T = m(g-a)$ = 10(980 – 400) = 5800 dyne

49. (d) $T = 2\pi\sqrt{\frac{l}{g}}$. T will decrease, If g increases.

It is possible when rocket moves up with uniform acceleration.

50. (c) We know that in the given condition $s \propto \frac{1}{m^2}$

$\therefore \frac{s_2}{s_1} = \left(\frac{m_1}{m_2}\right)^2 \Rightarrow s_2 = \left(\frac{m_1}{m_2}\right)^2 \times s_1$

51. (a) $m = \frac{F}{a} = \frac{\sqrt{6^2 + 8^2 + 10^2}}{1} = \sqrt{200} = 10\sqrt{2}\,kg$

52. (b) In the absence of external force, position of centre of mass remain same therefore they will meet at their centre of mass.

53. (d) Force $= m\left(\frac{dv}{dt}\right) = \frac{0.25 \times [(10) - (-10)]}{0.01} = 25 \times 20 = 500\ N$

54. (d) $T = mg = 50 \times 10^{-3} \times 10 = 0.5\ N$

55. (a) $F = u\left(\frac{dm}{dt}\right) = 20 \times \frac{50}{60} = 16.66\ N$

56. (d) $u = 250\, m/s$, $v = 0$, $s = 0.12\, metre$

$F = ma = m\left(\frac{u^2 - v^2}{2s}\right) = \frac{20 \times 10^{-3} \times (250)^2}{2 \times 0.12}$

$\therefore$ $F = 5.2 \times 10^3\ N$

57. (a) $F = m\left(\frac{v-u}{t}\right) = \frac{5(65-15) \times 10^{-2}}{0.2} = 12.5\ N$

58. (d)

59. (c) $v = u + \frac{F}{m}t = 10 + \left(\frac{1000-500}{1000}\right) \times 10 = 15\, m/s$

60. (b) $F = ma = \frac{m(u-v)}{t} = \frac{2 \times (8-0)}{4} = 4N$

61. (d) $R = m(g+a) = 10 \times (9.8 + 2) = 118\ N$

62. (a) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{T'}{T} = \sqrt{\frac{g}{g'}} = \sqrt{\frac{g}{g + \frac{g}{4}}} = \sqrt{\frac{4}{5}} = \frac{2}{\sqrt{5}}$

63. (d) $F = \frac{m(u^2 - v^2)}{2S} = \frac{30 \times 10^{-3} \times (120)^2}{2 \times 12 \times 10^{-2}} = 1800\ N$

64. (b) $dp = F \times dt = 10 \times 10 = 100\ kg\ m/s$

65. (d) $R = m(g-a) = m(10-10) =$ zero

66. (b) Force exerted by the ball

$\Rightarrow F = m\left(\frac{dv}{dt}\right) = 0.15 \times \frac{20}{0.1} = 30\ N$

67. (d) If rope of lift breaks suddenly, acceleration becomes equal to g so that tension, $T = m(g-g) = 0$

68. (d) $R = m(g+a) = 50 \times (10+2) = 600\ N = 60\,kg\,wt$

69. (b) $F = u\left(\frac{dm}{dt}\right) = 500 \times 50 \times 10^{-3} = 25\ N$

70. (a) $S_{\text{Horizontal}} = ut = 1.5 \times 4 = 6\,m$

$S_{\text{Vertical}} = \frac{1}{2}at^2 = \frac{1}{2}\frac{F}{m}t^2 = \frac{1}{2} \times 1 \times 16 = 8\,m$

$S_{\text{Net}} = \sqrt{6^2 + 8^2} = 10\,m$

71. (c) $T = m(g+a) = 1000(9.8+1) = 10800\ N$

72. (d) The effective acceleration of ball observed by observer on earth = $(a - a)$

As $a_0 < a$, hence net acceleration is in downward direction.

73. (c) Due to relative motion, acceleration of ball observed by observer in lift = $(g - a)$ and for man on earth the acceleration remains g.

74. (c) For accelerated upward motion

$R = m(g+a) = 80(10+5) = 1200\ N$

75. (c) Tension the string $= m(g+a) =$ Breaking force

$\Rightarrow 20(g+a) = 25 \times g \Rightarrow a = g/4 = 2.5\ m/s^2$

76. (b) Rate of flow will be more when lift will move in upward direction with some acceleration because the net downward pull will be more and vice-versa.

$F_{\text{upward}} = m(g+a)$ and $F_{\text{downward}} = m(g-a)$

77. (c) Initial thrust must be

$m[g+a] = 3.5\times10^4(10+10) = 7\times10^5\,N$

78. (b) When the lift is stationary $W = mg$

$\Rightarrow 49 = m\times9.8 \Rightarrow m = 5\,kg.$

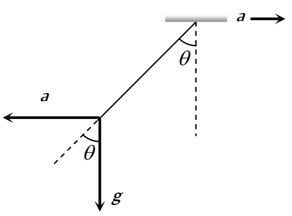
When the lift is moving downward with an acceleration $R = m(9.8-a) = 5[9.8-5] = 24\,N$

79. (a) When car moves towards right with acceleration a then due to pseudo force the plumb line will tilt in backward direction making an angle θ with vertical.

From the figure,

$\tan\theta = a/g$

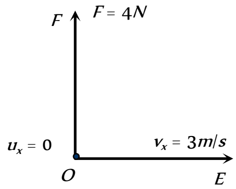
$\therefore\ \theta = \tan^{-1}(a/g)$



80. (a) $R = m(g-a) = 0$

81. (b) Displacement of body in 4 *sec* along *OE*

$s_x = v_x t = 3\times4 = 12\,m$



Force along *OF* (perpendicular to *OE*) = 4 *N*

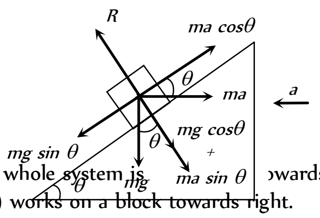
$\therefore\ a_y = \frac{F}{m} = \frac{4}{2} = 2\,m/s^2$

Displacement of body in 4 *sec* along *OF*

$\Rightarrow s_y = u_y t + \frac{1}{2}a_y t^2 = \frac{1}{2}\times2\times(4)^2 = 16\,m$ [As $u_y = 0$]

$\therefore$ Net displacement $s = \sqrt{s_x^2 + s_y^2} = \sqrt{(12)^2+(16)^2} = 20\,m$

82. (d)



When the whole system is moving towards left then pseudo force (*ma*) works on a block towards right.

For the condition of equilibrium

$mg\sin\theta = ma\cos\theta \Rightarrow a = \frac{g\sin\theta}{\cos\theta}$

$\therefore$ Force exerted by the wedge on the block

$R = mg\cos\theta + ma\sin\theta$

$R = mg\cos\theta + m\left(\frac{g\sin\theta}{\cos\theta}\right)\sin\theta = \frac{mg(\cos^2\theta+\sin^2\theta)}{\cos\theta}$

$R = \frac{mg}{\cos\theta}$

83. (d) u = velocity of bullet

$\frac{dm}{dt}$ = Mass fired per second by the gun

$\frac{dm}{dt}$ = Mass of bullet (m) × Bullets fired per sec (N)

Maximum force that man can exert $F = u\left(\frac{dm}{dt}\right)$

$\therefore\ F = u\times m_B\times N$

$\Rightarrow N = \frac{F}{m_B\times u} = \frac{144}{40\times10^{-3}\times1200} = 3$

84. (d) The stopping distance, $S\propto u^2$ ($\because v^2 = u^2 - 2as$)

$\Rightarrow \frac{S_2}{S_1} = \left(\frac{u_2}{u_1}\right)^2 = \left(\frac{120}{60}\right)^2 = 4$

$\Rightarrow S_2 = 4\times S_1 = 4\times20 = 80\,m$

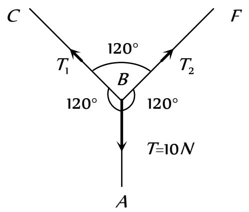
85. (d) The apparent weight,

$R = m(g+a) = 75(10+5) = 1125\,N$

86. (c) By drawing the free body diagram of point *B*

Let the tension in the section *BC* and *BF* are T_1 and T_2 respectively.

From Lami's theorem



$\frac{T_1}{\sin120°} = \frac{T_2}{\sin120°} = \frac{T}{\sin120°}$

$\Rightarrow T = T_1 = T_2 = 10\,N.$

87. (d) $F = \frac{dp}{dt} \equiv \frac{d}{dt}(a+bt^2) = 2bt\ \therefore\ F\propto t$

88. (a) When the lift moves upwards, the apparent weight, $= m(g+a)$. Hence reading of spring balance increases.

89. (c) When lift is at rest, $T = 2\pi\sqrt{l/g}$

If acceleration becomes *g*/4 then

$T' = 2\pi\sqrt{\frac{l}{g/4}} = 2\pi\sqrt{\frac{4l}{g}} = 2\times T$

90. (b) The apparent weight of man,

$R = m(g+a) = 80(10+6) = 1280\,N$

91. (b) $v = u + at = 0 + \left(\frac{F}{m}\right)t = \left(\frac{100}{5}\right)\times10 = 200\,cm/\text{sec}$

92. (b)

93. (a) $\Delta p = p_i - p_f = mv - (-mv) = 2mv$

94. (d) In the condition of free fall apparent weight becomes zero.

95. (a) Total mass of bullets = *Nm*, time $t = \frac{N}{n}$

Momentum of the bullets striking the wall = *Nmv*

Rate of change of momentum (Force) = $\frac{Nmv}{t}$ = *nmv*.

96. (b)

97. (c) If man slides down with some acceleration then its apparent weight decreases. For critical condition rope can bear only 2/3 of his weight. If a is the minimum acceleration then,

Tension in the rope $= m(g-a) =$ Breaking strength

$\Rightarrow m(g-a) = \frac{2}{3}mg \Rightarrow a = g - \frac{2g}{3} = \frac{g}{3}$

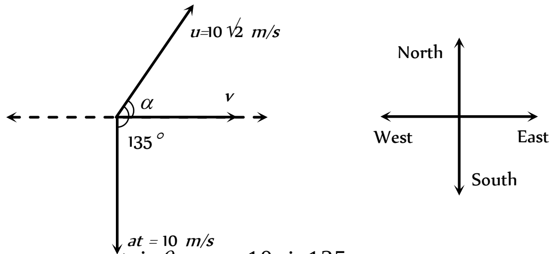
98. (a) For exerted by ball on wall

= rate of change in momentum of ball

$= \frac{mv-(-mv)}{t} = \frac{2mv}{t}$

99. (a) $\vec{v} = \vec{u} + \vec{a}t \therefore v = \sqrt{u^2 + a^2t^2 + 2u\,at\cos\theta}$

$v = \sqrt{200 + 100 + 2\times 10\sqrt{2}\times 10\times\cos 135} = 10\,m/s$



$\tan\alpha = \frac{at\sin\theta}{u + at\cos\theta}\ \frac{10\sin 135}{10\sqrt{2} + 10\cos 135} = 1 \therefore \alpha = 45°$

i.e. resultant velocity is 10 *m/s* towards East.

100. (c) $u_y = 40\,m/s$, $F_y = -5N$, $m = 5\,kg$.

So $a_y = \frac{F_y}{m} = -1\,m/s^2$ (As $v = u + at$)

$\therefore v_y = 40 - 1\times t = 0 \Rightarrow t = 40$ sec.

101. (a) Increment in kinetic energy = work done

$\Rightarrow \frac{1}{2}m(v^2 - u^2) = \int_{x_1}^{x_2} F.dx = \int_2^{10}(3x)\,dx$

$\Rightarrow \frac{1}{2}mv^2 = \frac{3}{2}[x^2]_2^{10} = \frac{3}{2}[100-4]$

$\Rightarrow \frac{1}{2}\times 8\times v^2 = \frac{3}{2}\times 96 \Rightarrow v = 6m/s$

102. (c) $\vec{F} = \frac{d\vec{p}}{dt} = \frac{d}{dt}(a + bt^2) = 2bt$ *i.e.* $F \propto t$

103. (a) $F_{av} = \frac{\Delta p}{\Delta t} = \frac{mv-(-mv)}{\Delta t} = \frac{2mv}{\Delta t} = \frac{2\times 0.5\times 2}{10^{-3}} = 2000\ N$

104. (a) Given that $\vec{p} = p_x\hat{i} + p_y\hat{j} = 2\cos t\,\hat{i} + 2\sin t\,\hat{j}$

$\therefore \vec{F} = \frac{d\vec{p}}{dt} = -2\sin t\,\hat{i} + 2\cos t\,\hat{j}$

Now, $\vec{F}.\vec{p} = 0$ *i.e.* angle between $\vec{F}$ and $\vec{p}$ is 90°.

105. (b) $\vec{F} = \frac{d\vec{p}}{dt} =$ Rate of change of momentum

As balls collide elastically hence, rate of change of momentum of ball = $n[mu - (mu)] = 2mnu$

i.e. $F = 2mnu$

106. (a) Velocity by which the ball hits the bat

$v_1 = \sqrt{2gh_1} = \sqrt{2\times 10\times 5}$ or $\vec{v_1} = +10\,m/s = 10\,m/s$

velocity of rebound

$v_2 = \sqrt{2gh_2} = \sqrt{2\times 10\times 20} = 20\,m/s$ or $\vec{v_2} = -20\,m/s$

$F = m\frac{dv}{dt} = \frac{m(\vec{v_2} - \vec{v_1})}{dt} = \frac{0.4(-20-10)}{dt} = 100\ N$

by solving $dt = 0.12$ sec

107. (a) $\vec{F} = \frac{\Delta\vec{p}}{\Delta t} \Rightarrow \Delta t = \frac{|\Delta\vec{p}|}{|\vec{F}|} = \frac{0.4}{2} = 0.2\ s$

108. (c) Rate of change of momentum of the bullet in forward direction = Force required to hold the gun.

$F = nmv = 4\times 20\times 10^{-3}\times 300 = 24\ N$

109. (d) Rate of flow of water $\frac{V}{t} = \frac{10\,cm^3}{\text{sec}} = 10\times 10^{-6}\,\frac{m^3}{\text{sec}}$

Density of water $\rho = \frac{10^3 kg}{m^3}$

Cross-sectional area of pipe $A = \pi(0.5\times 10^{-3})^2$

Force $= m\frac{dv}{dt} = \frac{mv}{t} = \frac{V\rho v}{t} = \frac{\rho V}{t}\times\frac{V}{At} = \left(\frac{V}{t}\right)^2\frac{\rho}{A}$

$\left(\because v = \frac{V}{At}\right)$

By substituting the value in the above formula we get

$F = 0.127\,N$

110. (a) Weight of the disc will be balanced by the force applied by the bullet on the disc in vertically upward direction.

$F = nmv = 40\times 0.05\times 6 = Mg$

$\Rightarrow M = \frac{40\times 0.05\times 6}{10} = 1.2\,kg$

111. (a)

112. (c) $F = \frac{dp}{dt} = v\left(\frac{dM}{dt}\right) = \alpha v^2 \therefore a = \frac{F}{M} = \frac{\alpha v^2}{M}$

113. (d) $P = \frac{F}{A} = \frac{n[mv - (-mv)]}{A} = \frac{2mnv}{A}$

$= \frac{2\times 10^{-3}\times 10^4\times 10^2}{10^{-4}} = 2\times 10^7\,N/m^2$

Third Law of Motion

1. (c) Swimming is a result of pushing water in the opposite direction of the motion.

2. (b) Because for every action there is an equal and opposite reaction takes place.

3. (b)

4. (a) The force exerted by the air of fan on the boat is internal and for motion external force is required.

5. (c)

6. (c)

7. (a) Up thrust on the body $= v\sigma g$. For freely falling body effective g becomes zero. So up thrust becomes zero

8. (d)

9. (c) Total weight in right hand = 10 + 1 = 1 *kg*

10. (c)

11. (a) For jumping he presses the spring platform, so the reading of spring balance increases first and finally it becomes zero.

12. (c) Gas will come out with sufficient speed in forward direction, so reaction of this forward force will change the reading of the spring balance.

13. (b)

14. (b) Since the cage is closed and we can treat bird, cage and the air as a closed (isolated) system. In this condition the force applied by the bird on cage is an internal force, due to this the reading of spring balance will not change.

15. (b) As the spring balance are massless therefore both the scales read M kg each.

16. (d) $F = mnv = 150\times10^{-3}\times20\times800 = 2400\ N.$

17. (c) $5N$ force will not produce any tension in spring without support of other $5N$ force. So here the tension in the spring will be $5N$ only.

18. (d) Since action and reaction acts in opposite direction on same line, hence angle between them is 180°.

19. (a)

20. (d) As by an internal force momentum of the system can not be changed.

21. (b)

22. (b) Since downward force along the inclined plane

$= mg\sin\theta = 5\times10\times\sin30° = 25N$

23. (c) At 11th second lift is moving upward with acceleration

$$a = \frac{0-3.6}{2} = -1.8 m/s^2$$

Tension in rope, $T = m(g-a)$

$= 1500(9.8-1.8) = 12000N$

24. (d) Distance travelled by the lift

= Area under velocity time graph

$$= \left(\frac{1}{2}\times2\times3.6\right)+(8\times3.6)+\left(\frac{1}{2}\times2\times3.6\right) = 36m$$

Conservation of Linear Momentum and Impulse

1. (b)

2. (b) Force exerted by the ball on hands of the player

$$= \frac{mdv}{dt} = \frac{0.15\times20}{0.1} = 30\ N$$

3. (b) $F = u\left(\frac{dm}{dt}\right) = 500\times1 = 500\ N$

4. (c) If momentum remains constant then force will be zero because $F = \frac{dP}{dt}$

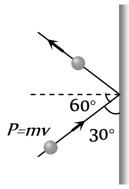
5. (c) According to principle of conservation of linear momentum $1000\times50 = 1250\times v \Rightarrow v = 40\,km/hr$

6. (a) Change in momentum = Impulse

$$\Rightarrow \Delta p = F\times\Delta t \Rightarrow \Delta t = \frac{\Delta p}{F} = \frac{125}{250} = 0.5\text{ sec}$$

7. (a) During collision of ball with the wall horizontal momentum changes (vertical momentum remains constant)

$$\therefore F = \frac{\text{Change in horizontal momentum}}{\text{Time of contact}}$$



$$= \frac{2P\cos\theta}{0.1} = \frac{2mv\cos\theta}{0.1}$$

$$= \frac{2\times0.1\times10\times\cos60°}{0.1} = 10\ N$$

8. (c) Impulse = Force × time = $m\ a\ t$

$= 0.15\times20\times0.1 = 0.3\ N\text{-}s$

9. (b) For a given mass $P\propto v$. If the momentum is constant then it's velocity must have constant.

10. (c)

11. (c) $T = \frac{F(L-x)}{L} = \frac{5(5-1)}{5} = 4N$

12. (a)

13. (a) $F = u\left(\frac{dm}{dt}\right) = 3000\times4 = 12000\ N$

14. (b)

15. (c) It works on the principle of conservation of momentum.

16. (c) $v_G = \frac{m_B v_B}{m_G} = \frac{0.2\times5}{1} = 1\ m/s$

17. (a) By the conservation of linear momentum $m_B v_B = m_a v_a$

$$\Rightarrow v_G = \frac{m_B\times v_B}{m_G} = \frac{5\times10^{-3}\times500}{5} = 0.5\ m/s$$

18. (c) Impulse, $I = F\times\Delta t = 50\times10^{-5}\times3 = 1.5\times10^{-3}\ N\text{-}s$

19. (c) Momentum of one piece $= \frac{M}{4}\times3$

Momentum of the other piece $= \frac{M}{4}\times4$

$\therefore$ Resultant momentum $= \sqrt{\frac{9M^2}{16}+M^2} = \frac{5M}{4}$

The third piece should also have the same momentum. Let its velocity be v, then

$$\frac{5M}{4} = \frac{M}{2}\times v \text{ or } v = \frac{5}{2} = 2.5\ m/sec$$

20. (c)

21. (d) Using law of conservation of momentum, we get

$100\times v = 0.25\times100 \Rightarrow v = 0.25\ m/s$

22. (c) $F = 600-2\times10^5 t = 0 \Rightarrow t = 3\times10^{-3}$ sec

Impulse $I = \int_0^t F\,dt = \int_0^{3\times10^{-3}}(600-2\times10^3 t)dt$

$= [600t-10^5 t^2]_0^{3\times10^{-3}} = 0.9\ N\times\text{sec}$

23. (a) According to principle of conservation of linear momentum, $m_G v_G = m_B v_B$

$$\Rightarrow v_G = \frac{m_B v_B}{m_G} = \frac{0.1\times10^2}{50} = 0.2 m/s$$

24. (d) $m_G v_G = m_B v_B \Rightarrow v_B = \dfrac{m_G v_G}{m_B} = \dfrac{1 \times 5}{10 \times 10^{-3}} = 500 m/s$

25. (d)

26. (b) The acceleration of a rocket is given by

$$a = \frac{v}{m}\left(\frac{\Delta m}{\Delta t}\right) - g = \frac{400}{100}\left(\frac{5}{1}\right) - 10$$

$$= (20 - 10) = 10\ m/s^2$$

27. (c)

Equilibrium of Forces

1. (d) Application of Bernoulli's theorem.

2. (c)

3. (b) $F = \sqrt{(F)^2 + (F)^2 + 2F.F\cos\theta} \Rightarrow \theta = 120°$

4. (a) $F_{net}^2 = F_1^2 + F_2^2 + 2F_1F_2\cos\theta$

$$\Rightarrow \left(\frac{F}{3}\right)^2 = F^2 + F^2 + 2F^2\cos\theta \Rightarrow \cos\theta = \left(-\frac{17}{18}\right)$$

5. (c) Direction of second force should be at 180°.

6. (c) $F_{max} = 5 + 10 = 15N$ and $F_{min} = 10 - 5 = 5N$

Range of resultant $5 \le F \le 15$

7. (b) $R^2 = (3P)^2 + (2P)^2 + 2 \times 3P \times 2P \times \cos\theta$ ...(i)

$(2R)^2 = (6P)^2 + (2P)^2 + 2 \times 6P \times 2P \times \cos\theta$ ...(ii)

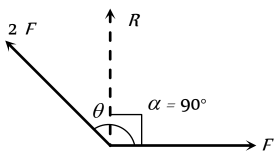
by solving (i) and (ii), $\cos\theta = -1/2 \Rightarrow \theta = 120°$

8. (b) $\tan\alpha = \dfrac{2F\sin\theta}{F + 2F\cos\theta} = \infty$ (as α = 90°)

$\Rightarrow F + 2F\cos\theta = 0$

$\Rightarrow \cos\theta = -\dfrac{1}{2}$

$\theta = 120°$



9. (b) $A + B = 18$ ...(i)

$12 = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ ...(ii)

$\tan\alpha = \dfrac{B\sin\theta}{A + B\cos\theta} = \tan 90° \Rightarrow \cos\theta = -\dfrac{A}{B}$ ...(iii)

By solving (i), (ii) and (iii), $A = 13N$ and $B = 5N$

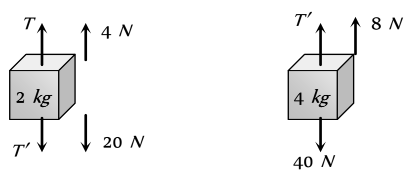
10. (c)

11. (d) Range of resultant of F_1 and F_2 varies between (3+5)=8*N* and $(5-3) = 2N$. It means for some value of angle (θ), resultant 6 can be obtained. So, the resultant of 3*N*, 5*N* and 6*N* may be zero and the forces may be in equilibrium.

12. (a) Net force on the particle is zero so the $\vec{v}$ remains unchanged.

13. (a) For equilibrium of forces, the resultant of two (smaller) forces should be equal and opposite to third one.

14. (a) FBD of mass 2 *kg* FBD of mass 4*kg*



$T - T' - 20 = 4$ ....(i) $T' - 40 = 8$ ...(ii)

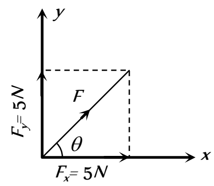
By solving (i) and (ii) $T' = 47.23\ N$ and $T = 70.8\ N$

15. (a)

16. (b) $|\vec{F}| = \sqrt{5^2 + 5^2} = 5\sqrt{2}\ N.$

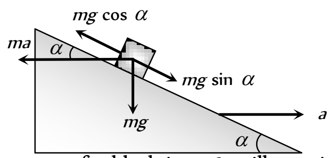
and $\tan\theta = \dfrac{5}{5} = 1$

$\Rightarrow \theta = \pi/4.$



17. (b)

18. (b)

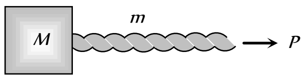


Let the mass of a block is *m*. It will remains stationary if forces acting on it are in equilibrium *i.e,* $ma\cos\alpha = mg\sin\alpha \Rightarrow a = g\tan\alpha$

Here ma = Pseudo force on block, *mg* = Weight.

Motion of Connected Bodies

1. (c)

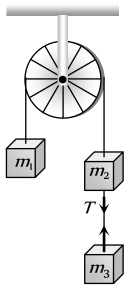


Acceleration of the system $= \dfrac{P}{m + M}$

The force exerted by rope on the mass $= \dfrac{MP}{m + M}$

2. (b)

3. (b) Tension between m_2 and m_3 is given by



$$T = \frac{2m_1m_3}{m_1 + m_2 + m_3} \times g$$

$$= \frac{2 \times 2 \times 2}{2 + 2 + 2} \times 9.8 = 13\ N$$

4. (b) $a = \dfrac{m_2}{m_1 + m_2} \times g = \dfrac{5}{4 + 5} \times 9.8 = \dfrac{49}{9} = 5.44\ m/s^2$

5. (d) $T = \dfrac{2m_1m_2}{m_1 + m_2} g = \dfrac{2 \times 2 \times 3}{2 + 3} g = \dfrac{12}{5} g$

$$a = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) g = \left(\frac{3 - 2}{3 + 2}\right) g = \frac{g}{5}$$

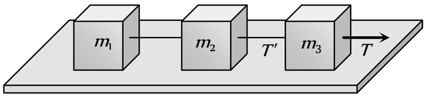
6. (b) $T_2 = (m_A + m_B) \times \dfrac{T_3}{m_A + m_B + m_C}$

$T_2 = (1+8)\times\frac{36}{(1+8+27)} = 9\ N$

7. (c) Acceleration $= \frac{(m_2 - m_1)}{(m_2 + m_1)}g$

$= \frac{4-3}{4+3}\times 9.8 = \frac{9.8}{7} = 1.4\,m/\sec^2$

8. (c)



$T' = (m_1 + m_2)\times\frac{T}{m_1+m_2+m_3}$

9. (d) $T_2 = (m_1+m_2)\times\frac{T_3}{m_1+m_2+m_3} = \frac{(10+6)\times 40}{20} = 32\ N$

10. (a)

11. (a) Acceleration $= \frac{m_2}{m_1+m_2}\times g\ = \frac{1}{2+1}\times 9.8 = 3.27\ m/s^2$

and $T = m_1 a = 2\times 3.27 = 6.54\ N$

12. (d) $T = \frac{2m_1m_2}{m_1+m_2}g = \frac{2\times10\times6}{10+6}\times 9.8 = 73.5N$

13. (c) $a = \frac{m_2-m_1}{m_1+m_2}g = \frac{10-5}{10+5}g = \frac{g}{3}$

14. (b) $a = \frac{m_2}{m_1+m_2}g = \frac{3}{7+3}10 = 3\ m/s^2$

15. (c) $T_1 = \left(\frac{m_2+m_3}{m_1+m_2+m_3}\right)g = \frac{3+5}{2+3+5}\times 10 = 8N$

16. (c) $a = \left(\frac{m_2-m_1}{m_1+m_2}\right)g = \left(\frac{10-6}{10+6}\right)\times 10 = 2.5\ m/s^2$

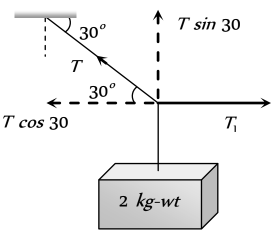
17. (c) $T\sin 30 = 2kg\ wt$

$\Rightarrow T = 4\ kg\ wt$

$T_1 = T\cos 30^\circ$

$= 4\cos 30^\circ$

$= 2\sqrt{3}$



18. (c) If monkey move downward with acceleration a then its apparent weight decreases. In that condition

Tension in string $= m(g-a)$

This should not be exceed over breaking strength of the rope *i.e.* $360 \ge m(g-a) \Rightarrow 360 \ge 60(10-a)$

$\Rightarrow a \ge 4\ m/s^2$

19. (b) $a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g \Rightarrow \frac{g}{8} = \left(\frac{m_1-m_2}{m_1+m_2}\right)g \Rightarrow \frac{m_1}{m_2} = \frac{9}{7}$

20. (a) $a = \left[\frac{m_1-m_2}{m_1+m_2}\right]g = \left[\frac{5-4.8}{5+4.8}\right]\times 9.8 = 0.2\ m/s^2$

21. (c) As the spring balances are massless therefore the reading of both balance should be equal.

22. (a) $a = \left(\frac{m_2-m_1}{m_1+m_2}\right)g = \left(\frac{m-m/2}{m+m/2}\right)g = \frac{g}{3}$

23. (a) Acceleration of each mass $= a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g$

Now acceleration of centre of mass of the system

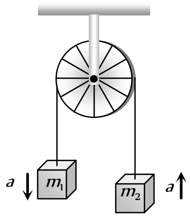
$A_{cm} = \frac{m_1\vec{a_1} + m_1\vec{a_2}}{m_1+m_2}$

As both masses move with same acceleration but in opposite direction so $\vec{a_1} = -\vec{a_2} = a$ (let)

$\therefore A_{cm} = \frac{m_1 a - m_2 a}{m_1+m_2}$

$= \left(\frac{m_1-m_2}{m_1+m_2}\right)\times\left(\frac{m_1-m_2}{m_1+m_2}\right)\times g$

$= \left(\frac{m_1-m_2}{m_1+m_2}\right)^2\times g$



Critical Thinking Questions

1. (c) Due to acceleration in forward direction, vessel is an accelerated frame therefore a Pseudo force will be exerted in backward direction. Therefore water will be displaced in backward direction.

2. (b) The pressure on the rear side would be more due to fictitious force (acting in the opposite direction of acceleration) on the rear face. Consequently the pressure in the front side would be lowered.

3. (c) $v^2 = 2as = 2\left(\frac{F}{m}\right)s$ $[As\ u = 0]$

$\Rightarrow v^2 = 2\left(\frac{5\times10^4}{3\times10^7}\right)\times 3 = \frac{1}{100}$

$\Rightarrow v = 0.1\ m/s$

4. (c) Mass measured by physical balance remains unaffected due to variation in acceleration due to gravity.

5. (c) For W, $2W$, $3W$ apparent weight will be zero because the system is falling freely. So the distances of the weight from the rod will be same.

6. (a) For equilibrium of system, $F_1 = \sqrt{F_2^2 + F_3^2}$ As $\theta = 90^\circ$

In the absence of force F_1, Acceleration $= \frac{\text{Net force}}{\text{Mass}}$

$= \frac{\sqrt{F_2^2+F_3^2}}{m} = \frac{F_1}{m}$

7. (b,c) Force of upthrust will be there on mass m shown in figure, so A weighs less than 2 kg. Balance will show sum of load of beaker and reaction of upthrust so it reads more than 5 kg.

8. (d) Heavier gas will acquire largest momentum *i.e.* Argon.

9. (c) $\vec{F}\Delta t = m\Delta\vec{v} \Rightarrow F = \frac{m\Delta\vec{v}}{t}$

By doing so time of change in momentum increases and impulsive force on knees decreases.

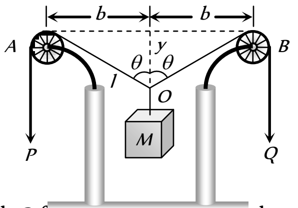
10. (b) When false balance has equal arms then, $W = \frac{X+Y}{2}$

11. (a) Let two vectors be $\vec{A}$ and $\vec{B}$ then $(\vec{A}+\vec{B}).(\vec{A}-\vec{B}) = 0$

$\vec{A}.\vec{A} - \vec{B}.\vec{B} + \vec{B}.\vec{A} - \vec{B}.\vec{B} = 0$

$A^2 - B^2 = 0 \Rightarrow A^2 = B^2 \therefore A = B$

12. (d)



As P and Q fall down, the length l decreases at the rate of U m/s.

From the figure, $l^2 = b^2 + y^2$

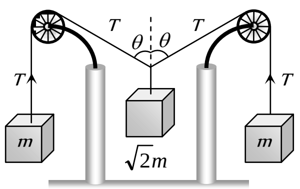
Differentiating with respect to time

$$2l \times \frac{dl}{dt} = 2b \times \frac{db}{dt} + 2y \times \frac{dy}{dt} \left(\text{As} \frac{db}{dt} = 0, \frac{dl}{dt} = U\right)$$

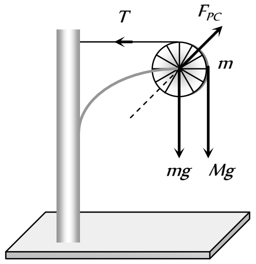
$$\Rightarrow \frac{dy}{dt} = \left(\frac{l}{y}\right) \times \frac{dl}{dt} \Rightarrow \frac{dy}{dt} = \left(\frac{1}{\cos\theta}\right) \times U = \frac{U}{\cos\theta}$$

13. (c) From the figure for the equilibrium of the system

$$2T\cos\theta = \sqrt{2}mg \Rightarrow \cos\theta = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45°$$



14. (d) Force on the pulley by the clamp



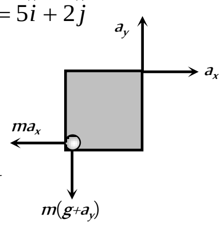
$$F_{pc} = \sqrt{T^2 + [(M+m)g]^2}$$

$$F_{pc} = \sqrt{(Mg)^2 + [(M+m)g]^2}$$

$$F_{pc} = \sqrt{M^2 + (M+m)^2}\, g$$

15. (b) $a_{cm} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 g = \left(\frac{3m - m}{3m + m}\right)^2 g = \frac{g}{4}$

16. (c) As $\vec{v} = 5t\hat{i} + 2t\hat{j} \therefore \vec{a} = a_x\hat{i} + a_y\hat{j} = 5\hat{i} + 2\hat{j}$



$\vec{F} = ma_x\hat{i} + m(g + a_y)\hat{j}$

$\therefore |\vec{F}| = m\sqrt{a_x^2 + (g + a_y)^2} = 26\ N$

17. (c) $l = l_0\sqrt{1 - \frac{v^2}{c^2}} = 1\sqrt{1 - \left(\frac{2.7 \times 10^8}{3 \times 10^8}\right)^2} \Rightarrow l = 0.44\ m$

18. (c) $T = \frac{T_0}{[1 - (v^2/c^2)]^{1/2}}$

By substituting $T_0 = 1$ day and $T = 2$ days we get

$v = 2.6 \times 10^8\ ms^{-1}$

19. (d) Force acting on plate, $F = \frac{dp}{dt} = v\left(\frac{dm}{dt}\right)$

Mass of water reaching the plate per $sec = \frac{dm}{dt}$

$= Av\rho = A(v_1 + v_2)\rho = \frac{V}{v_2}(v_1 + v_2)\rho$

($v = v_1 + v_2 =$ velocity of water coming out of jet *w.r.t.* plate)

($A =$ Area of cross section of jet $= \frac{V}{v_2}$)

$$\therefore F = \frac{dm}{dt}v = \frac{V}{v_2}(v_1 + v_2)\rho \times (v_1 + v_2) = \rho\left[\frac{V}{v_2}\right](v_1 + v_2)^2$$

Graphical Questions

1. (d) If the applied force is less than limiting friction between block A and B, then whole system move with common acceleration

i.e. $a_A = a_B = \frac{F}{m_A + m_B}$

But the applied force increases with time, so when it becomes more than limiting friction between A and B, block B starts moving under the effect of net force $F - F_k$

Where $F_k =$ Kinetic friction between block A and B

$\therefore$ Acceleration of block B, $a_B = \frac{F - F_k}{m_B}$

As F is increasing with time so a_B will increase with time

Kinetic friction is the cause of motion of block A

$\therefore$ Acceleration of block A, $a_A = \frac{F_k}{m_A}$

It is clear that $a_B > a_A$. *i.e.* graph (d) correctly represents the variation in acceleration with time for block A and B.

2. (b) Velocity between $t = 0$ and $t = 2\sec$

$\Rightarrow v_i = \frac{dx}{dt} = \frac{4}{2} = 2\ m/s$

Velocity at $t = 2\sec$, $v_f = 0$

Impulse = Change in momentum $= m(v_f - v_i)$

$= 0.1(0-2) \;= -0.2\ kg\ m\ \sec^{-1}$

3. (d) Momentum acquired by the particle is numerically equal to area enclosed between the *F-t* curve and time axis. For the given diagram area in upper half is positive and in lower half is negative (and equal to upper half), so net area is zero. Hence the momentum acquired by the particle will be zero.

4. (a,c) In region *AB* and *CD*, slope of the graph is constant *i.e.* velocity is constant. It means no force acting on the particle in this region.

5. (c) Impulse = Change in momentum $= m(v_2 - v_1)$ ....(i)

Again impulse = Area between the graph and time axis

$= \frac{1}{2} \times 2 \times 4 + 2 \times 4 + \frac{1}{2}(4 + 2.5) \times 0.5 + 2 \times 2.5$

$= 4 + 8 + 1.625 + 5 \;= 18.625$ ....(ii)

From (i) and (ii), $m(v_2 - v_1) = 18.625$

$\Rightarrow v_2 = \frac{18.625}{m} + v_1 = \frac{18.625}{2} + 5 = 14.25\ m/s$

6. (d) $K = \frac{F}{x}$ and increment in length is proportional the original length *i.e.* $x \propto l \;\therefore\; K \propto \frac{1}{l}$

It means graph between *K* and *l* should be hyperbolic in nature.

7. (b) In elastic one dimensional collision particle rebounds with same speed in opposite direction

i.e. change in momentum $= 2mu$

But Impulse $= F \times T =$ Change in momentum

$\Rightarrow F_0 \times T = 2mu \Rightarrow F_0 = \frac{2mu}{T}$

8. (c) Initially particle was at rest. By the application of force its momentum increases.

Final momentum of the particle = Area of *F - t* graph

$\Rightarrow mu =$ Area of semi circle

$mu = \frac{\pi r^2}{2} = \frac{\pi r_1 r_2}{2} = \frac{\pi (F_0)(T/2)}{2} \Rightarrow u = \frac{\pi F_0 T}{4m}$

9. (d) momentum acquired = Area of force-time graph

$= \frac{1}{2} \times (2) \times (10) + 4 \times 10 = 10 + 40 = 50\ N\text{-}S$

10. (c) $F = \frac{dp}{dt}$, so the force is maximum when slope of graph is maximum

11. (c) Impulse = Area between force and time graph and it is maximum for graph (III) and (IV)

Assertion and Reason

1. (e) Inertia is the property by virtue of which the body is unable to change by itself not only the state of rest, but also the state of motion.

2. (c) According to Newton's second law

Acceleration = $\frac{\text{Force}}{\text{Mass}}$ *i.e.* if net external force on the body is zero then acceleration will be zero

3. (a) According to second law $F = \frac{dp}{dt} = ma$.

If we know the values of *m* and *a*, the force acting on the body can be calculated and hence second law gives that how much force is applied on the body.

4. (b) When a body is moving in a circle, its speed remains same but velocity changes due to change in the direction of motion of body. According to first law of motion, force is required to change the state of a body. As in circular motion the direction of velocity of body is changing so the acceleration cannot be zero. But for a uniform motion acceleration is zero (for rectilinear motion).

5. (c) According to definition of momentum

$P = mv$ if *P* = constant then mv = constant or $v \propto \frac{1}{m}$.

As velocity is inversely proportional to mass, therefore lighter body possess greater velocity.

6. (a) The wings of the aeroplane pushes the external air backward and the aeroplane move forward by reaction of pushed air. At low altitudes. density of air is high and so the aeroplane gets sufficient force to move forward.

7. (c) Force is required to change the state of the body. In uniform motion body moves with constant speed so acceleration should be zero.

8. (a) According to Newton's second law of motion $a = \frac{F}{m}$ *i.e.* magnitude of the acceleration produced by a given force is inversely proportional to the mass of the body. Higher is the mass of the body, lesser will be the acceleration produced *i.e.* mass of the body is a measure of the opposition offered by the body to change a state, when the force is applied *i.e.* mass of a body is the measure of its inertia.

9. (d) $F = \frac{dp}{dt}$ = Slope of momentum-time graph

i.e. Rate of change of momentum = Slope of momentum- time graph = force.

10. (c) The purpose of bending is to acquire centripetal force for circular motion. By doing so component of normal reaction will counter balance the centrifugal force.

11. (c) Work done in moving an object against gravitational force (conservative force) depends only on the initial and final position of the object, not upon the path taken. But gravitational force on the body along the inclined plane is not same as that along the vertical and it varies with the angle of inclination.

12. (b) In uniform circular motion of a body the speed remains constant but velocity changes as direction of motion changes.

As linear momentum = mass × velocity, therefore linear momentum of a body changes in a circle.

On the other hand, if the body is moving uniformly along a straight line then its velocity remains constant and hence acceleration is equal to zero. So force is equal to zero.

13. (d) Law of conservation of linear momentum is correct when no external force acts . When bullet is fired from a rifle then both should possess equal momentum but different kinetic energy. E $= \frac{P^2}{2m}$ $\therefore$ Kinetic energy of the rifle is less than that of bullet because $E \propto 1/m$

14. (a) As the fuel in rocket undergoes combustion, the gases so produced leave the body of the rocket with large velocity and give upthrust to the rocket. If we assume that the fuel is burnt at a constant rate, then the rate of change of momentum of the rocket will be constant. As more and more fuel gets burnt, the mass of the rocket goes on decreasing and it leads to increase of the velocity of rocket more and more rapidly.

15. (c) The apparent weight of a body in an elevator moving with downward acceleration *a* is given by $W = m(g-a)$.

16. (e) For uniform motion apparent weight = Actual weight
For downward accelerated motion,
Apparent weight < Actual weight

17. (a)

18. (a) By lowering his hand player increases the time of catch, by doing so he experience less force on his hand because $F \propto 1/dt$.

19. (b) According to Newton's second law,
$F = ma \Rightarrow a = F/m$
For constant *F*, acceleration is inversely proportional to mass *i.e.* acceleration produced by a force depends only upon the mass of the body and for larger mass acceleration will be less.

20. (c) In uniform circular motion, the direction of motion changes, therefore velocity changes.
As *P* = *mv* therefore momentum of a body also changes in uniform circular motion.

21. (e) According to third law of motion it is impossible to have a single force out of mutual interaction between two bodies, whether they are moving or at rest. While, Newton's third law is applicable for all types of forces.

22. (d) An inertial frame of reference is one which has zero acceleration and in which law of inertia hold good i.e. Newton's law of motion are applicable equally. Since earth is revolving around the sun and earth is rotating about its own axis also, the forces are acting on the earth and hence there will be acceleration of earth due to these factors. That is why earth cannot be taken as inertial frame of reference.

23. (b) According to law of inertia (Newton's first law), when cloth is pulled from a table, the cloth come in state of motion but dishes remains stationary due to inertia. Therefore when we pull the cloth from table the dishes remains stationary.

24. (e) A body subjected to three concurrent forces is found to in equilibrium if sum of these force is equal to zero.
i.e. $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... = 0$.

25. (e) From Newton's second law
Impulse = Change of momentum.
So they have equal dimensions

Newton's Laws of Motion

SET Self Evaluation Test -4

1. A car is moving with uniform velocity on a rough horizontal road. Therefore, according to Newton's first law of motion
   (a) No force is being applied by its engine
   (b) A force is surely being applied by its engine
   (c) An acceleration is being produced in the car
   (d) The kinetic energy of the car is increasing

2. A person is sitting in a travelling train and facing the engine. He tosses up a coin and the coin falls behind him. It can be concluded that the train is [SCRA 1994]
   (a) Moving forward and gaining speed
   (b) Moving forward and losing speed
   (c) Moving forward with uniform speed
   (d) Moving backward with uniform speed

3. A block can slide on a smooth inclined plane of inclination θ kept on the floor of a lift. When the lift is descending with a retardation *a*, the acceleration of the block relative to the incline is
   (a) $(g+a)\sin\theta$ (b) $(g-a)$
   (c) $g\sin\theta$ (d) $(g-a)\sin\theta$

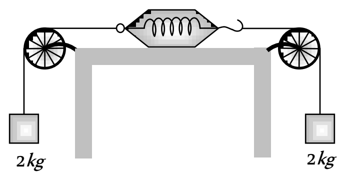
4. A 60 *kg* man stands on a spring scale in the lift. At some instant he finds, scale reading has changed from 60 *kg* to 50*kg* for a while and then comes back to the original mark. What should we conclude ?
   (a) The lift was in constant motion upwards
   (b) The lift was in constant motion downwards
   (c) The lift while in constant motion upwards, is stopped suddenly
   (d) The lift while in constant motion downwards, is suddenly stopped

5. When a body is acted by a constant force, then which of the following quantities remains constant
   (a) Velocity (b) Acceleration
   (c) Momentum (d) None of these

6. A man of weight *mg* is moving up in a rocket with acceleration 4 *g*. The apparent weight of the man in the rocket is
   (a) Zero (b) 4 *mg*
   (c) 5 *mg* (d) *mg*

7. A spring balance and a physical balance are kept in a lift. In these balances equal masses are placed. If now the lift starts moving upwards with constant acceleration, then
   (a) The reading of spring balance will increase and the equilibrium position of the physical balance will disturb
   (b) The reading of spring balance will remain unchanged and physical balance will remain in equilibrium
   (c) The reading of spring balance will decrease and physical balance will remain in equilibrium
   (d) The reading of spring balance will increase and the physical balance will remain in equilibrium

8. As shown in the figure, two equal masses each of 2 *kg* are suspended from a spring balance. The reading of the spring balance will be



   (a) Zero
   (b) 2 *kg*
   (c) 4 *kg*
   (d) Between zero and 2 *kg*

9. A player kicks a football of mass 0.5 *kg* and the football begins to move with a velocity of 10 *m/s*. If the contact between the leg and the football lasts for $\frac{1}{50}$ *sec*, then the force acted on the football should be
   (a) 2500 *N* (b) 1250 *N*
   (c) 250 *N* (d) 625 *N*

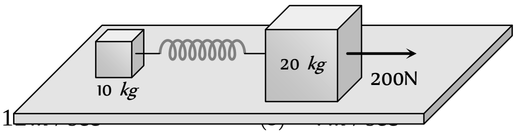
10. The engine of a jet aircraft applies a thrust force of $10^5\ N$ during take off and causes the plane to attain a velocity of 1 *km/sec* in 10 *sec*. The mass of the plane is
   (a) $10^2\ kg$ (b) $10^3\ kg$
   (c) $10^4\ kg$ (d) $10^5\ kg$

11. A force of 50 *dynes* is acted on a body of mass 5 *g* which is at rest for an interval of 3 seconds, then impulse is [AFMC 1998]
   (a) 0.15×10^{-3} *N-s* (b) 0.98×10^{-3} *N-s*
   (c) 1.5×10^{-3} *N-s* (d) 2.5×10^{-3} *N-s*

12. Two weights w_1 and w_2 are suspended from the ends of a light string passing over a smooth fixed pulley. If the pulley is pulled up at an acceleration *g*, the tension in the string will be
   (a) $\frac{4w_1w_2}{w_1+w_2}$
   (b) $\frac{2w_1w_2}{w_1+w_2}$
   (c) $\frac{w_1w_2}{w_1+w_2}$

(d) $\frac{w_1 w_2}{2(w_1 + w_2)}$

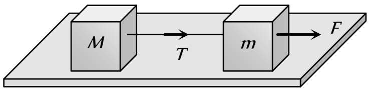
13. The masses of 10 *kg* and 20 *kg* respectively are connected by a massless spring as shown in figure. A force of 200 *N* acts on the 20 *kg* mass. At the instant shown, the 10 *kg* mass has acceleration $12\, m / \sec^2$. What is the acceleration of 20 *kg* mass



(a) 1[illegible] (b) [illegible]

(c) $10\, m / \sec^2$ (d) Zero

14. Two masses *M* and *m* are connected by a weightless string. They are pulled by a force *F* on a frictionless horizontal surface. The tension in the string will be



(a) $\frac{FM}{m + M}$ (b) $\frac{F}{M + m}$

(c) $\frac{FM}{m}$ (d) $\frac{Fm}{M + m}$

15. In the above question, the acceleration of mass *m* is

(a) $\frac{F}{m}$ (b) $\frac{F - T}{m}$

(c) $\frac{F + T}{m}$ (d) $\frac{F}{M}$

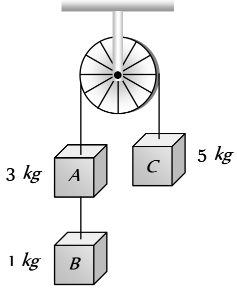
16. Three weight *A*, *B* and *C* are connected by string as shown in the figure. The system moves over a frictionless pulley. The tension in the string connecting *A* and *B* is (where *g* is acceleration due to gravity)

(a) g

(b) $\frac{g}{9}$

(c) $\frac{8g}{9}$

(d) $\frac{10g}{9}$



Answers and Solutions

(SET –4)

1. (b) Since, force needed to overcome frictional force.

2. (a) The coin falls behind him it means the velocity of train was increasing otherwise the coin fall directly into the hands of thrower.

3. (a) Acceleration of block in a stationary lift = $g \sin\theta$

If lift is descending with acc. then it will be $(g - a)\sin\theta$.

but in the problem acceleration = $-\,a$ (retardation)

$\therefore$ Acceleration of block = $[g - (-a)]\sin\theta$ = $(g + a)\sin\theta$

4. (c) For upward acceleration apparent weight $= m(g + a)$

If lift suddenly stops during upward motion then apparent weight = $m(g-a)$ because instead of acceleration, we will consider retardation.

In the problem it is given that scale reading initially was 60 *kg* and due to sudden jerk reading decreasing and finally comes back to the original mark *i.e.,* 60 *kg*.

So, we can conclude that lift was moving upward with constant speed and suddenly stops.

5. (b) $F = ma$ for a given body if $F =$ constant then a = constant.

6. (c) $R = m(g+a) = m(g+4g) = 5mg$

7. (d) The fictitious force will act downwards. So the reading of spring balance will increase. In case of physical balance, the fictitious force will act on both the pans, so the equilibrium is not affected.

8. (b) In this case, one 2 *kg wt* on the left will act as the support for the spring balance. Hence its reading will be 2 *kg*.

9. (c) Force on the football $F = m\dfrac{dv}{dt}$

$$F = \frac{m(v_2 - v_1)}{dt} = \frac{0.5 \times (10-0)}{1/50} = 250N.$$

10. (b) Acceleration produced in jet = $\dfrac{\text{Change in velocity}}{\text{Time}}$

$$a = \frac{(10^3 - 0)}{10} = 100 m/s^2$$

$\therefore$ Mass = $\dfrac{\text{Force}}{\text{Acceleration}} = \dfrac{10^5}{10^2} = 10^3 kg$.

11. (c) Impulse = Force × Time = $50 \times 10^{-5} \times 3$

$= 1.5 \times 10^{-3}$ *N-s*

12. (a) $T = \dfrac{2m_1 m_2}{(m_1+m_2)}(g+a) = \dfrac{2m_1 m_2 (g+g)}{m_1+m_2}$

$$\Rightarrow T = \frac{4m_1 m_2}{m_1+m_2} g = \frac{4w_1 w_2}{w_1+w_2}$$

13. (b) As the mass of 10 *kg* has acceleration 12 *m/s* therefore it apply 120*N* force on mass 20*kg* in a backward direction.

$\therefore$ Net forward force on 20 *kg* mass = 200 – 120 = 80*N*

$\therefore$ Acceleration $= \dfrac{80}{20} = 4 m/s^2$.

14. (a) $T = M \times a = M \times \left(\dfrac{F}{m+M}\right)$

15. (b) Net force on mass *m*, $ma = F - T \therefore a = \dfrac{F-T}{m}$

16. (d) $T = \dfrac{2 \times m_B m_C}{m_A + m_B + m_C} \times g = \dfrac{2 \times 1 \times 5}{3+1+5} \times g = \dfrac{10}{9} g$.

***

Chapter 5 Friction

Introduction

If we slide or try to slide a body over a surface, the motion is resisted by a bonding between the body and the surface. This resistance is represented by a single force and is called friction force.

The force of friction is parallel to the surface and opposite to the direction of intended motion.

Types of Friction

(1) **Static friction :** The opposing force that comes into play when one body tends to move over the surface of another, but the actual motion has yet not started is called static friction.

(i) If applied force is P and the body remains at rest then static friction F = P.

(ii) If a body is at rest and no pulling force is acting on it, force of friction on it is zero.

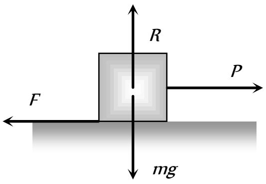


Fig. 5.1

(iii) Static friction is a self-adjusting force because it changes itself in accordance with the applied force and is always equal to net external force.

(2) **Limiting friction :** If the applied force is increased, the force of static friction also increases. If the applied force exceeds a certain (maximum) value, the body starts moving. This maximum value of static friction upto which body does not move is called limiting friction.

(i) The magnitude of limiting friction between any two bodies in contact is directly proportional to the normal reaction between them.

$F_l \propto R$ or $F_l = \mu_s R$

(ii) Direction of the force of limiting friction is always opposite to the direction in which one body is at the verge of moving over the other

(iii) Coefficient of static friction : (a) μ_s is called coefficient of static friction and is defined as the ratio of force of limiting friction and normal reaction $\mu_s = \dfrac{F}{R}$

(b) Dimension : $[M^0L^0T^0]$

(c) Unit : It has no unit.

(d) Value of μ depends on material and nature of surfaces in contact that means whether dry or wet ; rough or smooth polished or non-polished.

(e) Value of μ does not depend upon apparent area of contact.

(3) **Kinetic or dynamic friction :** If the applied force is increased further and sets the body in motion, the friction opposing the motion is called kinetic friction.

(i) Kinetic friction depends upon the normal reaction.

$F_k \propto R$ or $F_k = \mu_k R$ where μ_k is called the coefficient of kinetic friction

(ii) Value of μ_k depends upon the nature of surface in contact.

(iii) Kinetic friction is always lesser than limiting friction $F_k < F_l$

$\therefore \; \mu_k < \mu_s$

i.e. coefficient of kinetic friction is always less than coefficient of static friction. Thus we require more force to start a motion than to maintain it against friction. This is because once the motion starts actually ; inertia of rest has been overcome. Also when motion has actually started, irregularities of one surface have little time to get locked again into the irregularities of the other surface.

(iv) Kinetic friction does not depend upon the velocity of the body.

(v) Types of kinetic friction

(a) **Sliding friction** : The opposing force that comes into play when one body is actually sliding over the surface of the other body is called sliding friction. *e.g.* A flat block is moving over a horizontal table.

(b) **Rolling friction** : When objects such as a wheel (disc or ring), sphere or a cylinder rolls over a surface, the force of friction that comes into play is called rolling friction.

❑ Rolling friction is directly proportional to the normal reaction (*R*) and inversely proportional to the radius (*r*) of the rolling cylinder or wheel.

$$F_{rolling} = \mu_r \frac{R}{r}$$

μ_r is called coefficient of rolling friction. It would have the dimensions of length and would be measured in *metre*.

❑ Rolling friction is often quite small as compared to the sliding friction. That is why heavy loads are transported by placing them on carts with wheels.

❑ In rolling the surfaces at contact do not rub each other.

❑ The velocity of point of contact with respect to the surface remains zero all the times although the centre of the wheel moves forward.

Graph Between Applied Force and Force of Friction

(1) Part *OA* of the curve represents static friction (F_s). Its value increases linearly with the applied force

(2) At point *A* the static friction is maximum. This represent limiting friction (F_l).

(3) Beyond *A*, the force of friction is seen to decrease slightly. The portion *BC* of the curve represents the kinetic friction (F_k).

(4) As the portion *BC* of the curve is parallel to *x*-axis therefore kinetic friction does not change with the applied force, it remains constant, whatever be the applied force.

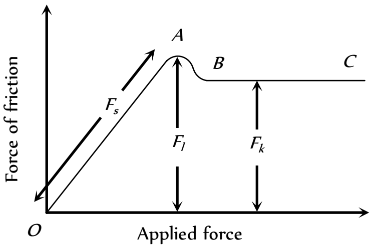


Fig. 5.2

Friction is a Cause of Motion

It is a general misconception that friction always opposes the motion. No doubt friction opposes the motion of a moving body but in many cases it is also the cause of motion. For example :

(1) While moving, a person or vehicle pushes the ground backwards (action) and the rough surface of ground reacts and exerts a forward force due to friction which causes the motion. If there had been no friction there will be slipping and no motion.

Fig. 5.3

(2) During cycling, the rear wheel moves by the force communicated to it by pedalling while front wheel moves by itself. So, when pedalling a bicycle, the force exerted by rear wheel on ground makes force of friction act on it in the forward direction (like walking). Front wheel moving by itself experience force of friction in backward direction (like rolling of a ball). [However, if pedalling is stopped both wheels move by themselves and so experience force of friction in backward direction].

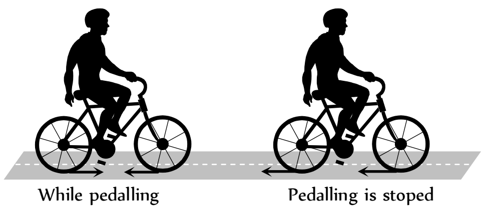


Fig. 5.4

(3) If a body is placed in a vehicle which is accelerating, the force of friction is the cause of motion of the body along with the vehicle (*i.e.*, the body will remain at rest in the accelerating vehicle until $ma < \mu_s mg$). If there had been no friction between body and vehicle, the body will not move along with the vehicle.

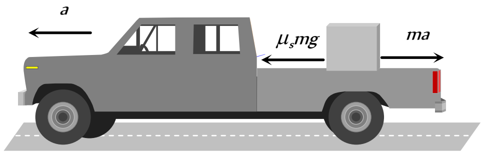


Fig. 5.5

From these examples it is clear that without friction motion cannot be started, stopped or transferred from one body to the other.

Advantages and Disadvantages of Friction

(1) **Advantages of friction**

(i) Walking is possible due to friction.

(ii) Two body sticks together due to friction.

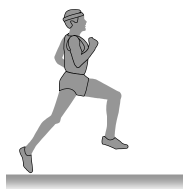


Fig. 5.6

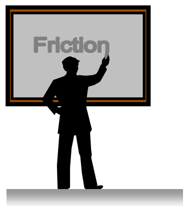


Fig. 5.7

(iii) Brake works on the basis of friction.

(iv) Writing is not possible without friction.

(v) The transfer of motion from one part of a machine to other part through belts is possible by friction.

(2) **Disadvantages of friction**

(i) Friction always opposes the relative motion between any two bodies in contact. Therefore extra energy has to be spent in over coming friction. This reduces the efficiency of machine.

(ii) Friction causes wear and tear of the parts of machinery in contact. Thus their lifetime reduces.

(iii) Frictional force result in the production of heat, which causes damage to the machinery.

Methods of Changing Friction

We can reduce friction

(1) By polishing.

(2) By lubrication.

(3) By proper selection of material.

(4) By streamlining the shape of the body.

(5) By using ball bearing.

Also we can increase friction by throwing some sand on slippery ground. In the manufacturing of tyres, synthetic rubber is preferred because its coefficient of friction with the road is larger.

Angle of Friction

Angle of friction may be defined as the angle which the resultant of limiting friction and normal reaction makes with the normal reaction.

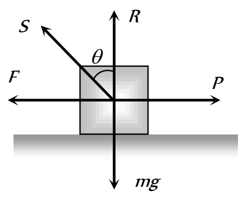


Fig. 5.8

By definition angle θ is called the angle of friction

$$\tan\theta = \frac{F_l}{R}$$

$\therefore$ $\tan\theta = \mu$ [As we know $\frac{F_l}{R} = \mu_s$]

or $\theta = \tan^{-1}(\mu_L)$

Hence coefficient of static friction is equal to tangent of the angle of friction.

Resultant Force Exerted by Surface on Block

In the above figure resultant force $S = \sqrt{F^2 + R^2}$

$$S = \sqrt{(\mu mg)^2 + (mg)^2}$$

$$S = mg\sqrt{\mu^2 + 1}$$

when there is no friction $(\mu = 0)$ S will be minimum

i.e. $S = mg$

Hence the range of S can be given by,

$$mg \le S \le mg\sqrt{\mu^2 + 1}$$

Angle of Repose

Angle of repose is defined as the angle of the inclined plane with horizontal such that a body placed on it is just begins to slide.

By definition, α is called the angle of repose.

In limiting condition $F = mg\sin\alpha$ and $R = mg\cos\alpha$

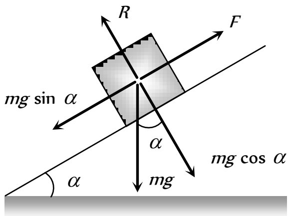


Fig. 5.9

So $\frac{F}{R} = \tan\alpha$

$\therefore$ $\frac{F}{R} = \mu_s = \tan\theta = \tan\alpha$ [As we know $\frac{F}{R} = \mu_s = \tan\theta$]

Thus the coefficient of limiting friction is equal to the tangent of angle of repose.

As well as $\alpha = \theta$ *i.e.* angle of repose = angle of friction.

Calculation of Required Force in Different Situation

If W = weight of the body, θ = angle of friction, $\mu = \tan\theta$ = coefficient of friction

Then we can calculate required force for different situation in the following manner :

(1) **Minimum pulling force P at an angle α from the horizontal**

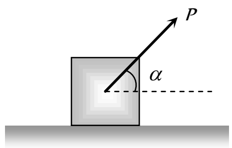


Fig. 5.10

By resolving P in horizontal and vertical direction (as shown in figure)

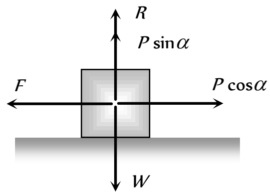


Fig. 5.11

For the condition of equilibrium

$F = P\cos\alpha$ and $R = W - P\sin\alpha$

By substituting these value in $F = \mu R$

$$P\cos\alpha = \mu(W - P\sin\alpha)$$

$\Rightarrow$ $P\cos\alpha = \frac{\sin\theta}{\cos\theta}(W - P\sin\alpha)$ [As $\mu = \tan\theta$]

$\Rightarrow$ $P = \frac{W\sin\theta}{\cos(\alpha - \theta)}$

(2) **Minimum pushing force P at an angle α from the horizontal**

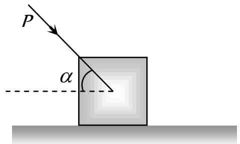


Fig. 5.12

By Resolving P in horizontal and vertical direction (as shown in the figure)

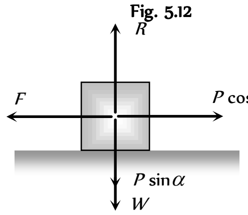


Fig. 5.13

For the condition of equilibrium

$F = P\cos\alpha$ and $R = W + P\sin\alpha$

By substituting these value in $F = \mu R$

$\Rightarrow$ $P\cos\alpha = \mu(W + P\sin\alpha)$

$\Rightarrow$ $P\cos\alpha = \frac{\sin\theta}{\cos\theta}(W + P\sin\alpha)$ [As $\mu = \tan\theta$]

$\Rightarrow$ $P = \frac{W\sin\theta}{\cos(\alpha + \theta)}$

(3) **Minimum pulling force P to move the body up on an inclined plane**

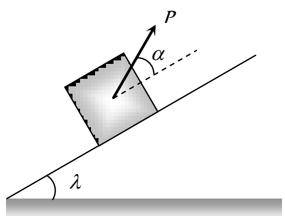


Fig. 5.14

By Resolving P in the direction of the plane and perpendicular to the plane (as shown in the figure)

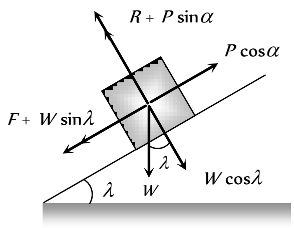


Fig. 5.15

For the condition of equilibrium

$R + P\sin\alpha = W\cos\lambda$

$\therefore \quad R = W\cos\lambda - P\sin\alpha$ and $F + W\sin\lambda = P\cos\alpha$

$\therefore \quad F = P\cos\alpha - W\sin\lambda$

By substituting these values in $F = \mu R$ and solving we get

$$P = \frac{W\sin(\theta+\lambda)}{\cos(\alpha-\theta)}$$

(4) **Minimum force to move a body in downward direction along the surface of inclined plane**

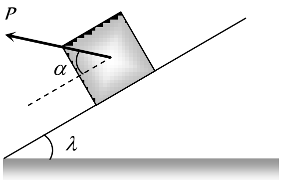


Fig. 5.16

By Resolving P in the direction of the plane and perpendicular to the plane (as shown in the figure)

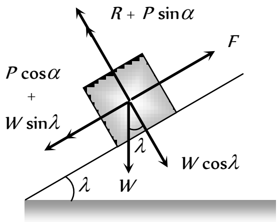


Fig. 5.17

For the condition of equilibrium

$R + P\sin\alpha = W\cos\lambda$

$\therefore \; R = W\cos\lambda - P\sin\alpha$ and $F = P\cos\alpha + W\sin\lambda$

By substituting these values in $F = \mu R$ and solving we get

$$P = \frac{W\sin(\theta-\lambda)}{\cos(\alpha-\theta)}$$

(5) **Minimum force to avoid sliding of a body down on an inclined plane**

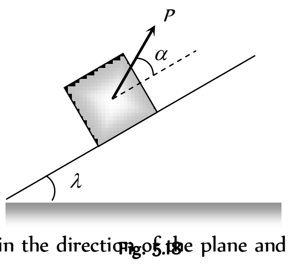


Fig. 5.18

By Resolving P in the direction of the plane and perpendicular to the plane (as shown in the figure)

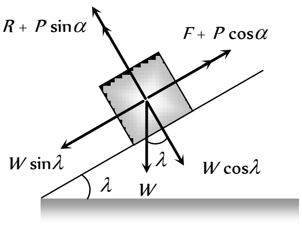


Fig. 5.19

For the condition of equilibrium

$R + P\sin\alpha = W\cos\lambda$

$\therefore \; R = W\cos\lambda - P\sin\alpha$ and $P\cos\alpha + F = W\sin\lambda$

$\therefore \; F = W\sin\lambda - P\cos\alpha$

By substituting these values in $F = \mu R$ and solving we get

$$P = W\left[\frac{\sin(\lambda-\theta)}{\cos(\theta+\alpha)}\right]$$

(6) **Minimum force for motion along horizontal surface and its direction**

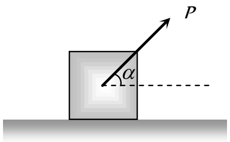


Fig. 5.20

Let the force P be applied at an angle α with the horizontal.

By resolving P in horizontal and vertical direction (as shown in figure)

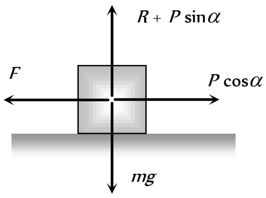


Fig. 5.21

For vertical equilibrium

$R + P\sin\alpha = mg$

$\therefore \; R = mg - P\sin\alpha$ ...(i)

and for horizontal motion

$P\cos\alpha \geq F$

i.e. $P\cos\alpha \geq \mu R$ ...(ii)

Substituting value of R from (i) in (ii)

$P\cos\alpha \geq \mu(mg - P\sin\alpha)$

$$P \geq \frac{\mu mg}{\cos\alpha + \mu\sin\alpha} \quad ...(iii)$$

For the force P to be minimum $(\cos\alpha + \mu\sin\alpha)$ must be maximum *i.e.*

$\frac{d}{d\alpha}[\cos\alpha + \mu\sin\alpha] = 0$

$\Rightarrow \; -\sin\alpha + \mu\cos\alpha = 0$

$\therefore \quad \tan\alpha = \mu$

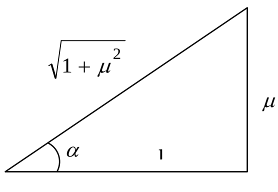


Fig. 5.22

or $\quad \alpha = \tan^{-1}(\mu) = \text{angle of friction}$

i.e. For minimum value of P its angle from the horizontal should be equal to angle of friction

As $\tan\alpha = \mu$ so from the figure, $\sin\alpha = \frac{\mu}{\sqrt{1+\mu^2}}$

and $\cos\alpha = \frac{1}{\sqrt{1+\mu^2}}$

By substituting these value in equation (iii)

$$P \geq \frac{\mu mg}{\frac{1}{\sqrt{1+\mu^2}} + \frac{\mu^2}{\sqrt{1+\mu^2}}} \geq \frac{\mu mg}{\sqrt{1+\mu^2}}$$

$$\therefore \quad P_{\min} = \frac{\mu mg}{\sqrt{1+\mu^2}}$$

Acceleration of a Block Against Friction

(1) **Acceleration of a block on horizontal surface**

When body is moving under application of force *P*, then kinetic friction opposes its motion.

Let a is the net acceleration of the body

From the figure

$$ma = P - F_k$$

$$\therefore \; a = \frac{P - F_k}{m}$$

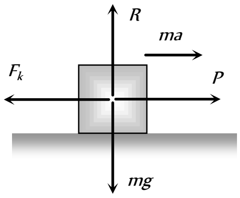


Fig. 5.23

(2) **Acceleration of a block sliding down over a rough inclined plane**

When angle of inclined plane is more than angle of repose, the body placed on the inclined plane slides down with an acceleration *a*.

From the figure $ma = mg\sin\theta - F$

$\Rightarrow \; ma = mg\sin\theta - \mu R$

$\Rightarrow \; ma = mg\sin\theta - \mu mg\cos\theta$

$\therefore$ Acceleration $a = g[\sin\theta - \mu\cos\theta]$

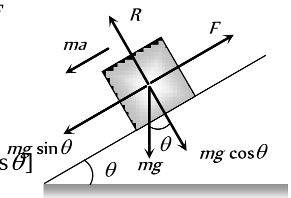


Fig. 5.24

Note : ❑ For frictionless inclined plane $\mu = 0 \; \therefore a = g\sin\theta$.

(3) **Retardation of a block sliding up over a rough inclined plane**

When angle of inclined plane is less than angle of repose, then for the upward motion

$$ma = mg\sin\theta + F$$

$$ma = mg\sin\theta + \mu mg\cos\theta$$

Retardation $a = g[\sin\theta + \mu\cos\theta]$

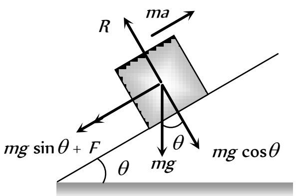


Fig. 5.25

Note : ❑ For frictionless inclined plane $\mu = 0 \; \therefore a = g\sin\theta$

Work done against friction

(1) **Work done over a rough inclined surface**

If a body of mass *m* is moved up slowly on a rough inclined plane through distance *s*, then

Work done = force × distance

= $ma \times s = mg[\sin\theta + \mu\cos\theta]s = mg\,s[\sin\theta + \mu\cos\theta]$

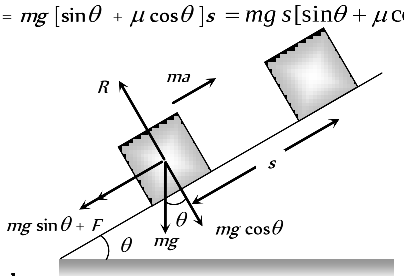


Fig. 5.26

(2) **Work done over a horizontal surface**

In the above expression if we put $\theta = 0$ then

Work done = force × distance = $F \times s = \mu\, mg\, s$

It is clear that work done depends upon

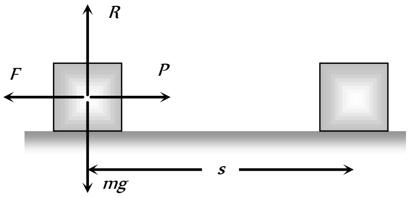


Fig. 5.27

(i) Weight of the body.

(ii) Material and nature of surface in contact.

(iii) Distance moved.

Motion of Two Bodies one Resting on the Other

When a body *A* of mass *m* is resting on a body *B* of mass *M* then two conditions are possible

(1) A force *F* is applied to the upper body, (2) A force *F* is applied to the lower body

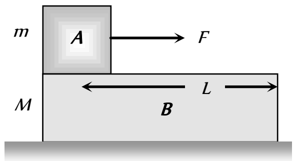


Fig. 5.28

We will discuss above two cases one by one in the following manner :

(1) **A force *F* is applied to the upper body, then following four situations are possible**

(i) **When there is no friction**

(a) The body *A* will move on body *B* with acceleration (*F*/*m*).

$$a_A = F/m$$

(b) The body *B* will remain at rest

$$a_B = 0$$

(c) If *L* is the length of *B* as shown in figure, *A* will fall from *B* after time *t*

$$t = \sqrt{\frac{2L}{a}} = \sqrt{\frac{2mL}{F}} \qquad \left[\text{As } s = \frac{1}{2}at^2 \text{ and } a = F/m\right]$$

(ii) **If friction is present between *A* and *B* only and applied force is less than limiting friction ($F < F_l$)**

(F = Applied force on the upper body, F_l = limiting friction between *A* and *B*, F_k = Kinetic friction between *A* and *B*)

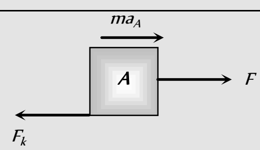
(a) The body *A* will not slide on body *B* till $F < F_l$ *i.e.* $F < \mu_s mg$

(b) Combined system (*m* + *M*) will move together with common acceleration $a_A = a_B = \frac{F}{M+m}$

(iii) **If friction is present between *A* and *B* only and applied force is greater than limiting friction ($F > F_l$)**

In this condition the two bodies will move in the same direction (*i.e.* of applied force) but with different acceleration. Here force of kinetic friction $\mu_k mg$ will oppose the motion of *A* while cause the motion of *B*.

$F - F_k = m a_A$ — Free body diagram of *A*



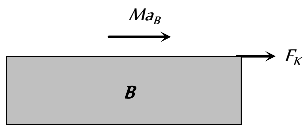
i.e. $a_A = \frac{F - F_k}{m}$

$a_A = \frac{(F - \mu_k mg)}{m}$

$F_k = M a_B$ — Free body diagram of *B*

i.e. $a_B = \frac{F_k}{M}$

$\therefore$ $a_B = \frac{\mu_k mg}{M}$



Note : ❑ As both the bodies are moving in the same direction.

Acceleration of body *A* relative to *B* will be

$$a = a_A - a_B = \frac{MF - \mu_k mg\,(m + M)}{mM}$$

So, A will fall from *B* after time

$$t = \sqrt{\frac{2L}{a}} = \sqrt{\frac{2\,m\,ML}{MF - \mu_k mg\,(m + M)}}$$

(iv) **If there is friction between *B* and floor**

(where $F_l' = \mu'(M + m)g$ = limiting friction between *B* and floor, F_k = kinetic friction between *A* and *B*)

B will move only if $F_k > F_l'$ and then $F_k - F_l' = M\,a_B$

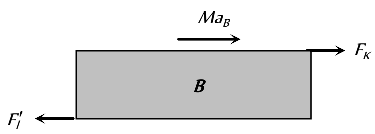


Fig. 5.29

However if *B* does not move then static friction will work (not limiting friction) between body *B* and the floor *i.e.* friction force = applied force (= *F*) not F_l'.

(2) **A force *F* is applied to the lower body, then following four situations are possible**

(i) **When there is no friction**

(a) *B* will move with acceleration (*F*/*M*) while *A* will remain at rest (relative to ground) as there is no pulling force on *A*.

$$a_B = \left(\frac{F}{M}\right) \text{ and } a_A = 0$$

(b) As relative to *B*, *A* will move backwards with acceleration (*F*/*M*) and so will fall from it in time *t*.

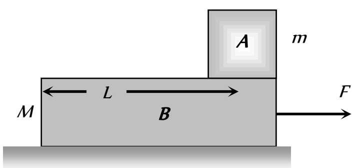


Fig. 5.30

$$\therefore \quad t = \sqrt{\frac{2L}{a}} = \sqrt{\frac{2ML}{F}}$$

(ii) **If friction is present between *A* and *B* only and $F' < F_l$**

(where F' = Pseudo force on body *A* and F_l = limiting friction between body *A* and *B*)

(a) Both the body will move together with common acceleration $a = \frac{F}{M + m}$

(b) Pseudo force on the body *A*,

$$F' = ma = \frac{mF}{m + M} \text{ and } F_l = \mu_s mg$$

(c) $F' < F_l \Rightarrow \frac{mF}{m + M} < \mu_s mg \Rightarrow F < \mu_s (m + M)g$

So both bodies will move together with acceleration $a_A = a_B = \frac{F}{m + M}$ if $F < \mu_s [m + M]g$

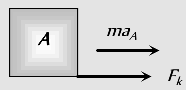
(iii) **If friction is present between *A* and *B* only and $F > F_l'$**

(where $F_l' = \mu_s mg$ = limiting friction between body *A* and *B*)

Both the body will move with different acceleration. Here force of kinetic friction $\mu_k mg$ will oppose the motion of *B* while will cause the motion of *A*.

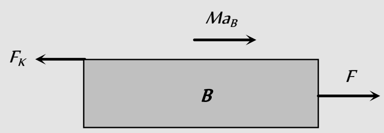
$ma_A = \mu_k mg$ — Free body diagram of *A*

i.e. $a_A = \mu_k g$



$F - F_k = Ma_B$ — Free body diagram of *B*

i.e. $a_B = \frac{[F - \mu_k mg]}{M}$



Note : ❑ As both the bodies are moving in the same direction

Acceleration of body *A* relative to *B* will be

$$a = a_A - a_B = -\left[\frac{F - \mu_k g(m + M)}{M}\right]$$

Negative sign implies that relative to *B*, A will move backwards and will fall it after time

$$t = \sqrt{\frac{2L}{a}} = \sqrt{\frac{2ML}{F - \mu_k g(m + M)}}$$

(iv) **If there is friction between *B* and floor and $F > F_l''$:**

(where $F_l'' = \mu_k (m+M)g$ = limiting friction between body *B* and surface)

The system will move only if $F > F_l''$ then replacing *F* by $F - F_l''$. The entire case (iii) will be valid.

However if $F < F_1''$ the system will not move and friction between *B* and floor will be *F* while between *A* and *B* is zero.

Motion of an Insect in the Rough Bowl

The insect crawl up the bowl, up to a certain height h only till the component of its weight along the bowl is balanced by limiting frictional force.

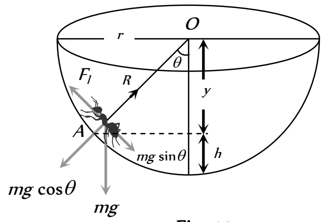


Fig. 5.31

Let m = mass of the insect, r = radius of the bowl, μ = coefficient of friction

for limiting condition at point A

$R = mg\cos\theta$ ......(i) and $F_l = mg\sin\theta$ ......(ii)

Dividing (ii) by (i)

$$\tan\theta = \frac{F_l}{R} = \mu \qquad [\text{As} F_l = \mu R]$$

$$\therefore \frac{\sqrt{r^2 - y^2}}{y} = \mu \quad \text{or} \quad y = \frac{r}{\sqrt{1+\mu^2}}$$

So $h = r - y = r\left[1 - \frac{1}{\sqrt{1+\mu^2}}\right]$, $\therefore$ $h = r\left[1 - \frac{1}{\sqrt{1+\mu^2}}\right]$

Minimum Mass Hung from the String to Just Start the Motion

(1) **When a mass m_1 placed on a rough horizontal plane** Another mass m_2 hung from the string connected by frictionless pulley, the tension (T) produced in string will try to start the motion of mass m_1.

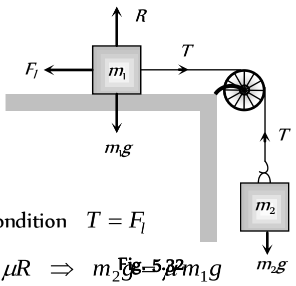


Fig. 5.32

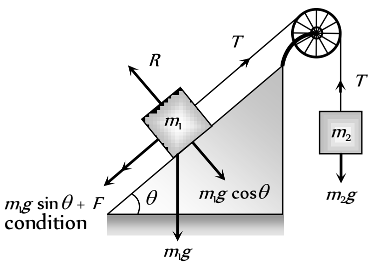
At limiting condition $T = F_l$

$\Rightarrow$ $m_2 g = \mu R$ $\Rightarrow$ $m_2 g = \mu m_1 g$

$\therefore$ $m_2 = \mu m_1$ this is the minimum value of m_2 to start the motion.

Note : ❑ In the above condition Coefficient of friction $\mu = \frac{m_2}{m_1}$

(2) **When a mass m_1 placed on a rough inclined plane** Another mass m_2 hung from the string connected by frictionless pulley, the tension (T) produced in string will try to start the motion of mass m_1.



At limiting condition

Fig. 5.33

For m_2 $T = m_2 g$ ...(i)

For m_1 $T = m_1 g\sin\theta + F$

$\Rightarrow$ $T = m_1 g\sin\theta + \mu R$

$\Rightarrow$ $T = m_1 g\sin\theta + \mu m_1 g\cos\theta$ ...(ii)

From equation (i) and (ii) $m_2 = m_1[\sin\theta + \mu\cos\theta]$

this is the minimum value of m_2 to start the motion

Note : ❑ In the above condition Coefficient of friction

$$\mu = \left[\frac{m_2}{m_1\cos\theta} - \tan\theta\right]$$

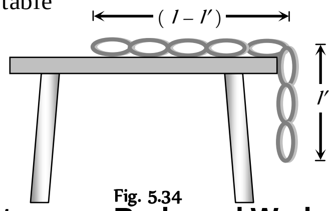
Maximum Length of Hung Chain

A uniform chain of length l is placed on the table in such a manner that its l' part is hanging over the edge of table without sliding. Since the chain have uniform linear density therefore the ratio of mass and ratio of length for any part of the chain will be equal.

We know $\mu = \frac{m_2}{m_1} = \frac{\text{mass hanging from the table}}{\text{mass lying on the table}}$

$\therefore$ For this case we can rewrite above expression in the following manner

$\mu = \frac{\text{length hanging from the table}}{\text{length lying on the table}}$ [As chain have uniform linear density]



$\therefore$ $\mu = \frac{l'}{l - l'}$

by solving $l' = \frac{\mu l}{(\mu + 1)}$

Fig. 5.34

Coefficient of Friction Between a Body and Wedge

A body slides on a smooth wedge of angle θ and its time of descent is t.

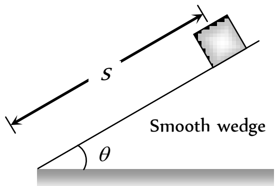


Fig. 5.35

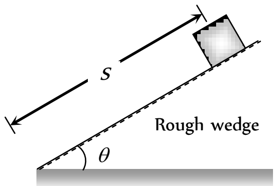


Fig. 5.36

If the same wedge made rough then time taken by it to come down becomes n times more (*i.e.* nt)

The length of path in both the cases are same.

For smooth wedge, $S = ut + \frac{1}{2}at^2$

$$S = \frac{1}{2}(g\sin\theta)t^2 \qquad \text{...(i)}$$

$$[\text{As } u = 0 \text{ and } a = g\sin\theta]$$

For rough wedge, $S = ut + \frac{1}{2}at^2$

$$S = \frac{1}{2}g(\sin\theta - \mu\cos\theta)(nt)^2 \qquad \text{...(ii)}$$

$$[\text{As } u = 0 \text{ and } a = g(\sin\theta - \mu\cos\theta)]$$

From equation (i) and (ii)

$$\frac{1}{2}(g\sin\theta)t^2 = \frac{1}{2}g(\sin\theta - \mu\cos\theta)(nt)^2$$

$$\Rightarrow \sin\theta = (\sin\theta - \mu\cos\theta)n^2$$

$$\Rightarrow \mu = \tan\theta\left[1 - \frac{1}{n^2}\right]$$

Stopping of Block Due to Friction

(1) **On horizontal road**

(i) **Distance travelled before coming to rest :** A block of mass m is moving initially with velocity u on a rough surface and due to friction, it comes to rest after covering a distance S.

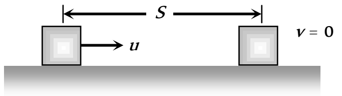


Fig. 5.37

Retarding force $F = ma = \mu R \Rightarrow ma = \mu mg$

$\therefore a = \mu g$

From $v^2 = u^2 - 2aS \Rightarrow 0 = u^2 - 2\mu g S$

[As $v = 0,\ a = \mu g$]

$$\therefore \quad S = \frac{u^2}{2\mu g} \quad \text{or} \quad S = \frac{P^2}{2\mu m^2 g}$$

[As momentum $P = mu$]

(ii) **Time taken to come to rest**

From equation $v = u - at \Rightarrow 0 = u - \mu g t$

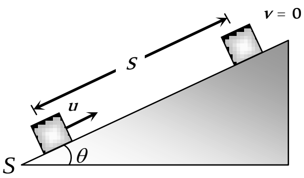
[As $v = 0, a = \mu g$]

$$\therefore \quad t = \frac{u}{\mu g}$$

(2) **On inclined road :** When block starts with velocity u its kinetic energy will be converted into potential energy and some part of it goes against friction and after travelling distance S it comes to rest *i.e.* $v = 0$.

We know that retardation $a = g[\sin\theta + \mu\cos\theta]$

By substituting the value of v and a in the following equation



$v^2 = u^2 - 2aS$

Fig. 5.38

$$\Rightarrow \quad 0 = u^2 - 2g[\sin\theta + \mu\cos\theta]S$$

$$\therefore \quad S = \frac{u^2}{2g(\sin\theta + \mu\cos\theta)}$$

Stopping of Two Blocks Due to Friction

When two masses compressed towards each other and suddenly released then energy acquired by each block will be dissipated against friction and finally block comes to rest

i.e., $F \times S = E$ [Where F = Friction, S = Distance covered by block, E = Initial kinetic energy of the block]

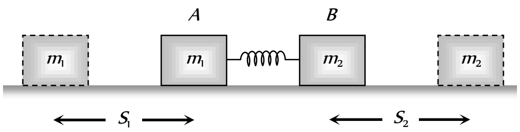


Fig. 5.39

$$\Rightarrow \quad F \times S = \frac{P^2}{2m}$$ [Where P = momentum of block]

$$\Rightarrow \quad \mu mg \times S = \frac{P^2}{2m}$$ [As $F = \mu mg$]

$$\Rightarrow \quad S = \frac{P^2}{2\mu m^2 g}$$

In the given condition P and μ are same for both the blocks.

So, $S \propto \frac{1}{m^2}$; $\therefore \frac{S_1}{S_2} = \left[\frac{m_2}{m_1}\right]^2$

Velocity at the Bottom of Rough Wedge

A body of mass m which is placed at the top of the wedge (of height h) starts moving downward on a rough inclined plane.

Loss of energy due to friction = FL (Work against friction)

PE at point $A = mgh$

KE at point $B = \frac{1}{2}mu^2$

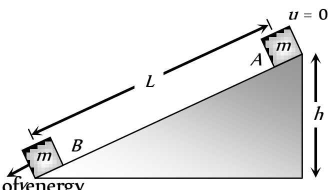


Fig. 5.40

By the law of conservation of energy

i.e. $\frac{1}{2}mv^2 = mgh - FL$

$$v = \sqrt{\frac{2}{m}(mgh - FL)}$$

Sticking of a Block With Accelerated Cart

When a cart moves with some acceleration toward right then a pseudo force (ma) acts on block toward left.

This force (ma) is action force by a block on cart.

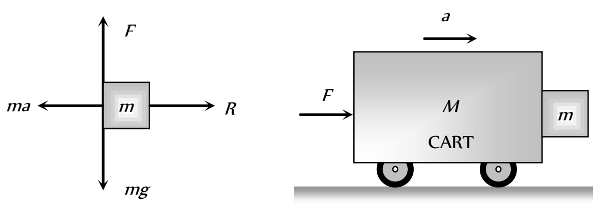


Fig. 5.41

Now block will remain static *w.r.t.* cart. If friction force $\mu R \geq mg$

$\Rightarrow \mu ma \geq mg$ [As $R = ma$]

$$\Rightarrow \quad a \geq \frac{g}{\mu}$$

$$\therefore \quad a_{min} = \frac{g}{\mu}$$

This is the minimum acceleration of the cart so that block does not fall.

and the minimum force to hold the block together

$$F_{min} = (M + m)a_{min}$$

$$F_{min} = (M + m)\frac{g}{\mu}$$

Sticking of a Person with the Wall of Rotor

A person with a mass m stands in contact against the wall of a cylindrical drum (rotor). The coefficient of friction between the wall and the clothing is μ.

If Rotor starts rotating about its axis, then person thrown away from the centre due to centrifugal force at a particular speed ω, the person stuck to the wall even the floor is removed, because friction force balances its weight in this condition.

From the figure.

Friction force (F) = weight of person (mg)

$\Rightarrow \mu R = mg \Rightarrow \mu F_c = mg$

[Here, F_c = centrifugal force]

$\Rightarrow \mu m \omega_{\min}^2 r = mg$

$\therefore \omega_{\min} = \sqrt{\dfrac{g}{\mu r}}$

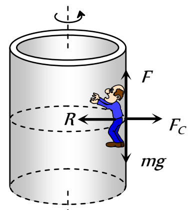


Fig. 5.42

Tips & Tricks

✍ Force of friction is non-conservative force.

✍ Force of friction always acts in a direction opposite to that of the relative motion between the surfaces.

✍ Rolling friction is much less than the sliding friction. This knowledge was used by man to invent the wheels.

✍ The friction between two surfaces increases (rather than to decrease), when the surfaces are made highly smooth.

✍ The atomic and molecular forces of attraction between the two surfaces at the point of contact give rise to friction between the surfaces.

Ordinary Thinking

Objective Questions

Static and limiting friction

1. The coefficient of friction μ and the angle of friction λ are related as

(a) $\sin\lambda = \mu$ (b) $\cos\lambda = \mu$

(c) $\tan\lambda = \mu$ (d) $\tan\mu = \lambda$

2. A force of 98 N is required to just start moving a body of mass 100 kg over ice. The coefficient of static friction is

(a) 0.6 (b) 0.4

(c) 0.2 (d) 0.1

3. A block weighs W is held against a vertical wall by applying a horizontal force F. The minimum value of F needed to hold the block is [MP PMT 1993]

(a) Less than W (b) Equal to W

(c) Greater than W (d) Data is insufficient

4. The maximum static frictional force is

(a) Equal to twice the area of surface in contact

(b) Independent of the area of surface in contact

(c) Equal to the area of surface in contact

(d) None of the above

5. Maximum value of static friction is called [BHU 1995; RPET 2000]

(a) Limiting friction (b) Rolling friction

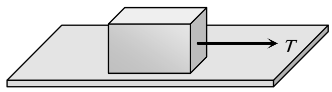
(c) Normal reaction (d) Coefficient of friction

6. Pulling force making an angle θ to the horizontal is applied on a block of weight W placed on a horizontal table. If the angle of friction is α, then the magnitude of force required to move the body is equal to [EAMCET 1987]

(a) $\dfrac{W\sin\alpha}{g\tan(\theta-\alpha)}$ (b) $\dfrac{W\cos\alpha}{\cos(\theta-\alpha)}$

(c) $\dfrac{W\sin\alpha}{\cos(\theta-\alpha)}$ (d) $\dfrac{W\tan\alpha}{\sin(\theta-\alpha)}$

7. In the figure shown, a block of weight 10 N resting on a horizontal surface. The coefficient of static friction between the block and the surface $\mu_s = 0.4$. A force of 3.5 N will keep the block in uniform motion, once it has been set in motion. A horizontal force of 3 N is applied to the block, then the block will



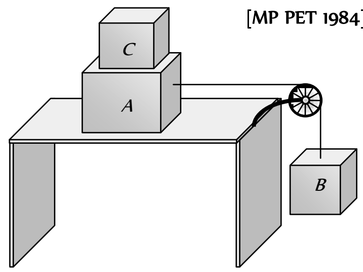
(a) Move over the surface with constant velocity

(b) Move having accelerated motion over the surface

(c) Not move

(d) First it will move with a constant velocity for some time and then will have accelerated motion

8. Two masses A and B of 10 kg and 5 kg respectively are connected with a string passing over a frictionless pulley fixed at the corner of a table as shown. The coefficient of static friction of A with table is 0.2. The minimum mass of C that may be placed on A to prevent it from moving is [MP PET 1984]



(a) 15 kg

(b) 10 kg

(c) 5 kg

(d) 12 kg

9. The limiting friction is

(a) Always greater than the dynamic friction

(b) Always less than the dynamic friction

(c) Equal to the dynamic friction

(d) Sometimes greater and sometimes less than the dynamic friction

10. Which is a suitable method to decrease friction

(a) Ball and bearings (b) Lubrication

(c) Polishing (d) All the above

11. A uniform rope of length *l* lies on a table. If the coefficient of friction is μ, then the maximum length l_1 of the part of this rope which can overhang from the edge of the table without sliding down is **[DPMT 2001]**

(a) $\frac{l}{\mu}$ (b) $\frac{l}{\mu+l}$

(c) $\frac{\mu l}{1+\mu}$ (d) $\frac{\mu l}{\mu-1}$

12. Which of the following statements is not true

[CMC Vellore 1989]

(a) The coefficient of friction between two surfaces increases as the surface in contact are made rough

(b) The force of friction acts in a direction opposite to the applied force

(c) Rolling friction is greater than sliding friction

(d) The coefficient of friction between wood and wood is less than 1

13. A block of 1 *kg* is stopped against a wall by applying a force *F* perpendicular to the wall. If $\mu = 0.2$ then minimum value of *F* will be **[MP PMT 2003]**

(a) 980 *N* (b) 49 *N*

(c) 98 *N* (d) 490 *N*

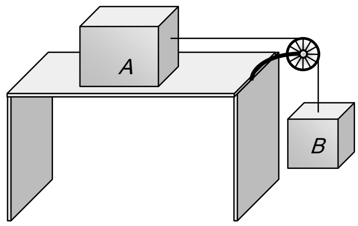
14. A heavy uniform chain lies on a horizontal table-top. If the coefficient of friction between the chain and table surface is 0.25, then the maximum fraction of length of the chain, that can hang over one edge of the table is **[CBSE PMT 1990]**

(a) 20% (b) 25%

(c) 35% (d) 15%

15. The blocks A and B are arranged as shown in the figure. The pulley is frictionless. The mass of *A* is 10 *kg*. The coefficient of friction of *A* with the horizontal surface is 0.20. The minimum mass of *B* to start the motion will be

[MP PET 1994]



(a) 2 *kg*

(b) 0.2 *kg*

(c) 5 *kg*

(d) 10 *kg*

16. Work done by a frictional force is

(a) Negative (b) Positive

(c) Zero (d) All of the above

17. A uniform chain of length *L* changes partly from a table which is kept in equilibrium by friction. The maximum length that can withstand without slipping is *l*, then coefficient of friction between the table and the chain is

[EAMCET (Engg.) 1995]

(a) $\frac{l}{L}$ (b) $\frac{l}{L+l}$

(c) $\frac{l}{L-l}$ (d) $\frac{L}{L+l}$

18. When two surfaces are coated with a lubricant, then they

[AFMC 1998, 99; AIIMS 2001]

(a) Stick to each other (b) Slide upon each other

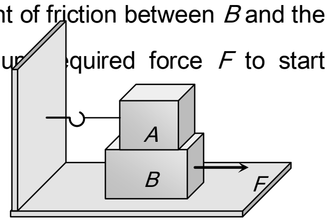
(c) Roll upon each other (d) None of these

19. A 20 *kg* block is initially at rest on a rough horizontal surface. A horizontal force of 75 *N* is required to set the block in motion. After it is in motion, a horizontal force of 60 *N* is required to keep the block moving with constant speed. The coefficient of static friction is **[AMU 1999]**

(a) 0.38 (b) 0.44

(c) 0.52 (d) 0.60

20. A block *A* with mass 100 *kg* is resting on another block *B* of mass 200 *kg*. As shown in figure a horizontal rope tied to a wall holds it. The coefficient of friction between *A* and *B* is 0.2 while coefficient of friction between *B* and the ground is 0.3. The minimum required force *F* to start moving *B* will be



[RPET 1999]

(a) 900 *N*

(b) 100 *N*

(c) 1100 *N*

(d) 1200 *N*

21. To avoid slipping while walking on ice, one should take smaller steps because of the **[BHU 1999; BCECE 2004]**

(a) Friction of ice is large

(b) Larger normal reaction

(c) Friction of ice is small

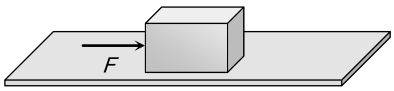
(d) Smaller normal reaction

22. A box is lying on an inclined plane what is the coefficient of static friction if the box starts sliding when an angle of inclination is 60° **[KCET 2000]**

(a) 1.173 (b) 1.732

(c) 2.732 (d) 1.677

23. A block of mass 2 *kg* is kept on the floor. The coefficient of static friction is 0.4. If a force *F* of 2.5 *Newtons* is applied on the block as shown in the figure, the frictional force between the block and the floor will be **[MP PET 2000]**



(a) 2.5 *N*

(b) 5 *N*

(c) 7.84 *N*

(d) 10 *N*

24. Which one of the following is not used to reduce friction **[Kerala (Engg.) 2001]**

(a) Oil (b) Ball bearings

(c) Sand (d) Graphite

25. If a ladder weighing 250*N* is placed against a smooth vertical wall having coefficient of friction between it and floor is 0.3, then what is the maximum force of friction available at the point of contact between the ladder and the floor **[AIIMS 2002]**

(a) 75 *N* (b) 50 *N*

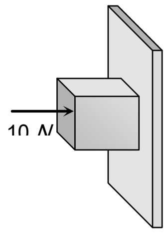
(c) 35 *N* (d) 25 *N*

26. A body of mass 2 *kg* is kept by pressing to a vertical wall by a force of 100 *N*. The coefficient of friction between wall and body is 0.3. Then the frictional force is equal to **[Orissa JEE 2003]**

(a) 6 *N* (b) 20 *N*

(c) 600 *N* (d) 700 *N*

27. A horizontal force of 10 *N* is necessary to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2. the weight of the block is **[AIEEE 2003]**



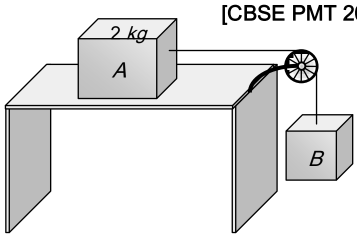
(a) 2 *N*

(b) 20 *N*

(c) 50 *N*

(d) 100 *N*

28. The coefficient of static friction, μ_s, between block *A* of mass 2 *kg* and the table as shown in the figure is 0.2. What would be the maximum mass value of block *B* so that the two blocks do not move? The string and the pulley are assumed to be smooth and massless. $(g = 10\, m/s^2)$ **[CBSE PMT 2004]**



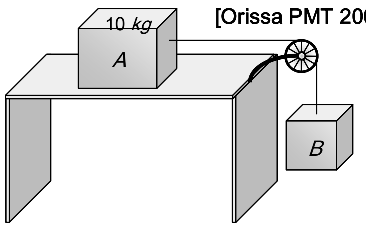
(a) 2.0 *kg*

(b) 4.0 *kg*

(c) 0.2 *kg*

(d) 0.4 *kg*

29. If mass of $A = 10\ kg$, coefficient of static friction = 0.2, coefficient of kinetic friction = 0.2. Then mass of *B* to start motion is **[Orissa PMT 2004]**



(a) 2 *kg*

(b) 2.2 *kg*

(c) 4.8 *kg*

(d) 200 *gm*

30. A uniform metal chain is placed on a rough table such that one end of chain hangs down over the edge of the table. When one-third of its length hangs over the edge, the chain starts sliding. Then, the coefficient of static friction is

[Kerala PET 2005]

(a) $\frac{3}{4}$ (b) $\frac{1}{4}$

(c) $\frac{2}{3}$ (d) $\frac{1}{2}$

31. A lift is moving downwards with an acceleration equal to acceleration due to gravity. A body of mass *m* kept on the floor of the lift is pulled horizontally. If the coefficient of friction is μ, then the frictional resistance offered by the body is **[DPMT 2004]**

(a) *mg* (b) μmg

(c) $2\mu mg$ (d) Zero

32. If a ladder weighing 250 *N* is placed against a smooth vertical wall having coefficient of friction between it and floor is 0.3, then what is the maximum force of friction available at the point of contact between the ladder and the floor **[BHU 2004]**

(a) 75 *N* (b) 50 *N*

(c) 35 *N* (d) 25 *N*

Kinetic Friction

1. Which one of the following statements is correct

(a) Rolling friction is greater than sliding friction

(b) Rolling friction is less than sliding friction

(c) Rolling friction is equal to sliding friction

(d) Rolling friction and sliding friction are same

2. The maximum speed that can be achieved without skidding by a car on a circular unbanked road of radius *R* and coefficient of static friction μ , is

(a) μRg (b) $Rg\sqrt{\mu}$

(c) $\mu\sqrt{Rg}$ (d) $\sqrt{\mu Rg}$

3. A car is moving along a straight horizontal road with a speed v_0 . If the coefficient of friction between the tyres and the road is μ , the shortest distance in which the car can be stopped is **[MP PET 1985; BHU 2002]**

(a) $\frac{v_0^2}{2\mu g}$ (b) $\frac{v_0}{\mu g}$

(c) $\left(\frac{v_0}{\mu g}\right)^2$ (d) $\frac{v_0}{\mu}$

4. A block of mass 5 *kg* is on a rough horizontal surface and is at rest. Now a force of 24 *N* is imparted to it with negligible impulse. If the coefficient of kinetic friction is 0.4 and $g = 9.8\, m/s^2$, then the acceleration of the block is

(a) $0.26\, m/s^2$ (b) $0.39\, m/s^2$

(c) $0.69\, m/s^2$ (d) $0.88\, m/s^2$

5. A body of mass 2 *kg* is being dragged with uniform velocity of 2 *m/s* on a rough horizontal plane. The coefficient of friction between the body and the surface is 0.20. The amount of heat generated in 5 sec is

$(J = 4.2\, joule/cal$ and $g = 9.8\, m/s^2)$

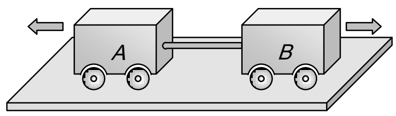
[MH CET (Med.) 2001]

(a) 9.33 *cal* (b) 10.21 *cal*

(c) 12.67 *cal* (d) 13.34 *cal*

6. Two carts of masses 200 *kg* and 300 *kg* on horizontal rails are pushed apart. Suppose the coefficient of friction between the carts and the rails are same. If the 200 *kg* cart travels a distance of 36 *m* and stops, then the distance travelled by the cart weighing 300 *kg* is

[CPMT 1989; DPMT 2002]



(a) 32 *m* (b) 24 *m*

(c) 16 *m* (d) 12 *m*

[NCERT 1990]

7. A body *B* lies on a smooth horizontal table and another body *A* is placed on *B*. The coefficient of friction between

A and *B* is μ. What acceleration given to B will cause slipping to occur between *A* and *B*

(a) μg (b) g/μ

(c) μ/g (d) $\sqrt{\mu g}$

8. A 60 *kg* body is pushed with just enough force to start it moving across a floor and the same force continues to act afterwards. The coefficient of static friction and sliding friction are 0.5 and 0.4 respectively. The acceleration of the body is

(a) $6\,m/s^2$ (b) $4.9\,m/s^2$

(c) $3.92\,m/s^2$ (d) $1\,m/s^2$

9. A car turns a corner on a slippery road at a constant speed of $10\,m/s$. If the coefficient of friction is 0.5, the minimum radius of the arc in meter in which the car turns is

(a) 20 (b) 10

(c) 5 (d) 4

10. A motorcyclist of mass *m* is to negotiate a curve of radius *r* with a speed *v*. The minimum value of the coefficient of friction so that this negotiation may take place safely, is **[Haryana CEE 1996]**

(a) v^2rg (b) $\frac{v^2}{gr}$

(c) $\frac{gr}{v^2}$ (d) $\frac{g}{v^2r}$

11. On a rough horizontal surface, a body of mass 2 *kg* is given a velocity of 10 *m/s*. If the coefficient of friction is 0.2 and $g=10\,m/s^2$, the body will stop after covering a distance of **[MP PMT 1999]**

(a) 10 *m* (b) 25 *m*

(c) 50 *m* (d) 250 *m*

12. A block of mass 50 *kg* can slide on a rough horizontal surface. The coefficient of friction between the block and the surface is 0.6. The least force of pull acting at an angle of 30° to the upward drawn vertical which causes the block to just slide is **[ISM Dhanbad 1994]**

(a) 29.43 *N* (b) 219.6 *N*

(c) 21.96 *N* (d) 294.3 *N*

13. A body of 10 *kg* is acted by a force of 129.4 *N* if $g=9.8\,m/\sec^2$. The acceleration of the block is $10\,m/s^2$. What is the coefficient of kinetic friction **[EAMCET 1994]**

(a) 0.03 (b) 0.01

(c) 0.30 (d) 0.25

14. Assuming the coefficient of friction between the road and tyres of a car to be 0.5, the maximum speed with which the car can move round a curve of 40.0 *m* radius without slipping, if the road is unbanked, should be **[AMU 1995]**

(a) 25 *m/s* (b) 19 *m/s*

(c) 14 *m/s* (d) 11 *m/s*

15. Consider a car moving along a straight horizontal road with a speed of 72 *km/h*. If the coefficient of kinetic friction between the tyres and the road is 0.5, the shortest distance in which the car can be stopped is $[g=10\,ms^{-2}]$ **[CBSE PMT 1992]**

(a) 30 *m* (b) 40 *m*

(c) 72 *m* (d) 20 *m*

16. A 500 *kg* horse pulls a cart of mass 1500 *kg* along a level road with an acceleration of $1\,ms^{-2}$. If the coefficient of sliding friction is 0.2, then the force exerted by the horse in forward direction is **[SCRA 1998]**

(a) 3000 *N* (b) 4000 *N*

(c) 5000 *N* (d) 6000 *N*

17. The maximum speed of a car on a road turn of radius 30*m*, if the coefficient of friction between the tyres and the road is 0.4; will be **[MH CET (Med.) 1999]**

(a) 9.84 *m/s* (b) 10.84 *m/s*

(c) 7.84 *m/s* (d) 5.84 *m/s*

18. A block of mass 50 *kg* slides over a horizontal distance of 1 *m*. If the coefficient of friction between their surfaces is 0.2, then work done against friction is

[BHU 2001; CBSE PMT 1999, 2000; AIIMS 2000]

(a) 98 *J* (b) 72*J*

(c) 56 *J* (d) 34 *J*

19. On the horizontal surface of a truck (μ = 0.6), a block of mass 1 *kg* is placed. If the truck is accelerating at the rate of 5*m/sec*² then frictional force on the block will be

[CBSE PMT 2001]

(a) 5 *N* (b) 6 *N*

(c) 5.88 *N* (d) 8 *N*

20. A vehicle of mass *m* is moving on a rough horizontal road with momentum *P*. If the coefficient of friction between the tyres and the road be μ, then the stopping distance is

[CBSE PMT 2001]

(a) $\frac{P}{2\mu m g}$ (b) $\frac{P^2}{2\mu m g}$

(c) $\frac{P}{2\mu m^2 g}$ (d) $\frac{P^2}{2\mu m^2 g}$

21. A body of weight 64 *N* is pushed with just enough force to start it moving across a horizontal floor and the same force continues to act afterwards. If the coefficients of static and dynamic friction are 0.6 and 0.4 respectively, the acceleration of the body will be (Acceleration due to gravity = *g*)

[EAMCET 2001]

(a) $\frac{g}{6.4}$ (b) 0.64 *g*

(c) $\frac{g}{32}$ (d) 0.2 *g*

22. When a body is moving on a surface, the force of friction is called **[MP PET 2002]**

(a) Static friction (b) Dynamic friction

(c) Limiting friction (d) Rolling friction

23. A block of mass 10 *kg* is placed on a rough horizontal surface having coefficient of friction μ = 0.5. If a horizontal force of 100 *N* is acting on it, then acceleration of the block will be **[AIIMS 2002]**

(a) 0.5 m/s^2 (b) 5 m/s^2

(c) 10 m/s^2 (d) 15 m/s^2

24. It is easier to roll a barrel than pull it along the road. This statement is **[BVP 2003]**

(a) False (b) True

(c) Uncertain (d) Not possible

25. A marble block of mass 2 *kg* lying on ice when given a velocity of 6 *m/s* is stopped by friction in 10*s*. Then the coefficient of friction is **[AIEEE 2003]**

(a) 0.01 (b) 0.02

(c) 0.03 (d) 0.06

26. A horizontal force of 129.4 *N* is applied on a 10 *kg* block which rests on a horizontal surface. If the coefficient of friction is 0.3, the acceleration should be

(a) $9.8\, m/s^2$ (b) $10\, m/s^2$

(c) $12.6\, m/s^2$ (d) $19.6\, m/s^2$

27. A 60 *kg* weight is dragged on a horizontal surface by a rope upto 2 *metres*. If coefficient of friction is $\mu = 0.5$, the angle of rope with the surface is 60° and $g = 9.8\, m/\sec^2$, then work done is **[MP PET 1995]**

(a) 294 *joules* (b) 315 *joules*

(c) 588 *joules* (d) 197 *joules*

28. A car having a mass of 1000 *kg* is moving at a speed of 30 *metres/sec*. Brakes are applied to bring the car to rest. If the frictional force between the tyres and the road surface is 5000 *newtons*, the car will come to rest in **[MP PMT 1995]**

(a) 5 *seconds* (b) 10 *seconds*

(c) 12 *seconds* (d) 6 *seconds*

29. If μ_s, μ_k and μ_r are coefficients of static friction, sliding friction and rolling friction, then **[EAMCET (Engg.) 1995]**

(a) $\mu_s < \mu_k < \mu_r$ (b) $\mu_k < \mu_r < \mu_s$

(c) $\mu_r < \mu_k < \mu_s$ (d) $\mu_r = \mu_k = \mu_s$

30. A body of mass 5*kg* rests on a rough horizontal surface of coefficient of friction 0.2. The body is pulled through a distance of 10*m* by a horizontal force of 25 *N*. The kinetic energy acquired by it is (g = 10 ms^{-2})

[EAMCET (Med.) 2000]

(a) 330 *J* (b) 150 *J*

(c) 100 *J* (d) 50 *J*

31. A motorcycle is travelling on a curved track of radius 500*m*. If the coefficient of friction between road and tyres is 0.5, the speed avoiding skidding will be

(a) 50 *m/s* (b) 75 *m/s*

(c) 25 *m/s* (d) 35 *m/s*

32. A fireman of mass 60 *kg* slides down a pole. He is pressing the pole with a force of 600 *N*. The coefficient of friction between the hands and the pole is 0.5, with what acceleration will the fireman slide down (g = 10 m/s^2)

[Pb. PMT 2002]

(a) 1 m/s^2 (b) 2.5 m/s^2

(c) 10 m/s^2 (d) 5 m/s^2

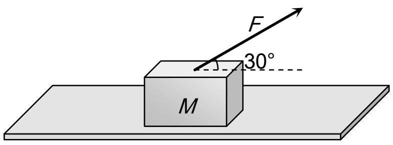
33. A block of mass $M = 5\,kg$ is resting on a rough horizontal surface for which the coefficient of friction is 0.2. When a force $F = 40\ N$ is applied, the acceleration of the block will be $(g = 10\ m/s^2)$ **[MP PMT 2004]**

(a) $5.73\ m/\sec^2$

(b) $8.0\ m/\sec^2$

(c) $3.17\ m/\sec^2$

(d) $10.0\ m/\sec^2$



34. A body is moving along a rough horizontal surface with an initial velocity $6\ m/s$. If the body comes to rest after travelling 9 *m*, then the coefficient of sliding friction will be

[BCECE 2004]

(a) 0.4 (b) 0.2

(c) 0.6 (d) 0.8

35. Consider a car moving on a straight road with a speed of 100 *m/s*. The distance at which car can be stopped is $[\mu_k = 0.5]$ **[AIEEE 2005]**

(a) 100 *m* (b) 400 *m*

(c) 800 *m* (d) 1000 *m*

36. A cylinder of 10 *kg* is sliding in a plane with an initial velocity of 10 *m/s*. If the coefficient of friction between the surface and cylinder is 0.5 then before stopping, it will

[MH CET (Med.) 2001]

cover. $(g = 10\ m/s^2)$ **[Pb. PMT 2004]**

(a) 2.5 *m* (b) 5 *m*

(c) 7.5 *m* (d) 10 *m*

Motion on Inclined Surface

1. When a body is lying on a rough inclined plane and does not move, the force of friction

(a) is equal to μR (b) is less than μR

(c) is greater than μR (d) is equal to R

2. When a body is placed on a rough plane inclined at an angle θ to the horizontal, its acceleration is

(a) $g(\sin\theta - \cos\theta)$ (b) $g(\sin\theta - \mu\cos\theta)$

(c) $g(\mu\sin\theta 1 - \cos\theta)$ (d) $g\mu(\sin\theta - \cos\theta)$

3. A block is at rest on an inclined plane making an angle α with the horizontal. As the angle α of the incline is increased, the block starts slipping when the angle of inclination becomes θ. The coefficient of static friction between the block and the surface of the inclined plane is

or

A body starts sliding down at an angle θ to horizontal. Then coefficient of friction is equal to **[CBSE PMT 1993]**

(a) $\sin\theta$ (b) $\cos\theta$

(c) $\tan\theta$ (d) Independent of θ

4. A given object takes *n* times as much time to slide down a 45° rough incline as it takes to slide down a perfectly smooth 45° incline. The coefficient of kinetic friction between the object and the incline is given by

(a) $\left(1-\frac{1}{n^2}\right)$ (b) $\frac{1}{1-n^2}$

(c) $\sqrt{\left(1-\frac{1}{n^2}\right)}$ (d) $\sqrt{\frac{1}{1-n^2}}$

5. The force required just to move a body up an inclined plane is double the force required just to prevent the body sliding down. If the coefficient of friction is 0.25, the angle of inclination of the plane is

(a) 36.8° (b) 45°

(c) 30° (d) 42.6°

6. Starting from rest, a body slides down a 45° inclined plane in twice the time it takes to slide down the same distance in the absence of friction. The coefficient of friction between the body and the inclined plane is

[CBSE PMT 1990]

(a) 0.33 (b) 0.25

(c) 0.75 (d) 0.80

7. The coefficient of friction between a body and the surface of an inclined plane at 45° is 0.5. If $g = 9.8\, m/s^2$, the acceleration of the body downwards in m/s^2 is

[EAMCET 1994]

(a) $\frac{4.9}{\sqrt{2}}$ (b) $4.9\sqrt{2}$

(c) $19.6\sqrt{2}$ (d) 4.9

8. A box is placed on an inclined plane and has to be pushed down. The angle of inclination is

[EAMCET 1994]

(a) Equal to angle of friction

(b) More than angle of friction

(c) Equal to angle of repose

(d) Less than angle of repose

9. A force of 750 *N* is applied to a block of mass 102 *kg* to prevent it from sliding on a plane with an inclination angle 30° with the horizontal. If the coefficients of static friction and kinetic friction between the block and the plane are 0.4 and 0.3 respectively, then the frictional force acting on the block is

[RPET 1999; AMU 2000] [SCRA 1994]

(a) 750 *N* (b) 500 *N*

(c) 345 *N* (d) 250 *N*

10. A block is lying on an inclined plane which makes 60° with the horizontal. If coefficient of friction between block and plane is 0.25 and $g = 10\, m/s^2$, then acceleration of the block when it moves along the plane will be [RPET 1997]

(a) $2.50\, m/s^2$ (b) $5.00\, m/s^2$

(c) $7.4\, m/s^2$ (d) $8.66\, m/s^2$

11. A body of mass 100 *g* is sliding from an inclined plane of inclination 30°. What is the frictional force experienced if $\mu = 1.7$ [BHU 1998]

(a) $1.7 \times \sqrt{2} \times \frac{1}{\sqrt{3}}\, N$ (b) $1.7 \times \sqrt{3} \times \frac{1}{2}\, N$

(c) $1.7 \times \sqrt{3}\, N$ (d) $1.7 \times \sqrt{2} \times \frac{1}{3}\, N$

12. A body takes just twice the time as long to slide down a plane inclined at 30° to the horizontal as if the plane were frictionless. The coefficient of friction between the body and the plane is [JIPMER 1999]

(a) $\frac{\sqrt{3}}{4}$ (b) $\sqrt{3}$

(c) $\frac{4}{3}$ (d) $\frac{3}{4}$

13. A brick of mass 2 *kg* begins to slide down on a plane inclined at an angle of 45° with the horizontal. The force of friction will be [CPMT 2000]

(a) 19.6 *sin* 45° (b) 19.6 cos 45°

(c) 9.8 *sin* 45° (d) 9.8 cos 45°

14. The upper half of an inclined plane of inclination θ is perfectly smooth while the lower half is rough. A body starting from the rest at top comes back to rest at the bottom if the coefficient of friction for the lower half is given by

[Pb. PMT 2000]

(a) $\mu = \sin\theta$ (b) $\mu = \cot\theta$

(c) $\mu = 2\cos\theta$ (d) $\mu = 2\tan\theta$

15. A body is sliding down an inclined plane having coefficient of friction 0.5. If the normal reaction is twice that of the resultant downward force along the incline, the angle between the inclined plane and the horizontal is

[EAMCET (Engg.) 2000]

(a) 15° (b) 30° (c) 45° (d) 60°

16. A body of mass 10 *kg* is lying on a rough plane inclined at an angle of 30° to the horizontal and the coefficient of friction is 0.5. the minimum force required to pull the body up the plane is **[JIPMER 2000]**

(a) 914 *N* (b) 91.4 *N* (c) 9.14 *N* (d) 0.914 *N*

17. A block of mass 1 *kg* slides down on a rough inclined plane of inclination 60° starting from its top. If the coefficient of kinetic friction is 0.5 and length of the plane is 1 *m*, then work done against friction is (Take *g* = 9.8 m/s^2)

[AFMC 2000; KCET 2001]

(a) 9.82 *J* (b) 4.94 *J* (c) 2.45*J* (d) 1.96 *J*

18. A block of mass 10 *kg* is placed on an inclined plane. When the angle of inclination is 30°, the block just begins to slide down the plane. The force of static friction is

[Kerala (Engg.) 2001]

(a) 10 *kg wt* (b) 89 *kg w* (c) 49 *kg wt* (d) 5 *kg wt*

19. A body of 5 *kg* weight kept on a rough inclined plane of angle 30° starts sliding with a constant velocity. Then the coefficient of friction is (assume *g* = 10 m/s^2)

(a) $1/\sqrt{3}$ (b) $2/\sqrt{3}$ (c) $\sqrt{3}$ (d) $2\sqrt{3}$

20. 300 *Joule* of work is done in sliding up a 2 *kg* block on an inclined plane to a height of 10 *metres*. Taking value of acceleration due to gravity '*g*' to be 10 m/s^2, work done against friction is **[MP PMT 2002]**

(a) 100 *J* (b) 200 *J* (c) 300 *J* (d) Zero

21. A 2 *kg* mass starts from rest on an inclined smooth surface with inclination 30° and length 2 *m*. How much will it travel before coming to rest on a frictional surface with frictional coefficient of 0.25

(a) 4 *m* (b) 6 *m* (c) 8 *m* (d) 2 *m*

22. A block rests on a rough inclined plane making an angle of 30^o with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 *N*, the mass of the block (in *kg*) is (take $g = 10\ m/s^2$) **[AIEEE 2004]**

(a) 2.0 (b) 4.0 (c) 1.6 (d) 2.5

23. A body takes time *t* to reach the bottom of an inclined plane of angle θ with the horizontal. If the plane is made rough, time taken now is 2*t*. The coefficient of friction of the rough surface is

(a) $\frac{3}{4}\tan\theta$ (b) $\frac{2}{3}\tan\theta$ (c) $\frac{1}{4}\tan\theta$ (d) $\frac{1}{2}\tan\theta$

24. A block is kept on an inclined plane of inclination θ of length *l*. The velocity of particle at the bottom of inclined is (the coefficient of friction is μ)

(a) $\sqrt{2gl(\mu\cos\theta - \sin\theta)}$ (b) $\sqrt{2gl(\sin\theta - \mu\cos\theta)}$

(c) $\sqrt{2gl(\sin\theta + \mu\cos\theta)}$ (d) $\sqrt{2gl(\cos\theta + \mu\sin\theta)}$

Critical Thinking

Objective Questions

[JIPMER 2002]

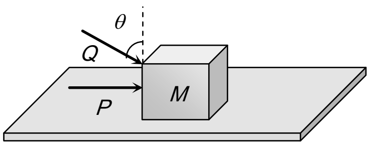
1. A block of mass *m* lying on a rough horizontal plane is acted upon by a horizontal force *P* and another force *Q* inclined at an angle θ to the vertical. The block will remain in equilibrium, if the coefficient of friction between it and the surface is **[Haryana CEE 1996]**

(a) $\frac{(P+Q\sin\theta)}{(mg+Q\cos\theta)}$

(b) $\frac{(P\cos\theta+Q)}{(mg-Q\sin\theta)}$

(c) $\frac{(P+Q\cos\theta)}{(mg+Q\sin\theta)}$

(d) $\frac{(P\sin\theta-Q)}{(mg-Q\cos\theta)}$



2. Which of the following is correct, when a person walks on a rough surface **[IIT 1981]**

(a) The frictional force exerted by the surface keeps him moving

(b) The force which the man exerts on the floor keeps him moving

(c) The reaction of the force which the man exerts on floor keeps him moving

(d) None of the above

3. A block of mass 0.1 *kg* is held against a wall by applying a horizontal force of 5 *N* on the block. If the coefficient of friction between the block and the wall is 0.5, the magnitude of the frictional force acting on the block is **[IIT 1994]**

(a) 2.5 *N* (b) 0.98 *N*

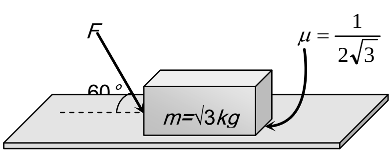
(c) 4.9 *N* (d) 0.49 *N*

4. A body of mass *M* is kept on a rough horizontal surface (friction coefficient μ). A person is trying to pull the body by applying a horizontal force but the body is not moving. The force by the surface on the body is *F*, where **[MP PET 1997]**

(a) $F = Mg$ (b) $F = \mu Mgf$

(c) $Mg \le F \le Mg\sqrt{1+\mu^2}$ (d) $Mg \ge F \ge Mg\sqrt{1+\mu^2}$

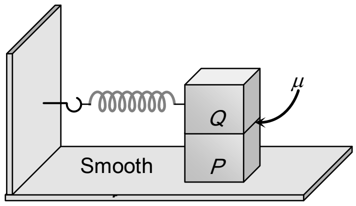
5. What is the maximum value of the force *F* such that the block shown in the arrangement, does not move **[IIT-JEE Screening 2003]**



(a) 20 *N* (b) 10 *N*

(c) 12 *N* (d) 15 *N*

6. A block *P* of mass *m* is placed on a frictionless horizontal surface. Another block *Q* of same mass is kept on *P* and connected to the wall with the help of a spring of spring constant *k* as shown in the figure. μ_s is the coefficient of friction between *P* and *Q*. The blocks move together performing *SHM* of amplitude *A*. The maximum value of the friction force between *P* and *Q* is **[IIT-JEE (Screening) 2004]**



(a) kA

(b) $\frac{kA}{2}$

(c) Zero

(d) $\mu_s\, mg$

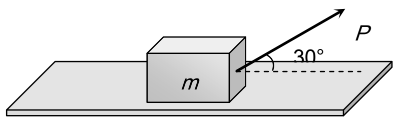
7. A body of mass *m* rests on horizontal surface. The coefficient of friction between the body and the surface is μ. If the mass is pulled by a force *P* as shown in the figure, the limiting friction between body and surface will be **[BHU 2004]**

(a) μmg

(b) $\mu\left[mg+\left(\frac{P}{2}\right)\right]$

(c) $\mu\left[mg-\left(\frac{P}{2}\right)\right]$

(d) $\mu\left[mg-\left(\frac{\sqrt{3}\,P}{2}\right)\right]$



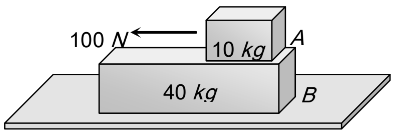
8. A 40 *kg* slab rests on a frictionless floor as shown in the figure. A 10 *kg* block rests on the top of the slab. The static coefficient of friction between the block and slab is 0.60 while the kinetic friction is 0.40. The 10 *kg* block is acted upon by a horizontal force 100 *N*. If $g = 9.8\, m/s^2$, the resulting acceleration of the slab will be **[NCERT 1982]**

(a) $0.98\,m/s^2$

(b) $1.47\,m/s^2$

(c) $1.52\,m/s^2$

(d) $6.1\,m/s^2$



9. A block of mass 2 *kg* rests on a rough inclined plane making an angle of 30° with the horizontal. The coefficient of static friction between the block and the plane is 0.7. The frictional force on the block is **[IIT 1980; J & K CET 2004]**

(a) 9.8 *N*

(b) $0.7 \times 9.8 \times \sqrt{3}\ N$

(c) $9.8 \times \sqrt{3}\ N$

(d) $0.8 \times 9.8\ N$

10. When a bicycle is in motion, the force of friction exerted by the ground on the two wheels is such that it acts

[IIT 1990; Manipal MEE 1995; MP PET 1996]

(a) In the backward direction on the front wheel and in the forward direction on the rear wheel

(b) In the forward direction on the front wheel and in the backward direction on the rear wheel

(c) In the backward direction on both front and the rear wheels

(d) In the forward direction on both front and the rear wheels

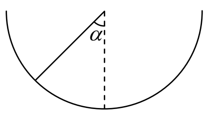
11. An insect crawls up a hemispherical surface very slowly (see the figure). The coefficient of friction between the insect and the surface is 1/3. If the line joining the centre of the hemispherical surface to the insect makes an angle α with the vertical, the maximum possible value of α is given by **[IIT-JEE 2001]**

(a) $\cot\alpha = 3$

(b) $\tan\alpha = 3$

(c) $\sec\alpha = 3$

(d) $\text{cosec}\,\alpha = 3$



Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : On a rainy day, it is difficult to drive a car or bus at high speed.

Reason : The value of coefficient of friction is lowered due to wetting of the surface.

2. Assertion : When a bicycle is in motion, the force of friction exerted by the ground on the two wheels is always in forward direction.

Reason : The frictional force acts only when the bodies are in contact.

3. Assertion : Pulling a lawn roller is easier than pushing it.

Reason : Pushing increases the apparent weight and hence the force of friction.

4. Assertion : Angle of repose is equal to angle of limiting friction.

Reason : When the body is just at the point of motion, the force of friction in this stage is called as limiting friction.

5. Assertion : Two bodies of masses *M* and *m* (*M* > *m*) are allowed to fall from the same height if the air resistance for each be the same then both the bodies will reach the earth simultaneously.

Reason : For same air resistance, acceleration of both the bodies will be same.

6. Assertion : Friction is a self adjusting force.

Reason : Friction does not depend upon mass of the body.

7. Assertion : The value of dynamic friction is less than the limiting friction.

Reason : Once the motion has started, the inertia of rest has been overcome.

8. Assertion : The acceleration of a body down a rough inclined plane is greater than the acceleration due to gravity.

Reason : The body is able to slide on a inclined plane only when its acceleration is greater than acceleration due to gravity.

Answers

Static and Limiting Friction

1	c	2	d	3	c	4	b	5	a
6	c	7	c	8	a	9	a	10	d
11	c	12	c	13	b	14	a	15	a
16	d	17	c	18	b	19	a	20	c
21	c	22	b	23	a	24	c	25	a
26	b	27	a	28	d	29	a	30	d
31	d	32	a						

Kinetic Friction

1	b	2	d	3	a	4	d	5	a
6	c	7	a	8	d	9	a	10	b
11	b	12	d	13	c	14	c	15	b
16	d	17	b	18	a	19	a	20	d
21	d	22	b	23	b	24	b	25	d
26	b	27	b	28	d	29	c	30	b
31	a	32	d	33	a	34	b	35	d
36	d								

Motion on Inclined Surface

1	b	2	b	3	c	4	a	5	a
6	c	7	a	8	d	9	d	10	c
11	b	12	a	13	a	14	d	15	c
16	b	17	c	18	d	19	a	20	a
21	a	22	a	23	a	24	b		

Critical Thinking Questions

1	a	2	c	3	b	4	c	5	a
6	b	7	c	8	a	9	a	10	ac
11	a								

Assertion & Reason

1	a	2	e	3	a	4	b	5	d
6	d	7	a	8	d				

Answers and Solutions

Static and Limiting Friction

1. (c)

2. (d) $\mu = \frac{F}{R} = \frac{F}{mg} = \frac{98}{100 \times 9.8} = \frac{1}{10} = 0.1$

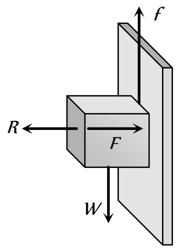
3. (c) Here applied horizontal force F acts as normal reaction.

For holding the block

Force of friction = Weight of block

$f = W \Rightarrow \mu R = W \Rightarrow \mu F = W$

$\Rightarrow F = \frac{W}{\mu}$



As $\mu < 1 \therefore F > W$

4. (b)

5. (a)

6. (c)

7. (c) $F_l = \mu_s R = 0.4 \times mg = 0.4 \times 10 = 4N$ *i.e.* minimum 4*N* force is required to start the motion of a body. But applied force is only 3*N*. So the block will not move.

8. (a) For limiting condition $\mu = \frac{m_B}{m_A + m_C} \Rightarrow 0.2 = \frac{5}{10 + m_C}$

$\Rightarrow 2 + 0.2 m_C = 5 \Rightarrow m_C = 15 kg$

9. (a)

10. (d) Ball and bearing produce rolling motion for which force of friction is low. Lubrication and polishing reduce roughness of surface.

11. (c) For given condition we can apply direct formula

$l_1 = \left(\frac{\mu}{\mu + 1}\right) l$

12. (c) Sliding friction is greater than rolling friction.

13. (b) $F = \frac{W}{\mu} = \frac{1 \times 9.8}{0.2} = 49N$

14. (a) $l' = \left(\frac{\mu}{\mu+1}\right) l = \left(\frac{0.25}{0.25+1}\right) l = \frac{l}{5} = 20\%$ of *l*.

15. (a) $\mu = \frac{m_B}{m_A} \Rightarrow 0.2 = \frac{m_B}{10} \Rightarrow m_B = 2kg$

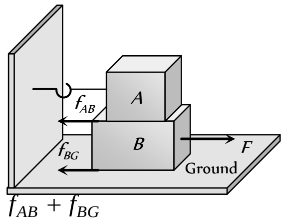
16. (d) Work done by friction can be positive, negative and zero depending upon the situation.

17. (c) $\mu = \frac{\text{Lenght of chain hanging from the table}}{\text{Lenght of chain lying on the table}} = \frac{l}{L - l}$

18. (b) Surfaces always slide over each other.

19. (a) Coefficient of friction $\mu_s = \frac{F_l}{R} = \frac{75}{mg} = \frac{75}{20 \times 9.8} = 0.38$

20. (c)



$F = f_{AB} + f_{BG}$

$= \mu_{AB} m_a g + \mu_{BG}(m_A + m_B) g$

$= 0.2 \times 100 \times 10 + 0.3(300) \times 10$

$= 200 + 900 = 1100\ N$

21. (c)

22. (b) $\mu = \tan$ (Angle of repose) $= \tan 60° = 1.732$

23. (a) Applied force $= 2.5\ N$

Limiting friction $= \mu mg = 0.4 \times 2 \times 9.8 = 7.84\ N$

For the given condition applied force is very smaller than limiting friction.

$\therefore$ Static friction on a body = Applied force = 2.5 *N*

24. (c) Sand is used to increase the friction.

25. (a) $F = \mu R = 0.3 \times 250 = 75\ N$

26. (b) For the given condition, Static friction

= Applied force = Weight of body $= 2 \times 10 = 20\ N$

27. (a) $F = \frac{W}{\mu} \quad \therefore W = \mu F = 0.2 \times 10 = 2N$

28. (d) $\mu_s = \frac{m_B}{m_A} \Rightarrow 0.2 = \frac{m_B}{2} \Rightarrow m_B = 0.4\ kg$

29. (a) $\mu_s = \frac{m_B}{m_A} \Rightarrow 0.2 = \frac{m_B}{10} \Rightarrow m_B = 2\ kg$

30. (d) $\mu_s = \frac{\text{Lenght of the chain hanging from the table}}{\text{Length of the chain lying on the table}}$

$= \frac{l/3}{l - l/3} = \frac{l/3}{2l/3} = \frac{1}{2}$

31. (d)

32. (a)

Kinetic Friction

1. (b)

2. (d) In the given condition the required centripetal force is provided by frictional force between the road and tyre.

$\frac{mv^2}{R} = \mu mg \quad \therefore \quad v = \sqrt{\mu Rg}$

3. (a) Retarding force $F = ma = \mu R = \mu mg \quad \therefore \quad a = \mu g$

Now from equation of motion $v^2 = u^2 - 2as$

$\Rightarrow 0 = u^2 - 2as \Rightarrow s = \frac{u^2}{2a} = \frac{u^2}{2\mu g} \quad \therefore \quad = \frac{v_0^2}{2\mu g}$

4. (d) Net force = Applied force – Friction force

$ma = 24 - \mu\, mg = 24 - 0.4 \times 5 \times 9.8 = 24 - 19.6$

$\Rightarrow a = \frac{4.4}{5} = 0.88\ m/s^2$

5. (a) Work done = Force × Displacement = $\mu\, mg \times (v \times t)$

$W = (0.2) \times 2 \times 9.8 \times 2 \times 5\ joule$

Heat generated $Q = \frac{W}{J} = \frac{0.2 \times 2 \times 9.8 \times 2 \times 5}{4.2} = 9.33\ cal$

6. (c) For given condition $s \propto \frac{1}{m^2}$ $\therefore \frac{s_2}{s_1} = \left(\frac{m_1}{m_2}\right)^2 = \left(\frac{200}{300}\right)^2$

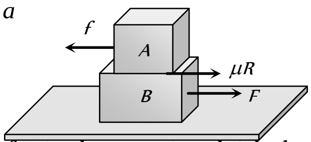
$\Rightarrow s_2 = s_1 \times \frac{4}{9} = 36 \times \frac{4}{9} = 16\ m$

7. (a) There is no friction between the body *B* and surface of the table. If the body *B* is pulled with force *F* then

$$F = (m_A + m_B)a$$

Due to this force upper body *A* will feel the pseudo force in a backward direction.

$f = m_A \times a$



But due to friction between *A* and *B*, body will not move. The body *A* will start moving when pseudo force is more than friction force.

i.e. for slipping, $m_A a = \mu\, m_A g$ $\therefore a = \mu g$

8. (d) Limiting friction $= \mu_s R = \mu_s mg = 0.5 \times 60 \times 10 = 300\ N$

Kinetic friction $= \mu_k R = \mu_k mg = 0.4 \times 60 \times 10 = 240\ N$

Force applied on the body = 300 *N* and if the body is moving then, Net accelerating force

=Applied force – Kinetic friction

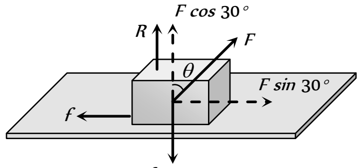
$\Rightarrow ma = 300 - 240 = 60$ $\therefore a = \frac{60}{60} = 1\ m/s^2$

9. (a) $v = \sqrt{\mu\, g\, r} \Rightarrow r = \frac{v^2}{\mu g} = \frac{100}{0.5 \times 10} = 20$

10. (b)

11. (b) $S = \frac{u^2}{2\mu g} = \frac{(10)^2}{2 \times 0.2 \times 10} = 25\ m$

12. (d)



For limiting condition $f = \mu R$

$F \sin 30° = \mu(mg - F \cos 30°)$, By solving $F = 294.3\ N$

13. (c) Net force on the body = Applied force – Friction

$ma = F - \mu_k mg \Rightarrow \mu_k = \frac{F - ma}{mg} = \frac{129.4 - 10 \times 10}{10 \times 9.8} = 0.3$

14. (c) $v = \sqrt{\mu g r} = \sqrt{0.5 \times 9.8 \times 40} = \sqrt{196} = 14\ m/s$

15. (b) $s = \frac{u^2}{2\mu\, g} = \frac{(20)^2}{2 \times 0.5 \times 10} = 40\ m$

16. (d) Net force in forward direction = Accelerating force + Friction

$= ma + \mu\, mg = m(a + \mu\, g) = (1500 + 500)(1 + 0.2 \times 10)$

$= 2000 \times 3 = 6000\ N$

17. (b) $v = \sqrt{\mu rg} = \sqrt{0.4 \times 30 \times 9.8} = 10.84\ m/s$

18. (a) $W = \mu mgS = 0.2 \times 50 \times 9.8 \times 1 = 98\ J$

19. (a) $F_l = \mu mg = 0.6 \times 1 \times 9.8 = 5.88\ N$

Pseudo force on the block = $ma = 1 \times 5 = 5\ N$

Pseudo is less then limiting friction hence static force of friction = 5 *N*.

20. (d) $S = \frac{u^2}{2\mu g} = \frac{m^2 u^2}{2\mu g m^2} = \frac{P^2}{2\mu m^2 g}$

21. (d) Weight of the body = 64*N*

so mass of the body $m = 6.4\ kg$, $\mu_s = 0.6$, $\mu_k = 0.4$

Net acceleration $= \frac{\text{Applied force - Kinetic friction}}{\text{Mass of the body}}$

$= \frac{\mu_s mg - \mu_k mg}{m} = (\mu_s - \mu_k)g = (0.6 - 0.4)g = 0.2\, g$

22. (b)

23. (b) $a = \frac{\text{Applied force} - \text{Kinetic friction}}{\text{mass}}$

$= \frac{100 - 0.5 \times 10 \times 10}{10} = 5 m/s^2$

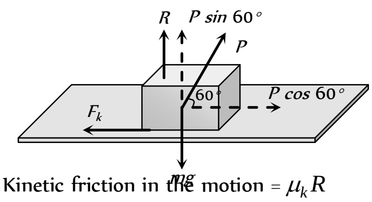
24. (b)

25. (d) $v = u - at \Rightarrow u - \mu gt = 0$ $\therefore \mu = \frac{u}{gt} = \frac{6}{10 \times 10} = 0.06$

26. (b) From the relation $F - \mu mg = ma$

$a = \frac{F - \mu mg}{m} = \frac{129.4 - 0.3 \times 10 \times 9.8}{10} = 10\ m/s^2$

27. (b) Let body is dragged with force *P*, making an angle 60° with the horizontal.



F_k = Kinetic friction in the motion = $\mu_k R$

From the figure $F_k = P \cos 60°$ and $R = mg - P \sin 60°$

$\therefore P \cos 60° = \mu_k (mg - P \sin 60°)$

$\Rightarrow \frac{P}{2} = 0.5\left(60 \times 10 - \frac{P\sqrt{3}}{2}\right) \Rightarrow P = 315.1\ N$

$\therefore F_k = P \cos 60° = \frac{315.1}{2} N$

Work done $= F_k \times s = \frac{315.1}{2} \times 2 = 315\ Joule$

28. (d) $v = u - at \Rightarrow t = \frac{u}{a}$ [As $v = 0$]

$t = \frac{u \times m}{F} = \frac{30 \times 1000}{5000} = 6$ sec

29. (c)

30. (b) Kinetic energy acquired by body

= (Total work done on the body) – (work against friction)

$= F \times S - \mu mgS = 25 \times 10 - 0.2 \times 5 \times 10 \times 10$

$= 250 - 100 = 150$ *Joule*

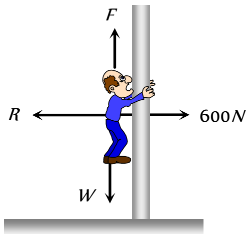
31. (a) $v = \sqrt{\mu rg} = \sqrt{0.5 \times 500 \times 10} = 50\ m/s$

32. (d) Net downward acceleration $= \frac{\text{Weight- Friction force}}{\text{Mass}}$

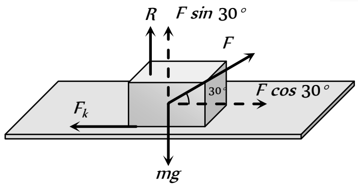
$= \frac{(mg - \mu R)}{m}$

$= \frac{60 \times 10 - 0.5 \times 600}{60}$

$= \frac{300}{60} = 5\ m/s^2$



33. (a)



Kinetic friction = $\mu_k R = 0.2(mg - F \sin 30°)$

$= 0.2\left(5 \times 10 - 40 \times \frac{1}{2}\right) = 0.2(50 - 20) = 6\ N$

Acceleration of the block $= \frac{F \cos 30° - \text{Kinetic friction}}{\text{Mass}}$

$= \frac{40 \times \frac{\sqrt{3}}{2} - 6}{5} = 5.73\ m/s^2$

34. (b) We know $s = \frac{u^2}{2\mu g}$ $\therefore$ $\mu = \frac{u^2}{2gs} = \frac{(6)^2}{2 \times 10 \times 9} = 0.2$

35. (d) $s = \frac{u^2}{2\mu g} = \frac{(100)^2}{2 \times 0.5 \times 10} = 1000\ m$

36. (d) Kinetic energy of the cylinder will go against friction

$\therefore \frac{1}{2}mv^2 = \mu mgs \Rightarrow s = \frac{u^2}{2\mu g} = \frac{(10)^2}{2 \times (0.5) \times 10} = 10\,m$

Motion on Inclined Surface

1. (b) When the body is at rest then static friction works on it, which is less than limiting friction (μR).

2. (b)

3. (c) Coefficient of friction = Tangent of angle of repose

$\therefore \mu = \tan\theta$

4. (a) $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right) = 1 - \frac{1}{n^2}$ [As $\theta = 45°$]

5. (a) Retardation in upward motion $= g(\sin\theta + \mu\cos\theta)$

$\therefore$ Force required just to move up $F_{up} = mg(\sin\theta + \mu\cos\theta)$

Similarly for down ward motion $a = g(\sin\theta - \mu\cos\theta)$

$\therefore$ Force required just to prevent the body sliding down

$F_{dn} = mg(\sin\theta - \mu\cos\theta)$

According to problem $F_{up} = 2F_{dn}$

$\Rightarrow mg(\sin\theta + \mu\cos\theta) = 2mg(\sin\theta - \mu\cos\theta)$

$\Rightarrow \sin\theta + \mu\cos\theta = 2\sin\theta - 2\mu\cos\theta$

$\Rightarrow 3\mu\cos\theta = \sin\theta \Rightarrow \tan\theta = 3\mu$

$\Rightarrow \theta = \tan^{-1}(3\mu) = \tan^{-1}(3 \times 0.25) = \tan^{-1}(0.75) = 36.8°$

6. (c) $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right)$

$\theta = 45°$ and $n = 2$ (Given)

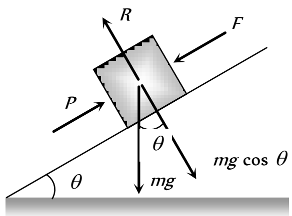
$\therefore \mu = \tan 45°\left(1 - \frac{1}{2^2}\right) = 1 - \frac{1}{4} = \frac{3}{4} = 0.75$

7. (a) $a = g(\sin\theta - \mu\cos\theta) = 9.8(\sin 45^o - 0.5\cos 45^o)$

$= \frac{4.9}{\sqrt{2}}\ m/\sec^2$

8. (d) Because if the angle of inclination is equal to or more than angle of repose then box will automatically slides down the plane.

9. (d)



Net force along the plane

$= P - mg\sin\theta = 750 - 500 = 250\ N$

Limiting friction = $F_l = \mu_s R = \mu_s mg\cos\theta$

= 0.4 × 102 × 9.8 × cos 30 = 346 N

As net external force is less than limiting friction therefore friction on the body will be 250 N.

10. (c) $a = g(\sin\theta - \mu\cos\theta) = 10(\sin 60° - 0.25\cos 60°)$

$a = 7.4\ m/s^2$

11. (b) $F_k = \mu_k R = \mu_k mg\cos\theta$

$F_k = 1.7 \times 0.1 \times 10 \times \cos 30° = 1.7 \times \frac{\sqrt{3}}{2} N$

12. (a) $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right) = \tan 30\left(1 - \frac{1}{2^2}\right) = \frac{\sqrt{3}}{4}$

13. (a) For angle of repose,

Friction =Component of weight along the plane

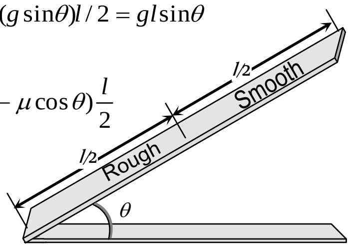
$= mg\sin\theta = 2\times 9.8\times \sin 45^o = 19.6\sin 45^o$

14. (d) For upper half

$v^2 = u^2 + 2al/2 = 2(g\sin\theta)l/2 = gl\sin\theta$

For lower half

$\Rightarrow 0 = u^2 + 2g(\sin\theta - \mu\cos\theta)\frac{l}{2}$



$\Rightarrow -gl\sin\theta = gl(\sin\theta - \mu\cos\theta)$

$\Rightarrow \mu\cos\theta = 2\sin\theta \Rightarrow \mu = 2\tan\theta$

15. (c) Resultant downward force along the incline

$= mg(\sin\theta - \mu\cos\theta)$

Normal reaction $= mg\cos\theta$

Given : $mg\cos\theta = 2mg(\sin\theta - \mu\cos\theta)$

By solving $\theta = 45^o$.

16. (b) $F = mg(\sin\theta + \mu\cos\theta)$

$= 10\times 9.8(\sin 30° + 0.5\cos 30°) = 91.4\ N$.

17. (c) $W = \mu mg\cos\theta S = 0.5\times 1\times 9.8\times\frac{1}{2}\times 1 = 2.45\ J$

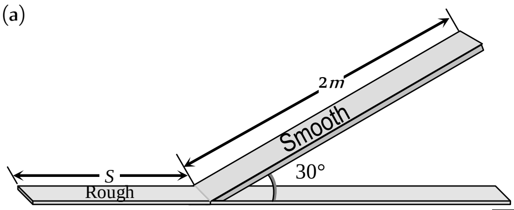
18. (d) $F = mg\sin 30° = 50N = 5kg\text{-}wt$.

19. (a) $\mu = \tan 30° = \frac{1}{\sqrt{3}}$.

20. (a) Work done against gravity $= mgh = 2\times 10\times 10 = 200\ J$

Work done against friction = (Total work done – work done against gravity) $= 300 - 200 = 100J$

21. (a)



$v^2 = u^2 + 2as = 0 + 2\times g\sin 30\times 2 \Rightarrow v = \sqrt{20}$

Let it travel distance 'S' before coming to rest

$S = \frac{v^2}{2\mu g} = \frac{20}{2\times 0.25\times 10} = 4m$

22. (a) Angle of repose $\alpha = \tan^{-1}(\mu) = \tan^{-1}(0.8) = 38.6°$

Angle of inclined plane is given $\theta = 30°$. It means block is at rest therefore,

Static friction = component of weight in downward direction

$= mg\sin\theta = 10\ N \quad \therefore\ m = \frac{10}{9\times\sin 30°} = 2\ kg$

23. (a) $\mu = \tan\theta\left(1 - \frac{1}{n^2}\right) = \tan\theta\left(1 - \frac{1}{2^2}\right) = \frac{3}{4}\tan\theta$

24. (b) Acceleration (a) $= g(\sin\theta - \mu\cos\theta)$ and $s = l$

$v = \sqrt{2as} = \sqrt{2gl(\sin\theta - \mu\cos\theta)}$

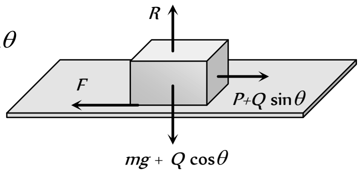
Critical Thinking Questions

1. (a) By drawing the free body diagram of the block for critical condition

$F = \mu R \Rightarrow P + Q\sin\theta$

$= \mu(mg + Q\cos\theta)$

$\therefore\ \mu = \frac{P + Q\sin\theta}{mg + Q\cos\theta}$

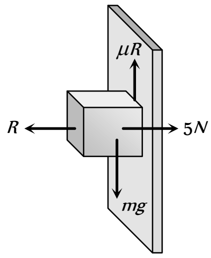


2. (c)

3. (b) Limiting friction

$F_l = \mu_s R = 0.5\times(5) = 2.5\ N$

Since downward force is less than limiting friction therefore block is at rest so the static force of friction will work on it.



F_s = downward force = Weight

$= 0.1\times 9.8 = 0.98\ N$

4. (c) Maximum force by surface when friction works

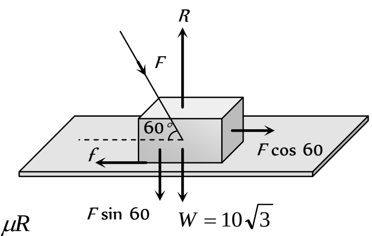
$F = \sqrt{f^2 + R^2} = \sqrt{(\mu R)^2 + R^2} = R\sqrt{\mu^2 + 1}$

Minimum force $= R$ when there is no friction

Hence ranging from R to $R\sqrt{\mu^2 + 1}$

We get, $Mg \le F \le Mg\sqrt{\mu^2 + 1}$

5. (a)



$f = \mu R$

$F\cos 60° = \mu(W + F\sin 60°)$

Substituting $\mu = \frac{1}{2\sqrt{3}}$ & $W = 10\sqrt{3}$ we get $F = 20N$

6. (b) When two blocks performs simple harmonic motion together then at the extreme position (at amplitude $= A$)

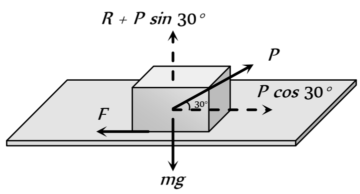
Restoring force $F = KA = 2ma \Rightarrow a = \frac{KA}{2m}$

There will be no relative motion between P and Q if pseudo force on block P is less than or just equal to limiting friction between P and Q.

i.e. $m\left(\frac{KA}{2m}\right)$ = Limiting friction

$\therefore$ Maximum friction $= \frac{KA}{2}$

7. (c) Normal reaction $R = mg - P\sin 30^o = mg - \frac{P}{2}$



$\therefore$ Limiting friction between body and surface is given by, $F = \mu R = \mu\left(mg - \frac{P}{2}\right)$.

8. (a) Limiting friction between block and slab $= \mu_s m_A g$

$$= 0.6 \times 10 \times 9.8 = 58.8 N$$

But applied force on block A is 100 N. So the block will slip over a slab.

Now kinetic friction works between block and slab $F_k = \mu_k m_A g = 0.4 \times 10 \times 9.8 = 39.2\ N$

This kinetic friction helps to move the slab

$\therefore$ Acceleration of slab $= \frac{39.2}{m_B} = \frac{39.2}{40} = 0.98\ m/s^2$

9. (a) Limiting friction $F_l = \mu\, mg \cos\theta$

$F_l = 0.7 \times 2 \times 10 \times \cos 30° = 12\ N$ (approximately)

But when the block is lying on the inclined plane then component of weight down the plane $= mg \sin\theta$

$$= 2 \times 9.8 \times \sin 30° = 9.8\ N$$

It means the body is stationary, so static friction will work on it

$\therefore$ Static friction = Applied force = 9.8 N

10. (a,c) In cycling, the rear wheel moves by the force communicated to it by pedalling while front wheel moves by it self. So, while pedalling a bicycle, the force exerted by rear wheel on ground makes force of friction act on it in the forward direction (like walking). Front wheel moving by itself experience force of friction in backward direction (like rolling of a ball). [However, if pedalling is stopped both wheels move by themselves and so experience force of friction in backward direction].

11. (a)

Assertion & Reason

1. (a) On a rainy day, the roads are wet. Wetting of roads lowers the coefficient of friction between the tyres and the road. Therefore, grip of car on the road reduces and thus chances of skidding increases.

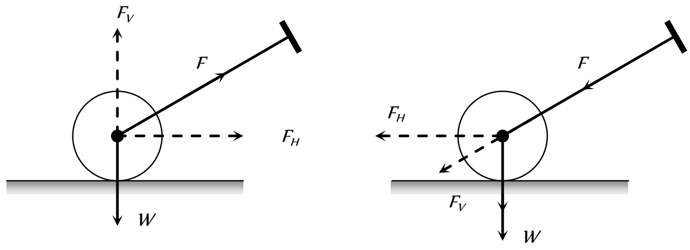
2. (e) When a bicycle is in motion, two cases may arise :

(i) When the bicycle is being pedalled. In this case, the applied force has been communicated to rear wheel. Due to which the rear wheel pushes the earth backwards. Now the force of friction acts in the forward direction on the rear wheel but front wheel move forward due to inertia, so force of friction works on it in backward direction

(ii) When the bicycle is not being pedalled :

In this case both the wheels move in forward direction, due to inertia. Hence force of friction on both the wheels acts in backward direction.

3. (a) Suppose the roller is pushed as in figure (b). The force F is resolved into two components, horizontal component F_H which helps the roller to move forward, and the vertical component acting downwards adds to the weight. Thus weight is increased. But in the case of pull [fig (a)] the vertical component is opposite to its weight. Thus weight is reduced. So pulling is easier than pushing the lawn roller.



(a) (b)

4. (b)

5. (d) The force acting on the body of mass M are its weight Mg acting vertically downwards and air resistance F acting vertically upward.

$\therefore$ Acceleration of the body, $a = \frac{Mg - F}{M} = g - \frac{F}{M}$

Now, $M > m$, therefore, the body with larger mass will have greater acceleration and it will reach the ground first.

6. (d) Only static friction is a self adjusting force. This is because force of static friction is equal and opposite to applied force (so long as actual motion does not start). Frictional force = μmg *i.e.* friction depends on mass.

7. (a)

8. (d) Acceleration down a rough inclined plane

$a = g(\sin\theta - \mu \cos\theta)$ and this is less than g.

Friction

SET Self Evaluation Test -5

1. A force of 19.6 N when applied parallel to the surface just moves a body of mass 10 kg kept on a horizontal surface. If a 5 kg mass is kept on the first mass, the force applied parallel to the surface to just move the combined body is

(a) 29.4 N (b) 39.2 N

(c) 18.6 N (d) 42.6 N

2. If the normal force is doubled, the coefficient of friction is

(a) Not changed (b) Halved

(c) Doubled (d) Tripled

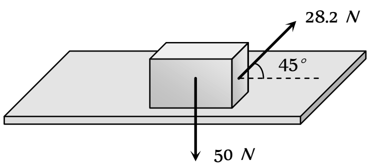
3. A body of weight 50 N placed on a horizontal surface is just moved by a force of 28.2 N. The frictional force and the normal reaction are

(a) 10 N, 15 N

(b) 20 N, 30 N

(c) 2 N, 3 N

(d) 5 N, 6 N



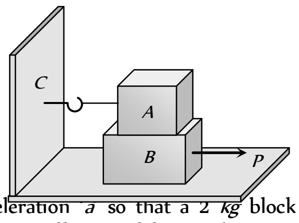
4. Block A weighing 100 kg rests on a block B and is tied with a horizontal string to the wall at C. Block B weighs 200 kg. The coefficient of friction between A and B is 0.25 and between B and the surface is 1/3. The horizontal force P necessary to move the block B should be $(g = 10\, m/s^2)$

(a) 1150 N

(b) 1250 N

(c) 1300 N

(d) 1420 N



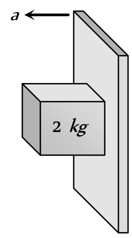
5. A rough vertical board has an acceleration 'a' so that a 2 kg block pressing against it does not fall. The coefficient of friction between the block and the board should be

(a) $> g/a$

(b) $< g/a$

(c) $= g/a$

(d) $> a/g$



6. A stone weighing 1 kg and sliding on ice with a velocity of 2 m/s is stopped by friction in 10 sec. The force of friction (assuming it to be constant) will be

(a) $-20\, N$ (b) $-0.2\, N$

(c) 0.2 N (d) 20 N

7. A body of mass 10 kg slides along a rough horizontal surface. The coefficient of friction is $1/\sqrt{3}$. Taking $g = 10\, m/s^2$, the least force which acts at an angle of 30° to the horizontal is

(a) 25 N (b) 100 N

(c) 50 N (d) $\frac{50}{\sqrt{3}} N$

8. A lift is moving downwards with an acceleration equal to acceleration due to gravity. A body of mass M kept on the floor of the lift is pulled horizontally. If the coefficient of friction is μ, then the frictional resistance offered by the body is

(a) Mg (b) μMg

(c) $2\mu Mg$ (d) Zero

9. In the above question, if the lift is moving upwards with a uniform velocity, then the frictional resistance offered by the body is

(a) Mg (b) μMg

(c) $2\mu Mg$ (d) Zero

10. A body of mass 2 kg is moving on the ground comes to rest after some time. The coefficient of kinetic friction between the body and the ground is 0.2. The retardation in the body is

(a) $9.8\, m/s^2$ (b) $4.73\, m/s^2$

(c) $2.16\, m/s^2$ (d) $1.96\, m/s^2$

11. A cyclist moves in a circular track of radius 100 m. If the coefficient of friction is 0.2, then the maximum velocity with which the cyclist can take the turn with leaning inwards is

(a) 9.8 m/s (b) 1.4 m/s

(c) 140 m/s (d) 14 m/s

12. A block of mass 5 kg lies on a rough horizontal table. A force of 19.6 N is enough to keep the body sliding at uniform velocity. The coefficient of sliding friction is

(a) 0.5 (b) 0.2

(c) 0.4 (d) 0.8

13. A motor car has a width 1.1 m between wheels. Its centre of gravity is 0.62 m above the ground and the coefficient of friction between the wheels and the road is 0.8. What is the maximum possible speed, if the centre of gravity inscribes a circle of radius 15 m ? (Road surface is horizontal)

(a) 7.64 m/s (b) 6.28 m/s

(c) 10.84 m/s (d) 11.23 m/s

14. A child weighing 25 kg slides down a rope hanging from the branch of a tall tree. If the force of friction acting against him is 2 N, what is the acceleration of the child (Take $g = 9.8\, m/s^2$)

(a) $22.5\, m/s^2$ (b) $8\, m/s^2$

(c) $5\, m/s^2$ (d) $9.72\, m/s^2$

AS Answers and Solutions

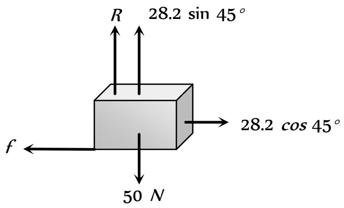
(SET -5)

1. (a) $F_l \propto R \quad \therefore \quad F_l \propto m$ *i.e.* limiting friction depends upon the mass of body. So, $\frac{(F_l)'}{(F_l)} = \frac{m'}{m} = \frac{10+5}{10}$

$\Rightarrow (F_l)' = \frac{3}{2} \times F_l = \frac{3}{2} \times 19.6 = 29.4\ N$

2. (a) Coefficient of friction is constant for two given surface in contact. It does not depend upon the weight or normal reaction.

3. (b)



Frictional force = $f = 28.2 \cos 45° = 28.2 \times \frac{1}{\sqrt{2}} = 20\ N$

Normal reaction $R = 50 - 28.2 \sin 45° = 30\ N$

4. (b) Friction between block *A* and block *B* & between block *B* and surface will oppose the *P*

$\therefore\ P = F_{AB} + F_{BS} = \mu_{AB} m_A g + \mu_{BS}(m_A + m_B) g$

$= 0.25 \times 100 \times 10 + \frac{1}{3}(100 + 200) \times 10 = 1250\ N$

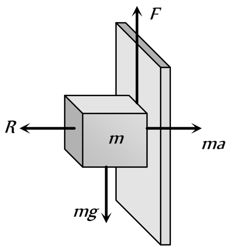
5. (a) For the limiting condition upward friction force between board and block will balance the weight of the block.

i.e. $F > mg$

$\Rightarrow \mu(R) > mg$

$\Rightarrow \mu(ma) > mg$

$\Rightarrow \mu > \frac{g}{a}$



6. (b) $u = 2\ m/s, v = 0, t = 10$ sec

$\therefore\ a = \frac{v-u}{t} = \frac{0-2}{10} = -\frac{2}{10} = -\frac{1}{5} = -0.2\ m/s^2$

$\therefore$ Friction force $= ma = 1 \times (-0.2) = -0.2\ N$

7. (c) Let *P* force is acting at an angle 30° with the horizontal.

For the condition of motion $F = \mu R$

$P \cos 30° = \mu(mg - P \sin 30°)$

$\Rightarrow P\frac{\sqrt{3}}{2} = \frac{1}{\sqrt{3}}\left(100 - P\frac{1}{2}\right) \Rightarrow \frac{3P}{2} = \left(100 - \frac{P}{2}\right)$

$\Rightarrow 2P = 100 \quad \therefore\ P = 50\ N$

8. (d) $R = m(g - a)$ for downward motion of lift

If $a = g$ then $R = 0 \quad \therefore\ F = \mu R = 0$

9. (b) When the lift is moving upward with constant velocity then, $R = mg \quad \therefore\ F = \mu R = \mu mg$

10. (d) We know that $a = \mu g = 0.2 \times 9.8 = 1.96\ m/s^2$

11. (d) $v = \sqrt{\mu r g} = \sqrt{0.2 \times 100 \times 10} = 10\sqrt{2} = 14\ m/s$

12. (c) $\mu_k = \frac{F}{R} = \frac{19.6}{5 \times 9.8} = \frac{2}{5} = 0.4$

13. (c) $v = \sqrt{\mu g r} = \sqrt{0.8 \times 9.8 \times 15} = 10.84\ m/s$

14. (d) Net downward force = Weight – Friction

$\therefore\ ma = 25 \times 9.8 - 2 \Rightarrow a = \frac{25 \times 9.8 - 2}{25} = 9.72\ m/s^2$

***

Chapter 6

Work, Energy, Power and Collision

Introduction

The terms 'work', 'energy' and 'power' are frequently used in everyday language. A farmer clearing weeds in his field is said to be working hard. A woman carrying water from a well to her house is said to be working. In a drought affected region she may be required to carry it over large distances. If she can do so, she is said to have a large stamina or energy. Energy is thus the capacity to do work. The term power is usually associated with speed. In karate, a powerful punch is one delivered at great speed. In physics we shall define these terms very precisely. We shall find that there is a loose correlation between the physical definitions and the physiological pictures these terms generate in our minds.

Work is said to be done when a force applied on the body displaces the body through a certain distance in the direction of force.

Work Done by a Constant Force

Let a constant force $\vec{F}$ be applied on the body such that it makes an angle θ with the horizontal and body is displaced through a distance s

By resolving force $\vec{F}$ into two components :

(i) $F\cos\theta$ in the direction of displacement of the body.

(ii) $F\sin\theta$ in the perpendicular direction of displacement of the body.

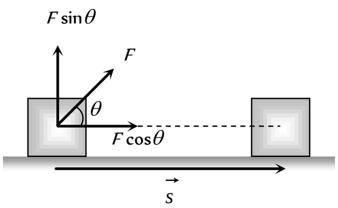


Fig. 6.1

Since body is being displaced in the direction of $F\cos\theta$, therefore work done by the force in displacing the body through a distance s is given by

$$W = (F\cos\theta)s = Fs\cos\theta$$

or $W = \vec{F}.\vec{s}$

Thus work done by a force is equal to the scalar (or dot product) of the force and the displacement of the body.

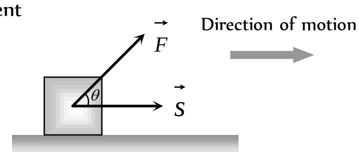
If a number of forces $\vec{F}_1, \vec{F}_2, \vec{F}_3 ...... \vec{F}_n$ are acting on a body and it shifts from position vector $\vec{r}_1$ to position vector $\vec{r}_2$ then

$$W = (\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... \vec{F}_n).(\vec{r}_2 - \vec{r}_1)$$

Nature of Work Done

Positive work

Positive work means that force (or its component) is parallel to displacement



$$0^o \le \theta < 90^o$$

Fig. 6.2

The positive work signifies that the external force favours the motion of the body.

Example: (i) When a person lifts a body from the ground, the work done by the (upward) lifting force is positive

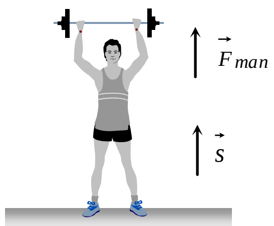


Fig. 6.3

(ii) When a lawn roller is pulled by applying a force along the handle at an acute angle, work done by the applied force is positive.

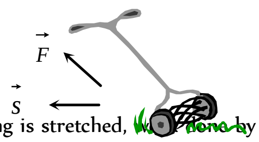


Fig. 6.4

(iii) When a spring is stretched, work done by the external (stretching) force is positive.

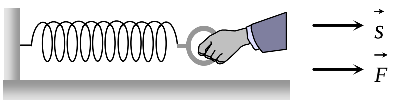
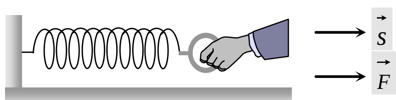


Fig. 6.5



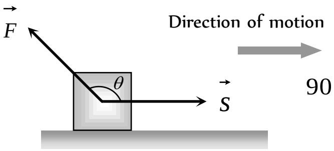
Maximum work : $W_{\max} = F\,s$

When $\cos\theta = \text{maximum} = 1$ *i.e.* $\theta = 0^o$

It means force does maximum work when angle between force and displacement is zero.

Negative work

Negative work means that force (or its component) is opposite to displacement *i.e.*



$90^o < \theta \le 180^o$

Fig. 6.6

The negative work signifies that the external force opposes the motion of the body.

Example: (i) When a person lifts a body from the ground, the work done by the (downward) force of gravity is negative.

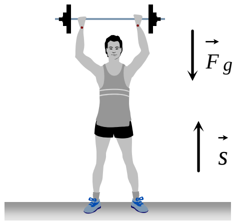


Fig. 6.7

(ii) When a body is moved over a rough surface, the work done by the frictional force is negative.

Minimum work : $W_{\min} = -F\,s$

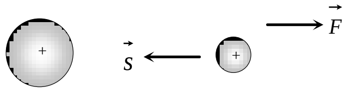


Fig. 6.8

When $\cos\theta = \text{minimum} = -1$ *i.e* $\theta = 180^o$

It means force does minimum [maximum negative] work when angle between force and displacement is 180°.

(iii) When a positive charge is moved towards another positive charge. The work done by electrostatic force between them is negative.

Zero work

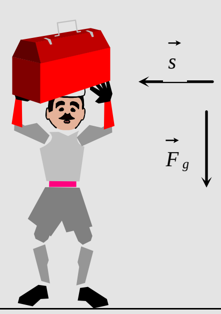
Under three condition, work done becomes zero $W = Fs\cos\theta = 0$

(1) **If the force is perpendicular to the displacement** $[\vec{F} \perp \vec{s}\,]$

Example: (i) When a coolie travels on a horizontal platform with a load on his head, work done against gravity by the coolie is zero.

(ii) When a body moves in a circle the work done by the centripetal force is always zero.

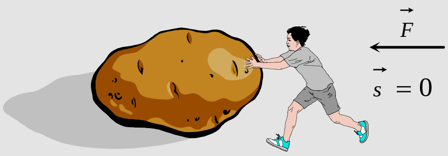
(iii) In case of motion of a charged particle in a magnetic field as force $[\vec{F} = q(\vec{v} \times \vec{B})]$ is always perpendicular to motion, work done by this force is always zero.



(2) **If there is no displacement** [s = 0]

Example: (i) When a person tries to displace a wall or heavy stone by applying a force and it does not move, then work done is zero.

(ii) A weight lifter does work in lifting the weight off the ground but does not work in holding it up.



(3) **If there is no force acting on the body** [F = 0]

Example: Motion of an isolated body in free space.

Work Done by a Variable Force

When the magnitude and direction of a force varies with position, the work done by such a force for an infinitesimal displacement is given by $dW = \vec{F}.d\vec{s}$

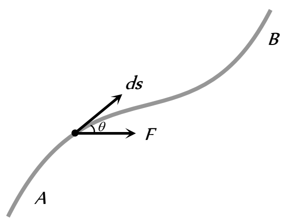


Fig. 6.9

The total work done in going from A to B as shown in the figure is

$W = \int_A^B \vec{F}.d\vec{s} = \int_A^B (F\cos\theta)ds$

In terms of rectangular component $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$

$d\vec{s} = dx\hat{i} + dy\hat{j} + dz\hat{k}$

$\therefore\ W = \int_A^B (F_x\hat{i} + F_y\hat{j} + F_z\hat{k}).(dx\hat{i} + dy\hat{j} + dz\hat{k})$

or $W = \int_{x_A}^{x_B} F_x\,dx + \int_{y_A}^{y_B} F_y\,dy + \int_{z_A}^{z_B} F_z\,dz$

Dimension and Units of Work

Dimension : As work = Force × displacement

$$[W]=[MLT^{-2}]\times[L]=[ML^2T^{-2}]$$

Units : The units of work are of two types

Absolute units	Gravitational units
Joule [S.I.]: Work done is said to be one *Joule*, when 1 *Newton* force displaces the body through 1 *metre* in its own direction. From, $W = F.s$ 1 *Joule* = 1 *Newton* ×1 *m*	*kg-m* [S.I.]: 1 *kg-m* of work is done when a force of 1*kg-wt.* displaces the body through 1*m* in its own direction. From $W = F\,s$ 1 *kg-m* = 1 *kg-wt* × 1 *m* = 9.81 *N* × 1 *metre* = 9.81 *Joule*
erg [C.G.S.] : Work done is said to be one *erg* when 1 *dyne* force displaces the body through 1 *cm* in its own direction. From $W = F\,s$ $1\,erg = 1 dyne \times 1cm$ **Relation between Joule and erg** 1 *Joule* = 1 *N* × 1 *m* = 10^5 *dyne* × 10^2 *cm* = 10^7 *dyne* × *cm* = 10^7 *erg*	*gm-cm* [C.G.S.] : 1 *gm-cm* of work is done when a force of 1*gm-wt* displaces the body through 1*cm* in its own direction. From $W = F\,s$ 1 *gm-cm* = 1*gm-wt* × 1*cm.* = 981 *dyne* × 1*cm* = 981 *erg*

Work Done Calculation by Force Displacement Graph

Let a body, whose initial position is x_i, is acted upon by a variable force (whose magnitude is changing continuously) and consequently the body acquires its final position x_f.

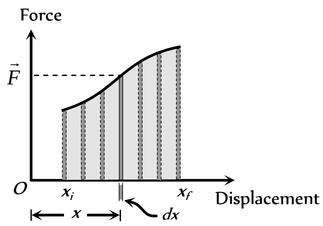


Fig. 6.10

Let F be the average value of variable force within the interval dx from position x to $(x + dx)$ *i.e.* for small displacement dx. The work done will be the area of the shaded strip of width dx. The work done on the body in displacing it from position x_i to x_f will be equal to the sum of areas of all the such strips

$$dW=\vec{F}\,dx$$

$$\therefore W=\int_{x_i}^{x_f}dW=\int_{x_i}^{x_f}F\,dx$$

$$\therefore W=\int_{x_i}^{x_f}(\text{Area of strip of width } dx)$$

$$\therefore W=\text{Area under curve between } x_i \text{ and } x_f$$

i.e. Area under force-displacement curve with proper algebraic sign represents work done by the force.

Work Done in Conservative and Non-conservative Field

(1) In conservative field, work done by the force (line integral of the force *i.e.* $\int\vec{F}.\vec{dl}$) is independent of the path followed between any two points.

$$\underset{\text{Path I}}{W_{A\rightarrow B}}=\underset{\text{Path II}}{W_{A\rightarrow B}}=\underset{\text{Path III}}{W_{A\rightarrow B}}$$

or $$\underset{\text{Path I}}{\int\vec{F}.\vec{dl}}=\underset{\text{Path II}}{\int\vec{F}.\vec{dl}}=\underset{\text{Path III}}{\int\vec{F}.\vec{dl}}$$

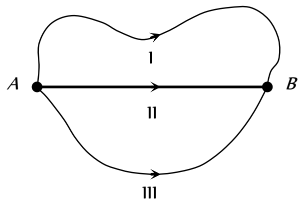


Fig. 6.11

(2) In conservative field work done by the force (line integral of the force *i.e.* $\int\vec{F}.\vec{dl}$) over a closed path/loop is zero.

$$W_{A\rightarrow B}+W_{B\rightarrow A}=0$$

or $$\oint\vec{F}.\vec{dl}=0$$

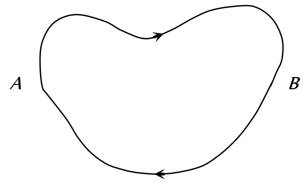


Fig. 6.12

Conservative force : The forces of these type of fields are known as conservative forces.

Example : Electrostatic forces, gravitational forces, elastic forces, magnetic forces *etc* and all the central forces are conservative in nature.

If a body of mass m lifted to height h from the ground level by different path as shown in the figure

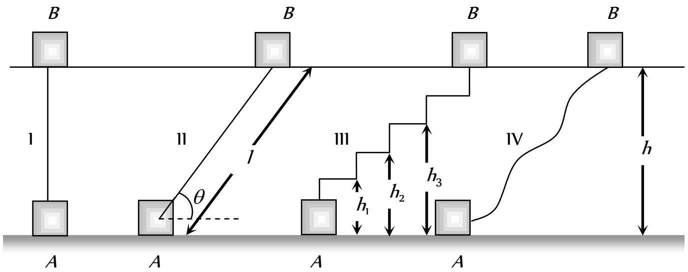


Fig. 6.13

Work done through different paths

$$W_I=F.s=mg\times h=mgh$$

$$W_{II}=F.s=mg\sin\theta\times l=mg\sin\theta\times\frac{h}{\sin\theta}=mgh$$

$$W_{III}=mgh_1+0+mgh_2+0+mgh_3+0+mgh_4$$

$$=mg(h_1+h_2+h_3+h_4)=mgh$$

$$W_{IV}=\int\vec{F}.\vec{ds}=mgh$$

It is clear that $W_I=W_{II}=W_{III}=W_{IV}=mgh$.

Further if the body is brought back to its initial position A, similar amount of work (energy) is released from the system, it means $W_{AB}=mgh$ and $W_{BA}=-mgh$.

Hence the net work done against gravity over a round trip is zero.

$$W_{Net}=W_{AB}+W_{BA}=mgh+(-mgh)=0$$

i.e. the gravitational force is conservative in nature.

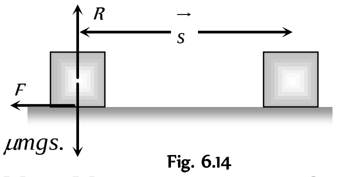
Non-conservative forces : A force is said to be non-conservative if work done by or against the force in moving a body from one position to another, depends on the path followed between these two positions and for complete cycle this work done can never be zero.

Example: Frictional force, Viscous force, Airdrag *etc.*

If a body is moved from position *A* to another position *B* on a rough table, work done against frictional force shall depend on the length of the path between *A* and *B* and not only on the position *A* and *B.*

$$W_{AB} = \mu mgs$$

Further if the body is brought back to its initial position *A*, work has to be done against the frictional force, which opposes the motion. Hence the net work done against the friction over a round trip is not zero.



$W_{BA} = \mu mgs.$

Fig. 6.14

$\therefore W_{Net} = W_{AB} + W_{BA} = \mu mgs + \mu mgs = 2\mu mgs \neq 0.$

i.e. the friction is a non-conservative force.

Work Depends on Frame of Reference

With change of frame of reference (inertial), force does not change while displacement may change. So the work done by a force will be different in different frames.

Examples : (1) If a porter with a suitcase on his head moves up a staircase, work done by the upward lifting force relative to him will be zero (as displacement relative to him is zero) while relative to a person on the ground will be *mgh.*

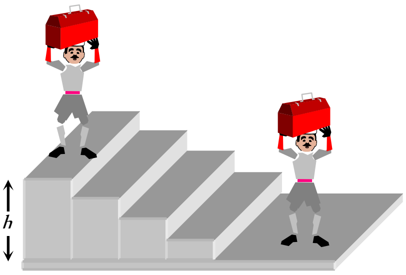


Fig. 6.15

(2) If a person is pushing a box inside a moving train, the work done in the frame of train will $\vec{F}.\vec{s}$ while in the frame of earth will be $\vec{F}.(\vec{s} + \vec{s}_0)$ where $\vec{s}_0$ is the displacement of the train relative to the ground.

Energy

The energy of a body is defined as its capacity for doing work.

(1) Since energy of a body is the total quantity of work done, therefore it is a scalar quantity.

(2) Dimension: $[ML^2T^{-2}]$ it is same as that of work or torque.

(3) Units : *Joule* [S.I.], *erg* [C.G.S.]

Practical units : *electron volt* (*eV*), Kilowatt hour (*KWh*), Calories (*cal*)

Relation between different units:

1 *Joule* = 10^7 *erg*

1 *eV* = 1.6×10^{-19} *Joule*

1 *kWh* = 3.6×10^6 *Joule*

1 *calorie* = 4.18 *Joule*

(4) Mass energy equivalence : Einstein's special theory of relativity shows that material particle itself is a form of energy.

The relation between the mass of a particle *m* and its equivalent energy is given as

$E = mc^2$ where *c* = velocity of light in vacuum.

If $m = 1\,amu = 1.67 \times 10^{-27}\,kg$

then $E = 931\,MeV = 1.5 \times 10^{-10}\,Joule$.

If $m = 1kg$ then $E = 9 \times 10^{16}\,Joule$

Examples : (i) Annihilation of matter when an electron (e^-) and a positron (e^+) combine with each other, they annihilate or destroy each other. The masses of electron and positron are converted into energy. This energy is released in the form of γ -rays.

$$e^- + e^+ \rightarrow \gamma + \gamma$$

Each γ photon has energy = 0.51 *MeV.*

Here two γ photons are emitted instead of one γ photon to conserve the linear momentum.

(ii) Pair production : This process is the reverse of annihilation of matter. In this case, a photon (γ) having energy equal to 1.02 *MeV* interacts with a nucleus and give rise to electron (e^-) and positron (e^+). Thus energy is converted into matter.

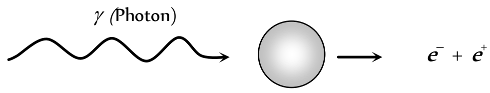


Fig. 6.16

(iii) Nuclear bomb : When the nucleus is split up due to mass defect (The difference in the mass of nucleons and the nucleus), energy is released in the form of γ -radiations and heat.

(5) Various forms of energy

(i) Mechanical energy (Kinetic and Potential)

(ii) Chemical energy

(iii) Electrical energy

(iv) Magnetic energy

(v) Nuclear energy

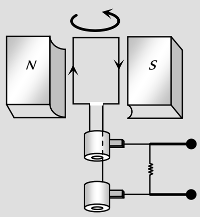
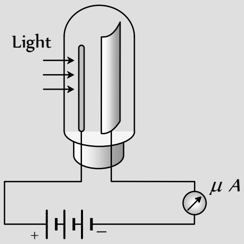
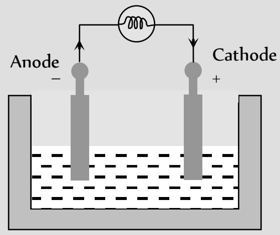
(vi) Sound energy

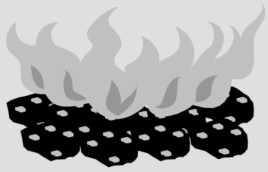
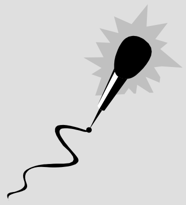
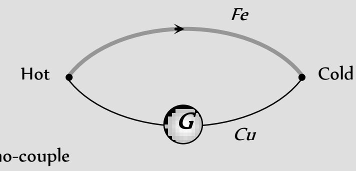
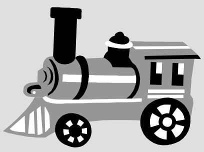
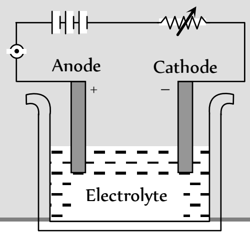
(vii) Light energy

(viii) Heat energy

(6) Transformation of energy : Conversion of energy from one form to another is possible through various devices and processes.

Table : 6.1 Various devices for energy conversion from one form to another

Mechanical → electrical	Light → Electrical	Chemical → electrical
Dynamo 	Photoelectric cell 	Primary cell 

Chemical → heat	Sound → Electrical	Heat → electrical
Coal Burning 	Microphone 	Thermo-couple 
Heat → Mechanical	**Electrical → Mechanical**	**Electrical → Heat**
Engine 	Motor 	Heater 
Electrical → Sound	**Electrical → Chemical**	**Electrical → Light**
Speaker 	Voltameter 	Bulb 

Kinetic Energy

The energy possessed by a body by virtue of its motion, is called kinetic energy.

Examples : (i) Flowing water possesses kinetic energy which is used to run the water mills.

(ii) Moving vehicle possesses kinetic energy.

(iii) Moving air (*i.e.* wind) possesses kinetic energy which is used to run wind mills.

(iv) The hammer possesses kinetic energy which is used to drive the nails in wood.

(v) A bullet fired from the gun has kinetic energy and due to this energy the bullet penetrates into a target.

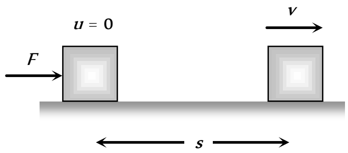


Fig. 6.17

(1) **Expression for kinetic energy :**

Let m = mass of the body,

u = Initial velocity of the body (= 0)

F = Force acting on the body,

a = Acceleration of the body,

s = Distance travelled by the body,

v = Final velocity of the body

From $v^2 = u^2 + 2as$

$$\Rightarrow v^2 = 0 + 2as \quad \therefore s = \frac{v^2}{2a}$$

Since the displacement of the body is in the direction of the applied force, then work done by the force is

$$W = F \times s = ma \times \frac{v^2}{2a}$$

$$\Rightarrow W = \frac{1}{2}mv^2$$

This work done appears as the kinetic energy of the body $KE = W = \frac{1}{2}mv^2$

(2) **Calculus method :** Let a body is initially at rest and force $\vec{F}$ is applied on the body to displace it through small displacement $d\vec{s}$ along its own direction then small work done

$$dW = \vec{F}.d\vec{s} = F\,ds$$

$$\Rightarrow \quad dW = m\,a\,ds \qquad [\text{As } F = ma]$$

$$\Rightarrow \quad dW = m\frac{dv}{dt}ds \qquad \left[\text{As } a = \frac{dv}{dt}\right]$$

$$\Rightarrow dW = mdv.\frac{ds}{dt}$$

$$\Rightarrow dW = m\,v\,dv \qquad ...(i)$$

$$\left[As\ \frac{ds}{dt} = v\right]$$

Therefore work done on the body in order to increase its velocity from zero to v is given by

$$W = \int_0^v mv\,dv = m\int_0^v v\,dv = m\left[\frac{v^2}{2}\right]_0^v = \frac{1}{2}mv^2$$

This work done appears as the kinetic energy of the body $KE = \frac{1}{2}mv^2$.

In vector form $KE = \frac{1}{2}m(\vec{v}.\vec{v})$

As m and $\vec{v}.\vec{v}$ are always positive, kinetic energy is always positive scalar *i.e.* kinetic energy can never be negative.

(3) **Kinetic energy depends on frame of reference :** The kinetic energy of a person of mass m, sitting in a train moving with speed v, is zero in the frame of train but $\frac{1}{2}mv^2$ in the frame of the earth.

(4) **Kinetic energy according to relativity :** As we know $E = \frac{1}{2}mv^2$.

But this formula is valid only for ($v << c$) If v is comparable to c (speed of light in free space = $3\times10^8\ m/s$) then according to Einstein theory of relativity

$$E = \frac{mc^2}{\sqrt{1-(v^2/c^2)}} - mc^2$$

(5) **Work-energy theorem:** From equation (i) $dW = mv\,dv$.

Work done on the body in order to increase its velocity from u to v is given by

$$W = \int_u^v mv\,dv = m\int_u^v v\,dv = m\left[\frac{v^2}{2}\right]_u^v$$

$$\Rightarrow W = \frac{1}{2}m[v^2 - u^2]$$

Work done = change in kinetic energy

$W = \Delta E$

This is work energy theorem, it states that work done by a force acting on a body is equal to the change in the kinetic energy of the body.

This theorem is valid for a system in presence of all types of forces (external or internal, conservative or non-conservative).

If kinetic energy of the body increases, work is positive *i.e.* body moves in the direction of the force (or field) and if kinetic energy decreases, work will be negative and object will move opposite to the force (or field).

Examples : (i) In case of vertical motion of body under gravity when the body is projected up, force of gravity is opposite to motion and so kinetic energy of the body decreases and when it falls down, force of gravity is in the direction of motion so kinetic energy increases.

(ii) When a body moves on a rough horizontal surface, as force of friction acts opposite to motion, kinetic energy will decrease and the decrease in kinetic energy is equal to the work done against friction.

(6) **Relation of kinetic energy with linear momentum:** As we know

$$E = \frac{1}{2}mv^2 = \frac{1}{2}\left[\frac{P}{v}\right]v^2 \qquad [\text{As } P = mv]$$

$$\therefore\ E = \frac{1}{2}Pv$$

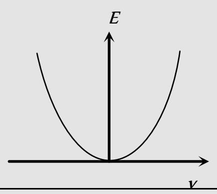
$$\text{or}\quad E = \frac{P^2}{2m} \qquad \left[\text{As } v = \frac{P}{m}\right]$$

So we can say that kinetic energy $E = \frac{1}{2}mv^2 = \frac{1}{2}Pv = \frac{p^2}{2m}$

and Momentum $P = \frac{2E}{v} = \sqrt{2mE}$

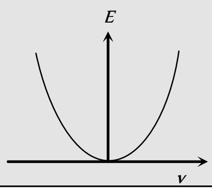
From above relation it is clear that a body can not have kinetic energy without having momentum and vice-versa.

(7) **Various graphs of kinetic energy**



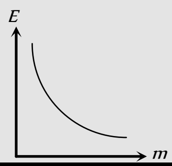
$E \propto v$

m = constant



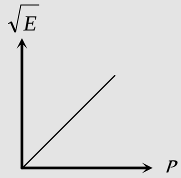
$E \propto P^2$

m = constant



$E \propto \frac{1}{m}$

P = constant



$P \propto \sqrt{E}$

m = constant

Stopping of Vehicle by Retarding Force

If a vehicle moves with some initial velocity and due to some retarding force it stops after covering some distance after some time.

(1) **Stopping distance :** Let m = Mass of vehicle,

v = Velocity, P = Momentum, E = Kinetic energy

F = Stopping force, x = Stopping distance,

t = Stopping time

Then, in this process stopping force does work on the vehicle and destroy the motion.

By the work- energy theorem

$$W = \Delta K = \frac{1}{2}mv^2$$

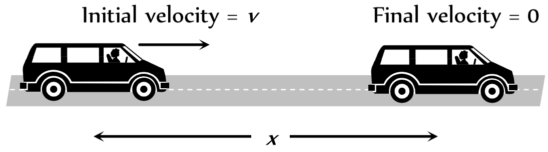


Fig. 6.18

$\Rightarrow$ Stopping force (F) × Distance (x) = Kinetic energy (E)

$\Rightarrow$ Stopping distance (x) $= \dfrac{\text{Kinetic energy } (E)}{\text{Stopping force } (F)}$

$$\Rightarrow \; x = \frac{mv^2}{2F} \qquad \text{...(i)}$$

(2) **Stopping time :** By the impulse-momentum theorem

$$F \times \Delta t = \Delta P \Rightarrow F \times t = P$$

$$\therefore \; t = \frac{P}{F}$$

$$\text{or } \; t = \frac{mv}{F} \qquad \text{...(ii)}$$

(3) **Comparison of stopping distance and time for two vehicles :** Two vehicles of masses m_1 and m_2 are moving with velocities v_1 and v_2 respectively. When they are stopped by the same retarding force (F).

The ratio of their stopping distances $\dfrac{x_1}{x_2} = \dfrac{E_1}{E_2} = \dfrac{m_1 v_1^2}{m_2 v_2^2}$

and the ratio of their stopping time $\dfrac{t_1}{t_2} = \dfrac{P_1}{P_2} = \dfrac{m_1 v_1}{m_2 v_2}$

(i) If vehicles possess same velocities

$v_1 = v_2$

$$\frac{x_1}{x_2} = \frac{m_1}{m_2} \; ; \; \frac{t_1}{t_2} = \frac{m_1}{m_2}$$

(ii) If vehicle possess same kinetic momentum

$P_1 = P_2$

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = \left(\frac{P_1^2}{2m_1}\right)\left(\frac{2m_2}{P_2^2}\right) = \frac{m_2}{m_1}$$

$$\frac{t_1}{t_2} = \frac{P_1}{P_2} = 1$$

(iii) If vehicle possess same kinetic energy

$$\frac{x_1}{x_2} = \frac{E_1}{E_2} = 1$$

$$\frac{t_1}{t_2} = \frac{P_1}{P_2} = \frac{\sqrt{2m_1E_1}}{\sqrt{2m_2E_2}} = \sqrt{\frac{m_1}{m_2}}$$

Note : ❑ If vehicle is stopped by friction then

Stopping distance $x = \dfrac{\frac{1}{2}mv^2}{F} = \dfrac{\frac{1}{2}mv^2}{ma} = \dfrac{v^2}{2\mu g}$ [As $a = \mu g$]

Stopping time $t = \dfrac{mv}{F} = \dfrac{mv}{m\mu g} = \dfrac{v}{\mu g}$

Potential Energy

Potential energy is defined only for conservative forces. In the space occupied by conservative forces every point is associated with certain energy which is called the energy of position or potential energy. Potential energy generally are of three types : Elastic potential energy, Electric potential energy and Gravitational potential energy.

(1) **Change in potential energy :** Change in potential energy between any two points is defined in the terms of the work done by the associated conservative force in displacing the particle between these two points without any change in kinetic energy.

$$U_2 - U_1 = -\int_{r_1}^{r_2} \vec{F}.d\vec{r} = -W \qquad \text{...(i)}$$

We can define a unique value of potential energy only by assigning some arbitrary value to a fixed point called the reference point. Whenever and wherever possible, we take the reference point at infinity and assume potential energy to be zero there, *i.e.* if we take $r_1 = \infty$ and $r_2 = r$ then from equation (i)

$$U = -\int_{\infty}^{r} \vec{F}.d\vec{r} = -W$$

In case of conservative force (field) potential energy is equal to negative of work done by conservative force in shifting the body from reference position to given position.

This is why, in shifting a particle in a conservative field (say gravitational or electric), if the particle moves opposite to the field, work done by the field will be negative and so change in potential energy will be positive *i.e.* potential energy will increase. When the particle moves in the direction of field, work will be positive and change in potential energy will be negative *i.e.* potential energy will decrease.

(2) **Three dimensional formula for potential energy:** For only conservative fields $\vec{F}$ equals the negative gradient $(-\vec{\nabla})$ of the potential energy.

So $\vec{F} = -\vec{\nabla}U$ ($\vec{\nabla}$ read as Del operator or Nabla operator and $\vec{\nabla} = \dfrac{\partial}{\partial x}\hat{i} + \dfrac{\partial}{\partial y}\hat{j} + \dfrac{\partial}{\partial z}\hat{k}$)

$$\Rightarrow \vec{F} = -\left[\frac{\partial U}{\partial x}\hat{i} + \frac{\partial U}{\partial y}\hat{j} + \frac{\partial U}{\partial z}\hat{k}\right]$$

where,

$\dfrac{\partial U}{\partial x}$ = Partial derivative of U *w.r.t.* x (keeping y and z constant)

$\dfrac{\partial U}{\partial y}$ = Partial derivative of U *w.r.t.* y (keeping x and z constant)

$\dfrac{\partial U}{\partial z}$ = Partial derivative of U *w.r.t.* z (keeping x and y constant)

(3) **Potential energy curve :** A graph plotted between the potential energy of a particle and its displacement from the centre of force is called potential energy curve.

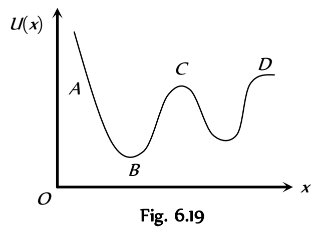


Fig. 6.19

Figure shows a graph of potential energy function $U(x)$ for one dimensional motion.

As we know that negative gradient of the potential energy gives force.

$$\therefore\ -\frac{dU}{dx} = F$$

(4) **Nature of force**

(i) Attractive force :

On increasing x, if U increases,

$\frac{dU}{dx} = \text{positive}$, then F is in negative direction

i.e. force is attractive in nature.

In graph this is represented in region *BC*.

(ii) Repulsive force :

On increasing x, if U decreases,

$\frac{dU}{dx} = \text{negative}$, then F is in positive direction

i.e. force is repulsive in nature.

In graph this is represented in region *AB*.

(iii) Zero force :

On increasing x, if U does not change,

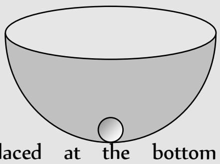
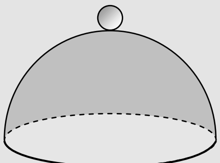
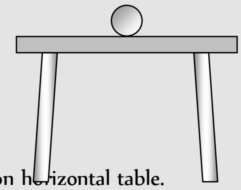
$\frac{dU}{dx} = 0$ then F is zero

i.e. no force works on the particle.

Point *B*, *C* and *D* represents the point of zero force or these points can be termed as position of equilibrium.

(5) **Types of equilibrium :** If net force acting on a particle is zero, it is said to be in equilibrium.

For equilibrium $\frac{dU}{dx} = 0$, but the equilibrium of particle can be of three types :

Stable	Unstable	Neutral
When a particle is displaced slightly from its present position, then a force acting on it brings it back to the initial position, it is said to be in stable equilibrium position.	When a particle is displaced slightly from its present position, then a force acting on it tries to displace the particle further away from the equilibrium position, it is said to be in unstable equilibrium.	When a particle is slightly displaced from its position then it does not experience any force acting on it and continues to be in equilibrium in the displaced position, it is said to be in neutral equilibrium.
Potential energy is minimum.	Potential energy is maximum.	Potential energy is constant.
$F = -\frac{dU}{dx} = 0$	$F = -\frac{dU}{dx} = 0$	$F = -\frac{dU}{dx} = 0$
$\frac{d^2U}{dx^2} = \text{positive}$ *i.e.* rate of change of $\frac{dU}{dx}$ is positive.	$\frac{d^2U}{dx^2} = \text{negative}$ *i.e.* rate of change of $\frac{dU}{dx}$ is negative.	$\frac{d^2U}{dx^2} = 0$ *i.e.* rate of change of $\frac{dU}{dx}$ is zero.
Example :  A marble placed at the bottom of a hemispherical bowl.	*Example* :  A marble balanced on top of a hemispherical bowl.	*Example* :  A marble placed on horizontal table.

Elastic Potential Energy

(1) **Restoring force and spring constant :** When a spring is stretched or compressed from its normal position ($x = 0$) by a small distance x, then a restoring force is produced in the spring to bring it to the normal position.

According to Hooke's law this restoring force is proportional to the displacement x and its direction is always opposite to the displacement.

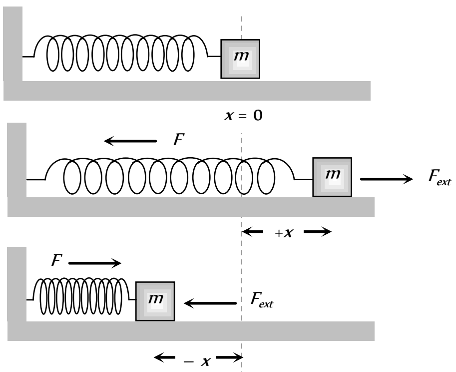


Fig. 6.20

i.e. $\vec{F} \propto -\vec{x}$

or $\vec{F} = -k\,\vec{x}$ ...(i)

where k is called spring constant.

If $x = 1$, $F = k$ (Numerically)

or $k = F$

Hence spring constant is numerically equal to force required to produce unit displacement (compression or extension) in the spring. If required force is more, then spring is said to be more stiff and vice-versa.

Actually k is a measure of the stiffness/softness of the spring.

Dimension : As $k = \frac{F}{x}$

$\therefore\ [k] = \frac{[F]}{[x]} = \frac{[MLT^{-2}]}{L} = [MT^{-2}]$

Units : S.I. unit *Newton/metre*, C.G.S unit *Dyne/cm*.

Note : ❑ Dimension of force constant is similar to surface tension.

(2) **Expression for elastic potential energy :** When a spring is stretched or compressed from its normal position (x = 0), work has to be done by external force against restoring force. $\vec{F}_{ext} = -\vec{F}_{restoring} = k\vec{x}$

Let the spring is further stretched through the distance *dx*, then work done

$$dW = \vec{F}_{ext} . d\vec{x} = F_{ext} . dx \cos 0^o = kx\ dx \quad [\text{As } \cos 0^\circ = 1]$$

Therefore total work done to stretch the spring through a distance x from its mean position is given by

$$W = \int_0^x dW = \int_0^x kx\ dx = k\left[\frac{x^2}{2}\right]_0^x = \frac{1}{2}kx^2$$

This work done is stored as the potential energy in the stretched spring.

$\therefore$ Elastic potential energy $U = \frac{1}{2}kx^2$

$$U = \frac{1}{2}Fx \qquad \left[\text{As } k = \frac{F}{x}\right]$$

$$U = \frac{F^2}{2k} \qquad \left[\text{As } x = \frac{F}{k}\right]$$

$\therefore$ Elastic potential energy $U = \frac{1}{2}kx^2 = \frac{1}{2}Fx = \frac{F^2}{2k}$

Note : ❑ If spring is stretched from initial position x_1 to final position x_2 then work done

= Increment in elastic potential energy

$= \frac{1}{2}k(x_2^2 - x_1^2)$

❑ Work done by the spring-force on the block in various situation are shown in the following table

Table : 6.2 Work done for spring

Initial state of the spring	Final state of the spring	Initial position (x_1)	Final position (x_2)	Work done (W)
Natural	Compressed	0	$-x$	$-1/2\ kx^2$
Natural	Elongated	0	x	$-1/2\ kx^2$
Elongated	Natural	x	0	$1/2\ kx^2$
Compressed	Natural	$-x$	0	$1/2\ kx^2$
Elongated	Compressed	x	$-x$	0
Compressed	Elongated	$-x$	x	0

(3) **Energy graph for a spring :** If the mass attached with spring performs simple harmonic motion about its mean position then its potential energy at any position (x) can be given by

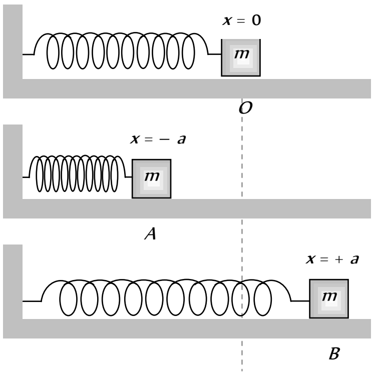


Fig. 6.21

$$U = \frac{1}{2}kx^2 \qquad \text{...(i)}$$

So for the extreme position

$$U = \frac{1}{2}ka^2 \qquad [\text{As } x = \pm a \text{ for extreme}]$$

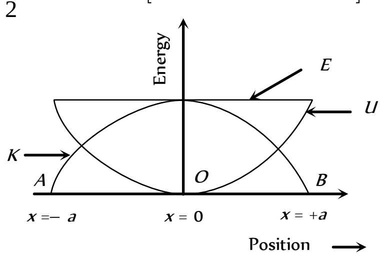


Fig. 6.22

This is maximum potential energy or the total energy of mass.

$\therefore$ Total energy $E = \frac{1}{2}ka^2$ ...(ii)

[Because velocity of mass is zero at extreme position]

$\therefore\ K = \frac{1}{2}mv^2 = 0\ ]$

Now kinetic energy at any position

$$K = E - U = \frac{1}{2}k\,a^2 - \frac{1}{2}k\,x^2$$

$$K = \frac{1}{2}k(a^2 - x^2) \qquad \text{...(iii)}$$

From the above formula we can check that

$U_{max} = \frac{1}{2}ka^2$ [At extreme $x = \pm a$]

and $U_{min} = 0$ [At mean $x = 0$]

$K_{max} = \frac{1}{2}ka^2$ [At mean $x = 0$]

and $K_{min} = 0$ [At extreme $x = \pm a$]

$E = \frac{1}{2}ka^2 =$ constant (at all positions)

It means kinetic energy and potential energy changes parabolically *w.r.t.* position but total energy remain always constant irrespective to position of the mass

Electrical Potential Energy

It is the energy associated with state of separation between charged particles that interact via electric force. For two point charge q_1 and q_2, separated by distance *r*.

$$U = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r}$$

While for a point charge *q* at a point in an electric field where the potential is *V*

$U = qV$

As charge can be positive or negative, electric potential energy can be positive or negative.

Gravitational Potential Energy

It is the usual form of potential energy and this is the energy associated with the state of separation between two bodies that interact via gravitational force.

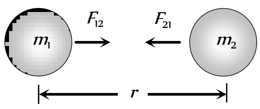


Fig. 6.23

For two particles of masses m_1 and m_2 separated by a distance *r*

Gravitational potential energy $U = -\frac{G m_1 m_2}{r}$

(1) If a body of mass *m* at height *h* relative to surface of earth then

Gravitational potential energy $U = \frac{mgh}{1 + \frac{h}{R}}$

Where *R* = radius of earth, *g* = acceleration due to gravity at the surface of the earth.

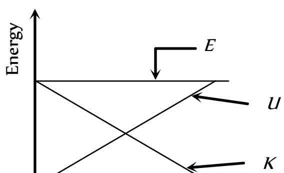
(2) If *h* << *R* then above formula reduces to $U = mgh$.

(3) If *V* is the gravitational potential at a point, the potential energy of a particle of mass *m* at that point will be

$U = mV$

(4) Energy height graph : When a body projected vertically upward from the ground level with some initial velocity then it possess kinetic energy but its initial potential energy is zero.

As the body moves upward its potential energy increases due to increase in height but kinetic energy decreases (due to decrease in velocity). At maximum height its kinetic energy becomes zero and potential energy maximum but through out the complete motion, total energy remains constant as shown in the figure.



Work Done in Pulling the Chain Against Gravity

A chain of length *L* and mass *M* is held on a frictionless table with $(1/n)^{th}$ of its length hanging over the edge.

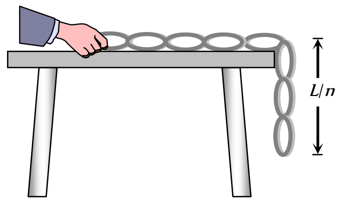


Fig. 6.25

Let $m = \frac{M}{L} =$ mass per unit length of the chain and *y* is the length of the chain hanging over the edge. So the mass of the chain of length *y* will be *ym* and the force acting on it due to gravity will be *mgy*.

The work done in pulling the *dy* length of the chain on the table.

$dW = F(-dy)$ [As *y* is decreasing]

i.e. $dW = mgy(-dy)$

So the work done in pulling the hanging portion on the table.

$$W = -\int_{L/n}^{0} mgy\,dy = -mg\left[\frac{y^2}{2}\right]_{L/n}^{0} = \frac{mg L^2}{2n^2}$$

$\therefore\ W = \frac{MgL}{2n^2}$ [As $m = M/L$]

Alternative method :

If point mass *m* is pulled through a height *h* then work done $W = mgh$

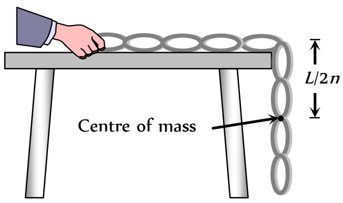


Fig. 6.26

Similarly for a chain we can consider its centre of mass at the middle point of the hanging part *i.e.* at a height of $L/(2n)$ from the lower end and mass of the hanging part of chain $= \frac{M}{n}$

So work done to raise the centre of mass of the chain on the table is given by

$W = \frac{M}{n} \times g \times \frac{L}{2n}$ [As $W = mgh$]

or $W = \frac{MgL}{2n^2}$

Velocity of Chain While Leaving the Table

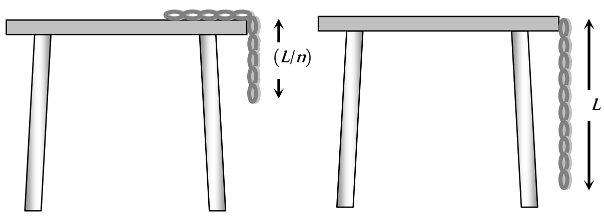


Fig. 6.27

Taking surface of table as a reference level (zero potential energy)

Potential energy of chain when $1/n$ length hanging from the edge $= \frac{-MgL}{2n^2}$

Potential energy of chain when it leaves the table $= -\frac{MgL}{2}$

Kinetic energy of chain = loss in potential energy

$$\Rightarrow \frac{1}{2}Mv^2 = \frac{MgL}{2} - \frac{MgL}{2n^2}$$

$$\Rightarrow \frac{1}{2}Mv^2 = \frac{MgL}{2}\left[1 - \frac{1}{n^2}\right]$$

$\therefore$ Velocity of chain $v = \sqrt{gL\left(1 - \frac{1}{n^2}\right)}$

Law of Conservation of Energy

(1) **Law of conservation of energy**

For a body or an isolated system by work-energy theorem we have $K_2 - K_1 = \int \vec{F}.d\vec{r}$ ....(i)

But according to definition of potential energy in a conservative field $U_2 - U_1 = -\int \vec{F}.d\vec{r}$ ....(ii)

So from equation (i) and (ii) we have

$$K_2 - K_1 = -(U_2 - U_1)$$

or $K_2 + U_2 = K_1 + U_1$

i.e. $K + U$ = constant.

For an isolated system or body in presence of conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time. This is known as the law of conservation of mechanical energy.

$$\Delta(K + U) = \Delta E = 0$$

[As E is constant in a conservative field]

$$\therefore \ \Delta K + \Delta U = 0$$

i.e. if the kinetic energy of the body increases its potential energy will decrease by an equal amount and vice-versa.

(2) **Law of conservation of total energy :** If some non-conservative force like friction is also acting on the particle, the mechanical energy is no more constant. It changes by the amount equal to work done by the frictional force.

$$\Delta(K + U) = \Delta E = W_f$$

[where W_f is the work done against friction]

The lost energy is transformed into heat and the heat energy developed is exactly equal to loss in mechanical energy.

We can, therefore, write $\Delta E + Q = 0$

[where Q is the heat produced]

This shows that if the forces are conservative and non-conservative both, it is not the mechanical energy which is conserved, but it is the total energy, may be heat, light, sound or mechanical *etc.*, which is conserved.

In other words : "*Energy may be transformed from one kind to another but it cannot be created or destroyed. The total energy in an isolated system remain constant*". This is the law of conservation of energy.

Power

Power of a body is defined as the rate at which the body can do the work.

Average power $(P_{av.}) = \frac{\Delta W}{\Delta t} = \frac{W}{t}$

Instantaneous power $(P_{inst.}) = \frac{dW}{dt} = \frac{\vec{F}.d\vec{s}}{dt}$ [As $dW = \vec{F}.d\vec{s}$]

$P_{inst} = \vec{F}.\vec{v}$ [As $\vec{v} = \frac{d\vec{s}}{dt}$]

i.e. power is equal to the scalar product of force with velocity.

Important Points

(1) Dimension : $[P] = [F][v] = [MLT^{-2}][LT^{-1}]$

$\therefore \ [P] = [ML^2T^{-3}]$

(2) Units : *Watt* or *Joule/sec* [S.I.]

Erg/sec [C.G.S.]

Practical units : *Kilowatt* (*KW*), *Mega watt* (*MW*) and Horse power (*hp*)

Relations between different units :

$1\,Watt = 1\,Joule/\sec = 10^7\,erg/\sec$

$1hp = 746\,Watt$

$1\,MW = 10^6\,Watt$

$1\,KW = 10^3\,Watt$

(3) If work done by the two bodies is same then power $\propto \frac{1}{\text{time}}$

i.e. the body which perform the given work in lesser time possess more power and vice-versa.

(4) As power = work/time, any unit of power multiplied by a unit of time gives unit of work (or energy) and not power, *i.e.* Kilowatt-hour or watt-day are units of work or energy.

$$1\,KWh = 10^3\,\frac{J}{sec} \times (60 \times 60 sec) = 3.6 \times 10^6\ Joule$$

(5) The slope of work time curve gives the instantaneous power. As $P = dW/dt = \tan\theta$

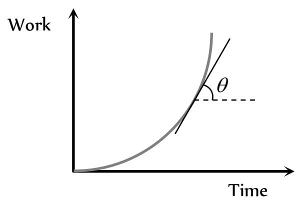


Fig. 6.28

(6) Area under power-time curve gives the work done as $P = \frac{dW}{dt}$

$\therefore \ W = \int P\,dt$

$\therefore$ W = Area under P-t curve

Position and Velocity of an Automobile w.r.t Time

An automobile of mass m accelerates, starting from rest, while the engine supplies constant power P, its position and velocity changes *w.r.t* time.

(1) **Velocity :** As $Fv = P$ = constant

i.e. $m\frac{dv}{dt}v = P$ $\left[\text{As}\,F = \frac{mdv}{dt}\right]$

or $\int v\,dv = \int \frac{P}{m} dt$

By integrating both sides we get $\frac{v^2}{2} = \frac{P}{m}t + C_1$

As initially the body is at rest *i.e.* $v = 0$ at $t = 0$, so $C_1 = 0$

$\therefore\ v = \left(\frac{2Pt}{m}\right)^{1/2}$

(2) **Position :** From the above expression $v = \left(\frac{2Pt}{m}\right)^{1/2}$

or $\frac{ds}{dt} = \left(\frac{2Pt}{m}\right)^{1/2}$ $\left[\text{As} v = \frac{ds}{dt}\right]$

i.e. $\int ds = \int \left(\frac{2Pt}{m}\right)^{1/2} dt$

By integrating both sides we get

$s = \left(\frac{2P}{m}\right)^{1/2} . \frac{2}{3} t^{3/2} + C_2$

Now as at $t = 0$, $s = 0$, so $C_2 = 0$

$s = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$

Collision

Collision is an isolated event in which a strong force acts between two or more bodies for a short time as a result of which the energy and momentum of the interacting particle change.

In collision particles may or may not come in real touch e.g. in collision between two billiard balls or a ball and bat, there is physical contact while in collision of alpha particle by a nucleus (*i.e.* Rutherford scattering experiment) there is no physical contact.

(1) **Stages of collision :** There are three distinct identifiable stages in collision, namely, before, during and after. In the before and after stage the interaction forces are zero. Between these two stages, the interaction forces are very large and often the dominating forces governing the motion of bodies. The magnitude of the interacting force is often unknown, therefore, Newton's second law cannot be used, the law of conservation of momentum is useful in relating the initial and final velocities.

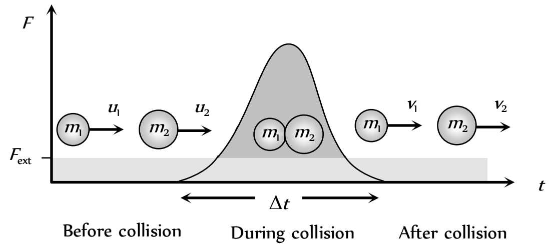


Fig. 6.29

(2) **Momentum and energy conservation in collision**

(i) Momentum conservation : In a collision, the effect of external forces such as gravity or friction are not taken into account as due to small duration of collision (Δt) average impulsive force responsible for collision is much larger than external force acting on the system and since this impulsive force is 'Internal' therefore the total momentum of system always remains conserved.

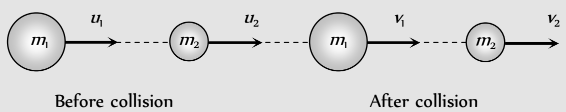
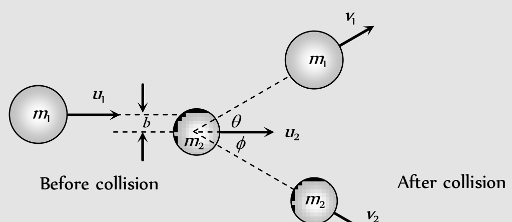
(ii) Energy conservation : In a collision 'total energy' is also always conserved. Here total energy includes all forms of energy such as mechanical energy, internal energy, excitation energy, radiant energy or even mass energy.

These laws are the fundamental laws of physics and applicable for any type of collision but this is not true for conservation of kinetic energy.

(3) **Types of collision :** (i) On the basis of conservation of kinetic energy.

Perfectly elastic collision	Inelastic collision	Perfectly inelastic collision
If in a collision, kinetic energy after collision is equal to kinetic energy before collision, the collision is said to be perfectly elastic.	If in a collision kinetic energy after collision is not equal to kinetic energy before collision, the collision is said to inelastic.	If in a collision two bodies stick together or move with same velocity after the collision, the collision is said to be perfectly inelastic.
Coefficient of restitution $e = 1$	Coefficient of restitution $0 < e < 1$	Coefficient of restitution $e = 0$
$(KE)_{final} = (KE)_{initial}$	Here kinetic energy appears in other forms. In some cases $(KE)_{final} < (KE)_{initial}$ such as when initial KE is converted into internal energy of the product (as heat, elastic or excitation) while in other cases $(KE)_{final} > (KE)_{initial}$ such as when internal energy stored in the colliding particles is released	The term 'perfectly inelastic' does not necessarily mean that all the initial kinetic energy is lost, it implies that the loss in kinetic energy is as large as it can be. (Consistent with momentum conservation).
Examples : (1) Collision between atomic particles (2) Bouncing of ball with same velocity after the collision with earth.	*Examples* : (1) Collision between two billiard balls. (2) Collision between two automobile on a road. In fact all majority of collision belong to this category.	*Example* : Collision between a bullet and a block of wood into which it is fired. When the bullet remains embedded in the block.

(ii) On the basis of the direction of colliding bodies

Head on or one dimensional collision	Oblique collision
In a collision if the motion of colliding particles before and after the collision is along the same line, the collision is said to be head on or one dimensional.	If two particle collision is 'glancing' *i.e.* such that their directions of motion after collision are not along the initial line of motion, the collision is called oblique. If in oblique collision the particles before and after collision are in same plane, the collision is called 2-dimensional otherwise 3-dimensional.
Impact parameter b is zero for this type of collision.	Impact parameter b lies between 0 and $(r_1 + r_2)$ *i.e.* $0 < b < (r_1 + r_2)$ where r_1 and r_2 are radii of colliding bodies.
	

Example : collision of two gliders on an air track.	*Example* : Collision of billiard balls.

Perfectly elastic head on collision

Let two bodies of masses m_1 and m_2 moving with initial velocities u_1 and u_2 in the same direction and they collide such that after collision their final velocities are v_1 and v_2 respectively.

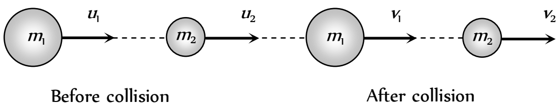


Fig. 6.30

According to law of conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \quad \text{... (i)}$$

$$\Rightarrow \quad m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{...(ii)}$$

According to law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad \text{...(iii)}$$

$$\Rightarrow \quad m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{...(iv)}$$

Dividing equation (iv) by equation (ii)

$$v_1 + u_1 = v_2 + u_2 \quad \text{...(v)}$$

$$\Rightarrow \quad u_1 - u_2 = v_2 - v_1 \quad \text{...(vi)}$$

Relative velocity of separation is equal to relative velocity of approach.

Note : ❑ The ratio of relative velocity of separation and relative velocity of approach is defined as coefficient of restitution.

$$e = \frac{v_2 - v_1}{u_1 - u_2}$$

or $\quad v_2 - v_1 = e(u_1 - u_2)$

❑ For perfectly elastic collision, $e = 1$

$\therefore \quad v_2 - v_1 = u_1 - u_2$ [As shown in eq. (vi)]

❑ For perfectly inelastic collision, $e = 0$

$\therefore \quad v_2 - v_1 = 0$ or $v_2 = v_1$

It means that two body stick together and move with same velocity.

❑ For inelastic collision, $0 < e < 1$

$\therefore \quad v_2 - v_1 = e(u_1 - u_2)$

In short we can say that e is the degree of elasticity of collision and it is dimensionless quantity.

Further from equation (v) we get

$$v_2 = v_1 + u_1 - u_2$$

Substituting this value of v_2 in equation (i) and rearranging

we get, $$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2} \quad \text{...(vii)}$$

Similarly we get,

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2} \quad \text{...(viii)}$$

(1) **Special cases of head on elastic collision**

(i) **If projectile and target are of same mass *i.e.* $m_1 = m_2$**

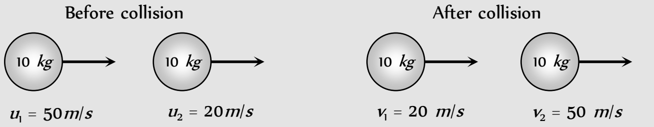
Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2}{m_1 + m_2}u_2$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

Substituting $m_1 = m_2$ we get

$v_1 = u_2$ and $v_2 = u_1$

It means when two bodies of equal masses undergo head on elastic collision, their velocities get interchanged.

Example : Collision of two billiard balls



Sub case : $u_2 = 0$ *i.e.* target is at rest

$v_1 = 0$ and $v_2 = u_1$

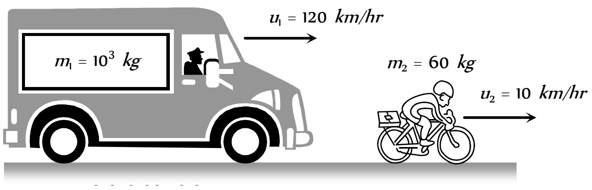
(ii) **If massive projectile collides with a light target *i.e.* $m_1 >> m_2$**

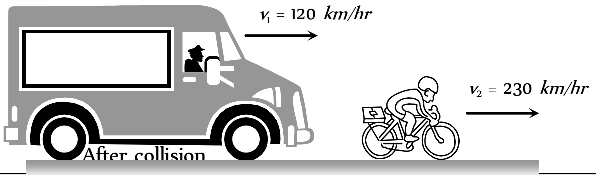
Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

Substituting $m_2 = 0$, we get

$v_1 = u_1$ and $v_2 = 2u_1 - u_2$

Example : Collision of a truck with a cyclist





Sub case : $u_2 = 0$ i.*e.* target is at rest

$v_1 = u_1$ and $v_2 = 2u_1$

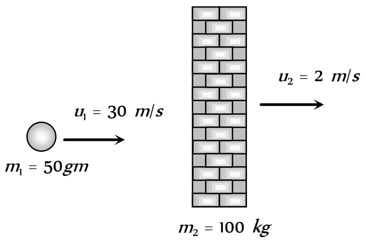
(iii) If light projectile collides with a very heavy target *i.e.* $m_1 << m_2$

Since $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$ and $v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2 + \frac{2m_1u_1}{m_1 + m_2}$

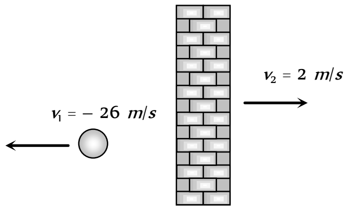
Substituting $m_1 = 0$, we get

$v_1 = -u_1 + 2u_2$ and $v_2 = u_2$

Example : Collision of a ball with a massive wall.



Before collision



After collision

Sub case : $u_2 = 0$ i.e. target is at rest

$v_1 = -u_1$ and $v_2 = 0$

i.e. the ball rebounds with same speed in opposite direction when it collide with stationary and very massive wall.

(2) **Kinetic energy transfer during head on elastic collision**

Kinetic energy of projectile before collision $K_i = \frac{1}{2}m_1u_1^2$

Kinetic energy of projectile after collision $K_f = \frac{1}{2}m_1v_1^2$

Kinetic energy transferred from projectile to target ΔK = decrease in kinetic energy in projectile

$$\Delta K = \frac{1}{2}m_1u_1^2 - \frac{1}{2}m_1v_1^2 = \frac{1}{2}m_1(u_1^2 - v_1^2)$$

Fractional decrease in kinetic energy

$$\frac{\Delta K}{K} = \frac{\frac{1}{2}m_1(u_1^2 - v_1^2)}{\frac{1}{2}m_1u_1^2} = 1 - \left(\frac{v_1}{u_1}\right)^2 \quad \text{...(i)}$$

We can substitute the value of v_1 from the equation

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$$

If the target is at rest *i.e.* u_2 = 0 then $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$

From equation (i) $\frac{\Delta K}{K} = 1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$ ...(ii)

or $\frac{\Delta K}{K} = \frac{4m_1m_2}{(m_1 + m_2)^2}$ ...(iii)

or $\frac{\Delta K}{K} = \frac{4m_1m_2}{(m_1 - m_2)^2 + 4m_1m_2}$ ...(iv)

Note : ❑ Greater the difference in masses, lesser will be transfer of kinetic energy and vice versa

❑ Transfer of kinetic energy will be maximum when the difference in masses is minimum

i.e. $m_1 - m_2 = 0$ or $m_1 = m_2$ then

$$\frac{\Delta K}{K} = 1 = 100\%$$

So the transfer of kinetic energy in head on elastic collision (when target is at rest) is maximum when the masses of particles are equal i.e. mass ratio is 1 and the transfer of kinetic energy is 100%.

❑ If $m_2 = n\, m_1$ then from equation (iii) we get

$$\frac{\Delta K}{K} = \frac{4n}{(1+n)^2}$$

❑ Kinetic energy retained by the projectile

$$\left(\frac{\Delta K}{K}\right)_{\text{Retained}} = 1 - \text{ kinetic energy transferred by projectile}$$

$$\Rightarrow \left(\frac{\Delta K}{K}\right)_{\text{Retained}} = 1 - \left[1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2\right] = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2$$

(3) **Velocity, momentum and kinetic energy of stationary target after head on elastic collision**

(i) Velocity of target : We know

$$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) u_2 + \frac{2 m_1 u_1}{m_1 + m_2}$$

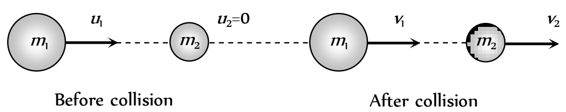


Fig. 6.31

$$\Rightarrow \ v_2 = \frac{2 m_1 u_1}{m_1 + m_2}$$

$$= \frac{2u_1}{1 + m_2 / m_1} \quad \text{As } u_2 = 0 \text{ and}$$

Assuming $\dfrac{m_2}{m_1} = n$

$$\therefore \ v_2 = \frac{2u_1}{1+n}$$

(ii) Momentum of target : $P_2 = m_2 v_2 = \dfrac{2 n m_1 u_1}{1+n}$

$$\left[\text{As } m_2 = m_1 n \text{ and } v_2 = \frac{2u_1}{1+n}\right]$$

$$\therefore \ P_2 = \frac{2 m_1 u_1}{1 + (1/n)}$$

(iii) Kinetic energy of target :

$$K_2 = \frac{1}{2} m_2 v_2^2 = \frac{1}{2} n\, m_1 \left(\frac{2u_1}{1+n}\right)^2 = \frac{2\, m_1 u_1^2 n}{(1+n)^2}$$

$$= \frac{4(K_1) n}{(1-n)^2 + 4n} \qquad \left[\text{As } K_1 = \frac{1}{2} m_1 u_1^2\right]$$

(iv) Relation between masses for maximum velocity, momentum and kinetic energy

Velocity	$v_2 = \dfrac{2u_1}{1+n}$	For v_2 to be maximum n must be minimum *i.e.* $n = \dfrac{m_2}{m_1} \to 0 \ \therefore \ m_2 << m_1$	Target should be very light.
Momentum	$P_2 = \dfrac{2 m_1 u_1}{(1 + 1/n)}$	For P_2 to be maximum, $(1/n)$ must be minimum or n must be maximum. *i.e.* $n = \dfrac{m_2}{m_1} \to \infty \ \therefore \ m_2 >> m_1$	Target should be massive.
Kinetic energy	$K_2 = \dfrac{4 K_1 n}{(1-n)^2 + 4n}$	For K_2 to be maximum $(1-n)^2$ must be minimum. *i.e.* $1 - n = 0 \Rightarrow n = 1 = \dfrac{m_2}{m_1} \ \therefore \ m_2 = m_1$	Target and projectile should be of equal mass.

Perfectly Elastic Oblique Collision

Let two bodies moving as shown in figure.

By law of conservation of momentum

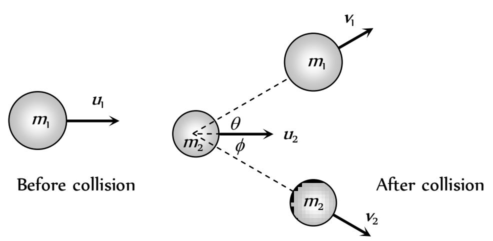


Fig. 6.32

Along *x*-axis, $m_1 u_1 + m_2 u_2 = m_1 v_1 \cos\theta + m_2 v_2 \cos\phi$ ...(i)

Along *y*-axis, $0 = m_1 v_1 \sin\theta - m_2 v_2 \sin\phi$ ...(ii)

By law of conservation of kinetic energy

$$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2 \quad \text{...(iii)}$$

In case of oblique collision it becomes difficult to solve problem unless some experimental data is provided, as in these situations more unknown variables are involved than equations formed.

Special condition : If $m_1=m_2$ and $u_2=0$ substituting these values in equation (i), (ii) and (iii) we get

$$u_1=v_1\cos\theta+v_2\cos\phi \quad \text{...(iv)}$$

$$0=v_1\sin\theta-v_2\sin\phi \quad \text{...(v)}$$

and $u_1^2=v_1^2+v_2^2$ ...(vi)

Squaring (iv) and (v) and adding we get

$$u_1^2=v_1^2+v_2^2+2v_1v_2\cos(\theta+\phi) \quad \text{...(vii)}$$

Using (vi) and (vii) we get $\cos(\theta+\phi)=0$

$\therefore\ \theta+\phi=\pi/2$

i.e. after perfectly elastic oblique collision of two bodies of equal masses (if the second body is at rest), the scattering angle $\theta+\phi$ would be 90^o.

Head on Inelastic Collision

(1) **Velocity after collision :** Let two bodies *A* and *B* collide inelastically and coefficient of restitution is *e*.

Where

$$e=\frac{v_2-v_1}{u_1-u_2}=\frac{\text{Relative velocity of separation}}{\text{Relative velocity of approach}}$$

$\Rightarrow v_2-v_1=e(u_1-u_2)$

$\therefore\ v_2-v_1=e(u_1-u_2)$ ...(i)

From the law of conservation of linear momentum

$$m_1u_1+m_2u_2=m_1v_1+m_2v_2 \quad \text{...(ii)}$$

By solving (i) and (ii) we get

$$v_1=\left(\frac{m_1-em_2}{m_1+m_2}\right)u_1+\left(\frac{(1+e)m_2}{m_1+m_2}\right)u_2$$

Similarly $v_2=\left[\frac{(1+e)m_1}{m_1+m_2}\right]u_1+\left(\frac{m_2-e\,m_1}{m_1+m_2}\right)u_2$

By substituting $e=1$, we get the value of v_1 and v_2 for perfectly elastic head on collision.

(2) **Ratio of velocities after inelastic collision :** A sphere of mass *m* moving with velocity *u* hits inelastically with another stationary sphere of same mass.

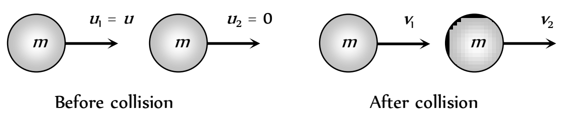


Fig. 6.33

$$\therefore\ e=\frac{v_2-v_1}{u_1-u_2}=\frac{v_2-v_1}{u-0}$$

$\Rightarrow\ v_2-v_1=eu$ ...(i)

By conservation of momentum :

Momentum before collision = Momentum after collision

$mu=mv_1+mv_2$

$\Rightarrow v_1+v_2=u$ ...(ii)

Solving equation (i) and (ii) we get $v_1=\frac{u}{2}(1-e)$

and $v_2=\frac{u}{2}(1+e)$

$\therefore \frac{v_1}{v_2}=\frac{1-e}{1+e}$

(3) **Loss in kinetic energy**

Loss in K.E. (ΔK) = Total initial kinetic energy – Total final kinetic energy

$$=\left(\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2\right)-\left(\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2\right)$$

Substituting the value of v_1 and v_2 from the above expressions

$$\text{Loss } (\Delta K)=\frac{1}{2}\left(\frac{m_1m_2}{m_1+m_2}\right)(1-e^2)(u_1-u_2)^2$$

By substituting $e = 1$ we get $\Delta K = 0$ *i.e.* for perfectly elastic collision, loss of kinetic energy will be zero or kinetic energy remains same before and after the collision.

Rebounding of Ball After Collision With Ground

If a ball is dropped from a height *h* on a horizontal floor, then it strikes with the floor with a speed.

$v_0=\sqrt{2gh_0}$ [From $v^2=u^2+2gh$]

and it rebounds from the floor with a speed

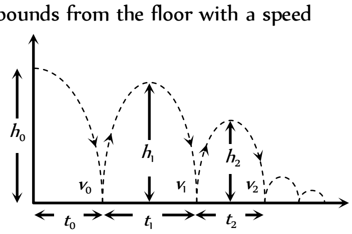


Fig. 6.34

$$v_1=e\,v_0=e\sqrt{2gh_0}$$

$$\left[\text{As } e=\frac{\text{velocity after collision}}{\text{velocity before collision}}\right]$$

(1) **First height of rebound :** $h_1=\frac{v_1^2}{2g}=e^2h_0$

$\therefore\ h_1=e^2h_0$

(2) **Height of the ball after n^{th} rebound :** Obviously, the velocity of ball after n^{th} rebound will be

$$v_n = e^n v_0$$

Therefore the height after n rebound will be

$$h_n = \frac{v_n^2}{2g} = e^{2n} h_0$$

$$\therefore \; h_n = e^{2n} h_0$$

(3) **Total distance travelled by the ball before it stops bouncing**

$$H = h_0 + 2h_1 + 2h_2 + 2h_3 + \ldots = h_0 + 2e^2 h_0 + 2e^4 h_0 + 2e^6 h_0 + \ldots$$

$$H = h_0[1 + 2e^2(1 + e^2 + e^4 + e^6 \ldots.)]$$

$$= h_0\left[1 + 2e^2\left(\frac{1}{1-e^2}\right)\right]$$

$$\left[\text{As } 1 + e^2 + e^4 + \ldots. = \frac{1}{1-e^2}\right]$$

$$\therefore \; H = h_0\left[\frac{1+e^2}{1-e^2}\right]$$

(4) **Total time taken by the ball to stop bouncing**

$$T = t_0 + 2t_1 + 2t_2 + 2t_3 + .. = \sqrt{\frac{2h_0}{g}} + 2\sqrt{\frac{2h_1}{g}} + 2\sqrt{\frac{2h_2}{g}} + ..$$

$$= \sqrt{\frac{2h_0}{g}} \; [1 + 2e + 2e^2 + \ldots\ldots] \quad [\text{As } h_1 = e^2 h_0 \,;\; h_2 = e^4 h_0]$$

$$= \sqrt{\frac{2h_0}{g}} \; [1 + 2e(1 + e + e^2 + e^3 + \ldots\ldots)]$$

$$= \sqrt{\frac{2h_0}{g}} \left[1 + 2e\left(\frac{1}{1-e}\right)\right] = \sqrt{\frac{2h_0}{g}}\left(\frac{1+e}{1-e}\right)$$

$$\therefore \; T = \left(\frac{1+e}{1-e}\right)\sqrt{\frac{2h_0}{g}}$$

Perfectly Inelastic Collision

In such types of collisions, the bodies move independently before collision but after collision as a one single body.

(1) **When the colliding bodies are moving in the same direction**

By the law of conservation of momentum

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v_{\text{comb}}$$

$$\Rightarrow \; v_{\text{comb}} = \frac{m_1u_1 + m_2u_2}{m_1 + m_2}$$

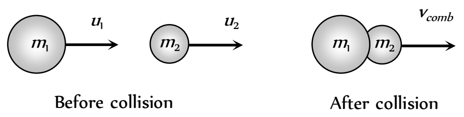


Fig. 6.35

Loss in kinetic energy

$$\Delta K = \left(\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right) - \frac{1}{2}(m_1 + m_2)v_{comb}^2$$

$$\Delta K = \frac{1}{2}\left(\frac{m_1m_2}{m_1 + m_2}\right)(u_1 - u_2)^2$$

[By substituting the value of v_{comb}]

(2) **When the colliding bodies are moving in the opposite direction**

By the law of conservation of momentum

$$m_1u_1 + m_2(-u_2) = (m_1 + m_2)v_{\text{comb}}$$

(Taking left to right as positive)

$$\therefore \; v_{\text{comb}} = \frac{m_1u_1 - m_2u_2}{m_1 + m_2}$$

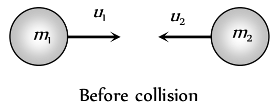


Fig. 3.36

when $m_1u_1 > m_2u_2$ then $v_{\text{comb}} > 0$ (positive)

i.e. the combined body will move along the direction of motion of mass m_1.

when $m_1u_1 < m_2u_2$ then $v_{\text{comb}} < 0$ (negative)

i.e. the combined body will move in a direction opposite to the motion of mass m_1.

(3) **Loss in kinetic energy**

ΔK = Initial kinetic energy – Final kinetic energy

$$= \left(\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2\right) - \left(\frac{1}{2}(m_1 + m_2)v_{\text{comb}}^2\right)$$

$$= \frac{1}{2}\frac{m_1m_2}{m_1 + m_2}(u_1 - u_2)^2$$

Collision Between Bullet and Vertically Suspended Block

A bullet of mass m is fired horizontally with velocity u in block of mass M suspended by vertical thread.

After the collision bullet gets embedded in block. Let the combined system raised upto height h and the string makes an angle θ with the vertical.

(1) **Velocity of system**

Let v be the velocity of the system (block + bullet) just after the collision.

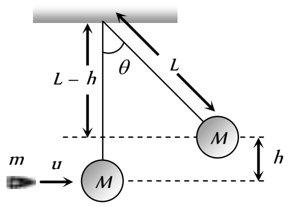


Fig. 3.37

Momentum$_{bullet}$ + Momentum$_{block}$ = Momentum$_{bullet\ and\ block\ system}$

$$mu + 0 = (m + M)v$$

$$\therefore \; v = \frac{mu}{(m + M)} \quad \ldots\text{(i)}$$

(2) **Velocity of bullet :** Due to energy which remains in the bullet-block system, just after the collision, the system (bullet + block) rises upto height h.

By the conservation of mechanical energy

$$\frac{1}{2}(m + M)v^2 = (m + M)gh \Rightarrow v = \sqrt{2gh}$$

Now substituting this value in the equation (i) we get $\sqrt{2gh} = \frac{mu}{m+M}$

$$\therefore \quad u = \left[\frac{(m+M)\sqrt{2gh}}{m}\right]$$

(3) **Loss in kinetic energy :** We know that the formula for loss of kinetic energy in perfectly inelastic collision

$$\Delta K = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$$ (When the bodies are moving in same direction.)

$$\therefore \quad \Delta K = \frac{1}{2}\frac{mM}{m+M}u^2$$

[As $u_1 = u$, $u_2 = 0$, $m_1 = m$ and $m_2 = M$]

(4) **Angle of string from the vertical**

From the expression of velocity of bullet $u = \left[\frac{(m+M)\sqrt{2gh}}{m}\right]$ we can get $h = \frac{u^2}{2g}\left(\frac{m}{m+M}\right)^2$

From the figure $\cos\theta = \frac{L-h}{L} = 1 - \frac{h}{L} = 1 - \frac{u^2}{2gL}\left(\frac{m}{m+M}\right)^2$

or $\quad \theta = \cos^{-1}\left[1 - \frac{1}{2gL}\left(\frac{mu}{m+M}\right)^2\right]$

Tips & Tricks

✍ The area under the force-displacement graph is equal to the work done.

✍ Work done by gravitation or electric force does not depend on the path followed. It depends on the initial and final positions of the body. Such forces are called conservative. When a body returns to the starting point under the action of conservative force, the net work done is zero that is $\oint dW = 0$.

✍ Work done against friction depends on the path followed. Viscosity and friction are not conservative forces. For non conservative forces, the work done on a closed path is not zero. That is $\oint dW \neq 0$.

✍ Work done is path independent only for a conservative field.

✍ Work done depends on the frame of reference.

✍ Work done by a centripetal force is always zero.

✍ Energy is a promise of work to be done in future. It is the stored ability to do work.

✍ Energy of a body is equal to the work done by the body and it has nothing to do with the time taken to perform the work. On the other hand, the power of the body depends on the time in which the work is done.

✍ When work is done on a body, its kinetic or potential energy increases.

✍ When the work is done by the body, its potential or kinetic energy decreases.

✍ According to the work energy theorem, the work done is equal to the change in energy. That is $W = \Delta E$.

✍ Work energy theorem is particularly useful in calculation of minimum stopping force or minimum stopping distance. If a body is brought to a halt, the work done to do so is equal to the kinetic energy lost.

✍ Potential energy of a system increases when a conservative force does work on it.

✍ The kinetic energy of a body is always positive.

✍ When the momentum of a body increases by a factor n, then its kinetic energy is increased by factor n.

✍ If the speed of a vehicle is made n times, then its stopping distance becomes n times.

✍ The total energy (including mass energy) of the universe remains constant.

✍ One form of energy can be changed into other form according to the law of conservation of energy. That is amount of energy lost of one form should be equal to energy or energies produced of other forms.

✍ Kinetic energy can change into potential energy and vice versa. When a body falls, potential energy is converted into kinetic energy.

✍ Pendulum oscillates due to conversion of kinetic energy into potential energy and vice versa. Same is true for the oscillations of mass attached to the spring.

✍ Conservation laws can be used to describe the behaviour of a mechanical system even when the exact nature of the forces involved is not known.

✍ Although the exact nature of the nuclear forces is not known, yet we can solve problems regarding the nuclear forces with the help of the conservation laws.

✍ Violation of the laws of conservation indicates that the event cannot take place.

✍ The gravitational potential energy of a mass m at a height h above the surface of the earth (radius R) is given by $U = \frac{mgh}{1 + h/R}$. When $h \ll R$, we find $U = mgh$.

✍ Electrostatic energy in capacitor - $U = \frac{1}{2}CV^2$, where C is capacitance, V = potential difference between the plates.

✍ Electric potential energy of a test charge q_0 at a place where electric potential is V, is given by : $U = q_0 V$.

✍ Electric potential energy between two charges (q_1 and q_2) separated by a distance r is given by $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$. Here ε_0 is permittivity of vacuum and $1/4\pi\varepsilon_0 = 9 \times 10^9\ Nm^2C^{-2}$.

✍ Magnetic energy stored in an inductor –

$U = \frac{1}{2}LI^2$, where L = inductance, I = current.

✍ Energy gained by a body of mass *m*, specific heat *C*, when its temperature changes by $\Delta\theta$ is given by : $Q = mC\Delta\theta$.

✍ The Potential energy associated with a spring of constant *k* when extended or compressed by distance *x* is given by $U = \frac{1}{2}kx^2$.

✍ Kinetic energy of a particle executing *SHM* is given by : $K = \frac{1}{2}m\omega^2(a^2 - y^2)$ where *m* = mass, ω = angular frequency, *a* = amplitude, *y* = displacement.

✍ Potential energy of a particle executing SHM is given by : $U = \frac{1}{2}m\omega^2 y^2$.

✍ Total energy of a particle executing SHM is given by : $E = K + U = \frac{1}{2}m\omega^2 a^2$.

✍ Energy density associated with a wave $= \frac{1}{2}\rho\omega^2 a^2$ where ρ =density of medium, ω = angular frequency, *a* = amplitude of the of the wave.

✍ Energy associated with a photon :

$E = h\nu = hc/\lambda$, where *h* = planck's constant, ν = frequency of the light wave, *c* = velocity of light, λ = wave length.

✍ Mass and energy are interconvertible. That is mass can be converted into energy and energy can be converted into mass.

✍ A mass *m* (in *kg*) is equivalent to energy (in *J*) which is equal to *mc* where *c* = speed of light.

✍ A stout spring has a large value of force constant, while for a delicate spring, the value of spring constant is low.

✍ The term energy is different from power. Whereas energy refers to the capacity to perform the work, power determines the rate of performing the work. Thus, in determining power, time taken to perform the work is significant but it is of no importance for measuring energy of a body.

✍ Collision is the phenomenon in which two bodies exert mutual force on each other.

✍ The collision generally occurs for very small interval of time.

✍ Physical contact between the colliding bodies is not essential for the collision.

✍ The mutual forces between the colliding bodies are action and reaction pair. In accordance with the Newton's third law of motion, they are equal and opposite to each other.

✍ The collision is said to be elastic when the kinetic energy is conserved.

✍ In the elastic collisions the forces involved are conservative.

✍ In the elastic collisions, the kinetic or mechanical energy is not converted into any other form of energy.

✍ Elastic collisions produce no sound or heat.

✍ There is no difference between the elastic and perfectly elastic collisions.

✍ In the elastic collisions, the relative velocity before collision is equal to the relative velocity after the collision. That is $\vec{u}_1 - \vec{u}_2 = \vec{v}_2 - \vec{v}_1$ where $\vec{u}_1$ and $\vec{u}_2$ are initial velocities and $\vec{v}_1$ and $\vec{v}_2$ are the velocities of the colliding bodies after the collision. This is called Newton's law of impact.

✍ The collision is said to be inelastic when the kinetic energy is not conserved.

✍ In the perfectly inelastic collision, the colliding bodies stick together. That is the relative velocity of the bodies after the collision is zero.

✍ In an elastic collision of two equal masses, their kinetic energies are exchanged.

✍ If a body of mass *m* moving with velocity *v*, collides elastically with a rigid wall, then the change in the momentum of the body is $2mv$.

✍ $e = \frac{\vec{v}_2 - \vec{v}_1}{\vec{u}_1 - \vec{u}_2}$ is called coefficient of restitution. Its value is 1 for elastic collisions. It is less than 1 for inelastic collisions and zero for perfectly inelastic collision.

✍ During collision, velocity of the colliding bodies changes.

✍ Linear momentum is conserved in all types of collisions.

✍ Perfectly elastic collision is a rare physical phenomenon.

✍ Collisions between two ivory or steel or glass balls are nearly elastic.

✍ The force of interaction in an inelastic collision is non-conservative in nature.

✍ In inelastic collision, the kinetic energy is converted into heat energy, sound energy, light energy etc.

✍ In head on collisions, the colliding bodies move along the same straight line before and after collision.

✍ Head on collisions are also called one dimensional collisions.

✍ In the oblique collisions the colliding bodies move at certain angles before and/or after the collisions.

✍ The oblique collisions are two dimensional collisions.

✍ When a heavy body collides head-on elastically with a lighter body, then the lighter body begins to move with a velocity nearly double the velocity of the heavier body.

✍ When a light body collides with a heavy body, the lighter body returns almost with the same speed.

✍ If a light and a heavy body have equal momenta, then lighter body has greater kinetic energy.

✍ Suppose, a body is dropped form a height h_0 and it strikes the ground with velocity v_0. After the (inelastic) collision let it rise to a height h_1. If v_1 be the velocity with which the body rebounds, then

$$e = \frac{v_1}{v_0} = \left[\frac{2gh_1}{2gh_0}\right]^{1/2} = \left[\frac{h_1}{h_0}\right]^{1/2}$$

✍ If after *n* collisions with the ground, the velocity is v_n and the height to which it rises be h_n, then

$$e^n = \frac{v_n}{v_0} = \left[\frac{h_n}{h_0}\right]^{1/2}$$

✍ $P = \vec{F}.\vec{v} = Fv\cos\theta$ where $\vec{v}$ is the velocity of the body and θ is the angle between $\vec{F}$ and $\vec{v}$.

✍ Area under the $F-v$ graph is equal to the power dissipated.

✍ Power dissipated by a conservative force (gravitation, electric force etc.) does not depend on the path followed. It depends on the initial and final positions of the body. That is $\oint dP = 0$.

✍ Power dissipated against friction depends on the path followed. That is $\oint dP \neq 0$.

✍ Power is also measured in horse power (*hp*). It is the *fps* unit of power. 1 *hp* = 746 *W*.

✍ An engine pulls a train of mass *m* with constant velocity. If the rails are on a plane surface and there is no friction, the power dissipated by the engine is zero.

✍ In the above case if the coefficient of friction for the rail is μ, the power of the engine is $P = \mu mgv$.

✍ In the above case if the engine pulls on a smooth track on an inclined plane (inclination θ), then its power $P = (mg\sin\theta)v$.

✍ In the above case if the engine pulls upwards on a rough inclined plane having coefficient of friction μ, then power of the engine is

$P = (\mu\cos\theta + \sin\theta)mg\,v$.

✍ If the engine pulls down on the inclined plane then power of the engine is

$P = (\mu\cos\theta - \sin\theta)mg\,v$.

Ordinary Thinking

Objective Questions

Work Done by Constant Force

1. A body of mass *m* is moving in a circle of radius *r* with a constant speed *v*. The force on the body is $\frac{mv^2}{r}$ and is directed towards the centre. What is the work done by this force in moving the body over half the circumference of the circle

(a) $\frac{mv^2}{\pi r^2}$ (b) Zero

(c) $\frac{mv^2}{r^2}$ (d) $\frac{\pi r^2}{mv^2}$

2. If the unit of force and length each be increased by four times, then the unit of energy is increased by [CPMT 1987]

(a) 16 times (b) 8 times

(c) 2 times (d) 4 times

3. A man pushes a wall and fails to displace it. He does [CPMT 1992]

(a) Negative work

(b) Positive but not maximum work

(c) No work at all

(d) Maximum work

4. The same retarding force is applied to stop a train. The train stops after 80 *m*. If the speed is doubled, then the distance will be

(a) The same (b) Doubled

(c) Halved (d) Four times

5. A body moves a distance of 10 *m* along a straight line under the action of a force of 5 *N*. If the work done is 25 *joules*, the angle which the force makes with the direction of motion of the body is [NCERT 1980; JIPMER 1997; CBSE PMT 1999; BHU 2000; RPMT 2000; Orissa JEE 2002]

(a) 0° (b) 30°

(c) 60° (d) 90°

6. You lift a heavy book from the floor of the room and keep it in the book-shelf having a height 2 *m*. In this process you take 5 seconds. The work done by you will depend upon [MP PET 1993]

(a) Mass of the book and time taken

(b) Weight of the book and height of the book-shelf

(c) Height of the book-shelf and time taken

(d) Mass of the book, height of the book-shelf and time taken

7. A body of mass *m kg* is lifted by a man to a height of one metre in 30 *sec*. Another man lifts the same mass to the same height in 60 *sec*. The work done by them are in the ratio

(a) 1 : 2 (b) 1 : 1

(c) 2 : 1 (d) 4 : 1

8. A force $\boldsymbol{F} = (5\hat{\boldsymbol{i}} + 3\hat{\boldsymbol{j}})$ *newton* is applied over a particle which displaces it from its origin to the point $\boldsymbol{r} = (2\hat{\boldsymbol{i}} - 1\hat{\boldsymbol{j}})$ *metres*. The work done on the particle is [MP PMT 1995; RPET 2003]

(a) – 7 *joules* (b) + 13 *joules*

(c) + 7 *joules* (d) + 11 *joules*

9. A force acts on a 30 *gm* particle in such a way that the position of the particle as a function of time is given by $x = 3t - 4t^2 + t^3$, where *x* is in *metres* and *t* is in seconds. The work done during the first 4 seconds is [NCERT 1977]

[CBSE PMT 1998]

(a) 5.28 *J* (b) 450 *mJ*

(c) 490 *mJ* (d) 530 *mJ*

10. A body of mass 10 *kg* is dropped to the ground from a height of 10 *metres*. The work done by the gravitational force is $(g = 9.8\ m/\sec^2)$ [SCRA 1994]

(a) – 490 *Joules* (b) + 490 *Joules*

(c) – 980 *Joules* (d) + 980 *Joules*

11. Which of the following is a scalar quantity [AFMC 1998]

(a) Displacement (b) Electric field

(c) Acceleration (d) Work

12. The work done in pulling up a block of wood weighing 2 *kN* for a length of 10*m* on a smooth plane inclined at an angle of 15° with the horizontal is [AFMC 1999; Pb PMT 2003]

(a) 4.36 *kJ* [CPMT 1984] (b) 5.17 *kJ*

(c) 8.91 *kJ* (d) 9.82 *kJ*

13. A force $\vec{F} = 5\hat{i} + 6\hat{j} - 4\hat{k}$ acting on a body, produces a displacement $\vec{s} = 6\vec{i} + 5\vec{k}$. Work done by the force is [KCET 1999]

(a) 18 units (b) 15 units

(c) 12 units (d) 10 units

14. A force of 5 *N* acts on a 15 *kg* body initially at rest. The work done by the force during the first second of motion of the body is

(a) 5 *J* (b) $\frac{5}{6}$ *J*

(c) 6 *J* (d) 75 *J*

15. A force of 5 *N*, making an angle θ with the horizontal, acting on an object displaces it by $0.4m$ along the horizontal direction. If the object gains kinetic energy of 1*J*, the horizontal component of the force is [EAMCET (Engg.) 2000]

(a) 1.5 *N* [MP PMT 1993] (b) 2.5 *N*

(c) 3.5 *N* (d) 4.5 *N*

16. The work done against gravity in taking 10 *kg* mass at 1*m* height in 1*sec* will be [RPMT 2000]

(a) 49 *J* (b) 98 *J*

(c) 196 *J* (d) None of these

17. The energy which an e^- acquires when accelerated through a potential difference of 1 volt is called [UPSEAT 2000]
(a) 1 *Joule* (b) 1 *Electron volt*
(c) 1 *Erg* (d) 1 *Watt*.

18. A body of mass 6*kg* is under a force which causes displacement in it given by $S = \frac{t^2}{4}$ *metres* where *t* is time. The work done by the force in 2 seconds is [EAMCET 2001]
(a) 12 *J* (b) 9 *J*
(c) 6 *J* (d) 3 *J*

19. A body of mass 10*kg* at rest is acted upon simultaneously by two forces 4 *N* and 3*N* at right angles to each other. The kinetic energy of the body at the end of 10 *sec* is [Kerala (Engg.) 2001]
(a) 100 *J* (b) 300 *J*
(c) 50 *J* (d) 125 *J*

20. A cylinder of mass 10*kg* is sliding on a plane with an initial velocity of 10*m/s*. If coefficient of friction between surface and cylinder is 0.5, then before stopping it will describe [Pb. PMT 2001]
(a) 12.5 *m* (b) 5 *m*
(c) 7.5 *m* (d) 10 *m*

21. A force of $(3\hat{i} + 4\hat{j})$ *Newton* acts on a body and displaces it by $(3\hat{i} + 4\hat{j})m$. The work done by the force is [AIIMS 2001]
(a) 10 *J* (b) 12 *J*
(c) 16 *J* (d) 25 *J*

22. A 50*kg* man with 20*kg* load on his head climbs up 20 steps of 0.25*m* height each. The work done in climbing is [JIPMER 2002]
(a) 5 *J* (b) 350 *J*
(c) 100 *J* (d) 3430 *J*

23. A force $\vec{F} = 6\hat{i} + 2\hat{j} - 3\hat{k}$ acts on a particle and produces a displacement of $\vec{s} = 2\hat{i} - 3\hat{j} + x\hat{k}$. If the work done is zero, the value of *x* is [Kerala PMT 2002]
(a) -2 (b) 1/2
(c) 6 (d) 2

24. A particle moves from position $\vec{r}_1 = 3\hat{i} + 2\hat{j} - 6\hat{k}$ to position $\vec{r}_2 = 14\hat{i} + 13\hat{j} + 9\hat{k}$ under the action of force $4\hat{i} + \hat{j} + 3\hat{k}\,N$. The work done will be [Pb. PMT 2002,03]
(a) 100 *J* (b) 50 *J*
(c) 200 *J* (d) 75 *J*

25. A force $(\vec{F}) = 3\hat{i} + c\hat{j} + 2\hat{k}$ acting on a particle causes a displacement: $(\vec{s}) = -4\hat{i} + 2\hat{j} + 3\hat{k}$ in its own direction. If the work done is $6\,J$, then the value of 'c' is [CBSE PMT 2002]
(a) 0 (b) 1
(c) 6 (d) 12

26. In an explosion a body breaks up into two pieces of unequal masses. In this [MP PET 2002]
(a) Both parts will have numerically equal momentum
(b) Lighter part will have more momentum
(c) Heavier part will have more momentum
(d) Both parts will have equal kinetic energy

27. Which of the following is a unit of energy [AFMC 2002]
(a) Unit (b) Watt
(c) Horse Power (d) None

28. If force and displacement of particle in direction of force are doubled. Work would be [AFMC 2002]
(a) Double (b) 4 times
(c) Half (d) $\frac{1}{4}$ times

29. A body of mass 5 *kg* is placed at the origin, and can move only on the x-axis. A force of 10 *N* is acting on it in a direction making an angle of 60^o with the x-axis and displaces it along the x-axis by 4 *metres*. The work done by the force is
(a) 2.5 *J* (b) 7.25 *J*
(c) 40 *J* (d) 20 *J*

30. A force $\vec{F} = (5\hat{i} + 4\hat{j})$ *N* acts on a body and produces a displacement $\vec{S} = (6\hat{i} - 5\hat{j} + 3\hat{k})\,m$. The work done will be [CPMT 2003]
(a) 10 *J* (b) 20 *J*
(c) 30 *J* (d) 40 *J*

31. A uniform chain of length 2*m* is kept on a table such that a length of 60*cm* hangs freely from the edge of the table. The total mass of the chain is 4*kg*. What is the work done in pulling the entire chain on the table [AIEEE 2004]
(a) 7.2 *J* (b) 3.6 *J*
(c) 120 *J* (d) 1200 *J*

32. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle, the motion of the particle takes place in a plane. It follows that
(a) Its velocity is constant
(b) Its acceleration is constant
(c) Its kinetic energy is constant
(d) It moves in a straight line

33. A ball of mass *m* moves with speed *v* and strikes a wall having infinite mass and it returns with same speed then the work done by the ball on the wall is [BCECE 2004]
(a) Zero (b) $mv\ J$
(c) *m/v.J* (d) *v/m J*

34. A force $\vec{F} = (5\hat{i} + 3\hat{j} + 2\hat{k})N$ is applied over a particle which displaces it from its origin to the point $\vec{r} = (2\hat{i} - \hat{j})m$. The work done on the particle in joules is [AIEEE 2004]
(a) -7 (b) +7
(c) +10 (d) +13

35. The kinetic energy acquired by a body of mass *m* is travelling some distance *s*, starting from rest under the actions of a constant force, is directly proportional to [Pb. PET 2000]
(a) m^0 (b) m
(c) m^2 (d) $\sqrt{m}$

36. If a force $\vec{F} = 4\hat{i} + 5\hat{j}$ causes a displacement $\vec{s} = 3\hat{i} + 6\hat{k}$, work done is [Pb. PET 2002]
(a) 4×6 unit (b) 6×3 unit

(c) 5×6 unit (d) 4×3 unit

37. A man starts walking from a point on the surface of earth (assumed smooth) and reaches diagonally opposite point. What is the work done by him [DCE 2004]

(a) Zero (b) Positive

(c) Negative (d) Nothing can be said

38. It is easier to draw up a wooden block along an inclined plane than to haul it vertically, principally because [CPMT 1977; JIPMER 1997]

(a) The friction is reduced

(b) The mass becomes smaller

(c) Only a part of the weight has to be overcome

(d) 'g' becomes smaller

39. Two bodies of masses 1 *kg* and 5 *kg* are dropped gently from the top of a tower. At a point 20 *cm* from the ground, both the bodies will have the same [SCRA 1998]

(a) Momentum (b) Kinetic energy

(c) Velocity (d) Total energy

40. Due to a force of $(6\hat{i} + 2\hat{j})N$ the displacement of a body is $(3\hat{i} - \hat{j})m$, then the work done is [Orissa JEE 2005]

(a) 16 *J* (b) 12 *J*

(c) 8 *J* (d) Zero

41. A ball is released from the top of a tower. The ratio of work done by force of gravity in first, second and third second of the motion of the ball is [Kerala PET 2005]

(a) 1 : 2 : 3 (b) 1 : 4 : 9

(c) 1 : 3 : 5 (d) 1 : 5 : 3

Work Done by Variable Force

1. A particle moves under the effect of a force $F = Cx$ from $x = 0$ to $x = x_1$. The work done in the process is [CPMT 1982; DCE 2002;Orissa JEE 2005]

(a) Cx_1^2 (b) $\frac{1}{2}Cx_1^2$

(c) Cx_1 (d) Zero

2. A cord is used to lower vertically a block of mass *M* by a distance *d* with constant downward acceleration $\frac{g}{4}$. Work done by the cord on the block is [CPMT 1972]

(a) $Mg\frac{d}{4}$ (b) $3Mg\frac{d}{4}$

(c) $-3Mg\frac{d}{4}$ (d) Mgd

3. Two springs have their force constant as k_1 and $k_2 (k_1 > k_2)$. When they are stretched by the same force [EAMCET 1981]

(a) No work is done in case of both the springs

(b) Equal work is done in case of both the springs

(c) More work is done in case of second spring

(d) More work is done in case of first spring

4. A spring of force constant 10 *N/m* has an initial stretch 0.20 *m*. In changing the stretch to 0.25 *m*, the increase in potential energy is about [CPMT 1977]

(a) 0.1 *joule* (b) 0.2 *joule*

(c) 0.3 *joule* (d) 0.5 *joule*

5. The potential energy of a certain spring when stretched through a distance '*S*' is 10 *joule*. The amount of work (in joule) that must be done on this spring to stretch it through an additional distance '*S*' will be [MNR 1991; CPMT 2002; UPSEAT 2000; Pb. PET 2004]

(a) 30 (b) 40

(c) 10 (d) 20

6. Two springs of spring constants 1500 *N/m* and 3000 *N/m* respectively are stretched with the same force. They will have potential energy in the ratio [MP PMT/PET 1998; Pb. PMT 2002]

(a) 4 : 1 (b) 1 : 4

(c) 2 : 1 (d) 1 : 2

7. A spring 40 *mm* long is stretched by the application of a force. If 10 *N* force required to stretch the spring through 1 *mm*, then work done in stretching the spring through 40 *mm* is

(a) 84 *J* (b) 68 *J*

(c) 23 *J* (d) 8 *J*

8. A position dependent force $F = 7 - 2x + 3x^2$ *newton* acts on a small body of mass 2 *kg* and displaces it from $x = 0$ to $x = 5\,m$. The work done in *joules* is [CBSE PMT 1994]

(a) 70 (b) 270

(c) 35 (d) 135

9. A body of mass 3 *kg* is under a force, which causes a displacement in it is given by $S = \frac{t^3}{3}$ (in *m*). Find the work done by the force in first 2 seconds [BHU 1998]

(a) 2 *J* (b) 3.8 *J*

(c) 5.2 *J* (d) 24 *J*

10. The force constant of a wire is *k* and that of another wire is $2k$. When both the wires are stretched through same distance, then the work done [MH CET 2000]

(a) $W_2 = 2W_1^2$ (b) $W_2 = 2W_1$

(c) $W_2 = W_1$ (d) $W_2 = 0.5W_1$

11. A body of mass 0.1 *kg* moving with a velocity of 10 *m/s* hits a spring (fixed at the other end) of force constant 1000 *N/m* and comes to rest after compressing the spring. The compression of the spring is

(a) $0.01m$ (b) $0.1m$

(c) $0.2m$ (d) $0.5m$

12. When a 1.0*kg* mass hangs attached to a spring of length 50 *cm*, the spring stretches by 2 *cm*. The mass is pulled down until the length of the spring becomes 60 *cm*. What is the amount of elastic energy stored in the spring in this condition, if *g* = 10 *m/s*

(a) 1.5 *Joule* (b) 2.0 *Joule*

(c) 2.5 *Joule* (d) 3.0 *Joule*

13. A spring of force constant 800 *N/m* has an extension of 5*cm*. The work done in extending it from 5*cm* to 15 *cm* is [AIEEE 2002]

(a) 16 *J* (b) 8 *J*

(c) 32 *J* (d) 24 *J*

14. When a spring is stretched by 2 *cm*, it stores 100 *J* of energy. If it is stretched further by 2 *cm*, the stored energy will be increased by

(a) 100 *J* (b) 200 *J*

(c) 300 *J* (d) 400 *J*

15. A spring when stretched by 2 mm its potential energy becomes 4 J. If it is stretched by 10 mm, its potential energy is equal to

(a) 4 *J* (b) 54 *J*

(c) 415 *J* (d) None

16. A spring of spring constant 5×10^3 *N/m* is stretched initially by 5*cm* from the unstretched position. Then the work required to stretch it further by another $5cm$ is

[AIEEE 2003]

(a) 6.25 *N-m* (b) 12.50 *N-m*

(c) 18.75 *N-m* (d) 25.00 *N-m*

17. A mass of 0.5*kg* moving with a speed of 1.5 *m/s* on a horizontal smooth surface, collides with a nearly weightless spring of force constant $k = 50\ N/m$. The maximum compression of the spring would be **[CBSE PMT 2004]**

(a) 0.15 *m* (b) 0.12 *m*

(c) 1.5 *m* (d) 0.5 *m*

18. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement *x* is proportional to **[AIEEE 2004]**

(a) x^2 (b) e^x

(c) x (d) $\log_e x$

19. A spring with spring constant *k* when stretched through 1 *cm*, the potential energy is *U*. If it is stretched by 4 *cm*. The potential energy will be **[Orissa PMT 2004]**

(a) 4*U* (b) 8*U*

(c) 16 *U* (d) 2*U*

20. A spring with spring constant *k* is extended from $x = 0$ to $x = x_1$. The work done will be **[Orissa PMT 2004]**

(a) kx_1^2 (b) $\frac{1}{2}kx_1^2$

(c) $2kx_1^2$ (d) $2kx_1$

21. If a long spring is stretched by 0.02 *m*, its potential energy is *U*. If the spring is stretched by 0.1 *m*, then its potential energy will be

[MP PMT 2002; CBSE PMT 2003; UPSEAT 2004]

(a) $\frac{U}{5}$ (b) U

(c) 5*U* (d) 25*U*

22. Natural length of a spring is 60 *cm*, and its spring constant is 4000 *N/m*. A mass of 20 *kg* is hung from it. The extension produced in the spring is, (Take $g = 9.8\ m/s^2$) **[DCE 2004]**

(a) 4.9 *cm* (b) 0.49 *cm*

(c) 9.4 *cm* (d) 0.94 *cm*

23. The spring extends by *x* on loading, then energy stored by the spring is :

(if *T* is the tension in spring and *k* is spring constant)

[Pb. PMT 2003]

(a) $\frac{T^2}{2k}$ **[Orissa JEE 2002]** (b) $\frac{T^2}{2k^2}$

(c) $\frac{2k}{T^2}$ (d) $\frac{2T^2}{k}$

24. The potential energy of a body is given by, **[BCECE 2003]** $U = A - Bx^2$ (Where *x* is the displacement). The magnitude of force acting on the particle is **[BHU 2002]**

(a) Constant

(b) Proportional to *x*

(c) Proportional to x^2

(d) Inversely proportional to *x*

25. The potential energy between two atoms in a molecule is given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$; where *a* and *b* are positive constants and *x* is the distance between the atoms. The atom is in stable equilibrium when **[CBSE PMT 1995]**

(a) $x = \sqrt[6]{\frac{11a}{5b}}$ (b) $x = \sqrt[6]{\frac{a}{2b}}$

(c) $x = 0$ (d) $x = \sqrt[6]{\frac{2a}{b}}$

26. Which one of the following is not a conservative force

[Kerala PMT 2005]

(a) Gravitational force

(b) Electrostatic force between two charges

(c) Magnetic force between two magnetic dipoles

(d) Frictional force

Conservation of Energy and Momentum

1. Two bodies of masses m_1 and m_2 have equal kinetic energies. If p_1 and p_2 are their respective momentum, then ratio $p_1 : p_2$ is equal to **[MP PMT 1985; CPMT 1990]**

(a) $m_1 : m_2$ (b) $m_2 : m_1$

(c) $\sqrt{m_1} : \sqrt{m_2}$ (d) $m_1^2 : m_2^2$

2. Work done in raising a box depends on

(a) How fast it is raised

(b) The strength of the man

(c) The height by which it is raised

(d) None of the above

3. A light and a heavy body have equal momenta. Which one has greater K.E

[MP PMT 1985; CPMT 1985; Kerala PMT 2004]

(a) The light body (b) The heavy body

(c) The K.E. are equal (d) Data is incomplete

4. A body at rest may have

(a) Energy (b) Momentum

(c) Speed (d) Velocity

5. The kinetic energy possessed by a body of mass *m* moving with a velocity *v* is equal to $\frac{1}{2}mv^2$, provided

(a) The body moves with velocities comparable to that of light

(b) The body moves with velocities negligible compared to the speed of light

(c) The body moves with velocities greater than that of light

(d) None of the above statement is correcst

6. If the momentum of a body is increased *n* times, its kinetic energy increases

(a) *n* times (b) 2*n* times

(c) $\sqrt{n}$ times (d) n^2 times

7. When work is done on a body by an external force, its

(a) Only kinetic energy increases

(b) Only potential energy increases

(c) Both kinetic and potential energies may increase

(d) Sum of kinetic and potential energies remains constant

8. The bob of a simple pendulum (mass *m* and length *l*) dropped from a horizontal position strikes a block of the same mass elastically placed on a horizontal frictionless table. The K.E. of the block will be

(a) 2 *mgl* (b) *mgl*/2

(c) *mgl* (d) 0

9. From a stationary tank of mass 125000 *pound* a small shell of mass 25 *pound* is fired with a muzzle velocity of 1000 *ft*/*sec*. The tank recoils with a velocity of [NCERT 1973]

(a) 0.1 *ft*/*sec* (b) 0.2 *ft*/*sec*

(c) 0.4 *ft*/sec (d) 0.8 *ft*/*sec*

10. A bomb of 12 *kg* explodes into two pieces of masses 4 *kg* and 8 *kg*. The velocity of 8*kg* mass is 6 *m*/*sec*. The kinetic energy of the other mass is

[MNR 1985; CPMT 1991; Manipal MEE 1995; Pb. PET 2004]

(a) 48 *J* (b) 32 *J*

(c) 24 *J* (d) 288 *J*

11. A rifle bullet loses 1/20th of its velocity in passing through a plank. The least number of such planks required just to stop the bullet is [EAMCET 1987; AFMC 2004]

(a) 5 (b) 10

(c) 11 (d) 20

12. A body of mass 2 *kg* is thrown up vertically with K.E. of 490 joules. If the acceleration due to gravity is $9.8\,m/s^2$, then the height at which the K.E. of the body becomes half its original value is given by [EAMCET 1986]

(a) 50 *m* (b) 12.5 *m*

(c) 25 *m* (d) 10 *m*

13. Two masses of 1 *gm* and 4 *gm* are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is

[AIIMS 1987; NCERT 1983; MP PMT 1993; IIT 1980; RPET 1996; CBSE PMT 1997; Orissa JEE 2003; KCET 1999; DCE 2004]

(a) 4 : 1 (b) $\sqrt{2}:1$

(c) 1 : 2 (d) 1 : 16

14. If the *K.E.* of a body is increased by 300%, its momentum will increase by [JIPMER 1978; AFMC 1993; RPET 1999; CBSE PMT 2002]

(a) 100% (b) 150%

(c) $\sqrt{300}\%$ (d) 175%

15. A light and a heavy body have equal kinetic energy. Which one has a greater momentum ?

[NCERT 1974; CPMT 1997; DPMT 2001]

(a) The light body

(b) The heavy body

(c) Both have equal momentum

(d) It is not possible to say anything without additional information

16. If the linear momentum is increased by 50%, the kinetic energy will increase by

[CPMT 1983; MP PMT 1994; MP PET 1996, 99; UPSEAT 2001]

(a) 50% (b) 100%

(c) 125% (d) 25%

17. A free body of mass 8 *kg* is travelling at 2 *meter* per second in a straight line. At a certain instant, the body splits into two equal parts due to internal explosion which releases 16 *joules* of energy. Neither part leaves the original line of motion finally

(a) Both parts continue to move in the same direction as that of the original body

(b) One part comes to rest and the other moves in the same direction as that of the original body

(c) One part comes to rest and the other moves in the direction opposite to that of the original body

(d) One part moves in the same direction and the other in the direction opposite to that of the original body

18. If the K.E. of a particle is doubled, then its momentum will

[EAMCET 1979; CPMT 2003: Kerala PMT 2005]

(a) Remain unchanged (b) Be doubled

(c) Be quadrupled (d) Increase $\sqrt{2}$ times

19. If the stone is thrown up vertically and return to ground, its potential energy is maximum [EAMCET 1979]

(a) During the upward journey

(b) At the maximum height

(c) During the return journey

(d) At the bottom

20. A body of mass 2 *kg* is projected vertically upwards with a velocity of $2\,m\,sec^{-1}$. The K.E. of the body just before striking the ground is [EAMCET 1980]

(a) 2 *J* (b) 1 *J*

(c) 4 *J* (d) 8 *J*

21. The energy stored in wound watch spring is

[EAMCET 1982]

(a) K.E. (b) P.E.

(c) Heat energy (d) Chemical energy

22. Two bodies of different masses m_1 and m_2 have equal momenta. Their kinetic energies E_1 and E_2 are in the ratio

[EAMCET 1990]

(a) $\sqrt{m_1}:\sqrt{m_2}$ (b) $m_1 : m_2$

(c) $m_2 : m_1$ (d) $m_1^2 : m_2^2$

23. A car travelling at a speed of 30 *km*/*hour* is brought to a halt in 8 *m* by applying brakes. If the same car is travelling at 60 *km*/*hour*, it can be brought to a halt with the same braking force in

(a) 8 *m* (b) 16 *m*

(c) 24 *m* (d) 32 *m*

24. Tripling the speed of the motor car multiplies the distance needed for stopping it by [NCERT 1978]

(a) 3 (b) 6

(c) 9 (d) Some other number

25. If the kinetic energy of a body increases by 0.1%, the percent increase of its momentum will be [MP PMT 1994]

(a) 0.05% (b) 0.1%

(c) 1.0% (d) 10%

26. If velocity of a body is twice of previous velocity, then kinetic energy will become [AFMC 1996]

(a) 2 times (b) $\frac{1}{2}$ times

(c) 4 times (d) 1 times

27. Two bodies *A* and *B* having masses in the ratio of 3 : 1 possess the same kinetic energy. The ratio of their linear momenta is then

(a) 3 : 1 (b) 9 : 1

(c) 1 : 1 (d) $\sqrt{3}:1$

28. In which case does the potential energy decrease [MP PET 1996]

(a) On compressing a spring

(b) On stretching a spring

(c) On moving a body against gravitational force

(d) On the rising of an air bubble in water

29. A sphere of mass *m*, moving with velocity *V*, enters a hanging bag of sand and stops. If the mass of the bag is *M* and it is raised by height *h*, then the velocity of the sphere was

(a) $\frac{M+m}{m}\sqrt{2gh}$ (b) $\frac{M}{m}\sqrt{2gh}$

(c) $\frac{m}{M+m}\sqrt{2gh}$ (d) $\frac{m}{M}\sqrt{2gh}$

30. Two bodies of masses *m* and 2*m* have same momentum. Their respective kinetic energies E_1 and E_2 are in the ratio [MP PET 1997; KCET 2004]

(a) 1 : 2 (b) 2 : 1

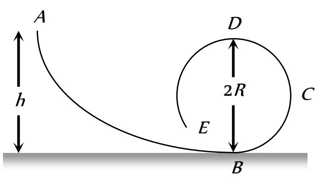
(c) $1:\sqrt{2}$ (d) 1 : 4

31. If a lighter body (mass M_1 and velocity V_1) and a heavier body (mass M_2 and velocity V_2) have the same kinetic energy, then

(a) $M_2V_2 < M_1V_1$ (b) $M_2V_2 = M_1V_1$

(c) $M_2V_1 = M_1V_2$ (d) $M_2V_2 > M_1V_1$

32. A frictionless track *ABCDE* ends in a circular loop of radius *R*. A body slides down the track from point *A* which is at a height *h* = 5 *cm*. Maximum value of *R* for the body to successfully complete the loop is [MP PMT/PET 1998]



(a) 5 *cm*

(b) $\frac{15}{4}$ *cm*

(c) $\frac{10}{3}$ *cm*

(d) 2 *cm*

33. The force constant of a weightless spring is 16 *N*/*m*. A body of mass 1.0 *kg* suspended from it is pulled down through 5 cm and then released. The maximum kinetic energy of the system (spring + body) will be [MP PET 1999; DPMT 2000]

(a) $2\times10^{-2}\ J$ (b) $4\times10^{-2}\ J$

(c) $8\times10^{-2}\ J$ (d) $16\times10^{-2}\ J$

34. Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is

(a) 1 : 2 (b) 1 : 1

(c) 4 : 1 (d) 1 : 4

35. If the kinetic energy of a body becomes four times of its initial value, then new momentum will [AIIMS 1998; AIIMS 2002; KCET 2000; J & K CET 2004]

(a) Becomes twice its initial value [Haryana CEE 1996]

(b) Become three times its initial value

(c) Become four times its initial value

(d) Remains constant

36. A bullet is fired from a rifle. If the rifle recoils freely, then the kinetic energy of the rifle is [AIIMS 1998; JIPMER 2001; UPSEAT 2000]

(a) Less than that of the bullet

(b) More than that of the bullet

(c) Same as that of the bullet

(d) Equal or less than that of the bullet [MP PET 1997]

37. If the water falls from a dam into a turbine wheel 19.6 *m* below, then the velocity of water at the turbine is $(g = 9.8\ m/s^2)$

(a) 9.8 *m*/*s* (b) 19.6 *m*/*s*

(c) 39.2 *m*/*s* (d) 98.0 *m*/*s*

38. Two bodies of masses 2*m* and *m* have their K.E. in the ratio 8 : 1, then their ratio of momenta is [EAMCET (Engg.) 1995]

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 8 : 1

39. A bomb of 12 *kg* divides in two parts whose ratio of masses is 1 : 3. If kinetic energy of smaller part is 216 *J*, then momentum of bigger part in *kg-m*/*sec* will be [MP PMT 1997] [RPET 1997]

(a) 36 (b) 72

(c) 108 (d) Data is incomplete

40. A 4 *kg* mass and a 1 *kg* mass are moving with equal kinetic energies. The ratio of the magnitudes of their linear momenta is [CBSE PMT 1993; Orissa JE

(a) 1 : 2 (b) 1 : 1

(c) 2 : 1 (d) 4 : 1

41. Two identical cylindrical vessels with their bases at same level each contains a liquid of density ρ. The height of the liquid in one vessel is h_1 and that in the other vessel is h_2. The area of either base is *A*. The work done by gravity in equalizing the levels when the two vessels are connected, is [SCRA 1996]

(a) $(h_1 - h_2)g\rho$ (b) $(h_1 - h_2)gA\rho$

(c) $\frac{1}{2}(h_1 - h_2)^2 gA\rho$ (d) $\frac{1}{4}(h_1 - h_2)^2 gA\rho$

42. If the increase in the kinetic energy of a body is 22%, then the increase in the momentum will be

[RPET 1996; DPMT 2000]

(a) 22% (b) 44%

(c) 10% (d) 300%

43. If a body of mass 200 g falls from a height 200 m and its total P.E. is converted into K.E. at the point of contact of the body with earth surface, then what is the decrease in P.E. of the body at the contact $(g = 10\, m/s^2)$ [AFMC 1997]

(a) 200 J (b) 400 J

(c) 600 J (d) 900 J

44. If momentum is increased by 20%, then K.E. increases by

[AFMC 1997; MP PMT 2004]

(a) 44% (b) 55%

(c) 66% (d) 77%

45. The kinetic energy of a body of mass 2 kg and momentum of 2 Ns is

(a) 1 J (b) 2 J

(c) 3 J (d) 4 J

46. The decrease in the potential energy of a ball of mass 20 kg which falls from a height of 50 cm is [AIIMS 1997]

(a) 968 J (b) 98 J

(c) 1980 J (d) None of these

47. An object of 1 kg mass has a momentum of 10 $kg\ m/sec$ then the kinetic energy of the object will be [RPMT 1999]

(a) 100 J (b) 50 J

(c) 1000 J (d) 200 J

48. A ball is released from certain height. It loses 50% of its kinetic energy on striking the ground. It will attain a height again equal to

(a) One fourth the initial height

(b) Half the initial height

(c) Three fourth initial height

(d) None of these

49. A 0.5 kg ball is thrown up with an initial speed 14 m/s and reaches a maximum height of 8.0m. How much energy is dissipated by air drag acting on the ball during the ascent

[AMU (Med.) 2000]

(a) $19.6\, Joule$ (b) $4.9\, Joule$

(c) $10\, Joule$ (d) $9.8\, Joule$

50. An ice cream has a marked value of 700 $kcal$. How many kilowatt-hour of energy will it deliver to the body as it is digested

(a) $0.81 kWh$ (b) $0.90 kWh$

(c) $1.11 kWh$ (d) $0.71 kWh$

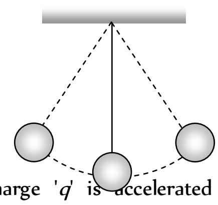
51. What is the velocity of the bob of a simple pendulum at its mean position, if it is able to rise to vertical height of $10 cm$ (Take $g = 9.8\, m/s^2$) [BHU 2000]

(a) 0.6 m/s

(b) 1.4 m/s

(c) 1.8 m/s

(d) 2.2 m/s



52. A particle of mass 'm' and charge 'q' is accelerated through a potential difference of 'V' volt. Its energy is [UPSEAT 2001]

(a) qV (b) mqV

(c) $\left(\frac{q}{m}\right)V$ (d) $\frac{q}{mV}$

53. A running man has half the kinetic energy of that of a boy of half of his mass. The man speeds up by 1m/s so as to have same $K.E.$ as that of the boy. The original speed of the man will be

(a) $\sqrt{2}\, m/s$ (b) $(\sqrt{2}-1) m/s$

(c) $\frac{1}{(\sqrt{2}-1)} m/s$ (d) $\frac{1}{\sqrt{2}} m/s$

54. The mass of two substances are 4gm and $9 gm$ respectively. If their kinetic energies are same, then the ratio of their momenta will be

(a) 4 : 9 (b) 9 : 4

(c) 3 : 2 (d) 2 : 3

55. If the momentum of a body is increased by 100%, then the percentage increase in the kinetic energy is

[AFMC 1998; DPMT 2000]

[BHU 1999; Pb. PMT 1999; CPMT 2000; CBSE PMT 2001; BCECE 2004]

(a) 150% (b) 200%

(c) 225% (d) 300%

56. If a body looses half of its velocity on penetrating 3 cm in a wooden block, then how much will it penetrate more before coming to rest

(a) 1 cm (b) 2 cm

(c) 3 cm (d) 4 cm

57. A bomb of mass 9kg explodes into 2 pieces of mass 3kg and 6kg. The velocity of mass 3kg is 1.6 m/s, the K.E. of mass 6kg is

(a) 3.84 J (b) 9.6 J

(c) 1.92 J (d) 2.92 J

58. Two masses of 1kg and 16kg are moving with equal K.E. The ratio of magnitude of the linear momentum is [RPMT 2000] [AIEEE 2002]

(a) 1 : 2 (b) 1 : 4

(c) $1 : \sqrt{2}$ (d) $\sqrt{2} : 1$

59. A machine which is 75 percent efficient, uses 12 joules of energy in lifting up a 1 kg mass through a certain distance. The mass is then allowed to fall through that distance. The velocity at the end of its fall is (in ms^{-1}) [Kerala PMT 2002]

(a) $\sqrt{24}$ (b) $\sqrt{32}$

(c) $\sqrt{18}$ (d) $\sqrt{9}$

60. Two bodies moving towards each other collide and move away in opposite [AMU (Med.) 2000] There is some rise in temperature of bodies because a part of the kinetic energy is converted into

(a) Heat energy (b) Electrical energy

(c) Nuclear energy (d) Mechanical energy

61. A particle of mass m at rest is acted upon by a force F for a time t. Its Kinetic energy after an interval t is

[Kerala PET 2002]

(a) $\frac{F^2t^2}{m}$ (b) $\frac{F^2t^2}{2m}$

(c) $\frac{F^2t^2}{3m}$ (d) $\frac{Ft}{2m}$

62. The potential energy of a weight less spring compressed by a distance a is proportional to [MP PET 2003]

(a) a (b) a^2

(c) a^{-2} (d) a^{0}

63. Two identical blocks A and B, each of mass 'm' resting on smooth floor are connected by a light spring of natural length L and spring constant K, with the spring at its natural length. A third identical block 'C' (mass m) moving with a speed v along the line joining A and B collides with A. the maximum compression in the spring is [EAMCET 2003]

(a) $v\sqrt{\frac{m}{2k}}$ (b) $m\sqrt{\frac{v}{2k}}$

(c) $\sqrt{\frac{mv}{k}}$ (d) $\frac{mv}{2k}$

64. Two bodies of masses m and 4 m are moving with equal K.E. The ratio of their linear momentums is

[Orissa JEE 2003; AIIMS 1999]

(a) 4 : 1 (b) 1 : 1

(c) 1 : 2 (d) 1 : 4

65. A stationary particle explodes into two particles of a masses m and m which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1/E_2 is

[CBSE PMT 2003]

(a) m_1/m_2 (b) 1

(c) m_1v_2/m_2v_1 (d) m_2/m_1

66. The kinetic energy of a body of mass 3 *kg* and momentum 2 *Ns* is

(a) 1 *J* (b) $\frac{2}{3}J$

(c) $\frac{3}{2}J$ (d) 4 *J*

67. A bomb of mass 3.0 *Kg* explodes in air into two pieces of masses 2.0 *kg* and 1.0 *kg*. The smaller mass goes at a speed of 80 *m/s*.The total energy imparted to the two fragments is

[AIIMS 2004]

(a) 1.07 *kJ* (b) 2.14 *kJ*

(c) 2.4 *kJ* (d) 4.8 *kJ*

68. A bullet moving with a speed of 100 ms^{-1} can just penetrate two planks of equal thickness. Then the number of such planks penetrated by the same bullet when the speed is doubled will be

(a) 4 (b) 8

(c) 6 (d) 10

69. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then

(a) $E_1 < E_2$ (b) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$

(c) $E_1 > E_2$ (d) $E_1 = E_2$

70. A ball of mass 2*kg* and another of mass 4*kg* are dropped together from a 60 *feet* tall building. After a fall of 30 *feet* each towards earth, their respective kinetic energies will be in the ratio of

(a) $\sqrt{2}:1$ (b) $1:4$

(c) $1:2$ (d) $1:\sqrt{2}$

71. Four particles given, have same momentum which has maximum kinetic energy [Orissa PMT 2004]

(a) Proton (b) Electron

(c) Deutron (d) α -particles

72. A body moving with velocity v has momentum and kinetic energy numerically equal. What is the value of v

[Pb. PMT 2002; J&K CET 2004]

(a) 2*m/s* (b) $\sqrt{2}m/s$

(c) 1*m/s* (d) $0.2\ m/s$

73. If a man increase his speed by 2 *m/s* , his K.E. is doubled, the original speed of the man is [Pb. PET 2002]

(a) $(1+2\sqrt{2})\ m/s$ (b) 4 *m/s*

(c) $(2+2\sqrt{2})m/s$ (d) $(2+\sqrt{2})\ m/s$

74. An object of mass 3m splits into three equal fragments. Two fragments have velocities $v\hat{j}$ and $v\hat{i}$. The velocity of the third fragment is [UPSEAT 2004]

(a) $v(\hat{j}-\hat{i})$ (b) $v(\hat{i}-\hat{j})$

(c) $-v(\hat{i}+\hat{j})$ (d) $\frac{v(\hat{i}+\hat{j})}{\sqrt{2}}$

[MP PET 2004]

75. A bomb is kept stationary at a point. It suddenly explodes into two fragments of masses 1 g and 3 g. The total K.E. of the fragments is $6.4\times10^4\ J$. What is the K.E. of the smaller fragment

(a) $2.5\times10^4\ J$ (b) $3.5\times10^4\ J$

(c) $4.8\times10^4\ J$ (d) $5.2\times10^4\ J$

76. Which among the following, is a form of energy [DCE 2004]

(a) Light (b) Pressure

(c) Momentum (d) Power

77. A body is moving with a velocity v, breaks up into two equal parts. One of the part retraces back with velocity v. Then the velocity of the other part is [DCE 2004]

(a) v in forward direction [KCET 2004] (b) 3v in forward direction

(c) v in backward direction (d) 3v in backward direction

78. If a shell fired from a cannon, explodes in mid air, then

[Pb. PET 2004]

(a) Its total kinetic energy increases

(b) Its total momentum increases

[CBSE PMT 2004]

(c) Its total momentum decreases

(d) None of these

79. A particle of mass m moving with velocity V_0 strikes a simple pendulum of mass m and sticks to it. The maximum height attained by the pendulum will be [RPET 2002]

(a) $h=\frac{V_0^2}{8g}$ [CBSE PMT 2004] (b) $\sqrt{V_0 g}$

(c) $2\sqrt{\frac{V_0}{g}}$ (d) $\frac{V_0^2}{4g}$

80. Masses of two substances are 1 *g* and 9 *g* respectively. If their kinetic energies are same, then the ratio of their momentum will be

(a) 1 : 9 (b) 9 : 1

(c) 3 : 1 (d) 1 : 3

81. A body of mass 5 *kg* is moving with a momentum of 10 *kg-m/s*. A force of 0.2 *N* acts on it in the direction of motion of the body for 10 *seconds*. The increase in its kinetic energy is **[MP PET 1999]**

(a) 2.8 *Joule* (b) 3.2 *Joule*

(c) 3.8 *Joule* (d) 4.4 *Joule*

82. If the momentum of a body increases by 0.01%, its kinetic energy will increase by **[MP PET 2001]**

(a) 0.01% (b) 0.02%

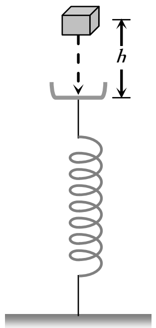
(c) 0.04% (d) 0.08%

83. 1 *a.m.u.* is equivalent to **[UPSEAT 2001]**

(a) 1.6×10^{-12} *Joule* (b) 1.6×10^{-19} *Joule*

(c) 1.5×10^{-10} *Joule* (d) 1.5×10^{-19} *Joule*

84. A block of mass *m* initially at rest is dropped from a height *h* on to a spring of force constant *k*. the maximum compression in the spring is *x* then **[BCECE 2005]**



(a) $mgh = \frac{1}{2}kx^2$

(b) $mg(h+x) = \frac{1}{2}kx^2$

(c) $mgh = \frac{1}{2}k(x+h)^2$

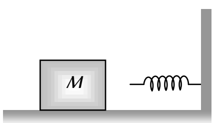
(d) $mg(h+x) = \frac{1}{2}k(x+h)^2$

85. A spherical ball of mass 20 *kg* is stationary at the top of a hill of height 100 *m*. It slides down a smooth surface to the ground, then climbs up another hill of height 30 *m* and finally slides down to a horizontal base at a height of 20 *m* above the ground. The velocity attained by the ball is **[AIEEE 2005]**

(a) 10 *m/s* (b) $10\sqrt{30}$ *m/s*

(c) 40 *m/s* (d) 20 *m/s*

86. The block of mass *M* moving on the frictionless horizontal surface collides with the spring of spring constant *K* and compresses it by length *L*. The maximum momentum of the block after collision is



(a) Zero

(b) $\frac{ML^2}{K}$

(c) $\sqrt{MK}\ L$

(d) $\frac{KL^2}{2M}$

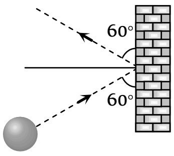
87. A bomb of mass $30\,kg$ at rest explodes into two pieces of masses $18\ kg$ and $12\ kg$. The velocity of $18\ kg$ mass is $6\ ms^{-1}$. The kinetic energy of the other mass is **[CBSE PMT 2005]**

(a) 256 *J* (b) 486 *J*

(c) 524 *J* (d) 324 *J*

[BHU 2004]

88. A mass of 100 *g* strikes the wall with speed 5 *m/s* at an angle as shown in figure and it rebounds with the same speed. If the contact time is 2×10^{-3} sec, what is the force applied on the mass by the wall **[Orissa JEE 2005]**



100 *g*

(a) $250\sqrt{3}$ *N* to right

(b) 250 *N* to right

(c) $250\sqrt{3}$ *N* to left

(d) 250 *N* to left

Power

1. If a force *F* is applied on a body and it moves with a velocity *v*, the power will be **[CPMT 1985, 97; DCE 1999; UPSEAT 2004]**

(a) $F\times v$ (b) F/v

(c) F/v^2 (d) $F\times v^2$

2. A body of mass *m* accelerates uniformly from rest to v_1 in time t_1. As a function of time *t*, the instantaneous power delivered to the body is **[AIEEE 2004]**

(a) $\frac{mv_1t}{t_1}$ (b) $\frac{mv_1^2t}{t_1}$

(c) $\frac{mv_1t^2}{t_1}$ (d) $\frac{mv_1^2t}{t_1^2}$

3. A man is riding on a cycle with velocity 7.2 *km/hr* up a hill having a slope 1 in 20. The total mass of the man and cycle is 100 *kg*. The power of the man is

(a) 200 *W* (b) 175 *W*

(c) 125 *W* (d) 98 *W*

4. A 12 *HP* motor has to be operated 8 *hours/day*. How much will it cost at the rate of 50 *paisa/kWh* in 10 days

(a) Rs. 350/- (b) Rs. 358/-

(c) Rs. 375/- (d) Rs. 397/-

5. A motor boat is travelling with a speed of 3.0 *m/sec*. If the force on it due to water flow is 500 *N*, the power of the boat is

(a) 150 *kW* (b) 15 *kW*

(c) 1.5 *kW* (d) 150 *W*

[AIEEE 2005]

6. An electric motor exerts a force of 40 *N* on a cable and pulls it by a distance of 30 *m* in one minute. The power supplied by the motor (in *Watts*) is **[EAMCET 1984]**

(a) 20 (b) 200

(c) 2 (d) 10

7. An electric motor creates a tension of 4500 *newton* in a hoisting cable and reels it in at the rate of 2 *m/sec*. What is the power of electric motor **[MNR 1984]**

(a) 15 *kW* (b) 9 *kW*

(c) 225 *W* (d) 9000 *HP*

8. A weight lifter lifts 300 *kg* from the ground to a height of 2 *meter* in 3 *second*. The average power generated by him is **[CPMT 1989; JIPMER 2001,02]**

(a) 5880 *watt* (b) 4410 *watt*

(c) 2205 *watt* (d) 1960 *watt*

9. Power of a water pump is 2 *kW*. If $g = 10\,m/\sec^2$, the amount of water it can raise in one minute to a height of 10 *m* is

(a) 2000 *litre* (b) 1000 *litre*

(c) 100 *litre* (d) 1200 *litre*

10. An engine develops 10 *kW* of power. How much time will it take to lift a mass of 200 *kg* to a height of 40 *m*. $(g = 10\,m/\sec^2)$

(a) 4 *sec* (b) 5 *sec*

(c) 8 *sec* (d) 10 *sec*

11. A car of mass '*m*' is driven with acceleration '*a*' along a straight level road against a constant external resistive force '*R*'. When the velocity of the car is '*V*', the rate at which the engine of the car is doing work will be

[MP PMT/PET 1998; JIPMER 2000]

(a) RV (b) maV

(c) $(R + ma)V$ (d) $(ma - R)V$

12. The average power required to lift a 100 *kg* mass through a height of 50 *metres* in approximately 50 *seconds* would be

[SCRA 1994; MH CET 2000]

(a) 50 *J/s* (b) 5000 *J/s*

(c) 100 *J/s* (d) 980 *J/s*

13. From a waterfall, water is falling down at the rate of 100 *kg/s* on the blades of turbine. If the height of the fall is 100 *m*, then the power delivered to the turbine is approximately equal to[KCET 1994; BHU 1997; MP PET 2000]

(a) 100 *kW* (b) 10 *kW*

(c) 1 *kW* (d) 1000 *kW*

14. The power of a pump, which can pump 200*kg* of water to a height of 200*m* in 10*sec* is $(g = 10m/s^2)$ [CBSE PMT 2000]

(a) 40 *kW* (b) 80 *kW*

(c) 400 *kW* (d) 960 *kW*

15. A 10 *H.P.* motor pumps out water from a well of depth 20*m* and fills a water tank of volume 22380 *litres* at a height of 10*m* from the ground. the running time of the motor to fill the empty water tank is $(g = 10ms^{-2})$

[EAMCET (Engg.) 2000]

(a) 5 *minutes* (b) 10 *minutes*

(c) 15 *minutes* (d) 20 *minutes*

16. A car of mass 1250 *kg* is moving at 30*m/s*. Its engine delivers 30 *kW* while resistive force due to surface is 750*N*. What max acceleration can be given in the car

[RPET 2000]

(a) $\frac{1}{3}m/s^2$ (b) $\frac{1}{4}m/s^2$

(c) $\frac{1}{5}m/s^2$ (d) $\frac{1}{6}m/s^2$

17. A force applied by an engine of a train of mass $2.05 \times 10^6 kg$ changes its velocity from $5m/s$ to 25 m/s in 5 minutes. The power of the engine is [EAMCET 2001]

(a) $1.025MW$ (b) $2.05MW$

(c) $5MW$ (d) $6MW$

18. A truck of mass 30,000*kg* moves up an inclined plane of slope 1 in 100 at a speed of 30 *kmph*. The power of the truck is (given $g = 10ms^{-1}$) [Kerala (Engg.) 2001]

(a) 25 *kW* (b) 10 *kW*

(c) 5 *kW* (d) 2.5 *kW*

[CBSE PMT 1990; Kerala PMT 2004]

19. A 60 *kg* man runs up a staircase in 12 seconds while a 50 *kg* man runs up the same staircase in 11, seconds, the ratio of the rate of doing their work is [AMU (Engg.) 2001]

(a) 6 : 5 (b) 12 : 11

(c) 11 : 10 (d) 10 : 11

20. A pump motor is used to deliver water at a certain rate from a given pipe. To obtain twice as much water from the same pipe in the same time, power of the motor has to be increased to [CPMT 1999]

(a) 16 times (b) 4 times

(c) 8 times (d) 2 times

21. What average horsepower is developed by an 80 *kg* man while climbing in 10 *s* a flight of stairs that rises 6 *m* vertically

(a) 0.63 *HP* (b) 1.26 *HP*

(c) 1.8 *HP* (d) 2.1 *HP*

22. A car of mass 1000 *kg* accelerates uniformly from rest to a velocity of 54 km/hour in 5*s*. The average power of the engine during this period in watts is (neglect friction)

[Kerala PET 2002]

(a) 2000 *W* (b) 22500 *W*

(c) 5000 *W* (d) 2250 *W*

23. A quarter horse power motor runs at a speed of 600 *r.p.m.* Assuming 40% efficiency the work done by the motor in one rotation will be [Kerala PET 2002]

(a) 7.46 *J* (b) 7400 *J*

(c) 7.46 *ergs* (d) 74.6 *J*

24. An engine pumps up 100 *kg* of water through a height of 10 *m* in 5 *s*. Given that the efficiency of the engine is 60% . If $g = 10ms^{-2}$, the power of the engine is [DPMT 2004]

(a) $3.3kW$ (b) $0.33kW$

(c) $0.033kW$ (d) $33kW$

25. A force of $2\hat{i} + 3\hat{j} + 4\hat{k}\ N$ acts on a body for 4 second, produces a displacement of $(3\hat{i} + 4\hat{j} + 5\hat{k})m$. The power used is [Pb. PET 2001; CBSE PMT 2

(a) 9.5 *W* (b) 7.5 *W*

(c) 6.5 *W* (d) 4.5 *W*

26. The power of pump, which can pump 200 *kg* of water to a height of 50 *m* in 10 *sec*, will be [DPMT 2003]

(a) 10×10^3 *watt* (b) 20×10^3 *watt*

(c) 4×10^3 *watt* (d) 60×10^3 *watt*

27. From an automatic gun a man fires 360 bullet per minute with a speed of 360 *km/hour*. If each weighs 20 *g*, the power of the gun is

(a) $600\,W$ (b) $300\,W$

(c) $150\,W$ (d) $75\,W$

28. An engine pump is used to pump a liquid of density ρ continuously through a pipe of cross-sectional area *A*. If the speed of flow of the liquid in the pipe is *v*, then the rate at which kinetic energy is being imparted to the liquid is

(a) $\frac{1}{2}A\rho v^3$ (b) $\frac{1}{2}A\rho v^2$

(c) $\frac{1}{2}A\rho v$ (d) $A\rho v$

29. If the heart pushes 1 cc of blood in one second under pressure 20000 *N/m* the power of heart is [J&K CET 2005]

(a) 0.02 *W* (b) 400 *W*

(c) $5 \times 10^{-}$ *W* (d) 0.2 *W*

30. A man does a given amount of work in 10 sec. Another man does the same amount of work in 20 sec. The ratio of the output power of first man to the second man is

[J&K CET 2005]

(a) 1 (b) 1/2

(c) 2/1 (d) None of these

Elastic and Inelastic Collision

1. The coefficient of restitution *e* for a perfectly elastic collision is

(a) 1 (b) 0

(c) ∞ (d) – 1

2. The principle of conservation of linear momentum can be strictly applied during a collision between two particles provided the time of impact is

(a) Extremely small

(b) Moderately small

(c) Extremely large

(d) Depends on a particular case

3. A shell initially at rest explodes into two pieces of equal mass, then the two pieces will

[CPMT 1982; EAMCET 1988; Orissa PMT 2004]

(a) Be at rest

(b) Move with different velocities in different directions

(c) Move with the same velocity in opposite directions

(d) Move with the same velocity in same direction

4. A sphere of mass *m* moving with a constant velocity *u* hits another stationary sphere of the same mass. If *e* is the coefficient of restitution, then the ratio of the velocity of two spheres after collision will be [RPMT 1996; BHU 1997]

(a) $\frac{1-e}{1+e}$ (b) $\frac{1+e}{1-e}$

(c) $\frac{e+1}{e-1}$ (d) $\frac{e-1}{e+1}t^2$

5. Two solid rubber balls *A* and *B* having masses 200 and 400 *gm* respectively are moving in opposite directions with velocity of *A* equal to 0.3 *m/s*. After collision the two balls come to rest, then the velocity of *B* is [CPMT 1978, 86, 88]

(a) 0.15 *m/sec* (b) 1.5 *m/sec*

(c) – 0.15 *m/sec* (d) None of the above

6. Two perfectly elastic particles *P* and *Q* of equal mass travelling along the line joining them with velocities 15 *m/sec* and 10 *m/sec*. After collision, their velocities respectively (in *m/sec*) will be

(a) 0, 25 (b) 5, 20

(c) 10, 15 (d) 20, 5

7. A cannon ball is fired with a velocity 200 *m/sec* at an angle of 60° with the horizontal. At the highest point of its flight it explodes into 3 equal fragments, one going vertically upwards with a velocity 100 *m/sec*, the second one falling vertically downwards with a velocity 100 *m/sec*. The third fragment will be moving with a velocity

[NCERT 1983; AFMC 1997]

(a) 100 *m/s* in the horizontal direction

(b) 300 *m/s* in the horizontal direction

(c) 300 *m/s* in a direction making an angle of 60° with the horizontal

(d) 200 *m/s* in a direction making an angle of 60° with the horizontal

8. A lead ball strikes a wall and falls down, a tennis ball having the same mass and velocity strikes the wall and bounces back. Check the correct statement

(a) The momentum of the lead ball is greater than that of the tennis ball

(b) The lead ball suffers a greater change in momentum compared with the tennis ball [CBSE PMT 1988]

(c) The tennis ball suffers a greater change in momentum as compared with the lead ball

(d) Both suffer an equal change in momentum

9. When two bodies collide elastically, then

[CPMT 1974; MP PMT 2001; RPET 2000; Kerala PET 2005]

(a) Kinetic energy of the system alone is conserved

(b) Only momentum is conserved

(c) Both energy and momentum are conserved

(d) Neither energy nor momentum is conserved

10. Two balls at same temperature collide. What is conserved

[NCERT 1974; CPMT 1983; DCE 2004]

(a) Temperature (b) Velocity

(c) Kinetic energy (d) Momentum

11. A body of mass 5 *kg* explodes at rest into three fragments with masses in the ratio 1 : 1 : 3. The fragments with equal masses fly in mutually perpendicular directions with speeds of 21 *m/s*. The velocity of the heaviest fragment will be

[CBSE PMT 1991]

(a) 11.5 *m/s* (b) 14.0 *m/s*

(c) 7.0 *m/s* (d) 9.89 *m/s*

12. A heavy steel ball of mass greater than 1 *kg* moving with a speed of $2\,m\,\text{sec}^{-1}$ collides head on with a stationary ping-pong ball of mass less than 0.1 gm. The collision is elastic. After the collision the ping-pong ball moves approximately with speed

(a) $2\,m\,\text{sec}^{-1}$ (b) $4\,m\,\text{sec}^{-1}$

(c) $2 \times 10^4\,m\,\text{sec}^{-1}$ (d) $2 \times 10^3\,m\,\text{sec}^{-1}$

13. A body of mass 'M' collides against a wall with a velocity *v* and retraces its path with the same speed. The change in momentum is (take initial direction of velocity as positive)

[EAMCET 1982]

(a) Zero (b) 2M*v*

(c) M*v* (d) – 2 M*v*

14. A gun fires a bullet of mass 50 gm with a velocity of $30\,m\,\text{sec}^{-1}$. [CPMT 1988; MP PMT 1994] Because of this the gun is pushed back with a velocity of $1\,m\,\text{sec}^{-1}$. The mass of the gun is

[EAMCET 1989; AIIMS 2001]

(a) 15 *kg* (b) 30 *kg*

(c) 1.5 *kg* (d) 20 *kg*

15. In an elastic collision of two particles the following is conserved[MP PET 1994; D

(a) Momentum of each particle
(b) Speed of each particle
(c) Kinetic energy of each particle
(d) Total kinetic energy of both the particles

16. A ^{238}U nucleus decays by emitting an alpha particle of speed $v\,ms^{-1}$. The recoil speed of the residual nucleus is (in ms^{-1}) [CBSE PMT 1995; AIEEE 2003]

(a) $-4v/234$ (b) $v/4$
(c) $-4v/238$ (d) $4v/238$

17. A smooth sphere of mass *M* moving with velocity *u* directly collides elastically with another sphere of mass *m* at rest. After collision their final velocities are *V* and *v* respectively. The value of *v* is

(a) $\frac{2uM}{m}$ (b) $\frac{2um}{M}$
(c) $\frac{2u}{1+\frac{m}{M}}$ (d) $\frac{2u}{1+\frac{M}{m}}$

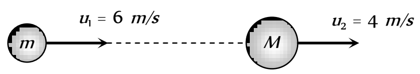
18. A body of mass *m* having an initial velocity *v*, makes head on collision with a stationary body of mass *M*. After the collision, the body of mass *m* comes to rest and only the body having mass *M* moves. This will happen only when [MP PMT 1995]

(a) $m >> M$ (b) $m << M$
(c) $m = M$ (d) $m = \frac{1}{2}M$

19. A particle of mass *m* moving with a velocity $\vec{V}$ makes a head on elastic collision with another particle of same mass initially at rest. The velocity of the first particle after the collision will be [MP PMT 1997; MP PET 2001; UPSEAT 2001]

(a) $\vec{V}$ (b) $-\vec{V}$
(c) $-2\vec{V}$ (d) Zero

20. A particle of mass m moving with horizontal speed 6 *m/sec* as shown in figure. If $m << M$ then for one dimensional elastic collision, the speed of lighter particle after collision will be



(a) 2*m/sec* in original direction
(b) 2 *m/sec* opposite to the original direction
(c) 4 *m/sec* opposite to the original direction
(d) 4 *m/sec* in original direction

21. A shell of mass *m* moving with velocity *v* suddenly breaks into 2 pieces. The part having mass *m*/4 remains stationary. The velocity of the other shell will be [CPMT 1999]

(a) *v* (b) 2*v*
(c) $\frac{3}{4}v$ (d) $\frac{4}{3}v$

22. Two equal masses m_1 and m_2 moving along the same straight line with velocities + 3 *m/s* and – 5 *m/s* respectively collide elastically. Their velocities after the collision will be respectively [CBSE PMT 1994, 98; AIIMS 2000]

(a) + 4 *m/s* for both (b) – 3 *m/s* and +5 *m/s*
(c) – 4 *m/s* and + 4 *m/s* (d) – 5 *m/s* and + 3 *m/s*

23. A rubber ball is dropped from a height of 5 *m* on a planet where the acceleration due to gravity is not known. On bouncing, it rises to 1.8 *m*. The ball loses its velocity on bouncing by a factor of

(a) 16/25 (b) 2/5
(c) 3/5 (d) 9/25

24. A metal ball falls from a height of 32 *metre* on a steel plate. If the coefficient of restitution is 0.5, to what height will the ball rise after second bounce [EAMCET 1994]

(a) 2 *m* (b) 4 *m*
(c) 8 *m* (d) 16 *m*

25. At high altitude, a body explodes at rest into two equal fragments with one fragment receiving horizontal velocity of 10 *m/s*. Time taken by the two radius vectors connecting point of explosion to fragments to make 90° is [EAMCET (Engg.) 1995; DPMT 2000]

(a) 10[MP PET 1995] (b) 4 *s*
(c) 2 *s* (d) 1 *s*

26. A ball of mass 10 *kg* is moving with a velocity of 10 *m/s*. It strikes another ball of mass 5 *kg* which is moving in the same direction with a velocity of 4 *m/s*. If the collision is elastic, their velocities after the collision will be, respectively [CMEET Bihar 1995]

(a) 6 *m/s*, 12 *m/s* (b) 12 *m/s*, 6 *m/s*
(c) 12 *m/s*, 10 *m/s* (d) 12 *m/s*, 25 *m/s*

27. A body of mass 2 *kg* collides with a wall with speed 100 *m/s* and rebounds with same speed. If the time of contact was 1/50 second, the force exerted on the wall is [CPMT 1993]

(a) 8 *N* (b) $2\times10^4\ N$
(c) 4 *N* (d) $10^4\ N$

28. A body falls on a surface of coefficient of restitution 0.6 from a height of 1 *m*. Then the body rebounds to a height of [CPMT 1993; Pb. PET 2001]

(a) 0.6 *m* (b) 0.4 *m*
(c) 1 *m* (d) 0.36 *m*

29. A ball is dropped from a height *h*. If the coefficient of restitution be *e*, then to what height will it rise after jumping twice from the ground [MP PMT 2003] [RPMT 1996; Pb. PET 2001]

(a) *eh*/2 (b) 2*eh*
(c) *eh* (d) e^4h

30. A ball of weight 0.1 *kg* coming with speed 30 *m/s* strikes with a bat and returns in opposite direction with speed 40 *m/s*, then the impulse is (Taking final velocity as positive) [AFMC 1997]

(a) $-0.1\times(40)-0.1\times(30)$ (b) $0.1\times(40)-0.1\times(-30)$
(c) $0.1\times(40)+0.1\times(-30)$ (d) $0.1\times(40)-0.1\times(20)$

31. A billiard ball moving with a speed of 5 *m/s* collides with an identical ball originally at rest. If the first ball stops after collision, then the second ball will move forward with a speed of

(a) $10\,ms^{-1}$ (b) $5\,ms^{-1}$
(c) $2.5\,ms^{-1}$ (d) $1.0\,ms^{-1}$

32. If two balls each of mass 0.06 *kg* moving in opposite directions with speed 4 *m/s* collide and rebound with the same speed, then the impulse imparted to each ball due to other is [CBSE PMT 1998]

(a) 0.48 *kg-m/s* (b) 0.24 *kg-m/s*

(c) 0.81 *kg-m/s* (d) Zero

33. A ball of mass m falls vertically to the ground from a height h_1 and rebound to a height h_2. The change in momentum of the ball on striking the ground is [AMU (Engg.) 1999]

(a) $mg(h_1 - h_2)$ (b) $m(\sqrt{2gh_1} + \sqrt{2gh_2})$

(c) $m\sqrt{2g(h_1 + h_2)}$ (d) $m\sqrt{2g}(h_1 + h_2)$

34. A body of mass 50 *kg* is projected vertically upwards with velocity of 100 *m/sec*. 5 seconds after this body breaks into 20 *kg* and 30 *kg*. If 20 *kg* piece travels upwards with 150 *m/sec*, then the velocity of other block will be [RPMT 1999]

(a) 15 *m/sec* downwards (b) 15 *m/sec* upwards

(c) 51 *m/sec* downwards (d) 51 *m/sec* upwards

35. A steel ball of radius 2 *cm* is at rest on a frictionless surface. Another ball of radius 4*cm* moving at a velocity of 81 *cm/sec* collides elastically with first ball. After collision the smaller ball moves with speed of [RPMT 1999]

(a) 81 *cm/sec* (b) 63 *cm/sec*

(c) 144 *cm/sec* (d) None of these

36. A space craft of mass M is moving with velocity V and suddenly explodes into two pieces. A part of it of mass m becomes at rest, then the velocity of other part will be

[RPMT 1999]

(a) $\frac{MV}{M-m}$ (b) $\frac{MV}{M+m}$

(c) $\frac{mV}{M-m}$ (d) $\frac{(M+m)V}{m}$

37. A ball hits a vertical wall horizontally at 10*m/s* bounces back at 10 *m/s* [JIPMER 1999]

(a) There is no acceleration because $10\frac{m}{s} - 10\frac{m}{s} = 0$

(b) There may be an acceleration because its initial direction is horizontal

(c) There is an acceleration because there is a momentum change

(d) Even though there is no change in momentum there is a change in direction. Hence it has an acceleration

38. A bullet of mass 50 *gram* is fired from a 5 *kg* gun with a velocity of 1*km/s*. the speed of recoil of the gun is

[JIPMER 1999]

(a) $5 m/s$ (b) $1 m/s$

(c) $0.5 m/s$ (d) $10 m/s$

39. A body falling from a height of 10m rebounds from hard floor. If it loses 20% energy in the impact, then coefficient of restitution is

(a) 0.89 (b) 0.56

(c) 0.23 (d) 0.18

40. A body of mass m_1 moving with a velocity 3 *ms*⁻¹ collides with another body at rest of mass m_2. After collision the velocities of the two bodies are 2 *ms*⁻¹ and 5*ms*⁻¹ respectively along the direction of motion of m_1 The ratio m_1/m_2 is

[EAMCET (Engg.) 2000]

(a) $\frac{5}{12}$ (b) 5

(c) $\frac{1}{5}$ (d) $\frac{12}{5}$

41. 100 *g* of a iron ball having velocity 10 *m/s* collides with a wall at an angle 30^o and rebounds with the same angle. If the period of contact between the ball and wall is 0.1 second, then the force experienced by the ball is

[DPMT 2000]

(a) 100*N* (b) 10 *N*

(c) 0.1 *N* (d) 1.0 *N*

42. Two bodies having same mass 40 *kg* are moving in opposite directions, one with a velocity of $10 m/s$ and the other with $7m/s$. If they collide and move as one body, the velocity of the combination is [Pb. PMT 2000]

(a) $10 m/s$ (b) $7 m/s$

(c) $3 m/s$ (d) $1.5 m/s$

43. A body at rest breaks up into 3 parts. If 2 parts having equal masses fly off perpendicularly each after with a velocity of 12*m/s*, then the velocity of the third part which has 3 times mass of each part is

(a) $4\sqrt{2}\, m/s$ at an angle of 45^o from each body

(b) $24\sqrt{2}\, m/s$ at an angle of 135^o from each body

(c) $6\sqrt{2}\, m/s$ at 135^o from each body

(d) $4\sqrt{2}\, m/s$ at 135^o from each body

44. A particle falls from a height h upon a fixed horizontal plane and rebounds. If e is the coefficient of restitution, the total distance travelled before rebounding has stopped is

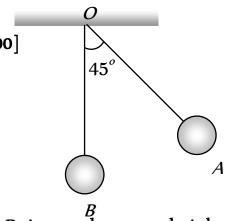
[EAMCET 2001]

(a) $h\left(\frac{1+e^2}{1-e^2}\right)$ (b) $h\left(\frac{1-e^2}{1+e^2}\right)$

(c) $\frac{h}{2}\left(\frac{1-e^2}{1+e^2}\right)$ (d) $\frac{h}{2}\left(\frac{1+e^2}{1-e^2}\right)$

45. The bob A of a simple pendulum is released when the string makes an angle of 45^o with the vertical. It hits another bob B of the same material and same mass kept at rest on the table. If the collision is elastic [Kerala (Engg.) 2001]

[AIIMS 2000]



(a) Both A and B rise to the same height

(b) Both A and B come to rest at B

(c) Both A and B move with the same velocity of A

(d) A comes to rest and B moves with the velocity of A

46. A big ball of mass M, moving with velocity u strikes a small ball of mass m, which is at rest. Finally small ball obtains velocity u and big ball v. Then what is the value of v [RPET 2001]

(a) $\frac{M-m}{M+m}u$ (b) $\frac{m}{M+m}u$

(c) $\frac{2m}{M+m}u$ (d) $\frac{M}{M+m}u$

47. A body of mass 5 kg moving with a velocity 10 m/s collides with another body of the mass 20 kg at, rest and comes to rest. The velocity of the second body due to collision is

[Pb. PMT 1999; KCET 2001]

(a) 2.5 m/s (b) 5 m/s

(c) 7.5 m/s (d) 10 m/s

48. A ball of mass m moving with velocity V, makes a head on elastic collision with a ball of the same mass moving with velocity $2V$ towards it. Taking direction of V as positive velocities of the two balls after collision are [MP PMT 2002]

(a) $-V$ and $2V$ (b) $2V$ and $-V$

(c) V and $-2V$ (d) $-2V$ and V

49. A body of mass M_1 collides elastically with another mass M_2 at rest. There is maximum transfer of energy when

[Orissa JEE 2002; DCE 2001, 02]

(a) $M_1 > M_2$

(b) $M_1 < M_2$

(c) $M_1 = M_2$

(d) Same for all values of M_1 and M_2

50. A body of mass $2kg$ makes an elastic collision with another body at rest and continues to move in the original direction with one fourth of its original speed. The mass of the second body which collides with the first body is [Kerala PET 2002]

(a) 2 kg (b) 1.2 kg

(c) 3 kg (d) 1.5 kg

51. In the elastic collision of objects [RPET 2003]

(a) Only momentum remains constant

(b) Only K.E. remains constant

(c) Both remains constant

(d) None of these

52. Two particles having position vectors $\vec{r}_1 = (3\hat{i} + 5\hat{j})$ *metres* and $\vec{r}_2 = (-5\hat{i} - 3\hat{j})$ *metres* are moving with velocities $\vec{v}_1 = (4\hat{i} + 3\hat{j})\,m/s$ and $\vec{v}_2 = (\alpha\hat{i} + 7\hat{j})\ m/s$. If they collide after 2 seconds, the value of 'α' is [EAMCET 2003]

(a) 2 (b) 4

(c) 6 (d) 8

53. A neutron makes a head-on elastic collision with a stationary deuteron. The fractional energy loss of the neutron in the collision is

(a) 16/81 (b) 8/9

(c) 8/27 (d) 2/3

54. A body of mass m is at rest. Another body of same mass moving with velocity V makes head on elastic collision with the first body. After collision the first body starts to move with velocity

(a) V (b) $2V$

(c) Remain at rest (d) No predictable

55. A body of mass M moves with velocity v and collides elastically with a another body of mass m ($M>>m$) at rest then the velocity of body of mass m is [BCECE 2004]

(a) v (b) $2v$

(c) $v/2$ (d) Zero

56. Four smooth steel balls of equal mass at rest are free to move along a straight line without friction. The first ball is given a velocity of 0.4 m/s. It collides head on with the second elastically, the second one similarly with the third and so on. The velocity of the last ball is[UPSEAT 2

(a) $0.4 m/s$ (b) $0.2 m/s$

(c) $0.1 m/s$ (d) $0.05 m/s$

57. A space craft of mass 'M' and moving with velocity 'v' suddenly breaks in two pieces of same mass m. After the explosion one of the mass 'm' becomes stationary. What is the velocity of the other part of craft [DCE 2003]

(a) $\frac{Mv}{M-m}$ (b) v

(c) $\frac{Mv}{m}$ (d) $\frac{M-m}{m}v$

58. Two masses m_A and m_B moving with velocities v_A and v_B in opposite directions collide elastically. After that the masses m_A and m_B move with velocity v_B and v_A respectively. The ratio (m_A / m_B) is

[RPMT 2003, AFMC 2002]

(a) 1 (b) $\frac{v_A - v_B}{v_A + v_B}$

(c) $(m_A + m_B)/m_A$ (d) v_A / v_B

59. A ball is allowed to fall from a height of 10 m. If there is 40% loss of energy due to impact, then after one impact ball will go up to

(a) 10 m (b) 8 m

(c) 4 m (d) 6 m

60. Which of the following statements is true [NCERT 1984]

(a) In elastic collisions, the momentum is conserved but not in inelastic collisions

(b) Both kinetic energy and momentum are conserved in elastic as well as inelastic collisions

(c) Total kinetic energy is not conserved but momentum is conserved in inelastic collisions

(d) Total kinetic energy is conserved in elastic collisions but momentum is not conserved in elastic collisions

61. A tennis ball dropped from a height of 2 m rebounds only 1.5 m after hitting the ground. What fraction of its energy is lost in the impact

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) $\frac{1}{3}$ (d) $\frac{1}{8}$

62. A body of mass m moving with velocity v makes a head-on collision with another body of mass 2 m which is initially at rest. The loss of kinetic energy of the colliding body (mass m) is [AIIMS 2003]

(a) $\frac{1}{2}$ of its initial kinetic energy

[Orissa PMT 2004]

(b) $\frac{1}{9}$ of its initial kinetic energy

(c) $\frac{8}{9}$ of its initial kinetic energy

(d) $\frac{1}{4}$ of its initial kinetic energy

63. The quantities remaining constant in a collision are

(a) Momentum, kinetic energy and temperature

(b) Momentum and kinetic energy but not temperature

(c) Momentum and temperature but not kinetic energy

(d) Momentum but neither kinetic energy nor temperature

64. An inelastic ball is dropped from a height of 100 *m*. Due to earth, 20% of its energy is lost. To what height the ball will rise

(a) 80 *m* (b) 40 *m*

(c) 60 *m* (d) 20 *m*

65. A ball is projected vertically down with an initial velocity from a height of 20 *m* onto a horizontal floor. During the impact it loses 50% of its energy and rebounds to the same height. The initial velocity of its projection is

[EAMCET (Engg.) 2000]

(a) $20 ms^{-1}$ (b) $15 ms^{-1}$

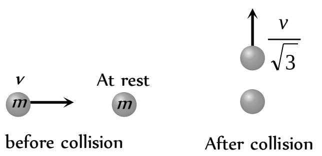
(c) $10 ms^{-1}$ (d) $5 ms^{-1}$

66. A tennis ball is released from height *h* above ground level. If the ball makes inelastic collision with the ground, to what height will it rise after third collision [RPET 2002]

(a) he^6 (b) e^2h

(c) e^3h (d) None of these

67. A mass '*m*' moves with a velocity '*v*' and collides inelastically with another identical mass. After collision the 1st mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the initial direction of motion. Find the speed of the 2nd mass after collision



(a) $\frac{2}{\sqrt{3}}v$

(b) $\frac{v}{\sqrt{3}}$

(c) v

(d) $\sqrt{3}\,v$

68. A sphere collides with another sphere of identical mass. After collision, the two spheres move. The collision is inelastic. Then the angle between the directions of the two spheres is

(a) 90° (b) 0°

(c) 45° (d) Different from 90°

Perfectly Inelastic Collision

1. A particle of mass *m* moving eastward with a speed *v* collides with another particle of the same mass moving northward with the same speed *v*. The two particles coalesce on collision. The new particle of mass 2*m* will move in the north-easterly direction with a velocity[NCERT 1980; CPMT 1991; MP PET 1999; DPMT 1999, 2005]

(a) *v*/2 (b) 2*v*

(c) $v/\sqrt{2}$ (d) *v*

2. The coefficient of restitution *e* for a perfectly inelastic collision is

(a) 1 (b) 0

(c) ∞ (d) – 1

3. When two bodies stick together after collision, the collision is said to be

[MP PET 1997]

(a) Partially elastic (b) Total elastic

(c) Total inelastic (d) None of the above

4. A bullet of mass *a* and velocity *b* is fired into a large block of mass *c*. The final velocity of the system is

[AFMC 1981, 94, 2000; NCERT 1971; MNR 1998]

(a) $\frac{c}{a+b}\cdot b$ [RPMT 1996] (b) $\frac{a}{a+c}\cdot b$

(c) $\frac{a+b}{c}.a$ (d) $\frac{a+c}{a}\cdot b$

5. A mass of 10 *gm* moving with a velocity of 100 *cm*/*s* strikes a pendulum bob of mass 10 *gm*. The two masses stick together. The maximum height reached by the system now is $(g = 10\, m/s^2)$

(a) Zero (b) 5 *cm*

(c) 2.5 *cm* (d) 1.25 *cm*

6. A completely inelastic collision is one in which the two colliding particles

(a) Are separated after collision

(b) Remain together after collision

(c) Split into small fragments flying in all directions

(d) None of the above

7. A bullet hits and gets embedded in a solid block resting on a horizontal frictionless table. What is conserved ?

[NCERT 1973; CPMT 1970; AFMC 1996; BHU 2001]

(a) Momentum and kinetic energy

(b) Kinetic energy alone

(c) Momentum alone [AIEEE 2005]

(d) Neither momentum nor kinetic energy

8. A body of mass 2 *kg* moving with a velocity of 3 *m*/*sec* collides head on with a body of mass 1 *kg* moving in opposite direction with a velocity of 4 *m*/*sec*. After collision, two bodies stick together and move with a common velocity which in *m*/*sec* is equal to

[NCERT 1984; MNR 1995, 98; UPSEAT 2000]

(a) 1/4 (b) 1/3

(c) 2/3 (d) 3/4

9. A body of mass *m* moving with a constant velocity *v* hits another body of the same mass moving with the same velocity *v* but in the opposite direction and sticks to it. The velocity of the compound body after collision is [KCET 1994]

[NCERT 1977; RPMT 1999]

(a) *v* (b) 2*v*

(c) Zero (d) *v*/2

10. In the above question, if another body is at rest, then velocity of the compound body after collision is

(a) *v*/2 (b) 2*v*

(c) *v* (d) Zero

11. A bag (mass *M*) hangs by a long thread and a bullet (mass *m*) comes horizontally with velocity *v* and gets caught in the bag. Then for the combined (bag + bullet) system

[CPMT 1989; Kerala PMT 2002]

(a) Momentum is $\frac{mvM}{M+m}$

(b) Kinetic energy is $\frac{mv^2}{2}$

(c) Momentum is $\frac{mv(M+m)}{M}$

(d) Kinetic energy is $\frac{m^2v^2}{2(M+m)}$

12. A 50 *g* bullet moving with velocity 10 *m/s* strikes a block of mass 950 *g* at rest and gets embedded in it. The loss in kinetic energy will be [MP PET 1994]

(a) 100% (b) 95%

(c) 5% (d) 50%

13. Two putty balls of equal mass moving with equal velocity in mutually perpendicular directions, stick together after collision. If the balls were initially moving with a velocity of $45\sqrt{2}\ ms^{-1}$ each, the velocity of their combined mass after collision is[Haryana CEE 1996; BVP 2003]

(a) $45\sqrt{2}\ ms^{-1}$ (b) $45\ ms^{-1}$

(c) $90\ ms^{-1}$ (d) $22.5\sqrt{2}\ ms^{-1}$

14. A particle of mass *m* moving with velocity *v* strikes a stationary particle of mass $2m$ and sticks to it. The speed of the system will be [MP PMT/PET 1998; AIIMS 1999; JIPMER 2001, 02]

(a) $v/2$ (b) $2v$

(c) $v/3$ (d) $3v$

15. A moving body of mass *m* and velocity 3 *km/h* collides with a rest body of mass $2m$ and sticks to it. Now the combined mass starts to move. What will be the combined velocity [CBSE PMT 1996; JIPMER 2001, 02]

(a) 3 *km/h* (b) 2 *km/h*

(c) 1 *km/h* (d) 4 *km/h*

16. If a skater of weight 3 *kg* has initial speed 32 *m/s* and second one of weight 4 *kg* has 5 *m/s*. After collision, they have speed (couple) 5 *m/s*. Then the loss in K.E. is [CPMT 1996]

(a) 48 *J* (b) 96 *J*

(c) Zero (d) None of these

17. A ball is dropped from height 10 *m*. Ball is embedded in sand 1 *m* and stops, then [AFMC 1996]

(a) Only momentum remains conserved

(b) Only kinetic energy remains conserved

(c) Both momentum and K.E. are conserved

(d) Neither K.E. nor momentum is conserved

18. A metal ball of mass 2 *kg* moving with a velocity of 36 *km/h* has an head on collision with a stationary ball of mass 3 *kg*. If after the collision, the two balls move together, the loss in kinetic energy due to collision is [CBSE PMT 1997; AIIMS 2001]

(a) 40 *J* (b) 60 *J*

(c) 100 *J* (d) 140 *J*

19. A body of mass $2kg$ is moving with velocity 10 *m/s* towards east. Another body of same mass and same velocity moving towards north collides with former and coalsces and moves towards north-east. Its velocity is [CPMT 1997; JIPMER 2000]

(a) 10 *m/s* (b) 5 *m/s*

(c) 2.5 *m/s* (d) $5\sqrt{2}\ m/s$

20. Which of the following is not a perfectly inelastic collision [BHU 1998; JIPMER 2001, 02; BHU 2005]

(a) Striking of two glass balls

(b) A bullet striking a bag of sand

(c) An electron captured by a proton

(d) A man jumping onto a moving cart

21. A mass of 20 *kg* moving with a speed of 10*m/s* collides with another stationary mass of $5kg$. As a result of the collision, the two masses stick together. The kinetic energy of the composite mass will be

(a) 600 *Joule* (b) 800 *Joule*

(c) 1000 *Joule* (d) 1200 *Joule*

22. A neutron having mass of $1.67\times10^{-27}kg$ and moving at $10^8 m/s$ collides with a deutron at rest and sticks to it. If the mass of the deutron is $3.34\times10^{-27}kg$ then the speed of the combination is [CBSE PMT 2000]

(a) $2.56\times10^3 m/s$ (b) $2.98\times10^5 m/s$

(c) $3.33\times10^7 m/s$ (d) $5.01\times10^9 m/s$

23. The quantity that is not conserved in an inelastic collision is [Pb. PMT 2000]

(a) Momentum (b) Kinetic energy

(c) Total energy (d) All of these

24. A body of mass 40*kg* having velocity 4 *m/s* collides with another body of mass 60*kg* having velocity 2 *m/s*. If the collision is inelastic, then loss in kinetic energy will be [Pb. PMT 2001]

(a) 440 *J* (b) 392 *J*

(c) 48 *J* (d) 144 *J*

25. A body of mass m_1 is moving with a velocity V. It collides with another stationary body of mass m_2. They get embedded. At the point of collision, the velocity of the system

(a) Increases

(b) Decreases but does not become zero

(c) Remains same

(d) Become zero

26. A bullet of mass *m* moving with velocity *v* strikes a block of mass *M* at rest and gets embedded into it. The kinetic energy of the composite block will be [MP PET 2002]

(a) $\frac{1}{2}mv^2\times\frac{m}{(m+M)}$ (b) $\frac{1}{2}mv^2\times\frac{M}{(m+M)}$

(c) $\frac{1}{2}mv^2\times\frac{(M+m)}{M}$ (d) $\frac{1}{2}Mv^2\times\frac{m}{(m+M)}$

27. In an inelastic collision, what is conserved [DCE 2004]

(a) Kinetic energy (b) Momentum

(c) Both (a) and (b) (d) Neither (a) nor (b)

28. Two bodies of masses 0.1 *kg* and 0.4 *kg* move towards each other with the velocities 1 *m/s* and 0.1 *m/s* respectively, After collision they stick together. In 10 *sec* the combined mass travels

(a) 120 *m* (b) 0.12 *m*

(c) 12 *m* (d) 1.2 *m*

29. A body of mass 4 *kg* moving with velocity 12 *m/s* collides with another body of mass 6 *kg* at rest. If two bodies stick together after collision, then the loss of kinetic energy of system is

(a) Zero (b) 288 J

(c) 172.8 J (d) 144 J

30. Which of the following is not an example of perfectly inelastic collision [AFMC 2005]

(a) A bullet fired into a block if bullet gets embedded into block

(b) Capture of electrons by an atom

(c) A man jumping on to a moving boat

(d) A ball bearing striking another ball bearing

Critical Thinking

Objective Questions

1. A ball hits the floor and rebounds after inelastic collision. In this case [IIT 1986]

(a) The momentum of the ball just after the collision is the same as that just before the collision

(b) The mechanical energy of the ball remains the same in the collision

(c) The total momentum of the ball and the earth is conserved

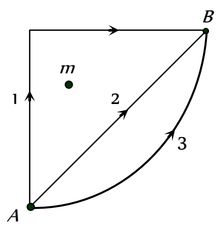
(d) The total energy of the ball and the earth is conserved

2. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part on to the table is [IIT 1985; MNR 1990; AIEEE 2002; MP PMT 1994, 97, 2000; JIPMER 2000]

(a) MgL (b) $MgL/3$

(c) $MgL/9$ (d) $MgL/18$

3. If W_1, W_2 and W_3 represent the work done in moving a particle from A to B along three different paths 1, 2 and 3 respectively (as shown) in the gravitational field of a point mass m, find the correct relation between W_1, W_2 and W_3



(a) $W_1 > W_2 > W_3$

(b) $W_1 = W_2 = W_3$

(c) $W_1 < W_2 < W_3$

(d) $W_2 > W_1 > W_3$

4. A particle of mass m is moving in a horizontal circle of radius r under a centripetal force equal to $-K/r^2$, where K is a constant. The total energy of the particle is [IIT 1977]

(a) $\frac{K}{2r}$ (b) $-\frac{K}{2r}$

(c) $-\frac{K}{r}$ (d) $\frac{K}{r}$

5. The displacement x of a particle moving in one dimension under the action of a constant force is related to the time t by the equation $t = \sqrt{x} + 3$, where x is in meters and t is in seconds. The work done by the force in the first 6 seconds is [IIT 1979]

(a) 9 *J* (b) 6 *J*

(c) 0 *J* (d) 3 *J*

6. A force $\mathbf{F} = -K(y\mathbf{i} + x\mathbf{j})$ (where K is a positive constant) acts on a particle moving in the xy-plane. Starting from the origin, the particle is taken along the positive x-axis to the point $(a, 0)$ and then parallel to the y-axis to the point (a, a). The total work done by the force F on the particles is [J&K CET 2005] [IIT 1998]

(a) $-2Ka^2$ (b) $2Ka^2$

(c) $-Ka^2$ (d) Ka^2

7. If g is the acceleration due to gravity on the earth's surface, the gain in the potential energy of an object of mass m raised from the surface of earth to a height equal to the radius of the earth R, is

(a) $\frac{1}{2}mgR$ (b) $2\ mgR$

(c) mgR (d) $\frac{1}{4}mgR$

8. A lorry and a car moving with the same K.E. are brought to rest by applying the same retarding force, then [IIT 1973; MP PMT 2003]

(a) Lorry will come to rest in a shorter distance

(b) Car will come to rest in a shorter distance

(c) Both come to rest in a same distance

(d) None of the above

9. A particle free to move along the x-axis has potential energy given by $U(x) = k[1 - \exp(-x)^2]$ for $-\infty \le x \le +\infty$, where k is a positive constant of appropriate dimensions. Then [IIT-JEE 1999; UPSEAT 2003]

(a) At point away from the origin, the particle is in unstable equilibrium

(b) For any finite non-zero value of x, there is a force directed away from the origin

(c) If its total mechanical energy is $k/2$, it has its minimum kinetic energy at the origin

(d) For small displacements from x = 0, the motion is simple harmonic [IIT-JEE Screening 2003]

10. The kinetic energy acquired by a mass m in travelling a certain distance d starting from rest under the action of a constant force is directly proportional to [CBSE PMT 1994]

(a) $\sqrt{m}$ (b) Independent of m

(c) $1/\sqrt{m}$ (d) m

11. An open knife edge of mass 'm' is dropped from a height 'h' on a wooden floor. If the blade penetrates upto the depth 'd' into the wood, the average resistance offered by the wood to the knife edge is [BHU 2002]

(a) mg (b) $mg\left(1 - \frac{h}{d}\right)$

(c) $mg\left(1 + \frac{h}{d}\right)$ (d) $mg\left(1 + \frac{h}{d}\right)^2$

12. Consider the following two statements

1. Linear momentum of a system of particles is zero
2. Kinetic energy of a system of particles is zero

Then [AIEEE 2003]

(a) 1 implies 2 and 2 implies 1

(b) 1 does not imply 2 and 2 does not imply 1

(c) 1 implies 2 but 2 does not imply 1

(d) 1 does not imply 2 but 2 implies 1

13. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to

[IIT 1984; BHU 1984, 95; MP PET 1996; JIPMER 2000; AMU (Med.) 1999]

(a) $t^{1/2}$ (b) $t^{3/4}$

(c) $t^{3/2}$ (d) t^2

14. A shell is fired from a cannon with velocity v *m/sec* at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed in *m/sec* of the other piece immediately after the explosion is

[IIT 1984; RPET 1999, 2001; UPSEAT 2002]

(a) $3v\cos\theta$ (b) $2v\cos\theta$

(c) $\frac{3}{2}v\cos\theta$ (d) $\frac{\sqrt{3}}{2}v\cos\theta$

15. A vessel at rest explodes into three pieces. Two pieces having equal masses fly off perpendicular to one another with the same velocity 30 *meter* per *second*. The third piece has three times mass of each of other piece. The magnitude and direction of the velocity of the third piece will be

[AMU (Engg.) 1999]

(a) $10\sqrt{2}\ m/second$ and 135° from either

(b) $10\sqrt{2}\ m/second$ and 45° from either

(c) $\frac{10}{\sqrt{2}}\ m/second$ and 135° from either

(d) $\frac{10}{\sqrt{2}}\ m/second$ and 45° from either

16. Two particles of masses m_1 and m_2 in projectile motion have velocities $\vec{v}_1$ and $\vec{v}_2$ respectively at time $t = 0$. They collide at time t_0. Their velocities become $\vec{v}_1'$ and $\vec{v}_2'$ at time $2t_0$ while still moving in air. The value of $|(m_1\overrightarrow{v_1}' + m_2\overrightarrow{v_2}') - (m_1\overrightarrow{v_1} + m_2\overrightarrow{v_2})|$ is

[IIT-JEE Screening 2001]

(a) Zero (b) $(m_1 + m_2)gt_0$

(c) $2(m_1 + m_2)gt_0$ (d) $\frac{1}{2}(m_1 + m_2)gt_0$

17. Consider elastic collision of a particle of mass m moving with a velocity u with another particle of the same mass at rest. After the collision the projectile and the struck particle move in directions making angles θ_1 and θ_2 respectively with the initial direction of motion. The sum of the angles. $\theta_1 + \theta_2$, is

(a) 45° (b) 90°

(c) 135° (d) 180°

18. A body of mass m moving with velocity v collides head on with another body of mass $2m$ which is initially at rest. The ratio of K.E. of colliding body before and after collision will be

(a) 1 : 1 (b) 2 : 1

(c) 4 : 1 (d) 9 : 1

19. A particle P moving with speed v undergoes a head -on elastic collision with another particle Q of identical mass but at rest. After the collision **[Roorkee 2000]**

(a) Both P and Q move forward with speed $\frac{v}{2}$

(b) Both P and Q move forward with speed $\frac{v}{\sqrt{2}}$

(c) P comes to rest and Q moves forward with speed v

(d) P and Q move in opposite directions with speed $\frac{v}{\sqrt{2}}$

20. A set of n identical cubical blocks lies at rest parallel to each other along a line on a smooth horizontal surface. The separation between the near surfaces of any two adjacent blocks is L. The block at one end is given a speed v towards the next one at time $t = 0$. All collisions are completely inelastic, then

(a) The last block starts moving at $t = \frac{(n-1)L}{v}$

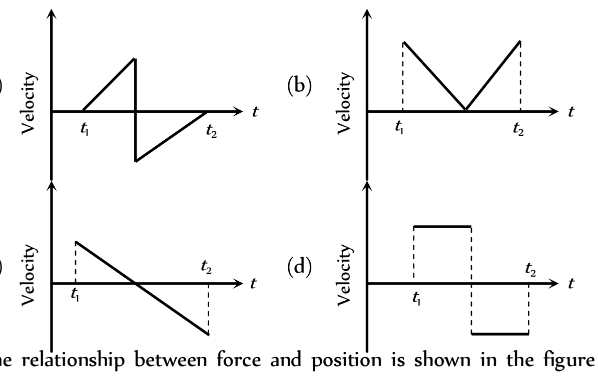
(b) The last block starts moving at $t = \frac{n(n-1)L}{2v}$

(c) The centre of mass of the system will have a final speed v

(d) The centre of mass of the system will have a final speed $\frac{v}{n}$

GQ Graphical Questions

1. A batsman hits a sixer and the ball touches the ground outside the cricket ground. Which of the following graph describes the variation of the cricket ball's vertical velocity v with time between the time t_1 as it hits the bat and time t_2 when it touches the ground



2. The relationship between force and position is shown in the figure given (in one dimensional case). The work done by the force in displacing a body from $x = 1\ cm$ to $x = 5\ cm$ is

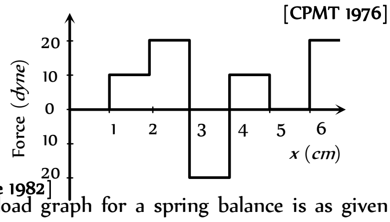
[UPSEAT 2004] **[CPMT 1976]**

(a) 20 *ergs*

(b) 60 *ergs*

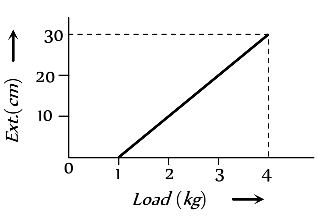
(c) 70 *ergs*

(d) 700 *ergs*



[Roorkee 1982]

3. The pointer reading *v/s* load graph for a spring balance is as given in the figure. The spring constant is



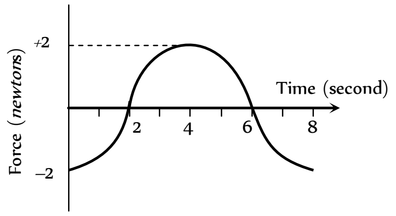
(a) 0.1 *kg/cm*

(b) 5 *kg/cm*

(c) 0.3 *kg/cm*

(d) 1 *kg/cm*

4. A force-time graph for a linear motion is shown in figure where the segments are circular. The linear momentum gained between zero and 8 *second* is [CPMT 1989]



(a) $-2\pi\ newton \times second$ (b) $Zero\ newton \times second$

(c) $+4\pi\ newton \times second$ (d) $-6\pi\ newton \times second$

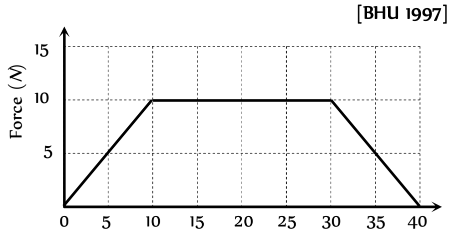
5. Adjacent figure shows the force-displacement graph of a moving body, the work done in displacing body from $x = 0$ to $x = 35\,m$ is equal to [BHU 1997]

(a) 50 *J*

(b) 25 *J*

(c) 287.5 *J*

(d) 200 *J*



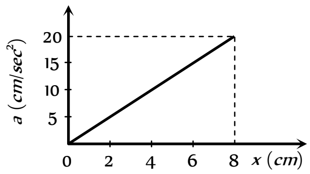
6. A 10*kg* mass moves along *x*-axis. Its acceleration as a function of its position is shown in the figure. What is the total work done on the mass by the force as the mass moves from $x = 0$ to $x = 8\,cm$

(a) $8 \times 10^{-2}\ joules$

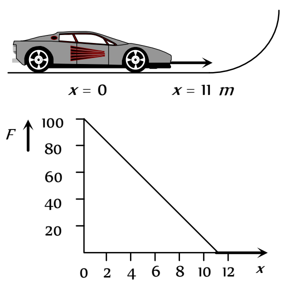
(b) $16 \times 10^{-2}\ joules$

(c) $4 \times 10^{-4}\ joules$

(d) $1.6 \times 10^{-3}\ joules$



7. A toy car of mass 5 *kg* moves up a ramp under the influence of force *F* plotted against displacement *x*. The maximum height attained is given by



(a) $y_{max} = 20m$

(b) $y_{max} = 15m$

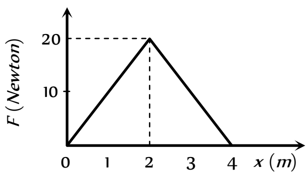
(c) $y_{max} = 11m$

(d) $y_{max} = 5m$

8. The graph between the resistive force *F* acting on a body and the distance covered by the body is shown in the figure. The mass of the body is 25 *kg* and initial velocity is 2 *m/s*. When the distance covered by the body is 4*m*, its kinetic energy would be

(a) 50 *J*

(b) 40 *J*



(c) 20 *J*

(d) 10 *J*

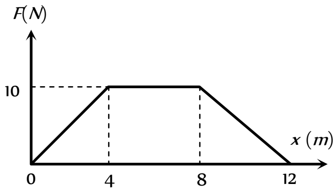
9. A particle of mass 0.1 *kg* is subjected to a force which varies with distance as shown in fig. If it starts its journey from rest at $x = 0$, its velocity at $x = 12\,m$ is [AIIMS 1995]

(a) 0 *m/s*

(b) $20\sqrt{2}\ m/s$

(c) $20\sqrt{3}\ m/s$

(d) $40\ m/s$



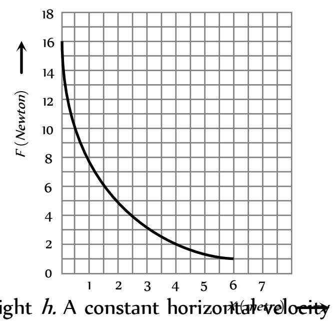
10. The relation between the displacement *X* of an object produced by the application of the variable force *F* is represented by a graph shown in the figure. If the object undergoes a displacement from $X = 0.5\,m$ to $X = 2.5\,m$ the work done will be approximately equal to [CPMT 1986]

(a) 16 *J*

(b) 32 *J*

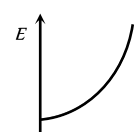
(c) 1.6 *J*

(d) 8 *J*

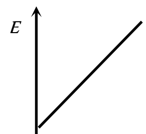


11. A particle is dropped from a height *h*. A constant horizontal velocity is given to the particle. Taking *g* to be constant every where, kinetic energy *E* of the particle *w. r. t.* time *t* is correctly shown in [AMU (Med.) 2000]

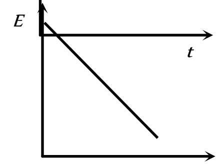
(a)



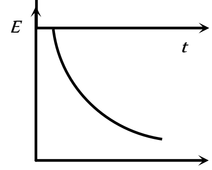
(b)



(c)



(d)



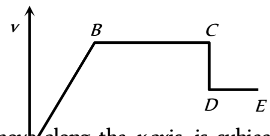
12. The adjoining diagram shows the velocity versus time plot for a particle. The work done by the force on the particle is positive from

(a) *A* to *B*

(b) *B* to *C*

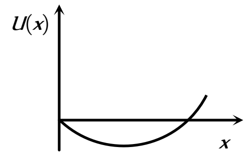
(c) *C* to *D*

(d) *D* to *E*

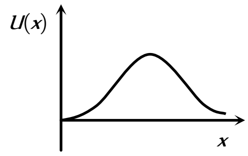


13. A particle which is constrained to move along the *x*-axis, is subjected to a force in the same direction which varies with the distance *x* of the particle from the origin as $F(x) = -kx + ax^3$. Here *k* and *a* are positive constants. For $x \geq 0$, the functional from of the potential energy $U(x)$ of the particle is [IIT-JEE (Screening) 2002]

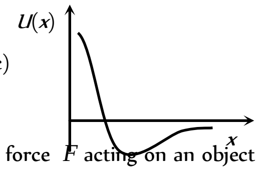
(a)



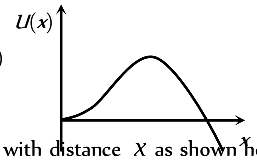
(b)



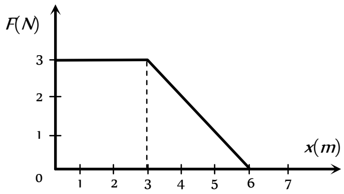
(c)



(d)



14. A force F acting on an object varies with distance X as shown here. The force is in *newton* and X in *metre*. The work done by the force in moving the object from $x = 0$ to $x = 6m$ is



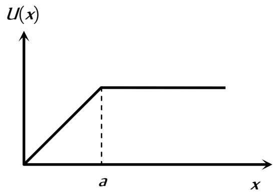
(a) 4.5 J

(b) 13.5 J

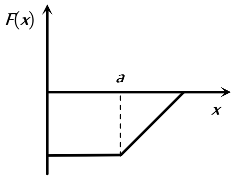
(c) 9.0 J

(d) 18.0 J

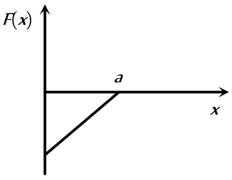
15. The potential energy of a system is represented in the first figure. the force acting on the system will be represented by



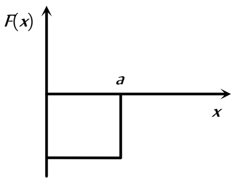
(a)



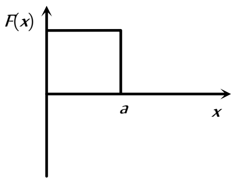
(b)



(c)

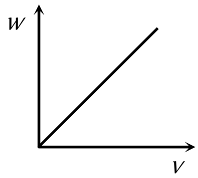


(d)

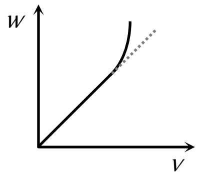


16. A particle, initially at rest on a frictionless horizontal surface, is acted upon by a horizontal force which is constant in size and direction. A graph is plotted between the work done (W) on the particle, against the speed of the particle, (v). If there are no other horizontal forces acting on the particle the graph would look like

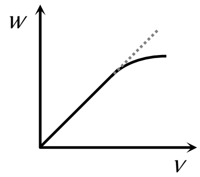
(a)



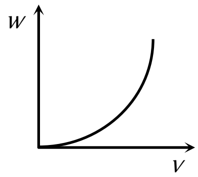
(b)



(c)

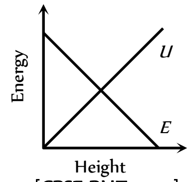


(d)



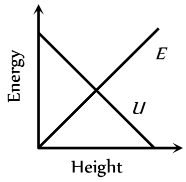
17. Which of the following graphs is correct between kinetic energy (E), potential energy (U) and height (h) from the ground of the particle

(a)

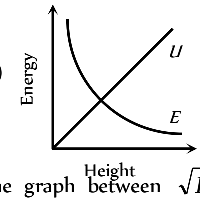


[CBSE PMT 2005]

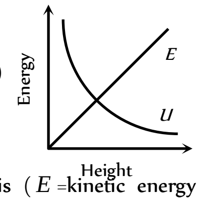
(b)



(c)

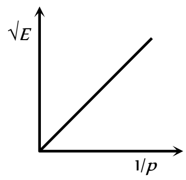


(d)

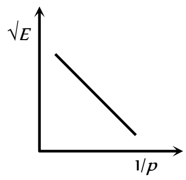


18. The graph between $\sqrt{E}$ and $\frac{1}{p}$ is (E =kinetic energy and p = momentum)

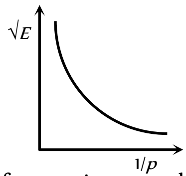
(a)



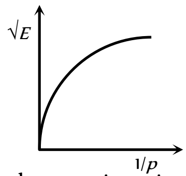
(b)



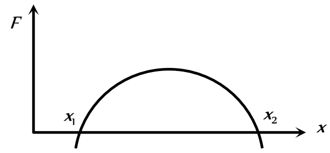
(c)



(d)



19. The force acting on a body moving along x-axis varies with the position of the particle as shown in the fig.



The body is in stable equilibrium at

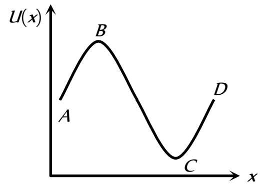
(a) $x = x_1$

(b) $x = x_2$

(c) both x_1 and x_2

(d) neither x_1 nor x_2

20. The potential energy of a particle varies with distance x as shown in the graph.



The force acting on the particle is zero at

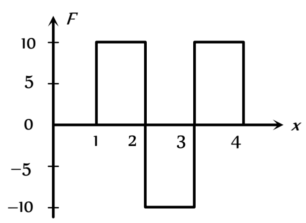
(a) C

(b) B

(c) B and C

(d) A and D

21. Figure shows the F-x graph. Where F is the force applied and x is the distance covered



by the body along a straight line path. Given that F is in *newton* and x in *metre*, what is the work done ?

(a) 10 *J* (b) 20 *J*

(c) 30 *J* (d) 40 *J*

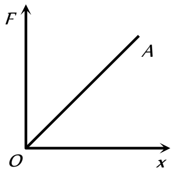
22. The force required to stretch a spring varies with the distance as shown in the figure. If the experiment is performed with the above spring of half length, the line OA will

(a) Shift towards F-axis

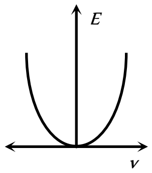
(b) Shift towards X-axis

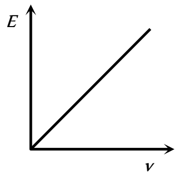
(c) Remain as it is

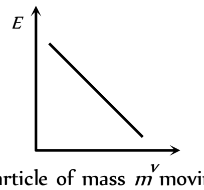
(d) Become double in length

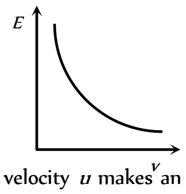


23. The graph between E and v is

(a) 

(b) 

(c) 

(d) 

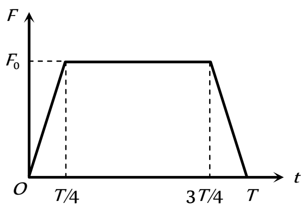
24. A particle of mass m moving with a velocity u makes an elastic one dimensional collision with a stationary particle of mass m establishing a contact with it for extremely small time T. Their force of contact increases from zero to F linearly in time $\frac{T}{4}$, remains constant for a further time $\frac{T}{2}$ and decreases linearly from F to zero in further time $\frac{T}{4}$ as shown. The magnitude possessed by F is

(a) $\frac{mu}{T}$

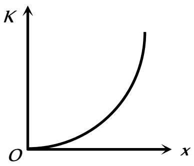
(b) $\frac{2mu}{T}$

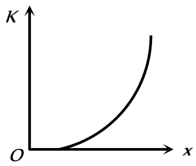
(c) $\frac{4mu}{3T}$

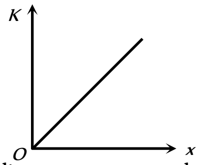
(d) $\frac{3mu}{4T}$

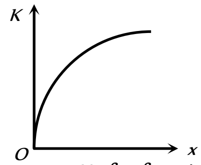


25. A body moves from rest with a constant acceleration. Which one of the following graphs represents the variation of its kinetic energy K with the distance travelled x ?

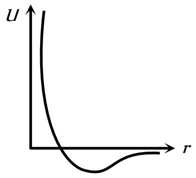
(a) 

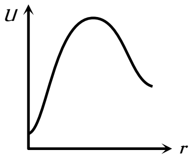
(b) 

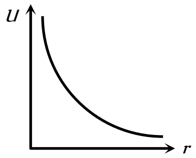
(c) 

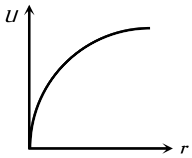
(d) 

26. The diagrams represent the potential energy U of a function of the inter-atomic distance r. Which diagram corresponds to stable molecules found in nature.

(a) 

(b) 

(c) 

(d) 

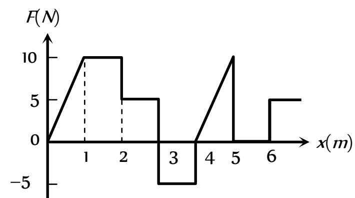
27. The relationship between the force F and position x of a body is as shown in figure. The work done in displacing the body from $x = 1$ *m* to $x = 5$ *m* will be [KCET 2005]

(a) 30 *J*

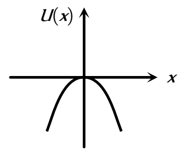
(b) 15 *J*

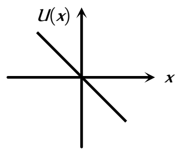
(c) 25 *J*

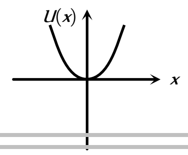
(d) 20 *J*

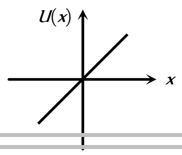


28. A particle is placed at the origin and a force $F = kx$ is acting on it (where k is positive constant). If $U(0) = 0$, the graph of $U(x)$ versus x will be (where U is the potential energy function)[IIT-JEE (Screening) 20

(a) 

(b) 

(c) 

(d) 

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*

(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*

(c) *If assertion is true but reason is false.*

(d) *If the assertion and reason both are false.*

(e) *If assertion is false but reason is true.*

1. Assertion : A person working on a horizontal road with a load on his head does no work.

Reason : No work is said to be done, if directions of force and displacement of load are perpendicular to each other.

2. Assertion : The work done during a round trip is always zero.
Reason : No force is required to move a body in its round trip.

3. Assertion : Work done by friction on a body sliding down an inclined plane is positive.
Reason : Work done is greater than zero, if angle between force and displacement is acute or both are in same direction.

4. Assertion : When a gas is allowed to expand, work done by gas is positive.
Reason : Force due to gaseous pressure and displacement (of piston) are in the same direction.

5. Assertion : A light body and heavy body have same momentum. Then they also have same kinetic energy.
Reason : Kinetic energy does not depend on mass of the body.

6. Assertion : The instantaneous power of an agent is measured as the dot product of instantaneous velocity and the force acting on it at that instant.
Reason : The unit of instantaneous power is watt.

7. Assertion : The change in kinetic energy of a particle is equal to the work done on it by the net force.
Reason : Change in kinetic energy of particle is equal to the work done only in case of a system of one particle.

8. Assertion : A spring has potential energy, both when it is compressed or stretched.
Reason : In compressing or stretching, work is done on the spring against the restoring force.

9. Assertion : Comets move around the sun in elliptical orbits. The gravitational force on the comet due to sun is not normal to the comet's velocity but the work done by the gravitational force over every complete orbit of the comet is zero.
Reason : Gravitational force is a non conservative force.

10. Assertion : The rate of change of total momentum of a many particle system is proportional to the sum of the internal forces of the system.
Reason : Internal forces can change the kinetic energy but not the momentum of the system.

11. Assertion : Water at the foot of the water fall is always at different temperature from that at the top.
Reason : The potential energy of water at the top is converted into heat energy during falling.

12. Assertion : The power of a pump which raises 100 kg of water in 10sec to a height of 100 m is 10 KW.
Reason : The practical unit of power is horse power.

13. Assertion : According to law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy.
Reason : Mechanical energy is not a conserved quantity.

14. Assertion : When the force retards the motion of a body, the work done is zero.
Reason : Work done depends on angle between force and displacement.

15. Assertion : In an elastic collision of two bodies, the momentum and energy of each body is conserved.
Reason : If two bodies stick to each other, after colliding, the collision is said to be perfectly elastic.

16. Assertion : A body cannot have energy without having momentum but it can have momentum without having energy.
Reason : Momentum and energy have same dimensions.

17. Assertion : Power developed in circular motion is always zero.
Reason : Work done in case of circular motion is zero.

18. Assertion : A kinetic energy of a body is quadrupled, when its velocity is doubled.
Reason : Kinetic energy is proportional to square of velocity.

19. Assertion : A quick collision between two bodies is more violent than slow collision, even when initial and final velocities are identical.
Reason : The rate of change of momentum determine that force is small or large.

20. Assertion : Work done by or against gravitational force in moving a body from one point to another is independent of the actual path followed between the two points.
Reason : Gravitational forces are conservative forces.

21. Assertion : Wire through which current flows gets heated.
Reason : When current is drawn from a cell, chemical energy is converted into heat energy.

22. Assertion : Graph between potential energy of a spring versus the extension or compression of the spring is a straight line.
Reason : Potential energy of a stretched or compressed spring, proportional to square of extension or compression.

23. Assertion : Heavy water is used as moderator in nuclear reactor.
Reason : Water cool down the fast neutron.

24. Assertion : Mass and energy are not conserved separately, but are conserved as a single entity called mass-energy.
Reason : Mass and energy conservation can be obtained by Einstein equation for energy.

25. Assertion : If two protons are brought near one another, the potential energy of the system will increase.
Reason : The charge on the proton is $+1.6\times10^{-19}\ C$.

26. Assertion : In case of bullet fired from gun, the ratio of kinetic energy of gun and bullet is equal to ratio of mass of bullet and gun.
Reason : In firing, momentum is conserved.

27. Assertion : Power of machine gun is determined by both, the number of bullet fired per second and kinetic energy of bullets.
Reason : Power of any machine is defined as work done (by it) per unit time.

28. Assertion : A work done in moving a body over a closed loop is zero for every force in nature.
Reason : Work done does not depend on nature of force.

29. Assertion : Mountain roads rarely go straight up the slope.

Reason : Slope of mountains are large therefore more chances of vehicle to slip from roads.

30. Assertion : Soft steel can be made red hot by continued hammering on it, but hard steel cannot.

Reason : Energy transfer in case of soft iron is large as in hard steel.

Answers

Work Done by Constant Force

1	b	2	a	3	c	4	d	5	c
6	b	7	b	8	c	9	a	10	d
11	d	12	b	13	d	14	b	15	b
16	b	17	b	18	d	19	d	20	d
21	d	22	d	23	d	24	a	25	c
26	a	27	d	28	b	29	d	30	a
31	b	32	c	33	a	34	b	35	a
36	d	37	a	38	c	39	c	40	a
41	c								

Work Done by Variable Force

1	b	2	c	3	c	4	a	5	a
6	c	7	d	8	d	9	d	10	b
11	b	12	c	13	b	14	c	15	d
16	c	17	a	18	a	19	c	20	b
21	d	22	a	23	a	24	b	25	d
26	d								

Conservation of Energy and Momentum

1	c	2	c	3	a	4	a	5	b
6	d	7	c	8	c	9	b	10	d
11	c	12	b	13	c	14	a	15	b
16	c	17	b	18	d	19	b	20	c
21	b	22	c	23	d	24	c	25	a
26	c	27	d	28	d	29	a	30	b
31	d	32	d	33	a	34	d	35	a
36	a	37	b	38	c	39	a	40	c
41	d	42	c	43	b	44	a	45	a
46	b	47	b	48	b	49	d	50	a
51	b	52	a	53	c	54	d	55	d
56	a	57	c	58	b	59	c	60	a
61	b	62	b	63	a	64	c	65	d
66	b	67	d	68	b	69	a	70	c
71	b	72	a	73	c	74	c	75	c
76	a	77	b	78	a	79	a	80	d
81	d	82	b	83	c	84	b	85	c
86	c	87	b	88	c				

Power

1	a	2	d	3	d	4	b	5	c
6	a	7	b	8	d	9	d	10	c
11	c	12	d	13	a	14	a	15	c
16	c	17	b	18	a	19	c	20	c
21	a	22	b	23	a	24	a	25	a
26	a	27	a	28	a	29	a	30	c

Elastic and Inelastic collision

1	a	2	a	3	c	4	a	5	c
6	c	7	b	8	c	9	c	10	d
11	d	12	b	13	d	14	c	15	d
16	a	17	c	18	c	19	d	20	a
21	d	22	d	23	b	24	a	25	c
26	a	27	b	28	d	29	d	30	b
31	b	32	a	33	b	34	a	35	c
36	a	37	c	38	d	39	a	40	b
41	b	42	d	43	d	44	a	45	d
46	a	47	a	48	d	49	c	50	b
51	c	52	d	53	b	54	a	55	b
56	a	57	a	58	a	59	d	60	c
61	a	62	c	63	d	64	a	65	a
66	a	67	a	68	d				

Perfectly Inelastic Collision

1	c	2	b	3	c	4	b	5	d
6	b	7	c	8	c	9	c	10	a
11	d	12	b	13	b	14	c	15	c
16	d	17	a	18	b	19	d	20	a
21	b	22	c	23	b	24	c	25	b
26	a	27	b	28	d	29	c	30	d

Critical Thinking Questions

1	c	2	d	3	b	4	b	5	c
6	c	7	a	8	c	9	d	10	b
11	c	12	d	13	c	14	a	15	a
16	c	17	b	18	d	19	c	20	bd

Graphical Questions

1	c	2	a	3	a	4	b	5	c
6	a	7	c	8	d	9	d	10	a
11	a	12	a	13	d	14	b	15	c
16	d	17	a	18	c	19	b	20	c
21	a	22	a	23	a	24	c	25	c
26	a	27	b	28	a				

Assertion and Reason

1	a	2	d	3	e	4	a	5	d
6	b	7	c	8	a	9	c	10	e
11	a	12	b	13	c	14	e	15	d
16	d	17	e	18	a	19	a	20	a
21	c	22	e	23	c	24	a	25	b
26	a	27	a	28	d	29	a	30	a

Answers and Solutions

Work Done by Constant Force

1. (b) Work done by centripetal force is always zero, because force and instantaneous displacement are always perpendicular.

$W = \vec{F}.\vec{s} = Fs\cos\theta = Fs\cos(90°) = 0$

2. (a) Work = Force × Displacement (length)

If unit of force and length be increased by four times then the unit of energy will increase by 16 times.

3. (c) No displacement is there.

4. (d) Stopping distance $S \propto u^2$. If the speed is doubled then the stopping distance will be four times.

5. (c) $W = Fs\cos\theta \Rightarrow \cos\theta = \frac{W}{Fs} = \frac{25}{50} = \frac{1}{2} \Rightarrow \theta = 60°$

6. (b) Work done = Force × displacement

= Weight of the book × Height of the book shelf

7. (b) Work done does not depend on time.

8. (c) $W = \vec{F}.\vec{s} = (5\hat{i} + 3\hat{j}).(2\hat{i} - \hat{j})$ = 10 − 3 = 7 J

9. (a) $v = \frac{dx}{dt} = 3 - 8t + 3t^2$

$\therefore\ v_0 = 3\,m/s$ and $v_4 = 19\,m/s$

$W = \frac{1}{2}m(v_4^2 - v_0^2)$ (According to work energy theorem)

$= \frac{1}{2} \times 0.03 \times (19^2 - 3^2) = 5.28\,J$

10. (d) As the body moves in the direction of force therefore work done by gravitational force will be positive.

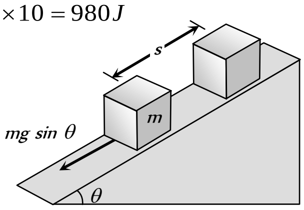
$W = Fs = mgh = 10 \times 9.8 \times 10 = 980\,J$

11. (d)

12. (b) $W = mg\sin\theta \times s$

$= 2 \times 10^3 \times \sin 15° \times 10$

$= 5.17\,kJ$



13. (d) $W = \vec{F}.\vec{s} = (5\hat{i} + 6\hat{j} - 4\hat{k}).(6\hat{i} + 5\hat{k}) = 30 - 20 = 10$ *units*

14. (b) $W = Fs = F \times \frac{1}{2}at^2$ $\left[\text{from } s = ut + \frac{1}{2}at^2\right]$

$\Rightarrow W = F\left[\frac{1}{2}\left(\frac{F}{m}\right)t^2\right] = \frac{F^2t^2}{2m} = \frac{25 \times (1)^2}{2 \times 15} = \frac{25}{30} = \frac{5}{6}\ J$

15. (b) Work done on the body = K.E. gained by the body

$Fs\cos\theta = 1 \Rightarrow F\cos\theta = \frac{1}{s} = \frac{1}{0.4} = 2.5\,N$

16. (b) Work done $= mgh = 10 \times 9.8 \times 1 = 98\,J$

17. (b)

18. (d) $s = \frac{t^2}{4}\ \therefore ds = \frac{t}{2}dt$

$F = ma = \frac{md^2s}{dt^2} = \frac{6d^2}{dt^2}\left[\frac{t^2}{4}\right] = 3N$

Now

$W = \int_0^2 F\,ds = \int_0^2 3\frac{t}{2}dt = \frac{3}{2}\left[\frac{t^2}{2}\right]_0^2 = \frac{3}{4}\left[(2)^2 - (0)^2\right] = 3J$

19. (d) Net force on body $= \sqrt{4^2 + 3^2} = 5N$

$\therefore a = F/m = 5/10 = 1/2\,m/s^2$

Kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2}m(at)^2 = 125\,J$

20. (d) $s = \frac{u^2}{2\mu g} = \frac{10 \times 10}{2 \times 0.5 \times 10} = 10\,m$

21. (d) $W = \vec{F}.\vec{s} = (3\hat{i} + 4\hat{j}).(3\hat{i} + 4\hat{j}) = 9 + 16 = 25\,J$

22. (d) Total mass = (50 + 20) = 70 *kg*

Total height = 20 × 0.25 = 5 *m*

∴ Work done = *mgh* = 70 × 9.8 × 5 = 3430 *J*

23. (d) $W = \vec{F}.\vec{s} = (6\hat{i} + 2\hat{j} - 3\hat{k}).(2\hat{i} - 3\hat{j} + x\hat{k}) = 0$

$12 - 6 - 3x = 0 \Rightarrow x = 2$

24. (a) $W = \vec{F}.(\vec{r_2} - \vec{r_1}) = (4\hat{i} + \hat{j} + 3\hat{k})(11\hat{i} + 11\hat{j} + 15\hat{k})$

$W = 44 + 11 + 45 = 100\ Joule$

25. (c) $W = (3\hat{i} + c\hat{j} + 2\hat{k}).(-4\hat{i} + 2\hat{j} + 3\hat{k}) = 6\,J$

$W = -12 + 2c + 6 = 6 \Rightarrow c = 6$

26. (a) Both part will have numerically equal momentum and lighter part will have more velocity.

27. (d) *Watt* and *Horsepower* are the unit of power

28. (b) Work = Force × Displacement

If force and displacement both are doubled then work would be four times.

29. (d) $W = FS\cos\theta = 10 \times 4 \times \cos 60° = 20\ Joule$

30. (a) $W = \vec{F}.\vec{s} = (5\hat{i} + 4\hat{j}).(6\hat{i} - 5\hat{j} + 3\hat{k}) = 30 - 20 = 10\,J$

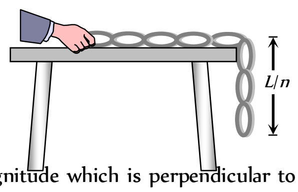
31. (b) Fraction of length of the chain hanging from the table

$= \frac{1}{n} = \frac{60cm}{200cm} = \frac{3}{10} \Rightarrow n = \frac{10}{3}$

Work done in pulling the chain on the table

$W = \frac{mgL}{2n^2}$

$= \frac{4 \times 10 \times 2}{2 \times (10/3)^2} = 3.6\,J$



32. (c) When a force of constant magnitude which is perpendicular to the velocity of particle acts on a particle, work done is zero and hence change in kinetic energy is zero.

33. (a) The ball rebounds with the same speed. So change in it's Kinetic energy will be zero *i.e.* work done by the ball on the wall is zero.

34. (b) $W = \vec{F}.\vec{r} = (5\hat{i} + 3\hat{j} + 2\hat{k}).(2\hat{i} - \hat{j}) = 10 - 3 = 7\,J$

35. (a) K.E. acquired by the body = work done on the body

$K.E. = \frac{1}{2}mv^2 = Fs$ *i.e.* it does not depend upon the mass of the body although velocity depends upon the mass

$v^2 \propto \frac{1}{m}$ [If F and s are constant]

36. (d) $W = \vec{F}.\vec{s} = (4\hat{i} + 5\hat{j} + 0\hat{k}).(3\hat{i} + 0\hat{j} + 6\hat{k}) = 4 \times 3$ *units*

37. (a) As surface is smooth so work done against friction is zero. Also the displacement and force of gravity are perpendicular so work done against gravity is zero.

38. (c) Opposing force in vertical pulling = mg

But opposing force on an inclined plane is $mg\sin\theta$, which is less than mg.

39. (c) Velocity of fall is independent of the mass of the falling body.

40. (a) Work done $= \vec{F}.\vec{s}$

$= (6\hat{i} + 2\hat{j}) \cdot (3\hat{i} - \hat{j}) = 6 \times 3 - 2 \times 1 = 18 - 2 = 16\ J$

41. (c) When the ball is released from the top of tower then ratio of distances covered by the ball in first, second and third second

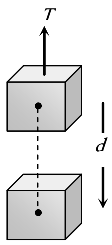
$h_I : h_{II} : h_{III} = 1 : 3 : 5 :$ [because $h_n \propto (2n-1)$]

$\therefore$ Ratio of work done $mgh_I : mgh_{II} : mgh_{III}$ = 1:3:5

Work Done by Variable Force

1. (b) $W \int_0^{x_1} F.dx = \int_0^{x_1} Cx\ dx = C\left[\frac{x^2}{2}\right]_0^{x_1} = \frac{1}{2}Cx_1^2$

2. (c) When the block moves vertically downward with acceleration $\frac{g}{4}$ then tension in the cord



$T = M\left(g - \frac{g}{4}\right) = \frac{3}{4}Mg$

Work done by the cord = $\vec{F}.\vec{s} = Fs\cos\theta$

$= Td\cos(180°) = -\left(\frac{3Mg}{4}\right) \times d = -3Mg\frac{d}{4}$

3. (c) $W = \frac{F^2}{2k}$

If both springs are stretched by same force then $W \propto \frac{1}{k}$

As $k_1 > k_2$ therefore $W_1 < W_2$

i.e. more work is done in case of second spring.

4. (a) $\Delta P.E. = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 10[(0.25)^2 - (0.20)^2]$

$= 5 \times 0.45 \times 0.05 = 0.1\ J$

5. (a) $\frac{1}{2}kS^2 = 10\ J$ (given in the problem)

$\frac{1}{2}k\left[(2S)^2 - (S)^2\right] = 3 \times \frac{1}{2}kS^2 = 3 \times 10 = 30\ J$

6. (c) $U = \frac{F^2}{2k} \Rightarrow \frac{U_1}{U_2} = \frac{k_2}{k_1}$ (if force are same)

$\therefore \frac{U_1}{U_2} = \frac{3000}{1500} = \frac{2}{1}$

7. (d) Here $k = \frac{F}{x} = \frac{10}{1 \times 10^{-3}} = 10^4\ N/m$

$W = \frac{1}{2}kx^2 = \frac{1}{2} \times 10^4 \times (40 \times 10^{-3})^2 = 8\ J$

8. (d) $W = \int_0^5 F dx = \int_0^5 (7 - 2x + 3x^2)\ dx = [7x - x^2 + x^3]_0^5$

$= 35 - 25 + 125 = 135\ J$

9. (d) $S = \frac{t^3}{3} \therefore dS = t^2 dt$

$a = \frac{d^2S}{dt^2} = \frac{d^2}{dt^2}\left[\frac{t^3}{3}\right] = 2t\ m/s^2$

Now work done by the force $W = \int_0^2 F.dS = \int_0^2 ma.dS$

$\int_0^2 3 \times 2t \times t^2 dt = \int_0^2 6t^3 dt = \frac{3}{2}\left[t^4\right]_0^2 = 24\ J$

10. (b) $W = \frac{1}{2}kx^2$

If both wires are stretched through same distance then $W \propto k$. As $k_2 = 2k_1$ so $W_2 = 2W_1$

11. (b) $\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow x = v\sqrt{\frac{m}{k}} = 10\sqrt{\frac{0.1}{1000}} = 0.1\,m$

12. (c) Force constant of a spring

$k = \frac{F}{x} = \frac{mg}{x} = \frac{1 \times 10}{2 \times 10^{-2}} \Rightarrow k = 500\ N/m$

Increment in the length = 60 – 50 = 10 *cm*

$U = \frac{1}{2}kx^2 = \frac{1}{2}500(10 \times 10^{-2})^2 = 2.5\ J$

13. (b) $W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 800 \times (15^2 - 5^2) \times 10^{-4} = 8\ J$

14. (c) $100 = \frac{1}{2}kx^2$ (given)

$W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2}k[(2x)^2 - x^2]$

$= 3 \times \left(\frac{1}{2}kx^2\right) = 3 \times 100 = 300\ J$

15. (d) $U = \frac{1}{2}kx^2$ if x becomes 5 times then energy will become 25 times *i.e.* $4 \times 25 = 100\ J$

16. (c) $W = \frac{1}{2}k(x_2^2 - x_1^2) = \frac{1}{2} \times 5 \times 10^3(10^2 - 5^2) \times 10^{-4}$

$= 18.75\ J$

17. (a) The kinetic energy of mass is converted into potential energy of a spring

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow x = \sqrt{\frac{mv^2}{k}} = \sqrt{\frac{0.5 \times (1.5)^2}{50}} = 0.15\,m$

18. (a) This condition is applicable for simple harmonic motion. As particle moves from mean position to extreme position its potential energy increases according to expression $U = \frac{1}{2}kx^2$ and accordingly kinetic energy decreases.

19. (c) Potential energy $U = \frac{1}{2}kx^2$

$\therefore U \propto x^2$ [if k = constant]

If elongation made 4 times then potential energy will become 16 times.

20. (b)

21. (d) $U \propto x^2 \Rightarrow \frac{U_2}{U_1} = \left(\frac{x_2}{x_1}\right)^2 = \left(\frac{0.1}{0.02}\right)^2 = 25 \therefore U_2 = 25U$

22. (a) If x is the extension produced in spring.

$$F = kx \Rightarrow x = \frac{F}{k} = \frac{mg}{k} = \frac{20 \times 9.8}{4000} = 4.9\,cm$$

23. (a) $U = \frac{F^2}{2k} = \frac{T^2}{2k}$

24. (b) $U = A - Bx^2 \Rightarrow F = -\frac{dU}{dx} = 2Bx \Rightarrow F \propto x$

25. (d) Condition for stable equilibrium $F = -\frac{dU}{dx} = 0$

$$\Rightarrow -\frac{d}{dx}\left[\frac{a}{x^{12}} - \frac{b}{x^6}\right] = 0 \Rightarrow -12ax^{-13} + 6bx^{-7} = 0$$

$$\Rightarrow \frac{12a}{x^{13}} = \frac{6b}{x^7} \Rightarrow \frac{2a}{b} = x^6 \Rightarrow x = \sqrt[6]{\frac{2a}{b}}$$

26. (d) Friction is a non-conservative force.

Conservation of Energy and Momentum

1. (c) $P = \sqrt{2mE} \therefore P \propto \sqrt{m}$ (if E = const.) $\therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$

2. (c) Work in raising a box

= (weight of the box) × (height by which it is raised)

3. (a) $E = \frac{P^2}{2m}$ if P = constant then $E \propto \frac{1}{m}$

4. (a) Body at rest may possess potential energy.

5. (b) Due to theory of relativity.

6. (d) $E = \frac{P^2}{2m} \therefore E \propto P^2$

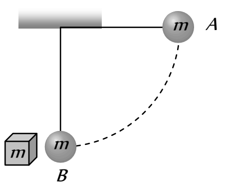
i.e. if P is increased n times then E will increase n times.

7. (c)

8. (c) P.E. of bob at point $A = mgl$

This amount of energy will be converted into kinetic energy

$\therefore$ K.E. of bob at point $B = mgl$



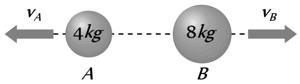
and as the collision between bob and block (of same mass) is elastic so after collision bob will come to rest and total Kinetic energy will be transferred to block. So kinetic energy of block = mgl

9. (b) According to conservation of momentum

Momentum of tank = Momentum of shell

$125000 \times v_{tank} = 25 \times 1000 \Rightarrow v_{tank}$ 0.2 *ft/sec.*

10. (d) As the initial momentum of bomb was zero, therefore after explosion two parts should possess numerically equal momentum



i.e. $m_A v_A = m_B v_B \Rightarrow 4 \times v_A = 8 \times 6 \Rightarrow v_A = 12\,m/s$

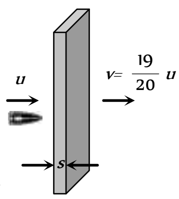
$\therefore$ Kinetic energy of other mass A, $= \frac{1}{2} m_A v_A^2$

$= \frac{1}{2} \times 4 \times (12)^2 = 288\,J.$

11. (c) Let the thickness of one plank is s

if bullet enters with velocity u then it leaves with velocity

$$v = \left(u - \frac{u}{20}\right) = \frac{19}{20}u$$

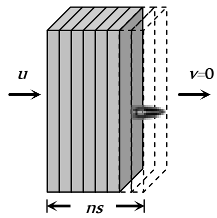


from $v^2 = u^2 - 2as$

$$\Rightarrow \left(\frac{19}{20}u\right)^2 = u^2 - 2as \Rightarrow \frac{400}{39} = \frac{u^2}{2as}$$

Now if the n planks are arranged just to stop the bullet then again from $v^2 = u^2 - 2as$

$0 = u^2 - 2ans$



$$\Rightarrow n = \frac{u^2}{2as} = \frac{400}{39}$$

$\Rightarrow n = 10.25$

As the planks are more than 10 so we can consider $n = 11$

12. (b) Let h is that height at which the kinetic energy of the body becomes half its original value *i.e.* half of its kinetic energy will convert into potential energy

$$\therefore mgh = \frac{490}{2} \Rightarrow 2 \times 9.8 \times h = \frac{490}{2} \Rightarrow h = 12.5m.$$

13. (c) $P = \sqrt{2mE}$. If E are same then $P \propto \sqrt{m}$

$$\Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

14. (a) Let initial kinetic energy, $E_1 = E$

Final kinetic energy, $E_2 = E + 300\%$ of $E = 4E$

As $P \propto \sqrt{E} \Rightarrow \frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{4E}{E}} = 2 \Rightarrow P_2 = 2P_1$

$\Rightarrow P_2 = P_1 + 100\%$ of P_1

i.e. Momentum will increase by 100%.

15. (b) $P = \sqrt{2mE}$ if E are equal then $P \propto \sqrt{m}$

i.e. heavier body will possess greater momentum.

16. (c) Let $P_1 = P$, $P_2 = P_1 + 50\%$ of $P_1 = P_1 + \frac{P_1}{2} = \frac{3P_1}{2}$

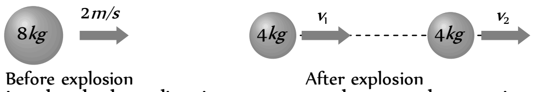
$E \propto P^2 \Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{3P_1/2}{P_1}\right)^2 = \frac{9}{4}$

$\Rightarrow E_2 = 2.25E = E_1 + 1.25E_1$

$\therefore E_2 = E_1 + 125\%$ of E_1

i.e. kinetic energy will increase by 125%.

17. (b)



As the body splits into two equal parts due to internal explosion therefore momentum of system remains conserved *i.e.* $8 \times 2 = 4v_1 + 4v_2 \Rightarrow v_1 + v_2 = 4$ ...(i)

By the law of conservation of energy

Initial kinetic energy + Energy released due to explosion

= Final kinetic energy of the system

$\Rightarrow \frac{1}{2} \times 8 \times (2)^2 + 16 = \frac{1}{2}4v_1^2 + \frac{1}{2}4v_2^2$

$\Rightarrow v_1^2 + v_2^2 = 16$ ...(ii)

By solving eq. (i) and (ii) we get $v_1 = 4$ and $v_2 = 0$

i.e. one part comes to rest and other moves in the same direction as that of original body.

18. (d) $P = \sqrt{2mE}$ $\therefore P \propto \sqrt{E}$

i.e. if kinetic energy of a particle is doubled the its momentum will becomes $\sqrt{2}$ times.

19. (b) Potential energy = *mgh*

Potential energy is maximum when *h* is maximum

20. (c) If particle is projected vertically upward with velocity of *2m/s* then it returns with the same velocity.

So its kinetic energy $= \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times (2)^2 = 4\ J$

21. (b)

22. (c) $E = \frac{P^2}{2m}$ if bodies possess equal linear momenta then

$E \propto \frac{1}{m}$ *i.e.* $\frac{E_1}{E_2} = \frac{m_2}{m_1}$

23. (d) $s \propto u^2$ *i.e.* if speed becomes double then stopping distance will become four times *i.e.* $8 \times 4 = 32m$

24. (c) $s \propto u^2$ *i.e.* if speed becomes three times then distance needed for stopping will be nine times.

25. (a) $P = \sqrt{2mE}$ $\therefore P \propto \sqrt{E}$

Percentage increase in $P = \frac{1}{2}$ (percentage increase in *E*)

$= \frac{1}{2}(0.1\%) = 0.05\%$

26. (c) Kinetic energy $= \frac{1}{2}mv^2$ $\therefore$ K.E. $\propto v$

If velocity is doubled then kinetic energy will become four times.

27. (d) $P = \sqrt{2mE}$ $\therefore \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$ (if *E* = constant)

$\therefore \frac{P_1}{P_2} = \sqrt{\frac{3}{1}}$

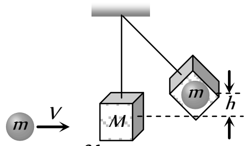
28. (d) In compression or extension of a spring work is done against restoring force.

In moving a body against gravity work is done against gravitational force of attraction.

It means in all three cases potential energy of the system increases.

But when the bubble rises in the direction of upthrust force then system works so the potential energy of the system decreases.

29. (a)



By the conservation of linear momentum

Initial momentum of sphere

= Final momentum of system

$mV = (m+M)v_{sys.}$ ...(i)

If the system rises up to height *h* then by the conservation of energy

$\frac{1}{2}(m+M)v_{sys.}^2 = (m+M)gh$ ...(ii)

$\Rightarrow v_{sys.} = \sqrt{2gh}$

Substituting this value in equation (i)

$V = \left(\frac{m+M}{m}\right)\sqrt{2gh}$

30. (b) $E = \frac{P^2}{2m}$. If momentum are same then $E \propto \frac{1}{m}$

$\therefore \frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{2m}{m} = \frac{2}{1}$

31. (d) $P = \sqrt{2mE}$. If kinetic energy are equal then $P \propto \sqrt{m}$

i.e., heavier body posses large momentum

As $M_1 < M_2$ therefore $M_1V_1 < M_2V_2$

32. (d) Condition for vertical looping $h = \frac{5}{2}r = 5cm$ $\therefore r = 2\ cm$

33. (a) Max. K.E. of the system = Max. P.E. of the system

$\frac{1}{2}kx^2 = = \frac{1}{2} \times (16) \times (5 \times 10^{-2})^2 = 2 \times 10^{-2}\ J$

34. (d) $E = \frac{p^2}{2m}$ $\therefore m \propto \frac{1}{E}$ (If momentum are constant)

$\frac{m_1}{m_2} = \frac{E_2}{E_1} = \frac{1}{4}$

35. (a) $P = \sqrt{2mE}$ $\therefore P \propto \sqrt{E}$ *i.e.* if kinetic energy becomes four time then new momentum will become twice.

36. (a) $E = \frac{P^2}{2m}$. If P = constant then $E \propto \frac{1}{m}$

i.e. kinetic energy of heavier body will be less. As the mass of gun is more than bullet therefore it possess less kinetic energy.

37. (b) Potential energy of water = kinetic energy at turbine

$$mgh = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 19.6} = 19.6\, m/s$$

38. (c) $p = \sqrt{2mE}$ $\therefore$ $\frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}\frac{E_1}{E_2}} = \sqrt{\frac{2}{1} \times \frac{8}{1}} = \frac{4}{1}$

39. (a) The bomb of mass 12*kg* divides into two masses

m and m then $m_1 + m_2 = 12$ ...(i)

and $\frac{m_1}{m_2} = \frac{1}{3}$ ...(ii)

by solving we get $m_1 = 3kg$ and $m_2 = 9kg$

Kinetic energy of smaller part = $\frac{1}{2}m_1 v_1^2 = 216J$

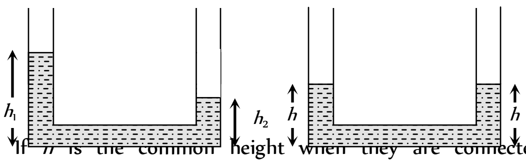
$\therefore v_1^2 = \frac{216 \times 2}{3} \Rightarrow v_1 = 12 m/s$

So its momentum = $m_1 v_1 = 3 \times 12 = 36\ kg\text{-}m/s$

As both parts possess same momentum therefore momentum of each part is $36\ kg\text{-}m/s$

40. (c) $P = \sqrt{2mE}$. If E are const. then $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{4}{1}} = 2$

41. (d)



If h is the common height when they are connected, by conservation of mass

$$\rho A_1 h_1 + \rho A_2 h_2 = \rho h(A_1 + A_2)$$

$h = (h_1 + h_2)/2$ [as $A_1 = A_2 = A$ given]

As $(h/2)$ and $(h/2)$ are heights of initial centre of gravity of liquid in two vessels., the initial potential energy of the system

$$U_i = (h_1 A\rho)g\frac{h_1}{2} + (h_2 A\rho)\frac{h_2}{2} = \rho g A\frac{(h_1^2 + h_2^2)}{2} \quad ...(i)$$

When vessels are connected the height of centre of gravity of liquid in each vessel will be $h/2$,

i.e. $(\frac{(h_1 + h_2)}{4}$ [as $h = (h_1 + h_2)/2$]

Final potential energy of the system

$$U_F = \left[\frac{(h_1 + h_2)}{2}A\rho\right]g\left(\frac{h_1 + h_2}{4}\right)$$

$$= A\rho g\left[\frac{(h_1 + h_2)^2}{4}\right] \quad ...(ii)$$

Work done by gravity

$$W = U_i - U_f = \frac{1}{4}\rho g A[2(h_1^2 + h_2^2) - (h_1 + h_2)^2]$$

$$= \frac{1}{4}\rho g A(h_1 \sim h_2)^2$$

42. (c) $P = \sqrt{2mE}$. If m is constant then

$$\frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{1.22E}{E}} \Rightarrow \frac{P_2}{P_1} = \sqrt{1.22} = 1.1$$

$\Rightarrow P_2 = 1.1P_1 \Rightarrow P_2 = P_1 + 0.1P_1 = P_1 + 10\%$ of P_1

So the momentum will increase by 10%

43. (b) $\Delta U = mgh = 0.2 \times 10 \times 200 = 400\ J$

$\therefore$ Gain in K.E. = decrease in P.E. = 400 *J*.

44. (a) $E = \frac{P^2}{2m}$. If m is constant then $E \propto P^2$

$$\Rightarrow \frac{E_2}{E_1} = \left(\frac{P_2}{P_1}\right)^2 = \left(\frac{1.2P}{P}\right)^2 = 1.44$$

$\Rightarrow E_2 = 1.44E_1 = E_1 + 0.44E_1$

$E_2 = E_1 + 44\%$ of E_1

i.e. the kinetic energy will increase by 44%

45. (a) $E = \frac{P^2}{2m} = \frac{(2)^2}{2 \times 2} = 1J$

46. (b) $\Delta U = mgh = 20 \times 9.8 \times 0.5 = 98\ J$

47. (b) $E = \frac{P^2}{2m} = \frac{(10)^2}{2 \times 1} = 50\ J$

48. (b) Because 50% loss in kinetic energy will affect its potential energy and due to this ball will attain only half of the initial height.

49. (d) If there is no air drag then maximum height

$$H = \frac{u^2}{2g} = \frac{14 \times 14}{2 \times 9.8} = 10\,m$$

But due to air drag ball reaches up to height 8*m* only. So loss in energy

$= mg(10 - 8) = 0.5 \times 9.8 \times 2 = 9.8\ J$

50. (a) $1\,kcal = 10^3\ Calorie = 4200\ J = \frac{4200}{3.6 \times 10^6}kWh$

$$\therefore\ 700\,kcal = \frac{700 \times 4200}{3.6 \times 10^6}kWh = 0.81\,kWh$$

51. (b) $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.1} = \sqrt{1.96} = 1.4\ m/s$

52. (a)

53. (c) Let m = mass of boy, M = mass of man

v = velocity of boy, V = velocity of man

$$\frac{1}{2}MV^2 = \frac{1}{2}\left[\frac{1}{2}mv^2\right] \quad .....(i)$$

$$\frac{1}{2}M(V+1)^2 = 1\left[\frac{1}{2}mv^2\right] \quad .....(ii)$$

Putting $m = \frac{M}{2}$ and solving $V = \frac{1}{\sqrt{2} - 1}$

54. (d) $P = \sqrt{2mE} \Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{4}{9}} = \frac{2}{3}$

55. (d) $E = \frac{P^2}{2m} \Rightarrow E_2 = E_1\left(\frac{P_2}{P_1}\right)^2 = E_1\left(\frac{2P}{P}\right)^2$

$\Rightarrow E_2 = 4E = E + 3E = E + 300\%$ of E

56. (a) For first condition

Initial velocity = u, Final velocity = $u/2$, s = 3 cm

From $v^2 = u^2 - 2as \Rightarrow \left(\frac{u}{2}\right)^2 = u^2 - 2as \Rightarrow a = \frac{3u^2}{8s}$

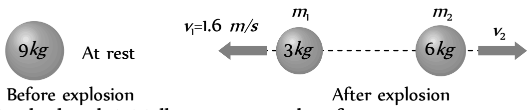
Second condition

Initial velocity = $u/2$, Final velocity = 0

From $v^2 = u^2 - 2ax \Rightarrow 0 = \frac{u^2}{4} - 2ax$

$\therefore x = \frac{u^2}{4 \times 2a} = \frac{u^2 \times 8s}{4 \times 2 \times 3u^2} = s/3 = 1\,cm$

57. (c)



As the bomb initially was at rest therefore

Initial momentum of bomb = 0

Final momentum of system = $m_1v_1 + m_2v_2$

As there is no external force

$\therefore m_1v_1 + m_2v_2 = 0 \Rightarrow 3 \times 1.6 + 6 \times v_2 = 0$

velocity of 6 kg mass $v_2 = 0.8\,m/s$ (numerically)

Its kinetic energy $= \frac{1}{2}m_2v_2^2 = \frac{1}{2} \times 6 \times (0.8)^2 = 1.92\,J$

58. (b) $P = \sqrt{2mE}$. $P \propto \sqrt{m}$ $\therefore \frac{P_1}{P_2} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

59. (c) Potential energy of a body = 75% of 12 J

$mgh = 9\,J \Rightarrow h = \frac{9}{1 \times 10} = 0.9m$

Now when this mass allow to fall then it acquire velocity

$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 0.9} = \sqrt{18}$ m/s.

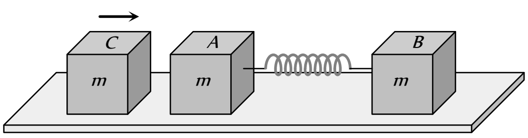
60. (a)

61. (b) Kinetic energy $E = \frac{P^2}{2m} = \frac{(Ft)^2}{2m} = \frac{F^2t^2}{2m}$ [As $P = F\,t$]

62. (b) Potential energy of spring = $\frac{1}{2}Kx^2$

$\therefore PE \propto x^2 \Rightarrow PE \propto a^2$

63. (a)



Initial momentum of the system (block C) = mv

After striking with A, the block C comes to rest and now both block A and B moves with velocity V, when compression in spring is maximum.

By the law of conservation of linear momentum

$mv = (m + m)\,V \Rightarrow V = \frac{v}{2}$

By the law of conservation of energy

K.E. of block C = K.E. of system + P.E. of system

$\frac{1}{2}mv^2 = \frac{1}{2}(2m)V^2 + \frac{1}{2}kx^2$

$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}(2m)\left(\frac{v}{2}\right)^2 + \frac{1}{2}kx^2$

$\Rightarrow kx^2 = \frac{1}{2}mv^2$

$\Rightarrow x = v\sqrt{\frac{m}{2k}}$

64. (c) $P = \sqrt{2mE}$ $\therefore P \propto \sqrt{m} \Rightarrow \frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{m}{4m}} = \frac{1}{2}$

65. (d) $E = \frac{P^2}{2m} \Rightarrow E \propto \frac{1}{m} \Rightarrow \frac{E_1}{E_2} = \frac{m_2}{m_1}$

66. (b) $E = \frac{P^2}{2m} = \frac{4}{2 \times 3} = \frac{2}{3}\,J$

67. (d) Both fragment will possess the equal linear momentum

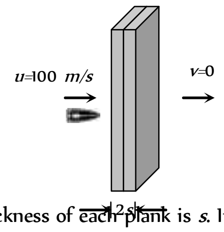
$m_1v_1 = m_2v_2 \Rightarrow 1 \times 80 = 2 \times v_2 \Rightarrow v_2 = 40\,m/s$

$\therefore$ Total energy of system $= \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

$= \frac{1}{2} \times 1 \times (80)^2 + \frac{1}{2} \times 2 \times (40)^2$

= 4800 J = 4.8 kJ

68. (b)



Let the thickness of each plank is s. If the initial speed of bullet is 100 m/s then it stops by covering a distance 2s

By applying $v^2 = u^2 - 2as \Rightarrow 0 = u^2 - 2as$

$s = \frac{u^2}{2a}$ $s \propto u^2$ [If retardation is constant]

If the speed of the bullet is double then bullet will cover four times distance before coming to rest

i.e. $s_2 = 4(s_1) = 4(2s) \Rightarrow s_2 = 8s$

So number of planks required = 8

69. (a) $E = \frac{P^2}{2m}$ if P = constant then $E \propto \frac{1}{m}$

According to problem $m_1 > m_2$ $\therefore E_1 < E_2$

70. (c) Kinetic energy $= \frac{1}{2}mv^2$

As both balls are falling through same height therefore they possess same velocity.

but $KE \propto m$ (If v = constant)

$\therefore \frac{(KE)_1}{(KE)_2} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$

71. (b) $E = \frac{P^2}{2m}$ $\therefore E \propto \frac{1}{m}$ (If P = constant)

i.e. the lightest particle will possess maximum kinetic energy and in the given option mass of electron is minimum.

72. (a) $P = E \Rightarrow mv = \frac{1}{2}mv^2 \Rightarrow v = 2\,m/s$

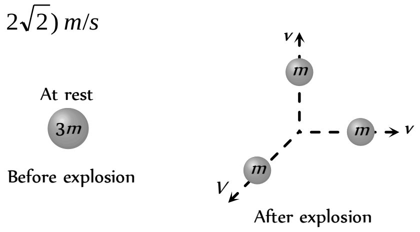
73. (c) Initial kinetic energy $E = \frac{1}{2}mv^2$ ...(i)

Final kinetic energy $2E = \frac{1}{2}m(v+2)^2$ ...(ii)

by solving equation (i) and (ii) we get

$v = (2 + 2\sqrt{2})\,m/s$

74. (c)



Initial momentum of $3m$ mass = 0 ...(i)

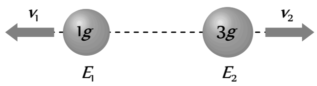
Due to explosion this mass splits into three fragments of equal masses.

Final momentum of system = $m\vec{V} + mv\hat{i} + mv\hat{j}$ ...(ii)

By the law of conservation of linear momentum

$m\vec{V} + mv\hat{i} + mv\hat{j} = 0 \Rightarrow \vec{V} = -v(\hat{i} + \hat{j})$

75. (c)



As the momentum of both fragments are equal therefore $\frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{3}{1}$ *i.e.* $E_1 = 3E_2$ ...(i)

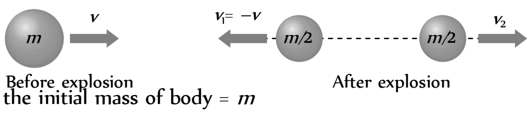
According to problem $E_1 + E_2 = 6.4 \times 10^4\,J$ ...(i)

By solving equation (i) and (ii) we get

$E_1 = 4.8 \times 10^4\,J$ and $E_2 = 1.6 \times 10^4\,J$

76. (a)

77. (b)



Let the initial mass of body = m

Initial linear momentum = mv ...(i)

When it breaks into equal masses then one of the fragment retrace back with same velocity

$\therefore$ Final linear momentum = $\frac{m}{2}(-v) + \frac{m}{2}(v_2)$ ...(ii)

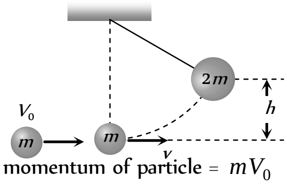
By the conservation of linear momentum

$\Rightarrow mv = \frac{-mv}{2} + \frac{mv_2}{2} \Rightarrow v_2 = 3v$

i.e. other fragment moves with velocity $3v$ in forward direction

78. (a)

79. (a)



Initial momentum of particle = mV_0

Final momentum of system (particle + pendulum) = $2mv$

By the law of conservation of momentum

$\Rightarrow mV_0 = 2mv \Rightarrow$ Initial velocity of system $v = \frac{V_0}{2}$

$\therefore$ Initial K.E. of the system = $\frac{1}{2}(2m)v^2 = \frac{1}{2}(2m)\left(\frac{V_0}{2}\right)^2$

If the system rises up to height h then P.E. = $2mgh$

By the law of conservation of energy

$\frac{1}{2}(2m)\left(\frac{V_0}{2}\right)^2 = 2mgh \Rightarrow h = \frac{V_0^2}{8g}$

80. (d) $\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{1}{9}} = \frac{1}{3}$

81. (d) Change in momentum = Force × time

$P_2 - P_1 = F \times t = 0.2 \times 10 = 2$

$\Rightarrow P_2 = 2 + P_1 = 2 + 10 = 12\,kg\text{-}m/s$

Increase in K.E. = $\frac{1}{2m}(P_2^2 - P_1^2) = \frac{1}{2 \times 5}\left[(12)^2 - (10)^2\right]$

$= \frac{44}{10} = 4.4\,J$

82. (b) $E \propto P^2$ (if m = constant)

Percentage increase in E = 2(Percentage increase in P)

= 2 × 0.01%=0.02%

83. (c) 1 $amu = 1.66 \times 10^{-27}\,kg$

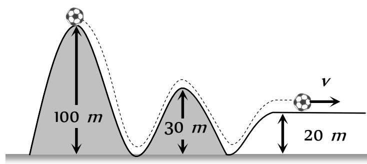
$E = mc^2 = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 = 1.5 \times 10^{-10}\,J$

84. (b) Change in gravitational potential energy

= Elastic potential energy stored in compressed spring

$\Rightarrow mg(h + x) = \frac{1}{2}kx^2$

85. (c)



Ball starts from the top of a hill which is 100 m high and finally rolls down to a horizontal base which is 20 m above the ground so from the conservation of energy

$$mg(h_1 - h_2) = \frac{1}{2}mv^2$$

$$\Rightarrow v = \sqrt{2g(h_1 - h_2)} = \sqrt{2 \times 10 \times (100 - 20)}$$

$$= \sqrt{1600} = 40\,m/s.$$

86. (c) When block of mass M collides with the spring its kinetic energy gets converted into elastic potential energy of the spring.

From the law of conservation of energy

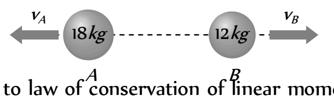
$$\frac{1}{2}Mv^2 = \frac{1}{2}KL^2 \quad \therefore \quad v = \sqrt{\frac{K}{M}}L$$

Where v is the velocity of block by which it collides with spring. So, its maximum momentum

$$P = Mv = M\sqrt{\frac{K}{M}}\,L = \sqrt{MK}\,L$$

After collision the block will rebound with same linear momentum.

87. (b)



According to law of conservation of linear momentum

$$m_A v_A = m_B v_B = 18 \times 6 = 12 \times v_B \Rightarrow v_B = 9\ m/s$$

K.E. of mass 12 kg, $E_B = \frac{1}{2}m_B v_B^2$

$$= \frac{1}{2} \times 12 \times (9)^2 = 486\,J$$

88. (c) Force = Rate of change of momentum

Initial momentum $\vec{P}_1 = mv\sin\theta\,\hat{i} + mv\cos\theta\,\hat{j}$

Final momentum $\vec{P}_2 = -mv\sin\theta\,\hat{i} + mv\cos\theta\,\hat{j}$

$$\therefore \vec{F} = \frac{\Delta\vec{P}}{\Delta t} = \frac{-2mv\sin\theta}{2 \times 10^{-3}}$$

Substituting $m = 0.1\ kg$, $v = 5\ m/s$, $\theta = 60°$

Force on the ball $\vec{F} = -250\sqrt{3}\,N$

Negative sign indicates direction of the force

Power

1. (a)

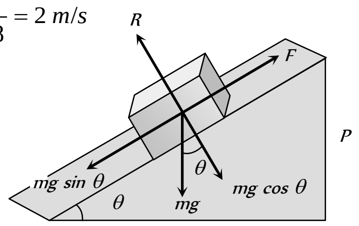
2. (d) $P = \vec{F}.\vec{v} = ma \times at = ma^2 t$ [as $u = 0$]

$$= m\left(\frac{v_1}{t_1}\right)^2 t = \frac{mv_1^2 t}{t_1^2} \qquad [\text{As } a = v_1 / t_1]$$

3. (d) $v = 7.2\frac{km}{h} = 7.2 \times \frac{5}{18} = 2\ m/s$

Slope is given 1 in 20

$$\therefore \sin\theta = \frac{1}{20}$$



When man and cycle moves up then component of weight opposes it motion *i.e.* $F = mg\sin\theta$

So power of the man $P = F \times v = mg\sin\theta \times v$

$$= 100 \times 9.8 \times \left(\frac{1}{20}\right) \times 2 = 98\ Watt$$

4. (b) If a motor of 12 HP works for 10 days at the rate of 8 hr/day then energy consumption = power × time

$$= 12 \times 746\frac{J}{\text{sec}} \times (80 \times 60 \times 60)\ \text{sec}$$

$$= 12 \times 746 \times 80 \times 60 \times 60\ J = 2.5 \times 10^9\ J$$

Rate of energy = $50\frac{paisa}{kWh}$

i.e. $3.6 \times 10^6\ J$ energy cost 0.5 Rs

So $2.5 \times 10^9\ J$ energy cost = $\frac{2.5 \times 10^9}{2 \times 3.6 \times 10^6} = 358\ Rs$

5. (c) $P = Fv = 500 \times 3 = 1500\,W = 1.5\,kW$

6. (a) $P = Fv = F \times \frac{s}{t} = 40 \times \frac{30}{60} = 20W$

7. (b) $P = Fv = 4500 \times 2 = 9000\,W = 9\,kW$

8. (d) $P = \frac{\text{Workdone}}{\text{Time}} = \frac{mgh}{t} = \frac{300 \times 9.8 \times 2}{3} = 1960\,W$

9. (d) $P = \frac{mgh}{t} \Rightarrow m = \frac{p \times t}{gh} = \frac{2 \times 10^3 \times 60}{10 \times 10} = 1200\ kg$

As volume = $\frac{\text{mass}}{\text{density}} \Rightarrow v = \frac{1200kg}{10^3\,kg/m^3} = 1.2m^3$

Volume = $1.2m^3 = 1.2 \times 10^3\,litre = 1200\ litre$

10. (c) $P = \frac{mgh}{t} = 10 \times 10^3 \Rightarrow t = \frac{200 \times 40 \times 10}{10 \times 10^3} = 8\ \text{sec}$

11. (c) Force required to move with constant velocity

$\therefore$ Power = FV

Force is required to oppose the resistive force R and also to accelerate the body of mass with acceleration a.

$\therefore$ Power = $(R + ma)V$

12. (d) $P = \frac{mgh}{t} = \frac{100 \times 9.8 \times 50}{50} = 980\,J/s$

13. (a) $P = \left(\frac{m}{t}\right)gh = 100 \times 10 \times 100 = 10^5\,W = 100\ kW$

14. (a) $p = \frac{mgh}{t} = \frac{200 \times 10 \times 200}{10} = 40\,kW$

15. (c) Volume of water to raise = 22380 l = $22380 \times 10^{-3}\,m^3$

$$P = \frac{mgh}{t} = \frac{V\rho gh}{t} \Rightarrow t = \frac{V\rho gh}{P}$$

$$t = \frac{22380 \times 10^{-3} \times 10^3 \times 10 \times 10}{10 \times 746} = 15\ min$$

16. (c) Force produced by the engine $F = \frac{P}{v} = \frac{30 \times 10^3}{30} = 10^3\,N$

$$\text{Acceleration} = \frac{\text{Forward force by engine} - \text{resistive force}}{\text{mass of car}}$$

$= \frac{1000-750}{1250} = \frac{250}{1250} = \frac{1}{5}\, m/s^2$

17. (b) Power $= \frac{\text{Work done}}{\text{time}} = \frac{\frac{1}{2}m(v^2-u^2)}{t}$

$P = \frac{1}{2} \times \frac{2.05\times10^6 \times [(25)^2-(5^2)]}{5\times60}$

$P = 2.05\times10^6\, W = 2.05\, MW$

18. (a) As truck is moving on an incline plane therefore only component of weight $(mg\sin\theta)$ will oppose the upward motion

Power = force × velocity = $mg\sin\theta \times v$

$= 30000 \times 10 \times \left(\frac{1}{100}\right) \times \frac{30\times5}{18} = 25\, kW$

19. (c) $P = \frac{mgh}{t} \Rightarrow \frac{P_1}{P_2} = \frac{m_1}{m_2} \times \frac{t_2}{t_1}$ (As h = constant)

$\therefore \frac{P_1}{P_2} = \frac{60}{50} \times \frac{11}{12} = \frac{11}{10}$

20. (c) Power of a pump $= \frac{1}{2}\rho A v^3$

To get twice amount of water from same pipe v has to be made twice. So power is to be made 8 times.

21. (a) $p = \frac{mgh}{t} = \frac{80\times9.8\times6}{10} W = \frac{470}{746} HP = 0.63\, HP$

22. (b) Power $= \frac{\text{Work done}}{\text{time}} = \frac{\text{Increase in K.E.}}{\text{time}}$

$P = \frac{\frac{1}{2}mv^2}{t} = \frac{\frac{1}{2}\times10^3\times(15)^2}{5} = 22500\, W$

23. (a) Motor makes 600 revolution per minute

$\therefore n = 600 \frac{\text{revolution}}{\text{minute}} = 10 \frac{rev}{sec}$

$\therefore$ Time required for one revolution $= \frac{1}{10}$ *sec*

Energy required for one revolution = power × time

$= \frac{1}{4} \times 746 \times \frac{1}{10} = \frac{746}{40} J$

But work done = 40% of input

$= 40\% \times \frac{746}{40} = \frac{40}{100} \times \frac{746}{40} = 7.46\, J$

24. (a) Work output of engine = mgh = $100\times10\times10 = 10^4\, J$

Efficiency (η) = $\frac{\text{output}}{\text{input}}$ $\therefore$ Input energy = $\frac{\text{output}}{\eta}$

$= \frac{10^4}{60} \times 100 = \frac{10^5}{6} J$

$\therefore$ Power = $\frac{\text{input energy}}{\text{time}} = \frac{10^5/6}{5} = \frac{10^5}{30} = 3.3\, kW$

25. (a) $P = \frac{\vec{F}.\vec{s}}{t} = \frac{(2\hat{i}+3\hat{j}+4\hat{k}).(3\hat{i}+4\hat{j}+5\hat{k})}{4} = \frac{38}{4} = 9.5\, W$

26. (a) $P = \frac{W}{t} = \frac{mgh}{t} = \frac{200\times10\times50}{10} = 10\times10^3\, W$

27. (a) Power of gun $= \frac{\text{Total K.E. of fired bullet}}{\text{time}}$

$= \frac{n\times\frac{1}{2}mv^2}{t} = \frac{360}{60} \times \frac{1}{2} \times 2\times10^{-2} \times (100)^2 = 600\, W$

28. (a) Energy supplied to liquid per second by the pump

$= \frac{1}{2}\frac{mv^2}{t} = \frac{1}{2}\frac{V\rho v^2}{t} = \frac{1}{2} A \times \left(\frac{l}{t}\right) \times \rho \times v^2 \quad \left[\frac{l}{t} = v\right]$

$= \frac{1}{2} A \times v \times \rho \times v^2 = \frac{1}{2} A\rho v^3$

29. (a) Power $= \frac{\text{workdone}}{\text{time}} = \frac{\text{pressure} \times \text{change in volume}}{\text{time}}$

$= \frac{20000\times1\times10^{-6}}{1} = 2\times10^{-2} = 0.02\, W$

30. (c) Power $= \frac{W}{t}$. If W is constant then $P \propto \frac{1}{t}$

i.e. $\frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{20}{10} = \frac{2}{1}$

Elastic and Inelastic Collision

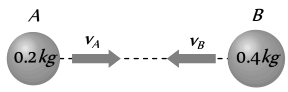
1. (a)

2. (a)

3. (c) According to law of conservation of linear momentum both pieces should possess equal momentum after explosion. As their masses are equal therefore they will possess equal speed in opposite direction.

4. (a)

5. (c)



Initial linear momentum of system = $m_A\vec{v}_A + m_B\vec{v}_B$

$= 0.2 \times 0.3 + 0.4 \times v_B$

Finally both balls come to rest

$\therefore$ final linear momentum = 0

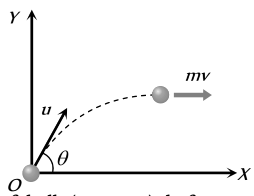
By the law of conservation of linear momenum

$0.2 \times 0.3 + 0.4 \times v_B = 0$

$\therefore \quad v_B = -\frac{0.2\times0.3}{0.4} = -0.15\, m/s$

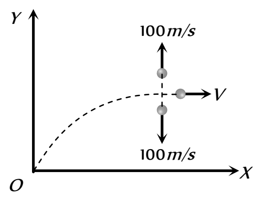
6. (c) For a collision between two identical perfectly elastic particles of equal mass, velocities after collision get interchanged.

7. (b)



Momentum of ball (mass m) before explosion at the highest point $= mv\hat{i} = mu\cos60°\hat{i}$

$= m \times 200 \times \frac{1}{2}\hat{i} = 100\, m\hat{i}\, kgms^{-1}$



Let the velocity of third part after explosion is V

After explosion momentum of system = $\vec{P}_1 + \vec{P}_2 + \vec{P}_3$

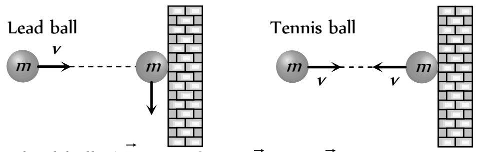
= $\frac{m}{3} \times 100\hat{j} - \frac{m}{3} \times 100\hat{j} + \frac{m}{3} \times V\hat{i}$

By comparing momentum of system before and after the explosion

$\frac{m}{3} \times 100\hat{j} - \frac{m}{3} \times 100\hat{j} + \frac{m}{3} V\hat{i} = 100m\hat{i} \Rightarrow V = 300\, m/s$

8. (c) Change in the momentum

= Final momentum – initial momentum



For lead ball $\Delta\vec{P}_{\text{lead}} = 0 - m\vec{v} = -m\vec{v}$

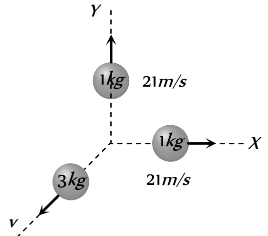
For tennis ball $\Delta\vec{P}_{\text{tennis}} = -m\vec{v} - m\vec{v} = -2m\vec{v}$

i.e. tennis ball suffers a greater change in momentum.

9. (c)

10. (d)

11. (d)



$P_x = m \times v_x = 1 \times 21 = 21\, kg\ m/s$

$P_y = m \times v_y = 1 \times 21 = 21\, kg\ m/s$

$\therefore$ Resultant = $\sqrt{P_x^2 + P_y^2} = 21\sqrt{2}\ kg\ m/s$

The momentum of heavier fragment should be numerically equal to resultant of $\vec{P}_x$ and $\vec{P}_y$.

$3 \times v = \sqrt{P_x^2 + P_y^2} = 21\sqrt{2} \therefore v = 7\sqrt{2}$ = 9.89 m/s

12. (b) We know that when heavier body strikes elastically with a lighter body then after collision lighter body will move with double velocity that of heavier body.

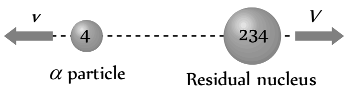
*i.e.*the ping pong ball move with speed of $2 \times 2 = 4\ m/s$

13. (d) Change in momentum $= m\vec{v}_2 - m\vec{v}_1 = -mv - mv = -2mv$

14. (c) $m_G = \frac{m_B v_B}{v_G}\ \frac{50 \times 10^{-3} \times 30}{1} = 1.5\ kg$

15. (d)

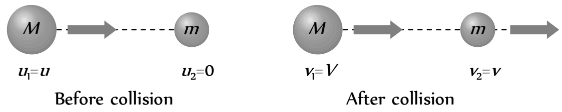
16. (a) Initially ^{238}U nucleus was at rest and after decay its part moves in opposite direction.



According to conservation of momentum

$4v + 234V = 238 \times 0 \Rightarrow V = -\frac{4v}{234}$

17. (c)

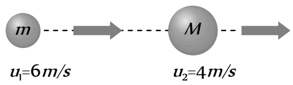


$v_2 = \left(\frac{m_2 - m_1}{m_1 + m_2}\right) u_2 + \frac{2m_1 u_1}{m_1 + m_2} = \frac{2Mu}{M + m} = \frac{2u}{1 + \frac{m}{M}}$

18. (c) Velocity exchange takes place when the masses of bodies are equal

19. (d) In perfectly elastic head on collision of equal masses velocities gets interchanged

20. (a)



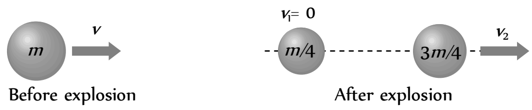
$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) u_1 + \frac{2m_2 u_2}{m_1 + m_2}$

Substituting $m_1 = 0$, $v_1 = -u_1 + 2u_2$

$\Rightarrow v_1 = -6 + 2(4) = 2 m/s$

i.e. the lighter particle will move in original direction with the speed of 2 *m/s*.

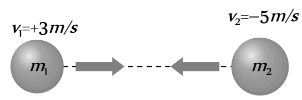
21. (d)



According to conservation of momentum

$mv = \left(\frac{m}{4}\right) v_1 + \left(\frac{3m}{4}\right) v_2 \Rightarrow v_2 = \frac{4}{3} v$

22. (d)

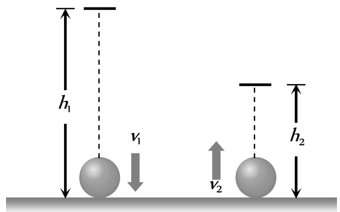


As $m_1 = m_2$ therefore after elastic collision velocities of masses get interchanged

i.e. velocity of mass $m_1 = -5\ m/s$

and velocity of mass $m_2 = +3\ m/s$

23. (b) If ball falls from height h_1 and bounces back up to height h_2 then $e = \sqrt{\frac{h_2}{h_1}}$



Similarly if the velocity of ball before and after collision are v_1 and v_2 respectively then $e = \frac{v_2}{v_1}$

So $\frac{v_2}{v_1} = \sqrt{\frac{h_2}{h_1}} = \sqrt{\frac{1.8}{5}} = \sqrt{\frac{9}{25}} = \frac{3}{5}$

i.e. fractional loss in velocity $= 1 - \frac{v_2}{v_1} = 1 - \frac{3}{5} = \frac{2}{5}$

24. (a) $h_n = he^{2n} = 32\left(\frac{1}{2}\right)^4 = \frac{32}{16} = 2m$ (here $n = 2$, $e = 1/2$)

25. (c) As the body at rest explodes into two equal parts, they acquire equal velocities in opposite directions according to conservation of momentum.

When the angle between the radius vectors connecting the point of explosion to the fragments is 90°, each radius vector makes an angle 45° with the vertical.

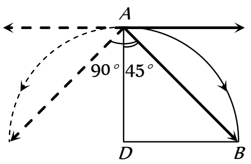
To satisfy this condition, the distance of free fall *AD* should be equal to the horizontal range in same interval of time.

$AD = DB$

$AD = 0 + \frac{1}{2} \times 10t^2 = 5t^2$

$DB = ut = 10t$

$\therefore\ 5t^2 = 10t \Rightarrow t = 2\,\text{sec}$



26. (a) $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2$ and

$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1 + \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_2$

on putting the values $v_1 = 6\,m/s$ and $v_2 = 12\,m/s$

27. (b) $F = \frac{dp}{dt} = m\frac{dv}{dt} = \frac{m \times 2v}{1/50} = \frac{2 \times 2 \times 100}{1/50} = 2 \times 10^4\,N$

28. (d) $h_n = he^{2n} = 1 \times e^{2 \times 1} = 1 \times (0.6)^2 = 0.36m$

29. (d) $h_n = he^{2n}$, if $n = 2$ then $h_n = he^4$

30. (b) Impulse = change in momentum

$mv_2 - mv_1 = 0.1 \times 40 - 0.1 \times (-30)$

31. (b) In elastic head on collision velocities gets interchanged.

32. (a) Impulse = change in momentum = 2 *mv*

$= 2 \times 0.06 \times 4 = 0.48\,kg\ m/s$

33. (b) When ball falls vertically downward from height h_1 its velocity

$\vec{v}_1 = \sqrt{2gh_1}$

and its velocity after collision $\vec{v}_2 = \sqrt{2gh_2}$

Change in momentum

$\Delta\vec{P} = m(\vec{v}_2 - \vec{v}_1) = m(\sqrt{2gh_1} + \sqrt{2gh_2})$

(because $\vec{v}_1$ and $\vec{v}_2$ are opposite in direction)

34. (a) Velocity of 50 *kg*. mass after 5 *sec* of projection

$v = u - gt = 100 - 9.8 \times 5 = 51\,m/s$

At this instant momentum of body is in upward direction

$P_{\text{initial}} = 50 \times 51 = 2550\,kg - m/s$

After breaking 20 *kg* piece travels upwards with 150 *m/s* let the speed of 30 *kg* mass is *V*

$P_{\text{final}} = 20 \times 150 + 30 \times V$

By the law of conservation of momentum

$P_{\text{initial}} = P_{\text{final}}$

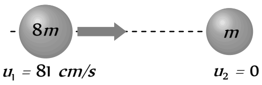
$\Rightarrow 2550 = 20 \times 150 + 30 \times V \Rightarrow V = -15\,m/s$

i.e. it moves in downward direction.

35. (c) Ratio in radius of steel balls = 1/2

So, ratio in their masses $= \frac{1}{8}$ [As $M \propto V \propto r^3$]

Let $m_1 = 8m$ and $m_2 = m$



$v_2 = \frac{2m_1u_1}{m_1 + m_2} = \frac{2 \times 8m \times 81}{8m + m} = 144\,cm/s$

36. (a) After explosion *m* mass comes at rest and let Rest $(M - m)$ mass moves with velocity *v*.

By the law of conservation of momentum $MV = (M - m)v$

$\Rightarrow v = \frac{MV}{(M - m)}$

37. (c) As the ball bounces back with same speed so change in momentum = 2 *mv*

and we know that force = rate of change of momentum

i.e. force will act on the ball so there is an acceleration.

38. (d) According to conservation of momentum

$m_Bv_B + m_Gv_G = 0 \Rightarrow v_G = -\frac{m_Bv_B}{m_G}$

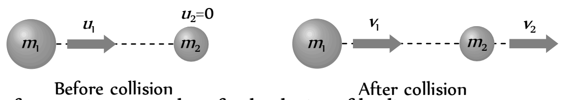
$v_G = \frac{-50 \times 10^{-3} \times 10^3}{5} = -10\,m/s$

39. (a) As 20% energy lost in collision therfore

$mgh_2 = 80\%\ \text{of}\ mgh_1 \Rightarrow \frac{h_2}{h_1} = 0.8$

but $e = \sqrt{\frac{h_2}{h_1}} = \sqrt{0.8} = 0.89$

40. (b)



If target is at rest then final velocity of bodies are

$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$ ...(i) and $v_2 = \frac{2m_1u_1}{m_1 + m_2}$ ...(ii)

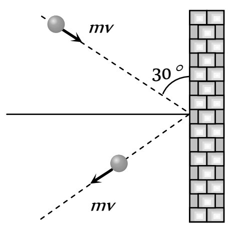
From (i) and (ii) $\frac{v_1}{v_2} = \frac{m_1 - m_2}{2m_1} = \frac{2}{5} \Rightarrow \frac{m_1}{m_2} = 5$

41. (b) *F* = Rate of change in momentum

$= \frac{2mv\sin\theta}{t}$

$= \frac{2 \times 10^{-1} \times 10\sin 30°}{0.1}$

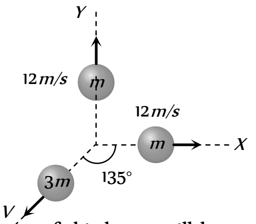
$\therefore F = 10\,N$



42. (d) By the conservation of momentum

$$40 \times 10 + (40) \times (-7) = 80 \times v \Rightarrow v = 1.5\, m/s$$

43. (d)



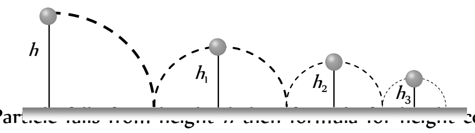
The momentum of third part will be equal and opposite to the resultant of momentum of rest two equal parts

let V is the velocity of third part.

By the conservation of linear momentum

$$3m \times V = m \times 12\sqrt{2} \Rightarrow V = 4\sqrt{2}\ m/s$$

44. (a)



Particle falls from height h then formula for height covered by it in nth rebound is given by

$$h_n = he^{2n}$$

where e = coefficient of restitution, n = No. of rebound

Total distance travelled by particle before rebounding has stopped

$$H = h + 2h_1 + 2h_2 + 2h_3 + 2h_n + ...$$

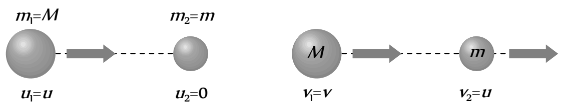
$$= h + 2he^2 + 2he^4 + 2he^6 + 2he^8 + ...$$

$$= h + 2h(e^2 + e^4 + e^6 + e^8 + ...)$$

$$= h + 2h\left[\frac{e^2}{1-e^2}\right] = h\left[1 + \frac{2e^2}{1-e^2}\right] = h\left(\frac{1+e^2}{1-e^2}\right)$$

45. (d) Due to the same mass of A and B as well as due to elastic collision velocities of spheres get interchanged after the collision.

46. (a)



Before collision After collision

From the formulae $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1$

We get $v = \left(\frac{M - m}{M + m}\right)u$

47. (a) Momentum conservation

$$5 \times 10 + 20 \times 0 = 5 \times 0 + 20 \times v \Rightarrow v = 2.5\, m/s$$

48. (d) Due to elastic collision of bodies having equal mass, their velocities get interchanged.

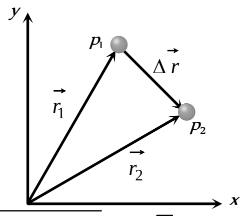
49. (c)

50. (b) $m_1 = 2\,kg$ and $v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 = \frac{u_1}{4}$ (given)

By solving we get $m_2 = 1.2\,kg$

51. (c)

52. (d) It is clear from figure that the displacement vector $\Delta\vec{r}$ between particles p_1 and p_2 is $\Delta\vec{r} = \vec{r}_2 - \vec{r}_1 = -8\hat{i} - 8\hat{j}$



$|\Delta\vec{r}| = \sqrt{(-8)^2 + (-8)^2} = 8\sqrt{2}$ .....(i)

Now, as the particles are moving in same direction ($\because \vec{v}_1$ and $\vec{v}_2$ are $+ve$), the relative velocity is given by

$$\vec{v}_{rel} = \vec{v}_2 - \vec{v}_1 = (\alpha - 4)\hat{i} + 4\hat{j}$$

$\vec{v}_{rel} = \sqrt{(\alpha - 4)^2 + 16}$ .....(ii)

Now, we know $|\vec{v}_{rel}| = \frac{|\Delta\vec{r}|}{t}$

Substituting the values of $\vec{v}_{rel}$ and $|\Delta\vec{r}|$ from equation (i) and (ii) and $t = 2s$, then on solving we get $\alpha = 8$

53. (b) Fractional decrease in kinetic energy of neutron

$$= 1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 \quad [\text{As } m_1 = 1 \text{ and } m_2 = 2]$$

$$= 1 - \left(\frac{1-2}{1+2}\right)^2 = 1 - \left(\frac{1}{3}\right)^2 = 1 - \frac{1}{9} = \frac{8}{9}$$

54. (a)

55. (b) When target is very light and at rest then after head on elastic collision it moves with double speed of projectile *i.e.* the velocity of body of mass m will be $2v$.

56. (a) In head on elastic collision velocity get interchanged (if masses of particle are equal). *i.e.* the last ball will move with the velocity of first ball *i.e* 0.4 *m/s*

57. (a) By the principle of conservation of linear momentum,

$$Mv = mv_1 + mv_2 \Rightarrow Mv = 0 + (M - m)v_2 \Rightarrow v_2 = \frac{Mv}{M - m}$$

58. (a) Since bodies exchange their velocities, hence their masses are equal so that $\frac{m_A}{m_B} = 1$

59. (d) mgh = initial potential energy

mgh' = final potential energy after rebound

As 40% energy lost during impact $\therefore mgh'$ = 60% of mgh

$$\Rightarrow h' = \frac{60}{100} \times h = \frac{60}{100} \times 10 = 6\,m$$

60. (c)

61. (a) Fractional loss $= \frac{\Delta U}{U} = \frac{mg(h - h')}{mgh} = \frac{2 - 1.5}{2} = \frac{1}{4}$

62. (c) $\frac{\Delta K}{K} = \left[1 - \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2\right] = \left[1 - \left(\frac{m - 2m}{m + 2m}\right)^2\right] = \frac{8}{9}$

$\Delta K = \frac{8}{9}K$ *i.e.* loss of kinetic energy of the colliding body is $\frac{8}{9}$ of its initial kinetic energy.

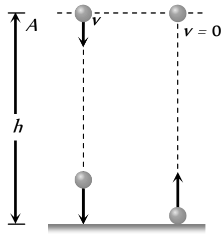
63. (d)

64. (a) $mgh = \frac{80}{100} \times mg \times 100 \Rightarrow h = 80\,m$

65. (a) Let ball is projected vertically downward with velocity v from height h

Total energy at point $A = \frac{1}{2}mv^2 + mgh$

During collision loss of energy is 50% and the ball rises up to same height. It means it possess only potential energy at same level.



$50\%\left(\frac{1}{2}mv^2 + mgh\right) = mgh$

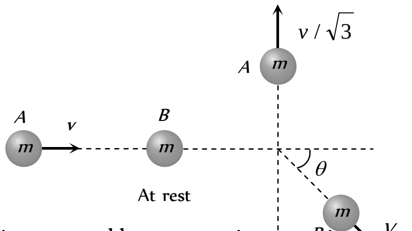
$\frac{1}{2}\left(\frac{1}{2}mv^2 + mgh\right) = mgh$

$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20}$

$\therefore v = 20\,m/s$

66. (a) $h_n = he^{2n}$ after third collision $h_3 = he^6$ [as $n = 3$]

67. (a) Let mass A moves with velocity v and collides inelastically with mass B, which is at rest.



According to problem mass A moves in a perpendicular direction and let the mass B moves at angle θ with the horizontal with velocity v.

Initial horizontal momentum of system

(before collision) $= mv$ ....(i)

Final horizontal momentum of system

(after collision) $= mV\cos\theta$ ....(ii)

From the conservation of horizontal linear momentum $mv = mV\cos\theta \Rightarrow v = V\cos\theta$ ...(iii)

Initial vertical momentum of system (before collision) is zero.

Final vertical momentum of system $\frac{mv}{\sqrt{3}} - mV\sin\theta$

From the conservation of vertical linear momentum

$\frac{mv}{\sqrt{3}} - mV\sin\theta = 0 \Rightarrow \frac{v}{\sqrt{3}} = V\sin\theta$ ...(iv)

By solving (iii) and (iv)

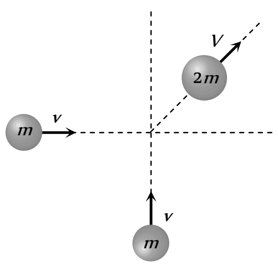
$$v^2 + \frac{v^2}{3} = V^2(\sin^2\theta + \cos^2\theta)$$

$$\Rightarrow \frac{4v^2}{3} = V^2 \Rightarrow V = \frac{2}{\sqrt{3}}v.$$

68. (d) Angle will be 90° if collision is perfectly elastic

Perfectly Inelastic Collision

1. (c)



Initial momentum of the system

$\vec{P_i} = mv\hat{i} + mv\hat{j}$

$|\vec{P_i}| = \sqrt{2}mv$

Final momentum of the system $= 2mV$

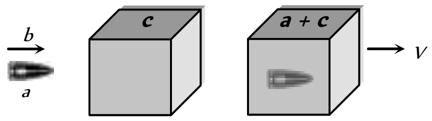
By the law of conservation of momentum

$\sqrt{2}mv = 2mV \Rightarrow V = \frac{v}{\sqrt{2}}$

2. (b)

3. (c)

4. (b)



Initially bullet moves with velocity b and after collision bullet get embedded in block and both move together with common velocity.

By the conservation of momentum

$\Rightarrow a \times b + 0 = (a + c)\,V \Rightarrow V = \frac{ab}{a+c}$

5. (d) Initially mass 10 gm moves with velocity 100 cm/s

$\therefore$ Initial momentum $= 10 \times 100 = 1000\,\frac{gm \times m}{\text{sec}}$

After collision system moves with velocity $v_{sys.}$ then

Final momentum $= (10 + 10) \times v_{sys.}$

By applying the conservation of momentum

$10000 = 20 \times v_{sys.} \Rightarrow v_{sys.} = 50\,cm/s$

If system rises upto height h then

$h = \frac{v_{sys.}^2}{2g} = \frac{50 \times 50}{2 \times 1000} = \frac{2.5}{2} = 1.25\,cm$

6. (b)

7. (c)

8. (c) $m_1v_1 - m_2v_2 = (m_1 + m_2)v$

$\Rightarrow 2 \times 3 - 1 \times 4 = (2 + 1)v \Rightarrow v = \frac{2}{3}\,m/s$

9. (c) Initial momentum of the system $= mv - mv = 0$

As body sticks together $\therefore$ final momentum $= 2mV$

By conservation of momentum $2mV = 0 \therefore V = 0$

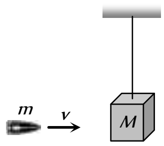
10. (a) If initially second body is at rest then

Initial momentum $= mv$

Final momentum $= 2mV$

By conservation of momentum $2mV = mv \Rightarrow V = \frac{v}{2}$

11. (d)



Initial momentum = mv

Final momentum = $(m+M)V$

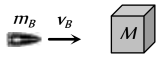
By conservation of momentum $mv = (m+M)V$

$\therefore$ Velocity of (bag + bullet) system $V = \dfrac{mv}{M+m}$

$\therefore$ Kinetic energy = $\dfrac{1}{2}(m+M)V^2$

$= \dfrac{1}{2}(m+M)\left(\dfrac{mv}{M+m}\right)^2 = \dfrac{1}{2}\dfrac{m^2v^2}{M+m}$

12. (b)



Initial K.E. of system = K.E. of the bullet = $\dfrac{1}{2}m_Bv_B^2$

By the law of conservation of linear momentum

$m_Bv_B + 0 = m_{sys.} \times v_{sys.}$

$\Rightarrow v_{sys.} = \dfrac{m_Bv_B}{m_{sys.}} = \dfrac{50\times 10}{50+950} = 0.5\ m/s$

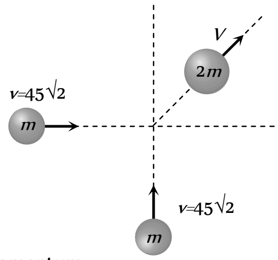
Fractional loss in K.E. = $\dfrac{\frac{1}{2}m_Bv_B^2 - \frac{1}{2}m_{sys.}v_{sys.}^2}{\frac{1}{2}m_Bv_B^2}$

By substituting $m_B = 50\times 10^{-3}\,kg, v_B = 10\ m/s$

$m_{sys.} = 1kg, v_s = 0.5\ m/s$ we get

Fractional loss = $\dfrac{95}{100}$ $\therefore$ Percentage loss = 95%

13. (b)



Initial momentum

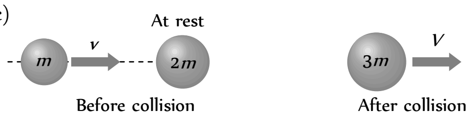
$\vec{P} = m45\sqrt{2}\ \hat{i} + m45\sqrt{2}\ \hat{j} \Rightarrow |\vec{P}| = m\times 90$

Final momentum $2m\times V$

By conservation of momentum $2m\times V = m\times 90$

$\therefore V = 45\,m/s$

14. (c)



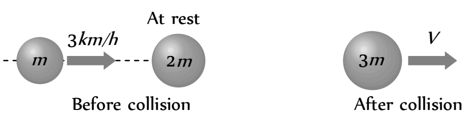
Initial momentum = mv

Final momentum = $3mV$

By the law of conservation of momentum $mv = 3mV$

$\therefore V = v/3$

15. (c)



Initial momentum = $m\times 3 + 2m\times 0 = 3m$

Final momentum = $3m\times V$

By the law of conservation of momentum

$3m = 3m\times V \Rightarrow V = 1\,km/h$

16. (d) Loss in K.E. = (initial K.E. – Final K.E.) of system

$\dfrac{1}{2}m_1u_1^2 + \dfrac{1}{2}m_2u_2^2 - \dfrac{1}{2}(m_1+m_2)V^2$

$= \dfrac{1}{2}3\times(32)^2 + \dfrac{1}{2}\times 4\times(5)^2 - \dfrac{1}{2}\times(3+4)\times(5)^2$

= 986.5 J

17. (a) Momentum of earth-ball system remains conserved.

18. (b) $v = 36\,km/h = 10\,m/s$

By law of conservation of momentum

$2\times 10 = (2+3)V \Rightarrow V = 4\,m/s$

Loss in K.E. $= \dfrac{1}{2}\times 2\times(10)^2 - \dfrac{1}{2}\times 5\times(4)^2 = 60\ J$

19. (d) Initial momentum = $\vec{P} = mv\hat{i} + mv\hat{j}$

$|\vec{P}| = \sqrt{2}mv$

Final momentum = $2m\times V$

By the law of conservation of momentum

$2m\times V = \sqrt{2}\ mv \Rightarrow V = \dfrac{v}{\sqrt{2}}$

In the problem $v = 10m/s$ (given) $\therefore V = \dfrac{10}{\sqrt{2}} = 5\sqrt{2}\ m/s$

20. (a) Because in perfectly inelastic collision the colliding bodies stick together and move with common velocity

21. (b) $m_1v_1 + m_2v_2 = (m_1+m_2)v_{sys.}$

$20\times 10 + 5\times 0 = (20+5)v_{sys.} \Rightarrow v_{sys.} = 8\,m/s$

K.E. of composite mass $= \dfrac{1}{2}(20+5)\times(8)^2 = 800\ J$

22. (c) According to law of conservation of momentum.

Momentum of neutron = Momentum of combination

$\Rightarrow 1.67\times 10^{-27}\times 10^8 = (1.67\times 10^{-27} + 3.34\times 10^{-27})v$

$\therefore v = 3.33\times 10^7\ m/s$

23. (b)

24. (c) Loss in kinetic energy

$= \dfrac{1}{2}\dfrac{m_1m_2(u_1-u_2)^2}{m_1+m_2} = \dfrac{1}{2}\left(\dfrac{40\times 60}{40+60}\right)(4-2)^2 = 48\ J$

25. (b) By momentum conservation before and after collision.

$m_1V + m_2\times 0 = (m_1+m_2)v \Rightarrow v = \dfrac{m_1}{m_1+m_2}V$

i.e. Velocity of system is less than V.

26. (a) By conservation of momentum, $mv + M \times 0 = (m+M)V$

Velocity of composite block $V = \left(\frac{m}{m+M}\right)v$

K.E. of composite block $= \frac{1}{2}(M+m)V^2$

$= \frac{1}{2}(M+m)\left(\frac{m}{M+m}\right)^2 v^2 = \frac{1}{2}mv^2\left(\frac{m}{m+M}\right)$

27. (b)

28. (d) Velocity of combined mass, $v = \frac{m_1v_1 - m_2v_2}{m_1+m_2}$

$= \frac{0.1\times 1 - 0.4\times 0.1}{0.5} = 0.12\ m/s$

$\therefore$ Distance travelled by combined mass

$= v\times t = 0.12 \times 10 = 1.2\ m.$

29. (c) Loss in K.E. $= \frac{m_1m_2}{2(m_1+m_2)}(u_1-u_2)^2$

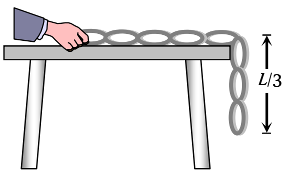
$= \frac{4\times 6}{2\times 10}\times(12-0)^2 = 172.8\ J$

30. (d) In case of perfectly inelastic collision, the bodies stick together after impact.

Critical Thinking Questions

1. (c) By the conservation of momentum in the absence of external force total momentum of the system (ball + earth) remains constant.

2. (d)



$W = \frac{MgL}{2n^2} = \frac{MgL}{2(3)^2} = \frac{MgL}{18}$ (n = 3 given)

3. (b) Gravitational force is a conservative force and work done against it is a point function *i.e.* does not depend on the path.

4. (b) Here $\frac{mv^2}{r} = \frac{K}{r^2}$ $\therefore$ K.E. $= \frac{1}{2}mv^2 = \frac{K}{2r}$

$U = -\int_\infty^r F.dr = -\int_\infty^r\left(-\frac{K}{r^2}\right)dr = -\frac{K}{r}$

Total energy $E = \text{K.E.} + \text{P.E.} = \frac{K}{2r} - \frac{K}{r} = -\frac{K}{2r}$

5. (c) $x = (t-3)^2 \Rightarrow v = \frac{dx}{dt} = 2(t-3)$

at $t=0$; $v_1 = -6\ m/s$ and at $t = 6$ sec, $v_2 = 6\ m/s$

so, change in kinetic energy $= W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = 0$

6. (c) While moving from (0,0) to (a,0)

Along positive x-axis, y = 0 $\therefore \vec{F} = -kx\hat{j}$

i.e. force is in negative y-direction while displacement is in positive x-direction.

$\therefore W_1 = 0$

Because force is perpendicular to displacement

Then particle moves from $(a,0)$ to (a,a) along a line parallel to y-axis $(x=+a)$ during this $\vec{F} = -k(y\hat{i} + a\hat{J})$

The first component of force, $-ky\hat{i}$ will not contribute any work because this component is along negative x-direction $(-\hat{i})$ while displacement is in positive y-direction (a,0) to (a,a). The second component of force *i.e.* $-ka\hat{j}$ will perform negative work

$\therefore W_2 = (-ka\hat{j})(a\hat{j}) = (-ka)(a) = -ka^2$

So net work done on the particle $W = W_1 + W_2$

$= 0 + (-ka^2) = -ka^2$

7. (a) Gain in potential energy $\Delta U = \frac{mgh}{1+\frac{h}{R}}$

If $h = R$ then $\Delta U = \frac{mgR}{1+\frac{R}{R}} = \frac{1}{2}mgR$

8. (c) $\text{Stopping distance} = \frac{\text{kinetic energy}}{\text{retarding force}} \Rightarrow s = \frac{1}{2}\frac{mu^2}{F}$

If lorry and car both possess same kinetic energy and retarding force is also equal then both come to rest in the same distance.

9. (d) Potential energy of the particle $U = k(1-e^{-x^2})$

Force on particle $F = \frac{-dU}{dx} = -k[-e^{-x^2}\times(-2x)]$

$F = -2kxe^{-x^2} = -2kx\left[1 - x^2 + \frac{x^4}{2!} - ......\right]$

For small displacement $F = -2kx$

$\Rightarrow F \propto -x$ *i.e.* motion is simple harmonic motion.

10. (b) Kinetic energy acquired by the body

= Force applied on it × Distance covered by the body

K.E. = $F \times d$

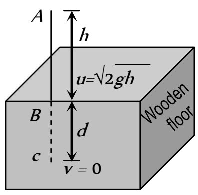
If F and d both are same then K.E. acquired by the body will be same

11. (c) Let the blade stops at depth d into the wood.

$v^2 = u^2 + 2aS$

$\Rightarrow 0 = (\sqrt{2gh})^2 + 2(g-a)d$

by solving $a = \left(1+\frac{h}{d}\right)g$



So the resistance offered by the wood $= mg\left(1+\frac{h}{d}\right)$

12. (d) Because linear momentum is vector quantity where as kinetic energy is a scalar quantity.

13. (c) $P = Fv = mav = m\left(\frac{dv}{dt}\right)v \Rightarrow \frac{P}{m}dt = v\,dv$

$\Rightarrow \frac{P}{m}\times t = \frac{v^2}{2} \Rightarrow v = \left(\frac{2P}{m}\right)^{1/2}(t)^{1/2}$

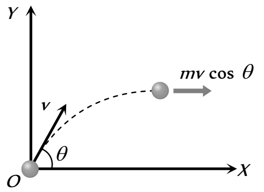
Now $s = \int v\,dt = \int \left(\frac{2P}{m}\right)^{1/2} t^{1/2}dt$

$\therefore\ s = \left(\frac{2P}{m}\right)^{1/2}\left[\frac{2t^{3/2}}{3}\right] \Rightarrow s \propto t^{3/2}$

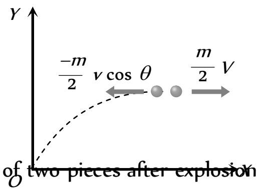
14. (a) Shell is fired with velocity v at an angle θ with the horizontal. So its velocity at the highest point

= horizontal component of velocity = $v\cos\theta$

So momentum of shell before explosion = $mv\cos\theta$



When it breaks into two equal pieces and one piece retrace its path to the canon, then other part move with velocity V.



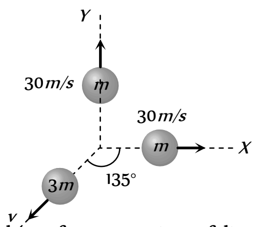
So momentum of two pieces after explosion

$= \frac{m}{2}(-v\cos\theta) + \frac{m}{2}V$

By the law of conservation of momentum

$mv\cos\theta = \frac{-m}{2}v\cos\theta + \frac{m}{2}V \Rightarrow V = 3v\cos\theta$

15. (a) Let two pieces are having equal mass m and third piece have a mass of $3m$.



According to law of conservation of linear momentum. Since the initial momentum of the system was zero, therefore final momentum of the system must be zero *i.e.* the resultant of momentum of two pieces must be equal to the momentum of third piece. We know that if two particle possesses same momentum and angle in between them is 90° then resultant will be given by $P\sqrt{2} = mv\sqrt{2} = m30\sqrt{2}$

Let the velocity of mass $3m$ is V. So $3mV = 30m\sqrt{2}$

$\therefore\ V = 10\sqrt{2}$ and angle 135° from either.

(as it is clear from the figure)

16. (c) The momentum of the two-particle system, at $t = 0$ is

$\vec{P}_i = m_1\vec{v}_1 + m_2\vec{v}_2$

Collision between the two does not affect the total momentum of the system.

A constant external force $(m_1 + m_2)g$ acts on the system.

The impulse given by this force, in time $t = 0$ to $t = 2t_0$ is $(m_1 + m_2)g \times 2t_0$

$\therefore$ |Change in momentum in this interval

$= |m_1\vec{v}'_1 + m_2\vec{v}'_2 - (m_1\vec{v}_1 + m_2\vec{v}_2)| = 2(m_1 + m_2)gt_0$

17. (b) If the masses are equal and target is at rest and after collision both masses moves in different direction. Then angle between direction of velocity will be 90°, if collision is elastic.

18. (d) K.E. of colliding body before collision $= \frac{1}{2}mv^2$

After collision its velocity becomes

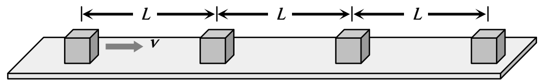
$v' = \frac{(m_1 - m_2)}{(m_1 + m_2)}v = \frac{m}{3m}v = \frac{v}{3}$

$\therefore$ K.E. after collision $\frac{1}{2}mv'^2 = \frac{1}{2}\frac{mv^2}{9}$

Ratio of kinetic energy = $\frac{\text{K.E.}_{\text{before}}}{\text{K.E.}_{\text{after}}} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}\frac{mv^2}{9}} = 9:1$

19. (c)

20. (b,d)



Since collision is perfectly inelastic so all the blocks will stick together one by one and move in a form of combined mass.

Time required to cover a distance 'L' by first block $= \frac{L}{v}$

Now first and second block will stick together and move with $v/2$ velocity (by applying conservation of momentum) and combined system will take time $\frac{L}{v/2} = \frac{2L}{v}$ to reach up to block third.

Now these three blocks will move with velocity $v/3$ and combined system will take time $\frac{L}{v/3} = \frac{3L}{v}$ to reach upto the block fourth.

So, total time $= \frac{L}{v} + \frac{2L}{v} + \frac{3L}{v} + ... \frac{(n-1)L}{v} = \frac{n(n-1)L}{2v}$

and velocity of combined system having n blocks as $\frac{v}{n}$.

Graphical questions

1. (c) At time t_1 the velocity of ball will be maximum and it goes on decreasing with respect to time.

At the highest point of path its velocity becomes zero, then it increases but direction is reversed

This explanation match with graph (c).

2. (a) Work done = area between the graph and position axis

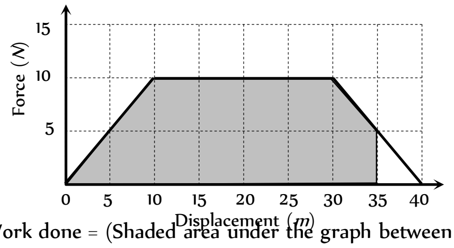
$$W = 10\times1 + 20\times1 - 20\times1 + 10\times1 = 20\,erg$$

3. (a) Spring constant $k = \frac{F}{x}$ = Slope of curve

$$\therefore k = \frac{4-1}{30} = \frac{3}{30} = 0.1\,kg/cm$$

4. (b) As the area above the time axis is numerically equal to area below the time axis therefore net momentum gained by body will be zero because momentum is a vector quantity.

5. (c)



Work done = (Shaded area under the graph between

$x = 0$ to $x = 35$ m) $= 287.5\ J$

6. (a) Work done = Area covered in between force displacement curve and displacement axis

= Mass × Area covered in between acceleration-displacement curve and displacement axis.

$$= 10\times\frac{1}{2}(8\times10^{-2}\times20\times10^{-2})$$

$$= 8\times10^{-2}\ J$$

7. (c) Work done = Gain in potential energy

Area under curve = mgh

$$\Rightarrow \frac{1}{2}\times11\times100 = 5\times10\times h$$

$$\Rightarrow h = 11m$$

8. (d) Initial K.E. of the body = $\frac{1}{2}mv^2 = \frac{1}{2}\times25\times4 = 50\ J$

Work done against resistive force

= Area between F-x graph

$$= \frac{1}{2}\times4\times20 = 40J$$

Final K.E. = Initial K.E. – Work done against resistive force

$$= 50 - 40 = 10\ J$$

9. (d) Area between curve and displacement axis

$$= \frac{1}{2}\times(12+4)\times10 = 80\ J$$

In this time body acquire kinetic energy = $\frac{1}{2}mv^2$

by the law of conservation of energy

$$\frac{1}{2}mv^2 = 80J$$

$$\Rightarrow \frac{1}{2}\times0.1\times v^2 = 80$$

$\Rightarrow v = 1600$

$\Rightarrow v = 40\ m/s$

10. (a) Work done = Area under curve and displacement axis

= Area of trapezium

$= \frac{1}{2}\times$(sum of two parallel lines) × distance between them

$$= \frac{1}{2}(10+4)\times(2.5-0.5)$$

$$= \frac{1}{2}14\times2 = 14\ J$$

As the area actually is not trapezium so work done will be more than 14 J *i.e.* approximately 16 J

11. (a) As particle is projected with some velocity therefore its initial kinetic energy will not be zero.

As it moves downward under gravity then its velocity increases with time K.E. $\propto v \propto t$ (As $v \propto t$)

So the graph between kinetic energy and time will be parabolic in nature.

12. (a) From the graph it is clear that force is acting on the particle in the region AB and due to this force kinetic energy (velocity) of the particle increases. So the work done by the force is positive.

13. (d) $F = \frac{-dU}{dx} \Rightarrow dU = -F\ dx$

$$\Rightarrow U = -\int_0^x(-Kx + ax^3)dx = \frac{kx^2}{2} - \frac{ax^4}{4}$$

$\therefore$ We get $U = 0$ at $x = 0$ and $x = \sqrt{2k/a}$

and also U = negative for $x > \sqrt{2k/a}$.

So $F = 0$ at $x = 0$

i.e. slope of $U - x$ graph is zero at $x = 0$.

14. (b) Work done = Area enclosed by $F - x$ graph

$$= \frac{1}{2}\times(3+6)\times3 = 13.5\ J$$

15. (c) As slope of problem graph is positive and constant upto certain distance and then it becomes zero.

So from $F = \frac{-dU}{dx}$, up to distance a, F = constant (negative) and becomes zero suddenly.

16. (d) Work done = change in kinetic energy

$W = \frac{1}{2}mv^2 \quad \therefore \quad W \propto v^2$ graph will be parabolic in nature

17. (a) Potential energy increases and kinetic energy decreases when the height of the particle increases it is clear from the graph (*a*).

18. (c) $P = \sqrt{2mE}$ it is clear that $P \propto \sqrt{E}$

So the graph between P and $\sqrt{E}$ will be straight line.

but graph between $\frac{1}{P}$ and $\sqrt{E}$ will be hyperbola

19. (b) When particle moves away from the origin then at position $x = x_1$ force is zero and at $x > x_1$, force is positive (repulsive in nature) so particle moves further and does not return back to original position.

i.e. the equilibrium is not stable.

Similarly at position $x = x_2$ force is zero and at $x > x_2$, force is negative (attractive in nature)

So particle return back to original position *i.e.* the equilibrium is stable.

20. (c) $F = \frac{-dU}{dx}$ it is clear that slope of $U - x$ curve is zero at point *B* and *C*. $\therefore$ $F = 0$ for point *B* and *C*

21. (a) Work done = area under curve and displacement axis

$= 1 \times 10 - 1 \times 10 + 1 \times 10 = 10\ J$

22. (a) When the length of spring is halved, its spring constant will becomes double. (because $k \propto \frac{1}{x} \propto \frac{1}{L} \therefore k \propto \frac{1}{L}$)

Slope of force displacement graph gives the spring constant (k) of spring.

If k becomes double then slope of the graph increases *i.e.* graph shifts towards force-axis.

23. (a) Kinetic energy $E = \frac{1}{2}mv^2 \Rightarrow E \propto v^2$

graph will be parabola symmetric to *E*-axis.

24. (c) Change in momentum = Impulse

= Area under force-time graph

$\therefore$ mv = Area of trapezium

$$\Rightarrow mv = \frac{1}{2}\left(T + \frac{T}{2}\right)F_0$$

$$\Rightarrow mv = \frac{3T}{4}F_0 \Rightarrow F_0 = \frac{4mu}{3T}$$

25. (c) When body moves under action of constant force then kinetic energy acquired by the body K.E. = $F \times S$

$\therefore$ KE $\propto$ S (If F = constant)

So the graph will be straight line.

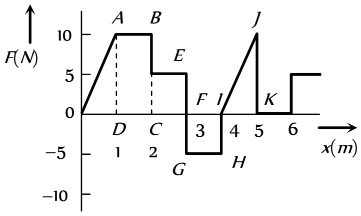
26. (a) When the distance between atoms is large then interatomic force is very weak. When they come closer, force of attraction increases and at a particular distance force becomes zero. When they are further brought closer force becomes repulsive in nature.

This can be explained by slope of $U - x$ curve shown in graph (a).

27. (b) Work done = area under *F-x* graph

= area of rectangle *ABCD* + area of rectangle *LCEF*

+ area of rectangle *GFIH* + area of triangle *IJK*



$$= (2-1)\times(10-0) + (3-2)(5-0) + (4-3)(-5-0)$$

$$+\frac{1}{2}(5-4)(10-0) = 15\ J$$

28. (a) $U = -\int F dx = -\int kx\ dx = -k\frac{x^2}{2}$

This is the equation of parabola symmetric to *U* axis in negative direction

Assertion and Reason

1. (a) The work done, $W = \vec{F}.\vec{s} = Fs\cos\theta$, when a person walk on a horizontal road with load on his head then $\theta = 90°$.

Hence $W = Fs\cos 90° = 0$

Thus no work is done by the person.

2. (d) In a round trip work done is zero only when the force is conservative in nature.

Force is always required to move a body in a conservative or non-conservative field

3. (e) When a body slides down on inclined plane,

work done by friction is negative because it opposes the motion (θ = 180° between force and displacement)

If $\theta < 90°$ then W =positive because $W = F.s.\cos\theta$

4. (a) Since the gaseous pressure and the displacement (of piston) are in the same direction. Therefore $\theta = 0°$

$\therefore$ Work done = $Fs\cos\theta = Fs$ = Positive

Thus during expansion work done by gas is positive.

5. (d) When two bodies have same momentum then lighter body possess more kinetic energy because $E = \frac{P^2}{2m}$

$\therefore E \propto \frac{1}{m}$ when P = constant

6. (b) $P = \vec{F}.\vec{v}$ and unit of power is *Watt*.

7. (c) Change in kinetic energy = work done by net force.

This relationship is valid for particle as well as system of particles.

8. (a) The work done on the spring against the restoring force is stored as potential energy in both conditions when it is compressed or stretched.

9. (c) The gravitational force on the comet due to the sun is a conservative force. Since the work done by a conservative force over a closed path is always zero (irrespective of the nature of path), the work done by the gravitational forces over every complete orbit of the comet is zero.

10. (e) Rate of change of momentum is proportional to external forces acting on the system. The total momentum of whole system remain constant when no external force is acted upon it.

Internal forces can change the kinetic energy of the system.

11. (a) When the water is at the top of the fall it has potential energy *mgh* (where *m* is the mass of the water and *h* is the height of the fall). On falling, this potential energy is converted into kinetic energy, which further converted into heat energy and so temperature of water increases.

12. (b) The power of the pump is the work done by it per sec.

$\therefore$ Power $= \frac{\text{work}}{\text{time}} = \frac{mgh}{t} = \frac{100 \times 10 \times 100}{10}$

$= 10^4 W = 10\, kW$

Also 1 *Horse power* (*hp*) =746 *W.*

13. (c) For conservative forces the sum of kinetic and potential energies at any point remains constant throughout the motion. This is known as law of conservation of mechanical energy. According to this law,

Kinetic energy + Potential energy = constant

or, $\Delta K + \Delta U = 0$ or, $\Delta K = -\Delta U$

14. (e) When the force retards the motion, the work done is negative.

Work done depends on the angle between force and displacement $W = Fs\cos\theta$

15. (d) In an elastic collision both the momentum and kinetic energy remains conserved. But this rule is not for individual bodies, but for the system of bodies before and after the collision. While collision in which there occurs some loss of kinetic energy is called inelastic collision. Collision in daily life are generally inelastic. The collision is said to be perfectly inelastic, if two bodies stick to each other.

16. (d) A body can have energy without having momentum if it possess potential energy but if body possess momentum then it must posses kinetic energy. Momentum and energy have different dimensions.

17. (e) Work done and power developed is zero in uniform circular motion only.

18. (a) $K = \frac{1}{2}mv^2 \;\therefore\; K \propto v^2$

If velocity is doubled then K.E. will be quadrupled.

19. (a) In a quick collision, time t is small. As $F \times t =$ constant, therefore, force involved is large, *i.e.* collision is more violent in comparison to slow collision.

20. (a) From, definition, work done in moving a body against a conservative force is independent of the path followed.

21. (c) When we supply current through the cell, chemical reactions takes place, so chemical energy of cell is converted into electrical energy. If a large amount of current is drawn from wire for a long time only then wire get heated.

22. (e) Potential energy $U = \frac{1}{2}kx^2$ *i.e.* $U \propto x^2$

This is a equation of parabola, so graph between U and x is a parabola, not straight line.

23. (c) When two bodies of same mass undergo an elastic collision, their velocities get interchanged after collision. Water and heavy water are hydrogenic materials containing protons having approximately the same mass as that of a neutron. When fast moving neutrons collide with protons, the neutrons come to rest and protons move with the velocity of that of neutrons.

24. (a) From Einstein equation $E = mc^2$

it can be observed that if mass is conserved then only energy is conserved and vice versa. Thus, both cannot be treated separately.

25. (b) If two protons are brought near one another, work has to be done against electrostatic force because same charge repel each other. This work done is stored as potential energy in the system.

26. (a) $E = \frac{P^2}{2m}$. In firing momentum is conserved $\therefore E \propto \frac{1}{m}$

So $\frac{E_{\text{gun}}}{E_{\text{bullet}}} = \frac{m_{\text{bullet}}}{m_{\text{gun}}}$

27. (a) K.E. of one bullet = k $\therefore$ K.E. of n bullet = nk

According to law of conservation of energy, the kinetic energy of bullets be equal to the work done by machine gun per sec.

28. (d) Work done in the motion of a body over a closed loop is zero only when the body is moving under the action of conservative forces (like gravitational or electrostatic forces). *i.e.* work done depends upon the nature of force.

29. (a) If roads of the mountain were to go straight up, the slope θ would have been large, the frictional force $\mu mg\cos\theta$ would be small. Due to small friction, wheels of vehicle would slip. Also for going up a large slope, a greater power shall be required.

30. (a) The rise in temperature of the soft steel is an example of transferring energy into a system by work and having it appear as an increase in the internal energy of the system. This works well for the soft steel because it is soft. This softness results in a deformation of the steel under blow of the hammer. Thus the point of application of the force is displaced by the hammer and positive work is done on the steel. With the hard steel, less deformation occur, thus, there is less displacement of point of application of the force and less work done on the steel. The soft steel is therefore better in absorbing energy from the hammer by means of work and its temperature rises more rapidly.

Work, Energy, Power and Collision

SET Self Evaluation Test - 6

1. How much work does a pulling force of 40 N do on the 20 kg box in pulling it 8 m across the floor at a constant speed. The pulling force is directed at 60° above the horizontal
(a) 160 J (b) 277 J
(c) 784 J (d) None of the above

2. A horizontal force of 5 N is required to maintain a velocity of 2 m/s for a block of 10 kg mass sliding over a rough surface. The work done by this force in one minute is
(a) 600 J (b) 60 J
(c) 6 J (d) 6000 J

3. Work done in time t on a body of mass m which is accelerated from rest to a speed v in time t_1 as a function of time t is given by
(a) $\frac{1}{2} m \frac{v}{t_1} t^2$ (b) $m \frac{v}{t_1} t^2$
(c) $\frac{1}{2}\left(\frac{mv}{t_1}\right)^2 t^2$ (d) $\frac{1}{2} m \frac{v^2}{t_1^2} t^2$

4. What is the shape of the graph between the speed and kinetic energy of a body
(a) Straight line (b) Hyperbola
(c) Parabola (d) Exponential

5. When a body moves with some friction on a surface
(a) It loses kinetic energy but momentum is constant
(b) It loses kinetic energy but gains potential energy
(c) Kinetic energy and momentum both decrease
(d) Mechanical energy is conserved

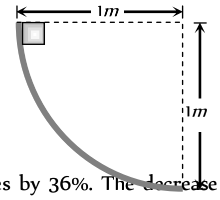
6. A bullet of mass m moving with velocity v strikes a suspended wooden block of mass M. If the block rises to a height h, the initial velocity of the block will be
(a) $\sqrt{2gh}$ (b) $\frac{M+m}{m}\sqrt{2gh}$
(c) $\frac{m}{M+m} 2gh$ (d) $\frac{M+m}{M}\sqrt{2gh}$

7. There will be decrease in potential energy of the system, if work is done upon the system by
(a) Any conservative or non-conservative force
(b) A non-conservative force
(c) A conservative force
(d) None of the above

8. The slope of kinetic energy displacement curve of a particle in motion is
(a) Equal to the acceleration of the particle
(b) Inversely proportional to the acceleration
(c) Directly proportional to the acceleration
(d) None of the above

9. The energy required to accelerate a car from 10 m/s to 20 m/s is how many times the energy required to accelerate the car from rest to 10 m/s
(a) Equal (b) 4 times
(c) 2 times (d) 3 times

10. A body of mass 2 kg slides down a curved track which is quadrant of a circle of radius 1 metre. All the surfaces are frictionless. If the body starts from rest, its speed at the bottom of the track is



(a) 4.43 m/sec
(b) 2 m/sec
(c) 0.5 m/sec
(d) 19.6 m/sec

11. The kinetic energy of a body decreases by 36%. The decrease in its momentum is
(a) 36% (b) 20%
(c) 8% (d) 6%

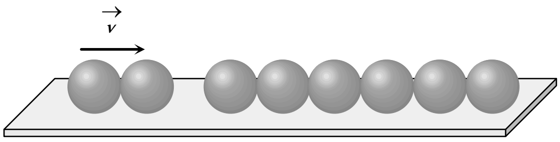
12. A bomb of mass 3m kg explodes into two pieces of mass m kg and 2m kg. If the velocity of m kg mass is 16 m/s, the total kinetic energy released in the explosion is
(a) 192 mJ (b) 96 mJ
(c) 384 mJ (d) 768 mJ

13. Which one of the following statement does not hold good when two balls of masses m_1 and m_2 undergo elastic collision
(a) When $m_1 << m_2$ and m_2 at rest, there will be maximum transfer of momentum
(b) When $m_1 >> m_2$ and m_2 at rest, after collision the ball of mass m_2 moves with four times the velocity of m_1
(c) When $m_1 = m_2$ and m_2 at rest, there will be maximum transfer of K.E.
(d) When collision is oblique and m_2 at rest with $m_1 = m_2$, after collision the balls move in opposite directions

14. A neutron travelling with a velocity v and K.E. E collides perfectly elastically head on with the nucleus of an atom of mass number A at rest. The fraction of total energy retained by neutron is
(a) $\left(\frac{A-1}{A+1}\right)^2$ (b) $\left(\frac{A+1}{A-1}\right)^2$
(c) $\left(\frac{A-1}{A}\right)^2$ (d) $\left(\frac{A+1}{A}\right)^2$

15. A body of mass m_1 moving with uniform velocity of 40 m/s collides with another mass m_2 at rest and then the two together begin to move with uniform velocity of 30 m/s. The ratio of their masses $\frac{m_1}{m_2}$ is
(a) 0.75 (b) 1.33
(c) 3.0 (d) 4.0

16. Six identical balls are lined in a straight groove made on a horizontal frictionless surface as shown. Two similar balls each moving with a velocity v collide elastically with the row of 6 balls from left. What will happen



(a) One ball from the right rolls out with a speed $2v$ and the remaining balls will remain at rest

(b) Two balls from the right roll out with speed v each and the remaining balls will remain stationary

(c) All the six balls in the row will roll out with speed $v/6$ each and the two colliding balls will come to rest

(d) The colliding balls will come to rest and no ball rolls out from right

17. A wooden block of mass M rests on a horizontal surface. A bullet of mass m moving in the horizontal direction strikes and gets embedded in it. The combined system covers a distance x on the surface. If the coefficient of friction between wood and the surface is μ, the speed of the bullet at the time of striking the block is (where m is mass of the bullet)

(a) $\sqrt{\frac{2Mg}{\mu m}}$ (b) $\sqrt{\frac{2\mu mg}{Mx}}$

(c) $\sqrt{2\mu gx}\left(\frac{M+m}{m}\right)$ (d) $\sqrt{\frac{2\mu mx}{M+m}}$

18. A ball moving with speed v hits another identical ball at rest. The two balls stick together after collision. If specific heat of the material of the balls is S, the temperature rise resulting from the collision is

(a) $\frac{v^2}{8S}$ (b) $\frac{v^2}{4S}$

(c) $\frac{v^2}{2S}$ (d) $\frac{v^2}{S}$

19. A bag of sand of mass M is suspended by a string. A bullet of mass m is fired at it with velocity v and gets embedded into it. The loss of kinetic energy in this process is

(a) $\frac{1}{2}mv^2$ (b) $\frac{1}{2}mv^2 \times \frac{1}{M+m}$

(c) $\frac{1}{2}mv^2 \times \frac{M}{m}$ (d) $\frac{1}{2}mv^2\left(\frac{M}{M+m}\right)$

Answers and Solutions

(SET -6)

1. (a) $W = \vec{F}.\vec{s} = 40 \times 8 \times \cos 60° = 160\ J$

2. (a) $W = F \times s = F \times v \times t = 5 \times 2 \times 60 = 600\ J$

3. (d) Work done $= F \times s = ma \times \frac{1}{2}at^2$ $\left[\text{from } s = ut + \frac{1}{2}at^2\right]$

$\therefore W = \frac{1}{2}ma^2t^2 = \frac{1}{2}m\left(\frac{v}{t_1}\right)^2 t^2$ $\left[\text{As } a = \frac{v}{t_1}\right]$

4. (c) Kinetic energy $k = \frac{1}{2}mv^2 \Rightarrow k \propto v^2$

It means the graph between the speed and kinetic energy will parabola

5. (c) Friction is a non-conservative external force to the system, it decreases momentum and kinetic energy both.

6. (a) Initial K.E. of block when bullet strikes to it

$= \frac{1}{2}(m+M)V^2$

Due to this K.E. block will rise to a height h.

Its potential energy = $(m+M)gh$.

By the law of conservation of energy

$\frac{1}{2}(m+M)V^2 = (m+M)gh \qquad \therefore V = \sqrt{2gh}$

7. (c)

8. (c) $E = \frac{1}{2}mv^2$. Differentiating *w.r.t. x*, we get

$\frac{dE}{dx} = \frac{1}{2}m \times 2v\frac{dv}{dx} = mv \times \frac{dv}{dt} \times \frac{dt}{dx} = mv \times \frac{a}{v} = ma$

9. (d) Kinetic energy for first condition

$= \frac{1}{2}m\left(v_2^2 - v_1^2\right) = \frac{1}{2}m\left(20^2 - 10^2\right) = 150\ mJ$

K.E. for second condition = $\frac{1}{2}m\left(10^2 - 0^2\right) = 50mJ$

$\therefore \frac{(K.E.)I}{(K.E.)II} = \frac{150m}{50m} = 3$

10. (a) By conservation of energy, $mgh = \frac{1}{2}mv^2$

$\Rightarrow v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 1} = \sqrt{19.6} = 4.43\ m/s$

11. (b) $P = \sqrt{2mE} \ \therefore\ P \propto \sqrt{E}$

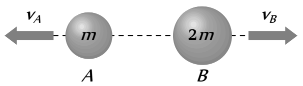
In given problem K.E. becomes 64% of the original value.

$\frac{P_2}{P_1} = \sqrt{\frac{E_2}{E_1}} = \sqrt{\frac{64E}{100E}} = 0.8 \Rightarrow P_2 = 0.8\ P$

$\therefore P_2 = 80\%$ of the original value.

i.e. decrease in momentum is 20%.

12. (a)



By the conservation of momentum, $m_A v_A = m_B v_B$

$\Rightarrow m \times 16 = 2m \times v_B \Rightarrow v_B = 8\ m/s$

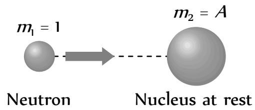
Kinetic energy of system $= \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$

$= \frac{1}{2} \times m \times (16)^2 + \frac{1}{2} \times (2m) \times 8^2 = 192\ mJ$

13. (b,d) When $m_1 > m_2$ and m_2 at rest, after collision the ball of mass m_2 moves with double the velocity of u_1. So option (b) is incorrect.

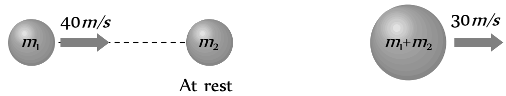
When collision is oblique and m_2 at rest with $m_1 = m_2$, after collision the ball moves in perpendicular direction. So option (d) is also incorrect.

14. (a)



$\left(\frac{\Delta k}{k}\right)_{\text{retained}} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)^2 = \left(\frac{1-A}{1+A}\right)^2$

15. (c)



Initial momentum of the system = $m_1 \times 40 + m_2 \times 0$

Final momentum of the system = $(m_1 + m_2) \times 30$

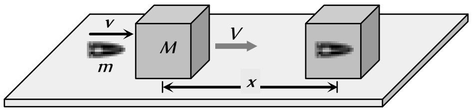
By the law of conservation of momentum

$m_1 \times 40 + m_2 \times 0 = (m_1 + m_2) \times 30$

$\Rightarrow 40m_1 = 30m_1 + 30m_2 \Rightarrow 10m_1 = 30m_2 = \frac{m_1}{m_2} = 3$

16. (b) Momentum and kinetic energy is conserved only in this case.

17. (c)



Let speed of the bullet = v

Speed of the system after the collision = V

By conservation of momentum $mv = (m+M)V$

$\Rightarrow V = \frac{mv}{M+m}$

So the initial K.E. acquired by the system

$= \frac{1}{2}(M+m)V^2 = \frac{1}{2}(m+M)\left(\frac{mv}{M+m}\right)^2 = \frac{1}{2}\frac{m^2v^2}{(m+M)}$

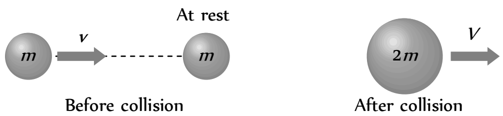
This kinetic energy goes against friction work done by friction $= \mu R \times x = \mu(m+M)g \times x$

By the law of conservation of energy

$\frac{1}{2}\frac{m^2v^2}{(m+M)} = \mu(m+M)g \times x \Rightarrow v^2 = 2\mu gx\left(\frac{m+M}{m}\right)^2$

$\therefore v = \sqrt{2\mu gx}\left(\frac{M+m}{m}\right)$

18. (a)



Initial momentum = mv

Final momentum = $2mV$

By the conservation of momentum, $mv = 2mV$

$\Rightarrow V = \frac{v}{2}$

***

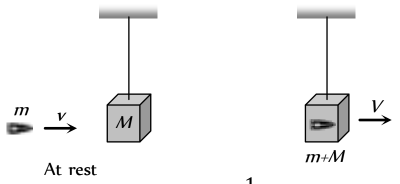
K.E. of the system after the collision = $\frac{1}{2}(2m)\left(\frac{v}{2}\right)^2$

$\therefore$ loss in K.E. $= \frac{1}{2}mv^2 - \frac{1}{4}mv^2 = \frac{1}{4}mv^2$

This loss in K.E. will increase the temperature

$\therefore\ 2m \times s \times \Delta t = \frac{1}{4}mv^2 \Rightarrow \Delta t = \frac{v^2}{8s}$

19. (d)



Initial kinetic energy of bullet = $\frac{1}{2}mv^2$

After inelastic collision system moves with velocity V

By the conservation of momentum

$mv + 0 = (m+M)V \Rightarrow V = \frac{mv}{m+M}$

Kinetic energy of system = $\frac{1}{2}(m+M)\,V^2$

$= \frac{1}{2}(m+M)\left(\frac{mv}{m+M}\right)^2$

Loss of kinetic energy = $\frac{1}{2}mv^2 - \frac{1}{2}(m+M)\left(\frac{mv}{m+M}\right)^2$

$= \frac{1}{2}mv^2\left(\frac{M}{m+M}\right)$

Chapter

8

Gravitation

Introduction

*N*ewton at the age of twenty-three is said to have seen an apple falling down from tree in his orchid. This was the year 1665. He started thinking about the role of earth's attraction in the motion of moon and other heavenly bodies.

Fig. 8.1

By comparing the acceleration due to gravity due to earth with the acceleration required to keep the moon in its orbit around the earth, he was able to arrive the Basic Law of Gravitation.

Newton's law of Gravitation

Newton's law of gravitation states that every body in this universe attracts every other body with a force, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. The direction of the force is along the line joining the particles.

Thus the magnitude of the gravitational force F that two particles of masses m_1 and m_2 are separated by a distance r exert on each other is given by $F \propto \frac{m_1 m_2}{r^2}$

or $F = G\frac{m_1 m_2}{r^2}$

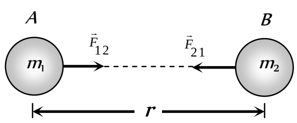


Fig. 8.2

Vector form : According to Newton's law of gravitation

$$\vec{F}_{12} = \frac{-Gm_1m_2}{r^2}\hat{r}_{21} = \frac{-Gm_1m_2}{r^3}\vec{r}_{21} = \frac{-Gm_1m_2}{|\vec{r}_{21}|^3}\vec{r}_{21}$$

Here negative sign indicates that the direction of $\vec{F}_{12}$ is opposite to that of $\hat{r}_{21}$.

Similarly $\vec{F}_{21} = \frac{-Gm_1m_2}{r^2}\hat{r}_{12} = \frac{-Gm_1m_2}{r^3}\vec{r}_{12} = \frac{-Gm_1m_2}{|\vec{r}_{12}|^3}\vec{r}_{12}$

$$= \frac{Gm_1m_2}{r^2}\hat{r}_{21} \quad [\because \hat{r}_{12} = -\hat{r}_{21}]$$

$\therefore$ It is clear that $\vec{F}_{12} = -\vec{F}_{21}$. Which is Newton's third law of motion.

Here G is constant of proportionality which is called 'Universal gravitational constant'.

If $m_1 = m_2$ and $r = 1$ then $G = F$

i.e. universal gravitational constant is equal to the force of attraction between two bodies each of unit mass whose centres are placed unit distance apart.

(i) The value of G in the laboratory was first determined by Cavendish using the torsional balance.

(ii) The value of G is 6.67×10^{-11} $N\text{–}m^2\ kg^{-2}$ in S.I. and 6.67×10^{-8} *dyne-cm*-g^{-2}2 – t——— in C.G.S. system.

(iii) Dimensional formula $[M^{-1}L^3T^{-2}]$.

(iv) The value of G does not depend upon the nature and size of the bodies.

(v) It also does not depend upon the nature of the medium between the two bodies.

(vi) As G is very small, hence gravitational forces are very small, unless one (or both) of the mass is huge.

Properties of Gravitational Force

(1) It is always attractive in nature while electric and magnetic force can be attractive or repulsive.

(2) It is independent of the medium between the particles while electric and magnetic force depend on the nature of the medium between the particles.

(3) It holds good over a wide range of distances. It is found true for interplanetary to inter atomic distances.

(4) It is a central force *i.e.* acts along the line joining the centres of two interacting bodies.

(5) It is a two-body interaction *i.e.* gravitational force between two particles is independent of the presence or absence of other particles; so the principle of superposition is valid *i.e.* force on a particle due to number of particles is the resultant of forces due to individual particles *i.e.* $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$

While nuclear force is many body interaction

(6) It is the weakest force in nature : As $F_{nuclear} > F_{electromagnetic} > F_{gravitational}$.

(7) The ratio of gravitational force to electrostatic force between two electrons is of the order of 10^{-43} .

(8) It is a conservative force *i.e.* work done by it is path independent or work done in moving a particle round a closed path under the action of gravitational force is zero.

(9) It is an action reaction pair *i.e.* the force with which one body (say earth) attracts the second body (say moon) is equal to the force with which moon attracts the earth. This is in accordance with Newton's third law of motion.

Note : ❑ The law of gravitation is stated for two point masses, therefore for any two arbitrary finite size bodies, as shown in the figure, It can not be applied as there is not unique value for the separation.

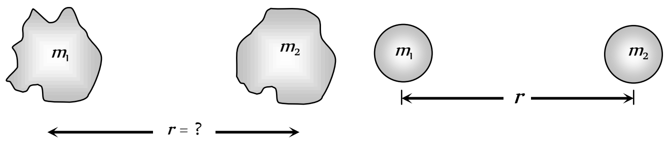


Fig. 8.3

But if the two bodies are uniform spheres then the separation r may be taken as the distance between their centres because a sphere of uniform mass behave as a point mass for any point lying outside it.

Acceleration Due to Gravity

The force of attraction exerted by the earth on a body is called gravitational pull or gravity.

We know that when force acts on a body, it produces acceleration. Therefore, a body under the effect of gravitational pull must accelerate.

The acceleration produced in the motion of a body under the effect of gravity is called acceleration due to gravity, it is denoted by g.

Consider a body of mass m is lying on the surface of earth then gravitational force on the body is given by

$$F = \frac{GMm}{R^2} \quad ...(i)$$

Where M = mass of the earth and R = radius of the earth.

If g is the acceleration due to gravity, then the force on the body due to earth is given by

Force = mass × acceleration

or $F = mg$ ...(ii)

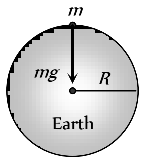


Fig. 8.4

From (i) and (ii) we have $mg = \frac{GMm}{R^2}$

$$\therefore \; g = \frac{GM}{R^2} \quad ...(iii)$$

$$\Rightarrow g = \frac{G}{R^2}\left(\frac{4}{3}\pi R^3 \rho\right)$$

[As mass (M) = volume ($\frac{4}{3}\pi R^3$) × density (ρ)]

$$\therefore \; g = \frac{4}{3}\pi \rho G R \quad ...(iv)$$

(i) From the expression $g = \frac{GM}{R^2} = \frac{4}{3}\pi\rho GR$ it is clear that its value depends upon the mass radius and density of planet and it is independent of mass, shape and density of the body placed on the surface of the planet. *i.e.* a given planet (reference body) produces same acceleration in a light as well as heavy body.

(ii) The greater the value of (M/R^2) or ρR, greater will be value of g for that planet.

(iii) Acceleration due to gravity is a vector quantity and its direction is always towards the centre of the planet.

(iv) Dimension $[g] = [LT^{-2}]$

(v) it's average value is taken to be 9.8 *m/s* or 981 *cm/sec* or 32 *feet/sec*, on the surface of the earth at mean sea level.

(vi) The value of acceleration due to gravity vary due to the following factors : (a) Shape of the earth, (b) Height above the earth surface, (c) Depth below the earth surface and (d) Axial rotation of the earth.

Variation in g Due to Shape of Earth

Earth is elliptical in shape. It is flattened at the poles and bulged out at the equator. The equatorial radius is about 21 *km* longer than polar radius, from $g = \frac{GM}{R^2}$

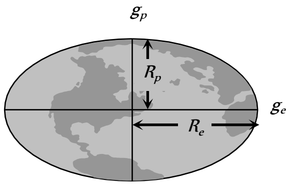


Fig. 8.5

At equator $g_e = \frac{GM}{R_e^2}$ ...(i)

At poles $g_p = \frac{GM}{R_p^2}$ ...(ii)

From (i) and (ii) $\frac{g_e}{g_p} = \frac{R_p^2}{R_e^2}$

Since $R_{equator} > R_{pole}$

$\therefore \; g_{pole} > g_{equator}$ and $g_p = g_e + 0.018 \; ms^{-2}$

Therefore the weight of body increases as it is taken from equator to the pole.

Variation in *g* With Height

Acceleration due to gravity at the surface of the earth

$g = \frac{GM}{R^2}$ ...(i)

Acceleration due to gravity at height h from the surface of the earth

$g' = \frac{GM}{(R+h)^2}$ ...(ii)

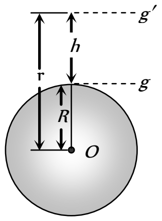


Fig. 8.6

From (i) and (ii) $g' = g\left(\frac{R}{R+h}\right)^2$ ...(iii)

$= g\frac{R^2}{r^2}$ ...(iv)

[As $r = R + h$]

(i) As we go above the surface of the earth, the value of g decreases because $g' \propto \frac{1}{r^2}$.

(ii) If $r = \infty$ then $g' = 0$, *i.e.*, at infinite distance from the earth, the value of g becomes zero.

(iii) If $h << R$ *i.e.*, height is negligible in comparison to the radius then from equation (iii) we get

$$g' = g\left(\frac{R}{R+h}\right)^2 = g\left(1+\frac{h}{R}\right)^{-2} = g\left[1-\frac{2h}{R}\right]$$

[As $h << R$]

(iv) If $h << R$ then decrease in the value of g with height :

Absolute decrease $\Delta g = g - g' = \frac{2hg}{R}$

Fractional decrease $\frac{\Delta g}{g} = \frac{g-g'}{g} = \frac{2h}{R}$

Percentage decrease $\frac{\Delta g}{g}\times 100\% = \frac{2h}{R}\times 100\%$

Variation in *g* With Depth

Acceleration due to gravity at the surface of the earth

$g = \frac{GM}{R^2} = \frac{4}{3}\pi\rho GR$ ...(i)

Acceleration due to gravity at depth d from the surface of the earth

$g' = \frac{4}{3}\pi\rho G(R-d)$ ...(ii)

From (i) and (ii) $g' = g\left[1-\frac{d}{R}\right]$

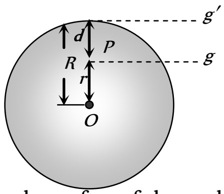


Fig. 8.7

(i) The value of g decreases on going below the surface of the earth. From equation (ii) we get $g' \propto (R-d)$.

So it is clear that if d increase, the value of g decreases.

(ii) At the centre of earth $d = R$ $\therefore$ $g' = 0$, *i.e.,* the acceleration due to gravity at the centre of earth becomes zero.

(iii) Decrease in the value of g with depth

Absolute decrease $\Delta g = g - g' = \frac{dg}{R}$

Fractional decrease $\frac{\Delta g}{g} = \frac{g-g'}{g} = \frac{d}{R}$

Percentage decrease $\frac{\Delta g}{g}\times 100\% = \frac{d}{R}\times 100\%$

(iv) The rate of decrease of gravity outside the earth (if $h << R$) is double to that of inside the earth.

Variation in *g* Due to Rotation of Earth

As the earth rotates, a body placed on its surface moves along the circular path and hence experiences centrifugal force, due to it, the apparent weight of the body decreases.

Since the magnitude of centrifugal force varies with the latitude of the place, therefore the apparent weight of the body varies with latitude due to variation in the magnitude of centrifugal force on the body.

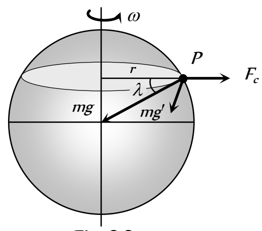


Fig. 8.8

If the body of mass m lying at point P, whose latitude is λ, then due to rotation of earth its apparent weight can be given by $\overrightarrow{mg'} = \overrightarrow{mg} + \overrightarrow{F_c}$

or $mg' = \sqrt{(mg)^2 + (F_c)^2 + 2mg\ F_c\ \cos(180-\lambda)}$

$\Rightarrow mg' = \sqrt{(mg)^2 + (m\omega^2 R\cos\lambda)^2 + 2mg\ m\omega^2 R\cos\lambda\,(-\cos\lambda)}$

[As $F_c = m\omega^2 r = m\omega^2 R\cos\lambda$]

By solving we get $g' = g - \omega^2 R\cos^2\lambda$

Note : ❑ The latitude at a point on the surface of the earth is defined as the angle, which the line joining that point to the centre of earth makes with equatorial plane. It is denoted by λ.

❑ For the poles $\lambda = 90^o$ and for equator $\lambda = 0^o$

(i) Substituting $\lambda = 90^o$ in the above expression we get $g_{pole} = g - \omega^2 R\cos^2 90^o$

$\therefore$ $g_{pole} = g$ ...(i)

i.e., there is no effect of rotational motion of the earth on the value of g at the poles.

(ii) Substituting $\lambda = 0^o$ in the above expression we get $g_{eqator} = g - \omega^2 R\cos^2 0^o$

$\therefore$ $g_{equator} = g - \omega^2 R$ ...(ii)

i.e., the effect of rotation of earth on the value of g at the equator is maximum.

From equation (i) and (ii)

$g_{pole} - g_{equator} = R\omega^2 = 0.034 m/s^2$

(iii) When a body of mass m is moved from the equator to the poles, its weight increases by an amount

$m(g_p - g_e) = m\omega^2 R$

(iv) Weightlessness due to rotation of earth : As we know that apparent weight of the body decreases due to rotation of earth. If ω is the angular velocity of rotation of earth for which a body at the equator will become weightless

$$g' = g - \omega^2 R\cos^2\lambda$$

$$\Rightarrow 0 = g - \omega^2 R\cos^2 0^o \quad [\text{As } \lambda = 0^o \text{ for equator}]$$

$$\Rightarrow g - \omega^2 R = 0$$

$$\therefore \omega = \sqrt{\frac{g}{R}}$$

or time period of rotation of earth $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{R}{g}}$

Substituting the value of $R = 6400 \times 10^3 m$ and $g = 10 m/s^2$ we get

$$\omega = \frac{1}{800} = 1.25 \times 10^{-3}\frac{rad}{sec} \text{ and } T = 5026.5\ sec = 1.40\ hr.$$

Note : ❑ This time is about $\frac{1}{17}$ times the present time period of earth. Therefore if earth starts rotating 17 times faster then all objects on equator will become weightless.

❑ If earth stops rotation about its own axis then at the equator the value of g increases by $\omega^2 R$ and consequently the weight of body lying there increases by $m\omega^2 R$.

❑ After considering the effect of rotation and elliptical shape of the earth, acceleration due to gravity at the poles and equator are related as

$$g_p = g_e + 0.034 + 0.018 m/s^2 \quad \therefore g_p = g_e + 0.052 m/s^2$$

Mass and Density of Earth

Newton's law of gravitation can be used to estimate the mass and density of the earth.

As we know $g = \frac{GM}{R^2}$, so we have $M = \frac{gR^2}{G}$

$$\therefore M = \frac{9.8 \times (6.4 \times 10^6)^2}{6.67 \times 10^{-11}} = 5.98 \times 10^{24} kg \approx 10^{25} kg$$

and as we know $g = \frac{4}{3}\pi\rho GR$, so we have $\rho = \frac{3g}{4\pi GR}$

$$\therefore \rho = \frac{3 \times 9.8}{4 \times 3.14 \times 6.67 \times 10^{-11} \times 6.4 \times 10^6} = 5478.4\ kg/m^3$$

Inertial and Gravitational Masses

(1) **Inertial mass** : It is the mass of the material of the body, which measures its inertia.

If an external force F acts on a body of mass m_i, then according to Newton's second law of motion

$$F = m_i a \text{ or } m_i = \frac{F}{a}$$

Hence inertial mass of a body may be measured as the ratio of the magnitude of the external force applied on it to the magnitude of acceleration produced in its motion.

(i) It is the measure of ability of the body to oppose the production of acceleration in its motion by an external force.

(ii) Gravity has no effect on inertial mass of the body.

(iii) It is proportional to the quantity of matter contained in the body.

(iv) It is independent of size, shape and state of body.

(v) It does not depend on the temperature of body.

(vi) It is conserved when two bodies combine physically or chemically.

(vii) When a body moves with velocity v, its inertial mass is given by

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$, where m_0 = rest mass of body, c = velocity of light in vacuum,

(2) **Gravitational Mass :** It is the mass of the material of body, which determines the gravitational pull acting upon it.

If M is the mass of the earth and R is the radius, then gravitational pull on a body of mass m_g is given by

$$F = \frac{GMm_g}{R^2} \text{ or } m_g = \frac{F}{GM/R^2} = \frac{F}{I}$$

Here m_g is the gravitational mass of the body, if $I = 1$ then $m_g = F$

Thus the gravitational mass of a body is defined as the gravitational pull experienced by the body in a gravitational field of unit intensity,

(3) **Comparison between inertial and gravitational mass**

(i) Both are measured in the same units.

(ii) Both are scalar.

(iii) Both do not depend on the shape and state of the body

(iv) Inertial mass is measured by applying Newton's second law of motion where as gravitational mass is measured by applying Newton's law of gravitation.

(v) Spring balance measure gravitational mass and inertial balance measure inertial mass.

(4) **Comparison between mass and weight of the body**

Mass *(m)*	Weight *(W)*
It is a quantity of matter contained in a body.	It is the attractive force exerted by earth on any body.
Its value does not change with *g*	Its value changes with *g*.
Its value can never be zero for any material particle.	At infinity and at the centre of earth its value is zero.
Its unit is kilogram and its	Its unit is Newton or *kg-wt* and

dimension is $[M]$.	dimension are $[MLT^{-2}]$
It is determined by a physical balance.	It is determined by a spring balance.
It is a scalar quantity.	It is a vector quantity.

Gravitational Field

The space surrounding a material body in which gravitational force of attraction can be experienced is called its gravitational field.

Gravitational field intensity : The intensity of the gravitational field of a material body at any point in its field is defined as the force experienced by a unit mass (test mass) placed at that point, provided the unit mass (test mass) itself does not produce any change in the field of the body.

So if a test mass m at a point in a gravitational field experiences a force $\vec{F}$ then

$$\vec{I} = \frac{\vec{F}}{m}$$

(i) It is a vector quantity and is always directed towards the centre of gravity of body whose gravitational field is considered.

(ii) Units : *Newton/kg* or *m/s*

(iii) Dimension : $[MLT^{-2}]$

(iv) If the field is produced by a point mass M and the test mass m is at a distance r from it then by Newton's law of gravitation $F = \frac{GMm}{r^2}$, then intensity of gravitational field

$$I = \frac{F}{m} = \frac{GMm/r^2}{m}$$

$$\therefore \quad I = \frac{GM}{r^2}$$

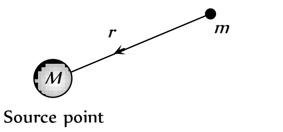


Fig. 8.9

(v) As the distance (r) of test mass from the point mass (M), increases, intensity of gravitational field decreases

$$I = \frac{GM}{r^2};$$

$$\therefore \quad I \propto \frac{1}{r^2}$$

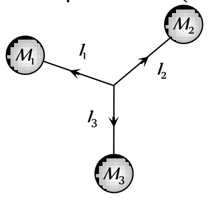


Fig. 8.10

(vi) Intensity of gravitational field $I = 0$, when $r = \infty$.

(vii) Intensity at a given point (P) due to the combined effect of different point masses can be calculated by vector sum of different intensities

$$\overrightarrow{I_{net}} = \vec{I_1} + \vec{I_2} + \vec{I_3} + ...$$

(viii) Point of zero intensity : If two bodies A and B of different masses m_1 and m_2 are d distance apart.

Let P be the point of zero intensity *i.e.*, the intensity at this point is equal and opposite due to two bodies A and B and if any test mass placed at this point it will not experience any force.

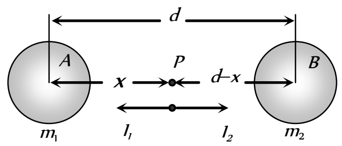


Fig. 8.11

For point P, $\vec{I_1} + \vec{I_2} = 0 \quad \Rightarrow \frac{-Gm_1}{x^2} + \frac{Gm_2}{(d-x)^2} = 0$

By solving $\quad x = \frac{\sqrt{m_1}\, d}{\sqrt{m_1} + \sqrt{m_2}}$ and $(d-x) = \frac{\sqrt{m_2}\, d}{\sqrt{m_1} + \sqrt{m_2}}$

(ix) Gravitational field line is a line, straight or curved such that a unit mass placed in the field of another mass would always move along this line. Field lines for an isolated mass m are radially inwards.

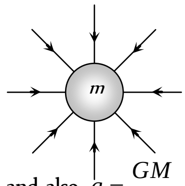


Fig. 8.12

(x) As $I = \frac{GM}{r^2}$ and also $g = \frac{GM}{R^2}$ $\quad \therefore \quad I = g$

Thus the intensity of gravitational field at a point in the field is equal to acceleration of test mass placed at that point.

Gravitational Field Intensity for Different Bodies

(1) **Intensity due to uniform solid sphere**

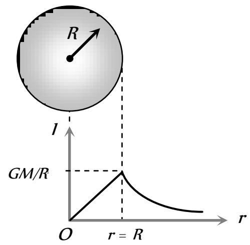


Fig. 8.13

Outside the surface $r > R$	On the surface $r = R$	Inside the surface $r < R$
$I = \frac{GM}{r^2}$	$I = \frac{GM}{R^2}$	$I = \frac{GMr}{R^3}$

(2) **Intensity due to spherical shell**

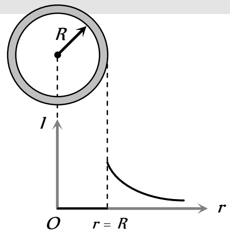


Fig. 8.14

Outside the surface $r > R$	On the surface $r = R$	Inside the surface $r < R$
$I = \frac{GM}{r^2}$	$I = \frac{GM}{R^2}$	$I = 0$

(3) **Intensity due to uniform circular ring**

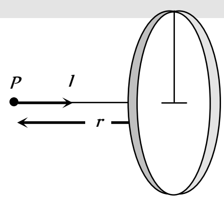


Fig. 8.15

At a point on its axis	At the centre of the ring
$I = \frac{GMr}{(a^2 + r^2)^{3/2}}$	$I = 0$

(4) **Intensity due to uniform disc**

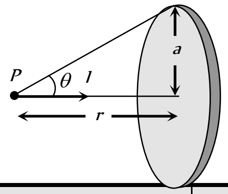


Fig. 8.16

At a point on its axis	At the centre of the disc
$I = \frac{2GMr}{a^2}\left[\frac{1}{r} - \frac{1}{\sqrt{r^2 + a^2}}\right]$ or $I = \frac{2GM}{a^2}(1 - \cos\theta)$	$I = 0$

Gravitational Potential

At a point in a gravitational field potential V is defined as negative of work done per unit mass in shifting a test mass from some reference point (usually at infinity) to the given point *i.e.,*

$$V = -\frac{W}{m} = -\int \frac{\vec{F}.d\vec{r}}{m} = -\int \vec{I}.d\vec{r} \qquad \left[\text{As } \frac{F}{m} = I\right]$$

$$\therefore \; I = -\frac{dV}{dr}$$

i.e., negative gradient of potential gives intensity of field or potential is a scalar function of position whose space derivative gives intensity. Negative sign indicates that the direction of intensity is in the direction where the potential decreases.

(i) It is a scalar quantity because it is defined as work done per unit mass.

(ii) Unit : *Joule/kg* or m/sec

(iii) Dimension : $[MLT]$

(iv) If the field is produced by a point mass then

$$V = -\int I\, dr = -\int \left(-\frac{GM}{r^2}\right) dr \qquad \left[\text{As } I = -\frac{GM}{r^2}\right]$$

$$\therefore \; V = -\frac{GM}{r} + c \qquad [\text{Here } c = \text{constant of integration}]$$

Assuming reference point at ∞ and potential to be zero there we get

$$0 = -\frac{GM}{\infty} + c \Rightarrow c = 0$$

$\therefore$ Gravitational potential $V = -\frac{GM}{r}$

(v) Gravitational potential difference : It is defined as the work done to move a unit mass from one point to the other in the gravitational field. The gravitational potential difference in bringing unit test mass m from point A to point B under the gravitational influence of source mass M is

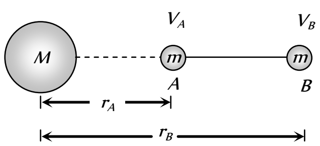


Fig. 8.17

$$\Delta V = V_B - V_A = \frac{W_{A \to B}}{m} = -GM\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

(vi) Potential due to large numbers of particle is given by scalar addition of all the potentials.

$$V = V_1 + V_2 + V_3 + \ldots\ldots\ldots$$

$$= -\frac{GM}{r_1} - \frac{GM}{r_2} - \frac{GM}{r_3} \ldots\ldots\ldots$$

$$= -G\sum_{i=1}^{i=n} \frac{M_i}{r_i}$$

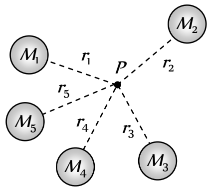


Fig. 8.18

Gravitational Potential for Different Bodies

(1) **Potential due to uniform ring**

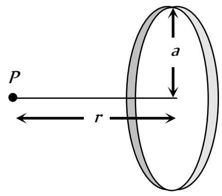


Fig. 8.19

At a point on its axis	At the centre
$V = -\frac{GM}{\sqrt{a^2 + r^2}}$	$V = -\frac{GM}{a}$

(2) **Potential due to spherical shell**

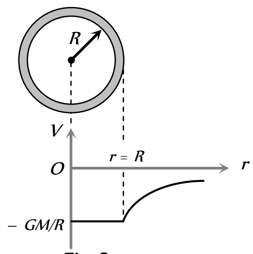


Fig. 8.20

Outside the surface $r > R$	On the surface $r = R$	Inside the surface $r < R$
$V = \frac{-GM}{r}$	$V = \frac{-GM}{R}$	$V = \frac{-GM}{R}$

(3) **Potential due to uniform solid sphere**

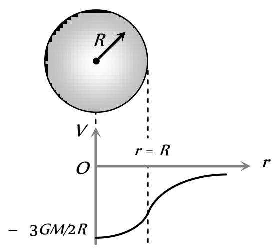


Fig. 8.21

Outside the surface $r > R$	On the surface $r = R$	Inside the surface $r < R$
$V = \frac{-GM}{r}$	$V_{surface} = \frac{-GM}{R}$	$V = \frac{-GM}{2R}\left[3 - \left(\frac{r}{R}\right)^2\right]$ at the centre $(r = 0)$ $V_{centre} = \frac{-3}{2}\frac{GM}{R}$ $(max.)$ $V_{centre} = \frac{3}{2}V_{surface}$

Gravitational Potential Energy

The gravitational potential energy of a body at a point is defined as the amount of work done in bringing the body from infinity to that point against the gravitational force.

$$W = \int_{\infty}^{r} \frac{GMm}{x^2} dx = -GMm\left[\frac{1}{x}\right]_{\infty}^{r}$$

$$W = -\frac{GMm}{r}$$

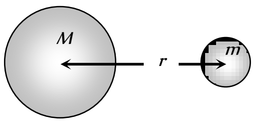


Fig. 8.22

This work done is stored inside the body as its gravitational potential energy

$$\therefore U = -\frac{GMm}{r}$$

(i) Potential energy is a scalar quantity.

(ii) *Unit* : Joule

(iii) *Dimension* : $[ML^2T^{-2}]$

(iv) Gravitational potential energy is always negative in the gravitational field because the force is always attractive in nature.

(v) As the distance r increases, the gravitational potential energy becomes less negative i.e., it increases.

(vi) If $r = \infty$ then it becomes zero (maximum)

(vii) In case of discrete distribution of masses

Gravitational potential energy

$$U = \sum u_i = -\left[\frac{Gm_1m_2}{r_{12}} + \frac{Gm_2m_3}{r_{23}} + ...\right]$$

(viii) If the body of mass m is moved from a point at a distance r_1 to a point at distance $r_2 (r_1 > r_2)$ then change in potential energy

$$\Delta U = \int_{r_1}^{r_2} \frac{GMm}{x^2} dx = -GMm\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$$

or $\Delta U = GMm\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

As r_1 is greater than r_2, the change in potential energy of the body will be negative. It means that if a body is brought closer to earth it's potential energy decreases.

(ix) Relation between gravitational potential energy and potential

$$U = -\frac{GMm}{r} = m\left[\frac{-GM}{r}\right]$$

$$\therefore U = mV$$

(x) Gravitational potential energy at the centre of earth relative to infinity.

$$U_{centre} = m V_{centre} = m\left(-\frac{3}{2}\frac{GM}{R}\right) = -\frac{3}{2}\frac{GMm}{R}$$

(xi) Gravitational potential energy of a body at height h from the earth surface is given by

$$U_h = -\frac{GMm}{R+h} = -\frac{gR^2m}{R+h} \equiv -\frac{mgR}{1+\frac{h}{R}}$$

Work Done Against Gravity

If the body of mass m is moved from the surface of earth to a point at distance h above the surface of earth, then change in potential energy or work done against gravity will be

$$W = \Delta U = GMm\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$\Rightarrow W = GMm\left[\frac{1}{R} - \frac{1}{R+h}\right] \quad [\text{As } r_1 = R \text{ and } r_2 = R + h]$$

$$\Rightarrow W = \frac{GMmh}{R^2\left(1+\frac{h}{R}\right)} = \frac{mgh}{1+\frac{h}{R}} \quad \left[\text{As } \frac{GM}{R^2} = g\right]$$

(i) When the distance h is not negligible and is comparable to radius of the earth, then we will use above formula.

(ii) If $h = nR$ then $W = mgR\left(\frac{n}{n+1}\right)$

(iii) If $h = R$ then $W = \frac{1}{2}mgR$

(iv) If h is very small as compared to radius of the earth then term h/R can be neglected

From $W = \frac{mgh}{1 + h/R} = mgh$ $\quad \left[\text{As } \frac{h}{R} \to 0\right]$

Escape Velocity

The minimum velocity with which a body must be projected up so as to enable it to just overcome the gravitational pull, is known as escape velocity.

The work done to displace a body from the surface of earth $(r = R)$ to infinity $(r = \infty)$ is

$$W = \int_{R}^{\infty} \frac{GMm}{x^2} dx = -GMm\left[\frac{1}{\infty} - \frac{1}{R}\right]$$

$$\Rightarrow W = \frac{GMm}{R}$$

This work required to project the body so as to escape the gravitational pull is performed on the body by providing an equal amount of kinetic energy to it at the surface of the earth.

If v_e is the required escape velocity, then kinetic energy which should be given to the body is $\frac{1}{2}mv_e^2$

$$\therefore \frac{1}{2}mv_e^2 = \frac{GMm}{R} \Rightarrow v_e = \sqrt{\frac{2GM}{R}}$$

$$\Rightarrow v_e = \sqrt{2gR} \qquad [\text{As } GM = gR^2]\text{s}$$

$$\text{or } v_e = \sqrt{2 \times \frac{4}{3}\pi\rho GR \times R} \Rightarrow v_e = R\sqrt{\frac{8}{3}\pi G\rho}$$

$$[\text{As } g = \frac{4}{3}\pi\rho GR]$$

(i) Escape velocity is independent of the mass and direction of projection of the body.

(ii) Escape velocity depends on the reference body. Greater the value of (M/R) or (gR) for a planet, greater will be escape velocity.

(iii) For the earth as $g = 9.8 m/s^2$ and $R = 6400 km$

$$\therefore v_e = \sqrt{2 \times 9.8 \times 6.4 \times 10^6} = 11.2 km/\text{sec}$$

(iv) A planet will have atmosphere if the velocity of molecule in its atmosphere $\left[v_{rms} = \sqrt{\frac{3RT}{M}}\right]$ is lesser than escape velocity. This is why earth has atmosphere (as at earth $v_{rms} < v_e$) while moon has no atmosphere (as at moon $v_{rms} > v_e$)

(v) If a body projected with velocity lesser than escape velocity ($v < v_e$), it will reach a certain maximum height and then may either move in an orbit around the planet or may fall down back to the planet.

(vi) Maximum height attained by body : Let a projection velocity of body (mass m) is v, so that it attains a maximum height h. At maximum height, the velocity of particle is zero, so kinetic energy is zero.

By the law of conservation of energy

Total energy at surface = Total energy at height h.

$$\Rightarrow -\frac{GMm}{R} + \frac{1}{2}mv^2 = -\frac{GMm}{R+h} + 0$$

$$\Rightarrow \frac{v^2}{2} = GM\left[\frac{1}{R} - \frac{1}{R+h}\right] = \frac{GMh}{R(R+h)}$$

$$\Rightarrow \frac{2GM}{v^2R} = \frac{R+h}{h} = 1 + \frac{R}{h}$$

$$\Rightarrow h = \frac{R}{\left(\frac{2GM}{v^2R} - 1\right)} = \frac{R}{\frac{v_e^2}{v^2} - 1} = R\left[\frac{v^2}{v_e^2 - v^2}\right]$$

$$[\text{As } v_e = \sqrt{\frac{2GM}{R}} \therefore \frac{2GM}{R} = v_e^2]$$

(vii) If a body is projected with velocity greater than escape velocity $(v > v_e)$ then by conservation of energy.

Total energy at surface = Total energy at infinite

$$\frac{1}{2}mv^2 - \frac{GMm}{R} = \frac{1}{2}m(v')^2 + 0$$

$$i.e., (v')^2 = v^2 - \frac{2GM}{R} \Rightarrow v'^2 = v^2 - v_e^2 \qquad [\text{As } \frac{2GM}{R} = v_e^2]$$

$$\therefore v' = \sqrt{v^2 - v_e^2}$$

i.e, the body will move in interplanetary or inter stellar space with velocity $\sqrt{v^2 - v_e^2}$.

(viii) Energy to be given to a stationary object on the surface of earth so that its total energy becomes zero, is called escape energy.

Total energy at the surface of the earth $= KE + PE = 0 - \frac{GMm}{R}$

$$\therefore \text{Escape energy} = \frac{GMm}{R}$$

(ix) If the escape velocity of a body is equal to the velocity of light then from such bodies nothing can escape, not even light. Such bodies are called black holes.

The radius of a black hole is given as

$$R = \frac{2GM}{C^2}$$

[As $C = \sqrt{\frac{2GM}{R}}$, where C is the velocity of light]

Kepler's Laws of Planetary Motion

Planets are large natural bodies rotating around a star in definite orbits. The planetary system of the star sun called solar system consists of nine planets, viz., Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Out of these planets Mercury is the smallest and closest to the sun and so hottest. Jupiter is largest and has maximum moons (12). Venus is closest to Earth and brightest. Kepler after a life time study, work out three empirical laws which govern the motion of these planets and are known as *Kepler's laws of planetary motion*. These are,

(1) **The law of Orbits** : Every planet moves around the sun in an elliptical orbit with sun at one of the foci.

(2) **The law of Area** : The line joining the sun to the planet sweeps out equal areas in equal interval of time. *i.e.* areal velocity is constant. According to this law planet will move slowly when it is farthest from sun and more rapidly when it is nearest to sun. It is similar to law of conservation of angular momentum.

$$\text{Areal velocity} = \frac{dA}{dt} = \frac{1}{2}\frac{r(vdt)}{dt} = \frac{1}{2}rv$$

$$\therefore \frac{dA}{dt} = \frac{L}{2m}$$

$$[\text{As } L = mvr \text{ ; } rv = \frac{L}{m}]$$

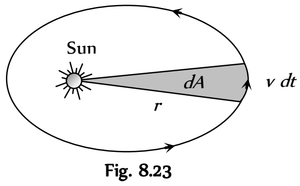


Fig. 8.23

(3) **The law of periods** : The square of period of revolution (T) of any planet around sun is directly proportional to the cube of the semi-major axis of the orbit.

$$T^2 \propto a^3 \text{ or } T^2 \propto \left(\frac{r_1 + r_2}{2}\right)^3$$

Proof : From the figure $AB = AF + FB$

$2a = r_1 + r_2 \quad \therefore a = \frac{r_1 + r_2}{2}$

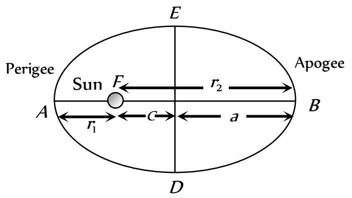


Fig. 8.24

where a = semi-major axis

$r_1 =$ Shortest distance of planet from sun (perigee).

$r_2 =$ Largest distance of planet from sun (apogee).

Important data

Planet	Semi-major axis a (10^{10} meter)	Period T(year)	T^2/a^3 (10^{-34} year²/meter³)
Mercury	5.79	0.241	2.99
Venus	10.8	0.615	3.00
Earth	15.0	1.00	2.96
Mars	22.8	1.88	2.98
Jupiter	77.8	11.9	3.01
Saturn	143	29.5	2.98
Uranus	287	84.0	2.98
Neptune	450	165	2.99
Pluto	590	248	2.99

Note : ❑ Kepler's laws are valid for satellites also.

Solar System

Fig. 8.25

Velocity of a Planet in Terms of Eccentricity

Applying the law of conservation of angular momentum at perigee and apogee

$$mv_p r_p = mv_a r_a$$

$$\Rightarrow \frac{v_p}{v_a} = \frac{r_a}{r_p} = \frac{a+c}{a-c} = \frac{1+e}{1-e}$$

[As $r_p = a - c, \quad r_a = a + c$ and eccentricity $e = \frac{c}{a}$]

Applying the conservation of mechanical energy at perigee and apogee

$$\frac{1}{2} m v_p^2 - \frac{GMm}{r_p} = \frac{1}{2} m v_a^2 - \frac{GMm}{r_a}$$

$$\Rightarrow v_p^2 - v_a^2 = 2GM \left[\frac{1}{r_p} - \frac{1}{r_a}\right]$$

$$\Rightarrow v_a^2 \left[\frac{r_a^2 - r_p^2}{r_p^2}\right] = 2GM \left[\frac{r_a - r_p}{r_a r_p}\right] \qquad \left[\text{As } v_p = \frac{v_a r_a}{r_p}\right]$$

$$\Rightarrow v_a^2 = \frac{2GM}{r_a + r_p}\left[\frac{r_p}{r_a}\right] \Rightarrow v_a^2 = \frac{2GM}{a}\left(\frac{a-c}{a+c}\right) = \frac{GM}{a}\left(\frac{1-e}{1+e}\right)$$

Thus the speeds of planet at apogee and perigee are

$$v_a = \sqrt{\frac{GM}{a}\left(\frac{1-e}{1+e}\right)},$$

$$v_p = \sqrt{\frac{GM}{a}\left(\frac{1+e}{1-e}\right)}$$

Note:: ❑ The gravitational force is a central force so torque on planet relative to sun is always zero, hence angular momentum of a planet or satellite is always constant irrespective of shape of orbit.

Som

	[illegible]	[illegible]	…th	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mea	[illegible]	[illegible]	…0	228	778	1430	2870	4500	5900
Period of revolution, *year*	0.241	0.615	1.00	1.88	11.9	29.5	84.0	165	248
Orbital speed, *km/s*	47.9	35.0	29.8	24.1	13.1	9.64	6.81	5.43	4.74
Equatiorial diameter, *km*	4880	12100	12800	6790	143000	120000	51800	49500	2300
Mass (Earth =1)	0.0558	0.815	1.000	0.107	318	95.1	14.5	17.2	0.002
Density (Water =1)	5.60	5.20	5.52	3.95	1.31	0.704	1.21	1.67	2.03
Surface value of *g*, *m/s*	3.78	8.60	9.78	3.72	22.9	9.05	7.77	11.0	0.5
Escape velocity, *km/s*	4.3	10.3	11.2	5.0	59.5	35.6	21.2	23.6	1.1
Known satellites	0	0	1	2	16+ring	18+rings	17+rings	8+rings	1

Orbital Velocity of Satellite

Satellites are natural or artificial bodies describing orbit around a planet under its gravitational attraction. Moon is a natural satellite while INSAT-1B is an artificial satellite of earth. Condition for establishment of artificial satellite is that the centre of orbit of satellite must coincide with centre of earth or satellite must move around great circle of earth.

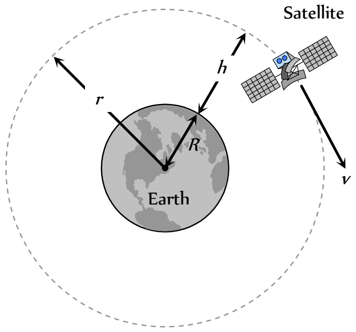


Fig. 8.26

Orbital velocity of a satellite is the velocity required to put the satellite into its orbit around the earth.

For revolution of satellite around the earth, the gravitational pull provides the required centripetal force.

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$

$$\Rightarrow \quad v = \sqrt{\frac{GM}{r}}$$

$$v = \sqrt{\frac{gR^2}{R+h}} = R\sqrt{\frac{g}{R+h}}$$

[As $GM = gR^2$ and $r = R + h$]

(i) Orbital velocity is independent of the mass of the orbiting body and is always along the tangent of the orbit *i.e.,* satellites of diferent masses have same orbital velocity, if they are in the same orbit.

(ii) Orbital velocity depends on the mass of central body and radius of orbit.

(iii) For a given planet, greater the radius of orbit, lesser will be the orbital velocity of the satellite $\left(v \propto 1/\sqrt{r}\right)$.

(iv) Orbital velocity of the satellite when it revolves very close to the surface of the planet

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{GM}{R+h}} \qquad \therefore \ v = \sqrt{\frac{GM}{R}} = \sqrt{gR}$$

[As $h = 0$ and $GM = gR^2$]

For the earth $v = \sqrt{9.8 \times 6.4 \times 10^6} = 7.9\, km/s \approx 8\, km/\sec$

(v) Close to the surface of planet $v = \sqrt{\frac{GM}{R}}$

[As $v_e = \sqrt{\frac{2GM}{R}}$]

$$\therefore \quad v = \frac{v_e}{\sqrt{2}} \ \ i.e., \ v_{escape} = \sqrt{2}\ v_{orbital}$$

It means that if the speed of a satellite orbiting close to the earth is made $\sqrt{2}$ times (or increased by 41%) then it will escape from the gravitational field.

(vi) If the gravitational force of attraction of the sun on the planet varies as $F \propto \frac{1}{r^n}$ then the orbital velocity varies as $v \propto \frac{1}{\sqrt{r^{n-1}}}$.

Time Period of Satellite

It is the time taken by satellite to go once around the earth.

$$\therefore \quad T = \frac{\text{Circumference of the orbit}}{\text{orbital velocity}}$$

$$\Rightarrow T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{r}{GM}} \qquad \left[\text{As } v = \sqrt{\frac{GM}{r}}\right]$$

$$\Rightarrow \ T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{r^3}{gR^2}} \quad [\text{As } GM = gR^2]$$

$$\Rightarrow \ T = 2\pi\sqrt{\frac{(R+h)^3}{g\,R^2}} = 2\pi\sqrt{\frac{R}{g}}\left(1+\frac{h}{R}\right)^{3/2} \quad [\text{As } r = R+h]$$

(i) From $T = 2\pi\sqrt{\frac{r^3}{GM}}$, it is clear that time period is independent of the mass of orbiting body and depends on the mass of central body and radius of the orbit

(ii) $T = 2\pi\sqrt{\frac{r^3}{GM}}$

$$\Rightarrow \ T^2 = \frac{4\pi^2}{GM}r^3 \ \ i.e., \ T^2 \propto r^3$$

This is in accordance with Kepler's third law of planetary motion r becomes *a* (semi major axis) if the orbit is elliptic.

(iii) Time period of nearby satellite,

From $T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{R^3}{gR^2}} = 2\pi\sqrt{\frac{R}{g}}$

[As $h = 0$ and $GM = gR^2$]

For earth $R = 6400 km$ and $g = 9.8 m/s^2$

$T = 84.6\,\text{minute} \approx 1.4\ hr$

(iv) Time period of nearby satellite in terms of density of planet can be given as

$$T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{R^3}{GM}} = \frac{2\pi\left(R^3\right)^{1/2}}{\left[G.\frac{4}{3}\pi R^3\rho\right]^{1/2}} = \sqrt{\frac{3\pi}{G\rho}}$$

(v) If the gravitational force of attraction of the sun on the planet varies as $F \propto \frac{1}{r^n}$ then the time period varies as $T \propto r^{\frac{n+1}{2}}$

(vi) If there is a satellite in the equatorial plane rotating in the direction of earth's rotation from west to east, then for an observer, on the earth, angular velocity of satellite will be $(\omega_S - \omega_E)$. The time interval between the two consecutive appearances overhead will be

$$T = \frac{2\pi}{\omega_s - \omega_E} = \frac{T_S T_E}{T_E - T_S} \qquad \left[\text{As } T = \frac{2\pi}{\omega}\right]$$

If $\omega_S = \omega_E$, $T = \infty$ *i.e.* satellite will appear stationary relative to earth. Such satellites are called geostationary satellites.

Height of Satellite

As we know, time period of satellite $T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$

By squaring and rearranging both sides $\frac{gR^2T^2}{4\pi^2} = (R+h)^3$

$$\Rightarrow h = \left(\frac{T^2 g R^2}{4\pi^2}\right)^{1/3} - R$$

By knowing the value of time period we can calculate the height of satellite from the surface of the earth.

Geostationary Satellite

The satellite which appears stationary relative to earth is called geostationary or geosynchronous satellite, communication satellite.

A geostationary satellite always stays over the same place above the earth such a satellite is never at rest. Such a satellite appears stationary due to its zero relative velocity *w.r.t.* that place on earth.

The orbit of a geostationary satellite is known as the parking orbit.

(i) It should revolve in an orbit concentric and coplanar with the equatorial plane.

(ii) Its sense of rotation should be same as that of earth about its own axis *i.e.,* in anti-clockwise direction (from west to east).

(iii) Its period of revolution around the earth should be same as that of earth about its own axis.

$$\therefore\ T = 24\ hr = 86400\ \text{sec}$$

(iv) Height of geostationary satellite

$$\text{As } T = 2\pi\sqrt{\frac{r^3}{GM}} \Rightarrow 2\pi\sqrt{\frac{(R+h)^3}{GM}} = 24hr$$

Substituting the value of G and M we get $R + h = r = 42000\ km = 7R$

$\therefore$ height of geostationary satellite from the surface of earh $h = 6R = 36000\ km$

(v) Orbital velocity of geo stationary satellite can be calculated by $v = \sqrt{\frac{GM}{r}}$

Substituting the value of G and M we get $v = 3.08\ km/\text{sec}$

Angular Momentum of Satellite

Angular momentum of satellite $L = mvr$

$$\Rightarrow L = m\sqrt{\frac{GM}{r}}\, r \quad \left[\text{As } v = \sqrt{\frac{GM}{r}}\ \right]$$

$$\therefore\quad L = \sqrt{m^2GMr}$$

i.e., Angular momentum of satellite depends on both the mass of orbiting and central body as well as the radius of orbit.

(i) In case of satellite motion, force is central so torque = 0 and hence angular momentum of satellite is conserved *i.e.,* L = constant

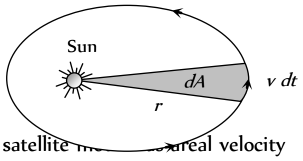


Fig. 8.27

(ii) In case of satellite motion, areal velocity

$$\frac{dA}{dt} = \frac{1}{2}\frac{(r)(vdt)}{dt} = \frac{1}{2}rv$$

$$\Rightarrow \frac{dA}{dt} = \frac{L}{2m} \qquad [\text{As } L = mvr\ ]$$

But as $L =$ constant, $\therefore$ areal velocity (*dA/dt*) = constant which is Kepler's II law

i.e., Kepler's II law or constancy of areal velocity is a consequence of conservation of angular momentum.

Energy of Satellite

When a satellite revolves around a planet in its orbit, it possesses both potential energy (due to its position against gravitational pull of earth) and kinetic energy (due to orbital motion).

(1) Potential energy : $U = mV = \frac{-GMm}{r} = \frac{-L^2}{mr^2}$

$$\left[\text{As } V = \frac{-GM}{r}, L^2 = m^2GMr\right]$$

(2) Kinetic energy : $K = \frac{1}{2}mv^2 = \frac{GMm}{2r} = \frac{L^2}{2mr^2}$

$$\left[\text{As } v = \sqrt{\frac{GM}{r}}\right]$$

(3) Total energy :

$$E = U + K = \frac{-GMm}{r} + \frac{GMm}{2r} = \frac{-GMm}{2r} = \frac{-L^2}{2mr^2}$$

(i) Kinetic energy, potential energy or total energy of a satellite depends on the mass of the satellite and the central body and also on the radius of the orbit.

(ii) From the above expressions we can say that

Kinetic energy (K) = – (Total energy)

Potential energy (U) = 2 (Total energy)

Potential energy (K) = – 2 (Kinetic energy)

(iii) Energy graph for a satellite

(iv) Energy distribution in elliptical orbit

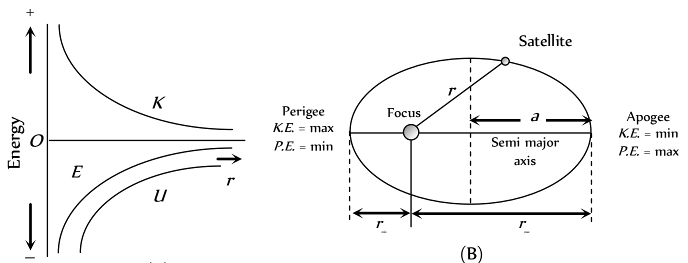


Fig. 8.28

(v) If the orbit of a satellite is elliptic then

(a) Total energy $(E) = \frac{-GMm}{2a}$ = constant ; where a is semi-major axis .

(b) Kinetic energy (K) will be maximum when the satellite is closest to the central body (at perigee) and minimum when it is farthest from the central body (at apogee)

(c) Potential energy (U) will be minimum when kinetic energy = maximum i.e., the satellite is closest to the central body (at perigee) and maximum when kinetic energy = minimum i.e., the satellite is farthest from the central body (at apogee).

(vi) Binding Energy : Total energy of a satellite in its orbit is negative. Negative energy means that the satellite is bound to the central body by an attractive force and energy must be supplied to remove it from the orbit to infinity. The energy required to remove the satellite from its orbit to infinity is called Binding Energy of the system, *i.e.*,

Binding Energy (B.E.) $= -E = \frac{GMm}{2r}$

Change in the Orbit of Satellite

When the satellite is transferred to a higher orbit $(r_2 > r_1)$ then variation in different quantities can be shown by the following table

Quantities	Variation	Relation with r
Orbital velocity	Decreases	$v \propto \frac{1}{\sqrt{r}}$
Time period	Increases	$T \propto r^{3/2}$
Linear momentum	Decreases	$P \propto \frac{1}{\sqrt{r}}$
Angular momentum	Increases	$L \propto \sqrt{r}$
Kinetic energy	Decreases	$K \propto \frac{1}{r}$
Potential energy	Increases	$U \propto -\frac{1}{r}$
Total energy	Increases	$E \propto -\frac{1}{r}$
Binding energy	Decreases	$BE \propto \frac{1}{r}$

Note: ❑ Work done in changing the orbit $W = E_2 - E_1$

$$W = \left(-\frac{GMm}{2r_2}\right) - \left(-\frac{GMm}{2r_1}\right)$$

$$W = \frac{GMm}{2}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

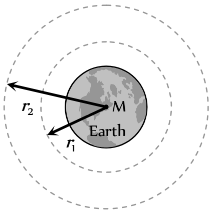


Fig. 8.29

Weightlessness

The weight of a body is the force with which it is attracted towards the centre of earth. When a body is stationary with respect to the earth, its weight equals the gravity. This weight of the body is known as its static or true weight.

We become conscious of our weight, only when our weight (which is gravity) is opposed by some other object. Actually, the secret of measuring the weight of a body with a weighing machine lies in the fact that as we place the body on the machine, the weighing machine opposes the weight of the body. The reaction of the weighing machine to the body gives the measure of the weight of the body.

The state of weightlessness can be observed in the following situations.

(1) **When objects fall freely under gravity** : For example, a lift falling freely, or an airship showing a feat in which it falls freely for a few seconds during its flight, are in state of weightlessness.

(2) **When a satellite revolves in its orbit around the earth** : Weightlessness poses many serious problems to the astronauts. It becomes quite difficult for them to control their movements. Everything in the satellite has to be kept tied down. Creation of artificial gravity is the answer to this problem.

(3) **When bodies are at null points in outer space** : On a body projected up, the pull of the earth goes on decreasing, but at the same time the gravitational pull of the moon on the body goes on increasing. At one particular position, the two gravitational pulls may be equal and opposite and the net pull on the body becomes zero. This is zero gravity region or the null point and the body in question is said to appear weightless.

Weightlessness in a Satellite

A satellite, which does not produce its own gravity moves around the earth in a circular orbit under the action of gravity. The acceleration of satellite is $\frac{GM}{r^2}$ towards the centre of earth.

If a body of mass m placed on a surface inside a satellite moving around the earth. Then force on the body are

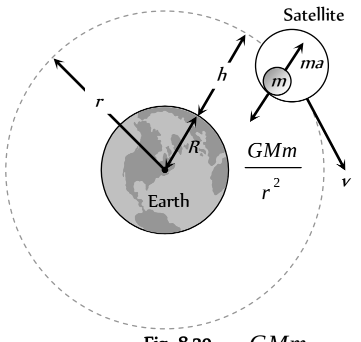


Fig. 8.30

(i) The gravitational pull of earth $= \frac{GMm}{r^2}$

(ii) The reaction by the surface $= R$

By Newton's law $\frac{GmM}{r^2} - R = m\,a$

$$\frac{GmM}{r^2} - R = m\left(\frac{GM}{r^2}\right)$$

$\therefore\ R = 0$

Thus the surface does not exert any force on the body and hence its apparent weight is zero.

A body needs no support to stay at rest in the satellite and hence all position are equally comfortable. Such a state is called weightlessness.

(i) One will find it difficult to control his movement, without weight he will tend to float freely. To get from one spot to the other he will have to push himself away from the walls or some other fixed objects.

(ii) As everything is in free fall, so objects are at rest relative to each other, *i.e.,* if a table is withdrawn from below an object, the object will remain where it was without any support.

(iii) If a glass of water is tilted and glass is pulled out, the liquid in the shape of container will float and will not flow because of surface tension.

(iv) If one tries to strike a match, the head will light but the stick will not burn. This is because in this situation convection currents will not be set up which supply oxygen for combustion

(v) If one tries to perform simple pendulum experiment, the pendulum will not oscillate. It is because there will not be any restoring torque and so $T = 2\pi\sqrt{(L/g')} = \infty$. [As $g' = 0$]

(vi) Condition of weightlessness can be experienced only when the mass of satellite is negligible so that it does not produce its own gravity.

e.g. Moon is a satellite of earth but due to its own weight it applies gravitational force of attraction on the body placed on its surface and hence weight of the body will not be equal to zero at the surface of the moon.

Tips & Tricks

✍ The reference frame attached to the earth is non-inertial, because the earth revolves about its own axis as well as about the sun.

✍ Gravity holds the atmosphere around to the earth.

✍ If the earth were at one fourth the present distance from the sun, the duration of the year will be one eighth of the present year.

✍ If a packet is just released from an artificial satellite, it does not fall to the earth. On the other hand it will continue orbiting along with the satellite.

✍ Astronauts orbiting around the earth cannot use a pendulum clock. however, they can use spring clock

✍ To the astronauts in space, the sky appears black due to the absence of atmosphere above them.

✍ The gravitational force is much smaller than the electrical force because the value of G is very very small.

✍ The dimensional formula of gravitational field is same as that of acceleration due to gravity.

✍ A body in gravitational field has maximum binding energy when it is at rest.

✍ The moon is the natural satellite of the earth, but a man does not feel weightlessness on the surface of the moon. This is because, the mass of the moon is very large and it exerts a gravitational force on the man. On the other hand, the mass of the artificial satellite is very small and it exerts negligible or no gravitational force on the astronaut, so astronaut feels weightlessness in the artificial satellite but not on the moon.

✍ The planets are heavenly bodies revolving around the sun. The sun and the nine planets, revolving around it, constitute the solar system.

✍ All other planets except mercury and pluto revolve around the sun in almost circular orbits.

✍ If the radius of planet decreases by x% keeping the mass constant. The acceleration due to gravity on its surface increases by $2x$%.

✍ If the mass of a planet increases by x% keeping radius constant, the acceleration due to gravity on its surface increases by x%.

✍ If the density of the planet decreases by x%, keeping the radius constant, the acceleration due to gravity decreases by x%.

✍ If the radius of the planet decreases by x%, keeping the density constant, the acceleration due to gravity decreases by x%.

✍ For the planets orbiting around the sun, angular speed, linear speed, kinetic energy etc. change with time but angular momentum remains constant.

✍ The ratio of inertial mass to gravitational mass is 1.

✍ Inertial mass m becomes infinite if the body moves with velocity of light.

✍ Intensity of gravitational field inside a shell is zero.

✍ If two spheres of same material, mass and radius are put in contact, the gravitational attraction between them is directly proportional to the fourth power of their radius.

✍ (a) There is no atmosphere on the moon because escape velocity on the moon is less than the *rms* velocity of the gas molecules.

(b) Two satellites are orbiting in circular orbits of radii r_1 and r_2. Their orbital speeds are in the ratio : $v_1 / v_2 = (r_2 / r_1)^{1/2}$. It is independent to their masses

✍ Planets describe equal area around the sun in equal intervals of time.

✍ If the gravitational attraction of the sun on the planets varies as nth power of distance (of the planet from the sun), then year of the planet will be proportional to $R^{(n+1)/2}$.

✍ An object will experience weightlessness at equator, if the angular speed of the earth about its axis becomes more than (1/800) rad s^{-1}.

✍ Orbital velocity very near the surface of the earth is about 7.92 kms^{-1}.

✍ Greater the height of the satellite, smaller is the orbital velocity.

✍ Orbital velocity independent of the mass of the satellite.

✍ Orbital velocity is depends on the mass of the planet as well as radius of the orbit.

✍ If the altitude of the satellite is n times the radius of the earth, then the orbital velocity will be $(1/\sqrt{1+n})$ times the orbital velocity near the surface of the earth.

✍ If the radius of the orbit of a sattelite is n times the radius of the earth, then its orbital velocity will be $(1/\sqrt{n})$ the orbital velocity near the surface of the earth.

✍ The centripetal acceleration of the satellite is equal to the acceleration due to gravity.

✍ The gravitational potential energy of a satellite of mass m is $U_p = -GMm/r$, where r is the radius of the orbit of satellite.

✍ Kinetic energy of the satellite

$$= \frac{GMm}{2r}$$

✍ Total energy of the satellite

$$E = U + K = \frac{GMm}{2r} - \frac{GMm}{r} = -\frac{GMm}{2r}$$

✍ When velocity of the satellite increases, its kinetic energy increases and hence total energy becomes less negative. That is the satellite begins to revolve in orbit of greater radius.

✍ If the total energy of the satellite becomes $+ve$, the satellite escapes from the gravitational pull of the earth.

✍ When the satellite is taken to greater height the potential energy increases (becomes less negative) and kinetic energy decreases.

✍ For the orbiting satellite, the kinetic energy is less than potential energy. When $KE = PE$, the satellite escapes away from the gravitation pull of the earth.

✍ No energy is dissipated in keeping the satellite in orbit around a planet

✍ Time period of the satellite very near the surface of the earth is about 84.6 minutes or 1.4 *hr*.

✍ Geo-stationary satellite is a satellite which appear stationary to the observers on the earth. It is also called geosynchronous satellite.

✍ The orbit of a geostationery satellite is known as the parking orbit.

✍ To throw an ant or an elephant out of the gravitational field, the required velocity of projection is same !

✍ Escape velocity depends on the mass and size of the planet. That is why escape velocity on the planet Jupiter is more than on the earth and escape velocity on the Moon is less than that on the earth.

✍ If a body is orbiting around the earth, then it will escape away, when its velocity is increased by 41.8%.

✍ If the radius of earth is doubled keeping the density unchanged the escape velocity will be doubled.

✍ Escape velocity $= \sqrt{2} \times$ orbital velocity.

✍ If the body is at a height h above the surface of the earth, then escape velocity is given by

$$v_{es} = \sqrt{2g(R+h)}$$

✍ It is the least velocity required by a body to escape away from the gravitational pull of the earth.

✍ Escape velocity from the surface of the earth $= \sqrt{2gR} = 11.20 kms^{-1}$

✍ Body does not return to the earth when fired with escape velocity, irrespective of the angle of projection

✍ The escape velocity from the moon is 2.4 kms.

✍ When a projectile is fired with velocity less than the escape velocity, the sum of its gravitational potential and kinetic energy is negative.

✍ If ratio of the radii of two planets is r and the ratio of the acceleration due to gravity on the their surface is a, then ratio of escape velocities is $\sqrt{ar}$.

✍ If the radius of the earth is doubled keeping the mass unchanged, the escape velocity will becomes $(1/\sqrt{2})$ times the present value

✍ If a body falls freely from infinite height, then it reaches the surface of the earth with velocity 11.2 *km/s*

✍ When a body falls from a height h to the surface of the earth, its velocity on reaching the surface of the earth is given by

$$= \left[2gR\left(\frac{h}{R+h}\right)\right]^{1/2}$$

When $h << R$, we find : $v = \sqrt{2gh}$

✍ The tail of the comets points away from the sun due to the radiation pressure the sun.

Ordinary Thinking

Objective Questions

Newton's Law of Gravitation

1. The tidal waves in the sea are primarily due to
   (a) The gravitational effect of the moon on the earth
   (b) The gravitational effect of the sun on the earth
   (c) The gravitational effect of venus on the earth
   (d) The atmospheric effect of the earth itself

2. If there were a smaller gravitational effect, which of the following forces do you think would alter in some respect [NCERT 1978]
   (a) Viscous forces (b) Archimedes uplift
   (c) Electrostatic force (d) None of the above

3. A satellite of the earth is revolving in a circular orbit with a uniform speed *v*. If the gravitational force suddenly disappears, the satellite will [AIIMS 1982; AIEEE 2002]
   (a) Continue to move with velocity *v* along the original orbit
   (b) Move with a velocity *v*, tangentially to the original orbit
   (c) Fall down with increasing velocity
   (d) Ultimately come to rest somewhere on the original orbit

4. The atmosphere is held to the earth by [IIT 1986]
   (a) Winds (b) Gravity
   (c) Clouds (d) None of the above

5. The weight of a body at the centre of the earth is [AFMC 1988]
   (a) Zero
   (b) Infinite
   (c) Same as on the surface of earth
   (d) None of the above

6. If the distance between two masses is doubled, the gravitational attraction between them [CPMT 1973; AMU (Med.) 2000]
   (a) Is doubled (b) Becomes four times
   (c) Is reduced to half (d) Is reduced to a quarter

7. Which of the following is the evidence to show that there must be a force acting on earth and directed towards the sun [AIIMS 1980]
   (a) Deviation of the falling bodies towards east
   (b) Revolution of the earth round the sun
   (c) Phenomenon of day and night
   (d) Apparent motion of sun round the earth

8. The gravitational force between two stones of mass 1 *kg* each separated by a distance of 1 *metre* in vacuum is [DPMT 1984]
   (a) Zero (b) 6.675×10^{-5} *newton*
   (c) 6.675×10^{-11} *newton* (d) 6.675×10^{-8} *newton*

9. Two particles of equal mass go round a circle of radius *R* under the action of their mutual gravitational attraction. The speed of each particle is [CBSE PMT 1995; RPMT 2003]
   (a) $v = \frac{1}{2R}\sqrt{\frac{1}{Gm}}$ (b) $v = \sqrt{\frac{Gm}{2R}}$
   (c) $v = \frac{1}{2}\sqrt{\frac{Gm}{R}}$ (d) $v = \sqrt{\frac{4Gm}{R}}$

10. The earth (mass $= 6 \times 10^{24}\ kg$)) revolves round the sun with angular velocity $2 \times 10^{-7}\ rad/s$ in a circular orbit of radius $1.5 \times 10^{8}\ km$. The force exerted by the sun on the earth in *newtons*, is [CBSE PMT 1995; AFMC 1999; Pb. PMT 2003]
    (a) 18×10^{25} (b) Zero
    (c) 27×10^{39} (d) 36×10^{21}

11. Gravitational mass is proportional to gravitational [AIIMS 1998]
    (a) Field (b) Force
    (c) Intensity (d) All of these

12. The gravitational force between two point masses m_1 and m_2 at separation *r* is given by $F = k\frac{m_1 m_2}{r^2}$
    The constant k [CPMT 1993]
    (a) Depends on system of units only
    (b) Depends on medium between masses only
    (c) Depends on both (a) and (b)
    (d) Is independent of both (a) and (b)

13. The distance of the centres of moon and earth is *D*. The mass of earth is 81 times the mass of the moon. At what distance from the centre of the earth, the gravitational force will be zero
    (a) $\frac{D}{2}$ (b) $\frac{2D}{3}$
    (c) $\frac{4D}{3}$ (d) $\frac{9D}{10}$

14. Who among the following gave first the experimental value of *G*
    (a) Cavendish (b) Copernicus
    (c) Brook Teylor (d) None of these

15. The mass of the moon is $7.34 \times 10^{22}\ kg$ and the radius is $1.74 \times 10^{6}\ m$. The value of gravitation force will be [AMU 1999]
    (a) 1.45 *N/kg* (b) 1.55 *N/kg*
    (c) 1.75 *N/kg* (d) 1.62 *N/kg*

16. The centripetal force acting on a satellite orbiting round the earth and the gravitational force of earth acting on the satellite both equal *F*. The net force on the satellite is [AMU 1999]
    (a) Zero (b) *F*
    (c) $F\sqrt{2}$ (d) 2 *F*

17. Reason of weightlessness in a satellite is [RPMT 2000]
    (a) Zero gravity
    (b) Centre of mass
    (c) Zero reaction force by satellite surface

(d) None

18. Mass M is divided into two parts xM and $(1-x)M$. For a given separation, the value of x for which the gravitational attraction between the two pieces becomes maximum is **[EAMCET 2001]**

(a) $\frac{1}{2}$ (b) $\frac{3}{5}$

(c) 1 (d) 2

19. The force of gravitation is **[AIIMS 2002]**

(a) Repulsive (b) Electrostatic

(c) Conservative (d) Non-conservative

20. The gravitational force F_g between two objects does not depend on **[RPET 2003]**

(a) Sum of the masses

(b) Product of the masses

(c) Gravitational constant

(d) Distance between the masses

21. Two sphere of mass m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be **[CBSE PMT 2003]**

(a) F (b) $\frac{F}{3}$

(c) $\frac{F}{9}$ (d) $3F$

22. Earth binds the atmosphere because of **[J&K CET 2005]**

(a) Gravity

(b) Oxygen between earth and atmosphere

(c) Both (a) and (b)

(d) None of these

23. Which of the following statements about the gravitational constant is true **[Kerala PET 2005]**

(a) It is a force

(b) It has no unit

(c) It has same value in all systems of units

(d) It depends on the value of the masses

(e) It does not depend on the nature of the medium in which the bodies are kept.

24. Two identical solid copper spheres of radius R placed in contact with each other. The gravitational attracton between them is proportional to **[Kerala PET 2005]**

(a) R^2 (b) R^{-2}

(c) R^4 (d) R^{-4}

Acceleration Due to Gravity

1. Weightlessness experienced while orbiting the earth in space-ship, is the result of **[NCERT 1978; DPMT 1982]**

(a) Inertia (b) Acceleration

(c) Zero gravity (d) Free fall towards earth

2. If the change in the value of 'g' at a height h above the surface of the earth is the same as at a depth x below it, then (both x and h being much smaller than the radius of the earth) **[NCERT 1983; BHU 2002]**

(a) $x = h$ (b) $x = 2h$

(c) $x = \frac{h}{2}$ (d) $x = h^2$

3. The time period of a simple pendulum on a freely moving artificial satellite is **[CPMT 1984; AFMC 2002]**

(a) Zero (b) 2 sec

(c) 3 sec (d) Infinite

4. Two planets have the same average density but their radii are R_1 and R_2. If acceleration due to gravity on these planets be g_1 and g_2 respectively, then **[AIIMS 1985]**

(a) $\frac{g_1}{g_2} = \frac{R_1}{R_2}$ (b) $\frac{g_1}{g_2} = \frac{R_2}{R_1}$

(c) $\frac{g_1}{g_2} = \frac{R_1^2}{R_2^2}$ (d) $\frac{g_1}{g_2} = \frac{R_1^3}{R_2^3}$

5. An iron ball and a wooden ball of the same radius are released from a height 'h' in vacuum. The time taken by both of them to reach the ground is **[NCERT 1975; AFMC 1998]**

(a) Unequal (b) Exactly equal

(c) Roughly equal (d) Zero

6. The correct answer to above question is based on **[NCERT 1975]**

(a) Acceleration due to gravity in vacuum is same irrespective of size and mass of the body

(b) Acceleration due to gravity in vacuum depends on the mass of the body

(c) There is no acceleration due to gravity in vacuum

(d) In vacuum there is resistance offered to the motion of the body and this resistance depends on the mass of the body

7. When a body is taken from the equator to the poles, its weight

(a) Remains constant

(b) Increases

(c) Decreases

(d) Increases at N-pole and decreases at S-pole

8. A body of mass m is taken to the bottom of a deep mine. Then

(a) Its mass increases (b) Its mass decreases

(c) Its weight increases (d) Its weight decreases

9. A body weighs 700 *gm wt* on the surface of the earth. How much will it weigh on the surface of a planet whose mass is $\frac{1}{7}$ and radius is half that of the earth **[CMC Vellore 1984; AFMC 2000]**

(a) 200 *gm wt* (b) 400 *gm wt*

(c) 50 *gm wt* (d) 300 *gm wt*

10. In order to find time, the astronaut orbiting in an earth satellite should use **[DPMT 1982]**

(a) A pendulum clock

(b) A watch having main spring to keep it going

(c) Either a pendulum clock or a watch

(d) Neither a pendulum clock nor a watch

11. A spherical planet far out in space has a mass M_0 and diameter D_0. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity which is equal to **[MP PMT 1987; DPMT 2002]**

(a) GM_0/D_0^2 (b) $4mGM_0/D_0^2$

(c) $4GM_0 / D_0^2$ (d) GmM_0 / D_0^2

12. If the earth stops rotating, the value of 'g' at the equator will [CPMT 1986]

(a) Increase (b) Remain same

(c) Decrease (d) None of the above

13. The mass and diameter of a planet have twice the value of the corresponding parameters of earth. Acceleration due to gravity on the surface of the planet is [NCERT 1971; Pb. PMT 2000]

(a) $9.8\, m/\sec^2$ (b) $4.9\, m/\sec^2$

(c) $980\, m/\sec^2$ (d) $19.6\, m/\sec^2$

14. As we go from the equator to the poles, the value of g [CPMT 1975; AFMC 1995; AFMC 2004]

(a) Remains the same

(b) Decreases

(c) Increases

(d) Decreases upto a latitude of 45°

15. Force of gravity is least at [CPMT 1992]

(a) The equator

(b) The poles

(c) A point in between equator and any pole

(d) None of these

16. The radius of the earth is 6400 *km* and $g = 10 m/\sec^2$. In order that a body of 5 *kg* weighs zero at the equator, the angular speed of the earth is [MP PMT 1985]

(a) 1/80 *radian/sec* (b) 1/400 *radian/sec*

(c) 1/800 *radian/sec* (d) 1/1600 *radian/sec*

17. The value of 'g' at a particular point is $9.8\, m/s^2$. Suppose the earth suddenly shrinks uniformly to half its present size without losing any mass. The value of 'g' at the same point (assuming that the distance of the point from the centre of earth does not shrink) will now be [NCERT 1984; DPMT 1999]

(a) $4.9\, m/\sec^2$ (b) $3.1\, m/\sec^2$

(c) $9.8\, m/\sec^2$ (d) $19.6\, m/\sec^2$

18. If R is the radius of the earth and g the acceleration due to gravity on the earth's surface, the mean density of the earth is MH CET (Med.) 1999; CBSE PMT 1995]

(a) $4\pi G / 3gR$ (b) $3\pi R / 4gG$

(c) $3g / 4\pi RG$ (d) $\pi RG / 12G$

19. The weight of an object in the coal mine, sea level, at the top of the mountain are W_1, W_2 and W_3 respectively, then [EAMCET 1990]

(a) $W_1 < W_2 > W_3$ (b) $W_1 = W_2 = W_3$

(c) $W_1 < W_2 < W_3$ (d) $W_1 > W_2 > W_3$

20. The radii of two planets are respectively R_1 and R_2 and their densities are respectively ρ_1 and ρ_2. The ratio of the accelerations due to gravity at their surfaces is [MP PET 1994]

(a) $g_1 : g_2 = \frac{\rho_1}{R_1^2} : \frac{\rho_2}{R_2^2}$ (b) $g_1 : g_2 = R_1 R_2 : \rho_1 \rho_2$

(c) $g_1 : g_2 = R_1\rho_2 : R_2\rho_1$ (d) $g_1 : g_2 = R_1\rho_1 : R_2\rho_2$

21. The mass of the earth is 81 times that of the moon and the radius of the earth is 3.5 times that of the moon. The ratio of the acceleration due to gravity at the surface of the moon to that at the surface of the earth is [MP PMT 1994]

(a) 0.15 (b) 0.04

(c) 1 (d) 6

22. Spot the *wrong* statement :

The acceleration due to gravity 'g' decreases if [MP PMT 1994]

(a) We go down from the surface of the earth towards its centre

(b) We go up from the surface of the earth

(c) We go from the equator towards the poles on the surface of the earth

(d) The rotational velocity of the earth is increased

23. Which of the following statements is true [Manipal MEE 1995]

(a) g is less at the earth's surface than at a height above it or a depth below it

(b) g is same at all places on the surface of the earth

(c) g has its maximum value at the equator

(d) g is greater at the poles than at the equator

24. A spring balance is graduated on sea level. If a body is weighed with this balance at consecutively increasing heights from earth's surface, the weight indicated by the balance

(a) Will go on increasing continuously

(b) Will go on decreasing continuously

(c) Will remain same

(d) Will first increase and then decrease

25. The value of g on the earth's surface is $980\, cm/\sec^2$. Its value at a height of 64 *km* from the earth's surface is [MP PMT 1995]

(a) $960.40\, cm/\sec^2$ (b) $984.90\, cm/\sec^2$

(c) $982.45\, cm/\sec^2$ (d) $977.55\, cm/\sec^2$

(Radius of the earth R = 6400 *kilometers*)

26. Choose the correct statement from the following :

[CPMT 1990; BHU 1998; Kerala PMT 2002]

Weightlessness of an astronaut moving in a satellite is a situation of

(a) Zero g (b) No gravity

(c) Zero mass (d) Free fall

27. If the earth rotates faster than its present speed, the weight of an object will [Haryana CEE 1996]

(a) Increase at the equator but remain unchanged at the poles

(b) Decrease at the equator but remain unchanged at the poles

(c) Remain unchanged at the equator but decrease at the poles

(d) Remain unchanged at the equator but increase at the poles

28. If the earth suddenly shrinks (without changing mass) to half of its present radius, the acceleration due to gravity will be [MNR 1998]

(a) $g/2$ (b) $4g$

(c) $g/4$ (d) $2g$

29. The moon's radius is 1/4 that of the earth and its mass is 1/80 times that of the earth. If g represents the acceleration due to gravity on the surface of the earth, that on the surface of the moon is

MP PET 2000, 01; RPET 2000; Pb. PET 2001]

(a) $g/4$ (b) $g/5$
(c) $g/6$ (d) $g/8$

30. R is the radius of the earth and ω is its angular velocity and g_p is the value of g at the poles. The effective value of g at the latitude $\lambda = 60°$ will be equal to [MP PMT 1999]

(a) $g_p - \frac{1}{4}R\omega^2$ (b) $g_p - \frac{3}{4}R\omega^2$
(c) $g_p - R\omega^2$ (d) $g_p + \frac{1}{4}R\omega^2$

31. The depth d at which the value of acceleration due to gravity becomes $\frac{1}{n}$ times the value at the surface, is [R = radius of the earth] [MP PMT 1999; Kerala PMT 2005]

(a) $\frac{R}{n}$ (b) $R\left(\frac{n-1}{n}\right)$
(c) $\frac{R}{n^2}$ (d) $R\left(\frac{n}{n+1}\right)$

32. At what height over the earth's pole, the free fall acceleration decreases by one percent (assume the radius of earth to be 6400 *km*) [KCET 1994]

(a) 32 *km* (b) 80 *km*
(c) 1.253 *km* (d) 64 *km*

33. The diameters of two planets are in the ratio 4 : 1 and their mean densities in the ratio 1 : 2. The acceleration due to gravity on the planets will be in ratio [ISM Dhanbad 1994]

(a) 1 : 2 (b) 2 : 3
(c) 2 : 1 (d) 4 : 1

34. At what altitude in metre will the acceleration due to gravity be 25% of that at the earth's surface (Radius of earth = *R metre*)

(a) $\frac{1}{4}R$ (b) R
(c) $\frac{3}{8}R$ (d) $\frac{R}{2}$

35. If the angular speed of the earth is doubled, the value of acceleration due to gravity (g) at the north pole

[EAMCET (Med.) 1995]

(a) Doubles (b) Becomes half
(c) Remains same (d) Becomes zero

36. At the surface of a certain planet, acceleration due to gravity is one-quarter of that on earth. If a brass ball is transported to this planet, then which one of the following statements is not correct

(a) The mass of the brass ball on this planet is a quarter of its mass as measured on earth
(b) The weight of the brass ball on this planet is a quarter of the weight as measured on earth
(c) The brass ball has the same mass on the other planet as on earth
(d) The brass ball has the same volume on the other planet as on earth

37. Weight of 1 *kg* becomes 1/6 on moon. If radius of moon is $1.768 \times 10^6\ m$, then the mass of moon will be [RPET 1997]

(a) $1.99 \times 10^{30}\ kg$ (b) $7.56 \times 10^{22}\ kg$
(c) $5.98 \times 10^{24}\ kg$ (d) $7.65 \times 10^{22}\ kg$

38. Radius of earth is around 6000 *km*. The weight of body at height of 6000 *km* from earth surface becomes

[RPMT 1997]

(a) Half (b) One-fourth
(c) One third (d) No change

39. Let g be the acceleration due to gravity at earth's surface and K be the rotational kinetic energy of the earth. Suppose the earth's radius decreases by 2% keeping all other quantities same, then

(a) g decreases by 2% and K decreases by 4%
(b) g decreases by 4% and K increases by 2%
(c) g increases by 4% and K increases by 4%
(d) g decreases by 4% and K increases by 4%

40. Where will it be profitable to purchase 1 kilogram sugar

[RPET 1996]

(a) At poles (b) At equator
(c) At 45° latitude (d) At 40° latitude

41. If the radius of the earth shrinks by 1.5% (mass remaining same), then the value of acceleration due to gravity changes by

(a) 1% (b) 2%
(c) 3% (d) 4%

42. If radius of the earth contracts 2% and its mass remains the same, then weight of the body at the earth surface

[CPMT 1997; KCET (Engg./Med.) 2001]

(a) Will decrease (b) Will increase
(c) Will remain the same (d) None of these

43. If mass of a body is M on the earth surface, then the mass of the same body on the moon surface is

[AIIMS 1997; RPMT 1997; JIPMER 2000]

(a) $M/6$ (b) Zero
(c) M (d) None of these

44. Mass of moon is 7.34×10^{22} *kg*. If the acceleration due to gravity on the moon is $1.4\ m/s^2$, the radius of the moon is [ISM Dhanbad 1994]

$(G = 6.667 \times 10^{-11}\ Nm^2/kg^2)$ [AFMC 1998]

(a) $0.56 \times 10^4\ m$ (b) $1.87 \times 10^6\ m$
(c) $1.92 \times 10^6\ m$ (d) $1.01 \times 10^8\ m$

45. What should be the velocity of earth due to rotation about its own axis so that the weight at equator become 3/5 of initial value. Radius of earth on equator is 6400 *km*

[AMU 1999]

(a) $7.4 \times 10^{-4}\ rad/\sec$ (b) $6.7 \times 10^{-4}\ rad/\sec$
(c) $7.8 \times 10^{-4}\ rad/\sec$ (d) $8.7 \times 10^{-4}\ rad/\sec$

[SCRA 1994]

46. Acceleration due to gravity is 'g' on the surface of the earth. The value of acceleration due to gravity at a height of 32 *km* above earth's surface is (Radius of the earth = 6400 *km*)

[KCET (Engg./Med.) 1999]

(a) 0.9 g (b) 0.99 g
(c) 0.8 g (d) 1.01 g

47. At what height from the ground will the value of 'g' be the same as that in 10 *km* deep mine below the surface of earth

[RPET 1999]

(a) 20 *km* (b) 10 *km*
(c) 15 *km* (d) 5 *km*

48. If the Earth losses its gravity, then for a body

[BHU 1999; MHCET 2003]

(a) Weight becomes zero, but not the mass
(b) Mass becomes zero, but not the weight
(c) Both mass and weight become zero
(d) Neither mass nor weight become zero

49. The height of the point vertically above the earth's surface, at which acceleration due to gravity becomes 1% of its value at the surface is (Radius of the earth = *R*) [EAMCET (Engg.) 2000]

(a) 8 *R* (b) 9 *R*
(c) 10 *R* (d) 20 *R*

50. An object weights 72 *N* on earth. Its weight at a height of *R*/2 from earth is [AIIMS 2000]

(a) 32 *N* (b) 56 *N*
(c) 72 *N* (d) Zero

51. The angular velocity of the earth with which it has to rotate so that acceleration due to gravity on 60° latitude becomes zero is (Radius of earth = 6400 *km*. At the poles $g = 10\,ms^{-2}$)

(a) $2.5 \times 10^{-3}\,rad/s$ (b) $5.0 \times 10^{-1}\,rad/s$
(c) $10 \times 10^{1}\,rad/s$ (d) $7.8 \times 10^{-2}\,rad/s$

52. Assuming earth to be a sphere of a uniform density, what is the value of gravitational acceleration in a mine 100 *km* below the earth's surface (Given *R* = 6400 *km*) [AFMC 2000; Pb. PMT 2000]

(a) $9.66\,m/s^2$ (b) $7.64\,m/s^2$
(c) $5.06\,m/s$ (d) $3.10\,m/s^2$

53. If radius of earth is *R* then the height '*h*' at which value of '*g*' becomes one-fourth is [BHU 2000]

(a) $\frac{R}{4}$ (b) $\frac{3R}{4}$
(c) *R* (d) $\frac{R}{8}$

54. *R* and *r* are the radii of the earth and moon respectively. ρ_e and ρ_m are the densities of earth and moon respectively. The ratio of the accelerations due to gravity on the surfaces of earth and moon is

(a) $\frac{R}{r}\frac{\rho_e}{\rho_m}$ (b) $\frac{r}{R}\frac{\rho_e}{\rho_m}$
(c) $\frac{r}{R}\frac{\rho_m}{\rho_e}$ (d) $\frac{R}{r}\frac{\rho_e}{\rho_m}$

55. If the mass of earth is 80 times of that of a planet and diameter is double that of planet and '*g*' on earth is $9.8\,m/s^2$, then the value of '*g*' on that planet is [Pb. PMT 1999; CPMT 2000]

(a) $4.9\,m/s^2$ (b) $0.98\,m/s^2$
(c) $0.49\,m/s^2$ (d) $49\,m/s^2$

56. Assume that the acceleration due to gravity on the surface of the moon is 0.2 times the acceleration due to gravity on the surface of the earth. If R_e is the maximum range of a projectile on the earth's surface, what is the maximum range on the surface of the moon for the same velocity of projection [Kerala (Engg.) 2001]

(a) $0.2\,R_e$ (b) $2\,R_e$
(c) $0.5\,R_e$ (d) $5\,R_e$

57. The angular speed of earth, so that the object on equator may appear weightless, is ($g = 10\,m/s^2$, radius of earth 6400 *km*)

(a) $1.25 \times 10^{-3}\,rad/sec$ (b) $1.56 \times 10^{-3}\,rad/sec$
(c) $1.25 \times 10^{-1}\,rad/sec$ (d) 1.56 *rad/sec*

58. At what distance from the centre of the earth, the value of acceleration due to gravity *g* will be half that on the surface (*R* = radius of earth) [MP PMT 2001]

(a) 2 *R* (b) *R*
(c) 1.414 *R* (d) 0.414 *R*

59. If density of earth increased 4 times and its radius become half of what it is, our weight will [AMU (Engg.) 2001]

(a) Be four times its present value
(b) Be doubled
(c) Remain same
(d) Be halved [EAMCET 2000]

60. A man can jump to a height of 1.5 *m* on a planet *A*. What is the height he may be able to jump on another planet whose density and radius are, respectively, one-quarter and one-third that of planet *A*

(a) 1.5 *m* (b) 15 *m*
(c) 18 *m* (d) 28 *m*

61. Weight of a body is maximum at [AFMC 2001]

(a) Moon (b) Poles of earth
(c) Equator of earth (d) Centre of earth

62. What will be the acceleration due to gravity at height *h* if *h* >> *R*. Where *R* is radius of earth and *g* is acceleration due to gravity on the surface of earth [RPET 2001]

(a) $\frac{g}{\left(1+\frac{h}{R}\right)^2}$ (b) $g\left(1-\frac{2h}{R}\right)$
(c) $\frac{g}{\left(1-\frac{h}{R}\right)^2}$ (d) $g\left(1-\frac{h}{R}\right)$

63. The acceleration due to gravity near the surface of a planet of radius *R* and density *d* is proportional to [EAMCET 2000] [MP PET 2002; AIEEE 2004]

(a) $\frac{d}{R^2}$ (b) dR^2
(c) *dR* (d) $\frac{d}{R}$

64. The acceleration due to gravity is *g* at a point distant *r* from the centre of earth of radius *R*. If $r < R$, then [CPMT 2002]

(a) $g \propto r$ (b) $g \propto r^2$
(c) $g \propto r^{-1}$ (d) $g \propto r^{-2}$

65. A body weight *W* newton at the surface of the earth. Its weight at a height equal to half the radius of the earth will be [UPSEAT 2002]

(a) $\frac{W}{2}$ (b) $\frac{2W}{3}$
(c) $\frac{4W}{9}$ (d) $\frac{8W}{27}$

66. If the density of the earth is doubled keeping its radius constant then acceleration due to gravity will be $(g = 9.8\, m/s^2)$ [Pb. PMT 2002; Orissa 2002]

(a) $19.6\, m/s^2$ (b) $9.8\, m/s^2$

(c) $4.9\, m/s^2$ (d) $2.45\, m/s^2$

67. The acceleration due to gravity at pole and equator can be related as [DPMT 2002]

(a) $g_p < g_e$ (b) $g_p = g_e = g$

(c) $g_p = g_e < g$ (d) $g_p > g_e$

68. If the value of 'g' acceleration due to gravity, at earth surface is $10\, m/s^2$, its value in m/s^2 at the centre of the earth, which is assumed to be a sphere of radius 'R' *metre* and uniform mass density is [AIIMS 2002]

(a) 5 (b) $10/R$

(c) $10/2R$ (d) Zero

69. A research satellite of mass 200 *kg* circles the earth in an orbit of average radius $3R/2$ where R is the radius of the earth. Assuming the gravitational pull on a mass of 1 *kg* on the earth's surface to be 10 *N*, the pull on the satellite will be [Kerala (Engg.) 2002]

(a) 880 *N* (b) 889 *N*

(c) 890 *N* (d) 892 *N*

70. Acceleration due to gravity on moon is 1/6 of the acceleration due to gravity on earth. If the ratio of densities of earth (ρ_e) and moon (ρ_m) is $\left(\frac{\rho_e}{\rho_m}\right) = \frac{5}{3}$ then radius of moon R_m in terms of R_e will be [MP PMT 2003]

(a) $\frac{5}{18} R_e$ (b) $\frac{1}{6} R_e$

(c) $\frac{3}{18} R_e$ (d) $\frac{1}{2\sqrt{3}} R_e$

71. The acceleration of a body due to the attraction of the earth (radius R) at a distance 2 R from the surface of the earth is (g = acceleration due to gravity at the surface of the earth) [MP PET 2003]

(a) $\frac{g}{9}$ (b) $\frac{g}{3}$

(c) $\frac{g}{4}$ (d) g

72. The depth at which the effective value of acceleration due to gravity is $\frac{g}{4}$ is [MP PET 2003]

(a) R (b) $\frac{3R}{4}$

(c) $\frac{R}{2}$ (d) $\frac{R}{4}$

73. Weight of a body of mass m decreases by 1% when it is raised to height h above the earth's surface. If the body is taken to a depth h in a mine, change in its weight is [KCET 2003; MP PMT 2003]

(a) 2% decrease (b) 0.5% decrease

(c) 1% increase (d) 0.5% increase

74. If both the mass and the radius of the earth decrease by 1%, the value of the acceleration due to gravity will [MP PET 2004]

(a) Decrease by 1% (b) Increase by 1%

(c) Increase by 2% (d) Remain unchanged

75. The density of a newly discovered planet is twice that of earth. The acceleration due to gravity at the surface of the planet is equal to that at the surface of the earth. If the radius of the earth is R, the radius of the planet would be [CBSE PMT 2004]

(a) $2R$ (b) $4R$

(c) $\frac{1}{4} R$ (d) $\frac{1}{2} R$

76. Two planets of radii in the ratio 2 : 3 are made from the material of density in the ratio 3 : 2. Then the ratio of acceleration due to gravity g_1 / g_2 at the surface of the two planets will be

(a) 1 (b) 2.25

(c) 4/9 (d) 0.12

77. A person will get more quantity of matter in *kg –wt.* at [J & K CET 2004]

(a) Poles (b) At latitude of 60°

(c) Equator (d) Satellite

78. At what depth below the surface of the earth, acceleration due to gravity g will be half its value 1600 *km* above the surface of the earth [Pb. PMT 2004]

(a) $4.2 \times 10^6\, m$ (b) $3.19 \times 10^6\, m$

(c) $1.59 \times 10^6\, m$ (d) None of these

79. What should be the angular speed of earth, so that body lying on equator may appear weightlessness

$(g = 10\, m/s^2,\ R = 6400\, km)$ [Pb. PET 2000]

(a) $\frac{1}{800} rad/s$ (b) $\frac{1}{400} rad/s$

(c) $\frac{1}{600} rad/s$ (d) $\frac{1}{100} rad/s$

80. A body weight 500 *N* on the surface of the earth. How much would it weigh half way below the surface of the earth [Pb. PET 2001; BHU 2004]

(a) 125 *N* (b) 250 *N*

(c) 500 *N* (d) 1000 *N*

81. If the density of a small planet is the same as that of earth, while the radius of the planet is 0.2 times that of the earth, the gravitational acceleration on the surface of that planet is [UPSEAT 2004; CBSE PMT 2005]

(a) 0.2 g (b) 0.4 g

(c) 2 g (d) 4 g

82. Acceleration due to gravity 'g' for a body of mass 'm' on earth's surface is proportional to (Radius of earth=R, mass of earth=M)

(a) GM/R^2 (b) m^0

(c) mM (d) $1/R^{3/2}$

83. A body has a weight 90 *kg* on the earth's surface, the mass of the moon is 1/9 that of the earth's mass and its radius is 1/2 that of the earth's radius. On the moon the weight of the body is

(a) 45 *kg* (b) 202.5 *kg*
(c) 90 *kg* (d) 40 *kg*

84. If it is assumed that the spinning motion of earth increases, then the weight of a body on equator [RPMT 2003]
(a) Decreases (b) Remains constant
(c) Increases (d) Becomes more at poles

85. The masses of two planets are in the ratio 1 : 2. Their radii are in the ratio 1 : 2. The acceleration due to gravity on the planets are in the ratio [MH CET 2004]
(a) 1 : 2 (b) 2 : 1
(c) 3 : 5 (d) 5 : 3

86. If earth is supposed to be a sphere of radius *R*, if $g_{30°}$ is value of acceleration due to gravity at latitude of 30° and *g* at the equator, the value of $g - g_{30^o}$ is [DCE 2005]
(a) $\frac{1}{4}\omega^2 R$ (b) $\frac{3}{4}\omega^2 R$
(c) $\omega^2 R$ (d) $\frac{1}{2}\omega^2 R$

87. If *M* the mass of the earth and *R* its radius, the ratio of the gravitational acceleration and the gravitational constant is [J&K CET 2005]
(a) $\frac{R^2}{M}$ (b) $\frac{M}{R^2}$
(c) MR^2 (d) $\frac{M}{R}$

Gravitation Potential, Energy and Escape Velocity

1. A body of mass *m* rises to height *h* = *R*/5 from the earth's surface, where *R* is earth's radius. If *g* is acceleration due to gravity at earth's surface, the increase in potential energy is [CPMT 1989; SCRA 1996; DPMT 2001]
(a) *mgh* (b) $\frac{4}{5}mgh$
(c) $\frac{5}{6}mgh$ (d) $\frac{6}{7}mgh$

2. In a gravitational field, at a point where the gravitational potential is zero [CPMT 1990]
(a) The gravitational field is necessarily zero
(b) The gravitational field is not necessarily zero
(c) Nothing can be said definitely about the gravitational field
(d) None of these

3. The gravitational field due to a mass distribution is $E = K/x^3$ in the *x*-direction. (*K* is a constant). Taking the gravitational potential to be zero at infinity, its value at a distance *x* is
(a) *K*/*x* (b) *K*/2x
(c) K/x^2 (d) $K/2x^2$

4. The mass of the earth is $6.00 \times 10^{24}\ kg$ and that of the moon is $7.40 \times 10^{22}\ kg$. The constant of gravitation $G = 6.67 \times 10^{-11}\ N-m^2/kg^2$. The potential energy of the system is $-7.79 \times 10^{28}\ joules$. The mean distance between the earth and moon is [MP PMT 1995]
(a) $3.80 \times 10^8\ metres$ (b) $3.37 \times 10^6\ metres$
(c) $7.60 \times 10^4\ metres$ (d) $1.90 \times 10^2\ metres$

5. The change in potential energy, when a body of mass *m* is raised to a height *nR* from the earth's surface is (*R* = Radius of earth)
(a) $mgR\frac{n}{n-1}$ (b) *nmgR*
(c) $mgR\frac{n^2}{n^2+1}$ (d) $mgR\frac{n}{n+1}$

6. The masses and radii of the earth and moon are M_1, R_1 and M_2, R_2 respectively. Their centres are distance *d* apart. The minimum velocity with which a particle of mass *m* should be projected from a point midway between their centres so that it escapes to infinity is [MP PET 1997]
(a) $2\sqrt{\frac{G}{d}(M_1+M_2)}$ (b) $2\sqrt{\frac{2G}{d}(M_1+M_2)}$
(c) $2\sqrt{\frac{Gm}{d}(M_1+M_2)}$ (d) $2\sqrt{\frac{Gm(M_1+M_2)}{d(R_1+R_2)}}$

7. If mass of earth is *M*, radius is *R* and gravitational constant is *G*, then work done to take 1 *kg* mass from earth surface to infinity will be [RPET 1997]
(a) $\sqrt{\frac{GM}{2R}}$ (b) $\frac{GM}{R}$
(c) $\sqrt{\frac{2GM}{R}}$ (d) $\frac{GM}{2R}$

8. A rocket is launched with velocity 10 *km*/*s*. If radius of earth is *R*, then maximum height attained by it will be [RPET 1997]
(a) 2*R* (b) 3*R*
(c) 4*R* (d) 5*R*

9. There are two bodies of masses 100 *kg* and 10000 *kg* separated by a distance 1 *m*. At what distance from the smaller body, the intensity of gravitational field will be zero [BHU 1997]
(a) $\frac{1}{9}m$ (b) $\frac{1}{10}m$
(c) $\frac{1}{11}m$ (d) $\frac{10}{11}m$

10. What is the intensity of gravitational field of the centre of a spherical shell [RPET 2000] [MP PET 1994]
(a) Gm/r^2 (b) *g*
(c) Zero (d) None of these

11. The gravitational potential energy of a body of mass '*m*' at the earth's surface $-mgR_e$. Its gravitational potential energy at a height R_e from the earth's surface will be (Here R_e is the radius of the earth) [AIIMS 2000; MP PET 2000; Pb. PMT 2004]
(a) $-2mgR_e$ (b) $2mgR_e$

(c) $\frac{1}{2}mgR_e$ (d) $-\frac{1}{2}mgR_e$

12. Escape velocity of a body of 1 kg mass on a planet is 100 *m/sec*. Gravitational Potential energy of the body at the Planet is

(a) – 5000 *J* (b) – 1000 *J*

(c) – 2400 *J* (d) 5000 *J*

13. A body of mass *m* is placed on the earth's surface. It is taken from the earth's surface to a height $h = 3R$. The change in gravitational potential energy of the body is [CBSE PMT 2002]

(a) $\frac{2}{3}mgR$ (b) $\frac{3}{4}mgR$

(c) $\frac{mgR}{2}$ (d) $\frac{mgR}{4}$

14. A body of mass *m kg.* starts falling from a point $2R$ above the Earth's surface. Its kinetic energy when it has fallen to a point '*R*' above the Earth's surface [*R*-Radius of Earth, *M*-Mass of Earth, *G*-Gravitational Constant] [MP PMT 2002]

(a) $\frac{1}{2}\frac{GMm}{R}$ (b) $\frac{1}{6}\frac{GMm}{R}$

(c) $\frac{2}{3}\frac{GMm}{R}$ (d) $\frac{1}{3}\frac{GMm}{R}$

15. A body is projected vertically upwards from the surface of a planet of radius *R* with a velocity equal to half the escape velocity for that planet. The maximum height attained by the body is [KCET (Engg./Med.) 2002]

(a) *R*/3 (b) *R*/2

(c) *R*/4 (d) *R*/5

16. Energy required to move a body of mass *m* from an orbit of radius 2*R* to 3*R* is [AIEEE 2002]

(a) $GMm/12R^2$ (b) $GMm/3R^2$

(c) $GMm/8R$ (d) $GMm/6R$

17. The kinetic energy needed to project a body of mass *m* from the earth surface (radius *R*) to infinity is [AIEEE 2002]

(a) *mgR*/2 (b) 2 *mgR*

(c) *mgR* (d) *mgR*/4

18. Radius of orbit of satellite of earth is *R*. Its kinetic energy is proportional to [BHU 2003; CPMT 2004]

(a) $\frac{1}{R}$ (b) $\frac{1}{\sqrt{R}}$

(c) R (d) $\frac{1}{R^{3/2}}$

19. In some region, the gravitational field is zero. The gravitational potential in this region [BVP 2003]

(a) Must be variable (b) Must be constant

(c) Cannot be zero (d) Must be zero

20. A particle falls towards earth from infinity. It's velocity on reaching the earth would be [Orissa JEE 2003]

(a) Infinity (b) $\sqrt{2gR}$

(c) $2\sqrt{gR}$ (d) Zero

21. Gas escapes from the surface of a planet because it acquires an escape velocity. The escape velocity will depend on which of the following factors : [MP PMT 2002]

I. Mass of the planet

II. Mass of the particle escaping

III. Temperature of the planet

IV. Radius of the planet

Select the correct answer from the codes given below : [SCRA 1994]

(a) I and II (b) II and IV

(c) I and IV (d) I, III and IV

22. v_e and v_p denotes the escape velocity from the earth and another planet having twice the radius and the same mean density as the earth. Then [NCERT 1974; MP PMT 1994]

(a) $v_e = v_p$ (b) $v_e = v_p / 2$

(c) $v_e = 2v_p$ (d) $v_e = v_p / 4$

23. The escape velocity of a sphere of mass *m* from earth having mass *M* and radius *R* is given by [NCERT 1981, 84; CBSE PMT 1999]

(a) $\sqrt{\frac{2GM}{R}}$ (b) $2\sqrt{\frac{GM}{R}}$

(c) $\sqrt{\frac{2GMm}{R}}$ (d) $\sqrt{\frac{GM}{R}}$

24. The escape velocity for a rocket from earth is 11.2 *km/sec*. Its value on a planet where acceleration due to gravity is double that on the earth and diameter of the planet is twice that of earth will be in *km/sec* [NCERT 1983; CPMT 1990; MP PMT 2000; UPSEAT 1999]

(a) 11.2 (b) 5.6

(c) 22.4 (d) 53.6

25. The escape velocity from the earth is about 11 *km/second*. The escape velocity from a planet having twice the radius and the same mean density as the earth, is [NCERT 1980; MP PMT 1987; MP PET 2001, 2003; AIIMS 2001; UPSEAT 1999]

(a) 22 *km/sec* (b) 11 *km/sec*

(c) 5.5 *km/sec* (d) 15.5 *km/sec*

26. A missile is launched with a velocity less than the escape velocity. The sum of its kinetic and potential energy is [MNR 1986; MP PET 1995]

(a) Positive

(b) Negative

(c) Zero

(d) May be positive or negative depending upon its initial velocity

27. If *g* is the acceleration due to gravity at the earth's surface and *r* is the radius of the earth, the escape velocity for the body to escape out of earth's gravitational field is [NCERT 1975; RPET 2003]

(a) *gr* (b) $\sqrt{2gr}$

(c) g / r (d) r / g

28. The escape velocity of a projectile from the earth is approximately[DPMT 1982, 8

(a) 11.2 *m/sec* (b) 112 *km/sec*

(c) 11.2 *km/sec* (d) 11200 *km/sec*

29. The escape velocity of a particle of mass m varies as [CPMT 1978; RPMT 1999; AIEEE 2002]

(a) m^2 (b) m

(c) m^0 (d) m^{-1}

30. For the moon to cease to remain the earth's satellite, its orbital velocity has to increase by a factor of [MP PET 1994]

(a) 2 (b) $\sqrt{2}$

(c) $1/\sqrt{2}$ (d) $\sqrt{3}$

31. The escape velocity of an object from the earth depends upon the mass of the earth (M), its mean density (ρ), its radius (R) and the gravitational constant (G). Thus the formula for escape velocity is

(a) $v = R\sqrt{\frac{8\pi}{3}G\rho}$ (b) $v = M\sqrt{\frac{8\pi}{3}GR}$

(c) $v = \sqrt{2GMR}$ (d) $v = \sqrt{\frac{2GM}{R^2}}$

32. Escape velocity on a planet is v_e. If radius of the planet remains same and mass becomes 4 times, the escape velocity becomes [MP PMT 1996; DPMT 1999]

(a) $4v_e$ (b) $2v_e$

(c) v_e (d) $\frac{1}{2}v_e$

33. The mass of the earth is 81 times that of the moon and the radius of the earth is 3.5 times that of the moon. The ratio of the escape velocity on the surface of earth to that on the surface of moon will be [MP PMT/PET 1998; JIPMER 2000]

(a) 0.2 (b) 2.57

(c) 4.81 (d) 0.39

34. The escape velocity from the surface of earth is V_e. The escape velocity from the surface of a planet whose mass and radius are 3 times those of the earth will be [MP PMT/PET 1998; JIPMER 2001, 02; Pb. PMT 2004]

(a) V_e (b) $3V_e$

(c) $9V_e$ (d) $27V_e$

35. How much energy will be necessary for making a body of 500 kg escape from the earth

$[g = 9.8\ m/s^2$, radius of earth $= 6.4\times10^6\ m]$ [MP PET 1999]

(a) About $9.8\times10^6\ J$ (b) About $6.4\times10^8\ J$

(c) About $3.1\times10^{10}\ J$ (d) About $27.4\times10^{12}\ J$

36. The escape velocity for the earth is 11.2 *km/sec*. The mass of another planet is 100 times that of the earth and its radius is 4 times that of the earth. The escape velocity for this planet will be [MP PMT 1999; Pb. PMT 2002]

(a) 112.0 *km/s* (b) 5.6 *km/s*

(c) 280.0 *km/s* (d) 56.0 *km/s*

37. The escape velocity of a planet having mass 6 times and radius 2 times as that of earth is [CPMT 1999; MP PET 2003; Pb. PET 2002]

(a) $\sqrt{3}\ V_e$ (b) $3\ V_e$

(c) $\sqrt{2}\ V_e$ (d) $2\ V_e$

38. The escape velocity of an object on a planet whose g value is 9 times on earth and whose radius is 4 times that of earth in *km/s* is

(a) 67.2 (b) 33.6

(c) 16.8 (d) 25.2

39. The escape velocity on earth is 11.2 *km/s*. On another planet having twice radius and 8 times mass of the earth, the escape velocity will be [Bihar CMEET 1995]

(a) 3.7 *km/s* (b) 11.2 *km/s*

(c) 22.4 *km/s* (d) 43.2 *km/s*

40. The escape velocity of a body on the surface of the earth is 11.2 *km/s*. If the earth's mass increases to twice its present value and the radius of the earth becomes half, the escape velocity would become

(a) 5.6 *km/s*

(b) 11.2 *km/s* (remain unchanged) [MP PMT 1995]

(c) 22.4 *km/s*

(d) 44.8 *km/s*

41. Given mass of the moon is 1/81 of the mass of the earth and corresponding radius is 1/4 of the earth. If escape velocity on the earth surface is 11.2 *km/s*, the value of same on the surface of the moon is [CPMT 1997; AIIMS 2000; Pb. PMT 2001]

(a) 0.14 *km/s* (b) 0.5 *km/s*

(c) 2.5 *km/s* (d) 5 *km/s*

42. The angular velocity of rotation of star (of mass M and radius R) at which the matter start to escape from its equator will be

(a) $\sqrt{\frac{2GM^2}{R}}$ (b) $\sqrt{\frac{2GM}{g}}$

(c) $\sqrt{\frac{2GM}{R^3}}$ (d) $\sqrt{\frac{2GR}{M}}$

43. The least velocity required to throw a body away from the surface of a planet so that it may not return is (radius of the planet is $6.4\times10^6 m,\ g = 9.8\ m/sec^2$) [AMU (Engg.) 1999]

(a) $9.8\times10^{-3} m/sec$ (b) $12.8\times10^3 m/sec$

(c) $9.8\times10^3 m/sec$ (d) $11.2\times10^3 m/sec$

44. How many times is escape velocity (V_e), of orbital velocity (V_0) for a satellite revolving near earth [RPMT 2000]

(a) $\sqrt{2}$ *times* (b) 2 *times*

(c) 3 *times* (d) 4 *times*

45. Escape velocity on earth is 11.2 *km/s*. What would be the escape velocity on a planet whose mass is 1000 times and radius is 10 times that of earth [DCE 2001; DPMT 2004]

(a) 112 *km/s* (b) 11.2 *km/s*

(c) 1.12 *km/s* (d) 3.7 *km/s*

46. If the radius of a planet is R and its density is ρ, the escape velocity from its surface will be [MP PMT 2001]

(a) $v_e \propto \rho R$ (b) $v_e \propto \sqrt{\rho}R$

(c) $v_e \propto \frac{\sqrt{\rho}}{R}$ (d) $v_e \propto \frac{1}{\sqrt{\rho}R}$

47. Escape velocity on the earth [BHU 2001]

(a) Is less than that on the moon

(b) Depends upon the mass of the body [EAMCET 1994]

(c) Depends upon the direction of projection

(d) Depends upon the height from which it is projected

48. If acceleration due to gravity on the surface of a planet is two times that on surface of earth and its radius is double that of earth. Then escape velocity from the surface of that planet in comparison to earth will be **[RPET 2001]**

(a) $2\ v_e$ (b) $3\ v_e$

(c) $4\ v_e$ (d) None of these

49. The escape velocity of a rocket launched from the surface of the earth **[UPSEAT 2001]**

(a) Does not depend on the mass of the rocket

(b) Does not depend on the mass of the earth

(c) Depends on the mass of the planet towards which it is moving

(d) Depends on the mass of the rocket

50. The ratio of the radii of planets A and B is k_1 and ratio of acceleration due to gravity on them is k_2. The ratio of escape velocities from them will be **[BHU 2002]**

(a) $k_1 k_2$ (b) $\sqrt{k_1 k_2}$

(c) $\sqrt{\frac{k_1}{k_2}}$ (d) $\sqrt{\frac{k_2}{k_1}}$

51. A mass of $6 \times 10^{24}\, kg$ is to be compressed in a sphere in such a way that the escape velocity from the sphere is $3 \times 10^8\, m/s$. Radius of the sphere should be $(G = 6.67 \times 10^{-11}\, N - m^2/kg^2)$

(a) 9 *km* (b) 9 *m*

(c) 9 *cm* (d) 9 *mm*

52. The escape velocity of a body on an imaginary planet which is thrice the radius of the earth and double the mass of the earth is (v_e is the escape velocity of earth)

[Kerala (Med.) 2002]

(a) $\sqrt{2/3}\, v_e$ (b) $\sqrt{3/2}\, v_e$

(c) $\sqrt{2}/3 v_e$ (d) $2/\sqrt{3}\, v_e$

53. Escape velocity on the surface of earth is $11.2\, km/s$. Escape velocity from a planet whose mass is the same as that of earth and radius 1/4 that of earth is

[CBSE PMT 2000; JIPMER 2002; BHU 2004]

(a) 2.8 *km/s* (b) 15.6 *km/s*

(c) 22.4 *km/s* (d) 44.8 *km/s*

54. The velocity with which a projectile must be fired so that it escapes earth's gravitation does not depend on

[AIIMS 2003]

(a) Mass of the earth

(b) Mass of the projectile

(c) Radius of the projectile's orbit

(d) Gravitational constant

55. The radius of a planet is $\frac{1}{4}$ of earth's radius and its acceleration due to gravity is double that of earth's acceleration due to gravity. How many times will the escape velocity at the planet's surface be as compared to its value on earth's surface **[BCECE 2003; MH CET 2000]**

(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$

(c) $2\sqrt{2}$ (d) 2

56. The escape velocity for the earth is v_e. The escape velocity for a planet whose radius is four times and density is nine times that of the earth, is **[MP PET 2003]**

(a) $36 v_e$ (b) $12 v_e$

(c) $6 v_e$ (d) $20 v_e$

57. The escape velocity for a body projected vertically upwards from the surface of earth is 11 *km/s*. If the body is projected at an angle of 45° with the vertical, the escape velocity will be

(a) $\frac{11}{\sqrt{2}} km/s$ (b) $11\sqrt{2}\, km/s$

(c) 22 *km/s* (d) 11 *km/s*

58. If *V*, *R* and *g* denote respectively the escape velocity from the surface of the earth radius of the earth, and acceleration due to gravity, then the correct equation is **[MP PMT 2004]**

(a) $V = \sqrt{gR}$ (b) $V = \sqrt{\frac{4}{3} g R^3}$

(c) $V = R\sqrt{g}$ (d) $V = \sqrt{2gR}$

59. The escape velocity for a body of mass 1 *kg* from the earth surface is $11.2\ kms^{-1}$. The escape velocity for a body of mass 100 *kg* would be **[UPSEAT 2002]** **[DCE 2003]**

(a) $11.2 \times 10^2\ kms^{-1}$ (b) $11.2\ kms^{-1}$

(c) $11.2 \times 10^{-2}\ kms^{-1}$ (d) None of these

60. The acceleration due to gravity on a planet is same as that on earth and its radius is four times that of earth. What will be the value of escape velocity on that planet if it is v_e on earth

(a) v_e (b) $2v_e$

(c) $4v_e$ (d) $\frac{v_e}{2}$

61. If the radius of a planet is four times that of earth and the value of *g* is same for both, the escape velocity on the planet will be

(a) $11.2\ km/s$ (b) $5.6\ km/s$

(c) $22.4\ km/s$ (d) None

62. If the radius and acceleration due to gravity both are doubled, escape velocity of earth will become

[RPMT 2002]

(a) 11.2 *km/s* (b) 22.4 *km/s*

(c) 5.6 *km/s* (d) 44.8 *km/s*

63. A planet has twice the radius but the mean density is $\frac{1}{4} th$ as compared to earth. What is the ratio of escape velocity from earth to that from the planet **[MH CET 2004]**

(a) 3 : 1 (b) 1 : 2

(c) 1 : 1 (d) 2 : 1

64. The escape velocity from earth is v_{es}. A body is projected with velocity $2v_{es}$ with what constant velocity will it move in the inter planetary space **[DCE 2002]**

(a) v_{es} (b) $3v_{es}$

(c) $\sqrt{3}v_{es}$ (d) $\sqrt{5}v_{es}$

65. A particle of mass 10 *g* is kept on the surface of a uniform sphere of mass 100 *kg* and radius 10 *cm*. Find the work to be done against the gravitational force between them to take the particle far away from the sphere (you may take $G = 6.67 \times 10^{-11}\ Nm^2/kg^2$)

(a) 6.67×10^{-9} *J* (b) 6.67×10^{-10} *J*

(c) 13.34×10^{-10} *J* (d) 3.33×10^{-10} *J*

66. For a satellite moving in an orbit around the earth, the ratio of kinetic energy to potential energy is **[CBSE PMT 2005]**

(a) 2 (b) $\frac{1}{2}$

(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

67. 3 particles each of mass *m* are kept at vertices of an equilateral triangle of side *L*. The gravitational field at centre due to these particles is **[DCE 2005]**

(a) Zero (b) $\frac{3GM}{L^2}$

(c) $\frac{9GM}{L^2}$ (d) $\frac{12}{\sqrt{3}}\frac{GM}{L^2}$

68. The value of escape velocity on a certain planet is 2 *km/s*. Then the value of orbital speed for a satellite orbiting close to its surface is

(a) 12 *km/s* (b) 1 *km/s*

(c) $\sqrt{2}$ *km/s* (d) $2\sqrt{2}\ km/s$

69. Four particles each of mass *M*, are located at the vertices of a square with side *L*. The gravitational potential due to this at the centre of the square is **[Kerala PET 2005]**

(a) $-\sqrt{32}\frac{GM}{L}$ (b) $-\sqrt{64}\frac{GM}{L^2}$

(c) Zero (d) $\sqrt{32}\frac{GM}{L}$

70. There are two planets. The ratio of radius of the two planets is *K* but ratio of acceleration due to gravity of both planets is *g*. What will be the ratio of their escape velocity **[BHU 2005]**

(a) $(Kg)^{1/2}$ (b) $(Kg)^{-1/2}$

(c) $(Kg)^2$ (d) $(Kg)^{-2}$

Motion of Satellite

1. If v_e and v_o represent the escape velocity and orbital velocity of a satellite corresponding to a circular orbit of radius *R*, then **[CPMT 1982; MP PMT 1997; KCET (Engg./Med.) 1999; AIIMS 2002]**

(a) $v_e = v_o$

(b) $\sqrt{2}v_o = v_e$

(c) $v_e = v_0/\sqrt{2}$

(d) v_e and v_o are not related

2. If *r* represents the radius of the orbit of a satellite of mass *m* moving around a planet of mass *M*, the velocity of the satellite is given by **[CPMT 1974; MP PMT 1987; RPMT 1999]**

(a) $v^2 = g\frac{M}{r}$ (b) $v^2 = \frac{GMm}{r}$

(c) $v = \frac{GM}{r}$ **[AIEEE 2005]** (d) $v^2 = \frac{GM}{r}$

3. Select the correct statement from the following **[MP PMT 1993]**

(a) The orbital velocity of a satellite increases with the radius of the orbit

(b) Escape velocity of a particle from the surface of the earth depends on the speed with which it is fired

(c) The time period of a satellite does not depend on the radius of the orbit

(d) The orbital velocity is inversely proportional to the square root of the radius of the orbit

4. An earth satellite of mass *m* revolves in a circular orbit at a height *h* from the surface of the earth. *R* is the radius of the earth and *g* is acceleration due to gravity at the surface of the earth. The velocity of the satellite in the orbit is given by **[NCERT 1983; AIEEE 2004]**

(a) $\frac{gR^2}{R+h}$ (b) gR

(c) $\frac{gR}{R+h}$ **[DCE 2005]** (d) $\sqrt{\frac{gR^2}{R+h}}$

5. Consider a satellite going round the earth in an orbit. Which of the following statements is wrong **[NCERT 1966]**

(a) It is a freely falling body

(b) It suffers no acceleration

(c) It is moving with a constant speed

(d) Its angular momentum remains constant

6. Two satellites of masses m_1 and $m_2 (m_1 > m_2)$ are revolving round the earth in circular orbits of radius r_1 and $r_2 (r_1 > r_2)$ respectively. Which of the following statements is true regarding their speeds v_1 and v_2 ? **[NCERT 1984; MNR 1995; BHU 1998]**

(a) $v_1 = v_2$ (b) $v_1 < v_2$

(c) $v_1 > v_2$ (d) $\frac{v_1}{r_1} = \frac{v_2}{r_2}$

7. A satellite which is geostationary in a particular orbit is taken to another orbit. Its distance from the centre of earth in new orbit is 2 times that of the earlier orbit. The time period in the second orbit is **[NCERT 19**

(a) 4.8 *hours* (b) $48\sqrt{2}$ *hours*

(c) 24 *hours* (d) $24\sqrt{2}$ *hours*

8. The ratio of the K.E. required to be given to the satellite to escape earth's gravitational field to the K.E. required to be given so that the satellite moves in a circular orbit just above earth atmosphere is

(a) One (b) Two

(c) Half (d) Infinity

9. An astronaut orbiting the earth in a circular orbit 120 *km* above the surface of earth, gently drops a spoon out of space-ship. The spoon will [NCERT 1971]

(a) Fall vertically down to the earth
(b) Move towards the moon
(c) Will move along with space-ship
(d) Will move in an irregular way then fall down to earth

10. The period of a satellite in a circular orbit around a planet is independent of [NCERT 1974; AIEEE 2004]

(a) The mass of the planet
(b) The radius of the planet
(c) The mass of the satellite
(d) All the three parameters (a), (b) and (c)

11. If a satellite is orbiting the earth very close to its surface, then the orbital velocity mainly depends on [NCERT 1982]

(a) The mass of the satellite only
(b) The radius of the earth only
(c) The orbital radius only
(d) The mass of the earth only

12. The relay satellite transmits the T.V. programme continuously from one part of the world to another because its

(a) Period is greater than the period of rotation of the earth
(b) Period is less than the period of rotation of the earth about its axis
(c) Period has no relation with the period of the earth about its axis
(d) Period is equal to the period of rotation of the earth about its axis
(e) Mass is less than the mass of the earth

13. Two satellites A and B go round a planet P in circular orbits having radii $4R$ and R respectively. If the speed of the satellite A is $3V$, the speed of the satellite B will be.

[MNR 1991; AIIMS 1995; UPSEAT 2000]

(a) $12\ V$ (b) $6\ V$
(c) $\frac{4}{3}V$ (d) $\frac{3}{2}V$

14. A geostationary satellite [CPMT 1990]

(a) Revolves about the polar axis
(b) Has a time period less than that of the near earth satellite
(c) Moves faster than a near earth satellite
(d) Is stationary in the space

15. A small satellite is revolving near earth's surface. Its orbital velocity will be nearly

[CPMT 1987; Orissa JEE 2002; JIPMER 2001, 02]

(a) 8 *km/sec* (b) 11.2 *km/sec*
(c) 4 *km/sec* (d) 6 *km/sec*

16. A satellite revolves around the earth in an elliptical orbit. Its speed [NCERT 1981; MP PET 2001]

(a) Is the same at all points in the orbit
(b) Is greatest when it is closest to the earth
(c) Is greatest when it is farthest from the earth
(d) Goes on increasing or decreasing continuously depending upon the mass of the satellite

17. The orbital velocity of an artificial satellite in a circular orbit just above the earth's surface is v. For a satellite orbiting at an altitude of half of the earth's radius, the orbital velocity is

[MNR 1994]

(a) $\frac{3}{2}v$ (b) $\sqrt{\frac{3}{2}}v$
(c) $\sqrt{\frac{2}{3}}v$ (d) $\frac{2}{3}v$

18. In a satellite if the time of revolution is T, then K.E. is proportional to [BHU 1995]

(a) $\frac{1}{T}$ (b) $\frac{1}{T^2}$
(c) $\frac{1}{T^3}$ (d) $T^{-2/3}$

19. If the height of a satellite from the earth is negligible in comparison to the radius of the earth R, the orbital velocity of the satellite is[MP PET 1995;

(a) gR (b) $gR/2$
(c) $\sqrt{g/R}$ (d) $\sqrt{gR}$

20. Choose the correct statement from the following : The radius of the orbit of a geostationary satellite depends upon [MNR 1984, 93]

[MP PMT 1995]

(a) Mass of the satellite, its time period and the gravitational constant
(b) Mass of the satellite, mass of the earth and the gravitational constant
(c) Mass of the earth, mass of the satellite, time period of the satellite and the gravitational constant
(d) Mass of the earth, time period of the satellite and the gravitational constant

21. Out of the following, the only incorrect statement about satellites is

(a) A satellite cannot move in a stable orbit in a plane passing through the earth's centre
(b) Geostationary satellites are launched in the equatorial plane
(c) We can use just one geostationary satellite for global communication around the globe
(d) The speed of a satellite increases with an increase in the radius of its orbit

22. A satellite is moving around the earth with speed v in a circular orbit of radius r. If the orbit radius is decreased by 1%, its speed will[MP PET 19

(a) Increase by 1% (b) Increase by 0.5%
(c) Decrease by 1% (d) Decrease by 0.5%

23. Orbital velocity of an artificial satellite does not depend upon

(a) Mass of the earth
(b) Mass of the satellite
(c) Radius of the earth
(d) Acceleration due to gravity

24. The time period of a geostationary satellite is

[EAMCET 1994; MP PMT 1999]

(a) 24 hours (b) 12 hours
(c) 365 days (d) One month

25. Orbital velocity of earth's satellite near the surface is 7 *km/s*. When the radius of the orbit is 4 times than that of earth's radius, then orbital velocity in that orbit is [EAMCET (Engg.) 1995]

(a) 3.5 *km/s* (b) 7 *km/s*

(c) 72 *km/s* (d) 14 *km/s*

26. Two identical satellites are at R and $7R$ away from earth surface, the wrong statement is (R = Radius of earth) [RPMT 1997]

(a) Ratio of total energy will be 4

(b) Ratio of kinetic energies will be 4

(c) Ratio of potential energies will be 4

(d) Ratio of total energy will be 4 but ratio of potential and kinetic energies will be 2

27. For a satellite escape velocity is 11 *km/s*. If the satellite is launched at an angle of 60° with the vertical, then escape velocity will be [CBSE PMT 1993; RPMT 1997]

(a) 11 *km/s* (b) $11\sqrt{3}$ *km/s*

(c) $\frac{11}{\sqrt{3}}$ *km/s* (d) 33 *km/s*

28. The mean radius of the earth is R, its angular speed on its own axis is ω and the acceleration due to gravity at earth's surface is g. The cube of the radius of the orbit of a geostationary satellite will be

(a) $R^2 g / \omega$ (b) $R^2 \omega^2 / g$

(c) Rg / ω^2 (d) $R^2 g / \omega^2$

29. Which one of the following statements regarding artificial satellite of the earth is incorrect [NDA 1995; MP PMT 2000]

(a) The orbital velocity depends on the mass of the satellite

(b) A minimum velocity of 8 *km/sec* is required by a satellite to orbit quite close to the earth

(c) The period of revolution is large if the radius of its orbit is large

(d) The height of a geostationary satellite is about 36000 *km* from earth

30. A ball is dropped from a spacecraft revolving around the earth at a height of 120 *km*. What will happen to the ball [CBSE PMT 1996; CPMT 2001; BHU 1999]

(a) It will continue to move with velocity v along the original orbit of spacecraft

(b) It will move with the same speed tangentially to the spacecraft

(c) It will fall down to the earth gradually

(d) It will go very far in the space

31. A satellite whose mass is M, is revolving in circular orbit of radius r around the earth. Time of revolution of satellite is [AMU 1999]

(a) $T \propto \frac{r^5}{GM}$ (b) $T \propto \sqrt{\frac{r^3}{GM}}$

(c) $T \propto \sqrt{\frac{r}{GM^2/3}}$ (d) $T \propto \sqrt{\frac{r^3}{GM^1/4}}$

32. An artificial satellite is placed into a circular orbit around earth at such a height that it always remains above a definite place on the surface of earth. Its height from the surface of earth is

(a) 6400 *km* (b) 4800 *km*

(c) 32000 *km* (d) 36000 *km*

33. The weight of an astronaut, in an artificial satellite revolving around the earth, is [BHU 1999]

(a) Zero

(b) Equal to that on the earth

(c) More than that on the earth

(d) Less than that on the earth

34. In the following four periods [AMU 2000]

(i) Time of revolution of a satellite just above the earth's surface (T_{st})

(ii) Period of oscillation of mass inside the tunnel bored along the diameter of the earth (T_{ma})

(iii) Period of simple pendulum having a length equal to the earth's radius in a uniform field of 9.8 *N/kg* (T_{sp})

(iv) Period of an infinite length simple pendulum in the earth's real gravitational field (T_{is})

(a) $T_{st} > T_{ma}$ (b) $T_{ma} > T_{st}$

(c) $T_{sp} > T_{is}$ [CBSE PMT 1992] (d) $T_{st} = T_{ma} = T_{sp} = T_{is}$

35. The periodic time of a communication satellite is [MP PMT 2000]

(a) 6 *hours* (b) 12 *hours*

(c) 18 *hours* (d) 24 *hours*

36. The orbital speed of an artificial satellite very close to the surface of the earth is V_o. Then the orbital speed of another artificial satellite at a height equal to three times the radius of the earth is

(a) $4\,V_o$ (b) $2\,V_o$

(c) $0.5\,V_o$ (d) $4\,V_o$

37. Which of the following statements is correct in respect of a geostationary satellite [MP PET 2001]

(a) It moves in a plane containing the Greenwich meridian

(b) It moves in a plane perpendicular to the celestial equatorial plane

(c) Its height above the earth's surface is about the same as the radius of the earth

(d) Its height above the earth's surface is about six times the radius of the earth

38. The distance of a geo-stationary satellite from the centre of the earth (Radius R = 6400 *km*) is nearest to [AFMC 2001]

(a) 5 R (b) 7 R

(c) 10 R (d) 18 R

39. If Gravitational constant is decreasing in time, what will remain unchanged in case of a satellite orbiting around earth

(a) Time period (b) Orbiting radius

(c) Tangential velocity (d) Angular velocity

40. Periodic time of a satellite revolving above Earth's surface at a height equal to R, radius of Earth, is

[g is acceleration due to gravity at Earth's surface]

[MP PMT 2002]

(a) $2\pi\sqrt{\frac{2R}{g}}$ (b) $4\sqrt{2}\pi\sqrt{\frac{R}{g}}$

(c) $2\pi\sqrt{\frac{R}{g}}$ (d) $8\pi\sqrt{\frac{R}{g}}$

41. Given radius of Earth 'R' and length of a day 'T' the height of a geostationary satellite is [G–Gravitational Constant, M–Mass of Earth] [MP PMT 2002]

(a) $\left(\frac{4\pi^2 GM}{T^2}\right)^{1/3}$ (b) $\left(\frac{4\pi GM}{R^2}\right)^{1/3} - R$

(c) $\left(\frac{GMT^2}{4\pi^2}\right)^{1/3} - R$ (d) $\left(\frac{GMT^2}{4\pi^2}\right)^{1/3} + R$

42. A geo-stationary satellite is orbiting the earth at a height of 6 R above the surface of earth, R being the radius of earth. The time period of another satellite at a height of 2.5 R from the surface of earth is

[UPSEAT 2002; AMU (Med.) 2002; Pb. PET 2003]

(a) 10 hr (b) $(6/\sqrt{2})hr$

(c) 6 hr (d) $6\sqrt{2}\ hr$

43. The distance between centre of the earth and moon is 384000 km. If the mass of the earth is $6\times10^{24}\ kg$ and $G = 6.66\times10^{-11}\ Nm^2/kg^2$. The speed of the moon is nearly

[MH CET 2002]

(a) 1 km/sec (b) 4 km/sec

(c) 8 km/sec (d) 11.2 km/sec

44. A satellite is launched into a circular orbit of radius 'R' around earth while a second satellite is launched into an orbit of radius 1.02 R. The percentage difference in the time periods of the two satellites is

(a) 0.7 (b) 1.0

(c) 1.5 (d) 3

45. Where can a geostationary satellite be installed

[MP PMT 2004]

(a) Over any city on the equator

(b) Over the north or south pole

(c) At height R above earth

(d) At the surface of earth

46. Distance of geostationary satellite from the surface of earth $radius(R_e = 6400\ km)$ in terms of R_e is [Pb. PET 2000]

(a) $13.76\ R_e$ (b) $10.76\ R_e$

(c) $6.56\ R_e$ (d) $2.56\ R_e$

47. A satellite is to revolve round the earth in a circle of radius 8000 km. The speed at which this satellite be projected into an orbit, will be [Pb. PET 2002]

(a) $3\ km/s$ (b) $16\ km/s$

(c) $7.15\ km/s$ (d) $8\ km/s$

48. Two satellite A and B, ratio of masses 3 : 1 are in circular orbits of radii r and $4r$. Then ratio of total mechanical energy of A to B is

(a) 1 : 3 (b) 3 : 1

(c) 3 : 4 (d) 12 : 1

49. The orbital velocity of a planet revolving close to earth's surface is

(a) $\sqrt{2gR}$ (b) $\sqrt{gR}$

(c) $\sqrt{\frac{2g}{R}}$ (d) $\sqrt{\frac{g}{R}}$

50. If the gravitational force between two objects were proportional to $1/R$ (and not as $1/R^2$) where R is separation between them, then a particle in circular orbit under such a force would have its orbital speed v proportional to [CBSE PMT 1994; JIPMER 2001, 02]

(a) $1/R^2$ (b) R^0

(c) R^1 (d) $1/R$

51. A satellite moves around the earth in a circular orbit of radius r with speed v. If the mass of the satellite is M, its total energy is

(a) $-\frac{1}{2}Mv^2$ (b) $\frac{1}{2}Mv^2$

(c) $\frac{3}{2}Mv^2$ (d) Mv^2

52. A satellite with kinetic energy E_k is revolving round the earth in a circular orbit. How much more kinetic energy should be given to it so that it may just escape into outer space

(a) E_k (b) $2\ E_k$

(c) $\frac{1}{2}E_k$ (d) $3\ E_k$

53. Potential energy of a satellite having mass 'm' and rotating at a height of $6.4\times10^6\ m$ from the earth surface is

[AIIMS 2000; CBSE PMT 2001; BHU 2001]

[EAMCET 2003]

(a) $-0.5\ mgR_e$ (b) $-mgR_e$

(c) $-2\ mgR_e$ (d) $4\ mgR_e$

54. When a satellite going round the earth in a circular orbit of radius r and speed v loses some of its energy, then r and v change as [JIPMER 2002; EAM

(a) r and v both with increase

(b) r and v both will decrease

(c) r will decrease and v will increase

(d) r will decrease and v will decrease

55. An earth satellite S has an orbit radius which is 4 times that of a communication satellite C. The period of revolution of S is

(a) 4 days (b) 8 days

(c) 16 days (d) 32 days

56. Which is constant for a satellite in orbit

[Bihar CMEET 1995]

(a) Velocity (b) Angular momentum

(c) Potential energy (d) Acceleration

(e) Kinetic energy

57. If satellite is shifted towards the earth. Then time period of satellite will be [RPMT 2000]

(a) Increase (b) Decrease

(c) Unchanged (d) Nothing can be said

58. Which of the following quantities does not depend upon the orbital radius of the satellite [DCE 2000,03]

(a) $\frac{T}{R}$ (b) $\frac{T^2}{R}$

(c) $\frac{T^2}{R^2}$ (d) $\frac{T^2}{R^3}$

59. The time period of a satellite of earth is 5 *hours*. If the separation between the earth and the satellite is increased to four times the previous value, the new time period will become

(a) 20 *hours* (b) 10 *hours*

(c) 80 *hours* (d) 40 *hours*

60. A satellite moves round the earth in a circular orbit of radius *R* making one revolution per day. A second satellite moving in a circular orbit, moves round the earth once in 8 days. The radius of the orbit of the second satellite is [UPSEAT 2004]

(a) 8 *R* (b) 4*R*

(c) 2*R* (d) *R*

61. A person sitting in a chair in a satellite feels weightless because

(a) The earth does not attract the objects in a satellite

(b) The normal force by the chair on the person balances the earth's attraction

(c) The normal force is zero

(d) The person in satellite is not accelerated

62. Two satellites *A* and *B* go round a planet in circular orbits having radii 4*R* and *R*, respectively. If the speed of satellite *A* is 3*v*, then speed of satellite *B* is [Pb. PET 2004]

(a) $\frac{3v}{2}$ (b) $\frac{4v}{2}$

(c) $6v$ (d) $12v$

63. If $g \propto \frac{1}{R^3}$ (instead of $\frac{1}{R^2}$), then the relation between time period of a satellite near earth's surface and radius *R* will be

(a) $T^2 \propto R^3$ (b) $T \propto R^2$

(c) $T^2 \propto R$ (d) $T \propto R$

64. To an astronaut in a spaceship, the sky appears [KCET 1994]

(a) Black (b) White

(c) Green (d) Blue

65. A geostationary satellite is revolving around the earth. To make it escape from gravitational field of earth, is velocity must be increased

(a) 100% (b) 41.4%

(c) 50% (d) 59.6%

66. A satellite moves in a circle around the earth. The radius of this circle is equal to one half of the radius of the moon's orbit. The satellite completes one revolution in [J&K CET 2005]

(a) $\frac{1}{2}$ lunar month (b) $\frac{2}{3}$ lunar month

(c) $2^{-3/2}$ lunar month (d) $2^{3/2}$ lunar month

67. A satellite of mass *m* is placed at a distance *r* from the centre of earth (mass *M*). The mechanical energy of the satellite is [J&K CET 2005]

(a) $-\frac{GMm}{r}$ (b) $\frac{GMm}{r}$

(c) $\frac{GMm}{2r}$ (d) $-\frac{GMm}{2r}$

Kepler's Laws of Planetary Motion

1. The distance of neptune and saturn from sun are nearly 10^{13} and 10^{12} meters respectively. Assuming that they move in circular orbits, their periodic times will be in the ratio [NCERT 1975; CBSE PMT 1994; MP

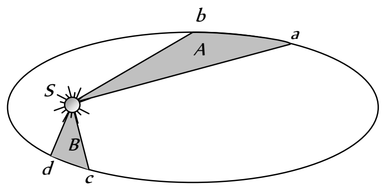
[AIIMS 1995; AIEEE 2003]

(a) $\sqrt{10}$ (b) 100

(c) $10\sqrt{10}$ (d) $1/\sqrt{10}$

2. The figure shows the motion of a planet around the sun in an elliptical orbit with sun at the focus. The shaded areas A and B are also shown in the figure which can be assumed to be equal. If t_1 and t_2 represent the time for the planet to move from *a* to *b* and *d* to *c* respectively, then [CPMT 1986, 88]

[UPSEAT 2004]



(a) $t_1 < t_2$

(b) $t_1 > t_2$

(c) $t_1 = t_2$

(d) $t_1 \le t_2$

3. The period of a satellite in a circular orbit of radius *R* is *T*, the period of another satellite in a circular orbit of radius 4*R* is AIIMS 2000; CBSE PMT 2002]

(a) 4*T* (b) *T*/4

(c) 8*T* (d) *T*/8

4. Orbit of a planet around a star is [CPMT 1982]

(a) A circle (b) An ellipse

(c) A parabola [RPMT 2002] (d) A straight line

5. If a body describes a circular motion under inverse square field, the time taken to complete one revolution T is related to the radius of the circular orbit as [NCERT 1975; RPMT 2000]

(a) $T \propto r$ (b) $T \propto r^2$

(c) $T^2 \propto r^3$ (d) $T \propto r^4$

6. If the earth is at one-fourth of its present distance from the sun, the duration of the year will be [EAMCET 1987] [J&K CET 2005]

(a) Half the present year

(b) One-eighth the present year

(c) One-fourth the present year

(d) One-sixth the present year

7. The earth revolves about the sun in an elliptical orbit with mean radius $9.3 \times 10^7\ m$ in a period of 1 year. Assuming that there are no outside influences

(a) The earth's kinetic energy remains constant

(b) The earth's angular momentum remains constant

(c) The earth's potential energy remains constant

(d) All are correct

8. Venus looks brighter than other planets because [MNR 1985]

(a) It is heavier than other planets

(b) It has higher density than other planets

(c) It is closer to the earth than other planets

(d) It has no atmosphere

9. A planet moves around the sun. At a given point P, it is closest from the sun at a distance d_1 and has a speed v_1. At another point Q, when it is farthest from the sun at a distance d_2, its speed will be [MP PMT 1987; DCE 2002]

(a) $\frac{d_1^2 v_1}{d_2^2}$ (b) $\frac{d_2 v_1}{d_1}$

(c) $\frac{d_1 v_1}{d_2}$ (d) $\frac{d_2^2 v_1}{d_1^2}$

10. The orbital speed of Jupiter is [MNR 1986; UPSEAT 2000]

(a) Greater than the orbital speed of earth

(b) Less than the orbital speed of earth

(c) Equal to the orbital speed of earth

(d) Zero

11. Two planets move around the sun. The periodic times and the mean radii of the orbits are T_1, T_2 and r_1, r_2 respectively. The ratio T_1 / T_2 is equal to [CPMT 1978]

(a) $(r_1 / r_2)^{1/2}$ (b) r_1 / r_2

(c) $(r_1 / r_2)^2$ (d) $(r_1 / r_2)^{3/2}$

12. Kepler's second law regarding constancy of aerial velocity of a planet is a consequence of the law of conservation of [CPMT 1990; AIIMS 2002]

(a) Energy (b) Angular momentum

(c) Linear momentum (d) None of these

13. The largest and the shortest distance of the earth from the sun are r_1 and r_2, its distance from the sun when it is at the perpendicular to the major axis of the orbit drawn from the sun

(a) $\frac{r_1 + r_2}{4}$ (b) $\frac{r_1 r_2}{r_1 + r_2}$

(c) $\frac{2 r_1 r_2}{r_1 + r_2}$ (d) $\frac{r_1 + r_2}{3}$

14. The rotation period of an earth satellite close to the surface of the earth is 83 minutes. The time period of another earth satellite in an orbit at a distance of three earth radii from its surface will be

(a) 83 minutes (b) $83 \times \sqrt{8}$ minutes

(c) 664 minutes (d) 249 minutes

15. A satellite of mass m is circulating around the earth with constant angular velocity. If radius of the orbit is R_0 and mass of the earth M, the angular momentum about the centre of the earth is [MP PMT 1996; RPMT 2000]

(a) $m\sqrt{GMR_0}$ (b) $M\sqrt{GmR_0}$

(c) $m\sqrt{\frac{GM}{R_0}}$ (d) $M\sqrt{\frac{GM}{R_0}}$

16. According to Kepler, the period of revolution of a planet (T) and its mean distance from the sun (r) are related by the equation [EAMCET (Med.) 1995; MH CET 2000; Pb. PET 2001]

(a) $T^3 r^3 =$ constant (b) $T^2 r^{-3} =$ constant

(c) $T r^3 =$ constant (d) $T^2 r =$ constant

17. A planet revolves around sun whose mean distance is 1.588 times the mean distance between earth and sun. The revolution time of planet will be [RPET 1997]

(a) 1.25 years (b) 1.59 years

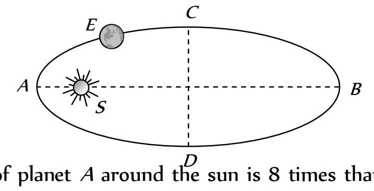
(c) 0.89 years (d) 2 years

18. A satellite A of mass m is at a distance of r from the centre of the earth. Another satellite B of mass $2m$ is at a distance of $2r$ from the earth's centre. Their time periods are in the ratio of

(a) 1 : 2 (b) 1 : 16

(c) 1 : 32 (d) $1 : 2\sqrt{2}$

19. The earth E moves in an elliptical orbit with the sun S at one of the foci as shown in figure. Its speed of motion will be maximum at the point [BHU 1994; CPMT 1997]



(a) C

(b) A

(c) B

(d) D

20. The period of revolution of planet A around the sun is 8 times that of B. The distance of A from the sun is how many times greater than that of B from the sun [CBSE PMT 1997; BHU 2001]

(a) 2 (b) 3

(c) 4 (d) 5

21. If the radius of earth's orbit is made 1/4, the duration of an year will become [BHU 1998; JIPMER 2001, 2002]

(a) 8 times (b) 4 times

(c) 1/8 times (d) 1/4 times

22. Planetary system in the solar system describes [DCE 1999]

(a) Conservation of energy

(b) Conservation of linear momentum

(c) Conservation of angular momentum [CBSE PMT 1991]

(d) None of these

23. If mass of a satellite is doubled and time period remain constant the ratio of orbit in the two cases will be [RPET 2000]

(a) 1 : 2 (b) 1 : 1

(c) 1 : 3 (d) None of these

24. The earth revolves round the sun in one year. If the distance between them becomes double, the new period of revolution will be [MP PMT 1994]

(a) 1/2 *year* (b) $2\sqrt{2}$ *years*

(c) 4 *years* (d) 8 *years*

25. Kepler discovered [DCE 2000]

(a) Laws of motion

(b) Laws of rotational motion

(c) Laws of planetory motion

(d) Laws of curvilinear motion

26. In the solar system, which is conserved [DCE 2001]

(a) Total Energy (b) K.E.

(c) Angular Velocity (d) Linear Momentum

27. The maximum and minimum distances of a comet from the sun are $8 \times 10^{12}\ m$ and $1.6 \times 10^{12}\ m$. If its velocity when nearest to the sun is 60 *m/s*, what will be its velocity in *m/s* when it is farthest

(a) 12 (b) 60

(c) 112 (d) 6

28. A body revolved around the sun 27 times faster then the earth what is the ratio of their radii [DPMT 2002]

(a) 1/3 (b) 1/9

(c) 1/27 (d) 1/4

29. The period of moon's rotation around the earth is nearly 29 *days*. If moon's mass were 2 fold, its present value and all other things remained unchanged, the period of moon's rotation would be nearly [Kerala (Engg.) 2002]

(a) $29\sqrt{2}$ *days* (b) $29/\sqrt{2}$ *days*

(c) 29×2 *days* (d) 29 *days*

30. Two planets at mean distance d_1 and d_2 from the sun and their frequencies are n_1 and n_2 respectively then [Kerala (Med.) 2002]

(a) $n_1^2 d_1^2 = n_2 d_2^2$ (b) $n_2^2 d_2^3 = n_1^2 d_1^3$

(c) $n_1 d_1^2 = n_2 d_2^2$ (d) $n_1^2 d_1 = n_2^2 d_2$

31. Which of the following astronomer first proposed that sun is static and earth rounds sun [AFMC 2002]

(a) Copernicus (b) Kepler

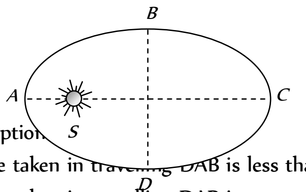
(c) Galileo (d) None

32. The distance of a planet from the sun is 5 times the distance between the earth and the sun. The time period of the planet is

(a) $5^{3/2}$ *years* (b) $5^{2/3}$ *years*

(c) $5^{1/3}$ *years* (d) $5^{1/2}$ *years*

33. A planet is revolving around the sun as shown in elliptical path



The correct option is

(a) The time taken in travelling DAB is less than that for BCD

(b) The time taken in travelling DAB is greater than that for BCD

(c) The time taken in travelling CDA is less than that for ABC

(d) The time taken in travelling CDA is greater than that for ABC

34. In the previous question the orbital velocity of the planet will be minimum at [UPSEAT 2003; RPET 2002]

(a) A (b) B

(c) C (d) D

35. The radius of orbit of a planet is two times that of the earth. The time period of planet is [BHU 2003; CPMT 2004]

(a) 4.2 *years* (b) 2.8 *years*

(c) 5.6 *years* (d) 8.4 *years*

36. The orbital angular momentum of a satellite revolving at a distance r from the centre is L. If the distance is increased to $16r$, then the new angular momentum will be [MP PET 2003]

(a) $16\ L$ (b) $64\ L$

(c) $\frac{L}{4}$ (d) $4\ L$

37. According to Kepler's law the time period of a satellite varies with its radius as [Orissa JEE 2003]

(a) $T^2 \propto R^3$ (b) $T^3 \propto R^2$

(c) $T^2 \propto (1/R^3)$ (d) $T^3 \propto (1/R^2)$

38. In planetary motion the areal velocity of position vector of a planet depends on angular velocity (ω) and the distance of the planet from sun (r). If so the correct relation for areal velocity is [EAMCET 2003]

(a) $\frac{dA}{dt} \propto \omega r$ (b) $\frac{dA}{dt} \propto \omega^2 r$

(c) $\frac{dA}{dt} \propto \omega r^2$ (d) $\frac{dA}{dt} \propto \sqrt{\omega r}$

39. The ratio of the distances of two planets from the sun is 1.38. The ratio of their period of revolution around the sun is

(a) 1.38 (b) $1.38^{3/2}$

(c) $1.38^{1/2}$ (d) 1.38^3

(e) 1.38^2.

40. Kepler's second law (law of areas) is nothing but a statement of

(a) Work energy theorem

(b) Conservation of linear momentum

(c) Conservation of angular momentum

(d) Conservation of energy

41. In an elliptical orbit under gravitational force, in general [UPSEAT 2003] [UPSEAT 2004]

(a) Tangential velocity is constant

(b) Angular velocity is constant

(c) Radial velocity is constant [UPSEAT 2003]

(d) Areal velocity is constant

42. If a new planet is discovered rotating around Sun with the orbital radius double that of earth, then what will be its time period (in earth's days) [DCE 2004]

(a) 1032 (b) 1023

(c) 1024 (d) 1043

43. Suppose the law of gravitational attraction suddenly changes and becomes an inverse cube law i.e. $F \propto 1/r^3$, but still remaining a central force. Then [UPSEAT 2002]

(a) Keplers law of areas still holds

(b) Keplers law of period still holds

(c) Keplers law of areas and period still hold

(d) Neither the law of areas, nor the law of period still holds

44. What does not change in the field of central force [MP PMT 2004]

(a) Potential energy (b) Kinetic energy

(c) Linear momentum (d) Angular momentum

45. The eccentricity of earth's orbit is 0.0167. The ratio of its maximum speed in its orbit to its minimum speed is [NCERT 1973]

(a) 2.507 (b) 1.033

(c) 8.324 (d) 1.000

46. The mass of a planet that has a moon whose time period and orbital radius are T and R respectively can be written as [AMU 1995]

(a) $4\pi^2 R^3 G^{-1} T^{-2}$ (b) $8\pi^2 R^3 G^{-1} T^{-2}$

(c) $12\pi^2 R^3 G^{-1} T^{-2}$ (d) $16\pi^2 R^3 G^{-1} T^{-2}$

47. If orbital velocity of planet is given by $v = G^a M^b R^c$, then [EAMCET 1994]

(a) $a = 1/3, b = 1/3, c = -1/3$

(b) $a = 1/2, b = 1/2, c = -1/2$

(c) $a = 1/2, b = -1/2, c = 1/2$

(d) $a = 1/2, b = -1/2, c = -1/2$

48. Hubble's law states that the velocity with which milky way is moving away from the earth is proportional to [Kerala PMT 2004]

(a) Square of the distance of the milky way from the earth

(b) Distance of milky way from the earth

(c) Mass of the milky way

(d) Product of the mass of the milky way and its distance from the earth

(e) Mass of the earth

49. Two satellite are revolving around the earth with velocities v_1 and v_2 and in radii r_1 and $r_2 (r_1 > r_2)$ respectively. Then [BHU 2005]

(a) $v_1 = v_2$ (b) $v_1 > v_2$

(c) $v_1 < v_2$ (d) $\frac{v_1}{r_1} = \frac{v_2}{r_2}$

50. The condition for a uniform spherical mass m of radius r to be a black hole is [G= gravitational constant and g= acceleration due to gravity] [AIIMS 2005]

(a) $(2Gm/r)^{1/2} \le c$ (b) $(2Gm/r)^{1/2} = c$

(c) $(2Gm/r)^{1/2} \ge c$ (d) $(gm/r)^{1/2} \ge c$

51. Earth is revolving around the sun if the distance of the Earth from the Sun is reduced to 1/4 of the present distance then the present day length reduced by [BHU 2005]

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) $\frac{1}{8}$ (d) $\frac{1}{6}$

CT Critical Thinking

Objective Questions

1. Imagine a light planet revolving around a very massive star in a circular orbit of radius R with a period of revolution T. If the gravitational force of attraction between planet and star is proportional to $R^{-\frac{5}{2}}$, then T^2 is proportional to [IIT 1989; RPMT 1997]

(a) R^3 (b) $R^{7/2}$

(c) $R^{5/2}$ (d) $R^{3/2}$

2. The magnitudes of the gravitational force at distances r_1 and r_2 from the centre of a uniform sphere of radius R and mass M are F_1 and F_2 respectively. Then [IIT 1994]

(a) $\frac{F_1}{F_2} = \frac{r_1}{r_2}$ if $r_1 < R$ and $r_2 < R$

(b) $\frac{F_1}{F_2} = \frac{r_1^2}{r_2^2}$ if $r_1 > R$ and $r_2 > R$

(c) $\frac{F_1}{F_2} = \frac{r_1}{r_2}$ if $r_1 > R$ and $r_2 > R$

(d) $\frac{F_1}{F_2} = \frac{r_2^2}{r_1^2}$ if $r_1 < R$ and $r_2 < R$

3. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of earth

(a) The acceleration of S is always directed towards the centre of the earth

(b) The angular momentum of S about the centre of the earth changes in direction but its magnitude remains constant

(c) The total mechanical energy of S varies periodically with time

(d) The linear momentum of S remains constant in magnitude

4. A mass M is split into two parts, m and $(M-m)$, which are then separated by a certain distance. What ratio of m/M maximizes the gravitational force between the two parts [AMU 2000]

(a) 1/3 (b) 1/2

(c) 1/4 (d) 1/5

5. Suppose the gravitational force varies inversely as the n^{th} power of distance. Then the time period of a planet in circular orbit of radius R around the sun will be proportional to

(a) $R^{\left(\frac{n+1}{2}\right)}$ (b) $R^{\left(\frac{n-1}{2}\right)}$

(c) R^n (d) $R^{\left(\frac{n-2}{2}\right)}$

6. If the radius of the earth were to shrink by 1% its mass remaining the same, the acceleration due to gravity on the earth's surface would [IIT 1981; CPMT 1981; MP PMT 1996, 97; Roorkee 1992; MP PET 1999; Kerala PMT 2004]

(a) Decrease by 2% (b) Remain unchanged

(c) Increase by 2% (d) Increase by 1%

7. The radius and mass of earth are increased by 0.5%. Which of the following statements are true at the surface of the earth

(a) g will increase

(b) g will decrease

(c) Escape velocity will remain unchanged

(d) Potential energy will remain unchanged

8. In order to make the effective acceleration due to gravity equal to zero at the equator, the angular velocity of rotation of the earth about its axis should be ($g = 10\,ms^{-2}$ and radius of earth is 6400 *kms*) [Roorkee 2000]

(a) $0\ rad sec^{-1}$ (b) $\frac{1}{800} rad sec^{-1}$

(c) $\frac{1}{80} rad sec^{-1}$ (d) $\frac{1}{8} rad sec^{-1}$

9. A simple pendulum has a time period T_1 when on the earth's surface and T_2 when taken to a height R above the earth's surface, where R is the radius of the earth. The value of T_2/T_1 is

(a) 1 (b) $\sqrt{2}$

(c) 4 (d) 2

10. A body of mass m is taken from earth surface to the height h equal to radius of earth, the increase in potential energy will be

[CBSE PMT 1991; Kurukshetra CEE 1996; CMEET Bihar 1995; MNR 1998; AIEEE 2004]

(a) mgR (b) $\frac{1}{2}mgR$

(c) $2\ mgR$ (d) $\frac{1}{4}mgR$

11. An artificial satellite moving in a circular orbit around the earth has a total (kinetic + potential) energy E_0. Its potential energy is

[IIT 1997 Cancelled; MH CET 2002; MP PMT 2000]

(a) $-E_0$ (b) $1.5\ E_0$

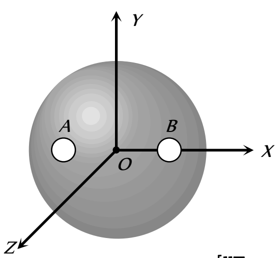
(c) $2\ E_0$ (d) E_0

12. A rocket of mass M is launched vertically from the surface of the earth with an initial speed V. Assuming the radius of the earth to be R and negligible air resistance, the maximum height attained by the rocket above the surface of the earth is

(a) $R/\left(\frac{gR}{2V^2}-1\right)$ (b) $R\left(\frac{gR}{2V^2}-1\right)$

(c) $R/\left(\frac{2gR}{V^2}-1\right)$ (d) $R\left(\frac{2gR}{V^2}-1\right)$

13. A solid sphere of uniform density and radius 4 units is located with its centre at the origin O of coordinates. Two spheres of equal radii 1 unit with their centres at $A(-2, 0, 0)$ and $B(2, 0, 0)$ respectively are taken out of the solid leaving behind spherical cavities as shown in figure



[IIT 1993]

(a) The gravitational force due to this object at the origin is zero

(b) The gravitational force at the point B (2, 0, 0) is zero

(c) The gravitational potential is the same at all points of the circle $y^2+z^2=36$

(d) The gravitational potential is the same at all points on the circle $y^2+z^2=4$

14. Two bodies of masses m_1 and m_2 are initially at rest at infinite distance apart. They are then allowed to move towards each other under mutual gravitational attraction. Their relative velocity of approach at a separation distance r between them is

(a) $\left[2G\frac{(m_1-m_2)}{r}\right]^{1/2}$ (b) $\left[\frac{2G}{r}(m_1+m_2)\right]^{1/2}$

(c) $\left[\frac{r}{2G(m_1m_2)}\right]^{1/2}$ (d) $\left[\frac{2G}{r}m_1m_2\right]^{1/2}$

15. A projectile is projected with velocity kv_e in vertically upward direction from the ground into the space. (v_e is escape velocity and $k<1$). If air resistance is considered to be negligible then the maximum height from the centre of earth to which it can go, will be : (R = radius of earth)

[Roorkee 1999; RPET 1999]

(a) $\frac{R}{k^2+1}$ (b) $\frac{R}{k^2-1}$

(c) $\frac{R}{1-k^2}$ (d) $\frac{R}{k+1}$

16. A satellite is launched into a circular orbit of radius R around the earth. A second satellite is launched into an orbit of radius $(1.01)R$. The period of the second satellite is larger than that of the first one by approximately

[IIT 1995]

(a) 0.5% (b) 1.0%

(c) 1.5% (d) 3.0%

17. If the distance between the earth and the sun becomes half its present value, the number of days in a year would have been

[NCERT 1971; CPMT 1971, 97; IIT 1983;

(a) 64.5 (b) 129

(c) 182.5 (d) 730

18. A geostationary satellite orbits around the earth in a circular orbit of radius 36000 km. Then, the time period of a satellite orbiting a few hundred kilometres above the earth's surface $(R_{\text{Earth}}=6400\,km)$ will approximately be

[IIT-JEE (Screening) 2002]

(a) 1/2 h (b) 1 h

(c) 2 h (d) 4 h

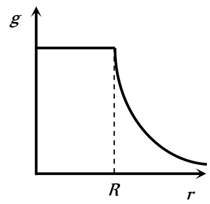
[AMU 1995]

GQ Graphical Questions

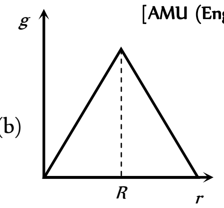
1. Assuming the earth to have a constant density, point out which of the following curves show the variation of acceleration due to gravity from the centre of earth to the points far away from the surface of earth

[AMU (Engg.) 2000]

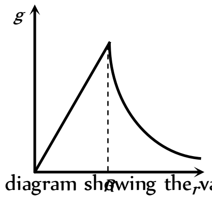
(a)



(b)



(c)

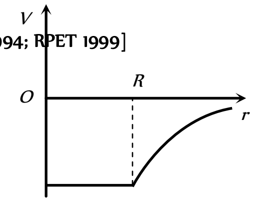


(d) None of these

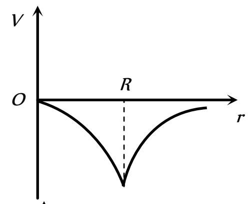
2. The diagram showing the variation of gravitational potential of earth with distance from the centre of earth is

[BHU 1994; RPET 1999]

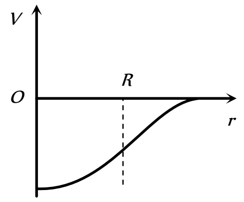
(a)



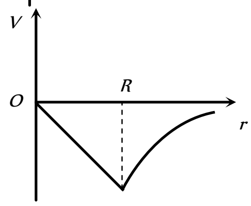
(b)



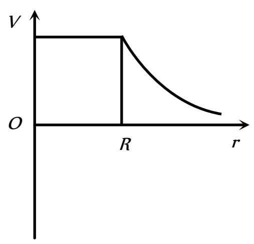
(c)

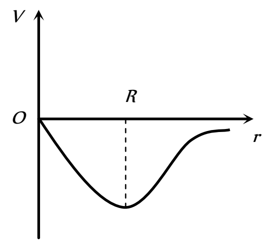


(d)



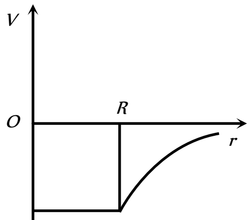
3. By which curve will the variation of gravitational potential of a hollow sphere of radius R with distance be depicted

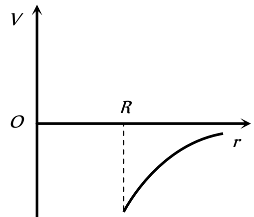




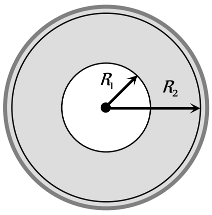
(a)

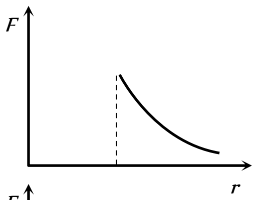
(b)

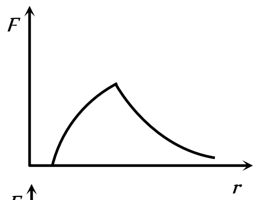
(c) 

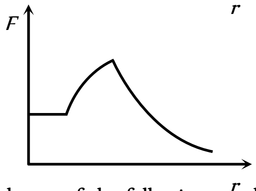
(d) 

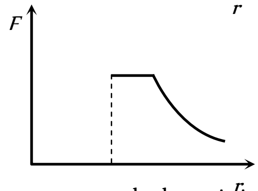
4. A sphere of mass M and radius R_2 has a concentric cavity of radius R_1 as shown in figure. The force F exerted by the sphere on a particle of mass m located at a distance r from the centre of sphere varies as $(0 \le r \le \infty)$



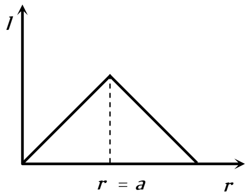
(a) 

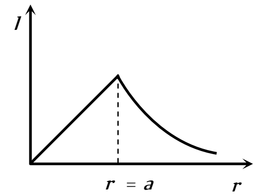
(b) 

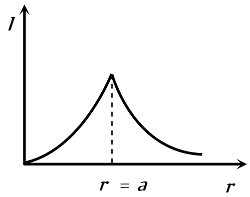
(c) 

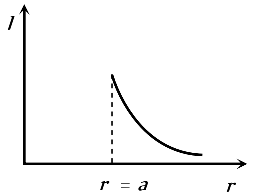
(d) 

5. Which one of the following graphs represents correctly the variation of the gravitational field (F) with the distance (r) from the centre of a spherical shell of mass M and radius a

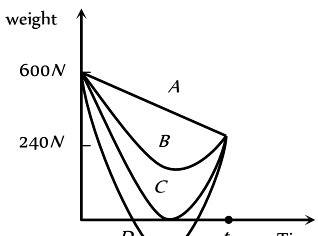
(a) 

(b) 

(c) 

(d) 

6. Suppose, the acceleration due to gravity at the earth's surface is 10 m/s and at the surface of Mars it is 4.0 m/s. A 60 kg passenger goes from the earth to the Mars in a spaceship moving with a constant velocity. Neglect all other objects in the sky. Which part of figure best represents the weight (net gravitational force)of the passenger as a function of time.



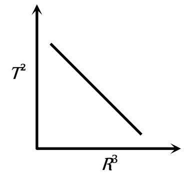
(a) A

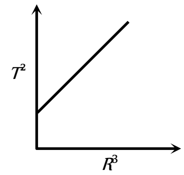
(b) B

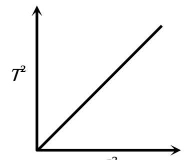
(c) C

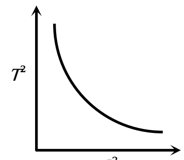
(d) D

7. Which of the following graphs represents the motion of a planet moving about the sun [NCERT 1983]

(a) 

(b) 

(c) 

(d) 

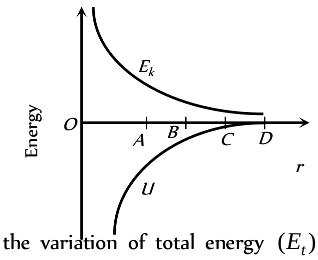
8. The curves for potential energy (U) and kinetic energy (E_k) of a two particle system are shown in figure. At what points the system will be bound?

(a) Only at point D

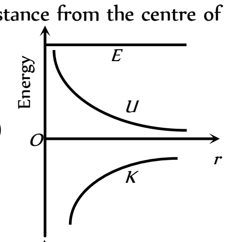
(b) Only at point A

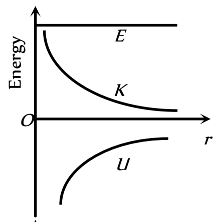
(c) At point D and A

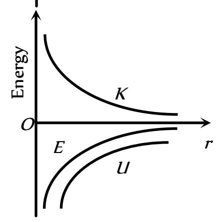
(d) At points A, B and C

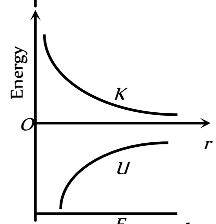


9. The correct graph representing the variation of total energy (E_t) kinetic energy (E_k) and potential energy (U) of a satellite with its distance from the centre of earth is

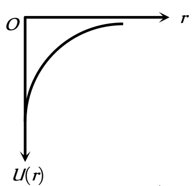
(a) 

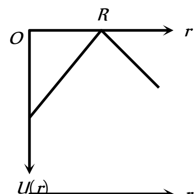
(b) 

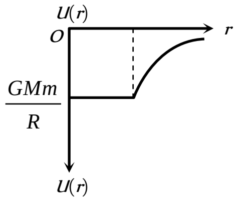
(c) 

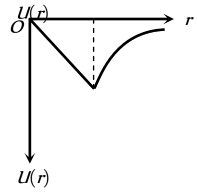
(d) 

10. A shell of mass M and radius R has a point mass m placed at a distance r from its centre. The gravitational potential energy U (r) vs r will be

(a) 

(b) 

(c) 

(d) 

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Smaller the orbit of the planet around the sun, shorter is the time it takes to complete one revolution.
Reason : According to Kepler's third law of planetary motion, square of time period is proportional to cube of mean distance from sun.

2. Assertion : Gravitational force between two particles is negligibly small compared to the electrical force.
Reason : The electrical force is experienced by charged particles only.

3. Assertion : The universal gravitational constant is same as acceleration due to gravity.
Reason : Gravitational constant and acceleration due to gravity have same dimensional formula.

4. Assertion : The value of acceleration due to gravity does not depend upon mass of the body on which force is applied.
Reason : Acceleration due to gravity is a constant quantity.

5. Assertion : If a pendulum is suspended in a lift and lift is falling freely, then its time period becomes infinite.
Reason : Free falling body has acceleration equal to acceleration due to gravity.

6. Assertion : If earth suddenly stops rotating about its axis, then the value of acceleration due to gravity will become same at all the places.
Reason : The value of acceleration due to gravity is independent of rotation of earth.

7. Assertion : The difference in the value of acceleration due to gravity at pole and equator is proportional to square of angular velocity of earth.
Reason : The value of acceleration due to gravity is minimum at the equator and maximum at the pole.

8. Assertion : There is no effect of rotation of earth on acceleration due to gravity at poles.
Reason : Rotation of earth is about polar axis.

9. Assertion : A force act upon the earth revolving in a circular orbit about the sun. Hence work should be done on the earth.
Reason : The necessary centripetal force for circular motion of earth comes from the gravitational force between earth and sun.

10. Assertion : The ratio of inertial mass to gravitational mass is equal to one.
Reason : The inertial mass and gravitational mass of a body are equivalent.

11. Assertion : Gravitational potential of earth at every place on it is negative.
Reason : Every body on earth is bound by the attraction of earth.

12. Assertion : Even when orbit of a satellite is elliptical, its plane of rotation passes through the centre of earth.
Reason : According to law of conservation of angular momentum plane of rotation of satellite always remain same.

13. Assertion : A planet moves faster, when it is closer to the sun in its orbit and vice versa.
Reason : Orbital velocity in orbital of planet is constant.

14. Assertion : Orbital velocity of a satellite is greater than its escape velocity.
Reason : Orbit of a satellite is within the gravitational field of earth whereas escaping is beyond the gravitational field of earth.

15. Assertion : If an earth satellite moves to a lower orbit, there is some dissipation of energy but the satellite speed increases.
Reason : The speed of satellite is a constant quantity.

16. Assertion : Earth has an atmosphere but the moon does not.
Reason : Moon is very small in comparison to earth.

17. Assertion : The time period of geostationary satellite is 24 hours.
Reason : Geostationary satellite must have the same time period as the time taken by the earth to complete one revolution about its axis.

18. Assertion : The principle of superposition is not valid for gravitational force.
Reason : Gravitational force is a conservative force.

19. Assertion : Two different planets have same escape velocity.
Reason : Value of escape velocity is a universal constant.

20. Assertion : The time period of revolution of a satellite close to surface of earth is smaller than that revolving away from surface of earth.
Reason : The square of time period of revolution of a satellite is directly proportional to cube of its orbital radius.

21. Assertion : When distance between two bodies is doubled and also mass of each body is also doubled, gravitational force between them remains the same.
Reason : According to Newton's law of gravitation, force is directly proportional to mass of bodies and inversely proportional to square of distance between them.

22. Assertion : Generally the path of a projectile from the earth is parabolic but it is elliptical for projectiles going to a very large height.
Reason : The path of a projectile is independent of the gravitational force of earth.

23. Assertion : A body becomes weightless at the centre of earth.
Reason : As the distance from centre of earth decreases, acceleration due to gravity increases.

24. Assertion : Space rockets are usually launched in the equatorial line from west to east.

Reason : The acceleration due to gravity is minimum at the equator.

25. Assertion : The binding energy of a satellite does not depend upon the mass of the satellite.

Reason : Binding energy is the negative value of total energy of satellite.

26. Assertion : We can not move even a finger without disturbing all the stars.

Reason : Every body in this universe attracts every other body with a force which is inversely proportional to the square of distance between them.

27. Assertion : If earth were a hollow sphere, gravitational field intensity at any point inside the earth would be zero.

Reason : Net force on a body inside the sphere is zero.

28. Assertion : For a satellite revolving very near to earth's surface the time period of revolution is given by 1 hour 24 minutes.

Reason : The period of revolution of a satellite depends only upon its height above the earth's surface.

29. Assertion : A person sitting in an artificial satellite revolving around the earth feels weightless.

Reason : There is no gravitational force on the satellite.

30. Assertion : The speed of satellite always remains constant in an orbit.

Reason : The speed of a satellite depends on its path.

31. Assertion : The speed of revolution of an artificial satellite revolving very near the earth is $8\,kms^{-1}$.

Reason : Orbital velocity of a satellite, become independent of height of near satellite.

32. Assertion : Gravitational field is zero both at centre and infinity.

Reason : The dimensions of gravitational field is $[LT^{-2}]$.

33. Assertion : For the planets orbiting around the sun, angular speed, linear speed, *K.E.* changes with time, but angular momentum remains constant.

Reason : No torque is acting on the rotating planet. So its angular momentum is constant.

Answers

Newton's Law of Gravitation

1	a	2	b	3	b	4	b	5	a
6	d	7	b	8	c	9	c	10	d
11	d	12	a	13	d	14	a	15	d
16	b	17	c	18	a	19	c	20	a
21	a	22	a	23	e	24	c		

Acceleration Due to Gravity

1	d	2	b	3	d	4	a	5	b
6	a	7	b	8	d	9	b	10	b
11	c	12	a	13	b	14	c	15	a
16	c	17	c	18	c	19	a	20	d
21	a	22	c	23	d	24	b	25	a
26	d	27	b	28	b	29	b	30	a
31	b	32	a	33	c	34	b	35	c
36	a	37	d	38	b	39	c	40	b
41	c	42	b	43	c	44	b	45	c
46	b	47	a	48	a	49	b	50	a
51	a	52	a	53	c	54	a	55	c
56	d	57	a	58	d	59	b	60	c
61	b	62	a	63	c	64	a	65	c
66	a	67	d	68	d	69	a	70	a
71	a	72	b	73	b	74	b	75	d
76	a	77	d	78	a	79	a	80	b
81	a	82	a	83	d	84	a	85	b
86	b	87	b						

Gravitation Potential, Energy and Escape Velocity

1	c	2	a	3	d	4	a	5	d
6	a	7	b	8	c	9	c	10	c
11	d	12	a	13	b	14	b	15	a
16	d	17	c	18	a	19	b	20	b
21	c	22	b	23	a	24	c	25	a
26	b	27	b	28	c	29	c	30	b
31	a	32	b	33	c	34	a	35	c
36	d	37	a	38	a	39	c	40	c
41	c	42	c	43	d	44	a	45	a
46	b	47	d	48	a	49	a	50	b
51	d	52	a	53	c	54	b	55	a
56	b	57	d	58	d	59	b	60	b
61	c	62	b	63	c	64	c	65	b
66	b	67	a	68	c	69	a	70	a

Motion of Satellite

1	b	2	d	3	d	4	d	5	b
6	b	7	b	8	b	9	c	10	c
11	b	12	d	13	b	14	a	15	a
16	b	17	c	18	d	19	d	20	d
21	d	22	b	23	b	24	a	25	a
26	d	27	a	28	d	29	a	30	a
31	b	32	d	33	a	34	c	35	d
36	c	37	d	38	b	39	c	40	b
41	c	42	d	43	a	44	d	45	a
46	c	47	c	48	d	49	b	50	b
51	a	52	a	53	a	54	c	55	b

56	b	57	b	58	d	59	d	60	b
61	c	62	c	63	b	64	a	65	b
66	c	67	d						

Kepler's laws of Planetary Motion

1	c	2	c	3	c	4	b	5	c
6	b	7	b	8	c	9	c	10	b
11	d	12	b	13	c	14	c	15	a
16	b	17	d	18	d	19	b	20	c
21	c	22	c	23	b	24	b	25	c
26	a	27	a	28	b	29	d	30	b
31	a	32	a	33	a	34	c	35	b
36	d	37	a	38	c	39	b	40	c
41	d	42	a	43	d	44	d	45	b
46	a	47	b	48	b	49	c	50	c
51	c								

Critical Thinking Questions

1	b	2	ab	3	a	4	b	5	a
6	c	7	bcd	8	b	9	d	10	b
11	c	12	c	13	acd	14	b	15	c
16	c	17	b	18	c				

Graphical Questions

1	c	2	c	3	c	4	b	5	d
6	c	7	c	8	d	9	c	10	c

Assertion and Reason

1	a	2	b	3	d	4	c	5	a
6	c	7	b	8	a	9	e	10	a
11	a	12	a	13	c	14	e	15	c
16	b	17	b	18	e	19	d	20	a
21	a	22	c	23	c	24	b	25	e
26	a	27	a	28	a	29	c	30	e
31	a	32	b	33	a				

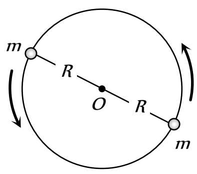
Answers and Solutions

Newton's Law of Gravitation

1. (a)
2. (b) As it depends on the weight of the body.
3. (b) Due to inertia of direction.
4. (b)
5. (a)
6. (d) $F \propto \frac{1}{r^2}$. If r becomes double then F reduces to $\frac{F}{4}$
7. (b)
8. (c) $F = G\frac{m_1 m_2}{r^2} = 6.675 \times \frac{1 \times 1}{1^2} \times 10^{-11} = 6.675 \times 10^{-11}\, N$
9. (c) Centripetal force provided by the gravitational force of attraction between two particles

   i.e. $\frac{mv^2}{R} = \frac{Gm \times m}{(2R)^2}$

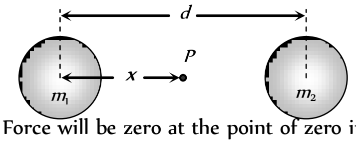
   $\Rightarrow v = \frac{1}{2}\sqrt{\frac{Gm}{R}}$



10. (d) $m = 6 \times 10^{24}\, kg,\ \omega = 2 \times 10^{-7}\, rad/s,\ R = 1.5 \times 10^{11}\, m$

    The force exerted by the sun on the earth $F = m\omega^2 R$

    By substituting the value we can get, $F = 36 \times 10^{21}\, N$
11. (d)
12. (a) k represents gravitational constant which depends only on the system of units.
13. (d)



    Force will be zero at the point of zero intensity

    $x = \frac{\sqrt{m_1}}{\sqrt{m_1} + \sqrt{m_2}} d = \frac{\sqrt{81M}}{\sqrt{81M} + \sqrt{M}} D = \frac{9}{10} D.$
14. (a)
15. (d) $g = \frac{GM}{R^2} = \frac{6.67 \times 10^{-11} \times 7.34 \times 10^{22}}{(1.74 \times 10^6)^2} = 1.62\, N/kg$
16. (b) Actually gravitational force provides the centripetal force.
17. (c)
18. (a) $F \propto xm \times (1-x)m = xm^2(1-x)$

    For maximum force $\frac{dF}{dx} = 0$

    $\Rightarrow \frac{dF}{dx} = m^2 - 2xm^2 = 0 \Rightarrow x = 1/2$
19. (c)
20. (a)
21. (a) Gravitational force does not depend on the medium.
22. (a)
23. (e)
24. (c) $F = \frac{G \times m \times m}{(2R)^2} = \frac{G \times \left(\frac{4}{3}\pi R^3 \rho\right)^2}{4R^2} = \frac{4}{9}\pi^2 \rho^2 R^4$

    $\therefore\ F \propto R^4$

Acceleration Due to Gravity

1. (d)
2. (b) The value of g at the height h from the surface of earth

   $g' = g\left(1 - \frac{2h}{R}\right)$

   The value of g at depth x below the surface of earth

   $g' = g\left(1 - \frac{x}{R}\right)$

   These two are given equal, hence $\left(1 - \frac{2h}{R}\right) = \left(1 - \frac{x}{R}\right)$

   On solving, we get $x = 2h$
3. (d) Time period of simple pendulum $T = 2\pi\sqrt{\frac{l}{g'}}$

   In artificial satellite $g' = 0\ \therefore\ T$ = infinite.
4. (a) $g = \frac{4}{3}\pi\rho GR$. If ρ = constant then $\frac{g_1}{g_2} = \frac{R_1}{R_2}$
5. (b) Time of decent $t = \sqrt{\frac{2h}{g}}$. In vacuum no other force works except gravity so time period will be exactly equal.
6. (a)

7. (b) Because acceleration due to gravity increases

8. (d) Because acceleration due to gravity decreases

9. (b) We know that $g = \frac{GM}{R^2}$

On the planet $g_p = \frac{GM/7}{R^2/4} = \frac{4g}{7} = \frac{4}{7}g$

Hence weight on the planet $= 700 \times \frac{4}{7} = 400\ gm\,wt$

10. (b) In pendulum clock the time period depends on the value of g, while in spring watch, the time period is independent of the value of g.

11. (c) $g = \frac{GM}{R^2} = \frac{GM_0}{(D_0/2)^2} = \frac{4GM_0}{D_0^2}$

12. (a)

13. (b) $\frac{g'}{g} = \frac{M'}{M}\left(\frac{R}{R'}\right)^2 = \left(\frac{2M}{M}\right)\left(\frac{R}{2R}\right)^2 = \frac{1}{2}$

$\Rightarrow g' = \frac{g}{2} = \frac{9.8}{2} = 4.9\ m/s^2$

14. (c)

15. (a)

16. (c) For the condition of weightlessness at equator

$\omega = \sqrt{\frac{g}{R}}\ \therefore\ \omega = \sqrt{\frac{1}{640 \times 10^3}} = \frac{1}{800} rad/s$

17. (c) $g = \frac{GM}{r^2}$. Since M and r are constant, so $g = 9.8\ m/s^2$

18. (c) $g = \frac{GM}{R^2}$ and $M = \frac{4}{3}\pi R^3 \times \rho$

$\therefore g = \frac{4}{3}\frac{\pi R^3 \times G\rho}{R^2} \Rightarrow \rho = \frac{3g.}{4\pi RG}$

19. (a) Because value of g decreases when we move either in coal mine or at the top of mountain.

20. (d) $g = \frac{4}{3}\pi\rho GR\ \therefore\ \frac{g_1}{g_2} = \frac{R_1\rho_1}{R_2\rho_2}$

21. (a) $g = \frac{GM}{R^2}$ (Given $M_e = 81M_m$, $R_e = 3.5R_m$)

Substituting the above values, $\frac{g_m}{g_e} = 0.15$

22. (c) Value of g decreases when we go from poles to equator.

23. (d)

24. (b) Because value of g decreases with increasing height.

25. (a) $\frac{g'}{g} = \left(\frac{R}{R+h}\right)^2 = \left(\frac{6400}{6400+64}\right)^2 \Rightarrow g' = 960.40\ cm/s^2$

26. (d)

27. (b) $g' = g - \omega^2 R\cos^2\lambda$

Rotation of the earth results in the decreased weight apparently. This decrease in weight is not felt at the poles as the angle of latitude is 90°.

28. (b) $g = \frac{GM}{R^2}$. If radius shrinks to half of its present value then g will becomes four times.

29. (b) Using $g = \frac{GM}{R^2}$ we get $g_m = g/5$

30. (a) $g = g_p - R\omega^2\cos^2\lambda = g_p - \omega^2 R\cos^2 60° = g_p - \frac{1}{4}R\omega^2$

31. (b) $g' = g\left(1 - \frac{d}{R}\right) \Rightarrow \frac{g}{n} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = \left(\frac{n-1}{n}\right)R$

32. (a) $g \propto \frac{GM}{r^2}\ \therefore\ g \propto \frac{1}{r^2}$ or $r \propto \frac{1}{\sqrt{g}}$

If g decrease by one percent then r should be increase by $\frac{1}{2}$% *i.e.* $R = \frac{1}{2 \times 100} \times 6400 = 32\ km$

33. (c) $g = \frac{4}{3}G\pi R\rho \Rightarrow \frac{g_1}{g_2} = \frac{\rho_1 R_1}{\rho_2 R_2} = \frac{1}{2} \times \frac{4}{1} = \frac{2}{1}$

34. (b) $g' = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{g}{4} = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{2} = \frac{R}{R+h}$

$\Rightarrow R + h = 2R\ \therefore\ h = R$

35. (c) Acceleration due to gravity at poles is independent of the angular spe

36. (a) Mass of the ball always remain constant. It does not depend upon the acceleration due to gravity

37. (d) $g_m = \frac{GM_m}{R_m^2}$ and $g_m = \frac{g_e}{6} = \frac{9.8}{6}\ m/s^2 = 1.63\ m/s^2$

Substituting $R_m = 1.768 \times 10^6 m$, $g_m = 1.63\ m/s^2$

and $G = 6.67 \times 10^{-11}\ N\text{-}m^2/kg^2$ We get

$M_m = 7.65 \times 10^{22} kg$

38. (b) $g' = g\left(\frac{R}{R+h}\right)^2 \Rightarrow$ when $h = R$ then $g' = \frac{g}{4}$

So the weight of the body at this height will become one-fourth.

39. (c) $g = \frac{GM}{R^2}$ and $K = \frac{L^2}{2I}$

If mass of the earth and its angular momentum remains constant then $g \propto \frac{1}{R^2}$ and $K \propto \frac{1}{R^2}$

i.e. if radius of earth decreases by 2% then g and K both increases by 4%.

40. (b) Weight is least at the equator.

41. (c) $g \propto \frac{1}{R^2}$

Percentage change in g = 2(percentage change in R)

$= 2 \times 1.5 = -3\%$

42. (b) $g \propto \frac{1}{R^2}$. If radius of earth decreases by 2% then g will increase by 4% *i.e.* weight of the body at earth surface will increase by 4%

43. (c) Mass does not vary from place to place.

44. (b) $g = \frac{GM}{R^2} \Rightarrow R = \sqrt{\frac{GM}{g}}$

Substituting the above values we get $R = 1.87 \times 10^6 m$.

45. (c) Weight of the body at equator = $\frac{3}{5}$ of initial weight

$\therefore g' = \frac{3}{5}g$ (because mass remains constant)

$g' = g - \omega^2 R\cos^2\lambda \Rightarrow \frac{3}{5}g = g - \omega^2 R\cos^2(0°)$

$\Rightarrow \omega^2 = \frac{2g}{5R} \Rightarrow \omega = \sqrt{\frac{2g}{5R}} = \sqrt{\frac{2\times 10}{5\times 6400\times 10^3}}$

$= 7.8\times 10^{-4}\ \frac{rad}{\sec}$

46. (b) $h = 32\,km$, $R = 6400\,km$, so $h << R$

$g' = g\left(1 - \frac{2h}{R}\right) = g\left(1 - \frac{2\times 32}{6400}\right) \Rightarrow g' = \frac{99}{100}g = 0.99\,g$

47. (a) Same change in the value of g can be observed at a depth x and height $2x$

given $d = x = 10\,km$ $\therefore h = 2x = 20\ km$

48. (a)

49. (b) $\frac{g'}{g} = \left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{100} = \left(\frac{R}{R+h}\right)^2 \Rightarrow h = 9R$

50. (a) $g' = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{R+\frac{R}{2}}\right)^2 = \frac{4}{9}g$

$\therefore W' = \frac{4}{9}\times W = \frac{4}{9}\times 72 = 32N$

51. (a) $g' = g - \omega^2 R\cos^2\lambda \Rightarrow 0 = g - \omega^2 R\cos^2 60^o$

$0 = g - \frac{\omega^2 R}{4} \Rightarrow \omega = 2\sqrt{\frac{g}{R}} = \frac{1}{400}\frac{rad}{\sec} = 2.5\times 10^{-3}\ \frac{rad}{sec}$

52. (a) $g' = g\left(1 - \frac{d}{R}\right) = 9.8\left(1 - \frac{100}{6400}\right) = 9.66\,m/s^2$

53. (c) $g' = g\left(\frac{R}{R+h}\right)^2 = \frac{g}{4}$. By solving $h = R$

54. (a) $g = \frac{4}{3}\pi\rho GR \therefore g \propto r\rho \therefore \frac{g_e}{g_m} = \frac{R}{r}\times\frac{\rho_e}{\rho_m}$

55. (c) $g_p = g_e\left(\frac{M_p}{M_e}\right)\left(\frac{R_e}{R_p}\right)^2 = 9.8\left(\frac{1}{80}\right)(2)^2$

$= 9.8/20 = 0.49\ m/s^2$

56. (d) Range of projectile $R = \frac{u^2\sin 2\theta}{g}$

if u and θ are constant then $R \propto \frac{1}{g}$

$\frac{R_m}{R_e} = \frac{g_e}{g_m} \Rightarrow \frac{R_m}{R_e} = \frac{1}{0.2} \Rightarrow R_m = \frac{R_e}{0.2} \Rightarrow R_m = 5R_e$

57. (a) For condition of weightlessness of equator

$\omega = \sqrt{\frac{g}{R}} = \frac{1}{800} = 1.25\times 10^{-3}\ \frac{rad}{s}$

58. (d) $g' = g\left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{\sqrt{2}} = \frac{R}{R+h}$

$\Rightarrow R + h = \sqrt{2}\,R \Rightarrow h = (\sqrt{2}-1)R = 0.414\,R$

59. (b) $g \propto \rho R$

60. (c) $H = \frac{u^2}{2g} \Rightarrow H \propto \frac{1}{g} \Rightarrow \frac{H_B}{H_A} = \frac{g_A}{g_B}$

Now $g_B = \frac{g_A}{12}$ as $g \propto \rho R$

$\therefore \frac{H_B}{H_A} = \frac{g_A}{g_B} = 12 \Rightarrow H_B = 12\times H_A = 12\times 1.5 = 18m$

61. (b)

62. (a) $g' = g\left(\frac{R}{R+h}\right)^2 = \frac{g}{\left(1+\frac{h}{R}\right)^2}$

63. (c) $g = \frac{4}{3}\pi\rho GR \Rightarrow g \propto dR$ ($\rho = d$ given in the problem)

64. (a) Inside the earth $g' = \frac{4}{3}\pi\rho Gr \therefore g' \propto r$

65. (c) $g' = g\left(\frac{R}{R+h}\right)^2 = \frac{4}{9}g \quad \therefore W' = \frac{4}{9}W$

66. (a) $g \propto \rho$

67. (d)

68. (d)

69. (a) $g' = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{3R/2}\right)^2 = \frac{4}{9}g$

$\therefore W' = \frac{4}{9}\times mg = \frac{4\times 200\times 9.8}{9} = 880\ N$

70. (a) $g = \frac{4}{3}\pi G\rho R \Rightarrow g \propto \rho R \Rightarrow \frac{g_e}{g_m} = \frac{\rho_e}{\rho_m}\times\frac{R_e}{R_m}$

$\Rightarrow \frac{6}{1} = \frac{5}{3}\times\frac{R_e}{R_m} \Rightarrow R_m = \frac{5}{18}R_e$

71. (a) $g' = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{R+2R}\right)^2 = \frac{g}{9}$

72. (b) $g' = g\left(1 - \frac{d}{R}\right) \Rightarrow \frac{g}{4} = g\left(1 - \frac{d}{R}\right) \Rightarrow d = \frac{3}{4}R$

73. (b) For height $\frac{\Delta g}{g}\times 100\% = \frac{2h}{R} = 1\%$;

For depth $\frac{\Delta g}{g}\times 100\% = \frac{d}{R} = \frac{h}{R} = \frac{1}{2}\% = 0.5\%$

74. (b) As $g = \frac{GM}{R^2}$ therefore 1% decrease in mass will decreases the value of g by 1%.

But 1% decrease in radius will increase the value of g by 2%.

As a whole value of g increase by 1%.

75. (d) $g = \frac{4}{3}\pi\rho GR \Rightarrow \frac{R_p}{R_e} = \left(\frac{g_p}{g_e}\right)\left(\frac{\rho_e}{\rho_p}\right) = (1)\times\left(\frac{1}{2}\right)$

$\Rightarrow R_p = \frac{R_e}{2} = \frac{R}{2}$

76. (a) $\frac{g_1}{g_2} = \frac{\rho_1}{\rho_2}\times\frac{R_1}{R_2} = \frac{3}{2}\times\frac{2}{3} = 1$

77. (d) Because the body weighs zero in satellite

78. (a) Radius of earth $R = 6400\ km \therefore\ h = \frac{R}{4}$

Acceleration due to gravity at a height h

$$g_h = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{R+\frac{R}{4}}\right)^2 = \frac{16}{25}g$$

At depth 'd value of acceleration due to gravity

$g_d = \frac{1}{2}g_h$ (According to problem)

$$\Rightarrow g_d = \frac{1}{2}\left(\frac{16}{25}\right)g \Rightarrow g\left(1-\frac{d}{R}\right) = \frac{1}{2}\left(\frac{16}{25}\right)g$$

By solving we get $d = 4.3\times10^6\ m$

79. (a) $g' = g - \omega^2 R\cos^2\lambda$

For weightlessness at equator $\lambda = 0°$ and $g' = 0$

$\therefore\ 0 = g - \omega^2 R \Rightarrow \omega = \sqrt{\frac{g}{R}} = \frac{1}{800}\frac{rad}{\sec}$

80. (b) Weight on surface of earth, $mg = 500\ N$

and weight below the surface of earth at $d = \frac{R}{2}$

$$mg' = mg\left(1-\frac{d}{R}\right) = mg\left(1-\frac{1}{2}\right) = \frac{mg}{2} = 250\ N$$

81. (a) $g = \frac{4}{3}\pi GR\rho$ and $g' = \frac{4}{3}\pi GR'\rho$

$\therefore\ \frac{g'}{g} = \frac{R'}{R} = 0.2 \Rightarrow g' = 0.2\,g$

82. (a)

83. (d) $\frac{g_m}{g_e} = \frac{M_m}{M_e}\times\left(\frac{R_e}{R_m}\right)^2 = \left(\frac{1}{9}\right)\left(\frac{2}{1}\right)^2 = \frac{4}{9} \Rightarrow g_m = \frac{4}{9}g_e$

$\therefore\ W_m = \frac{4}{9}\times W_e = \frac{4}{9}\times 90 = 40\ kg$

84. (a) $g' = g - \omega^2 R$, when ω increases g' decreases.

85. (b) $\frac{g'}{g} = \frac{M'}{M}\times\frac{R^2}{R'^2} = \frac{1}{2}\times\frac{4}{1} = \frac{2}{1}$

86. (b) Acceleration due to gravity at latitude λ is given by

$g' = g - R\omega^2\cos^2\lambda$

At 30^o, $g_{30°} = g - R\omega^2\cos^2 30^o = g - \frac{3}{4}R\omega^2$

$\therefore\ g - g_{30} = \frac{3}{4}\omega^2 R.$

87. (b) Acceleration due to gravity $g = \frac{GM}{R^2}\ \therefore\ \frac{g}{G} = \frac{M}{R^2}$

Gravitational Potential, Energy and Escape Velocity

1. (c) $\Delta U = \frac{mgh}{1+h/R}$

Substituting $R = 5h$ we get $\Delta U = \frac{mgh}{1+1/5} = \frac{5}{6}mgh$

2. (a) $I = \frac{-dV}{dx}$

If $V = 0$ then gravitational field is necessarily zero.

3. (d) Gravitational potential $= \int I\,dx = \int_x^\infty \frac{K}{x^3}dx$

$$= K\left(\frac{x^{-3+1}}{-3+1}\right)_x^\infty = \left|\frac{-K}{2x^2}\right|_x^\infty = \frac{K}{2x^2}$$

4. (a) $U = -\frac{GMm}{r}$

$$\Rightarrow 7.79\times10^{28} = \frac{6.67\times10^{-11}\times7.4\times10^{22}\times6\times10^{24}}{r}$$

$\Rightarrow r = 3.8\times10^8\ m$

5. (d) $\Delta U = \frac{mgh}{1+\frac{h}{R}} = \frac{mg\,nR}{1+\frac{nR}{R}} = \frac{nm\,gR}{n+1}$

6. (a) Gravitational potential at mid point

$V = \frac{-GM_1}{d/2} + \frac{-GM_2}{d/2}$

Now, $PE = m\times V = \frac{-2Gm}{d}(M_1+M_2)$

[m = mass of particle]

So, for projecting particle from mid point to infinity

$KE = |PE|$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{2Gm}{d}(M_1+M_2) \Rightarrow v = 2\sqrt{\frac{G(M_1+M_2)}{d}}$$

7. (b) Potential energy of the 1 kg mass which is placed at the earth surface $= -\frac{GM}{R}$

its potential energy at infinite = 0

$\therefore$ Work done = change in potential energy $= \frac{GM}{R}$

8. (c)

9. (c) $\frac{G\times100}{x^2} = \frac{G\times10000}{(1-x)^2} \Rightarrow \frac{10}{x} = \frac{100}{1-x} \Rightarrow x = \frac{1}{11}m$

10. (c)

11. (d) $\Delta U = U_2 - U_1 = \dfrac{mgh}{1+\dfrac{h}{R_e}} = \dfrac{mgR_e}{1+\dfrac{R_e}{R_e}} = \dfrac{mgR_e}{2}$

$\Rightarrow U_2 - (-mgR_e) = \dfrac{mgR_e}{2} \Rightarrow U_2 = -\dfrac{1}{2}mgR_e$

12. (a) $v_e = \sqrt{\dfrac{2GM}{R}} = 100 \Rightarrow \dfrac{GM}{R} = 5000$

Potential energy $U = -\dfrac{GMm}{R} = -5000\ J$

13. (b) $\Delta U = \dfrac{mgh}{1+\dfrac{h}{R}} = \dfrac{mg\times 3R}{1+\dfrac{3R}{R}} = \dfrac{3}{4}mgR$

14. (b) Potential energy $U = \dfrac{-GMm}{r} = -\dfrac{GMm}{R+h}$

$U_{initial} = -\dfrac{GMm}{3R}$ and $U_{final} = -\dfrac{-GMm}{2R}$

Loss in PE = gain in $KE = \dfrac{GMm}{2R} - \dfrac{GMm}{3R} = \dfrac{GMm}{6R}$

15. (a) If body is projected with velocity v $(v < v_e)$ then

height up to which it will rise, $h = \dfrac{R}{\dfrac{v_e^2}{v^2} - 1}$

$v = \dfrac{v_e}{2}$ (given) $\therefore h = \dfrac{R}{\left(\dfrac{v_e}{v_e/2}\right)^2 - 1} = \dfrac{R}{4-1} = \dfrac{R}{3}$

16. (d) Change in potential energy in displacing a body from r_1 to r_2 is given by

$\Delta U = GMm\left[\dfrac{1}{r_1} - \dfrac{1}{r_2}\right] = GMm\left(\dfrac{1}{2R} - \dfrac{1}{3R}\right) = \dfrac{GMm}{6R}$

17. (c) $\dfrac{1}{2}mv_e^2 = \dfrac{1}{2}m\ 2gR = mgR$

18. (a) $K.E. = \dfrac{GMm}{2R}$

19. (b) $I = \dfrac{-dV}{dr}$. If $I = 0$ then V = constant

20. (b) This should be equal to escape velocity *i.e.* $\sqrt{2gR}$

21. (c) $v_e = \sqrt{\dfrac{2GM}{R}}$ *i.e.* escape velocity depends upon the mass and radius of the planet.

22. (b) $v_e = \sqrt{\dfrac{2GM}{R}} = R\sqrt{\dfrac{8}{3}\pi G\rho}$

If mean density is constant then $v_e \propto R$

$\dfrac{v_e}{v_p} = \dfrac{R_e}{R_p} = \dfrac{1}{2} \Rightarrow v_e = \dfrac{v_p}{2}$

23. (a) Escape velocity does not depend on the mass of the projectile

24. (c) $\dfrac{v_p}{v_e} = \sqrt{\dfrac{g_p}{g_e}\times\dfrac{R_p}{R_e}} = \sqrt{2\times 2} = 2$

$\Rightarrow v_p = 2\times v_e = 2\times 11.2 = 22.4\ km/s$

25. (a) $v_e = \sqrt{\dfrac{2GM}{R}} = R\sqrt{\dfrac{8}{3}\pi G\rho}$ $\therefore v_e \propto R$ if ρ = constant

Since the planet having double radius in comparison to earth therefore the escape velocity becomes twice *i.e.* 22 *km/s.*

26. (b) If missile launched with escape velocity then it will escape from the gravitational field and at infinity its total energy becomes zero.

But if the velocity of projection is less than escape velocity then sum of energies will be negative. This shows that attractive force is working on the satellite.

27. (b)

28. (c)

29. (c) Because it does not depend on the mass of projectile

30. (b) $v_e = \sqrt{2}\,v_0$, *i.e.* if the orbital velocity of moon is increased by factor of $\sqrt{2}$ then it will escape out from the gravitational field of earth.

31. (a)

32. (b) $v_e = \sqrt{\dfrac{2GM}{R}} \Rightarrow v_e \propto \sqrt{M}$ if R = constant

If the mass of the planet becomes four times then escape velocity will become 2 times.

33. (c) Escape velocity $v_e = \sqrt{\dfrac{2GM}{R}}$

$\therefore \dfrac{v_e}{v_m} = \sqrt{\dfrac{M_eR_m}{M_mR_e}} = \sqrt{\dfrac{81}{3.5}} = 4.81$

34. (a) $v_e = \sqrt{\dfrac{2GM}{R}}$ $\therefore v_e \propto \sqrt{\dfrac{M}{R}}$

If mass and radius of the planet are three times than that of earth then escape velocity will be same.

35. (c) Potential energy of a body at the surface of earth

$PE = -\dfrac{GMm}{R} = -\dfrac{gR^2m}{R} = -mgR$

$= -500\times 9.8\times 6.4\times 10^6 = -3.1\times 10^{10}\ J$

So if we give this amount of energy in the form of kinetic energy then body escape from the earth.

36. (d) Escape velocity $v = \sqrt{\dfrac{2GM}{R}} \Rightarrow \dfrac{v_p}{v_e} = \sqrt{\dfrac{M_p}{M_e}\times\dfrac{R_e}{R_p}}$

$\Rightarrow v_p = 5v_e = 5\times 11.2 = 56\ km/s$

37. (a) $\dfrac{v_p}{v_e} = \sqrt{\dfrac{M_p}{M_e}\times\dfrac{R_e}{R_p}} = \sqrt{6\times\dfrac{1}{2}} = \sqrt{3}$ $\therefore v_p = \sqrt{3}\,v_e$

38. (a) $\frac{v_p}{v_e} = \sqrt{\frac{g_p}{g_e} \times \frac{R_p}{R_e}} = \sqrt{9 \times 4} = 6 \therefore v_p = 6 \times v_e = 67.2 km/s$

39. (c) $\frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e} \times \frac{R_p}{R_e}} = \sqrt{8 \times \frac{1}{2}} = 2 \therefore v_p = 2 \times v_e = 22.4 km/s$

40. (c) $v_e = \sqrt{\frac{2GM}{R}} \therefore v_e \propto \sqrt{\frac{M}{R}}$

If M becomes double and R becomes half then escape velocity becomes two times.

41. (c) On earth $v_e = \sqrt{\frac{2GM}{R}} = 11.2 \ km/s$

On moon $v_m = \sqrt{\frac{2GM \times 4}{81 \times R}} = \frac{2}{9}\sqrt{\frac{2GM}{R}}$

$= \frac{2}{9} \times 11.2 = 2.5 \ km/s$

42. (c) Escape velocity $v = \sqrt{\frac{2GM}{R}}$

If star rotates with angular velocity ω

then $\omega = \frac{v}{R} = \frac{1}{R}\sqrt{\frac{2GM}{R}} = \sqrt{\frac{2GM}{R^3}}$

43. (d) Escape velocity from surface of earth $v_e = \sqrt{2gR}$

$= \sqrt{2 \times 9.8 \times 6.4 \times 10^6} = 11.2 \times 10^3 \ m/s$

44. (a)

45. (a) $\frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e} \frac{R_e}{R_p}} = \sqrt{(1000) \times \left(\frac{1}{10}\right)} = 10$

$v_p = 10 \times 11.2 = 112 \ km/s$

46. (b) $v_e = R\sqrt{\frac{8}{3} G\pi\rho} \therefore v_e \propto R\sqrt{\rho}$

47. (d) $v_e = \sqrt{\frac{2GM}{(R+h)}}$

48. (a) $v = \sqrt{2gR}$. If acceleration due to gravity and radius of the planet, both are double that of earth then escape velocity will be two times. *i.e.* $v_p = 2v_e$

49. (a)

50. (b) $v = \sqrt{2gR} \Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{g_A}{g_B} \times \frac{R_A}{R_B}} = \sqrt{k_1 \times k_2} = \sqrt{k_1 k_2}$

51. (d) $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 6 \times 10^{24}}{R}} = 3 \times 10^8$

By solving $R = 9 \ mm$

52. (a) $\frac{v_p}{v_e} = \sqrt{\frac{M_p}{M_e} \times \frac{R_e}{R_p}} = \sqrt{2 \times \frac{1}{3}} = \sqrt{\frac{2}{3}} \therefore v_p = \sqrt{\frac{2}{3}} v_e$

53. (c) $v_e \propto \frac{1}{\sqrt{R}}$. If R becomes $\frac{1}{4}$ then v_e will be 2 times.

54. (b)

55. (a) $v = \sqrt{2gR} \Rightarrow \frac{v_p}{v_e} = \sqrt{\frac{g_p}{g_e} \times \frac{R_e}{R_p}} = \sqrt{2 \times \frac{1}{4}} = \frac{1}{\sqrt{2}}$

$\therefore v_p = \frac{v_e}{\sqrt{2}}$

56. (b) $v \propto R\sqrt{\rho} \therefore \frac{v_p}{v_e} = \frac{R_p}{R_e} \times \sqrt{\frac{\rho_p}{\rho_e}} = 4 \times \sqrt{9} = 12$

$\Rightarrow v_p = 12 v_e$

57. (d) Escape velocity does not depends upon the angle of projection.

58. (d)

59. (b) Escape velocity is independent of mass of object.

60. (b) $v = \sqrt{2gR} \Rightarrow \frac{v_p}{v_e} = \sqrt{\frac{g_p}{g_e} \times \frac{R_p}{R_e}} = \sqrt{1 \times 4} = 2$

$\therefore v_p = 2v_e$

61. (c) $v = \sqrt{2gR} \Rightarrow \frac{v_p}{v_e} = \sqrt{\frac{g_p}{g_e} \times \frac{R_p}{R_e}} = \sqrt{1 \times 4} = 2$

$\Rightarrow v_p = 2 \times v_e = 2 \times 11.2 = 22.4 \ km/s$

62. (b) $v = \sqrt{2gR}$. If g and R both are doubled then v will becomes two times *i.e.* 11.2 × 2 = 22.4 *km/s*

63. (c) $v = R\sqrt{\frac{8}{3}\pi\rho G} \Rightarrow \frac{v_p}{v_e} = \frac{R_p}{R_e}\sqrt{\frac{\rho_p}{\rho_e}} = 2\sqrt{\frac{1}{4}} = 1$

64. (c) Velocity of body in inter planetary space $v' = \sqrt{v^2 - v_{es}^2}$

where v_{es} = escape velocity and

v = velocity of projection

$\therefore \quad v' = \sqrt{(2v_{es})^2 - v_{es}^2} = \sqrt{3v_{es}^2} \Rightarrow v' = \sqrt{3} \ v_{es}$

65. (b) Potential energy of system of two mass

$U = \frac{-GMm}{R} = \frac{-6.67 \times 10^{-11} \times 100 \times 10 \times 10^{-3}}{10 \times 10^{-2}}$

$U = -6.67 \times 10^{-10} \ J$

So, the amount of work done to take the particle up to infinite will be $6.67 \times 10^{-10} \ J$

66. (b) For a moving satellite kinetic energy $= \frac{GMm}{2r}$

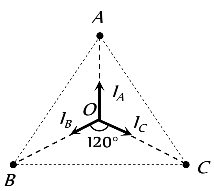
Potential energy $= \frac{-GMm}{r}$

$\therefore \frac{\text{Kinetic energy}}{\text{Potential energy}} = \frac{1}{2}$

67. (a) Due to three particles net intensity at the centre

$I = \vec{I}_A + \vec{I}_B + \vec{I}_C = 0$

because out of these three intensities one equal in magnitude and the angle between each other is 120°.



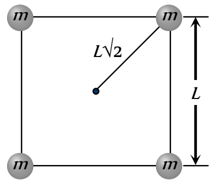
68. (c) $v_0 = \frac{v_e}{\sqrt{2}} = \frac{2}{\sqrt{2}} = \sqrt{2} \ km/s$

69. (a) Potential at the centre due to single mass = $\frac{-GM}{L/\sqrt{2}}$

Potential at the centre due to all four masses

$= -4\frac{GM}{L/\sqrt{2}} \quad -4\sqrt{2}\frac{GM}{L}$

$= -\sqrt{32} \times \frac{GM}{L}$.



70. (a) $v = \sqrt{2gR}$ $\therefore \frac{v_1}{v_2} = \sqrt{\frac{g_1}{g_2} \times \frac{R_1}{R_2}} = \sqrt{g \times K} = (Kg)^{1/2}$

Motion of Satellite

1. (b) $v_e = \sqrt{2gR}$ and $v_0 = \sqrt{gR}$ $\therefore$ $\sqrt{2}\, v_0 = v_e$

2. (d)

3. (d) $v_0 = \sqrt{\frac{GM}{r}}$

4. (d) $v_0 = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{R+h}}$

5. (b) Centripetal acceleration works on it.

6. (b) $v = \sqrt{\frac{GM}{r}}$ if $r_1 > r_2$ then $v_1 < v_2$

Orbital speed of satellite does not depends upon the mass of the satellite

7. (b) $T \propto r^{3/2}$. If r becomes double then time period will becomes $(2)^{3/2}$ times.

So new time period will be $24 \times 2\sqrt{2}\ hr$ *i.e.* $T = 48\sqrt{2}$

8. (b) *K.E.* required for satellite to escape from earth's gravitational field $\frac{1}{2}mv_e^2 = \frac{1}{2}m\left(\sqrt{\frac{2GM}{R}}\right)^2 = \frac{GMm}{R}$

K.E. required for satellite to move in circular orbit

$\frac{1}{2}mv_0^2 = \frac{1}{2}m\left(\sqrt{\frac{GM}{R}}\right)^2 = \frac{GMm}{2R}$

The ratio between these two energies = 2

9. (c) The velocity of the spoon will be equal to the orbital velocity when dropped out of the space-ship.

10. (c)

11. (b) $v_0 = \sqrt{gR}$

12. (d) Telecommunication satellites are geostationary satellite

13. (b) $v = \sqrt{\frac{GM}{R}} \Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{R_B}{R_A}} = \sqrt{\frac{R}{4R}} = \frac{1}{2}$

$\therefore \frac{v_A}{v_B} = \frac{3V}{v_B} = \frac{1}{2}$ $\therefore v_B = 6\,V$

14. (a)

15. (a)

16. (b)

17. (c) $v = \sqrt{\frac{GM}{R+h}}$

For first satellite $h = 0$, $v_1 = \sqrt{\frac{GM}{R}}$

For second satellite $h = \frac{R}{2}$, $v_2 = \sqrt{\frac{2GM}{3R}}$

$v_2 = \sqrt{\frac{2}{3}}v_1 = \sqrt{\frac{2}{3}}v$

18. (d) $v = \sqrt{\frac{GM}{r}}$ $\therefore$ $K.E. \propto v^2 \propto \frac{1}{r}$ and $T^2 \propto r^3$

$\therefore$ $K.E. \propto T^{-2/3}$

19. (d)

20. (d) $T = 2\pi\sqrt{\frac{r^3}{GM}} \Rightarrow r^3 = \frac{GMT^2}{4\pi^2} \Rightarrow r = \left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$

21. (d) $v \propto \frac{1}{\sqrt{r}}$. The speed of satellite decreases with an increase in the radius of its orbit.

22. (b) $v \propto \frac{1}{\sqrt{r}}$.

% increase in speed = $\frac{1}{2}$ (% decrease in radius)

$= \frac{1}{2}(1\%) = 0.5\%$

i.e. speed will increase by 0.5%

23. (b) $v = \sqrt{\frac{GM}{r}}$

24. (a)

25. (a) $v \propto \frac{1}{\sqrt{r}}$. If orbital radius becomes 4 times then orbital velocity will become half. *i.e.* $\frac{7}{2} = 3.5\ km/s$

26. (d) Orbital radius of satellites $r_1 = R + R = 2R$

$r_2 = R + 7R = 8R$

$U_1 = \frac{-GMm}{r_1}$ and $U_2 = \frac{-GMm}{r_2}$

$K_1 = \frac{GMm}{2r_1}$ and $K_2 = \frac{GMm}{2r_2}$

$E_1 = \frac{GMm}{2r_1}$ and $E_2 = \frac{GMm}{2r_2}$

$\therefore \frac{U_1}{U_2} = \frac{K_1}{K_2} = \frac{E_1}{E_2} = 4$

27. (a) Escape velocity is same for all angles of projection.

28. (d) Orbital velocity $v_0 = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{r}}$ and $v_0 = r\omega$

This gives $r^3 = \frac{R^2 g}{\omega^2}$

29. (a)

30. (a) Due to inertia it will continue to move along the original path of the space craft.

31. (b)

32. (d)

33. (a)

34. (c) (i) $T_{st} = 2\pi\sqrt{\frac{(R+h)^3}{GM}} = 2\pi\sqrt{\frac{R}{g}}$

[As $h << R$ and $GM = gR^2$]

(ii) $T_{ma} = 2\pi\sqrt{\frac{R}{g}}$

(iii) $T_{sp} = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{l}+\frac{1}{R}\right)}} = 2\pi\sqrt{\frac{R}{2g}}$

[As $l = R$]

(iv) $T_{is} = 2\pi\sqrt{\frac{R}{g}}$ [As $l = \infty$]

35. (d)

36. (c) $v \propto \frac{1}{\sqrt{r}}$, If $r = R$ then $v = V_0$

If $r = R + h = R + 3R = 4R$ then $v = \frac{V_0}{2} = 0.5V_0$

37. (d)

38. (b) 6R from the surface of earth and 7R from the centre.

39. (c) $T^2 = \frac{4\pi^2}{GM}r^3$. If G is variable then time period, angular velocity and orbital radius also changes accordingly.

40. (b) $T = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}} = 2\pi\sqrt{\frac{(2R)^3}{gR^2}} = 4\sqrt{2}\pi\sqrt{\frac{R}{g}}$

41. (c) $T = 2\pi\sqrt{\frac{r^3}{GM}} \Rightarrow T^2 = \frac{4\pi^2}{GM}(R+h)^3$

$\Rightarrow R + h = \left[\frac{GMT^2}{4\pi^2}\right]^{1/3} \Rightarrow h = \left[\frac{GMT^2}{4\pi^2}\right]^{\frac{1}{3}} - R$

42. (d) Distances of the satellite from the centre are 7R and 3.5R respectively.

$\frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{3.5R}{7R}\right)^{3/2} = 6\sqrt{2}\ hr$

43. (a) $v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}\times6\times10^{24}}{384000\times10^3}} = 1 km/s$

44. (d) % change in $T = \frac{3}{2}$ (% change in R) $= \frac{3}{2}\times(2)\% = 3\%$

45. (a)

46. (c)

47. (c) $v_0 = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{r}} = \sqrt{\frac{10\times(64\times10^5)^2}{8000\times10^3}}$

$= 71.5\times10^2\ m/s = 7.15 km/s$

48. (d) Total mechanical energy of satellite

$E = \frac{-GMm}{2r} \Rightarrow \frac{E_A}{E_B} = \frac{m_A}{m_B}\times\frac{r_B}{r_A} \Rightarrow \frac{3}{1}\times\frac{4r}{r} = \frac{12}{1}$

49. (b)

50. (b) Gravitational force provides the required centripetal force for orbiting the satellite

$\frac{mv^2}{R} = \frac{K}{R}$ because $\left(F \propto \frac{1}{R}\right)$

$\therefore v \propto R^\circ$

51. (a) Total energy = – (kinetic energy) = $-\frac{1}{2}Mv^2$

52. (a) Binding energy = – kinetic energy

And if this amount of energy (E_k) given to satellite then it will escape into outer space

53. (a) Potential energy = $\frac{-GMm}{r} = \frac{GMm}{R_e + h} = \frac{-GMm}{2R_e}$

$= -\frac{gR_e^2 m}{2R_e} = -\frac{1}{2}mgR_e = -0.5mgR_e$

54. (c) $B.E. = -\frac{GMm}{r}$. If $B.E.$ decreases then r also decreases and v increases as $v \propto \frac{1}{\sqrt{r}}$

55. (b) Time period of communication satellite $T_c = 1$ day

Time period of another satellite = T_s

$\frac{T_s}{T_c} = \left(\frac{r_s}{r_c}\right)^{3/2} = (4)^{3/2} \Rightarrow T_s = T_c\times(4)^{3/2} = 8$ days.

56. (b) Angular momentum is conserved in central field.

57. (b) $T^2 \propto r^3$

58. (d) $T^2 \propto R^3 \therefore \frac{T^2}{R^3} =$ constant

59. (d) $T_2 = T_1\left(\frac{R_2}{R_1}\right)^{3/2} = T_1(4)^{3/2} = 8T_1 = 40hr$

60. (b) Given that, $T_1 = 1$ day and $T_2 = 8$ days

$\therefore \frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} \Rightarrow \frac{r_2}{r_1} = \left(\frac{T_2}{T_1}\right)^{2/3} = \left(\frac{8}{1}\right)^{2/3} = 4$

$\Rightarrow r_2 = 4r_1 = 4R$

61. (c)

62. (c) $\frac{v_B}{v_A} = \sqrt{\frac{r_A}{r_B}} = \sqrt{\frac{4R}{R}} = 2$

$\Rightarrow v_B = 2\times v_A = 2\times3v = 6v$

63. (b) Gravitational force provides the required centripetal force

$m\omega^2 R = \frac{GMm}{R^3} \Rightarrow \frac{4\pi^2}{T^2} = \frac{GM}{R^4} \Rightarrow T \propto R^2$

64. (a)

65. (b) $v_e = \sqrt{2}v_0 = 1.414\, v_0$

Fractional increase in orbital velocity $\left(\frac{\Delta v}{v}\right)$

$$= \frac{v_e - v_0}{v_0} = 0.414$$

$\therefore$ Percentage increase = 41.4%

66. (c) Time period of revolution of moon around the earth = 1 lunar month.

$$\frac{T_s}{T_m} = \left(\frac{r_s}{r_m}\right)^{3/2} = \left(\frac{1}{2}\right)^{3/2} \Rightarrow T_s = 2^{-3/2} \text{ lunar month.}$$

67. (d)

Kepler's Laws of Planetary Motion

1. (c) $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{10^{13}}{10^{12}}\right)^{3/2} = (1000)^{1/2} = 10\sqrt{10}$

2. (c) Areal velocity of the planet remains constant. If the areas *A* and *B* are equal then $t_1 = t_2$.

3. (c) $\frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} \Rightarrow T_2 = 8T_1$

4. (b)

5. (c)

6. (b) Since $T^2 \propto r^3$ $\therefore \left(\frac{T'}{T}\right)^2 = \left(\frac{1}{4}\right)^3 \Rightarrow T' = \frac{1}{8}T$

7. (b) Kinetic and potential energies varies with position of earth *w.r.t.* sun. Angular momentum remains constant every where.

8. (c)

9. (c) Angular momentum remains constant

$$mv_1d_1 = mv_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$$

10. (b) Orbital radius of Jupiter > Orbital radius of Earth

$\frac{v_J}{v_e} = \frac{r_e}{r_J}$. As $r_J > r_e$ therefore $v_J < v_e$

11. (d) $T^2 \propto r^3 \Rightarrow \frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2}$

12. (b) $\frac{dA}{dt} = \frac{L}{2m} = \text{constant}$

13. (c) The earth moves around the sun is elliptical path. so by using the properties of ellipse

$r_1 = (1+e)a$ and $r_2 = (1-e)a$

$\Rightarrow a = \frac{r_1 + r_2}{2}$ and $r_1r_2 = (1-e^2)a^2$

where a = semi major axis

b = semi minor axis

e = eccentricity

Now required distance = semi latusrectum $= \frac{b^2}{a}$

$$= \frac{a^2(1-e^2)}{a} = \frac{(r_1r_2)}{(r_1+r_2)/2} = \frac{2r_1r_2}{r_1+r_2}$$

14. (c) For first satellite $r_1 = R$ and $T_1 = 83\; minute$

For second satellite $r_2 = 4R$

$$T_2 = T_1\left(\frac{r_2}{r_1}\right)^{3/2} = T_1(4)^{3/2} = 8T_1 = 8 \times 83 = 664 \textit{ minutes}$$

15. (a) Angular momentum = Mass ×Orbital velocity ×Radius

$$= m \times \left(\sqrt{\frac{GM}{R_0}}\right) \times R_0 = m\sqrt{GMR_0}$$

16. (b) $\frac{T^2}{r^3}$ = constant $\Rightarrow T^2r^{-3}$ = constant

17. (d) $\frac{T_{\text{plant}}}{T_{\text{earth}}} = \left(\frac{r_{\text{plant}}}{r_{\text{earth}}}\right)^{3/2} = (1.588)^{3/2} = 2 \;\therefore\; T_{\text{planet}} = 2\, year$

18. (d) Mass of the satellite does not effects on time period

$$\frac{T_A}{T_B} = \left(\frac{r_1}{r_2}\right)^{3/2} = \left(\frac{r}{2r}\right)^{3/2} = \left(\frac{1}{8}\right)^{1/2} = \frac{1}{2\sqrt{2}}$$

19. (b) Speed of the earth will be maximum when its distance from the sun is minimum because mvr = constant

20. (c) $\frac{T_A}{T_B} = \left(\frac{r_A}{r_B}\right)^{3/2} \Rightarrow 8 = \left(\frac{r_A}{r_B}\right)^{3/2} \Rightarrow r_A = (8)^{2/3}r_B = 4r_B$.

21. (c) $T^2 \propto r^3$. If *r* made half then *T* will become $\frac{T}{8}$.

22. (c)

23. (b) Mass of satellite does not affects on orbital radius.

24. (b) $\frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} = (2)^{3/2} = 2\sqrt{2} \Rightarrow T_2 = 2\sqrt{2}$ *years.*

25. (c)

26. (a)

27. (a) By conservation of angular momentum *mvr* = constant

$v_{\min} \times r_{\max} = v_{\max} \times r_{\min}$

$$\therefore v_{\min} = \frac{60 \times 1.6 \times 10^{12}}{8 \times 10^{12}} = \frac{60}{5} = 12\, m/s$$

28. (b) $\omega_{\text{body}} = 27\omega_{\text{earth}}$

$$T^2 \propto r^3 \Rightarrow \omega^2 \propto \frac{1}{r^3} \Rightarrow \omega \propto \frac{1}{r^{3/2}} \;\therefore r \propto \frac{1}{\omega^{2/3}}$$

$$\Rightarrow \frac{r_{\text{body}}}{r_{\text{earth}}} = \left(\frac{\omega_{\text{earth}}}{\omega_{\text{body}}}\right)^{2/3} = \left(\frac{1}{27}\right)^{2/3} = \frac{1}{9}$$

29. (d) Time period does not depends upon the mass of satellite.

30. (b) $\frac{T^2}{R^3} = \frac{T^2}{d^3} = \frac{1}{n^2d^3} = \text{constant}$

$\therefore\; n_1^2d_1^3 = n_2^2d_2^3$ [where *n* = frequency]

31. (a)

32. (a)

33. (a) During path *DAB* planet is nearer to sun as comparison with path *BCD*. So time taken in travelling *DAB* is less than that for *BCD* because velocity of planet will be more in region *DAB*.

34. (c) Because distance of point *C* is maximum from the sun.

35. (b) $T_2 = T_1\left(\frac{R_2}{R_1}\right)^{3/2} = 1\times(2)^{3/2} = 2.8\ year$

36. (d) $L = mvr = m\sqrt{\frac{GM}{r}}r = m\sqrt{GMr}\ \therefore\ L \propto \sqrt{r}$

37. (a)

38. (c) $\frac{dA}{dt} = \frac{L}{2m} = \frac{dA}{dt} \propto vr \propto \omega r^2$

39. (b)

40. (c)

41. (d)

42. (a) $T^2 \propto R^3 \Rightarrow \left(\frac{T_P}{T_E}\right)^2 = \left(\frac{R_P}{R_E}\right)^3 = \left(\frac{2R_E}{R_E}\right)^3$

$\Rightarrow \frac{T_P}{T_E} = (2)^{3/2} = 2\sqrt{2}$

$\Rightarrow T_P = 2\sqrt{2}\times 365 = 1032.37 = 1032$ days

43. (d)

44. (d) For central force, torque is zero.

$\because \tau = \frac{dL}{dt} = 0 \Rightarrow L$ = constant

i.e. Angular momentum is constant.

45. (b) $\frac{v_{max}}{v_{min}} = \frac{1+e}{1-e} = \frac{1+0.0167}{1-0.0167} = 1.033$

46. (a) $m\omega^2 R = \frac{GMm}{R^2} \Rightarrow \left(\frac{2\pi}{T}\right)^2 R = \frac{GM}{R^2} \Rightarrow M = \frac{4\pi^2 R^3}{GT^2}$

47. (b) $v = \sqrt{\frac{GM}{R}} = G^{1/2}M^{1/2}R^{-1/2}$

48. (b)

49. (c) $v = \sqrt{\frac{GM}{R}}$ if $r_1 > r_2$ then $v_1 < v_2$

50. (c) Escape velocity for that body $v_e = \sqrt{\frac{2Gm}{r}}$

v_e should be more than or equal to speed of light

i.e. $\sqrt{\frac{2Gm}{r}} \geq c$

51. (c) $\frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} = \left(\frac{1}{4}\right)^{3/2} = \frac{1}{8}$

Critical Thinking Questions

1. (b) For revolution of planet centripetal force is provided by gravitational force of attraction

$m\omega^2 R \propto R^{-5/2} \Rightarrow \frac{1}{T^2} \propto R^{-7/2} \Rightarrow T^2 \propto R^{7/2}$

2. (a, b) $g = \frac{4}{3}\pi\rho Gr\ \therefore\ g \propto r$ if $r < R$

$g = \frac{GM}{r^2}\ \therefore\ g \propto \frac{1}{r^2}$ if $r > R$

If $r_1 < R$ and $r_2 < R$ then $\frac{F_1}{F_2} = \frac{g_1}{g_2} = \frac{r_1}{r_2}$

If $r_1 > R$ and $r_2 > R$ then $\frac{F_1}{F_2} = \frac{g_1}{g_2} = \left(\frac{r_2}{r_1}\right)^2$

3. (a)

4. (b) $F = \frac{Gm(M-m)}{r^2}$

For maximum force $\frac{dF}{dm} = 0$

$\Rightarrow \frac{d}{dm}\left(\frac{GmM}{r^2} - \frac{Gm^2}{r^2}\right) = 0$

$\Rightarrow M - 2m = 0 \Rightarrow \frac{m}{M} = \frac{1}{2}$

5. (a) $m\omega^2 R \propto \frac{1}{R^n} \Rightarrow m\left(\frac{4\pi^2}{T^2}\right)R \propto \frac{1}{R^n} \Rightarrow T^2 \propto R^{n+1}$

$\therefore T \propto R^{\left(\frac{n+1}{2}\right)}$

6. (c) $g = \frac{GM}{R^2}$. If mass remains constant then $g \propto \frac{1}{R^2}$

% increase in g = 2(% decrease in R) =2 × 1% = 2%.

7. (b, c, d) $g = \frac{GM}{R^2}, v_e = \sqrt{\frac{2GM}{R}}$ and $U = \frac{-GMm}{R}$

$\therefore\ g \propto \frac{M}{R^2}, v_e \propto \sqrt{\frac{M}{R}}$ and $U \propto \frac{M}{R}$

If both mass and radius are increased by 0.5% then v_e and U remains unchanged where as g decrease by 0.5%.

8. (b) $g' = g - \omega^2 R\cos^2\lambda$

For weightlessness at equator $\lambda = 0$ and $g' = 0$

$\therefore\ 0 = g - \omega^2 R \Rightarrow \omega = \sqrt{\frac{g}{R}} = \frac{1}{800}\frac{rad}{s}$

9. (d) If acceleration due to gravity is g at the surface of earth then at height R it value becomes $g' = g\left(\frac{R}{R+h}\right)^2 = \frac{g}{4}$

$T_1 = 2\pi\sqrt{\frac{l}{g}}$ and $T_2 = 2\pi\sqrt{\frac{l}{g/4}}\ \therefore \frac{T_2}{T_1} = 2$

10. (b) $\Delta U = \frac{mgh}{1+\frac{h}{R}} = \frac{1}{2}mgR\ (\because\ h = R)$

11. (c) Potential energy = 2 × (Total energy) = $2E_0$

Because we know = $U = \frac{-GMm}{r}$ and $E_0 = \frac{-GMm}{2r}$

12. (c) $\Delta K.E. = \Delta U$

$\Rightarrow \frac{1}{2}MV^2 = GM_e M\left(\frac{1}{R} - \frac{1}{R+h}\right)$ ...(i)

Also $g = \frac{GM_e}{R^2}$ ...(ii)

On solving (i) and (ii) $h = \frac{R}{\left(\frac{2gR}{V^2} - 1\right)}$

13. (a, c, d) Since cavities are symmetrical *w.r.t. O.* So the gravitational force at the centre is zero.

The radius of the circle $z^2 + y^2 = 36$ is 6.

For all points for $r \geq 6$, the body behaves as if whole of the mass is concentrated at the centre. So the gravitational potential is same.

Above is true for $z^2 + y^2 = 4$ as well.

14. (b) Let velocities of these masses at *r* distance from each other be v_1 and v_2 respectively.

By conservation of momentum

$m_1 v_1 - m_2 v_2 = 0$

$\Rightarrow m_1 v_1 = m_2 v_2$ ... (i)

By conservation of energy

change in *P.E.*=change in *K.E.*

$\frac{Gm_1 m_2}{r} = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$

$\Rightarrow \frac{m_1^2 v_1^2}{m_1} + \frac{m_2^2 v_2^2}{m_2} = \frac{2Gm_1 m_2}{r}$ ...(ii)

On solving equation (i) and (ii)

$v_1 = \sqrt{\frac{2Gm_2^2}{r(m_1 + m_2)}}$ and $v_2 = \sqrt{\frac{2Gm_1^2}{r(m_1 + m_2)}}$

$\therefore v_{app} = |v_1| + |v_2| = \sqrt{\frac{2G}{r}(m_1 + m_2)}$

15. (c) Kinetic energy = Potential energy

$\frac{1}{2}m(kv_e)^2 = \frac{mgh}{1 + \frac{h}{R}} \Rightarrow \frac{1}{2}mk^2 2gR = \frac{mgh}{1 + \frac{h}{R}}$

$\Rightarrow h = \frac{Rk^2}{1 - k^2}$

Height of Projectile from the earth's surface = *h*

Height from the centre $r = R + h = R + \frac{Rk^2}{1 - k^2}$

By solving $r = \frac{R}{1 - k^2}$

16. (c) In the problem orbital radius is increased by 1%.

Time period of satellite $T \propto r^{3/2}$

Percentage change in time period

$= \frac{3}{2}$ (% change in orbital radius) $= \frac{3}{2}(1\%) = 1.5\%$

17. (b) According to Kepler's third law, the ratio of the squares of the periods of any two planets revolving about the sun is equal to the ratio of the cubes of their average distances from the sun *i.e.*

$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3 = \left[\frac{r_1}{\frac{1}{2}r_1}\right]^3 = 8 \Rightarrow \frac{T_1}{T_2} = 2\sqrt{2}$

$\therefore T_2 = \frac{T_1}{2\sqrt{2}} = \frac{365\ days}{2\sqrt{2}} = 129\ days$

18. (c) $\frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} \Rightarrow T_2 = 24\left(\frac{6400}{36000}\right)^{3/2} \cong 2\,hour$

Graphical Questions

1. (c) $g \propto r$ (if $r < R$) and $g \propto \frac{1}{r^2}$ (if $r > R$)

2. (c) $V_{in} = \frac{-Gm}{2R}\left[3 - \left(\frac{r}{R}\right)^2\right]$, $V_{surface} = \frac{-GM}{R}$, $V_{out} = \frac{-GM}{r}$

3. (c) For hollow sphere

$V_{in} = \frac{-GM}{R}$, $V_{surface} = \frac{-GM}{R}$, $V_{out} = \frac{-GM}{r}$

i.e. potential remain constant inside the sphere and it is equal to potential at the surface and increase when the point moves away from the surface of sphere.

4. (b) $F = 0$ when $0 \leq r \leq R_1$

because intensity is zero inside the cavity.

F increase when $R_1 \leq r \leq R_2$

$F \propto \frac{1}{r^2}$ when $r > R_2$

5. (d) Intensity will be zero inside the spherical shell.

$I = 0$ upto $r = a$ and $I \propto \frac{1}{r^2}$ when $r > a$

6. (c) Initially the weight of the passenger = 60 × 10 = 600 *N*

Finally the weight of the passenger = 60 × 4 = 240 *N*

and during the flight in between some where its weight will be zero because at that point gravitational pull of earth and mars will be equal.

7. (c) Kepler's law $T^2 \propto R^3$

8. (d) The system will be bound at points where total energy is negative. In the given curve at point A, B and C the P.E. is more than K.E.

9. (c) $U = \frac{-GMm}{r}$, $K = \frac{GMm}{2r}$ and $E = \frac{-GMm}{2r}$

For a satellite *U,K* and *E* varies with *r* and also *U* and *E* remains negative whereas *K* remain always positive.

10. (c) Gravitational P.E. = *m* × gravitational potential

$U = mV$ So the graph of *U* will be same as that of *V* for a spherical shell.

Assertion and Reason

1. (a) According to Kepler's third law $T^2 \propto r^3$

If r is small then T will also be small.

2. (b) For two electron $\frac{F_g}{F_e} = 10^{-43}$ *i.e.* gravitational force is negligible in comparison to electrostatic force of attraction.

3. (d) The universal gravitational constant G is totally different from g.

$$G = \frac{FR^2}{Mm}$$

The constant G is scalar and posses the dimensions $[M^{-1}L^3T^{-2}]$.

$$g = \frac{GM}{R^2}$$

g is a vector and has got the dimensions $[M^0LT^{-2}]$.

It is not a universal constant.

4. (c) Acceleration due to gravity is given by $g = \frac{GM}{R^2}$. Thus it does not depend on mass of body on which it is acting. Also it is not a constant quantity it changes with change in value of both M and R (distance between two bodies).

5. (a) If a pendulum is suspended in a lift and lift is moving downward with some acceleration a, then time period of pendulum is given by, $T = 2\pi\sqrt{\frac{l}{g-a}}$.

In the case of free fall, $a = g$ then $T = \infty$

i.e., the time period of pendulum becomes infinite.

6. (c) The value of g at any place is given by the relation, $g' = g - \omega^2 R_e \cos^2\lambda$

When λ is angle of latitude and ω is the angular velocity of earth. If earth suddenly stops rotating, then $\omega = 0$

$\therefore$ $g' = g$ *i.e.*, the value of g will be same at all places.

7. (b) Acceleration due to gravity,

$g' = g - R\omega^2\cos^2\lambda$

At equator, $\lambda = 0°$ *i.e.* $\cos 0° = 1$ $\therefore$ $g_e = g = R\omega^2$

At poles, $\lambda = 90°$ *i.e.* $\cos 90° = 0$ $\therefore$ $g_p = g$

Thus, $g_p - g_e = g - g + R\omega^2 = R\omega^2$

Also, the value of g is maximum at poles and minimum at equators.

8. (a) As the rotation of earth takes place about polar axis therefore body placed at poles will not feel any centrifugal force and its weight or acceleration due to gravity remains unaffected.

9. (e) Earth revolves around the sun in circular path and required centripetal force is provided by gravitational force between earth and sun but the work done by this centripetal force is zero.

10. (a) Inertial mass and gravitational mass are equivalent. Both are scalar quantities and measured in the same unit. They are quite different in the method of their measurement. Also gravitational mass of a body is affected by the presence of other bodies near it where as internal mass remain unaffected.

11. (a) Because gravitational force is always attractive in nature and every body is bound by this gravitational force of attraction of earth.

12. (a) As no torque is acting on the planet, its angular momentum must remain constant in magnitude as well as direction. Therefore, plane of rotation must pass through the centre of earth.

13. (c) According to Kepler's law of planetary motion, a planet revolves around the sun in such a way that its areal velocity is constant. *i.e.*, it move faster, when it is closer the sun and vice-versa.

14. (e) Escape velocity = $\sqrt{2}\times$ orbital velocity.

15. (c) Due to resistance force of atmosphere, the satellite revolving around the earth losses kinetic energy. Therefore in a particular orbit the gravitational attraction of earth on satellite becomes greater than that required for circular orbit there. Therefore satellite moves down to a lower orbit. In the lower orbit as the potential energy $(U = -GMm/r)$ becomes more negative,

Hence kinetic energy $(E_K = GMm/2r)$ increases, and hence speed of satellite increases.

16. (b) If root mean square velocity of the gas molecules is less than escape velocity from that planet (or satellite) then atmosphere will remain attached with that planet and if $v_{rms} > v_{escape}$ then there will be no atmosphere on the planet. This is the reason for no atmosphere at moon.

17. (b) As the geostationary satellite is established in an orbit in the plane of the equator at a particular place, so it move in the same sense as the earth and hence its time period of revolution is equal to 24 hours, which is equal to time period of revolution of earth about its axis.

18. (e) The total gravitational force on one particle due to number of particles is the resultant force of attraction (or gravitational force) exerted on the given particle due to individual particles. *i.e.*, $\vec{F} = \vec{F_1} + \vec{F_2} + \vec{F_3} + ...$ It means the principle of superposition is valid.

19. (d) As, escape velocity $= \sqrt{\frac{2GM}{R}}$, so its value depends on mass of planet and radius of the planet. The two different planets have same escape velocity, when these quantities (mass and radius) are equal.

20. (a) According to kepler's law $T^2 \propto r^3 \propto (R+h)^3$

i.e. if distance of satellite is more then its time period will be more.

21. (a) According to Newton's law of gravitation,

$F = \frac{Gm_1m_2}{r^2}$. When m_1, m_2 and r_2 all are doubled,

$F = \frac{G(2m_1)(2m_2)}{(2r)^2} = \frac{Gm_1m_2}{r^2}$, *i.e.* F remains the same.

22. (c) Upto ordinary heights, the change in the distance of a projectile from the centre of earth is negligible compared to the radius of earth. Hence the projectile moves under a nearly uniform gravitational force and the path is parabolic. But for the projectiles moving to a large height, the gravitational force decreases quite decreasing variable force, the path of the projectile becomes elliptical.

23. (c) As the distance from centre of earth decreases, acceleration due to gravity decreases and at the centre of earth it becomes zero.

$g' = g\left(1 - \frac{d}{R}\right)$. If $d = R$ then $g' = 0$

24. (b) We know that earth revolves from west to east about its polar axis. Therefore, all the particles on the earth have velocity from west to east.

This velocity is maximum in the equatorial line, as $v = R\omega$, where R is the radius of earth and ω is the angular velocity of revolution of earth about its polar axis.

When a rocket is launched from west to east in equatorial plane, the maximum linear velocity is added to the launching velocity of the rocket, due to which launching becomes easier.

25. (e) Binding energy $= \frac{GMm}{R} = -$ [Total energy of satellite]

and it is clear that it depends upon the mass of the satellite.

26. (a) According to Newton's law of gravitation, every body in this universe attracts every other body with a force which is inversely proportional to the square of the distance between them. When we move our finger, the distance of the objects with respect to finger changes, hence the force of attraction changes, disturbing the entire universe, including stars.

27. (a) Intensity inside a hollow sphere is zero, so force is also equal to zero. $\vec{F} = m\vec{E}$

28. (a) The time period of satellite which is very near to earth is given by

$$T = 2\pi\sqrt{\frac{R}{g}} \cong 84\ min = 1 hr.\ 24\ min$$

29. (c) A person feels his weight only when the surface on which he is standing exerts a reactionary force on him. Because the acceleration of the person and that of the satellite revolving round the earth are equal (= g), hence acceleration of the person with respect to the satellite is zero.

Therefore person feels weightless on satellite, although the gravitational force is acting on a satellite.

30. (e) If the orbital path of a satellite is circular, then its speed is constant and if the orbital path of a satellite is elliptical, then its speed in its orbit is not constant. In that case its areal velocity is constant.

31. (a) $v_0 = R_e\sqrt{\frac{g}{R_e + h}}$

For satellite revolving very near to earth $R_e + h = R_e$

As ($h << R$)

$v_o = \sqrt{R_e g} \simeq \sqrt{64 \times 10^5 \times 10} = 8 \times 10^3\ m/s = 8\ kms^{-1}$

Which is independent of height of a satellite.

32. (b)

33. (a) The torque on a body is given by $\vec{\tau} = \frac{d\vec{L}}{dt}$

In case of planet orbiting around sun no torque is acting on it.

$\frac{d\vec{L}}{dt} = 0 \Rightarrow \vec{L}$ = constant.

Gravitation

SET Self Evaluation Test - 8

1. Two identical spheres are placed in contact with each other. The force of gravitation between the spheres will be proportional to (R = radius of each sphere)
   (a) R (b) R^2
   (c) R^4 (d) None of these

2. Suppose that the force of earth's gravity suddenly disappears, choose the correct answer out of the following statements
   (a) The weight of the body will become zero but mass remains the same
   (b) The mass of the body will become zero but the weight remains the same
   (c) Both the mass and weight will be the same
   (d) Mass and weight will remain the same

3. An earth satellite is moved from one stable circular orbit to a further stable circular orbit, which one of the following quantities increase
   (a) Gravitational force (b) Gravitational P.E.
   (c) Linear orbital speed (d) Centripetal acceleration

4. Two planets revolve round the sun with frequencies N_1 and N_2 revolutions per year. If their average orbital radii be R_1 and R_2 respectively, then R_1 / R_2 is equal to
   (a) $(N_1 / N_2)^{3/2}$ (b) $(N_2 / N_1)^{3/2}$
   (c) $(N_1 / N_2)^{2/3}$ (d) $(N_2 / N_1)^{2/3}$

5. There is no atmosphere on the moon because
   (a) It is closer to the earth
   (b) It revolves round the earth
   (c) It gets light from the sun
   (d) The escape velocity of gas molecules is lesser than their root mean square velocity here

6. Two heavenly bodies S_1 and S_2, not far off from each other are seen to revolve in orbits
   (a) Around their common centre of mass
   (b) Which are arbitrary
   (c) With S_1 fixed and S_2 moving round S_1
   (d) With S_2 fixed and S_1 moving round S_2

7. The mass of the moon is about 1.2% of the mass of the earth. Compared to the gravitational force the earth exerts on the moon, the gravitational force the moon exerts on earth
   (a) Is the same (b) Is smaller
   (c) Is greater (d) Varies with its phase

8. A clock S is based on oscillation of a spring and a clock P is based on pendulum motion. Both clocks run at the same rate on earth. On a planet having the same density as earth but twice the radius
   (a) S will run faster than P
   (b) P will run faster than S
   (c) They will both run at the same rate as on the earth
   (d) None of these

9. Consider earth to be a homogeneous sphere. Scientist A goes deep down in a mine and scientist B goes high up in a balloon. The value of g measured by
   (a) A goes on decreasing and that by B goes on increasing
   (b) B goes on decreasing and that by A goes on increasing
   (c) Each decreases at the same rate
   (d) Each decreases at different rates

10. The mass of the moon is $\frac{1}{81}$ of the earth but the gravitational pull is $\frac{1}{6}$ of the earth. It is due to the fact that
   (a) The radius of the moon is $\frac{81}{6}$ of the earth
   (b) The radius of the earth is $\frac{9}{\sqrt{6}}$ of the moon
   (c) Moon is the satellite of the earth
   (d) None of the above

11. A weight is suspended from the ceiling of a lift by a spring balance. When the lift is stationary the spring balance reads W. If the lift suddenly falls freely under gravity, the reading on the spring balance will be
   (a) W (b) $2W$
   (c) $W/2$ (d) 0

12. If a planet consists of a satellite whose mass and radius were both half that of the earth, the acceleration due to gravity at its surface would be (g on earth = 9.8 m/sec^2)
   (a) $4.9\, m/sec^2$ (b) $8.9\, m/sec^2$
   (c) $19.6\, m/sec^2$ (d) $29.4\, m/sec^2$

13. At a given place where acceleration due to gravity is 'g' m/sec^2, a sphere of lead of density 'd' kg/m^3 is gently released in a column of liquid of density 'ρ' kg/m^3. If $d > \rho$, the sphere will
   (a) Fall vertically with an acceleration 'g' m/sec^2
   (b) Fall vertically with no acceleration
   (c) Fall vertically with an acceleration $g\left(\frac{d-\rho}{d}\right)$
   (d) Fall vertically with an acceleration $g\left(\frac{\rho}{d}\right)$

14. g_e and g_p denote the acceleration due to gravity on the surface of the earth and another planet whose mass and radius are twice as that of earth. Then
   (a) $g_p = g_e$ (b) $g_p = g_e / 2$
   (c) $g_p = 2g_e$ (d) $g_p = g_e / 4$

15. If the value of g at the surface of the earth is 9.8 m/sec^2, then the value of g at a place 480 km above the surface of the earth will be (Radius of the earth is 6400 km)

(a) $8.4\,m/\sec^2$ (b) $9.8\,m/\sec^2$

(c) $7.2\,m/\sec^2$ (d) $4.2\,m/\sec^2$

16. The acceleration due to gravity about the earth's surface would be half of its value on the surface of the earth at an altitude of (R = 4000 *mile*)

(a) 1200 *mile* (b) 2000 *mile*

(c) 1600 *mile* (d) 4000 *mile*

17. A pendulum clock is set to give correct time at the sea level. This clock is moved to hill station at an altitude of 2500 *m* above the sea level. In order to keep correct time of the hill station, the length of the pendulum

(a) Has to be reduced

(b) Has to be increased

(a) Needs no adjustment

(d) Needs no adjustment but its mass has to be increased

18. At some point the gravitational potential and also the gravitational field due to earth is zero. The point is

(a) On earth's surface

(b) Below earth's surface

(c) At a height R_e from earth's surface (R_e = radius of the earth)

(d) At infinity

19. A body falls freely under gravity. Its speed is v when it has lost an amount U of the gravitational energy. Then its mass is

(a) $\frac{Ug}{v^2}$ (b) $\frac{U^2}{g}$

(c) $\frac{2U}{v^2}$ (d) $2\,Ugv^2$

20. The ratio of the radius of the earth to that of the moon is 10. The ratio of acceleration due to gravity on the earth and on the moon is 6. The ratio of the escape velocity from the earth's surface to that from the moon is

(a) 10 (b) 6

(c) Nearly 8 (d) 1.66

21. Escape velocity from the moon surface is less than that on the earth surface, because

(a) Moon has no atmosphere while the earth has

(b) Radius of moon is less than that of the earth

(c) Moon is nearer to the sun

(d) Moon is attracted by other planets

22. The ratio of the radius of a planet '*A*' to that of planet '*B*' is '*r*'. The ratio of acceleration due to gravity on the planets is '*x*'. The ratio of the escape velocities from the two planets is

(a) xr (b) $\sqrt{\frac{r}{x}}$

(c) $\sqrt{rx}$ (d) $\sqrt{\frac{x}{r}}$

23. Time period of revolution of a nearest satellite around a planet of radius R is T. Period of revolution around another planet, whose radius is 3R but having same density is

(a) T (b) $3T$

(c) $9T$ (d) $3\sqrt{3}T$

24. The maximum possible velocity of a satellite orbiting round the earth in a stable orbit is

(a) $\sqrt{2R_e g}$ (b) $\sqrt{R_e g}$

(c) $\sqrt{\frac{R_e g}{2}}$ (d) Infinite

25. A man inside an artificial satellite feels weightlessness because the force of attraction due to earth is

(a) Zero at that place

(b) Is balanced by the force of attraction due to moon

(c) Equal to the centripetal force

(d) Non-effective due to particular design of the satellite

26. Two identical satellites A and B are circulating round the earth at the height of R and $2R$ respectively, (where R is radius of the earth). The ratio of kinetic energy of A to that of B is

(a) $\frac{1}{2}$ (b) $\frac{2}{3}$

(c) 2 (d) $\frac{3}{2}$

27. The mean radius of the earth's orbit round the sun is 1.5×10^{11}. The mean radius of the orbit of mercury round the sun is $6\times10^{10}\,m$. The mercury will rotate around the sun in

(a) A year (b) Nearly 4 years

(c) Nearly $\frac{1}{4}$ year (d) 2.5 years

Answers and Solutions

(SET - 8)

1. (c) $F = G\frac{M\times M}{R^2} = \frac{G\times\left(\frac{4}{3}\pi R^3\rho\right)^2}{(2R)^2} \Rightarrow F \propto \frac{R^6}{R^2} \propto R^4$

2. (a) In the absence of gravity weight of the bodies will become zero but mass will not change.

3. (b) $U = \frac{-GMm}{r}$. If r increases then U also increases.

4. (d) According to Kepler's law $T^2 \propto R^3$

If N is the frequencs then $N^2 \propto (R)^{-3}$

or $\frac{N_2}{N_1} = \left(\frac{R_2}{R_1}\right)^{-3/2} \Rightarrow \frac{R_1}{R_2} = \left(\frac{N_2}{N_1}\right)^{2/3}$

5. (d)

6. (a)

7. (a) Force between earth and moon $F = \frac{Gm_m m_e}{r^2}$

This amount of force, both earth and moon will exert on each other *i.e.* they exert same force on each other.

8. (b) $g = \frac{4}{3}\pi\rho GR$. If density is same then $g \propto R$

According to problem $R_p = 2R_e \therefore g_p = 2g_e$

For clock P (based on pendulum motion) $T = 2\pi\sqrt{\frac{l}{g}}$

Time period decreases on planet so it will run faster because $g_p > g_e$

For clock S (based on oscillation of spring) $T = 2\pi\sqrt{\frac{m}{k}}$

So it does not change.

9. (d) For scientist A which goes down in a mine $g' = g\left(1 - \frac{d}{R}\right)$

For scientist B, which goes up in a air $g' = g\left(1 - \frac{2h}{R}\right)$

So it is clear that value of g measured by each will decreases at different rates.

10. (b) Gravitational pull depends upon the acceleration due to gravity on that planet.

$M_m = \frac{1}{81}M_e, g_m = \frac{1}{6}g_e$

$g = \frac{GM}{R^2} \Rightarrow \frac{R_e}{R_m} = \left(\frac{M_e}{M_m} \times \frac{g_m}{g_e}\right)^{1/2} = \left(81 \times \frac{1}{6}\right)^{1/2}$

$\therefore R_e = \frac{9}{\sqrt{6}}R_m$

11. (d) Reading of spring balance $R = m(g - a)$

If the lift falls freely then $a = g \therefore R = 0$

12. (c) $g = \frac{GM}{R^2} \therefore g \propto \frac{M}{R^2}$

According to problem $M_p = \frac{M_e}{2}$ and $R_p = \frac{R_e}{2}$

$\therefore \frac{g_p}{g_e} = \left(\frac{M_p}{M_e}\right)\left(\frac{R_e}{R_p}\right)^2 = \left(\frac{1}{2}\right) \times (2)^2 = 2$

$\Rightarrow g_p = 2g_e = 2 \times 9.8 = 19.6 \ m/s^2$

13. (c) Apparent weight = actual weight – upthrust force

$Vdg' = Vdg - V\rho g$

$\Rightarrow g' = \left(\frac{d - \rho}{d}\right)g$

14. (b) $g \propto \frac{M}{R^2}$. If mass and radius of the planet are twice then g_ρ will be half that of g_e *i.e.* $g_p = \frac{g_e}{2}$

15. (a) The value of g on the surface of the earth $g \propto \frac{1}{R^2}$

At height h from the surface of the earth $g' \propto \frac{1}{(R+h)^2}$

$\therefore g' = g\frac{R^2}{(R+h)^2} = \frac{9.8 \times (6400)^2}{(6400 + 480)^2} = 8.4 \ m/s^2$

16. (c) $\frac{g'}{g} = \left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{2} = \left(\frac{R}{R+h}\right)^2 \Rightarrow \frac{1}{2} = \left(\frac{4000}{4000+h}\right)^2$

By solving we get $h = 1656.85 \ mile \approx 1600 \ mile$

17. (a) $T = 2\pi\sqrt{\frac{l}{g}}$. At the hill g will decrease so to keep the time period same the length of pendulum has to be reduced.

18. (d) $V = \frac{-GM}{r}$ and $I = \frac{GM}{r^2}$

$V = 0$ and $I = 0$ at $r = \infty$

19. (c) U = Loss in gravitational energy = gain in K.E.

So, $U = \frac{1}{2}mv^2 \Rightarrow m = \frac{2U}{v^2}$

20. (c) $\frac{v_e}{v_m} = \sqrt{\frac{g_e}{g_m}\frac{R_e}{R_m}} = \sqrt{6 \times 10} = \sqrt{60} \cong 8$ (nearly)

21. (b)

22. (c) $v_e = \sqrt{2gR} \Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{g_A}{g_B} \times \frac{R_A}{R_B}} = \sqrt{x \times r} \therefore \frac{v_A}{v_B} = \sqrt{rx}$

***

23. (a) Time period of satellite which is very near to planet

$$T = 2\pi\sqrt{\frac{R^3}{GM}} = 2\pi\sqrt{\frac{R^3}{G\frac{4}{3}\pi R^3\rho}} \therefore T \propto \sqrt{\frac{1}{\rho}}$$

i.e. time period of nearest satellite does not depends upon the radius of planet, it only depends upon the density of the planet.

In the problem, density is same so time period will be same.

24. (b) Otherwise centrifugal force exceeds the force of attraction or we can say that gravitational force won't be able to keep the satellite in circular motion.

25. (c)

26. (d) $\frac{K_A}{K_B} = \frac{r_B}{r_A} = \left(\frac{R + h_B}{R + h_A}\right) = \left(\frac{R + 2R}{R + R}\right) = \frac{3}{2}$

27. (c) $\frac{T_{\text{mercury}}}{T_{\text{earth}}} = \left(\frac{r_{\text{mercury}}}{r_{\text{earth}}}\right)^{3/2} = \left(\frac{6 \times 10^{10}}{1.5 \times 10^{11}}\right)^{3/2} = \frac{1}{4}$ (approx.)

$\therefore T_{\text{mercury}} = \frac{1}{4}$ year

Chapter 9
Elasticity

Interatomic Forces

The forces between the atoms due to electrostatic interaction between the charges of the atoms are called interatomic forces. These forces are electrical in nature and these are active if the distance between the two atoms is of the order of atomic size *i.e.* 10^{-10} *metre*.

(1) Every atom is electrically neutral, the number of electrons (negative charge) orbiting around the nucleus is equal to the number of protons (positive charge) in the nucleus. So if two atoms are placed at a very large distance from each other then there will be a very small (negligible) interatomic force working between them.

(2) When two atoms are brought closer to each other to a distance of the order of 10^{-10} *m*, the distances between their positive nuclei and negative electron clouds get disturbed, and due to this, attractive interatomic force is produced between two atoms.

(3) This attractive force increases continuously with decrease in r and becomes maximum for one value of r called critical distance, represented by x (as shown in the figure). Beyond this the attractive force starts decreasing rapidly with further decrease in the value of r.

(4) When the distance between the two atoms becomes r_0, the interatomic force will be zero. This distance r_0 is called normal or equilibrium distance.

(r_0 = 0.74 Å for hydrogen).

(5) When the distance between the two atoms further decreased, the interatomic force becomes repulsive in nature and increases very rapidly with decrease in distance between two atoms.

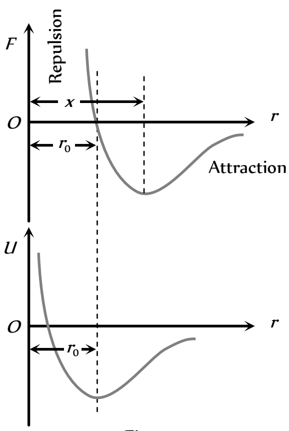


Fig. 9.1

(6) The potential energy U is related with the interatomic force F by the following relation.

$$F = \frac{-dU}{dr}$$

(i) When two atoms are at very large distance, the potential energy is negative and becomes more negative as r is decreased.

(ii) When the distance between the two atoms becomes r_0, the potential energy of the system of two atoms becomes minimum (*i.e.* attains maximum negative value). As the state of minimum potential energy is the state of equilibrium, hence the two atoms at separation r_0 will be in a state of equilibrium.

($U_0 = -7.2 \times 10^{-19}$ *Joule* for hydrogen).

(iii) When the distance between the two atoms is further decreased (*i.e.* $r < r_0$) the negative value of potential energy of the system starts decreasing. It becomes zero and then attains positive value with further decrease in r (as shown in the figure).

Intermolecular Forces

The forces between the molecules due to electrostatic interaction between the charges of the molecules are called intermolecular forces. These forces are also called Vander Waal forces and are quite weak as compared to inter-atomic forces. These forces are also electrical in nature and these are active if the separation between two molecules is of the order of molecular size *i.e.* $\approx 10^{-9}$ *m*.

(1) It is found that the force of attraction between molecules varies inversely as seventh power of the distance between them *i.e.*

$$F_{att} \propto \frac{1}{r^7} \quad \text{or} \quad F_{rep} = \frac{-a}{r^7}$$

The negative sign indicates that the force is attractive in nature.

(2) When the distance between molecules becomes less than r_0, the forces becomes repulsive in nature and is found to vary inversely as ninth power of the distance between them *i.e.*

$$F_{rep} \propto \frac{1}{r^9} \quad \text{or} \quad F_{rep} = \frac{b}{r^9}.$$

Therefore force between two molecules is given by $F = F_{att} + F_{rep} = \frac{-a}{r^7} + \frac{b}{r^9}$

The value of constants a and b depend upon the structure and nature of molecules.

(3) Intermolecular forces between two molecules has the same general nature as shown in the figure for interatomic forces.

(4) Potential Energy : Potential energy can be approximately expressed by the formula $U = \frac{A}{r^n} - \frac{B}{r^m}$

where the term $\frac{A}{r^n}$ represents repulsive contribution and term $\frac{B}{r^m}$ represents the attractive contribution. Constants A, B and numbers m and n are different for different molecules.

For majority of solids $n = 12$ and $m = 6$.

So potential energy can be expressed as $U = \frac{A}{r^{12}} - \frac{B}{r^6}$

Comparison Between Interatomic and Intermolecular Forces

(1) **Similarities**

(i) Both the forces are electrical in origin.

(ii) Both the forces are active over short distances.

(iii) General shape of force-distance graph is similar for both the forces.

(iv) Both the forces are attractive up to certain distance between atoms/molecules and become repulsive when the distance between them become less than that value.

(2) **Dissimilarities**

(i) Interatomic force depends upon the distance between the two atoms, whereas the intermolecular force depends upon the distance between the two molecules as well as their relative orientation.

(ii) Interatomic forces are about 50 to100 times stronger than intermolecular forces.

(iii) The value of r_0 for two atoms is smaller than the corresponding value for the molecules. Therefore one molecule is not restricted to attract only one molecule, but can attract many molecule. It is not so incase of atoms, since the atoms of one molecule cannot bind the atoms of other molecules.

States of Matter

The three states of matter differ from each other due to the following two factors.

(1) The different magnitudes of the interatomic and intermolecular forces.

(2) The extent of random thermal motion of atoms and molecules of a substance (which depends upon temperature).

Comparison Chart of Solid, Liquid and Gaseous States

Property	Solid	Liquid	Gas
Shape	Definite	Not definite	Not definite
Volume	Definite	Definite	Not definite
Density	Maximum	Less than solids but more than gases.	Minimum
Compressibility	Incompressible	Less than gases but more than solids.	Compressible
Crystallinity	Crystalline	Non-crystalline	
Interatomic or intermolecular distance	Constant	Not constant	Not constant
Relation between kinetic energy K and potential energy (U)	$K < U$	$K > U$	$K >> U$
Intermolecular force	Strongest	Less than solids but more than gases.	Weakest
Freedom of motion	Molecules vibrate about their mean position but cannot move freely.	Molecules have limited free motion.	Molecules are free to move.
Effect of temperature	Matter remains in solid form below a certain temperature.	Liquids are found at temperatures more than that of solid.	These are found at temperatures greater than that of solids and liquids.

Note :❑ The fourth state of matter in which the medium is in the form of positive and negative ions, is known as plasma. Plasma occurs in the atmosphere of stars (including the sun) and in discharge tubes.

Types of Solids

A solid is that state of matter in which its constituent atoms or molecules are held strongly at the position of minimum potential energy and it has a definite shape and volume. The solids can be classified into two categories, crystalline and glassy or amorphous solids.

Comparison chart of Crystalline and Amorphous Solids

Crystalline solids	Amorphous or glassy solids
The constituent atoms, ions or molecules are arranged in a regular repeated three dimensional pattern, within the	The constituent atoms, ions or molecules are not arranged in a regular repeated three dimensional pattern, within the

solid.	solid.
Definite external geometric shape.	No regularity in external shape.
All the bonds in ions, or atoms or molecules are equally strong.	All the bonds are not equally strong.
They are anisotropic.	They are isotropic.
They have sharp melting point.	They don't have sharp melting point.
They have a long-range order of atoms or ions or molecules in them.	They don't have a long-range order.
They are considered true and stable solids.	They are not regarded as true and stable solids.

Elastic Property of Matter

(1) **Elasticity :** The property of matter by virtue of which a body tends to regain its original shape and size after the removal of deforming force is called elasticity.

(2) **Plasticity :** The property of matter by virtue of which it does not regain its original shape and size after the removal of deforming force is called plasticity.

(3) **Perfectly elastic body :** If on the removal of deforming forces the body regain its original configuration completely it is said to be perfectly elastic.

A quartz fibre and phosphor bronze (an alloy of copper containing 4% to 10% tin, 0.05% to 1% phosphorus) is the nearest approach to the perfectly elastic body.

(4) **Perfectly plastic body :** If the body does not have any tendency to recover its original configuration, on the removal of deforming force, it is said to be perfectly plastic.

Paraffin wax, wet clay are the nearest approach to the perfectly plastic body.

Practically there is no material which is either perfectly elastic or perfectly plastic and the behaviour of actual bodies lies between the two extremes.

(5) **Reason of elasticity :** In a solids, atoms and molecules are arranged in such a way that each molecule is acted upon by the forces due to neighbouring molecules. These forces are known as intermolecular forces.

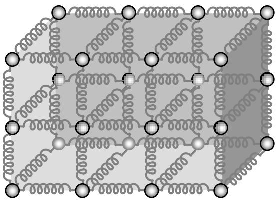


Fig. 9.2

For simplicity, the two molecules in their equilibrium positions (at inter-molecular distance $r = r$) are shown by connecting them with a spring.

In fact, the spring connecting the two molecules represents the inter-molecular force between them. On applying the deforming forces, the molecules either come closer or go far apart from each other and restoring forces are developed. When the deforming force is removed, these restoring forces bring the molecules of the solid to their respective equilibrium position ($r = r$) and hence the body regains its original form.

(6) **Elastic limit :** Elastic bodies show their property of elasticity upto a certain value of deforming force. If we go on increasing the deforming force then a stage is reached when on removing the force, the body will not return to its original state. The maximum deforming force upto which a body retains its property of elasticity is called elastic limit of the material of body.

Elastic limit is the property of a body whereas elasticity is the property of material of the body.

(7) **Elastic fatigue :** The temporary loss of elastic properties because of the action of repeated alternating deforming force is called elastic fatigue.

Due to elastic fatigue :

(i) Bridges are declared unsafe after a long time of their use.

(ii) Spring balances show wrong readings after they have been used for a long time.

(iii) We are able to break the wire by repeated bending.

(8) **Elastic after effect :** The time delay in which the substance regains its original condition after the removal of deforming force is called elastic after effect. It is the time for which restoring forces are present after the removal of the deforming force, it is negligible for perfectly elastic substance, like quartz, phosphor bronze and large for glass fibre.

Stress

When a force is applied on a body, there will be relative displacement of the particles and due to property of elasticity, an internal restoring force is developed which tends to restore the body to its original state.

The internal restoring force acting per unit area of cross section of the deformed body is called stress.

At equilibrium, restoring force is equal in magnitude to external force, stress can therefore also be defined as external force per unit area on a body that tends to cause it to deform.

If external force F is applied on the area A of a body then,

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Unit : N/m^2 (S.I.) , $dyne/cm^2$ (C.G.S.)

Dimension : $[ML^{-1}T^{-2}]$

Stress developed in a body depends upon how the external forces are applied over it.

On this basis there are two types of stresses : Normal and Shear or tangential stress

(1) **Normal stress :** Here the force is applied normal to the surface.

It is again of two types : Longitudinal and Bulk or volume stress

(i) *Longitudinal stress*

(a) It occurs only in solids and comes in to picture when one of the three dimensions *viz.* length, breadth, height is much greater than other two.

(b) Deforming force is applied parallel to the length and causes increase in length.

(c) Area taken for calculation of stress is the area of cross section.

(d) Longitudinal stress produced due to increase in length of a body under a deforming force is called tensile stress.

(e) Longitudinal stress produced due to decrease in length of a body under a deforming force is called compressive stress.

(ii) *Bulk or Volume stress*

(a) It occurs in solids, liquids or gases.

(b) In case of fluids only bulk stress can be found.

(c) It produces change in volume and density, shape remaining same.

(d) Deforming force is applied normal to surface at all points.

(e) Area for calculation of stress is the complete surface area perpendicular to the applied forces.

(f) It is equal to change in pressure because change in pressure is responsible for change in volume.

(2) **Shear or tangential stress :** It comes into picture when successive layers of solid move on each other *i.e.* when there is a relative displacement between various layers of solid.

(i) Here deforming force is applied tangential to one of the faces.

(ii) Area for calculation is the area of the face on which force is applied.

(iii) It produces change in shape, volume remaining the same.

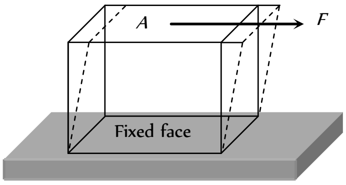


Fig. 9.3

Difference between Pressure and Stress	
Pressure	**Stress**
Pressure is always normal to the area.	Stress can be normal or tangential.
Always compressive in nature.	May be compressive or tensile in nature.

Strain

The ratio of change in configuration to the original configuration is called strain.

Being the ratio of two like quantities, it has no dimensions and units. Strain are of three types :

(1) **Linear strain :** If the deforming force produces a change in length alone, the strain produced in the body is called linear strain or tensile strain.

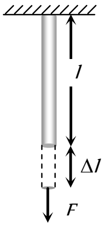


Fig. 9.4

$$\text{Linear strain} = \frac{\text{Change in length}(\Delta l)}{\text{Original length}(l)}$$

Linear strain in the direction of deforming force is called longitudinal strain and in a direction perpendicular to force is called lateral strain.

(2) **Volumetric strain :** If the deforming force produces a change in volume alone the strain produced in the body is called volumetric strain.

$$\text{Volumetric strain} = \frac{\text{Change in volume}(\Delta V)}{\text{Original volume}(V)}$$

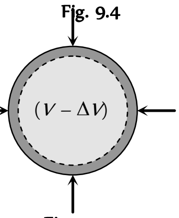


Fig. 9.5

(3) **Shearing strain :** If the deforming force produces a change in the shape of the body without changing its volume, strain produced is called shearing strain.

It is defined as angle in radians through which a plane perpendicular to the fixed surface of the cubical body gets turned under the effect of tangential force.

$$\phi = \frac{x}{L}$$

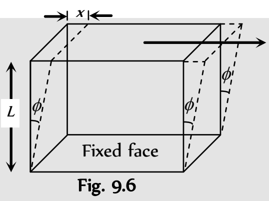


Fig. 9.6

Note : ❑ When a beam is bent both compression strain as well as an extension strain is produced.

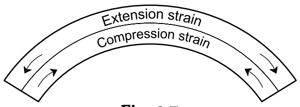


Fig. 9.7

Stress-strain Curve

If by gradually increasing the load on a vertically suspended metal wire, a graph is plotted between stress (or load) and longitudinal strain (or elongation) we get the curve as shown in figure. From this curve it is clear that :

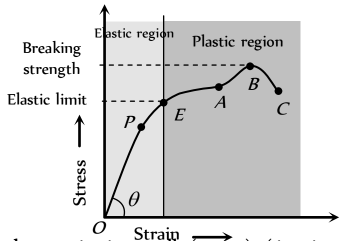


Fig. 9.8

(1) When the strain is small (< 2%) (*i.e.*, in region *OP*) stress is proportional to strain. This is the region where the so called Hooke's law is obeyed. The point *P* is called limit of proportionality and slope of line *OP* gives the Young's modulus *Y* of the material of the wire. If θ is the angle of *OP* from strain axis then $Y = \tan\theta$.

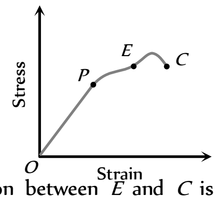
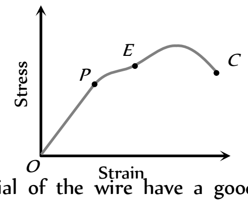
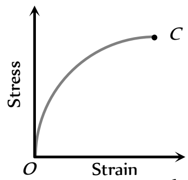
(2) If the strain is increased a little bit, *i.e.*, in the region *PE*, the stress is not proportional to strain. However, the wire still regains its original length after the removal of stretching force. This behaviour is shown up to point *E* known as elastic limit or yield-point. The region *OPE* represents the elastic behaviour of the material of wire.

(3) If the wire is stretched beyond the elastic limit *E*, *i.e.*, between *EA*, the strain increases much more rapidly and if the stretching force is removed the wire does not come back to its natural length. Some permanent increase in length takes place.

(4) If the stress is increased further, by a very small increase in it a very large increase in strain is produced (region *AB*) and after reaching point *B*, the strain increases even if the wire is unloaded and ruptures at *C*. In the region *BC* the wire literally flows. The maximum stress corresponding to *B* after which the wire begins to flow and breaks is called breaking or ultimate tensile strength. The region *EABC* represents the plastic behaviour of the material of wire.

(5) Stress-strain curve for different materials are as follows :

Brittle material	Ductile material	Elastomers

 The plastic region between E and C is small for brittle material and it will break soon after the elastic limit is crossed. Example : Glass, cast iron.	 The material of the wire have a good plastic range and such materials can be easily changed into different shapes and can be drawn into thin wires Example. Mild steel	 Stress-strain curve is not a straight line within the elastic limit for elastomers and strain produced is much larger than the stress applied. Such materials have no plastic range and the breaking point lies very close to elastic limit. Example rubber

Hooke's law and Modulus of Elasticity

According to this law, within the elastic limit, stress is proportional to the strain.

i.e. stress $\propto$ strain or $\dfrac{\text{stress}}{\text{strain}} = \text{constant} = E$

The constant E is called modulus of elasticity.

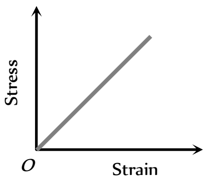


Fig. 9.9

(1) It's value depends upon the nature of material of the body and the manner in which the body is deformed.

(2) It's value depends upon the temperature of the body.

(3) It's value is independent of the dimensions (length, volume etc.) of the body.

There are three modulii of elasticity namely Young's modulus (Y), Bulk modulus (K) and modulus of rigidity (η) corresponding to three types of the strain.

Young's Modulus (Y)

It is defined as the ratio of normal stress to longitudinal strain within limit of proportionality.

$$Y = \frac{\text{Normal stress}}{\text{longitudinal strain}} = \frac{F/A}{l/L} = \frac{FL}{Al}$$

If force is applied on a wire of radius r by hanging a weight of mass M, then

$$Y = \frac{MgL}{\pi r^2 l}$$

(i) If the length of a wire is doubled,

Then longitudinal strain = $\dfrac{\text{change in length}(l)}{\text{initial length}(L)}$

$$= \frac{\text{final length} - \text{initial length}}{\text{Initial length}} = \frac{2L - L}{L} = 1$$

$\therefore$ Young's modulus = $\dfrac{\text{stress}}{\text{strain}}$ $\Rightarrow$ Y = stress

[As strain = 1]

So young's modulus is numerically equal to the stress which will double the length of a wire.

(ii) Increment in the length of wire $l = \dfrac{FL}{\pi r^2 Y}$

$\left[\text{As } Y = \dfrac{FL}{Al}\right]$

So if same stretching force is applied to different wires of same material, $l \propto \dfrac{L}{r^2}$ [As F and Y are constant]

i.e., greater the ratio $\dfrac{L}{r^2}$, greater will be the elongation in the wire.

(iii) Elongation in a wire by its own weight : The weight of the wire Mg act at the centre of gravity of the wire so that length of wire which is stretched will be L/2.

$\therefore$ Elongation $l = \dfrac{FL}{AY} = \dfrac{Mg(L/2)}{AY} = \dfrac{MgL}{2AY} = \dfrac{L^2dg}{2Y}$

[As mass (M) = volume (AL) $\times$ density (d)]

(iv) Thermal stress : If a rod is fixed between two rigid supports, due to change in temperature its length will change and so it will exert a normal stress (compressive if temperature increases and tensile if temperature decreases) on the supports. This stress is called thermal stress.

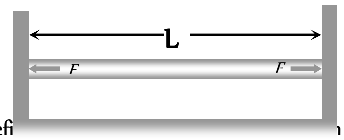


Fig. 9.10

As by defi ... $\alpha = \dfrac{l}{L\Delta\theta}$

$\Rightarrow$ thermal strain $\dfrac{l}{L} = \alpha\Delta\theta$

So thermal stress = $Y\alpha\,\Delta\theta$ [As Y = stress/strain]

And tensile or compressive force produced in the body = $YA\alpha\,\Delta\theta$

Note : In case of volume expansion Thermal stress $= K\gamma\Delta\theta$

Where K = Bulk modulus, γ = coefficient of cubical expansion

(v) **Force between the two rods** : Two rods of different metals, having the same area of cross section A, are placed end to end between two massive walls as shown in figure. The first rod has a length L_1, coefficient of linear expansion α_1 and young's modulus Y_1. The corresponding quantities for second rod are L_2, α_2 and Y_2. If the temperature of both the rods is now raised by T degrees.

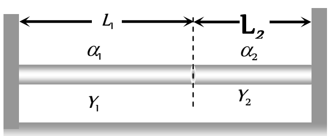


Fig. 9.11

Increase in length of the composite rod (due to heating) will be equal to

$l_1 + l_2 = [L_1\alpha_1 + L_2\alpha_2]T$ [As $l = L\,\alpha\,\Delta\theta$]

and due to compressive force F from the walls due to elasticity, decrease in length of the composite rod will be equal to

$\left[\frac{L_1}{Y_1} + \frac{L_2}{Y_2}\right]\frac{F}{A}$ $\left[\text{As}\, l = \frac{FL}{AY}\right]$

as the length of the composite rod remains unchanged the increase in length due to heating must be equal to decrease in length due to compression *i.e.* $\frac{F}{A}\left[\frac{L_1}{Y_1} + \frac{L_2}{Y_2}\right] = [L_1\alpha_1 + L_2\alpha_2]T$

or $F = \frac{A[L_1\alpha_1 + L_2\alpha_2]T}{\left[\frac{L_1}{Y_1} + \frac{L_2}{Y_2}\right]}$

(vi) **Force constant of wire** : Force required to produce unit elongation in a wire is called force constant of material of wire. It is denoted by k.

$\therefore\ k = \frac{F}{l}$ ...(i)

but from the definition of young's modulus

$\frac{F}{l} = \frac{YA}{L}$ ...(ii)

from (i) and (ii) $k = \frac{YA}{L}$

It is clear that the value of force constant depends upon the dimension (length and area of cross section) and material of a substance.

(vii) Actual length of the wire : If the actual length of the wire is L, then under the tension T_1 its length becomes L_1 and under the tension T_2 its length becomes L_2.

$L_1 = L + l_1 \Rightarrow L_1 = L + \frac{T_1}{k}$ ...(i)

and $L_2 = L + l_2 \Rightarrow L_2 = L + \frac{T_2}{k}$ ...(ii)

From (i) and (ii) we get $L = \frac{L_1T_2 - L_2T_1}{T_2 - T_1}$

Work Done in Stretching a Wire

In stretching a wire work is done against internal restoring forces. This work is stored in the wire as elastic potential energy or strain energy.

If a force F acts along the length L of the wire of cross-section A and stretches it by x then

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/L} = \frac{FL}{Ax} \Rightarrow F = \frac{YA}{L}x$$

So the work done for an additional small increase dx in length, $dW = Fdx = \frac{YA}{L}x\,.\,dx$

Hence the total work done in increasing the length by l, $W = \int_0^l dW = \int_0^l F dx = \int_0^l \frac{YA}{L}.x\,dx = \frac{1}{2}\frac{YA}{L}l^2$

This work done is stored in the wire.

$\therefore$ Energy stored in wire $U = \frac{1}{2}\frac{YAl^2}{L} = \frac{1}{2}Fl$ $\left[\text{As}\, F = \frac{YAl}{L}\right]$

Dividing both sides by volume of the wire we get energy stored in unit volume of wire.

$$U_V = \frac{1}{2}\times\frac{F}{A}\times\frac{l}{L} = \frac{1}{2}\times\text{stress}\times\text{strain} = \frac{1}{2}\times Y\times(\text{strain})^2$$

$= \frac{1}{2Y}(\text{stress})^2$ [As AL = volume of wire]

Total energy stored in wire (U)	Energy stored in per unit volume of wire (U)
$\frac{1}{2}Fl$	$\frac{1}{2}\frac{Fl}{\text{volume}}$
$\frac{1}{2}\times\text{stress}\times\text{strain}\times\text{volume}$	$\frac{1}{2}\times\text{stress}\times\text{strain}$
$\frac{1}{2}\times Y\times(\text{strain})^2\times\text{volume}$	$\frac{1}{2}\times Y\times(\text{strain})^2$
$\frac{1}{2Y}\times(\text{stress})^2\times\text{volume}$	$\frac{1}{2Y}\times(\text{stress})^2$

Note : ❑ If the force on the wire is increased from F_1 to F_2 and the elongation in wire is l then energy stored in the wire $U = \frac{1}{2}\frac{(F_1 + F_2)}{2}l$

❑ Thermal energy density = Thermal energy per unit volume = $\frac{1}{2}\times$ Thermal stress × strain

$= \frac{1}{2}\frac{F}{A}\frac{l}{L} = \frac{1}{2}(Y\alpha\Delta\theta)(\alpha\Delta\theta) = \frac{1}{2}Y\alpha^2(\Delta\theta)^2$

Breaking of Wire

When the wire is loaded beyond the elastic limit, then strain increases much more rapidly. The maximum stress corresponding to B (see stress-strain curve) after which the wire begin to flow and breaks, is called breaking stress or tensile strength and the force by application of which the wire breaks is called the breaking force.

(i) Breaking force depends upon the area of cross-section of the wire i.e., Breaking force ∝ A

∴ Breaking force = P × A

Here P is a constant of proportionality and known as breaking stress.

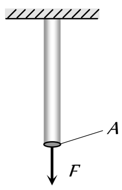


Fig. 9.12

(ii) Breaking stress is a constant for a given material and it does not depend upon the dimension (length or thickness) of wire.

(iii) If a wire of length L is cut into two or more parts, then again it's each part can hold the same weight. Since breaking force is independent of the length of wire.

(iv) If a wire can bear maximum force F, then wire of same material but double thickness can bear maximum force 4F

(v) The working stress is always kept lower than that of a breaking stress.

So that safety factor = $\frac{\text{breaking stress}}{\text{working stress}}$, may have large value.

(vi) Breaking of wire under its own weight.

Breaking force = Breaking stress × Area of cross section

Weight of wire = Mg = ALdg = PA   [P =Breaking stress]

[As mass = volume × density = ALd]

$$\Rightarrow \ Ldg = P \ \ \therefore \ L = \frac{P}{dg}$$

This is the length of wire if it breaks by its own weight.

Bulk Modulus

When a solid or fluid (liquid or gas) is subjected to a uniform pressure all over the surface, such that the shape remains the same, then there is a change in volume.

Then the ratio of normal stress to the volumetric strain within the elastic limits is called as Bulk modulus. This is denoted by K.

$$K = \frac{\text{Normal stress}}{\text{volumetric strain}}$$

$$K = \frac{F/A}{-\Delta V/V} = \frac{-pV}{\Delta V}$$

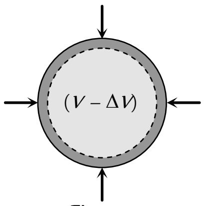


Fig. 9.13

where p = increase in pressure; V = original volume; ΔV = change in volume

The negative sign shows that with increase in pressure p, the volume decreases by ΔV i.e. if p is positive, ΔV is negative. The reciprocal of bulk modulus is called compressibility.

C = compressibility = $\frac{1}{K} = \frac{\Delta V}{pV}$

S.I. unit of compressibility is $N^{-1}m^2$ and C.G.S. unit is $dyne^{-1}\ cm^2$.

Gases have two bulk moduli, namely isothermal elasticity E_θ and adiabatic elasticity E_ϕ.

(1) Isothermal elasticity (E_θ) : Elasticity possess by a gas in isothermal condition is defined as isothermal elasticity.

For isothermal process, PV = constant   (Boyle's law)

Differentiating both sides

PdV + VdP = 0 ⇒ PdV = – VdP

$$P = \frac{dP}{(-dV/V)} = \frac{\text{stress}}{\text{strain}} = E_\theta \quad \therefore \ E_\theta = P$$

i.e., Isothermal elasticity is equal to pressure.

(2) Adiabatic elasticity (E_ϕ) : Elasticity possess by a gas in adiabatic condition is defined as adiabatic elasticity.

For adiabatic process, PV^γ = constant   (Poisson's law)

Differentiating both sides,

$$P\gamma V^{\gamma-1}dV + V^\gamma dP = 0 \ \Rightarrow \ \gamma PdV + VdP = 0$$

$$\gamma P = \frac{dP}{\left(\frac{-dV}{V}\right)} = \frac{\text{stress}}{\text{strain}} = E_\phi$$

$\therefore E_\phi = \gamma P$

i.e., adiabatic elasticity is equal to γ times pressure.

[Where $\gamma = \frac{C_p}{C_v}$]

Note : ❑ Ratio of adiabatic to isothermal elasticity

$$\frac{E_\phi}{E_\theta} = \frac{\gamma P}{P} = \gamma > 1 \quad \therefore \ E_\phi > E_\theta$$

i.e., adiabatic elasticity is always more than isothermal elasticity.

Density of Compressed Liquid

If a liquid of density ρ, volume V and bulk modulus K is compressed, then its density increases.

As density $\rho = \frac{m}{V}$ so $\frac{\Delta\rho}{\rho} = \frac{-\Delta V}{V}$ ...(i)

But by definition of bulk modulus

$$K = \frac{-V\Delta P}{\Delta V} \Rightarrow \ -\frac{\Delta V}{V} = \frac{\Delta P}{K} \quad ...(ii)$$

From (i) and (ii) $\frac{\Delta\rho}{\rho} = \frac{\rho' - \rho}{\rho} = \frac{\Delta P}{K}$ [As $\Delta\rho = \rho' - \rho$]

or $\rho' = \rho\left[1 + \frac{\Delta P}{K}\right] = \rho[1 + C\Delta P]$ $\left[\text{As} \frac{1}{K} = C\right]$

Fractional Change in the Radius of Sphere

A solid sphere of radius R made of a material of bulk modulus K is surrounded by a liquid in a cylindrical container.

A massless piston of area A floats on the surface of the liquid.

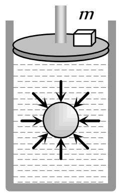


Fig. 9.14

Volume of the spherical body $V = \frac{4}{3}\pi R^3$

$$\frac{\Delta V}{V} = 3\frac{\Delta R}{R}$$

$$\therefore \ \frac{\Delta R}{R} = \frac{1}{3}\frac{\Delta V}{V} \quad ...(i)$$

Bulk modulus $K = -V\frac{\Delta P}{\Delta V}$

$$\therefore \ \left|\frac{\Delta V}{V}\right| = \frac{\Delta P}{K} = \frac{mg}{AK} \quad .....(ii)$$

$$\left[\text{As} \Delta P = \frac{mg}{A}\right]$$

Substituting the value of $\frac{\Delta V}{V}$ from equation (ii) in equation (i) we get $\frac{\Delta R}{R} = \frac{1}{3}\frac{mg}{AK}$

Modulus of Rigidity

Within limits of proportionality, the ratio of tangential stress to the shearing strain is called modulus of rigidity of the material of the body and is denoted by η, i.e. $\eta = \frac{\text{Shearing stress}}{\text{Shearing strain}}$

In this case the shape of a body changes but its volume remains unchanged.

Consider a cube of material fixed at its lower face and acted upon by a tangential force F at its upper surface having area A. The shearing stress, then, will be

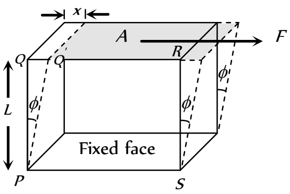


Fig. 9.15

Shearing stress $= \dfrac{F}{A}$

This shearing force causes the consecutive horizontal layers of the cube to be slightly displaced or sheared relative to one another, each line such as PQ or RS in the cube is rotated through an angle φ by this shear. The shearing strain is defined as the angle ϕ in radians through which a line normal to a fixed surface has turned. For small values of angle,

Shearing strain $= \phi = \dfrac{QQ'}{PQ} = \dfrac{x}{L}$

So $\eta = \dfrac{\text{shear stress}}{\text{shear strain}} = \dfrac{F/A}{\phi} = \dfrac{F}{A\phi}$

Only solids can exhibit a shearing as these have definite shape.

Poisson's Ratio

When a long bar is stretched by a force along its length then its length increases and the radius decreases as shown in the figure.

Lateral strain : The ratio of change in radius or diameter to the original radius or diameter is called lateral strain.

Longitudinal strain : The ratio of change in length to the original length is called longitudinal strain.

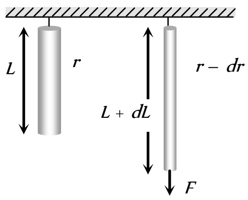


Fig. 9.16

The ratio of lateral strain to longitudinal strain is called Poisson's ratio (σ).

i.e. $\sigma = \dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

$\sigma = \dfrac{-dr/r}{dL/L}$

Negative sign indicates that the radius of the bar decreases when it is stretched.

Poisson's ratio is a dimensionless and a unitless quantity.

Relation Between Volumetric Strain, Lateral Strain and Poisson's Ratio

If a long bar have a length L and radius r then volume $V = \pi r^2 L$

Differentiating both the sides $dV = \pi r^2 dL + \pi 2rLdr$

Dividing both the sides by volume of bar

$\dfrac{dV}{V} = \dfrac{\pi r^2 dL}{\pi r^2 L} + \dfrac{\pi 2rLdr}{\pi r^2 L} = \dfrac{dL}{L} + 2\dfrac{dr}{r}$

⇒ Volumetric strain = longitudinal strain + 2(lateral strain)

$$\Rightarrow \frac{dV}{V} = \frac{dL}{L} + 2\sigma\frac{dL}{L} = (1+2\sigma)\frac{dL}{L}$$

$$\left[\text{As } \sigma = \frac{dr/r}{dL/L} \Rightarrow \frac{dr}{r} = \sigma\frac{dL}{L}\right]$$

or $\sigma = \dfrac{1}{2}\left[\dfrac{dV}{AdL} - 1\right]$

[where A = cross-section of bar]

(i) If a material having $\sigma = -0.5$ then $\dfrac{dV}{V} = [1+2\sigma]\dfrac{dL}{L} = 0$

∴ Volume = constant or $K = \infty$ *i.e.* the material is incompressible.

(ii) If a material having $\sigma = 0$, then lateral strain is zero *i.e.* when a substance is stretched its length increases without any decrease in diameter *e.g.* cork. In this case change in volume is maximum.

(iii) Theoretical value of Poisson's ratio $-1 < \sigma < 0.5$.

(iv) Practical value of Poisson's ratio $0 < \sigma < 0.5$

Relation between Y, k, η and σ

Moduli of elasticity are three, *viz.* Y, K and η while elastic constants are four, *viz*, Y, K, η and σ. Poisson's ratio σ is not modulus of elasticity as it is the ratio of two strains and not of stress to strain. Elastic constants are found to depend on each other through the relations :

$Y = 3K(1-2\sigma)$ ...(i)

$Y = 2\eta(1+\sigma)$ ...(ii)

Eliminating σ or Y between these, we get

$Y = \dfrac{9K\eta}{3K+\eta}$ ...(iii)

$\sigma = \dfrac{3K-2\eta}{6K+2\eta}$ ...(iv)

Torsion of Cylinder

If the upper end of a cylinder is clamped and a torque is applied at the lower end the cylinder gets twisted by angle θ. Simultaneously shearing strain ϕ is produced in the cylinder.

(i) The angle of twist θ is directly proportional to the distance from the fixed end of the cylinder.

At fixed end $\theta = 0^o$ and at free end θ = maximum.

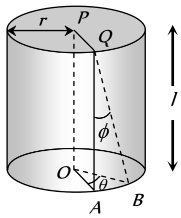


Fig. 9.17

(ii) The value of angle of shear ϕ is directly proportional to the radius of the cylindrical shell.

At the axis of cylinder ϕ = 0 and at the outermost shell ϕ = maximum.

(iii) Relation between angle of twist (θ) and angle of shear (ϕ)

$AB = r\theta = \phi l \quad \therefore \quad \phi = \frac{r\theta}{l}$

(iv) Twisting couple per unit twist or torsional rigidity or torque required to produce unit twist.

$$C = \frac{\pi\eta r^4}{2l} \quad \therefore \quad C \propto r^4 \propto A^2$$

(v) Work done in twisting the cylinder through an angle θ is

$$W = \frac{1}{2}C\theta^2 = \frac{\pi\eta r^4\theta^2}{4l}$$

Interatomic Force Constant

Behaviour of solids with respect to external forces is such that if their atoms are connected to springs. When an external force is applied on a solid, this distance between its atoms changes and interatomic force works to restore the original dimension.

The ratio of interatomic force to that of change in interatomic distance is defined as the interatomic force constant. $K = \frac{F}{\Delta r}$

It is also given by $K = Y \times r_0$ [Where Y = Young's modulus, r_0 = Normal distance between the atoms of wire]

Unit of interatomic force constant is N/m and Dimension MT^{-2}

Note : ❑ The number of atoms having interatomic distance r_0 in length l of a wire, $N = l/r_0$.

The number of atoms in area A of wire having interatomic separation r_0 is $N = A/r_0^2$.

Elastic Hysteresis

When a deforming force is applied on a body then the strain does not change simultaneously with stress rather it lags behind the stress. The lagging of strain behind the stress is defined as elastic hysteresis. This is the reason why the values of strain for same stress are different while increasing the load and while decreasing the load.

Hysteresis loop : The area of the stress-strain curve is called the hysteresis loop and it is numerically equal to the work done in loading the material and then unloading it.

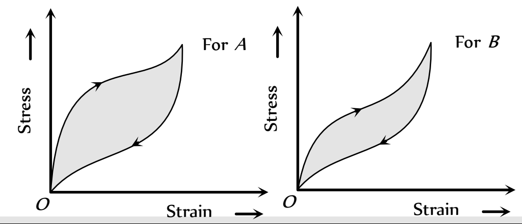


Fig. 9.18

If we have two tyres of rubber having different hysteresis loop then rubber B should be used for making the car tyres. It is because of the reason that area under the curve *i.e.* work done in case of rubber B is lesser and hence the car tyre will not get excessively heated and rubber A should be used to absorb vibration of the machinery because of the large area of the curve, a large amount of vibrational energy can be dissipated.

Factors Affecting Elasticity

(1) Hammering and rolling : Crystal grains break up into smaller units by hammering and rolling. This results in increase in the elasticity of material.

(2) Annealing : The metals are annealed by heating and then cooling them slowly. Annealing results in decrease in the elasticity of material.

(3) Temperature : Intermolecular forces decreases with rise in temperature. Hence the elasticity decreases with rise in temperature but the elasticity of invar steel (alloy) does not change with change of temperature.

(4) Impurities : Due to impurities in a material, elasticity can increase or decrease. The type of effect depends upon the nature of impurities present in the material.

Important Facts About Elasticity

(1) The body which requires greater deforming force to produce a certain change in dimension is more elastic.

Example : Ivory and steel balls are more elastic than rubber.

(2) When equal deforming force is applied on different bodies then the body which shows less deformation is more elastic.

Example : (i) For same load, more elongation is produced in rubber wire than in steel wire hence steel is more elastic than rubber.

(ii) Water is more elastic than air as volume change in water is less for same applied pressure.

(iii) Four identical balls of different materials are dropped from the same height then after collision, balls rises upto different heights.

The order of their height can be given by $h_{ivory} > h_{steel} > h_{rubber} > h_{clay}$ because $Y_{ivory} > Y_{steel} > Y_{rubber} > Y_{clay}$.

(3) The value of moduli of elasticity is independent of the magnitude of the stress and strain. It depends only on the nature of material of the body.

(4) For a given material there can be different moduli of elasticity depending on the type of stress applied and resulting strain.

Name of substance	Young's modulus (Y) 10 N/m	Bulk modulus (K) 10 N/m	Modulus of rigidity (η) 10 N/m
Aluminium	6.9	7.0	2.6
Brass	9.0	6.7	3.4
Copper	11.0	13.0	4.5
Iron	19.0	14.0	4.6
Steel	20.0	16.0	8.4
Tungsten	36.0	20.0	15.0
Diamond	83.0	55.0	34.0

Water	–	0.22	–
Glycerin	–	0.45	–
Air	–	1.01	–

(5) The moduli of elasticity has same dimensional formula and units as that of stress since strain is dimensionless. $\therefore$ Dimensional formula is $[ML^{-1}T^{-2}]$ while units *dyne/cm* or *Newton/m*.

(6) Greater the value of moduli of elasticity more elastic is the material. But as $Y \propto (1/l)$, $K \propto (1/\Delta V)$ and $\eta \propto (1/\phi)$ for a constant stress, so smaller change in shape or size for a given stress corresponds to greater elasticity.

(7) The moduli of elasticity Y and η exist only for solids as liquids and gases cannot be deformed along one dimension only and also cannot sustain shear strain. However K exist for all states of matter *viz.* solid, liquid or gas.

(8) Gases being most compressible are least elastic while solids are most *i.e.* the bulk modulus of gas is very low while that for liquids and solids is very high. $K_{solid} > K_{liquid} > K_{gas}$

(9) For a rigid body l, ΔV or $\phi = 0$ so Y, K or η will be ∞, *i.e.* elasticity of a rigid body is infinite.

Diamond and carborundum are nearest approach to rigid bodies.

(10) In a suspension bridge there is a stretch in the ropes by the load of the bridge. Due to which length of rope changes. Hence Young's modulus of elasticity is involved.

(11) In an automobile tyre as the air is compressed, volume of the air in tyre changes, hence the bulk modulus of elasticity is involved.

(12) In transmitting power, an automobile shaft is sheared as it rotates, so shearing strain is set up, hence modulus of rigidity is involved.

(13) The shape of rubber heels changes under stress, so modulus of rigidity is involved.

Practical Applications of Elasticity

(i) The metallic parts of machinery are never subjected to a stress beyond elastic limit, otherwise they will get permanently deformed.

(ii) The thickness of the metallic rope used in the crane in order to lift a given load is decided from the knowledge of elastic limit of the material of the rope and the factor of safety.

(iii) The bridges are declared unsafe after long use because during its long use, a bridge under goes quick alternating strains continuously. It results in the loss of elastic strength.

(iv) Maximum height of a mountain on earth can be estimated from the elastic behaviour of earth.

At the base of the mountain, the pressure is given by $P = h\rho g$ and it must be less than elastic limit (K) of earth's supporting material.

$$K > P > h\rho g \;\; \therefore \; h < \frac{K}{\rho g} \qquad \text{or} \qquad h_{max} = \frac{K}{\rho g}$$

(v) In designing a beam for its use to support a load (in construction of roofs and bridges), it is advantageous to increase its depth rather than the breadth of the beam because the depression in rectangular beam.

$$\delta = \frac{Wl^3}{4Ybd^3}$$

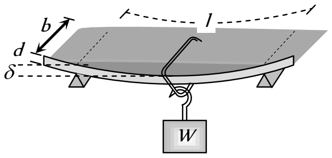


Fig. 9.19

To minimize the depression in the beam, it is designed as *I*-shaped girder.

(vi) For a beam with circular cross-section depression is given by $\delta = \dfrac{WL^3}{12\pi r^4 Y}$

(vii) A hollow shaft is stronger than a solid shaft made of same mass, length and material.

Torque required to produce a unit twist in a solid shaft

$$\tau_{solid} = \frac{\pi\eta r^4}{2l} \qquad ...(i)$$

and torque required to produce a unit twist in a hollow shaft

$$\tau_{hollow} = \frac{\pi\eta(r_2^4 - r_1^4)}{2l} \qquad ...(ii)$$

From (i) and (ii),

$$\frac{\tau_{hollow}}{\tau_{solid}} = \frac{r_2^4 - r_1^4}{r^4} = \frac{(r_2^2 + r_1^2)(r_2^2 - r_1^2)}{r^4} \qquad ...(iii)$$

Since two shafts are made from equal volume $\therefore$ $\pi r^2 l = \pi(r_2^2 - r_1^2)l \;\Rightarrow\; r^2 = r_2^2 - r_1^2$

Substituting this value in equation (iii) we get, $\dfrac{\tau_{hollow}}{\tau_{solid}} = \dfrac{r_2^2 + r_1^2}{r^2} > 1 \;\; \therefore \; \tau_{hollow} > \tau_{solid}$

i.e., the torque required to twist a hollow shaft is greater than the torque necessary to twist a solid shaft of the same mass, length and material through the same angle. Hence, a hollow shaft is stronger than a solid shaft.

Tips & Tricks

✍ Metals are polycrystalline materials.

✍ Metals are elastic for small strains and for large strains, metals become plastic.

✍ The substances having large molecular structure (formed by the union of two to several thousand simple molecules) are called polymers.

✍ Rubber is a polymer.

✍ Rubber is elastic for very large strains.

✍ It stretches easily at first but then becomes stiffer.

✍ Young's modulus is defined only for the solids.

✍ Bulk modulus was first defined by Maxwell.

✍ Bulk modulus is defined for all types of materials, solids, liquids and gases.

✍ Reciprocal of bulk modules is called compressibility.

✍ Hooke's law is obeyed only for small values of strain.

✍ Higher value of the elasticity (modulus) means greater force is required for producing a given change.

✍ The material which break as soon as the stress goes beyond the elastic limit are called brittle.

✍ The material which do not break well beyond the elastic limit are called ductile.

✍ The deformation beyond elastic limit is called plasticity.

✍ Rubber sustains elasticity even when stretched several times its length.

However it is not ductile. If breaks down as soon as the elastic limit is crossed.

✍ Within elastic limit, the force constant for a spring is given by $K = \frac{YA}{L}$

✍ Elastic after effect is a temporary absence of the elastic properties.

✍ Quartz is the best available example of perfectly elastic materials.

✍ Isothermal elasticity = pressure (P)

✍ Adiabatic elasticity = Ratio of specific heats × pressure $=\gamma P$

✍ Elasticity is meaningless for the rigid bodies. It is the property of the non rigid bodies.

✍ Diamond and carborundum are the nearest approach to the rigid body.

✍ Elastic fatigue occurs, when a metal is subjected to repeated loading and unloading.

✍ Theoretical value of Poisson's ratio lies between –1 and +1/2 but practical value lies between zero and +1/2.

✍ Negative value of poisson's ratio means that if length increases then radius decreases.

✍ Stress and pressure have the same units and dimensions, but the pressure is always normal to the surface but the stress may be parallel or perpendicular to the surface.

✍ Normal stress is also called tensile stress when the length of the body tends to increase.

✍ Normal stress is also called compressive stress when length of the body tends to decrease.

✍ Tangential stress is also called shearing stress.

✍ When the deforming force is inclined to the surface, both the tangential as well as normal stress are produced.

✍ When a body is sheared, two mutually perpendicular strains are produced. They are called longitudinal strain and compressional strain. Both are equal in magnitude.

✍ When a beam is bent, both extensional as well as compressional strain is produced.

✍ The energy stored by an elastic material is the area under the force-extension graph. The area under the stress-strain graph gives the energy stored per unit volume.

✍ Thermal stress in a rod $= Y\alpha\,\Delta\theta$. It is independent of the area of cross section or length of the wire.

✍ Breaking stress for a wire of unit cross-section is called tensile strength.

✍ Breaking stress does not depend on the length or area of cross section of the wire. However it depends on the material of the wire.

✍ Breaking force depends on the area of cross section. Breaking stress of a wire is called tensile strength.

✍ If we double the radius of rope its breaking force becomes four times. But the breaking stress remains unchanged.

✍ If a beam of rectangular cross-section is loaded its depression at the beam is inversely proportional to the cube of thickness.

✍ If a beam of circular cross-section is loaded, its depression is inversely proportional to the fourth power of radius. *i.e.* $\delta \propto \frac{1}{r^4}$

Ordinary Thinking

Objective Questions

Young's Modulus and Breaking Stress

1. The length of an iron wire is L and area of cross-section is A. The increase in length is l on applying the force F on its two ends. Which of the statement is correct [**NCERT 1976**]

(a) Increase in length is inversely proportional to its length L

(b) Increase in length is proportional to area of cross-section A

(c) Increase in length is inversely proportional to A

(d) Increase in length is proportional to Young's modulus

2. The increase in length is l of a wire of length L by the longitudinal stress. Then the stress is proportional to

[**MP PET 1986**]

(a) L/l (b) l/L

(c) $l \times L$ (d) $l^2 \times L$

3. The dimensions of four wires of the same material are given below. In which wire the increase in length will be maximum when the same tension is applied

[**IIT 1981; NCERT 1976; MP PET/PMT 1998; CPMT 1983, 90; MP PMT 1992, 94, 97; MP PET 1989, 90, 99**]

(a) Length 100 *cm*, Diameter 1 *mm*

(b) Length 200 *cm*, Diameter 2 *mm*

(c) Length 300 *cm*, Diameter 3 *mm*

(d) Length 50 *cm*, Diameter 0.5 *mm*

4. The ratio of the lengths of two wires *A* and *B* of same material is 1 : 2 and the ratio of their diameter is 2 : 1. They are stretched by the same force, then the ratio of increase in length will be[MP PMT 1986; MP PET/PMT 1988]

(a) 2 : 1 (b) 1 : 4

(c) 1 : 8 (d) 8 : 1

5. The Young's modulus of a wire of length *L* and radius *r* is *Y N/m*. If the length and radius are reduced to *L*/2 and *r*/2, then its Young's modulus will be

[MP PMT 1985; MP PET 1997; KCET 1999]

(a) *Y*/2 (b) *Y*

(c) 2*Y* (d) 4*Y*

6. A beam of metal supported at the two ends is loaded at the centre. The depression at the centre is proportional to

[CPMT 1983, 84]

(a) Y^2 (b) *Y*

(c) 1/*Y* (d) $1/Y^2$

7. When a certain weight is suspended from a long uniform wire, its length increases by one cm. If the same weight is suspended from another wire of the same material and length but having a diameter half of the first one then the increase in length will be

(a) 0.5 *cm* (b) 2 *cm*

(c) 4 *cm* (d) 8 *cm*

8. Hook's law defines [MP PMT/PET 1988]

(a) Stress (b) Strain

(c) Modulus of elasticity (d) Elastic limit

9. A wire is loaded by 6 kg at its one end, the increase in length is 12 *mm*. If the radius of the wire is doubled and all other magnitudes are unchanged, then increase in length will be[MP PMT 1987; AI SSCE 1982]

(a) 6 *mm* (b) 3 *mm*

(c) 24 *mm* (d) 48 *mm*

10. The area of cross-section of a wire of length 1.1 *metre* is 1 *mm*. It is loaded with 1 kg. If Young's modulus of copper is $1.1\times10^{11}\ N/m^2$, then the increase in length will be (If $g = 10\,m/s^2$) [MP PET 1989]

(a) 0.01 *mm* (b) 0.075 *mm*

(c) 0.1 *mm* (d) 0. 15 *mm*

11. On increasing the length by 0.5 *mm* in a steel wire of length 2 *m* and area of cross-section $2\,mm^2$, the force required is [*Y* for steel $= 2.2\times10^{11}\ N/m^2$]] [MP PET/PMT 1988]

(a) $1.1\times10^5\ N$ (b) $1.1\times10^4\ N$

(c) $1.1\times10^3\ N$ (d) $1.1\times10^2\ N$

12. If Young's modulus of iron is $2\times10^{11}\ N/m^2$ and the interatomic spacing between two molecules is 3×10^{-10} *metre*, the interatomic force constant is

[JIPMER 1978]

(a) 60 *N*/*m* (b) 120 *N*/*m*

(c) 30 *N*/*m* (d) 180 *N*/*m*

13. In CGS system, the Young's modulus of a steel wire is 2×10^{12}. To double the length of a wire of unit cross-section area, the force required is [MP PMT 1989]

(a) 4×10^6 *dynes* (b) 2×10^{12} *dynes*

(c) 2×10^{12} *newtons* (d) 2×10^8 *dynes*

14. The material which practically does not show elastic after effect is[JIPMER 1997;

(a) Copper (b) Rubber

(c) Steel (d) Quartz

15. If the temperature increases, the modulus of elasticity

(a) Decreases (b) Increases

(c) Remains constant (d) Becomes zero

16. A force *F* is needed to break a copper wire having radius *R*. The force needed to break a copper wire of radius 2*R* will be

[MP PET 1990]

(a) *F*/2 (b) 2*F*

(c) 4*F* (d) *F*/4

17. The relationship between Young's modulus *Y*, Bulk modulus K and modulus of rigidity η is

[MP PET 1991; MP PMT 1997]

(a) $Y = \frac{9\eta K}{\eta + 3K}$ [CPMT 1984, 90] (b) $\frac{9YK}{Y+3K}$

(c) $Y = \frac{9\eta K}{3+K}$ (d) $Y = \frac{3\eta K}{9\eta + K}$

18. The diameter of a brass rod is 4 *mm* and Young's modulus of brass is $9\times10^{10}\ N/m^2$. The force required to stretch by 0.1% of its length is [MP PET 1991; BVP 2003]

(a) $360\,\pi N$ (b) 36 *N*

(c) $144\pi\times10^3\ N$ (d) $36\pi\times10^5\ N$

19. If *x* longitudinal strain is produced in a wire of Young's modulus *y*, then energy stored in the material of the wire per unit volume is

[MP PMT 1987, 89, 92; CPMT 1997; Pb. PMT 1999; KCET 2000; AIIMS 2001]

(a) yx^2 (b) $2yx^2$

(c) $\frac{1}{2}y^2x$ (d) $\frac{1}{2}yx^2$

20. In a wire of length *L*, the increase in its length is *l*. If the length is reduced to half, the increase in its length will be

(a) *l* (b) 2*l*

(c) $\frac{l}{2}$ (d) None of the above

21. The Young's modulus of a rubber string 8 *cm* long and density $1.5\,kg/m^3$ is $5\times10^8\ N/m^2$, is suspended on the ceiling in a room. The increase in length due to its own weight will be

(a) $9.6\times10^{-5}\ m$ (b) $9.6\times10^{-11}\ m$

(c) $9.6\times10^{-3}\ m$ (d) 9.6 *m*

22. *A* and *B* are two wires. The radius of *A* is twice that of *B*. They are stretched by the some load. Then the stress on *B* is

[MP PMT 1993]

(a) Equal to that on *A* (b) Four times that on *A*

(c) Two times that on *A* (d) Half that on *A*

23. If the length of a wire is reduced to half, then it can hold the .... load
(a) Half (b) Same
(c) Double (d) One fourth

24. To double the length of a iron wire having $0.5\,cm^2$ area of cross-section, the required force will be $(Y = 10^{12}\, dyne / cm^2)$
(a) $1.0 \times 10^{-7}\, N$ (b) $1.0 \times 10^{7}\, N$
(c) $0.5 \times 10^{-7}\, N$ (d) 0.5×10^{12} *dyne*

25. The spring balance does not read properly after its long use, because
(a) The elasticity of spring increases
(b) The elasticity decreases
(c) Its plastic power decreases
(d) Its plastic power increases

26. Two wires of equal lengths are made of the same material. Wire *A* has a diameter that is twice as that of wire *B*. If identical weights are suspended from the ends of these wires, the increase in length is [EAMCET 1983; MP PMT 1990; MP PET 1995]
(a) Four times for wire *A* as for wire *B*
(b) Twice for wire *A* as for wire *B*
(c) Half for wire *A* as for wire *B*
(d) One-fourth for wire *A* as for wire *B*

27. Why the spring is made up of steel in comparison of copper
(a) Copper is more costly than steel
(b) Copper is more elastic than steel
(c) Steel is more elastic than copper
(d) None of the above

28. Steel and copper wires of same length are stretched by the same weight one after the other. Young's modulus of steel and copper are $2 \times 10^{11}\, N/m^2$ and $1.2 \times 10^{11}\, N/m^2$. The ratio of increase in length [MP PET 1984]
(a) $\frac{2}{5}$ (b) $\frac{3}{5}$
(c) $\frac{5}{4}$ (d) $\frac{5}{2}$

29. An area of cross-section of rubber string is $2\,cm^2$. Its length is doubled when stretched with a linear force of 2×10^5 *dynes*. The Young's modulus of the rubber in $dyne / cm^2$ will be
(a) 4×10^5 (b) 1×10^5
(c) 2×10^5 (d) 1×10^4

30. Increase in length of a wire is 1 *mm* when suspended by a weight. If the same weight is suspended on a wire of double its length and double its radius, the increase in length will be [CPMT 1976]
(a) 2 *mm* (b) 0.5 *mm*
(c) 4 *mm* (d) 0.25 *mm*

31. The temperature of a wire of length 1 *metre* and area of cross-section $1\,cm^2$ is increased from $0°C$ to $100°C$. If the rod is not allowed to increase in length, the force required will be $(\alpha = 10^{-5} / °C$ and $Y = 10^{11}\, N/m^2)$ [NCERT 1976; CPMT 1982, 91]
(a) $10^3\, N$ (b) $10^4\, N$
(c) $10^5\, N$ (d) $10^9\, N$

32. A rod of length *l* and area of cross-section *A* is heated from $0°C$ to $100°C$. The rod is so placed that it is not allowed to increase in length, then the force developed is proportional to
(a) *l* (b) l^{-1}
(c) *A* [MP PMT 1987] (d) A^{-1}

33. An aluminum rod (Young's modulus $= 7 \times 10^9\, N/m^2$) has a breaking strain of 0.2%. The minimum cross-sectional area of the rod in order to support a load of 10^4 Newton's is [MP PMT 1991]
(a) $1 \times 10^{-2}\, m^2$ (b) $1.4 \times 10^{-3}\, m^2$
(c) $3.5 \times 10^{-3}\, m^2$ (d) $7.1 \times 10^{-4}\, m^2$

34. Two wires of copper having the length in the ratio 4 : 1 and their radii ratio as 1 : 4 are stretched by the same force. The ratio of longitudinal strain in the two will be
(a) 1 : 16 (b) 16 : 1
(c) 1 : 64 (d) 64 : 1

35. A weight of 200 *kg* is suspended by vertical wire of length 600.5 *cm*. The area of cross-section of wire is $1\,mm^2$. When the load is removed, the wire contracts by 0.5 *cm*. The Young's modulus of the material of wire will be
(a) $2.35 \times 10^{12}\, N/m^2$ (b) $1.35 \times 10^{10}\, N/m^2$
(c) $13.5 \times 10^{11}\, N/m^2$ (d) $23.5 \times 10^{9}\, N/m^2$

36. If a load of 9 *kg* is suspended on a wire, the increase in length is 4.5 *mm*. The force constant of the wire is
(a) $0.49 \times 10^4\, N/m$ (b) $1.96 \times 10^4\, N/m$
(c) $4.9 \times 10^4\, N/m$ (d) $0.196 \times 10^4\, N/m$

37. The ratio of diameters of two wires of same material is *n* : 1. The length of wires are 4 *m* each. On applying the same load, the increase in length of thin wire will be
(a) n^2 times (b) *n* times
(c) 2*n* times (d) None of the above

38. Longitudinal stress of $1\,kg/mm^2$ is applied on a wire. The percentage increase in length is $(Y = 10^{11}\, N/m^2)$ [MP PET 1985]
(a) 0.002 (b) 0.001
(c) 0.003 (d) 0.01

39. A steel wire is stretched with a definite load. If the Young's modulus of the wire is *Y*. For decreasing the value of *Y*
(a) Radius is to be decreased
(b) Radius is to be increased
(c) Length is to be increased
(d) None of the above

40. The interatomic distance for a metal is $3 \times 10^{-10}\, m$. If the interatomic force constant is $3.6 \times 10^{-9}\, N/Å$, then the Young's modulus in N/m^2 will be
(a) 1.2×10^{11} (b) 4.2×10^{11}
(c) 10.8×10^{-19} (d) 2.4×10^{10}

41. Two identical wires of rubber and iron are stretched by the same weight, then the number of atoms in the iron wire will be
(a) Equal to that of rubber
(b) Less than that of the rubber
(c) More than that of the rubber
(d) None of the above

42. The force constant of a wire does not depend on
(a) Nature of the material (b) Radius of the wire
(c) Length of the wire (d) None of the above

43. The elasticity of *invar*
(a) Increases with temperature rise
(b) Decreases with temperature rise
(c) Does not depend on temperature
(d) None of the above

44. After effects of elasticity are maximum for
(a) Glass (b) Quartz
(c) Rubber (d) Metal

45. In suspended type moving coil galvanometer, quartz suspension is used because
(a) It is good conductor of electricity
(b) Elastic after effects are negligible
(c) Young's modulus is greater
(d) There is no elastic limit

46. A force of 200 *N* is applied at one end of a wire of length 2 *m* and having area of cross-section $10^{-2}\ cm^2$. The other end of the wire is rigidly fixed. If coefficient of linear expansion of the wire $\alpha = 8\times10^{-6}/°C$ and Young's modulus $Y = 2.2\times10^{11}\ N/m^2$ and its temperature is increased by 5°*C*, then the increase in the tension of the wire will be
(a) 4.2 *N* (b) 4.4 *N*
(c) 2.4 *N* (d) 8.8 *N*

47. When compared with solids and liquids, the gases have
(a) Minimum volume elasticity
(b) Maximum volume elasticity
(c) Maximum Young's modulus
(d) Maximum modulus of rigidity

48. The length of a wire is 1.0 *m* and the area of cross-section is $1.0\times10^{-2}\ cm^2$. If the work done for increase in length by 0.2 *cm* is 0.4 *joule*, then Young's modulus of the material of the wire is
(a) $2.0\times10^{10}\ N/m^2$ (b) $4\times10^{10}\ N/m^2$
(c) $2.0\times10^{11}\ N/m^2$ (d) $2\times10^{10}\ N/m^2$

49. The quality of the material which opposes the change in shape, volume or length is called
(a) Intermolecular repulsion
(b) Intermolecular behaviour
(c) Viscosity
(d) Elasticity

50. For silver, Young's modulus is $7.25\times10^{10}\ N/m^2$ and Bulk modulus is $11\times10^{10}\ N/m^2$. Its Poisson's ratio will be [DPMT 1999]
(a) – 1 (b) 0.5
(c) 0.39 (d) 0.25

51. The longitudinal strain is only possible in
(a) Gases (b) Fluids
(c) Solids (d) Liquids

52. If the density of the material increases, the value of Young's modulus
(a) Increases
(b) Decreases
(c) First increases then decreases
(d) First decreases then increases

53. Young's modulus of rubber is $10^4\ N/m^2$ and area of cross-section is $2\ cm^2$. If force of 2×10^5 dynes is applied along its length, then its initial length *l* becomes
(a) 3*L* (b) 4*L*
(c) 2*L* (d) None of the above

54. The elastic limit for a gas
(a) Exists
(b) Exists only at absolute zero
(c) Exists for a perfect gas
(d) Does not exist

55. If Young's modulus for a material is zero, then the state of material should be
(a) Solid (b) Solid but powder
(c) Gas (d) None of the above

56. Liquids have no Poisson's ratio, because
(a) It has no definite shape
(b) It has greater volume
(c) It has lesser density than solid
(d) None of the above

57. A wire of length L and radius *r* is rigidly fixed at one end. On stretching the other end of the wire with a force *F*, the increase in its length is *l*. If another wire of same material but of length 2*L* and radius 2*r* is stretched with a force of 2*F*, the increase in its length will be
[NCERT 1980; AIIMS 1980; MP PET 1989, 92; MP PET/PMT 1988; MP PMT 1996, 2002; UPSEAT 2002]
(a) *l* (b) 2*l*
(c) $\frac{l}{2}$ (d) $\frac{l}{4}$

58. In steel, the Young's modulus and the strain at the breaking point are $2\times10^{11}\ Nm^{-2}$ and 0.15 respectively. The stress at the breaking point for steel is therefore
[MP PET 1990; MP PMT 1992; DPMT 2001]
(a) $1.33\times10^{11}\ Nm^{-2}$ (b) $1.33\times10^{12}\ Nm^{-2}$
(c) $7.5\times10^{-13}\ Nm^{-2}$ (d) $3\times10^{10}\ Nm^{-2}$

59. Which of the following statements is correct [MP PET 1992]
(a) Hooke's law is applicable only within elastic limit

(b) The adiabatic and isothermal elastic constants of a gas are equal
(c) Young's modulus is dimensionless
(d) Stress multiplied by strain is equal to the stored energy

60. The force required to stretch a steel wire of $1\,cm^2$ cross-section to 1.1 times its length would be $(Y = 2\times10^{11}\ Nm^{-2})$ [MP PET 1992]
(a) $2\times10^6\ N$ (b) $2\times10^3\ N$
(c) $2\times10^{-6}\ N$ (d) $2\times10^{-7}\ N$

61. Which one of the following substances possesses the highest elasticity [MP PMT 1992; RPMT 1999; RPET 2000; MH CET (Med.) 2001]
(a) Rubber (b) Glass
(c) Steel (d) Copper

62. Which one of the following quantities does not have the unit of force per unit area [MP PMT 1992]
(a) Stress
(b) Strain
(c) Young's modulus of elasticity
(d) Pressure

63. A copper wire and a steel wire of the same diameter and length are connected end to end and a force is applied, which stretches their combined length by 1 cm. The two wires will have
(a) Different stresses and strains
(b) The same stress and strain
(c) The same strain but different stresses
(d) The same stress but different strains

64. A steel ring of radius *r* and cross-section area '*A*' is fitted on to a wooden disc of radius $R(R > r)$. If Young's modulus be *E*, then the force with which the steel ring is expanded is [EAMCET 1986]
(a) $AE\dfrac{R}{r}$ (b) $AE\left(\dfrac{R-r}{r}\right)$
(c) $\dfrac{E}{A}\left(\dfrac{R-r}{A}\right)$ (d) $\dfrac{Er}{AR}$

65. A wire extends by 1 *mm* when a force is applied. Double the force is applied to another wire of same material and length but half the radius of cross-section. The elongation of the wire in *mm* will be
(a) 8 (b) 4
(c) 2 (d) 1

66. Two wires of the same material have lengths in the ratio 1 : 2 and their radii are in the ratio $1:\sqrt{2}$. If they are stretched by applying equal forces, the increase in their lengths will be in the ratio
(a) $2:\sqrt{2}$ (b) $\sqrt{2}:2$
(c) 1 : 1 (d) 1 : 2

67. When a weight of 10 *kg* is suspended from a copper wire of length 3 *metres* and diameter 0.4 *mm*, its length increases by 2.4 *cm*. If the diameter of the wire is doubled, then the extension in its length will be [MP PMT 1994]
(a) 9.6 *cm* (b) 4.8 *cm*
(c) 1.2 *cm* (d) 0.6 *cm*

68. A force of 10^3 *newton* stretches the length of a hanging wire by 1 *millimetre*. The force required to stretch a wire of same material and length but having four times the diameter by 1 *millimetre* is
(a) $4\times10^3\ N$ (b) $16\times10^3\ N$
(c) $\dfrac{1}{4}\times10^3\ N$ (d) $\dfrac{1}{16}\times10^3\ N$

69. Two wires '*A*' and '*B*' of the same material have radii in the ratio 2 : 1 and lengths in the ratio 4 : 1. The ratio of the normal forces required to produce the same change in the lengths of these two wires is [Haryana CEE 1996]
(a) 1 : 1 (b) 2 : 1
(c) 1 : 4 (d) 1 : 2

70. Density of rubber is *d*. A thick rubber cord of length *L* and cross-section area *A* undergoes elongation under its own weight on suspending it. This elongation is proportional to
(a) dL (b) Ad/L
(c) Ad/L^2 (d) dL^2

71. The ratio of two specific heats of gas C_p/C_v for argon is 1.6 and for hydrogen is 1.4. Adiabatic elasticity of argon at pressure *P* is *E*. Adiabatic elasticity of hydrogen will also be equal to *E* at the pressure
(a) P [MP PMT 1992] (b) $\dfrac{8}{7}P$
(c) $\dfrac{7}{8}P$ (d) 1.4 *P*

72. The relation between γ, η and *K* for a elastic material is
(a) $\dfrac{1}{\eta}=\dfrac{1}{3\gamma}+\dfrac{1}{9K}$ (b) $\dfrac{1}{K}=\dfrac{1}{3\gamma}+\dfrac{1}{9\eta}$
(c) $\dfrac{1}{\gamma}=\dfrac{1}{3K}+\dfrac{1}{9\eta}$ (d) $\dfrac{1}{\gamma}=\dfrac{1}{3\eta}+\dfrac{1}{9K}$

73. A fixed volume of iron is drawn into a wire of length *L*. The extension *x* produced in this wire by a constant force *F* is proportional to [MP PMT 1999]
(a) $\dfrac{1}{L^2}$ (b) $\dfrac{1}{L}$
(c) L^2 (d) L

[EAMCET 1986]
74. A wire of cross-sectional area $3\,mm^2$ is first stretched between two fixed points at a temperature of 20°C. Determine the tension when the temperature falls to 10°*C*. Coefficient of linear expansion $\alpha = 10^{-5}\,{}^\circ C^{-1}$ and $Y = 2\times10^{11}\ N/m^2$
(a) 20 *N* (b) 30 *N*
(c) 60 *N* [MP PET 1994] (d) 120 *N*

75. To keep constant time, watches are fitted with balance wheel made of [EAMCET 1994]
(a) Invar (b) Stainless steel
(c) Tungsten (d) Platinum

76. A wire is stretched by 0.01 *m* by a certain force *F*. Another wire of same material whose diameter and length are double to the original wire is stretched by the same force. Then its elongation will be [EAMCET (Engg.

(a) 0.005 m (b) 0.01 m

(c) 0.02 m (d) 0.002 m

77. The possible value of Poisson's ratio is

[EAMCET (Med.) 1995]

(a) 1 (b) 0.9

(c) 0.8 (d) 0.4

78. The coefficient of linear expansion of brass and steel are α_1 and α_2. If we take a brass rod of length l_1 and steel rod of length l_2 at 0°C, their difference in length $(l_2 - l_1)$ will remain the same at a temperature if **[EAMCET (Med.) 1995]**

(a) $\alpha_1 l_2 = \alpha_2 l_1$ (b) $\alpha_1 l_2^2 = \alpha_2 l_1^2$

(c) $\alpha_1^2 l_1 = \alpha_2^2 l_2$ (d) $\alpha_1 l_1 = \alpha_2 l_2$

79. A rod is fixed between two points at 20°C. The coefficient of linear expansion of material of rod is $1.1 \times 10^{-5} / °C$ and Young's modulus is $1.2 \times 10^{11}\ N/m$. Find the stress developed in the rod if temperature of rod becomes 10°C

/RPET 1997]

(a) $1.32 \times 10^7\ N/m^2$ (b) $1.10 \times 10^{15}\ N/m^2$

(c) $1.32 \times 10^8\ N/m^2$ (d) $1.10 \times 10^6\ N/m^2$

80. The extension of a wire by the application of load is 3 mm. The extension in a wire of the same material and length but half the radius by the same load is **[CMEET Bihar 1995]**

(a) 12 mm (b) 0.75 mm

(c) 15 mm (d) 6 mm

81. A rubber pipe of density $1.5 \times 10^3\ N/m^2$ and Young's modulus $5 \times 10^6\ N/m^2$ is suspended from the roof. The length of the pipe is 8 m. What will be the change in length due to its own weight

(a) 9.6 m (b) $9.6 \times 10^3\ m$

(c) $19.2 \times 10^{-2}\ m$ (d) $9.6 \times 10^{-2}\ m$

82. In which case there is maximum extension in the wire, if same force is applied on each wire **[AFMC 1997]**

(a) L = 500 cm, d = 0.05 mm

(b) L = 200 cm, d = 0.02 mm

(c) L = 300 cm, d = 0.03 mm

(d) L = 400 cm, d = 0.01 mm

83. If a spring is extended to length l, then according to Hook's law

(a) $F = kl$ (b) $F = \frac{k}{l}$

(c) $F = k^2 l$ (d) $F = \frac{k^2}{l}$

84. Which of the following affects the elasticity of a substance

[AIIMS 1999]

(a) Hammering and annealing

(b) Change in temperature

(c) Impurity in substance

(d) All of these

85. An iron rod of length 2m and cross section area of $50\,mm^2$, stretched by 0.5 mm, when a mass of 250 kg is hung from its lower end. Young's modulus of the iron rod is

[AFMC 1999]

(a) $19.6 \times 10^{10}\ N/m^2$ (b) $19.6 \times 10^{15}\ N/m^2$

(c) $19.6 \times 10^{18}\ N/m^2$ (d) $19.6 \times 10^{20}\ N/m^2$

86. In solids, inter-atomic forces are **[DCE 1999]**

(a) Totally repulsive

(b) Totally attractive

(c) Combination of (a) and (b)

(d) None of these

87. A force F is applied on the wire of radius r and length L and change in the length of wire is l. If the same force F is applied on the wire of the same material and radius 2r and length 2L, Then the change in length of the other wire is

[RPMT 1999]

(a) l (b) 2l

(c) l/2 (d) 4l

88. The modulus of elasticity is dimensionally equivalent to

[MH CET (Med.) 1999]

(a) Surface tension (b) Stress

(c) Strain (d) None of these

89. Under elastic limit the stress is

[MH CET 1999; KCET 1999]

(a) Inversely, proportional to strain

(b) Directly proportional to strain

(c) Square root of strain

(d) Independent of strain

90. A steel wire of lm long and $1\,mm^2$ cross section area is hang from rigid end. **[RPET 1996]** When weight of 1kg is hung from it then change in length will be (given $Y = 2 \times 10^{11}\ N/m^2$)

[RPMT 2000]

(a) 0.5 mm (b) 0.25 mm

(c) 0.05 mm (d) 5 mm

91. A load W produces an extension of 1mm in a thread of radius r. Now if the load is made 4W and radius is made 2r all other things remaining same, the extension will become

[RPET 2000]

(a) 4 mm **[CPMT 1997]** (b) 16 mm

(c) 1 mm (d) 0.25 mm

92. The units of Young 's modulus of elasticity are

[CPMT 2000; KCET 2000]

(a) Nm^{-1} (b) N-m

(c) Nm^{-2} (d) N-m^2

93. Two similar wires under the same load yield elongation of 0.1 mm and 0.05 mm respectively. If the area of cross- section of the first wire is $4mm^2$, then the area of cross section of the second wire is**[CPMT 200**

(a) $6mm^2$ (b) $8mm^2$

(c) $10\,mm^2$ (d) $12\,mm^2$

94. A 5 *m* long aluminium wire ($Y = 7\times10^{10} N/m^2$) of diameter 3 *mm* supports a 40 *kg* mass. In order to have the same elongation in a copper wire $(Y = 12\times10^{10} N/m^2)$ of the same length under the same weight, the diameter should now be, in *mm*.

(a) 1.75 (b) 1.5
(c) 2.5 (d) 5.0

95. How much force is required to produce an increase of 0.2% in the length of a brass wire of diameter 0.6 *mm* [MP PMT 2000]

(Young's modulus for brass = $0.9\times10^{11} N/m^2$)

(a) Nearly 17 *N* (b) Nearly 34 *N*
(c) Nearly 51 *N* (d) Nearly 68 *N*

96. On applying a stress of 20×10^8 N/m^2 the length of a perfectly elastic wire is doubled. Its Young's modulus will be [MP PET 2000]

(a) $40\times10^8 N/m^2$ (b) $20\times10^8 N/m^2$
(c) $10\times10^8 N/m^2$ (d) $5\times10^8 N/m^2$

97. When a uniform wire of radius *r* is stretched by a 2*kg* weight, the increase in its length is 2.00 *mm*. If the radius of the wire is *r*/2 and other conditions remain the same, the increase in its length is[EAMCET (Engg.) 2000]

(a) 2.00 *mm* (b) 4.00 *mm*
(c) 6.00*mm* (d) 8.00 *mm*

98. The length of an elastic string is *a metre* when the longitudinal tension is 4 *N* and *b metre* when the longitudinal tension is 5 *N*. The length of the string in *metre* when the longitudinal tension is 9 *N* is [EAMCET 2001]

(a) $a - b$ (b) $5b - 4a$
(c) $2b - \frac{1}{4}a$ (d) $4a - 3b$

99. Stress to strain ratio is equivalent to [RPET 2001]

(a) Modulus of elasticity
(b) Poission's Ratio
(c) Reyhold number
(d) Fund number

100. Which is correct relation [RPET 2001]

(a) $Y < \sigma$ (b) $Y > \sigma$
(c) $Y = \sigma$ (d) $\sigma = +1$

101. If the interatomic spacing in a steel wire is 3.0Å and Y_{steel} = $20\times10^{10} N/m^2$ then force constant is [RPET 2001]

(a) $6\times10^{-2} N/Å$ (b) $6\times10^{-9} N/Å$
(c) $4\times10^{-5} N/Å$ (d) $6\times10^{-5} N/Å$

102. A copper wire of length 4.0*m* and area of cross-section $1.2\,cm^2$ is stretched with a force of 4.8×10^3 *N*. If Young's modulus for copper is $1.2\times10^{11} N/m^2$, the increase in the length of the wire will be [MP PET 2001]

(a) 1.33 *mm* (b) 1.33 *cm*
(c) 2.66 *mm* (d) 2.66 *cm*

103. A metal bar of length *L* and area of cross-section *A* is clamped between two rigid supports. For the material of the rod, its Young's modulus is *Y* and coefficient of linear expansion is α. If the temperature of the rod is increased by $\Delta t^o C$, the force exerted by the rod on the supports is [AMU 2000] [MP PMT 2001]

(a) $Y A L \Delta t$ (b) $Y A \alpha \Delta t$
(c) $\frac{YL\alpha\Delta t}{A}$ (d) $Y\alpha A L \Delta t$

104. According to Hook's law of elasticity, if stress is increased, the ratio of stress to strain [KCET 2000 AIIMS 2001]

(a) Increases (b) Decreases
(c) Becomes zero (d) Remains constant

105. A pan with set of weights is attached with a light spring. When disturbed, the mass-spring system oscillates with a time period of 0.6 s. When some additional weights are added then time period is 0.7*s*. The extension caused by the additional weights is approximately given by [UPSEAT 2002]

(a) 1.38 *cm* (b) 3.5 *cm*
(c) 1.75 *cm* (d) 2.45 *cm*

106. A uniform plank of Young's modulus *Y* is moved over a smooth horizontal surface by a constant horizontal force *F*. The area of cross section of the plank is *A*. The compressive strain on the plank in the direction of the force is [Kerala PET 2002]

(a) F/AY (b) $2F/AY$
(c) $\frac{1}{2}(F/AY)$ (d) $3F/AY$

107. The mean distance between the atoms of iron is $3\times10^{-10} m$ and interatomic force constant for iron is $7\ N/m$ The Young's modulus of elasticity for iron is [JIPMER 2002]

(a) $2.33\times10^5\ N/m^2$ (b) $23.3\times10^{10}\ N/m^2$
(c) $233\times10^{10}\ N/m^2$ (d) $2.33\times10^{10}\ N/m^2$

108. Two wires *A* and *B* are of same materials. Their lengths are in the ratio 1 : 2 and diameters are in the ratio 2 : 1 when stretched by force F_A and F_B respectively they get equal increase in their lengths. Then the ratio F_A / F_B should be [Orissa JEE 2002]

(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) 8 : 1

109. The breaking stress of a wire depends upon [AIIMS 2002]

(a) Length of the wire
(b) Radius of the wire
(c) Material of the wire
(d) Shape of the cross section

110. The area of cross section of a steel wire $(Y = 2.0 \times 10^{11} N/m^2)$ is $0.1\, cm^2$. The force required to double its length will be

(a) $2 \times 10^{12} N$ (b) $2 \times 10^{11} N$

(c) $2 \times 10^{10} N$ (d) $2 \times 10^{6} N$

111. A rubber cord catapult has cross-sectional area $25 mm^2$ and initial length of rubber cord is $10 cm$. It is stretched to $5\, cm$. and then released to project a missile of mass $5 gm$. Taking $Y_{rubber} = 5 \times 10^8 N/m^2$ velocity of projected missile is

[CPMT 2002]

(a) $20\, ms^{-1}$ (b) $100\, ms^{-1}$

(c) $250\, ms^{-1}$ (d) $200\, ms^{-1}$

112. According to Hook's law force is proportional to

[RPET 2003]

(a) $\frac{1}{x}$ (b) $\frac{1}{x^2}$

(c) x (d) x^2

113. In the Young's experiment, If length of wire and radius both are doubled then the value of Y will become [RPET 2003]

(a) 2 times (b) 4 times

(c) Remains same (d) Half

114. Minimum and maximum values of Poisson's ratio for a metal lies between

(a) $-\infty$ to $+\infty$ (b) 0 to 1

(c) $-\infty$ to 1 (d) 0 to 0.5

115. A wire of diameter 1*mm* breaks under a tension of 1000 *N*. Another wire, of same material as that of the first one, but of diameter 2 *mm* breaks under a tension of

[Orissa JEE 2003]

(a) 500 *N* (b) 1000 *N*

(c) 10000 *N* (d) 4000 *N*

116. Young's modulus of perfectly rigid body material is

[KCET 2003]

(a) Zero (b) Infinity

(c) $1 \times 10^{10}\, N/m^2$ (d) $10 \times 10^{10}\, N/m^2$

117. A wire of length 2 *m* is made from $10\, cm^3$ of copper. A force *F* is applied so that its length increases by 2 *mm*. Another wire of length 8 *m* is made from the same volume of copper. If the force *F* is applied to it, its length will increase by

(a) 0.8 *cm* (b) 1.6 *cm*

(c) 2.4 *cm* (d) 3.2 *cm*

118. A wire of cross section 4 *mm* is stretched by 0.1 *mm* by a certain weight. How far (length) will be wire of same material and length but of area 8 *mm* stretch under the action of same force

(a) 0.05 *mm* (b) 0.10 *mm*

(c) 0.15 *mm* (d) 0.20 *mm*

(e) 0.25 *mm*

119. A substance breaks down by a stress of 10^6 *N/m*. If the density of the material of the wire is 3×10^3 *kg/m*, then the length of the wire of the substance which will break under its own weight when suspended vertically, is [DPMT 2004]

[MP PET 2002]

(a) 66.6 *m* (b) 60.0 *m*

(c) 33.3 *m* (d) 30.0 *m*

120. A rubber cord 10 *m* long is suspended vertically. How much does it stretch under its own weight (Density of rubber is 1500 *kg/m*, *Y* = 5×10^8 *N/m*, g = 10 *m/s*) [Pb. PET 2001]

(a) 15×10^{-4} *m* (b) 7.5×10^{-4} *m*

(c) 12×10^{-4} *m* (d) 25×10^{-4} *m*

121. The value of Poisson's ratio lies between

[AIIMS 1985; MP PET 1986; DPMT 2002]

(a) –1 to $\frac{1}{2}$ (b) $-\frac{3}{4}$ to $-\frac{1}{2}$

(c) $-\frac{1}{2}$ to 1 (d) 1 to 2

122. The Poisson's ratio cannot have the value [EAMCET 1989]

(a) 0.7 (b) 0.2

(c) 0.1 (d) 0.5

123. There is no change in the volume of a wire due to change in its length on stretching. The Poisson's ratio of the material of the wire is [MH CET 2004]

(a) + 0.50 (b) – 0.50

(c) 0.25 (d) – 0.25

124. A material has Poisson's ratio 0.50. If a uniform rod of it suffers a longitudinal strain of 2×10^{-3}, then the percentage change in volume is [EAMCET 1987]

[Orissa JEE 2003]

(a) 0.6 (b) 0.4

(c) 0.2 (d) Zero

125. Four identical rods are stretched by same force. Maximum extension is produced in

(a) $L = 10 cm, D = 1 mm$ (b) $L = 100 cm, D = 2 mm$

(c) $L = 200 cm, D = 3 mm$ (d) $L = 300 cm, D = 4 mm$

Bulk Modulus

1. The isothermal elasticity of a gas is equal to

[CPMT 1981; MP PMT 2004]

(a) Density (b) Volume

(c) Pressure (d) Specific heat

2. The adiabatic elasticity of a gas is equal to [CPMT 1982]

(a) $\gamma \times$ density (b) $\gamma \times$ volume

(c) $\gamma \times$ pressure (d) $\gamma \times$ specific heat

[MP PET 2003]

3. The specific heat at constant pressure and at constant volume for an ideal gas are C_p and C_v and its adiabatic and isothermal elasticities are E_ϕ and E_θ respectively. The ratio of E_ϕ to E_θ is [MP PMT 19...

(a) C_v / C_p (b) C_p / C_v

[Kerala PMT 2004]

(c) $C_p C_v$ (d) $1 / C_p C_v$

4. The only elastic modulus that applies to fluids is

[BCECE 2003]

(a) Young's modulus (b) Shear modulus

(c) Modulus of rigidity (d) Bulk modulus

5. The ratio of the adiabatic to isothermal elasticities of a triatomic gas is [MP PET 1991]

(a) 3/4 (b) 4/3

(c) 1 (d) 5/3

6. If the volume of the given mass of a gas is increased four times, the temperature is raised from 27°C to 127°C. The elasticity will become

(a) 4 times (b) 1/4 times

(c) 3 times (d) 1/3 times

7. The compressibility of water is 4×10^{-5} per unit atmospheric pressure. The decrease in volume of 100 cubic centimeter of water under a pressure of 100 *atmosphere* will be

(a) 0.4 *cc* (b) $4\times10^{-5}\ cc$

(c) 0.025 *cc* (d) 0.004 *cc*

8. If a rubber ball is taken at the depth of 200 m in a pool, its volume decreases by 0.1%. If the density of the water is $1\times10^{3}\ kg/m^{3}$ and $g=10\ m/s^{2}$, then the volume elasticity in N/m^{2} will be

(a) 10^{8} (b) 2×10^{8}

(c) 10^{9} (d) 2×10^{9}

9. The compressibility of a material is

(a) Product of volume and its pressure

(b) The change in pressure per unit change in volume strain

(c) The fractional change in volume per unit change in pressure

(d) None of the above

10. When a pressure of 100 atmosphere is applied on a spherical ball, then its volume reduces to 0.01%. The bulk modulus of the material of the rubber in $dyne/cm^{2}$ is

[MP PET 1985; DPMT 2002]

(a) 10×10^{12} (b) 100×10^{12}

(c) 1×10^{12} (d) 20×10^{12}

11. In the three states of matter, the elastic coefficient can be

(a) Young's modulus

(b) Coefficient of volume elasticity

(c) Modulus of rigidity

(d) Poisson's ratio

12. Bulk modulus was first defined by [CPMT 1987]

(a) Young (b) Bulk

(c) Maxwell (d) None of the above

13. A uniform cube is subjected to volume compression. If each side is decreased by 1%, then bulk strain is

[EAMCET (Engg.) 1995; DPMT 2000]

(a) 0.01 (b) 0.06

(c) 0.02 (d) 0.03

14. A ball falling in a lake of depth 200 m shows 0.1% decrease in its volume at the bottom. What is the bulk modulus of the material of the ball [AFMC 1997]

(a) $19.6\times10^{8}\ N/m^{2}$ (b) $19.6\times10^{-10}\ N/m^{2}$

(c) $19.6\times10^{10}\ N/m^{2}$ (d) $19.6\times10^{-8}\ N/m^{2}$

15. The isothermal bulk modulus of a gas at atmospheric pressure is

KCET 1999; Pb. PMT 2003]

(a) $1\ mm$ of *Hg* (b) $13.6\ mm$ of *Hg*

(c) $1.013\times10^{5}\ N/m^{2}$ (d) $2.026\times10^{5}\ N/m^{2}$

16. Coefficient of isothermal elasticity E_θ and coefficient of adiabatic elasticity E_ϕ are related by $(\gamma=C_p/C_v)$

[MP PET 2000]

(a) $E_\theta=\gamma\,E_\phi$ (b) $E_\phi=\gamma\,E_\theta$

(c) $E_\theta=\gamma/E_\phi$ (d) $E_\theta=\gamma^{2}E_\phi$

17. The bulk modulus of an ideal gas at constant temperature [MP PMT 1990]

[MP PMT 2004]

(a) Is equal to its volume V (b) Is equal to $p/2$

(c) Is equal to its pressure p (d) Can not be determined

18. The Bulk modulus for an incompressible liquid is

[BHU 2004]

(a) Zero [MP PMT 1991] (b) Unity

(c) Infinity (d) Between 0 to 1

19. The pressure applied from all directions on a cube is P. How much its temperature should be raised to maintain the original volume ? The volume elasticity of the cube is β and the coefficient of volume expansion is α

(a) $\dfrac{P}{\alpha\beta}$ (b) $\dfrac{P\alpha}{\beta}$

(c) $\dfrac{P\beta}{\alpha}$ (d) $\dfrac{\alpha\beta}{P}$

20. The pressure of a medium is changed from 1.01×10^{5} *Pa* to 1.165×10^{5} *Pa* and change in volume is 10% keeping temperature constant. The Bulk modulus of the medium is

(a) 204.8×10^{5} *Pa* (b) 102.4×10^{5} *Pa*

(c) 51.2×10^{5} *Pa* (d) 1.55×10^{5} *Pa*

21. For a constant hydraulic stress on an object, the fractional change in the object's volume $\left(\dfrac{\Delta V}{V}\right)$ and its bulk modulus (B) are related as

(a) $\dfrac{\Delta V}{V}\propto B$ (b) $\dfrac{\Delta V}{V}\propto\dfrac{1}{B}$

(c) $\dfrac{\Delta V}{V}\propto B^{2}$ (d) $\dfrac{\Delta V}{V}\propto B^{-2}$

Rigidity Modulus

1. Modulus of rigidity of diamond is

(a) Too less

(b) Greater than all matters

(c) Less than all matters

(d) Zero

2. The ratio of lengths of two rods A and B of same material is 1 : 2 and the ratio of their radii is 2 : 1, then the ratio of modulus of rigidity of A and B will be

(a) 4 : [AIIMS 2000; (b) 16 : 1

(c) 8 : 1 (d) 1 : 1

3. Which statement is true for a metal [DPMT 2001]

(a) $Y < \eta$ (b) $Y = \eta$

(c) $Y > \eta$ (d) $Y < 1/\eta$

4. Which of the following relations is true [CPMT 1984]

(a) $3Y = K(1-\sigma)$ (b) $K = \frac{9\eta Y}{Y+\eta}$

(c) $\sigma = (6K+\eta)Y$ (d) $\sigma = \frac{0.5Y-\eta}{\eta}$

5. Two wires *A* and *B* of same length and of the same material have the respective radii r_1 and r_2. Their one end is fixed with a rigid support, and at the other end equal twisting couple is applied. Then the ratio of the angle of twist at the end of A and the angle of twist at the end of B will be

[AIIMS 1980]

(a) $\frac{r_1^2}{r_2^2}$ (b) $\frac{r_2^2}{r_1^2}$

(c) $\frac{r_2^4}{r_1^4}$ (d) $\frac{r_1^4}{r_2^4}$

6. When a spiral spring is stretched by suspending a load on it, the strain produced is called

(a) Shearing (b) Longitudinal

(c) Volume (d) Transverse

7. The Young's modulus of the material of a wire is $6\times10^{12}\ N/m^2$ and there is no transverse strain in it, then its modulus of rigidity will be

(a) $3\times10^{12}\ N/m^2$ (b) $2\times10^{12}\ N/m^2$

(c) $10^{12}\ N/m^2$ (d) None of the above

8. If the Young's modulus of the material is 3 times its modulus of rigidity, then its volume elasticity will be

(a) Zero (b) Infinity

(c) $2\times10^{10}\ N/m^2$ (d) $3\times10^{10}\ N/m^2$

9. Modulus of rigidity of a liquid [RPET 2000]

(a) Non zero constant

(b) Infinite

(c) Zero

(d) Can not be predicted

10. For a given material, the Young's modulus is 2.4 times that of rigidity modulus. Its Poisson's ratio is

[EAMCET 1990; RPET 2001]

(a) 2.4 (b) 1.2

(c) 0.4 (d) 0.2

11. A cube of aluminium of sides 0.1 *m* is subjected to a shearing force of 100 *N*. The top face of the cube is displaced through 0.02 cm with respect to the bottom face. The shearing strain would be

(a) 0.02 (b) 0.1

(c) 0.005 (d) 0.002

12. The reason for the change in shape of a regular body is

[EAMCET 1980]

(a) Volume stress (b) Shearing strain

(c) Longitudinal strain (d) Metallic strain

13. The lower surface of a cube is fixed. On its upper surface, force is applied at an angle of 30° from its surface. The change will be of the type

(a) Shape (b) Size

(c) None (d) Shape and size

14. The upper end of a wire of radius 4 *mm* and length 100 *cm* is clamped and its other end is twisted through an angle of 30°. Then angle of shear is [NCERT 1990; MP PMT 1996]

(a) 12° (b) 0.12°

(c) 1.2° (d) 0.012°

15. Mark the wrong statement [MP PMT 2003]

(a) Sliding of molecular layer is much easier than compression or expansion

(b) Reciprocal of bulk modulus of elasticity is called compressibility

(c) It is difficult to twist a long rod as compared to small rod

(d) Hollow shaft is much stronger than a solid rod of same length and same mass

16. A 2 *m* long rod of radius 1 *cm* which is fixed from one end is given a twist of 0.8 radians. The shear strain developed will be

(a) 0.002 (b) 0.004

(c) 0.008 (d) 0.016

17. A rod of length *l* and radius *r* is joined to a rod of length *l*/2 and radius *r*/2 of same material. The free end of small rod is fixed to a rigid base and the free end of larger rod is given a twist of $\theta°$, the twist angle at the joint will be [RPET 1997]

(a) $\theta/4$ (b) $\theta/2$

(c) $5\theta/6$ (d) $8\theta/9$

18. Shearing stress causes change in

[RPET 2002; BCECE 2001, 04]

(a) Length (b) Breadth

(c) Shape (d) Volume

Work Done in Stretching a Wire

1. If the potential energy of a spring is *V* on stretching it by 2 *cm*, then its potential energy when it is stretched by 10 *cm* will be

(a) *V*/25 (b) 5*V*

(c) *V*/5 (d) 25*V*

2. The work done in stretching an elastic wire per unit volume is or strain energy in a stretched string is

[NCERT 1981; EAMCET (Med.) 1995; MNR 1981; MP PET 1984; RPMT 1999; DCE 2003]

(a) Stress × Strain (b) $\frac{1}{2}\times$ Stress × Strain

(c) $2\times$strain$\times$stress (d) Stress/Strain

3. Calculate the work done, if a wire is loaded by '*Mg*' weight and the increase in length is '*l*

[CPMT 1999; DCE 1999, 2001; Pb. PET 2000, 01]

(a) Mgl (b) Zero

(c) $Mgl/2$ (d) $2Mgl$

4. Two wires of same diameter of the same material having the length l and $2l$. If the force F is applied on each, the ratio of the work done in the two wires will be [MP PET 1989]

(a) 1 : 2 (b) 1 : 4

(c) 2 : 1 (d) 1 : 1

5. A 5 *metre* long wire is fixed to the ceiling. A weight of 10 *kg* is hung at the lower end and is 1 *metre* above the floor. The wire was elongated by 1 *mm*. The energy stored in the wire due to stretching is [MP PET 1989]

(a) Zero (b) 0.05 *joule*

(c) 100 *joule* (d) 500 *joule*

6. If the force constant of a wire is K, the work done in increasing the length of the wire by l is [MP PMT 1989]

(a) $Kl/2$ (b) Kl

(c) $Kl^2/2$ (d) Kl^2

7. If the tension on a wire is removed at once, then

(a) It will break

(b) Its temperature will reduce

(c) There will be no change in its temperature

(d) Its temperature increases

8. When strain is produced in a body within elastic limit, its internal energy

(a) Remains constant (b) Decreases

(c) Increases (d) None of the above

9. When shearing force is applied on a body, then the elastic potential energy is stored in it. On removing the force, this energy

(a) Converts into kinetic energy

(b) Converts into heat energy

(c) Remains as potential energy

(d) None of the above

10. A brass rod of cross-sectional area $1\,cm^2$ and length 0.2 m is compressed lengthwise by a weight of 5 kg. If Young's modulus of elasticity of brass is $1\times10^{11}\ N/m^2$ and $g=10\,m/\sec^2$, then increase in the energy of the rod will be

(a) $10^{-5}\,J$ (b) $2.5\times10^{-5}\,J$

(c) $5\times10^{-5}\,J$ (d) $2.5\times10^{-4}\,J$

11. If one end of a wire is fixed with a rigid support and the other end is stretched by a force of 10 *N*, then the increase in length is 0.5 *mm*. The ratio of the energy of the wire and the work done in displacing it through 1.5 *mm* by the weight is

(a) $\frac{1}{3}$ (b) $\frac{1}{4}$

(c) $\frac{1}{2}$ (d) 1

12. A wire is suspended by one end. At the other end a weight equivalent to 20 *N* force is applied. If the increase in length is 1.0 *mm*, the increase in energy of the wire will be

(a) 0.01 *J* (b) 0.02 *J*

(c) 0.04 *J* (d) 1.00 *J*

13. In the above question, the ratio of the increase in energy of the wire to the decrease in gravitational potential energy when load moves downwards by 1 *mm*, will be

(a) 1 (b) $\frac{1}{4}$

(c) $\frac{1}{3}$ (d) $\frac{1}{2}$

14. The Young's modulus of a wire is Y. If the energy per unit volume is E, then the strain will be

(a) $\sqrt{\frac{2E}{Y}}$ (b) $\sqrt{2EY}$

(c) EY (d) $\frac{E}{Y}$

15. The ratio of Young's modulus of the material of two wires is 2 : 3. If the same stress is applied on both, then the ratio of elastic energy per unit volume will be

(a) 3 : 2 (b) 2 : 3

(c) 3 : 4 (d) 4 : 3

16. The length of a rod is 20 *cm* and area of cross-section $2\,cm^2$. The Young's modulus of the material of wire is $1.4\times10^{11}\ N/m^2$. If the rod is compressed by 5 *kg-wt* along its length, then increase in the energy of the rod in joules will be

(a) 8.57×10^{-6} (b) 22.5×10^{-4}

(c) 9.8×10^{-5} (d) 45.0×10^{-5}

17. If a spring extends by x on loading, then the energy stored by the spring is (if T is tension in the spring and k is spring constant)

(a) $\frac{T^2}{2x}$ (b) $\frac{T^2}{2k}$

(c) $\frac{2x}{T^2}$ (d) $\frac{2T^2}{k}$

18. On stretching a wire, the elastic energy stored per unit volume is [MP PMT 1991]

(a) $Fl/2AL$ (b) $FA/2L$

(c) $FL/2A$ (d) $FL/2$

19. When a force is applied on a wire of uniform cross-sectional area $3\times10^{-6}\ m^2$ and length 4*m*, the increase in length is 1 *mm*. Energy stored in it will be $(Y=2\times10^{11}\ N/m^2)$

[MP PET 1995; Pb. PET 2002]

(a) 6250 *J* (b) 0.177 *J*

(c) 0.075 *J* (d) 0.150 *J*

20. K is the force constant of a spring. The work done in increasing its extension from l_1 to l_2 will be

[MP PET 1995; MP PMT 1996]

(a) $K(l_2-l_1)$ (b) $\frac{K}{2}(l_2+l_1)$

(c) $K(l_2^2-l_1^2)$ (d) $\frac{K}{2}(l_2^2-l_1^2)$

21. When a 4 *kg* mass is hung vertically on a light spring that obeys Hooke's law, the spring stretches by 2 *cms*. The work required to be done by an external agent in stretching this spring by 5 *cms* will be $(g = 9.8\, metres / sexc^2)$

[MP PMT 1995]

(a) 4.900 *joule* (b) 2.450 *joule*
(c) 0.495 *joule* (d) 0.245 *joule*

22. A wire of length *L* and cross-sectional area *A* is made of a material of Young's modulus *Y*. It is stretched by an amount *x*. The work done is

[MP PET 1996; BVP 2003; UPSEAT 2001]

(a) $\frac{YxA}{2L}$ (b) $\frac{Yx^2A}{L}$
(c) $\frac{Yx^2A}{2L}$ (d) $\frac{2Yx^2A}{L}$

23. The elastic energy stored in a wire of Young's modulus *Y* is

[MP PMT 1999]

(a) $Y \times \frac{\text{Strain}^2}{\text{Volume}}$
(b) Stress × Strain × Volume
(c) $\frac{\text{Stress}^2 \times \text{Volume}}{2Y}$
(d) $\frac{1}{2}Y$ × Stress × Strain × Volume

24. A wire of length 50 *cm* and cross sectional area of 1 *sq. mm* is extended by 1 *mm*. The required work will be $(Y = 2 \times 10^{10}\ Nm^{-2})$ [RPET 1999]

(a) $6 \times 10^{-2}\ J$ (b) $4 \times 10^{-2}\ J$
(c) $2 \times 10^{-2}\ J$ (d) $1 \times 10^{-2}\ J$

25. The work per unit volume to stretch the length by 1% of a wire with cross sectional area of $1 mm^2$ will be. $[Y = 9 \times 10^{11}\ N/m^2]$

(a) $9 \times 10^{11}\ J$ (b) $4.5 \times 10^{7}\ J$
(c) $9 \times 10^{7}\ J$ (d) $4.5 \times 10^{11}\ J$

26. When load of 5*kg* is hung on a wire then extension of 3*m* takes place, then work done will be [RPMT 2000]

(a) 75 *joule* (b) 60 *joule*
(c) 50 *joule* (d) 100 *joule*

27. A stretched rubber has [AIIMS 2000]

(a) Increased kinetic energy
(b) Increased potential energy
(c) Decreased kinetic energy
(d) Decreased potential energy

28. Which of the following is true for elastic potential energy density

(a) Energy density = $\frac{1}{2} \times \text{strain} \times \text{stress}$
(b) Energy density = $(\text{strain})^2 \times \text{volume}$
(c) Energy density = (strain)× volume
(d) Energy density = (stress)× volume

29. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 *N* to the lower end. The weight stretches the wire by 1 *mm* Then the elastic energy stored in the wire is

(a) 0.1 *J* (b) 0.2 *J*
(c) 10 *J* (d) 20

30. Wires *A* and *B* are made from the same material. A has twice the diameter and three times the length of *B*. If the elastic limits are not reached, when each is stretched by the same tension, the ratio of energy stored in *A* to that in *B* is

[Kerala PMT 2004]

(a) 2 : 3 (b) 3 : 4
(c) 3 : 2 (d) 6 : 1

Critical Thinking

Objective Questions

1. An Indian rubber cord *L* metre long and area of cross-section $A\, metre^2$ is suspended vertically. Density of rubber is *D* $kg / metre^3$ and Young's modulus of rubber is *E* $newton / metre^2$. If the wire extends by *l metre* under its own weight, then extension *l* is

(a) L^2Dg/E (b) $L^2Dg/2E$
(c) $L^2Dg/4E$ (d) *L*

2. To break a wire, a force of $10^6\ N/m^2$ is required. If the density of the material is $3 \times 10^3\ kg/m^3$, then the length of the wire which will break by its own weight will be

[Roorkee 1979; DPMT 2004]

(a) 34 *m* (b) 30 *m*
(c) 300 *m* (d) 3 *m*

3. Two rods of different materials having coefficients of linear [RPET 1999] expansion α_1, α_2 and Young's moduli Y_1 and Y_2 respectively are fixed between two rigid massive walls. The rods are heated such that they undergo the same increase in temperature. There is no bending of rods. If $\alpha_1 : \alpha_2 = 2:3$, the thermal stresses developed in the two rods are equally provided $Y_1 : Y_2$ is equal to

(a) 2 : 3 (b) 1 : 1
(c) 3 : 2 (d) 4 : 9

4. The extension in a string obeying Hooke's law is *x*. The speed of sound in the stretched string is *v*. If the extension in the string is increased to 1.5*x*, the speed of sound will be

[IIT 1996]

(a) 1.22 *v* (b) 0.61 *v*
(c) 1.50 *v* (d) 0.75 *v*

5. One end of a uniform [RPET 2001] wire of length *L* and of weight *W* is attached rigidly to a point in the roof and a weight W_1 is suspended from its lower end. If *S* is the area of cross-section of the wire, the stress in the wire at a height 3*L*/4 from its lower end is

(a) $\frac{W_1}{S}$ (b) $\frac{W_1 + (W/4)}{S}$
(c) $\frac{W_1 + (3W/4)}{S}$ (d) $\frac{W_1 + W}{S}$

6. There are two wires of same material and same length while the diameter of second wire is 2 times the diameter of first wire, then ratio of extension produced in the wires by applying same load will be

[DCE 2000; Roorkee 2000; DCE 2003]

(a) 1 : 1 (b) 2 : 1

(c) 1 : 2 (d) 4 : 1

7. A particle of mass m is under the influence of a force F which varies with the displacement x according to the relation $F = -kx + F_0$ in which k and F_0 are constants. The particle when disturbed will oscillate [UPSEAT 2001]

(a) about $x = 0$, with $\omega \neq \sqrt{k/m}$

(b) about $x = 0$, with $\omega = \sqrt{k/m}$

(c) about $x = F_0/k$ with $\omega = \sqrt{k/m}$

(d) about $x = F_0/k$ with $\omega \neq \sqrt{k/m}$

8. An elastic material of Young's modulus Y is subjected to a stress S. The elastic energy stored per unit volume of the material is

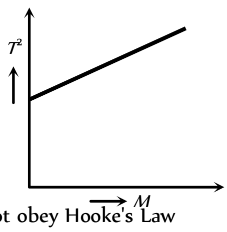
MP PMT 1990, 96; IIT 1992; AIIMS 1997]

(a) $\frac{2Y}{S^2}$ (b) $\frac{S^2}{2Y}$

(c) $\frac{S}{2Y}$ (d) $\frac{S^2}{Y}$

GQ Graphical Questions

1. The graph shown was obtained from experimental measurements of the period of oscillations T for different masses M placed in the scale pan on the lower end of the spring balance. The most likely reason for the line not passing through the origin is that the[NCERT 1978]



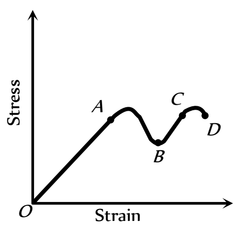
(a) Spring did not obey Hooke's Law

(b) Amplitude of the oscillations was too large

(c) Clock used needed regulating

(d) Mass of the pan was neglected

2. A graph is shown between stress and strain for a metal. The part in which Hooke's law holds good is



(a) *OA*

(b) *AB*

(c) *BC*

(d) *CD*

3. In the above graph, point B indicates

(a) Breaking point (b) Limiting point

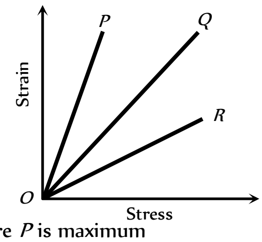
(c) Yield point (d) None of the above

4. In the above graph, point D indicates

(a) Limiting point (b) Yield point

(c) Breaking point (d) None of the above

5. The strain-stress curves of three wires of different materials are shown in the figure. P, Q and R are the elastic limits of the wires. The figure shows that



(a) Elasticity of wire P is maximum

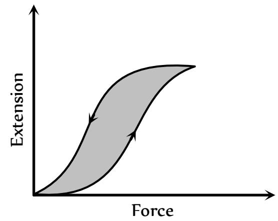
(b) Elasticity of wire Q is maximum

(c) Tensile strength of R is maximum

(d) None of the above is true

[MP PET 1991;

6. The diagram shows a force-extension graph for a rubber band. Consider the following statements [AMU 2001]



I. It will be easier to compress this rubber than expand it

II. Rubber does not return to its original length after it is stretched

III. The rubber band will get heated if it is stretched and released

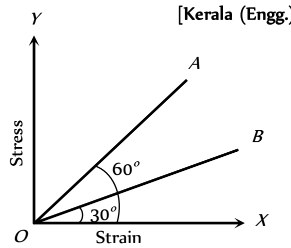
Which of these can be deduced from the graph

(a) III only (b) II and III

(c) I and III (d) I only

7. The stress versus strain graphs for wires of two materials A and B are as shown in the figure. If Y_A and Y_B are the Young 's modulii of the materials, then

[Kerala (Engg.) 2001]



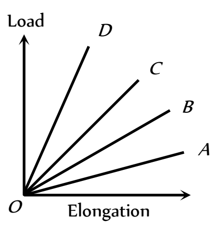
(a) $Y_B = 2Y_A$

(b) $Y_A = Y_B$

(c) $Y_B = 3Y_A$

(d) $Y_A = 3Y_B$

8. The load versus elongation graph for four wires of the same material is shown in the figure. The thickest wire is represented by the line [KCET 2001]



(a) *OD*

(b) *OC*

(c) OB

(d) OA

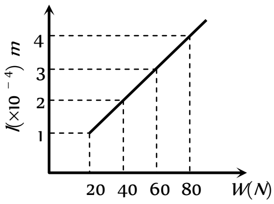
9. The adjacent graph shows the extension (Δl) of a wire of length 1m suspended from the top of a roof at one end with a load W connected to the other end. If the cross sectional area of the wire is $10^{-6} m^2$, calculate the young's modulus of the material of the wire [IIT-JEE (Screening) 2003]

(a) $2\times10^{11}\ N/m^2$

(b) $2\times10^{-11}\ N/m^2$

(c) $3\times10^{-12}\ N/m^2$

(d) $2\times10^{-13}\ N/m^2$



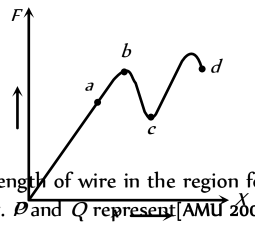
10. The graph is drawn between the applied force F and the strain (x) for a thin uniform wire. The wire behaves as a liquid in the part [CPMT 1988]

(a) ab

(b) bc

(c) cd

(d) oa



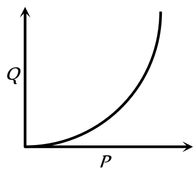
11. The graph shows the behaviour of a length of wire in the region for which the substance obeys Hook's law. P and Q represent [AMU 2001]

(a) P = applied force, Q = extension

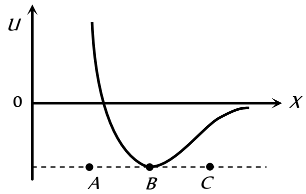
(b) P = extension, Q = applied force

(c) P = extension, Q = stored elastic energy

(d) P = stored elastic energy, Q = extension



12. The potential energy U between two molecules as a function of the distance X between them has been shown in the figure. The two molecules are [CPMT 1986, 88, 91]



(a) Attracted when x lies between A and B and are repelled when X lies between B and C

(b) Attracted when x lies between B and C and are repelled when X lies between A and B

(c) Attracted when they reach B

(d) Repelled when they reach B

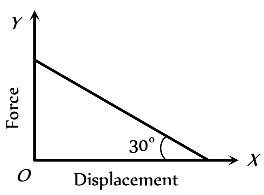
13. The value of force constant between the applied elastic force F and displacement will be

(a) $\sqrt{3}$

(b) $\frac{1}{\sqrt{3}}$

(c) $\frac{1}{2}$

(d) $\frac{\sqrt{3}}{2}$



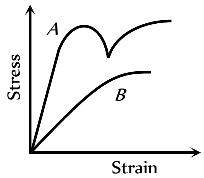
14. The diagram shows stress v/s strain curve for the materials A and B. From the curves we infer that [AIIMS 1987]

(a) A is brittle but B is ductile

(b) A is ductile and B is brittle

(c) Both A and B are ductile

(d) Both A and B are brittle



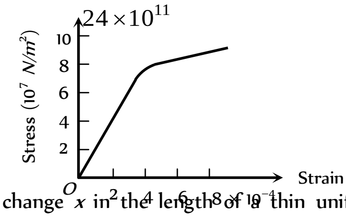
15. Which one of the following is the Young's modulus (in N/m) for the wire having the stress-strain curve shown in the figure

(a) 24×10^{11}

(b) 8.0×10^{11}

(c) 10×10^{11}

(d) 2.0×10^{11}



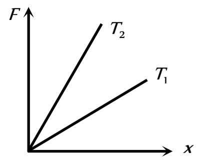
16. The diagram shows the change x in the length of a thin uniform wire caused by the application of stress F at two different temperatures T_1 and T_2. The variations shown suggest that

(a) $T_1 > T_2$

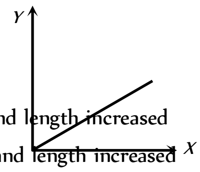
(b) $T_1 < T_2$

(c) $T_1 = T_2$

(d) None of these



17. A student plots a graph from his reading on the determination of Young's modulus of a metal wire but forgets to label. The quantities on X and Y axes may be respectively.



(a) Weight hung and length increased

(b) Stress applied and length increased

(c) Stress applied and strain developed

(d) Length increased and weight hung

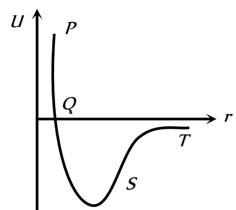
18. The points of maximum and minimum attraction in the curve between potential energy (U) and distance (r) of a diatomic molecules are respectively

(a) S and R

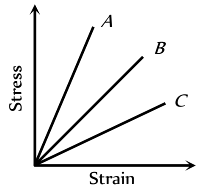
(b) T and S

(c) R and S

(d) S and T



19. The stress-strain curves for brass, steel and rubber are shown in the figure. The lines A, B and C are for



(a) Rubber, brass and steel respectively

(b) Brass, steel and rubber respectively

(c) Steel, brass and rubber respectively

(d) Steel, rubber and brass respectively

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) If assertion is false but reason is true.

1. Assertion : The stretching of a coil is determined by its shear modulus.
Reason : Shear modulus change only shape of a body keeping its dimensions unchanged.

2. Assertion : Spring balances show correct readings even after they had been used for a long time interval.
Reason : On using for long time, spring balances losses its elastic strength.

3. Assertion : Steel is more elastic than rubber.
Reason : Under given deforming force, steel is deformed less than rubber.

4. Assertion : Glassy solids have sharp melting point.
Reason : The bonds between the atoms of glassy solids get broken at the same temperature.

5. Assertion : A hollow shaft is found to be stronger than a solid shaft made of same material.
Reason : The torque required to produce a given twist in hollow cylinder is greater than that required to twist a solid cylinder of same size and material.

6. Assertion : Bulk modulus of elasticity (K) represents incompressibility of the material.
Reason : Bulk modulus of elasticity is proportional to change in pressure.

7. Assertion : Strain is a unitless quantity.
Reason : Strain is equivalent to force.

8. Assertion : The bridges declared unsafe after a long use.
Reason : Elastic strength of bridges losses with time.

9. Assertion : Two identical solid balls, one of ivory and the other of wet-clay are dropped from the same height on the floor. Both the balls will rise to same height after bouncing.
Reason : Ivory and wet-clay have same elasticity.

10. Assertion : Young's modulus for a perfectly plastic body is zero.
Reason : For a perfectly plastic body, restoring force is zero.

11. Assertion : Identical springs of steel and copper are equally stretched. More work will be done on the steel spring.
Reason : Steel is more elastic than copper.

12. Assertion : Sterss is the internal force per unit area of a body.
Reason : Rubber is less elastic than steel.

Answers

Young's Modulus and Breaking Stress

1	c	2	b	3	d	4	c	5	b
6	c	7	c	8	c	9	b	10	c
11	d	12	a	13	b	14	d	15	a
16	c	17	a	18	a	19	d	20	c
21	b	22	b	23	b	24	d	25	b
26	d	27	c	28	b	29	b	30	b
31	b	32	c	33	d	34	b	35	a
36	b	37	a	38	b	39	d	40	a
41	c	42	d	43	c	44	a	45	b
46	d	47	a	48	c	49	d	50	c
51	c	52	a	53	c	54	a	55	b
56	a	57	a	58	d	59	a	60	a
61	c	62	b	63	d	64	b	65	a
66	c	67	d	68	b	69	a	70	d
71	b	72	d	73	c	74	c	75	a
76	a	77	d	78	d	79	a	80	a
81	d	82	d	83	a	84	d	85	a
86	c	87	c	88	b	89	b	90	c
91	c	92	c	93	b	94	c	95	c
96	b	97	d	98	b	99	a	100	b
101	b	102	a	103	b	104	d	105	b
106	a	107	d	108	d	109	c	110	d
111	c	112	c	113	c	114	d	115	d
116	b	117	d	118	a	119	c	120	a
121	a	122	a	123	b	124	b	125	b

Bulk Modulus

1	c	2	c	3	b	4	d	5	b
6	d	7	a	8	d	9	c	10	c
11	b	12	c	13	d	14	a	15	c
16	b	17	c	18	c	19	a	20	d
21	b								

Rigidity Modulus

1	b	2	d	3	c	4	d	5	c
6	a	7	a	8	b	9	c	10	d
11	d	12	b	13	d	14	b	15	c
16	b	17	d	18	c				

Work Done in Stretching a Wire

1	d	2	b	3	c	4	a	5	b
6	c	7	d	8	c	9	b	10	b
11	c	12	a	13	d	14	a	15	a
16	a	17	b	18	a	19	c	20	d
21	b	22	c	23	c	24	c	25	b
26	a	27	b	28	a	29	a	30	b

Critical Thinking Questions

1	b	2	a	3	c	4	a	5	c
6	d	7	c	8	b				

Graphical Questions

1	d	2	a	3	c	4	c	5	d
6	a	7	d	8	a	9	a	10	b
11	c	12	b	13	b	14	b	15	d
16	a	17	c	18	d	19	c		

Assertion and Reason

1	a	2	e	3	a	4	d	5	a
6	a	7	c	8	a	9	d	10	a
11	a	12	b						

Answers and Solutions

Young's Modulus and Breaking Stress

1. (c) $l = \frac{FL}{YA} \Rightarrow l \propto \frac{1}{A}$

2. (b) Stress $\propto$ Strain $\Rightarrow$ Stress $\propto \frac{l}{L}$

3. (d) $Y = \frac{F}{A}\frac{L}{A} \Rightarrow l \propto \frac{L}{A} \propto \frac{L}{\pi d^2}$

   $\therefore\ l \propto \frac{L}{d^2}$ [As F and Y are constant]

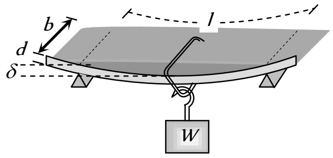
   The ratio of $\frac{L}{d^2}$ is maximum for case (d)

4. (c) $l = \frac{FL}{AY} \Rightarrow l \propto \frac{L}{d^2} \Rightarrow \frac{l_1}{l_2} = \frac{L_1}{L_2} \times \left(\frac{d_2}{d_1}\right)^2 = \frac{1}{2} \times \left(\frac{1}{2}\right)^2 = \frac{1}{8}$

5. (b) Young's modulus of wire does not varies with dimension of wire. It is the property of given material.

6. (c) Depression in beam

$\delta = \frac{WL^3}{4Ybd^3}$



$\therefore \delta \propto \frac{1}{Y}$

7. (c) $l = \frac{FL}{AY} \Rightarrow l \propto \frac{1}{r^2}$ (*F*, *L* and *Y* are constant)

$\frac{l_2}{l_1} = \left(\frac{r_1}{r_2}\right)^2 = (2)^2 = 4 \Rightarrow l_2 = 4l_1 = 4cm$

8. (c)

9. (b) $l \propto \frac{1}{r^2}$. If radius of the wire is doubled then increment in length will become $\frac{1}{4}$ times *i.e.* $\frac{12}{4} = 3mm$

10. (c) $l = \frac{mgL}{AY} = \frac{1 \times 10 \times 1.1}{1.1 \times 10^{11} \times 10^{-6}} m = 0.1\ mm$

11. (d) $F = \frac{YAl}{L} = \frac{2.2 \times 10^{11} \times 2 \times 10^{-6} \times 5 \times 10^{-4}}{2} = 1.1 \times 10^2\ N$

12. (a) Interatomic force constant $K = Y \times r_0$

$= 2 \times 10^{11} \times 3 \times 10^{-10} = 60\ N/m$

13. (b) To double the length of wire, Stress = Young's modulus

$\therefore \frac{F}{A} = 2 \times 10^{12} \frac{dyne}{cm^2}$.

If $A = 1$ then $F = 2 \times 10^{12}$ *dyne*

14. (d)

15. (a) Because due to increase in temperature intermolecular forces decreases.

16. (c) Breaking Force $\propto$ Area of cross section of wire (πr)

If radius of wire is double then breaking force will become four times.

17. (a) $Y = 3K(1 - 2\sigma)$ and $Y = 2\eta(1 + \sigma)$

Eliminating σ we get $Y = \frac{9\eta K}{\eta + 3K}$

18. (a) $F = \frac{YAl}{L} = \frac{9 \times 10^{10} \times \pi \times 4 \times 10^{-6} \times 0.1}{100} = 360\ \pi\ N$

19. (d) Energy stored per unit volume $= \frac{1}{2} \times \text{Stress} \times \text{Strain}$

$= \frac{1}{2} \times \text{Young's modulus} \times (\text{Strain})^2 = \frac{1}{2} \times Y \times x^2$

20. (c) $l \propto L$ *i.e.* if length is reduced to half then increase in length will be $\frac{l}{2}$.

21. (b) $l = \frac{L^2 dg}{2Y} = \frac{(8 \times 10^{-2})^2 \times 1.5 \times 9.8}{2 \times 5 \times 10^8} = 9.6 \times 10^{-11} m$

22. (b) $\text{Stress} = \frac{\text{force}}{\text{Area}}$ $\therefore$ $\text{Stress} \propto \frac{1}{\pi r^2}$

$\frac{S_B}{S_A} = \left(\frac{r_A}{r_B}\right)^2 = (2)^2 \Rightarrow S_B = 4S_A$

23. (b) Breaking force $\propto$ Area of cross section of wire *i.e.* load hold by the wire does not depend upon the length of the wire.

24. (d) If length of wire doubled then strain = 1

$Y = \text{stress} \Rightarrow F = Y \times A = 10^{12} \times 0.5 = 0.5 \times 10^{12}\ dyne$

25. (b) Due to elastic fatigue its elastic property decreases.

26. (d) $l = \frac{FL}{AY} \Rightarrow l \propto \frac{1}{r^2}$ (*F*,*L* and *Y* are same)

$\frac{l_A}{l_B} = \left(\frac{r_B}{r_A}\right)^2 = \left(\frac{r_B}{2r_B}\right)^2 = \frac{1}{4} \Rightarrow l_A = 4l_B$ or $l_B = \frac{l_A}{4}$

27. (c)

28. (b) $l = \frac{FL}{AY} \Rightarrow \frac{l_S}{l_{cu}} = \frac{Y_{cu}}{Y_S}$ (*F*,*L* and *Y* are constant)

$\therefore \frac{l_s}{l_{cu}} = \frac{1.2 \times 10^{11}}{2 \times 10^{11}} = \frac{3}{5}$

29. (b) If length of the wire is doubled then strain = 1

$\therefore$ Y = $\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{2 \times 10^5}{2} = 10^5 \frac{dyne}{cm^2}$

30. (b) $l = \frac{FL}{AY} \Rightarrow l \propto \frac{L}{r^2}$ (*F* and *Y* are same)

$\therefore \frac{l_2}{l_1} = \frac{L_2}{L_1}\left(\frac{r_1}{r_2}\right)^2 = 2 \times \left(\frac{1}{2}\right)^2 = \frac{1}{2} \Rightarrow l_2 = \frac{l_1}{2} = \frac{l}{2} = 0.5mm.$

31. (b) $F = \text{force developed} = YA\,\alpha(\Delta\theta)$

$= 10^{11} \times 10^{-4} \times 10^{-5} \times 100 = 10^4\ N$

32. (c) $F = YA\alpha\Delta\theta \therefore F \propto A$

33. (d) $Y = \frac{F/A}{\text{strain}} \Rightarrow A = \frac{F}{Y \times \text{strain}} = \frac{10^4}{7 \times 10^9 \times 0.002}$

$= \frac{1}{14} \times 10^{-2} = 7.1 \times 10^{-4} m^2$

34. (b) $\text{strain} \propto \text{stress} \propto \frac{\text{F}}{\text{A}}$

Ratio of strain $= \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{4}{1}\right)^2 = \frac{16}{1}$

35. (a) $F = 2000N,\ L = 6m,\ l = 0.5\ cm,\ A = 10^{-6} m^2$

$Y = \frac{FL}{Al} = \frac{2000 \times 6}{10^{-6} \times 0.5 \times 10^{-2}} = 2.35 \times 10^{12}\ N/m^2$

36. (b) $F = Kx \Rightarrow K = \frac{F}{x} = \frac{9 \times 9.8}{4.5 \times 10^{-3}} = 1.96 \times 10^4\ N/m$

37. (a) $l \propto \frac{FL}{r^2 Y} \Rightarrow l \propto \frac{1}{r^2}$ (*F*, *L* and *Y* are constant)

$\frac{l_2}{l_1} = \left(\frac{r_1}{r_2}\right)^2 = (n)^2 \Rightarrow l_2 = n^2 l_1$

38. (b) Longitudinal strain $\frac{l}{L} = \frac{\text{stress}}{Y} = \frac{10^6}{10^{11}} = 10^{-5}$

Percentage increase in length $= 10^{-5} \times 100 = 0.001\%$

39. (d) It is the specific property of a particular metal at a given temperature which can be changed only by temperature variations.

40. (a) $Y = \frac{3.6 \times 10^{-9} N/Å}{3 \times 10^{-10} m} = 1.2 \times 10^{11} N/m^2$

41. (c)

42. (d) $K = \frac{YA}{L} = \frac{Y \times \pi r^2}{L} \Rightarrow K \propto \frac{Yr^2}{L}$

i.e. force constant of a wire depends on young's modules (nature of the material), radius of the wire and length of the wire.

43. (c)

44. (a)

45. (b)

46. (d) Increase in tension of wire $= YA\,\alpha\Delta\theta$

$= 8 \times 10^{-6} \times 2.2 \times 10^{11} \times 10^{-2} \times 10^{-4} \times 5 = 8.8\ N$

47. (a) A small change in pressure produces a large change in volume.

48. (c) $W = \frac{1}{2}\frac{YAl^2}{L} \Rightarrow 0.4 = \frac{1}{2} \times \frac{Y \times 1^{-6} \times (0.2 \times 10^{-2})^2}{1}$

$\therefore Y = 2 \times 10^{11}\ N/m^2$

49. (d)

50. (c) $Y = 3K(1 - 2\sigma)$

$\sigma = \frac{3K - Y}{6K} = \frac{3 \times 11 \times 10^{10} - 7.25 \times 10^{10}}{6 \times 11 \times 10^{10}} \Rightarrow \sigma = 0.39$

51. (c)

52. (a) If density of the material increases then more force (stress) is required for same deformation *i.e.* the value of young's modulus increases.

53. (c) $Y = 10^4\ N/m^2, A = 2 \times 10^{-4} m^2, F = 2 \times 10^5 dyne = 2N$

$l = \frac{FL}{AY} = \frac{2 \times L}{2 \times 10^{-4} \times 10^4} = L$

$\therefore$ Final length = initial length + increment = $2L$

54. (a)

55. (b) Y is defined for solid only and for powders, $Y = 0$

56. (a)

57. (a) $l = \frac{FL}{AY} = \frac{FL}{\pi r^2 Y} \therefore l \propto \frac{FL}{r^2}$ (Y = constant)

$\therefore \frac{l_2}{l_1} = \frac{F_2}{F_1} \times \frac{L_2}{L_1}\left(\frac{r_1}{r_2}\right)^2 = 2 \times 2 \times \left(\frac{1}{2}\right)^2 = 1$

$\therefore l_2 = l_1$ *i.e.* increment in its length will be l.

58. (d) Breaking stress = strain × Young's modulus

$= 0.15 \times 2 \times^{11} = 3 \times 10^{10}\ Nm^{-2}$

59. (a) In accordance with Hooke's law.

60. (a) $F = A \times Y \times \text{strain} = 1 \times 10^{-4} \times 2 \times 10^{11} \times 0.1 = 2 \times 10^6 N$

61. (c)

62. (b) Because strain is a dimensionless and unitless quantity.

63. (d) $\text{Stress} = \frac{\text{Force}}{\text{area}}$.

In the present case, force applied and area of cross-section of wires are same, therefore stress has to be the same.

$\text{Strain} = \frac{\text{Stress}}{Y}$

Since the Young's modulus of steel wire is greater than the copper wire, therefore, strain in case of steel wire is less than that in case of copper wire.

64. (b) Initial length (circumference) of the ring = $2\pi r$

Final length (circumference) of the ring = $2\pi R$

Change in length = $2\pi R - 2\pi r$.

$\text{strain} = \frac{\text{change in length}}{\text{originallength}} = \frac{2\pi(R-r)}{2\pi r} = \frac{R-r}{r}$

Now Young's modulus $E = \frac{F/A}{l/L} = \frac{F/A}{(R-r)/r}$

$\therefore F = AE\left(\frac{R-r}{r}\right)$

65. (a) $l = \frac{FL}{\pi r^2 r} \Rightarrow l \propto \frac{F}{r^2}$ (Y and L are constant)

$\frac{l_2}{l_1} = \frac{F_2}{F_1} \times \left(\frac{r_1}{r_2}\right)^2 = 2 \times (2)^2 = 8 \therefore l_2 = 8l_1 = 8 \times 1 = 8mm$

66. (c) $l = \frac{FL}{\pi r^2 Y} \Rightarrow l \propto \frac{L}{r^2}$ (F and Y are constant)

$\frac{l_1}{l_2} = \frac{L_1}{L_2}\left(\frac{r_2}{r_1}\right)^2 = \frac{1}{2}\left(\sqrt{2}\right)^2 \therefore \frac{l_1}{l_2} = 1:1$

67. (d) $l \propto \frac{1}{r^2}$ (F,L and Y are constant)

$\frac{l_2}{l_1} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{1}{2}\right)^2 \Rightarrow l_2 = \frac{l_1}{4} = \frac{2.4}{4} \Rightarrow l_2 = 0.6\ cm$

68. (b) $F = Y \times A \times \frac{l}{L} \Rightarrow F \propto r^2$ (Y,l and L are constant)

If diameter is made four times then force required will be 16 times. *i.e.* 16 × 10' N

69. (a) $F = Y \times A \times \frac{l}{L} \Rightarrow F \propto \frac{r^2}{L}$ (Y and l are constant)

$\therefore \frac{F_1}{F_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{L_2}{L_1}\right) = \left(\frac{2}{1}\right)^2\left(\frac{1}{4}\right) = 1 \Rightarrow \frac{F_1}{F_2} = 1:1$

70. (d) Increment in length $l = \frac{L^2 dg}{2Y} \therefore l \propto L^2 d$

71. (b) Adiabatic elasticity $E = \gamma P$

For argon $E_{Ar} = 1.6\ P$ ....(i)

For hydrogen $E_{H2} = 1.4P'$ ....(ii)

As elasticity of hydrogen and argon are equal

$\therefore 1.6P = 1.4P' \Rightarrow P' = \frac{8}{7}P$

72. (d)

73. (c) $l = \frac{FL}{AY} = \frac{FL^2}{(AL)Y} = \frac{FL^2}{VY}$.

If volume is fixed then $l \propto L^2$

74. (c) $F = YA\,\alpha\Delta t = 2 \times 10^{11} \times 3 \times 10^{-6} \times 10^{-5} \times (20\text{–}10) = 60N$

75. (a) Because dimension of invar does not varies with temperature.

76. (a) $l = \frac{FL}{\pi r^2 Y} \therefore l \propto \frac{L}{r^2}$ (Y and F are constant)

$$\frac{l_2}{l_1}=\frac{L_2}{L_1}\times\left(\frac{r_1}{r_2}\right)^2=(2)\times\left(\frac{1}{2}\right)^2=\frac{1}{2}$$

$$\Rightarrow l_2=\frac{l_1}{2}=\frac{0.01m}{2}=0.005m$$

77. (d) Poisson's ratio varies between – 1 and 0.5

78. (d) $L_2=l_2(1+\alpha_2\Delta\theta)$ and $L_1=l_1(1+\alpha_1\Delta\theta)$

$\Rightarrow (L_2-L_1)=(l_2-l_1)+\Delta\theta(l_2\alpha_2-l_1\alpha_1)$

Now $(L_2-L_1)=(l_2-l_1)$ so, $l_2\alpha_2-l_1\alpha_1=0$

79. (a) Thermal stress = $Y\alpha\Delta\theta$

$=1.2\times10^{11}\times1.1\times10^{-5}\times(20-10)=1.32\times10^7\ N/m^2$

80. (a) $l=\frac{FL}{AY}\Rightarrow l\propto\frac{1}{r^2}$ (F,L and Y are constant)

$\frac{l_2}{l_1}=\left(\frac{r_1}{r_2}\right)^2=(2)^2\Rightarrow l_2=4l_1=4\times3=12mm$

81. (d) $l=\frac{L^2dg}{2Y}=\frac{(8)^2\times1.5\times10^3\times10}{2\times5\times10^6}=9.6\times10^{-2}m$

82. (d) $l\propto\frac{L}{r^2}$ (Y and F are constant)

Maximum extension takes place in that wire for which the ratio of $\frac{L}{r^2}$ will be maximum.

83. (a)

84. (d)

85. (a) $Y=\frac{MgL}{Al}=\frac{250\times9.8\times2}{50\times10^{-6}\times0.5\times10^{-3}}$

$=19.6\times10^{10}\ N/m^2$

86. (c)

87. (c) $l=\frac{FL}{AY}\Rightarrow l\propto\frac{L}{r^2}$ (F and Y are constant)

$\frac{l_2}{l_1}=\frac{L_2}{L_1}\times\left(\frac{r_1}{r_2}\right)^2=2\times\left(\frac{1}{2}\right)^2=\frac{1}{2}\ \therefore l_2=\frac{l_1}{2}$

i.e. the change in the length of other wire is $\frac{l}{2}$

88. (b)

89. (b)

90. (c) $l=\frac{MgL}{YA}=\frac{1\times10\times1}{2\times10^{11}\times10^{-6}}=0.05\ mm$

91. (c) $l=\frac{FL}{AY}\ \therefore l\propto\frac{F}{r^2}$

$\frac{l_1}{l_2}=\frac{F_2}{F_1}\left(\frac{r_1}{r_2}\right)^2=(4)\times\left(\frac{1}{2}\right)^2=1\ \therefore l_2=l_1=1mm$

92. (c)

93. (b) $l=\frac{FL}{AY}\ \therefore l\propto\frac{1}{A}$ (F,L and Y are constant)

$\frac{A_2}{A_1}=\frac{l_1}{l_2}\Rightarrow A_2=A_1\left(\frac{0.1}{0.05}\right)=2A_1=2\times4=8mm^2$

94. (c) $l=\frac{FL}{\pi r^2Y}\Rightarrow r^2\propto\frac{1}{Y}$ (F,L and l are constant)

$\frac{r_2}{r_1}=\left(\frac{Y_1}{Y_2}\right)^{1/2}=\left(\frac{7\times10^{10}}{12\times10^{10}}\right)^{1/2}$

$\Rightarrow r_2=1.5\times\left(\frac{7}{12}\right)^{1/2}=1.145\ mm\ \therefore$ dia = 2.29 mm

95. (c) $F=\frac{YAl}{L}=0.9\times10^{11}\times\pi\times(0.3\times10^{-3})^2\times\frac{0.2}{100}=51\ N$

96. (b) Young's modules = $\frac{\text{stress}}{\text{strain}}$

As the length of wire get doubled therefore strain = 1

$\therefore$ Y = strain = 20 ×10⁸ N/m

97. (d) $l=\frac{FL}{\pi r^2Y}\ \therefore l\propto\frac{1}{r^2}$ (F,L and Y are constant)

$\frac{l_2}{l_1}=\left(\frac{r_1}{r_2}\right)^2=(2)^2\Rightarrow l_2=4l_1=4\times2=8\ mm.$

98. (b) Let L is the original length of the wire and K is force constant of wire.

Final length = initial length + elongation

$L'=L+\frac{F}{K}$

For first condition $a=L+\frac{4}{K}$ ...(i)

For second condition $b=L+\frac{5}{K}$ ...(ii)

By solving (i) and (ii) equation we get

$L=5a-4b$ and $K=\frac{1}{b-a}$

Now when the longitudinal tension is 9N, length of the string = $L+\frac{9}{K}$ = $5a-4b+9(b-a)=5b-4a$.

99. (a)

100. (b)

101. (b) $K=Yr_0=20\times10^{10}\times3\times10^{-10}=60\ N/m$

$=6\times10^{-9}\ N/Å$

102. (a) $l=\frac{FL}{AY}=\frac{4.8\times10^3\times4}{1.2\times10^{-4}\times1.2\times10^{11}}=1.33\ mm$

103. (b)

104. (d) $Y=\frac{\text{Stress}}{\text{Strain}}=\text{Constant}$

It depends only on nature of material.

105. (b) $2\pi\sqrt{\frac{m}{k}}=0.6$ ...(i) and $2\pi\sqrt{\frac{m+m'}{k}}=0.7$ ...(ii)

Dividing (ii) by (i) we get $\left(\frac{7}{6}\right)^2=\frac{m+m'}{m}=\frac{49}{36}$

$\frac{m+m'}{m}-1=\frac{49}{36}-1\Rightarrow\frac{m'}{m}=\frac{13}{36}\Rightarrow m'=\frac{13m}{36}$

Also $\frac{k}{m}=\frac{4\pi^2}{(0.6)^2}$

Desired extension = $\frac{m'g}{k}=\frac{13}{36}\times\frac{mg}{k}$

$= \frac{13}{36} \times 10 \times \frac{0.36}{4\pi^2} \approx 3.5\ cm$

106. (a) $Y = \frac{F/A}{\text{Strain}} \Rightarrow \text{strain} = \frac{F}{AY}$

107. (d) $Y = \frac{k}{r_0} = \frac{7}{3 \times 10^{-10}} = 2.33 \times 10^{10}\ N/m^2$

108. (d) $F = Y \times A \times \frac{l}{L} \Rightarrow F \propto \frac{r^2}{L}$ (Y and l are constant)

$\frac{F_A}{F_B} = \left(\frac{r_A}{r_B}\right)^2 \times \left(\frac{L_B}{L_A}\right) = \left(\frac{2}{1}\right)^2 \times \left(\frac{2}{1}\right) = \frac{8}{1}$

109. (c)

110. (d) When the length of wire is doubled then $l = L$ and strain = 1

$\therefore$ Y = strain = $\frac{F}{A}$

$\therefore$ Force = $Y \times A = 2 \times 10^{11} \times 0.1 \times 10^{-4} = 2 \times 10^6\ N$

111. (c) Potential energy stored in the rubber cord catapult will be converted into kinetic energy of mass.

$\frac{1}{2}mv^2 = \frac{1}{2}\frac{YAl^2}{L} \Rightarrow v = \sqrt{\frac{YAl^2}{mL}}$

$= \sqrt{\frac{5 \times 10^8 \times 25 \times 10^{-6} \times (5 \times 10^{-2})^2}{5 \times 10^{-3} \times 10 \times 10^{-2}}} = 250\ m/s$

112. (c)

113. (c)

114. (d)

115. (d) Breaking force $\propto r$

If diameter becomes double then breaking force will become four times *i.e.* 1000 × 4 = 4000 N

116. (b)

117. (d) $l = \frac{FL}{AY} = \frac{FL^2}{(AL)Y} = \frac{FL^2}{VY}$

$\therefore\ l \propto L^2$ If volume of the wire remains constant

$\frac{l_2}{l_1} = \left(\frac{L_2}{L_1}\right)^2 = \left(\frac{8}{2}\right)^2 = 16$

$\therefore l_2 = 16 \times l_1 = 16 \times 2 = 32mm = 3.2cm$

118. (a) $l = \frac{FL}{AY}$ $\therefore$ $l \propto \frac{1}{A}$ (F, L and Y are constant]

$\frac{l_2}{l_1} = \frac{A_1}{A_2} = \frac{4}{8} = \frac{1}{2} \Rightarrow l_2 = \frac{l_1}{2} = \frac{0.1}{2} = 0.05mm$

119. (c) $L = \frac{p}{dg} = \frac{10^6}{3 \times 10^3 \times 10} = \frac{100}{3} = 33.3m$

120. (a) $l = \frac{L^2 dg}{2Y} = \frac{(10)^2 \times 1500 \times 10}{2 \times 5 \times 10^8} = 15 \times 10^{-4}\ m$

121. (a) $Y = 3K(1 - 2\sigma),\ Y = 2\eta(1 + \sigma)$

For $Y = 0$, we get $1 - 2\sigma = 0$, also $1 + \sigma = 0$

$\Rightarrow \sigma$ lies between $\frac{1}{2}$ and -1.

122. (a) Value of Poisson's ratio lie in range of -1 to $\frac{1}{2}$

123. (b) We know that $\frac{dV}{V} = (1 + 2\sigma)\frac{dL}{L}$

If $\sigma = -\frac{1}{2}$ then $\frac{dV}{V} = 0$

i.e. there is no change in volume.

124. (b) $\frac{dV}{V} = (1 + 2\sigma)\frac{dL}{L}$

$\frac{dV}{V} = 2 \times 2 \times 10^{-3} = 4 \times 10^{-3}$ $\left[\because \sigma = 0.5 = \frac{1}{2}\right]$

$\therefore$ Percentage change in volume = $4 \times 10^{-1} = 0.4\%$

125. (b) $l = \frac{FL}{\pi r^2 Y}$ $\therefore$ $l \propto \frac{L}{r^2}$

Ratio of $\frac{L}{r^2}$ is maximum for wire in option (b).

Bulk Modulus

1. (c) Isothermal elasticity $K_i = P$

2. (c) Adiabatic elasticity $K_a = \gamma P$

3. (b) Ratio of adiabatic and isothermal elasticities

$\frac{E\phi}{E\theta} = \frac{\gamma P}{P} = \gamma = \frac{C_p}{C_v}$

4. (d)

5. (b) For triatomic gas $\gamma = \frac{4}{3}$

6. (d) From the ideal gas equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{E_2}{E_1} = \frac{P_2}{P_1} = \frac{V_1}{V_2} \times \frac{T_2}{T_1} = \left(\frac{1}{4}\right) \times \left(\frac{400}{300}\right) = \frac{1}{3} \Rightarrow E_2 = \frac{E_1}{3}$

i.e. elasticity will become $\frac{1}{3}$ times.

7. (a) $C = \frac{1}{K} = \frac{\Delta V/V}{\Delta P} \Rightarrow \Delta V = C \times \Delta P \times V$

$= 4 \times 10^{-5} \times 100 \times 100 = 0.4cc$

8. (d) $K = \frac{\Delta P}{\Delta V/V} = \frac{h\rho g}{\Delta V/V} = \frac{200 \times 10^3 \times 10}{0.1/100} = 2 \times 10^9$

9. (c) $\frac{1}{K}$ = compressibility $= \left(\frac{-\Delta V/V}{\Delta P}\right)$

10. (c) $K = \frac{100}{0.01/100} = 10^6 atm = 10^{11}\ N/m^2 = 10^{12}\ dyne/cm^2$

11. (b)

12. (c)

13. (d) If side of the cube is L then $V = L^3 \Rightarrow \frac{dV}{V} = 3\frac{dL}{L}$

$\therefore$ % change in volume = 3 × (% change in length)

= 3 × 1% = 3% $\therefore$ Bulk strain $\frac{\Delta V}{V} = 0.03$

14. (a) $B = \frac{\Delta p}{\Delta V/V} = \frac{h\rho g}{0.1/100} = \frac{200 \times 10^3 \times 9.8}{1/1000}$

$= 19.6 \times 10^8\ N/m^2$

15. (c) Isothermal elasticity $K_i = P = 1atm = 1.013 \times 10^5\ N/m^2$

16. (b)

17. (c) Isothermal bulk modulus = Pressure of gas

18. (c)

19. (a) If coefficient of volume expansion is α and rise in temperature is $\Delta\theta$ then $\Delta V = V\alpha\Delta\theta \Rightarrow \frac{\Delta V}{V} = \alpha\Delta\theta$

Volume elasticity $\beta = \frac{P}{\Delta V/V} = \frac{P}{\alpha\Delta\theta} \Rightarrow \Delta\theta = \frac{P}{\alpha\beta}$

20. (d) $K = \frac{\Delta p}{\Delta V/V} = \frac{(1.165-1.01)\times 10^5}{10/100} = \frac{0.155\times 10^5}{1/10}$

$= 1.55\times 10^5\ pa$

21. (b) $B = \frac{\Delta p}{\Delta V/V} \Rightarrow \frac{1}{B} \propto \frac{\Delta V}{V}$ [Δp = constant]

Rigidity Modulus

1. (b)
2. (d) Modulus of rigidity is the property of material.
3. (c) $Y = 2\eta(1+\sigma)$
4. (d) $Y = 2\eta(1+\sigma) \Rightarrow \sigma = \frac{0.5Y-\eta}{\eta}$
5. (c) Twisting couple $C = \frac{\pi\eta r^4\theta}{2l}$

If material and length of the wires A and B are equal and equal twisting couple are applied then

$\theta \propto \frac{1}{r^4}$ $\therefore$ $\frac{\theta_1}{\theta_2} = \left(\frac{r_2}{r_1}\right)^4$

6. (a) A small part of the spring bear tangential stress, causing straining strain.
7. (a) $Y = 2\eta(1+\sigma)$

For no transverse strain (σ = 0)

$Y = 2\eta \Rightarrow \eta = \frac{Y}{2} = 3\times 10^{12}\ N/m^2$

8. (b) $Y = 2\eta(1+\sigma) \Rightarrow 3\eta = 2\eta(1+\sigma) \Rightarrow \sigma = \frac{3}{2} - 1 = \frac{1}{2}$

Now substituting the value of σ in the following expression.

$Y = 3K(1-2\sigma) \Rightarrow K = \frac{Y}{3(1-2\sigma)} = \infty$

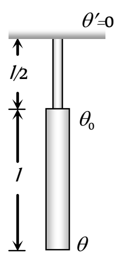
9. (c)
10. (d) $Y = 2\eta(1+\sigma)$

$2.4\eta = 2\eta(1+\sigma) \Rightarrow 1.2 = 1+\sigma \Rightarrow \sigma = 0.2$

11. (d) Shearing strain $\phi = \frac{x}{L} = \frac{0.02cm}{10cm}$ $\therefore$ $\phi = 0.002$
12. (b)
13. (d) There will be both shear stress and normal stress.
14. (b) Angle of shear $\phi = \frac{r\theta}{L} = \frac{4\times 10^{-1}}{100}\times 30^o = 0.12^o$
15. (c) For twisting, Angle of shear $\phi \propto \frac{1}{L}$

i.e. if L is more then ϕ will be small.

16. (b) $r\theta = L\phi \Rightarrow 10^{-2}\times 0.8 = 2\times\phi \Rightarrow \phi = 0.004$
17. (d) $\tau = C.\theta = \frac{\pi\eta r^4\theta}{2L}$ = Constant



$\Rightarrow \frac{\pi\eta r^4(\theta-\theta_0)}{2l} = \frac{\pi\eta(r/2)^4(\theta_0-\theta')}{2(l/2)}$

$\Rightarrow \frac{(\theta-\theta_0)}{2} = \frac{\theta_0}{16} \Rightarrow \theta_0 = \frac{8}{9}\theta$

18. (c)

Work Done in Stretching a Wire

1. (d) $U = \frac{1}{2}\left(\frac{YA}{L}\right)l^2$ $\therefore$ $U \propto l^2$

$\frac{U_2}{U_1} = \left(\frac{l_2}{l_1}\right)^2 = \left(\frac{10}{2}\right)^2 = 25 \Rightarrow U_2 = 25U_1$

i.e. potential energy of the spring will be 25 V

2. (b)
3. (c) Work done = $\frac{1}{2}Fl = \frac{Mgl}{2}$
4. (a) $W = \frac{1}{2}Fl$ $\therefore$ $W \propto l$ (F is constant)

$\therefore$ $\frac{W_1}{W_2} = \frac{l_1}{l_2} = \frac{l}{2l} = \frac{1}{2}$

5. (b) $W = \frac{1}{2}\times F\times l = \frac{1}{2}mgl$

$= \frac{1}{2}\times 10\times 10\times 1\times 10^{-1} = 0.05\ J$

6. (c) $K = \frac{F}{l}$ and $W = \frac{1}{2}Fl = \frac{1}{2}Kl\times l = \frac{1}{2}Kl^2$
7. (d) Due to tension, intermolecular distance between atoms is increased and therefore potential energy of the wire is increased and with the removal of force interatomic distance is reduced and so is the potential energy. This change in potential energy appears as heat in the wire and thereby increases the temperature.
8. (c) Due to increase in intermolecular distance.
9. (b)
10. (b) $U = \frac{1}{2}\times\frac{(\text{stress})^2}{Y}\times\text{volume} = \frac{1}{2}\times\frac{F^2\times A\times L}{A^2\times Y}$

$= \frac{1}{2}\times\frac{F^2L}{AY} = \frac{1}{2}\times\frac{(50)^2\times 0.2}{1\times 10^{-4}\times 1\times 10^{11}} = 2.5\times 10^{-5}\ J$

11. (c) Work done in stretching a wire

$W = \frac{1}{2}Fl = \frac{1}{2}\times 10\times 0.5\times 10^{-3} = 2.5\times 10^{-3}\ J$

Work done to displace it through 1.5 mm

$W = F\times l = 5\times 10^{-3}\ J$

The ratio of above two work = 1 : 2

12. (a) Increase in energy $= \frac{1}{2}\times 20\times 1\times 10^{-3} = 0.01J$
13. (d) Ratio of work done = $\frac{1/2Fl}{Fl} = \frac{1}{2}$
14. (a) Energy per unit volume $= \frac{1}{2}\times \text{Y}\times(\text{strain})^2$

$\therefore \text{strain} = \sqrt{\frac{2E}{Y}}$

15. (a) Energy per unit volume = $\frac{(\text{stress})^2}{2Y}$

$\frac{E_1}{E_2}=\frac{Y_2}{Y_1}$ (Stress is constant) $\therefore \frac{E_1}{E_2}=\frac{3}{2}$

16. (a) Energy = $\frac{1}{2}Fl=\frac{1}{2}\times F\times\left(\frac{FL}{AY}\right)=\frac{1}{2}\times\frac{F^2L}{AY}$

$=\frac{1}{2}\times\frac{(50)^2\times 20\times10^{-2}}{2\times10^{-4}\times1.4\times10^{11}}=8.57\times10^{-6}\,J$

17. (b) $U=\frac{F^2}{2K}=\frac{T^2}{2K}$

18. (a) Energy stored per unit volume = $\frac{1}{2}\left(\frac{F}{A}\right)\left(\frac{l}{L}\right)=\frac{Fl}{2AL}$

19. (c) $U=\frac{1}{2}\times\frac{YAl^2}{L}=\frac{1}{2}\times\frac{2\times10^{11}\times3\times10^{-6}\times(1\times10^{-3})^2}{4}$

$=0.075\,J$

20. (d) At extension l_1, the stored energy $=\frac{1}{2}Kl_1^2$

At extension l_2, the stored energy $=\frac{1}{2}Kl_2^2$

Work done in increasing its extension from l_1 to l_2

$=\frac{1}{2}K(l_2^2-l_1^2)$

21. (b) $K=\frac{F}{x}=\frac{40}{2\times10^{-2}}=0.2\,N/m$

Work done $=\frac{1}{2}Kx^2=\frac{1}{2}\times(0.2)\times(0.05)^2=2.5\,J$

22. (c)

23. (c)

24. (c) $W=\frac{YAl^2}{2L}=\frac{2\times10^{10}\times10^{-6}\times(10^{-3})^2}{2\times50\times10^{-2}}=2\times10^{-2}\,J$

25. (b) $U=\frac{1}{2}\times Y\times(\text{Strain})^2=\frac{1}{2}\times9\times10^{11}\times\left(\frac{1}{100}\right)^2$

$=4.5\times10^7\,J$

26. (a) $W=\frac{1}{2}Fl=\frac{1}{2}\times Mg\times l=\frac{1}{2}\times5\times10\times3=75\,J$

27. (b)

28. (a)

29. (a) $U=\frac{1}{2}\times F\times l=\frac{1}{2}\times200\times10^{-3}=0.1\,J$

30. (b) $U=\frac{1}{2}Fl=\frac{F^2L}{2AY}$. $U\propto\frac{L}{r^2}$ (*F* and *Y* are constant)

$\therefore \frac{U_A}{U_B}=\left(\frac{L_A}{L_B}\right)\times\left(\frac{r_A}{r_B}\right)^2=(3)\times\left(\frac{1}{2}\right)^2=\frac{3}{4}$

Critical Thinking Questions

1. (b)

2. (a) $L=\frac{P}{dg}=\frac{6}{3\times10^3\times10}=\frac{100}{3}=34m$

3. (c) Thermal stress = $Y\alpha\Delta\theta$.
If thermal stress and rise in temperature are equal then
$Y\propto\frac{1}{\alpha}\Rightarrow\frac{Y_1}{Y_2}=\frac{\alpha_2}{\alpha_1}=\frac{3}{2}$

4. (a) Speed of sound in a stretched string $v=\sqrt{\frac{T}{\mu}}$ ...(i)

Where T is the tension in the string and μ is mass per unit length.

According to Hooke's law, $F\propto x \;\therefore\; T\propto x$ ...(ii)

From (i) and (ii) $v\propto\sqrt{x}\;\therefore v'=\sqrt{1.5}\;v=1.22\,v$

5. (c) Total force at height $3L/4$ from its lower end
= Weight suspended + Weight of 3/4 of the chain
$=W_1+(3W/4)$

Hence stress $=\frac{W_1+(3W/4)}{S}$

6. (d) $l=\frac{FL}{AY}\;\therefore\; l\propto\frac{1}{r^2}$ (*F, L* and *Y* are constant)

$\frac{l_1}{l_2}=\left(\frac{r_2}{r_1}\right)^2=(2)^2=4$

7. (c) Restoring force is zero at mean position

$F=-Kx+F_0\Rightarrow 0=-Kx+F_0\Rightarrow x=\frac{F_0}{K}$

i.e. the particle will oscillate about $x=\frac{F_0}{K}$

8. (b)

Graphical Questions

1. (d) $T=2\pi\sqrt{\frac{M}{K}}\Rightarrow T^2\propto M$

If we draw a graph between T^2 and *M* then it will be straight line.

and for *M* = 0, *T* = 0

i.e. the graph should pass through the origin.

but from the it is not reflected it means the mass of pan was neglected.

2. (a) In the region *OA*, stress ∝ strain *i.e.* Hooke's law hold good.

3. (c)

4. (c)

5. (d) As stress is shown on *x*-axis and strain on *y*-axis

So we can say that $Y=\cot\theta=\frac{1}{\tan\theta}=\frac{1}{\text{slope}}$

So elasticity of wire *P* is minimum and of wire *R* is maximum

6. (a) Area of hysterisis loop gives the energy loss in the process of stretching and unstretching of rubber band and this loss will appear in the form of heating.

7. (d) $\frac{Y_A}{Y_B}=\frac{\tan\theta_A}{\tan\theta_B}=\frac{\tan60}{\tan30}=\frac{\sqrt{3}}{1/\sqrt{3}}=3\Rightarrow Y_A=3Y_B$

8. (a) $l=\frac{FL}{AY}\;\therefore\; l\propto\frac{1}{r^2}$ (*Y, L* and *F* are constant)

i.e. for the same load, thickest wire will show minimum elongation. So graph *D* represent the thickest wire.

9. (a) From the graph $l=10^{-4}m,\;F=20N$

$A=10^{-6}m^2,\;L=1m$

$\therefore Y = \frac{FL}{Al} = \frac{20 \times 1}{10^{-6} \times 10^{-4}} = 20 \times 10^{10} = 2 \times 10^{11} N/m^2$

10. (b) At point b, yielding of material starts.

11. (c) Graph between applied force and extension will be straight line because in elastic range,

Applied force $\propto$ extension

but the graph between extension and stored elastic energy will be parabolic in nature

As $U = 1/2\ kx^2$ or $U \propto x^2$.

12. (b) $F = -\left(\frac{dU}{dx}\right)$.

In the region *BC* slope of the graph is positive

$\therefore$ *F* = negative *i.e.* force is attractive in nature

In the region *AB* slope of the graph is negative

$\therefore$ *F* = positive *i.e.* force is repulsive in nature

13. (b) Force constant, K = tan 30° = $1/\sqrt{3}$

14. (b) In ductile materials, yield point exist while in Brittle material, failure would occur without yielding.

15. (d) Young's modulus is defined only in elastic region and

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{8 \times 10^7}{4 \times 10^{-4}} = 2 \times 10^{11}\ N/m^2$$

16. (a) Elasticity of wire decreases at high temperature *i.e.* at higher temperature slope of graph will be less.

So we can say that $T_1 > T_2$

17. (c)

18. (d) Attraction will be minimum when the distance between the molecule is maximum.

Attraction will be maximum at that point where the positive slope is maximum because $F = -\frac{dU}{dx}$

19. (c) $Y = \tan\theta$. According to figure $\theta_A > \theta_B > \theta_C$

i.e. $\tan\theta_A > \tan\theta_B > \tan\theta_C$

or $Y_A > Y_B > Y_C$

$\therefore$ *A, B,* and *C* graph are for steel, brass and rubber respectively.

Assertion and Reason

1. (a) Because, the stretching of coil simply changes its shape without any change in the length of the wire used in coil. Due to which shear modulus of elasticity is involved.

2. (e) When a spring balance has been used for a long time, the spring in the balance fatigued and there is loss of strength of the spring. In such a case, the extension in the spring is more for a given load and hence the balance gives wrong readings.

3. (a) Elasticity is a measure of tendency of the body to regain its original configuration. As steel is deformed less than rubber therefore steel is more elastic than rubber.

4. (d) In a glassy solid (*i.e.,* amorphous solid) the various bonds between the atoms or ions or molecules of a solid are not equally strong. Different bonds are broken at different temperatures. Hence there is no sharp melting point for a glassy solid.

5. (a)

6. (a) Bulk modulus of elasticity measures how good the body is to regain its original volume on being compressed. Therefore, it represents incompressibility of the material. $K = \frac{-PV}{\Delta V}$ where *P* is increase in pressure, ΔV is change in volume.

7. (c) Strain is the ratio of change in dimensions of the body to the original dimensions. Because this is a ratio, therefore it is dimensionless quantity.

8. (a) A bridge during its use undergoes alternating strains for a large number of times each day, depending upon the movement of vehicles on it when a bridge is used for long time, it losses its elastic strength. Due to which the amount of strain in the bridge for a given stress will become large and ultimately, the bridge may collapse. This may not happen, if the bridges are declared unsafe after long use.

9. (d) Ivory is more elastic than wet-clay. Hence the ball of ivory will rise to a greater height. In fact the ball of wet-clay will not rise at all, it will be somewhat flattened permanently.

10. (a) Young's modulus of a material, $Y = \frac{\text{Stress}}{\text{Strain}}$

Here, stress = $\frac{\text{Restoring force}}{\text{Area}}$.

As restoring force is zero $\therefore$ $Y = 0$.

11. (a) Work done $= \frac{1}{2} \times \text{Stress} \times \text{Strain} = \frac{1}{2} \times Y \times (\text{Strain})^2$.

Since, elasticity of steel is more than copper, hence more work has to be done in order to stretch the steel.

12. (b) Stress is defined as internal force (restoring force) per unit area of a body. Also, rubber is less elastic than steel, because restoring force is less for rubber than steel.

Elasticity

Self Evaluation Test - 9

1. Two wires A and B of same length, same area of cross-section having the same Young's modulus are heated to the same range of temperature. If the coefficient of linear expansion of *A* is 3/2 times of that of wire *B*. The ratio of the forces produced in two wires will be

(a) 2/3 (b) 9/4
(c) 4/9 (d) 3/2

2. A wire of area of cross-section $10^{-6} m^2$ is increased in length by 0.1%. The tension produced is 1000 *N*. The Young's modulus of wire is

(a) $10^{12}\ N/m^2$ (b) $10^{11}\ N/m^2$
(c) $10^{10}\ N/m^2$ (d) $10^{9}\ N/m^2$

3. To break a wire of one meter length, minimum 40 *kg wt.* is required. Then the wire of the same material of double radius and 6 *m* length will require breaking weight

(a) 80 *kg-wt* (b) 240 *kg-wt*
(c) 200 *kg-wt* (d) 160 *kg-wt*

4. The breaking stress of a wire of length L and radius r is 5 $kg-wt/m^2$. The wire of length $2l$ and radius $2r$ of the same material will have breaking stress in $kg-wt/m^2$

(a) 5 (b) 10
(c) 20 (d) 80

5. The increase in length on stretching a wire is 0.05%. If its Poisson's ratio is 0.4, then its diameter

(a) Reduce by 0.02% (b) Reduce by 0.1%
(c) Increase by 0.02% (d) Decrease by 0.4%

6. If Poisson's ratio σ is $-\frac{1}{2}$ for a material, then the material is

(a) Uncompressible (b) Elastic fatigue
(c) Compressible (d) None of the above

7. If the breaking force for a given wire is *F*, then the breaking force of two wires of same magnitude will be

(a) F (b) $4F$
(c) $8F$ (d) $2F$

8. If the thickness of the wire is doubled, then the breaking force in the above question will be

(a) $6F$ (b) $4F$
(c) $8F$ (d) F

9. On all the six surfaces of a unit cube, equal tensile force of F is applied. The increase in length of each side will be (Y = Young's modulus, σ = Poisson's ratio)

(a) $\frac{F}{Y(1-\sigma)}$ (b) $\frac{F}{Y(1+\sigma)}$
(c) $\frac{F(1-2\sigma)}{Y}$ (d) $\frac{F}{Y(1+2\sigma)}$

10. The mass and length of a wire are *M* and *L* respectively. The density of the material of the wire is *d*. On applying the force *F* on the wire, the increase in length is *l*, then the Young's modulus of the material of the wire will be

(a) $\frac{Fdl}{Ml}$ (b) $\frac{FL}{Mdl}$
(c) $\frac{FMl}{dl}$ (d) $\frac{FdL^2}{Ml}$

11. Two exactly similar wires of steel and copper are stretched by equal forces. If the difference in their elongations is 0.5 *cm*, the elongation (*l*) of each wire is

$Y_s(\text{steel}) = 2.0\times10^{11}\ N/m^2$

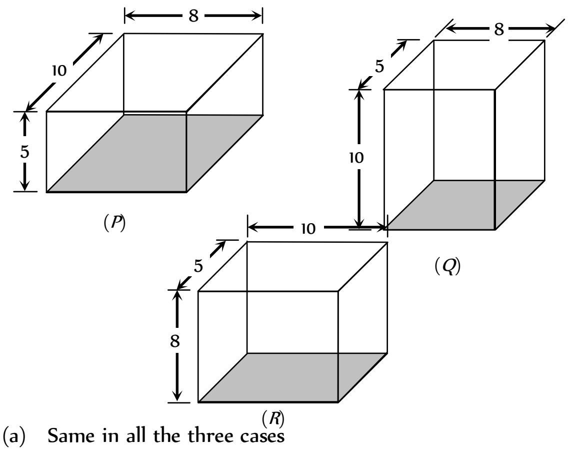
$Y_c(\text{copper}) = 1.2\times10^{11}\ N/m^2$

(a) $l_s = 0.75\,cm, l_c = 1.25\,cm$
(b) $l_s = 1.25\,cm, l_c = 0.75\,cm$
(c) $l_s = 0.25\,cm, l_c = 0.75\,cm$
(d) $l_s = 0.75\,cm, l_c = 0.25\,cm$

12. If the compressibility of water is σ per unit atmospheric pressure, then the decrease in volume V due to P atmospheric pressure will be

(a) $\sigma P/V$ (b) σPV
(c) σ/PV (d) $\sigma V/P$

13. A rectangular block of size $10\,cm\times8\,cm\times5\,cm$ is kept in three different positions *P*, *Q* and *R* in turn as shown in the figure. In each case, the shaded area is rigidly fixed and a definite force *F* is applied tangentially to the opposite face to deform the block. The displacement of the upper face will be



(a) Same in all the three cases
(b) Maximum in *P* position
(c) Maximum in *Q* position
(d) Maximum in *R* position

Answers and Solutions

(SET - 9)

1. (d) $F = YA\alpha\Delta\theta$

If Y, A and $\Delta\theta$ are constant then $\frac{F_A}{F_B} = \frac{\alpha_A}{\alpha_B} = \frac{3}{2}$

2. (a) $Y = \frac{FL}{Al} = \frac{1000 \times 100}{10^{-6} \times 0.1} = 10^{12}\ N/m^2$

3. (d) Breaking force = Breaking stress × Area of cross section of wire

$\therefore$ Breaking force $\propto r$ (Breaking distance is constant)

If radius becomes doubled then breaking force will become 4 times *i.e.* 40 × 4 = 160 *kg wt*

4. (a) Breaking stress depends on the material of wire.

5. (a) Poisson's ratio $= \frac{\text{Lateral strain}}{\text{Longitudinal strian}}$

$\therefore$ Lateral strain $= 0.4 \times \frac{0.05}{100}$

So reduced by 0.02%.

6. (a) $\frac{dV}{V} = (1 + 2\sigma)\frac{dL}{dL}$

if $\sigma = -\frac{1}{2}$ then $\frac{dV}{V} = 0$ *i.e.* $K = \infty$

7. (d) Breaking force $\propto$ Area of cross section

If area is double then breaking force will become two times.

8. (b) Breaking force $\propto \pi r^2$

If thickness (radius) of wire is doubled then breaking force will become four times.

9. (c) Tensile strain on each face $= \frac{F}{Y}$

Lateral strain due to the other two forces acting on perpendicular faces $= \frac{-2\sigma F}{Y}$

Total increase in length $= (1 - 2\sigma)\frac{F}{Y}$

10. (d) $Y = \frac{F}{A}\frac{L}{l} = \frac{FdL^2}{Ml}$

As M = volume × density $= A \times L \times d \ \therefore\ A = \frac{M}{Ld}$

11. (a) $l \propto \frac{1}{Y} \Rightarrow \frac{Y_s}{Y_c} = \frac{l_c}{l_s} \Rightarrow \frac{l_c}{l_s} = \frac{2 \times 10^{11}}{1.2 \times 10^{11}} = \frac{5}{3}$ ....(i)

Also $l_c - l_s = 0.5$ ....(ii)

On solving (i) and (ii) $l_c = 1.25\ cm$ and $l_s = 0.75\ cm$.

12. (b) Compressibility $= \frac{\Delta V/V}{P} \Rightarrow \sigma = \frac{\Delta V}{PV} \Rightarrow \Delta V = \sigma PV$

13. (d) $\eta = \frac{F/A}{x/L} \Rightarrow x = \frac{L}{\eta} \times \frac{F}{A}$

If η and F are constant then $x \propto \frac{L}{A}$

For maximum displacement area at which force applied should be minimum and vertical side should be maximum, this is given in the R position of rectangular block.

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Chapter 10

Surface Tension

Intermolecular Force

The force of attraction or repulsion acting between the molecules are known as intermolecular force. The nature of intermolecular force is electromagnetic.

The intermolecular forces of attraction may be classified into two types.

Cohesive force	Adhesive force
The force of attraction between molecules of same substance is called the force of cohesion. This force is lesser in liquids and least in gases.	The force of attraction between the molecules of the different substances is called the force of adhesion.
Ex. (i) Two drops of a liquid coalesce into one when brought in mutual contact. (ii) It is difficult to separate two sticky plates of glass welded with water. (iii) It is difficult to break a drop of mercury into small droplets because of large cohesive force between the mercury molecules.	Ex. (i) Adhesive force enables us to write on the blackboard with a chalk. (ii) A piece of paper sticks to another due to large force of adhesion between the paper and gum molecules. (iii) Water wets the glass surface due to force of adhesion.

Note : ❑ Cohesive or adhesive forces are inversely proportional to the eighth power of distance between the molecules.

Surface Tension

The property of a liquid due to which its free surface tries to have minimum surface area and behaves as if it were under tension somewhat like a stretched elastic membrane is called surface tension. A small liquid drop has spherical shape, as due to surface tension the liquid surface tries to have minimum surface area and for a given volume, the sphere has minimum surface area.

Surface tension of a liquid is measured by the force acting per unit length on either side of an imaginary line drawn on the free surface of liquid, the direction of this force being perpendicular to the line and tangential to the free surface of liquid. So if F is the force acting on one side of imaginary line of length L, then $T = (F/L)$

(1) It depends only on the nature of liquid and is independent of the area of surface or length of line considered.

(2) It is a scalar as it has a unique direction which is not to be specified.

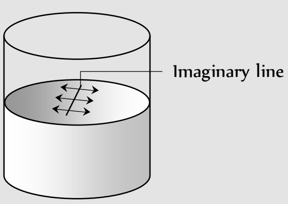
(3) Dimension : $[MT^{-2}]$. (Similar to force constant)

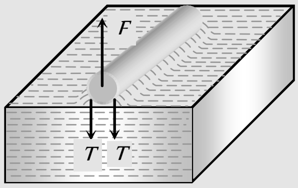
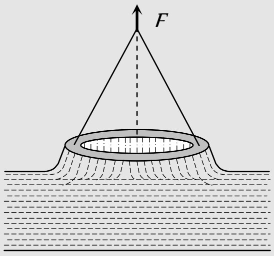
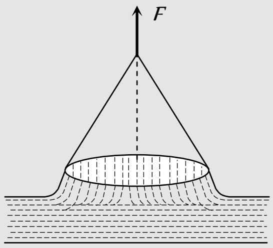
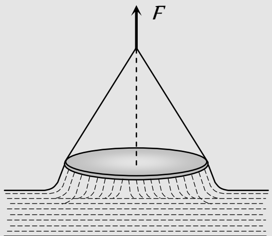
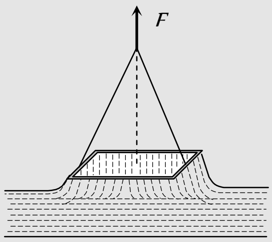
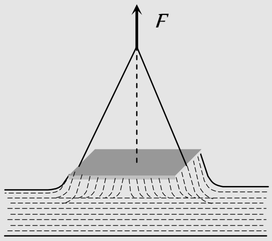
(4) Units : N/m (S.I.) and $Dyne/cm$ [C.G.S.]

(5) It is a molecular phenomenon and its root cause is the electromagnetic forces.

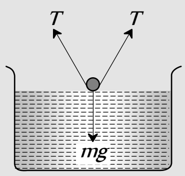
Force Due to Surface Tension

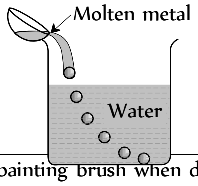
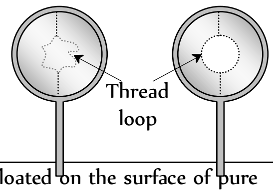
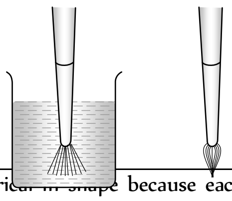
If a body of weight W is placed on the liquid surface, whose surface tension is T. If F is the minimum force required to pull it away from the water then value of F for different bodies can be calculated by the following table.

Body	Figure	Force
	 Fig. 10.1	

Needle (Length = l)		$F = 2lT + W$
Hollow disc (Inner radius = r_1 Outer radius = r_2)		$F = 2\pi(r_1 + r_2)T + W$
Thin ring (Radius = r)		$F = 2\pi(r + r)T + W$ $F = 4\pi rT + W$
Circular plate or disc (Radius = r)		$F = 2\pi rT + W$
Square frame (Side = l)		$F = 8lT + W$
Square plate		$F = 4lT + W$

Examples of Surface Tension

(1) When mercury is split on a clean glass plate, it forms globules. Tiny globules are spherical on the account of surface tension because force of gravity is negligible. The bigger globules get flattened from the middle but have round shape near the edges.	(2) When a greased iron needle is placed gently on the surface of water at rest, so that it does not prick the water surface, the needle floats on the surface of water despite it being heavier because the weight of needle is balanced by the vertical components of the forces of surface tension. If the water
	

	surface is pricked by one end of the needle, the needle sinks down.
(3) When a molten metal is poured into water from a suitable height, the falling stream of metal breaks up and the detached portion of the liquid in small quantity acquire the spherical shape. 	(4) Take a frame of wire and dip it in soap solution and take it out, a soap film will be formed in the frame. Place a loop of wet thread gently on the film. It will remain in the form, we place it on the film according to figure. Now, piercing the film with a pin at any point inside the loop, It immediately takes the circular form as shown in figure. 
(5) Hair of shaving brush/painting brush when dipped in water spread out, but as soon as it is taken out, its hair stick together. 	(6) If a small irregular piece of camphor is floated on the surface of pure water, it does not remain steady but dances about on the surface. This is because, irregular shaped camphor dissolves unequally and decreases the surface tension of the water locally. The unbalanced forces make it to move haphazardly in different directions.
(7) Rain drops are spherical in shape because each drop tends to acquire minimum surface area due to surface tension, and for a given volume, the surface area of sphere is minimum.	(8) Oil drop spreads on cold water. Whereas it may remain as a drop on hot water. This is due to the fact that the surface tension of oil is less than that of cold water and is more than that of hot water.

Factors Affecting Surface Tension

(1) **Temperature :** The surface tension of liquid decreases with rise of temperature. The surface tension of liquid is zero at its boiling point and it vanishes at critical temperature. At critical temperature, intermolecular forces for liquid and gases becomes equal and liquid can expand without any restriction. For small temperature differences, the variation in surface tension with temperature is linear and is given by the relation

$$T_t = T_0(1 - \alpha t)$$

where T_t, T_0 are the surface tensions at $t^o C$ and $0^o C$ respectively and α is the temperature coefficient of surface tension.

Examples : (i) Hot soup tastes better than the cold soup.

(ii) Machinery parts get jammed in winter.

(2) **Impurities :** The presence of impurities either on the liquid surface or dissolved in it, considerably affect the surface tension, depending upon the degree of contamination. A highly soluble substance like sodium chloride when dissolved in water, increases the surface tension of water. But the sparingly soluble substances like phenol when dissolved in water, decreases the surface tension of water.

Applications of Surface Tension

(1) The oil and grease spots on clothes cannot be removed by pure water. On the other hand, when detergents (like soap) are added in water, the surface tension of water decreases. As a result of this, wetting power of soap solution increases. Also the force of adhesion between soap solution and oil or grease on the clothes increases. Thus, oil, grease and dirt particles get mixed with soap solution easily. Hence clothes are washed easily.

(2) The antiseptics have very low value of surface tension. The low value of surface tension prevents the formation of drops that may otherwise block the entrance to skin or a wound. Due to low surface tension, the antiseptics spreads properly over wound.

(3) Surface tension of all lubricating oils and paints is kept low so that they spread over a large area.

(4) Oil spreads over the surface of water because the surface tension of oil is less than the surface tension of cold water.

(5) A rough sea can be calmed by pouring oil on its surface.

(6) In soldering, addition of 'flux' reduces the surface tension of molten tin, hence, it spreads.

Molecular Theory of Surface Tension

The maximum distance upto which the force of attraction between two molecules is appreciable is called molecular range $(\approx 10^{-9} m)$. A sphere with a molecule as centre and radius equal to molecular range is called the sphere of influence. The liquid enclosed between free surface (PQ) of the liquid and an imaginary plane (RS) at a distance r (equal to molecular range) from the free surface of the liquid form a liquid film.

To understand the concept of tension acting on the free surface of a liquid, let us consider four liquid molecules like A, B, C and D. Their sphere of influence are shown in the figure.

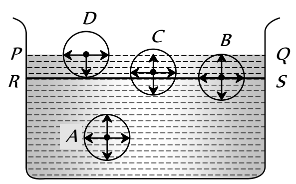


Fig. 10.2

(1) Molecule A is well within the liquid, so it is attracted equally in all directions. Hence the net force on this molecule is zero and it moves freely inside the liquid.

(2) Molecule B is little below the free surface of the liquid and it is also attracted equally in all directions. Hence the resultant force acts on it is also zero.

(3) Molecule C is just below the upper surface of the liquid film and the part of its sphere of influence is outside the free liquid surface. So the number of molecules in the upper half (attracting the molecules upward) is less than the number of molecule in the lower half (attracting the molecule downward). Thus the molecule C experiences a net downward force.

(4) Molecule D is just on the free surface of the liquid. The upper half of the sphere of influence has no liquid molecule. Hence the molecule D experiences a maximum downward force.

Thus all molecules lying on surface film experiences a net downward force. Therefore, free surface of the liquid behaves like a stretched membrane.

Surface Energy

The molecules on the liquid surface experience net downward force. So to bring a molecule from the interior of the liquid to the free surface, some work is required to be done against the intermolecular force of attraction, which will be stored as potential energy of the molecule on the surface. The potential energy of surface molecules per unit area of the surface is called surface energy.

Unit : $Joule/m^2$ (S.I.) erg/cm^2 (C.G.S.)

Dimension : $[MT^{-2}]$

If a rectangular wire frame *ABCD*, equipped with a sliding wire *LM* dipped in soap solution, a film is formed over the frame. Due to the surface tension, the film will have a tendency to shrink and thereby, the sliding wire *LM* will be pulled in inward direction. However, the sliding wire can be held in this position under a force *F*, which is equal and opposite to the force acting on the sliding wire *LM* all along its length due to surface tension in the soap film.

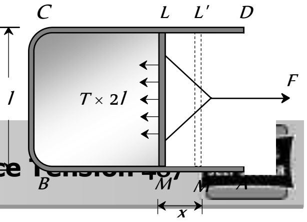


Fig. 10.3

If T is the force due to surface tension per unit length, then $F = T \times 2l$

Here l is length of the sliding wire *LM*. The length of the sliding wire has been taken as $2l$ for the reason that the film has got two free surfaces.

Suppose that the sliding wire *LM* is moved through a small distance x, so as to take the position $L'M'$. In this process, area of the film increases by $2l \times x$ (on the two sides) and to do so, the work done is given by

$W = F \times x = (T \times 2l) \times x = T \times (2lx) = T \times \Delta A$

$\therefore \quad W = T \times \Delta A \qquad [\Delta A$ = Total increase in area of the film]

If temperature of the film remains constant in this process, this work done is stored in the film as its surface energy.

From the above expression $T = \dfrac{W}{\Delta A}$ or $T = W$ [If $\Delta A = 1$]

i.e. surface tension may be defined as the amount of work done in increasing the area of the liquid surface by unity against the force of surface tension at constant temperature.

Work Done in Blowing a Liquid Drop or Soap Bubble

(1) If the initial radius of liquid drop is r_1 and final radius of liquid drop is r_2 then

$W = T \times$ Increment in surface area

$W = T \times 4\pi[r_2^2 - r_1^2]$ [drop has only one free surface]

(2) In case of soap bubble

$W = T \times 8\pi[r_2^2 - r_1^2]$ [Bubble has two free surfaces]

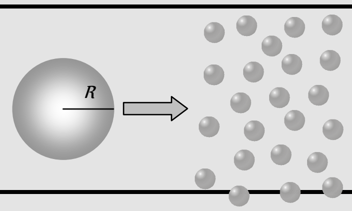
Splitting of Bigger Drop

When a drop of radius R splits into n smaller drops, (each of radius r) then surface area of liquid increases. Hence the work is to be done against surface tension.

Since the volume of liquid remains constant therefore $\frac{4}{3}\pi R^3 = n\frac{4}{3}\pi r^3 \quad \therefore \; R^3 = nr^3$

Work done = $T \times \Delta A = T \times$ [Total final surface area of n drops – surface area of big drop] = $T[n4\pi r^2 - 4\pi R^2]$

Various formulae of work done			
$4\pi T[nr^2 - R^2]$	$4\pi R^2 T[n^{1/3} - 1]$	$4\pi T r^2 n^{2/3}[n^{1/3} - 1]$	$4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$



If the work is not done by an external source then internal energy of liquid decreases, subsequently temperature decreases. This is the reason why spraying causes cooling.

By conservation of energy, Loss in thermal energy = work done against surface tension

$JQ = W$

$$\Rightarrow \quad JmS\,\Delta\theta = 4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Rightarrow J\frac{4}{3}\pi R^3 d\,S\Delta\theta = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

[As $m = V \times d = \frac{4}{3}\pi R^3 \times d$]

$\therefore$ Decrease in temperature $\Delta\theta = \dfrac{3T}{JSd}\left[\dfrac{1}{r} - \dfrac{1}{R}\right]$

where J = mechanical equivalent of heat, S = specific heat of liquid, d = density of liquid.

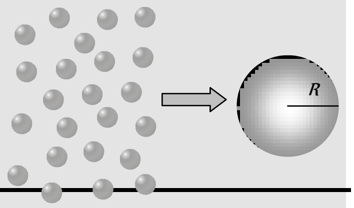
Formation of Bigger Drop

If n small drops of radius r coalesce to form a big drop of radius R then surface area of the liquid decreases.

Amount of surface energy released = Initial surface energy – final surface energy

$E = n4\pi r^2 T - 4\pi R^2 T$

Various formulae of released energy			
$4\pi T[nr^2 - R^2]$	$4\pi R^2 T(n^{1/3} - 1)$	$4\pi T r^2 n^{2/3}(n^{1/3} - 1)$	$4\pi TR^3\left[\frac{1}{r} - \frac{1}{R}\right]$



(i) If this released energy is absorbed by a big drop, its temperature increases and rise in temperature can be given by $\Delta\theta = \frac{3T}{JSd}\left[\frac{1}{r} - \frac{1}{R}\right]$

(ii) If this released energy is converted into kinetic energy of a big drop without dissipation then by the law of conservation of energy.

$$\frac{1}{2}mv^2 = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Rightarrow \frac{1}{2}\left[\frac{4}{3}\pi R^3 d\right]v^2 = 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right]$$

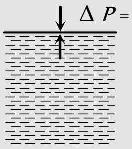
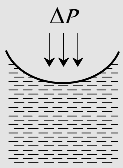
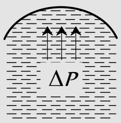
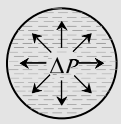
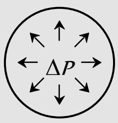
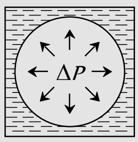
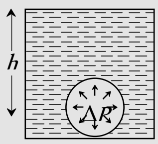
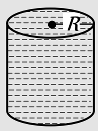
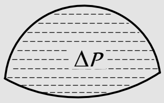
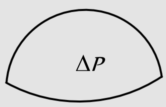
$$\Rightarrow v^2 = \frac{6T}{d}\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\therefore v = \sqrt{\frac{6T}{d}\left(\frac{1}{r} - \frac{1}{R}\right)}$$

Excess Pressure

Due to the property of surface tension a drop or bubble tends to contract and so compresses the matter enclosed. This in turn increases the internal pressure which prevents further contraction and equilibrium is achieved. So in equilibrium the pressure inside a bubble or drop is greater than outside and the difference of pressure between two sides of the liquid surface is called excess pressure. In case of a drop, excess pressure is provided by hydrostatic pressure of the liquid within the drop while in case of bubble the gauge pressure of the gas confined in the bubble provides it.

Excess pressure in different cases is given in the following table :

Plane surface	Concave surface
 $\Delta P = 0$	 $\Delta P = \frac{2T}{R}$
Convex surface	Drop
 $\Delta P = \frac{2T}{R}$	 $\Delta P = \frac{2T}{R}$
Bubble in air	Bubble in liquid
 $\Delta P = \frac{4T}{R}$	 $\Delta P = \frac{2T}{R}$
Bubble at depth h below the free surface of liquid of density d	Cylindrical liquid surface
 $\Delta P = \frac{2T}{R} + hdg$	 $\Delta P = \frac{T}{R}$
Liquid surface of unequal radii	Liquid film of unequal radii
 $\Delta P = T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$	 $\Delta P = 2T\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$

Note : ❑ Excess pressure is inversely proportional to the radius of bubble (or drop), *i.e.*, pressure inside a smaller bubble (or drop) is higher than inside a larger bubble (or drop). That is why when two bubbles of different sizes are put in communication with each other, the air will rush from smaller to larger bubble, so that the smaller will shrink while the larger will expand till the smaller bubble reduces to droplet.

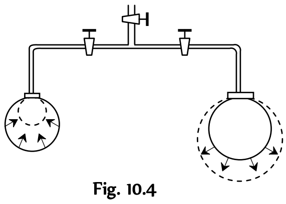


Fig. 10.4

Shape of Liquid Meniscus

We know that a liquid assumes the shape of the vessel in which it is contained *i.e.* it can not oppose permanently any force that tries to change its shape. As the effect of force is zero in a direction perpendicular to it, the free surface of liquid at rest adjusts itself at right angles to the resultant force.

When a capillary tube is dipped in a liquid, the liquid surface becomes curved near the point of contact. This curved surface is due to the resultant of two forces *i.e.* the force of cohesion and the force of adhesion. The curved surface of the liquid is called meniscus of the liquid.

If liquid molecule *A* is in contact with solid (*i.e.* wall of capillary tube) then forces acting on molecule *A* are

(i) Force of adhesion F_a (acts outwards at right angle to the wall of the tube).

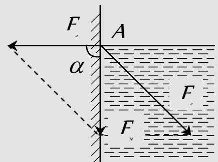
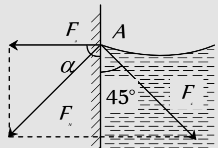
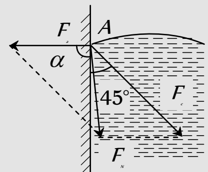
(ii) Force of cohesion F_c (acts at an angle 45° to the vertical).

Resultant force F_n depends upon the value of F_a and F_c.

If resultant force F_n make an angle α with F_a.

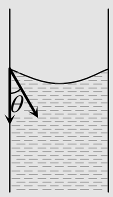
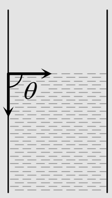
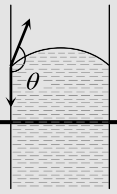
Then $\tan\alpha = \dfrac{F_c \sin 135^o}{F_a + F_c\cos 135^o} = \dfrac{F_c}{\sqrt{2}\,F_a - F_c}$

By knowing the direction of resultant force we can find out the shape of meniscus because the free surface of the liquid adjust itself at right angle to this resultant force.

If $F_c = \sqrt{2}Fa$ $\tan\alpha = \infty$ $\therefore$ $\alpha = 90^\circ$ *i.e.* the resultant force acts vertically downwards. Hence the liquid meniscus must be horizontal.	$F_c < \sqrt{2}Fa$ tan α = positive $\therefore$ α is acute angle *i.e.* the resultant force directed outside the liquid. Hence the liquid meniscus must be concave upward.	$F_c > \sqrt{2}Fa$ tan α = negative $\therefore$ α is obtuse angle *i.e.* the resultant force directed inside the liquid. Hence the liquid meniscus must be convex upward.
		
Example: Pure water in silver coated capillary tube.	Example: Water in glass capillary tube.	Example: Mercury in glass capillary tube.

Angle of Contact

Angle of contact between a liquid and a solid is defined as the angle enclosed between the tangents to the liquid surface and the solid surface inside the liquid, both the tangents being drawn at the point of contact of the liquid with the solid.

$\theta < 90^\circ$ $F_a > \dfrac{F_c}{\sqrt{2}}$ concave meniscus. Liquid wets the solid surface	
$\theta = 90^\circ$ $F_a = \dfrac{F_c}{\sqrt{2}}$ plane meniscus. Liquid does not wet the solid surface.	
$\theta > 90^\circ$ $F_a < \dfrac{F_c}{\sqrt{2}}$ convex meniscus. Liquid does not wet the solid surface.	

(i) Its value lies between 0° and 180°

$\theta = 0^o$ for pure water and glass, $\theta = 8^o$ for tap water and glass, $\theta = 90^o$ for water and silver

$\theta = 138^o$ for mercury and glass, $\theta = 160^o$ for water and chromium

(ii) It is particular for a given pair of liquid and solid. Thus the angle of contact changes with the pair of solid and liquid.

(iii) It does not depends upon the inclination of the solid in the liquid.

(iv) On increasing the temperature, angle of contact decreases.

(v) Soluble impurities increases the angle of contact.

(vi) Partially soluble impurities decreases the angle of contact.

Capillarity

If a tube of very narrow bore (called capillary) is dipped in a liquid, it is found that the liquid in the capillary either ascends or descends relative to the surrounding liquid. This phenomenon is called capillarity.

The root cause of capillarity is the difference in pressures on two sides of (concave and convex) curved surface of liquid.

Examples of capillarity :

(i) Ink rises in the fine pores of blotting paper leaving the paper dry.

(ii) A towel soaks water.

(iii) Oil rises in the long narrow spaces between the threads of a wick.

(iv) Wood swells in rainy season due to rise of moisture from air in the pores.

(v) Ploughing of fields is essential for preserving moisture in the soil.

(vi) Sand is drier soil than clay. This is because holes between the sand particles are not so fine as compared to that of clay, to draw up water by capillary action.

Ascent Formula

When one end of capillary tube of radius r is immersed into a liquid of density d which wets the sides of the capillary tube (water and capillary tube of glass), the shape of the liquid meniscus in the tube becomes concave upwards.

R = radius of curvature of liquid meniscus.

T = surface tension of liquid

P = atmospheric pressure

Pressure at point $A = P$, Pressure at point $B = P - \frac{2T}{R}$

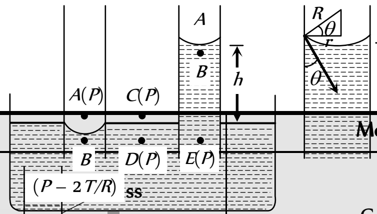


Fig. 10.5

Pressure at points C and D just above and below the plane surface of liquid in the vessel is also P (atmospheric pressure). The points B and D are in the same horizontal plane in the liquid but the pressure at these points is different.

In order to maintain the equilibrium the liquid level rises in the capillary tube upto height h.

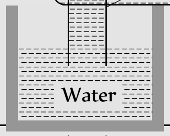
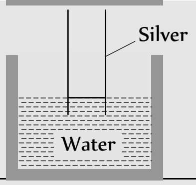
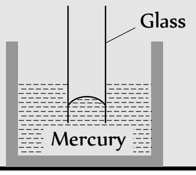
Pressure due to liquid column = pressure difference due to surface tension

$$\Rightarrow hdg = \frac{2T}{R}$$

$$\therefore \; h = \frac{2T}{Rdg} = \frac{2T\cos\theta}{rdg} \qquad \left[\text{As } R = \frac{r}{\cos\theta}\right]$$

(i) The capillary rise depends on the nature of liquid and solid both *i.e.* on T, d, θ and R.

(ii) Capillary action for various liquid-solid pair.

	Meniscus	Angle of contact	Level
	Concave	$\theta < 90^\circ$	Rises
	Plane	$\theta = 90^\circ$	No rise, no fall
	Convex	$\theta > 90^\circ$	Fall

(iii) For a given liquid and solid at a given place

$$h \propto \frac{1}{r} \qquad [\text{As } T, \theta, d \text{ and } g \text{ are constant}]$$

i.e. lesser the radius of capillary greater will be the rise and vice-versa. This is called **Jurin's law**.

(iv) If the weight of the liquid contained in the meniscus is taken into consideration then more accurate ascent formula is given by

$$h = \frac{2T\cos\theta}{rdg} - \frac{r}{3}$$

(v) In case of capillary of insufficient length *i.e.* $L < h$, the liquid will neither overflow from the upper end like a fountain nor will it tickle along the vertical sides of the tube. The liquid after reaching the upper end will increase the radius of its meniscus without changing nature such that :

$hr = Lr'$ $\quad \because \; L < h \; \therefore \; r' > r$

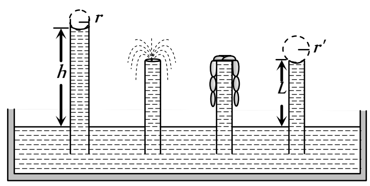


Fig. 10.6

(vi) If a capillary tube is dipped into a liquid and tilted at an angle α from vertical, then the vertical height of liquid column remains same whereas the length of liquid column (l) in the capillary tube increases.

$$h = l\cos\alpha \quad \text{or} \quad l = \frac{h}{\cos\alpha}$$

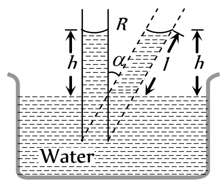


Fig. 10.7

(vii) It is important to note that in equilibrium, the height h is independent of the shape of capillary if the radius of meniscus remains the same. That is why the vertical height h of a liquid column in capillaries of different shapes and sizes will be same if the radius of meniscus remains the same.

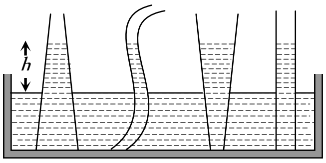


Fig. 10.8

Shape of Drops

Whether the liquid will be in equilibrium in the form of a drop or it will spread out; depends on the relative strength of the force due to surface tension at the three interfaces.

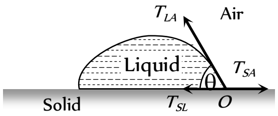


Fig. 10.9

T_{LA} = surface tension at liquid-air interface, T_{SA} = surface tension at solid-air interface.

T_{SL} = surface tension at solid-liquid interface, θ = angle of contact between the liquid and solid.

For the equilibrium of molecule

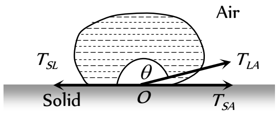


Fig. 10.10

$T_{SL} + T_{LA}\cos\theta = T_{SA}$ or $\cos\theta = \dfrac{T_{SA} - T_{SL}}{T_{LA}}$

Special Cases

$T_{SA} > T_{SL}$, $\cos\theta$ is positive *i.e.* $0^o < \theta < 90^o$.

This condition is fulfilled when the molecules of liquid are strongly attracted to that of solid.

Example : (i) Water on glass.

(ii) Kerosene oil on any surface.

$T_{SA} < T_{SL}$, $\cos\theta$ is negative *i.e.* $90^o < \theta < 180^o$.

This condition is fulfilled when the molecules of the liquid are strongly attracted *to* themselves and weakly *w.r.t.* that of solid.

Example : (i) Mercury on glass surface.

(ii) Water on lotus leaf (or a waxy or oily surface)

(T_{SL} + T_{LA} cosθ) > T_{SA}

In this condition, the molecule of liquid will not be in equilibrium and experience a net force at the interface. As a result, the liquid spreads.

Example : (i) Water on a clean glass plate.

Useful Facts and Formulae

(1) **Formation of double bubble** : If r_1 and r_2 are the radii of smaller and larger bubble and P_0 is the atmospheric pressure, then the pressure inside them will be $P_1 = P_0 + \dfrac{4T}{r_1}$ and $P_2 = P_0 + \dfrac{4T}{r_2}$.

Now as $r_1 < r_2$ $\therefore$ $P_1 > P_2$

So for interface

$$\Delta P = P_1 - P_2 = 4T\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \quad \text{...(i)}$$

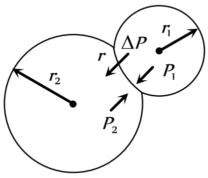


Fig. 10.11

As excess pressure acts from concave to convex side, the interface will be concave towards the smaller bubble and convex towards larger bubble and if r is the radius of interface.

$$\Delta P = \frac{4T}{r} \quad \text{...(ii)}$$

From (i) and (ii) $\dfrac{1}{r} = \dfrac{1}{r_1} - \dfrac{1}{r_2}$

$\therefore$ Radius of the interface $r = \dfrac{r_1 r_2}{r_2 - r_1}$

(2) **Formation of a single bubble**

(i) Under isothermal condition two soap bubble of radii '*a*' and '*b*' coalesce to form a single bubble of radius '*c*'.

If the external pressure is P_0 then pressure inside bubbles

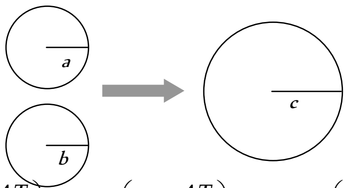


Fig. 10.12

$P_a = \left(P_0 + \dfrac{4T}{a}\right)$, $P_b = \left(P_0 + \dfrac{4T}{b}\right)$ and $P_c = \left(P_0 + \dfrac{4T}{c}\right)$

and volume of the bubbles

$V_a = \dfrac{4}{3}\pi a^3$, $V_b = \dfrac{4}{3}\pi b^3$, $V_c = \dfrac{4}{3}\pi c^3$

Now as mass is conserved $\mu_a + \mu_b = \mu_c$

$$\Rightarrow \frac{P_a V_a}{RT_a} + \frac{P_b V_b}{RT_b} = \frac{P_c V_c}{RT_c}$$

$$\left[\text{As } PV = \mu RT, \ \ i.e., \ \mu = \frac{PV}{RT}\right]$$

$$\Rightarrow P_a V_a + P_b V_b = P_c V_c \qquad \text{...(i)}$$

[As temperature is constant, *i.e.*, $T_a = T_b = T_c$]

Substituting the value of pressure and volume

$$\Rightarrow \left[P_0 + \frac{4T}{a}\right]\left[\frac{4}{3}\pi a^3\right] + \left[P_0 + \frac{4T}{b}\right]\left[\frac{4}{3}\pi b^3\right]$$

$$= \left[P_0 + \frac{4T}{c}\right]\left[\frac{4}{3}\pi c^3\right]$$

$$\Rightarrow 4T(a^2 + b^2 - c^2) = P_0(c^3 - a^3 - b^3)$$

$\therefore$ Surface tension of the liquid $T = \dfrac{P_0(c^3 - a^3 - b^3)}{4(a^2 + b^2 - c^2)}$

(ii) If two bubble coalesce in vacuum then by substituting $P_0 = 0$ in the above expression we get

$$a^2 + b^2 - c^2 = 0 \quad \therefore \ c^2 = a^2 + b^2$$

Radius of new bubble $= c = \sqrt{a^2 + b^2}$ or can be expressed as $r = \sqrt{r_1^2 + r_2^2}$.

(3) The difference of levels of liquid column in two limbs of *U*-tube of unequal radii r_1 and r_2 is

$$h = h_1 - h_2 = \frac{2T\cos\theta}{dg}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

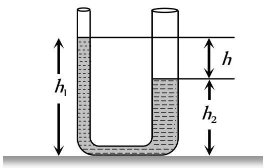


Fig. 10.13

(4) A large force (*F*) is required to draw apart two glass plate normally enclosing a thin water film because the thin water film formed between the two glass plates will have concave surface all around. Since on the concave side of a liquid surface, pressure is more, work will have to be done in drawing the plates apart.

$F = \dfrac{2AT}{t}$ where *T*= surface tension of water film, *t*= thickness of film, *A* = area of film.

(5) When a soap bubble is charged, then its size increases due to outward force on the bubble.

(6) The materials, which when coated on a surface and water does not enter through that surface are known as water proofing agents. For example wax *etc*. Water proofing agent increases the angle of contact.

(7) Values of surface tension of some liquids.

Liquid	Surface tension *Newton/metre*
Mercury	0.465
Water	0.075
Soap solution	0.030
Glycerine	0.063
Carbon tetrachloride	0.027
Ethyl alcohol	0.022

Tips & Tricks

- Surface tension does not depend on the area of the surface.
- When there is no external force, the shape of a liquid drop is determined by the surface tension of the liquid.
- Soap helps in better cleaning of clothes because it reduces the surface tension of the liquid.
- If a beaker is filled with liquid of density ρ upto a height *h*, then the mean pressure on the walls of the beaker is $h\rho g/2$.
- The pressure on the concave side of a curved surface is always greater than that on its convex side.
- Molecular forces do not obey the inverse square law of distance.
- The molecular forces are of electrical origin.
- Work done in forming a soap bubble of radius *R* is $8\pi R^2 T$, where $T =$ surface tension.
- Energy is always required to split a drop of liquid into a number of small drops. It is because, the surface area of the small drops formed is greater than the surface area of the original single drop.
- Work done in breaking a drop of radius *R* into *n* drops of equal size $= 4\pi R^2 T(n^{1/3} - 1)$.

Same amount of energy is liberated in combining *n* drops into a single drop.

- When the liquid drops merge into each other to form a larger drop, energy is released.
- Surface tension of molten cadmium increases with the increases in temperature.
- Detergents decrease both the angle of contact as well as surface tension.
- Angle of contact is independent of the angle of inclination of the walls.
- The materials used for water proofing increases the angle of contact as well as surface tension.
- A liquid does not wet the containing vessel if its angle of contact is obtuse.
- In case of liquids which do not wet the walls of the containing vessel, the force of adhesion is less than $1/\sqrt{2}$ times the force of cohesion.
- The liquid rises in a capillary tube, when the angle of contact is acute.
- The height of the liquid column in a capillary tube on the moon is six times that on the earth.
- Angle of contact between a liquid and a solid surface. Increases

with increase in temperature of the liquid and decreases on adding impurity to the liquid.

✍ For a liquid – solid interface, if the angle of contact is acute, then

(i) The liquid will wet the solid.

(ii) The liquid will rise in the capillary tube made of such a solid and

(iii) Meniscus of the liquid will be concave.

✍ In case the angle of contact is obtuse, then

(i) The liquid will not wet the solid.

(ii) The liquid will get depressed in the tube and

(iii) Meniscus of the liquid will be convex.

✍ When the capillary tube is of insufficient length, the liquid will not overflow. It rises upto the top end of the tube and then adjusts the radius of curvature of its meniscus.

Ordinary Thinking

Objective Questions

Surface Tension

1. The value of surface tension of a liquid at critical temperature is
   (a) Zero (b) Infinite
   (c) Between 0 and ∞ (d) Can not be determined

2. The spherical shape of rain-drop is due to
   [CPMT 1976, 90; NCERT 1982; AIIMS 1998; MH CET 2000; DCE 1999; AFMC 1999; CPMT 2001; AFMC 2001]
   (a) Density of the liquid (b) Surface tension
   (c) Atmospheric pressure (d) Gravity

3. Surface tension is due to
   (a) Frictional forces between molecules
   (b) Cohesive forces between molecules
   (c) Adhesive forces between molecules
   (d) Gravitational forces

4. When there is no external force, the shape of a liquid drop is determined by [CPMT 1988, 86; DPMT 1982]
   (a) Surface tension of the liquid
   (b) Density of liquid
   (c) Viscosity of liquid
   (d) Temperature of air only

5. Soap helps in cleaning clothes, because [DPMT 1983, 2001]
   (a) Chemicals of soap change
   (b) It increases the surface tension of the solution
   (c) It absorbs the dirt
   (d) It lowers the surface tension of the solution

6. A pin or a needle floats on the surface of water, the reason for this is [MP PET/PMT 1988; CPMT 1975]
   (a) Surface tension (b) Less weight
   (c) Upthrust of liquid (d) None of the above

7. Coatings used on raincoat are waterproof because
   (a) Water is absorbed by the coating
   (b) Cohesive force becomes greater
   (c) Water is not scattered away by the coating
   (d) Angle of contact decreases

8. If temperature increases, the surface tension of a liquid
   [MP PMT 1994; EAMCET (Engg.) 1995; RPET 2003]
   (a) Increases (b) Decreases
   (c) Remains the same (d) Increases then decreases

9. A drop of oil is placed on the surface of water. Which of the following statement is correct [NCERT 1976; DPMT 1982]
   (a) It will remain on it as a sphere
   (b) It will spread as a thin layer
   (c) It will be partly as spherical droplets and partly as thin film
   (d) It will float as a distorted drop on the water surface

10. The temperature at which the surface tension of water is zero
   (a) $0°C$ (b) $277\ K$
   (c) $370°C$ (d) Slightly less than $647\ K$

11. A small air bubble is at the inner surface of the bottom of a beaker filled with cold water. Now water of the beaker is heated. The size of bubble increases. The reason for this may be
   (a) Increase in the saturated vapour pressure of water
   (b) Root mean square velocity of air molecules inside the bubble increases
   (c) Decrease in surface tension of water
   (d) All of the above

12. The spiders and insects move and run about on the surface of water without sinking because
   (a) Elastic membrane is formed on water due to property of surface tension [AIIMS 1980]
   (b) Spiders and insects are lighter
   (c) Spiders and insects swim on water
   (d) Spider and insects experience upthrust

13. Small droplets of a liquid are usually more spherical in shape than larger drops of the same liquid because
   [EAMCET 1988]
   (a) Force of surface tension is equal and opposite to the force of gravity
   (b) Force of surface tension predominates the force of gravity
   (c) Force of gravity predominates the force of surface tension
   (d) Force of gravity and force of surface tension act in the same direction and are equal

14. Hairs of shaving brush cling together when it is removed from water due to
   (a) Force of attraction between hair
   (b) Surface tension
   (c) Viscosity of water
   (d) Characteristic property of hairs

15. A square frame of side L is dipped in a liquid. On taking out, a membrane is formed. If the surface tension of the liquid is T, the force acting on the frame will be
   [MP PMT 1990; DPMT 2004]
   (a) $2\ TL$ (b) $4\ TL$
   (c) $8\ TL$ (d) $10\ TL$

16. Water does not wet an oily glass because
   (a) Cohesive force of oil>> adhesive force between oil and glass
   (b) Cohesive force of oil > cohesive force of water
   (c) Oil repels water
   (d) Cohesive force for water > adhesive force between water and oil molecules

17. A water drop takes the shape of a sphere in a oil while the oil drop spreads in water, because
   (a) C.F. for water > A.F. for water and oil
   (b) C.F. for oil > A.F. for water and oil
   (c) C.F. for oil < A.F. for water and oil
   (d) None of the above
   (A.F. = adhesive force C.F. = cohesive force)

18. Which of the fact is not due to surface tension
   (a) Dancing of a camphor piece over the surface of water
   (b) Small mercury drop itself becomes spherical
   (c) A liquid surface comes at rest after stirring
   (d) Mercury does not wet the glass vessel

19. In the glass capillary tube, the shape of the surface of the liquid depends upon [MP PMT 1989]
   (a) Only on the cohesive force of liquid molecules

(b) Only on the adhesive force between the molecules of glass and liquid

(c) Only on relative cohesive and adhesive force between the atoms

(d) Neither on cohesive nor on adhesive force

20. Force necessary to pull a circular plate of 5 *cm* radius from water surface for which surface tension is 75 *dynes/cm*, is [MP PMT 1991]

(a) $30 dyne$ (b) 60 *dynes*

(c) 750 *dynes* (d) 750 π *dynes*

21. The property of surface tension is obtained in

(a) Solids, liquids and gases (b) Liquids

(c) Gases (d) Matter

22. The surface tension of a liquid [MNR 1990]

(a) Increases with area

(b) Decreases with area

(c) Increase with temperature

(d) Decrease with temperature

23. If two glass plates are quite nearer to each other in water, then there will be force of

(a) Attraction (b) Repulsion

(c) Attraction or repulsion (d) None of the above

24. On mixing the salt in water, the surface tension of water will

(a) Increase (b) Decrease

(c) Remain unchanged (d) None of the above

25. The maximum force, in addition to the weight required to pull a wire of 5.0 *cm* long from the surface of water at temperature 20°*C*, is 728 *dynes*. The surface tension of water is

(a) 7.28 *N/cm* (b) 7.28 *dyne/cm*

(c) 72.8 *dyne/cm* (d) 7.28×10^{2} *dyne/cm*

26. Consider a liquid contained in a vessel. The liquid solid adhesive force is very weak as compared to the cohesive force in the liquid. The shape of the liquid surface near the solid shall be

(a) Horizontal (b) Almost vertical

(c) Concave (d) Convex

27. At which of the following temperatures, the value of surface tension of water is minimum [MP PMT/PET 1998]

(a) 4°C (b) 25°C

(c) 50°C (d) 75°C

28. If a glass rod is dipped in mercury and withdrawn out, the mercury does not wet the rod because [MP PET 1995]

(a) Angle of contact is acute

(b) Cohesion force is more

(c) Adhesion force is more

(d) Density of mercury is more

29. Mercury does not wet glass, wood or iron because [MP PET 1997]

(a) Cohesive force is less than adhesive force

(b) Cohesive force is greater than adhesive force

(c) Angle of contact is less than 90°

(d) Cohesive force is equal to adhesive force

30. Surface tension of a liquid is found to be influenced by [ISM Dhanbad 1994]

(a) It increases with the increase of temperature

(b) Nature of the liquid in contact

(c) Presence of soap that increases it

(d) Its variation with the concentration of the liquid

31. When a drop of water is dropped on oil surface, then [RPMT 1997]

(a) It will mix up with oil

(b) It spreads in the form of a film

(c) It will deform

(d) It remains spherical

32. Two pieces of glass plate one upon the other with a little water in between them cannot be separated easily because of

(a) Inertia (b) Pressure

(c) Surface tension (d) Viscosity

33. Small liquid drops assume spherical shape because [JIPMER 1997]

(a) Atmospheric pressure exerts a force on a liquid drop

(b) Volume of a spherical drop is minimum

(c) Gravitational force acts upon the drop

(d) Liquid tends to have the minimum surface area due to surface tension

34. A thin metal disc of radius *r* floats on water surface and bends the surface downwards along the perimeter making an angle θ with vertical edge of the disc. If the disc displaces a weight of water *W* and surface tension of water is *T*, then the weight of metal disc is

(a) $2\pi rT + W$ (b) $2\pi rT\cos\theta - W$

(c) $2\pi r\mathrm{T}\cos\theta + W$ (d) $W - 2\pi rT\cos\theta$

35. A 10 *cm* long wire is placed horizontally on the surface of water and is gently pulled up with a force of 2×10^{-2} *N* to keep the wire in equilibrium. The surface tension, in Nm^{-1}, of water is

(a) 0.1 (b) 0.2

(c) 0.001 (d) 0.002

36. It is easy to wash clothes in hot water because its [RPMT 2000]

(a) Surface tension is more

(b) Surface tension is less

(c) Consumes less soap

(d) None of these

37. Due to which property of water, tiny particles of camphor dance on the surface of water [MNR 1994] [RPMT 1999]

(a) Viscosity (b) Surface tension

(c) Weight (d) Floating force

38. The force required to separate two glass plates of area $10^{-2} m^2$ with a film of water 0.05 *mm* thick between them, is (Surface tension of water is 70×10^{-3} *N/m*) [KCET 2000; Pb. PET 2001: RPET 2002]

(a) 28 *N* (b) 14 *N*

(c) 50 *N* (d) 38 *N*

39. Oil spreads over the surface of water whereas water does not spread over the surface of the oil, due to [MH CET 2001]

(a) Surface tension of water is very high

(b) Surface tension of water is very low

(c) Viscosity of oil is high

(d) Viscosity of water is high

40. Cohesive force is experienced between [MH CET 2001]

(a) Magnetic substances

(b) Molecules of different substances

(c) Molecules of same substances

(d) None of these

41. The property utilized in the manufacture of lead shots is [AIIMS 2002]

(a) Specific weight of liquid lead
(b) Specific gravity of liquid lead
(c) Compressibility of liquid lead
(d) Surface tension of liquid lead

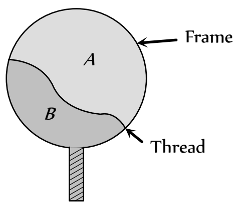
42. The dimensions of surface tension are [MH CET 2002]

(a) $[MLT^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^0T^{-2}]$ (d) $[ML^{-1}T^{-2}]$

43. A wooden stick 2*m* long is floating on the surface of water. The surface tension of water 0.07 *N/m*. By putting soap solution on one side of the sticks the surface tension is reduced to 0.06 *N/m*. The net force on the stick will be [Pb. PMT 2002]

(a) 0.07 *N* (b) 0.06 *N*
(c) 0.01 *N* (d) 0.02 *N*

44. A thread is tied slightly loose to a wire frame as in figure and the frame is dipped into a soap solution and taken out. The frame is completely covered with the film. When the portion *A* punctured with a pin, the thread. [KCET 2004]



(a) Becomes concave toward *A*
(b) Becomes convex towards *A*
(c) Remains in the initial position
(d) Either (a) or (b) depending on the size of *A w.r.t. B*

45. The force required to take away a flat circular plate of radius 2 *cm* from the surface of water, will be (the surface tension of water is 70 *dyne/cm*) [Pb. PET 2001]

(a) $280\pi\ dyne$ (b) $250\pi\ dyne$
(c) $140\pi\ dyne$ (d) $210\pi\ dyne$

46. Surface tension may be defined as [CPMT 1990]

(a) The work done per unit area in increasing the surface area of a liquid under isothermal condition
(b) The work done per unit area in increasing the surface area of a liquid under adiabatic condition
(c) The work done per unit area in increasing the surface area of a liquid under both isothermal and adiabatic conditions
(d) Free surface energy per unit volume

Surface Energy

1. Energy needed in breaking a drop of radius *R* into *n* drops of radii *r* is given by [CPMT 1982, 97]

(a) $4\pi T(nr^2 - R^2)$ (b) $\frac{4}{3}\pi(r^3n - R^2)$
(c) $4\pi T(R^2 - nr^2)$ (d) $4\pi T(nr^2 + R^2)$

2. The potential energy of a molecule on the surface of liquid compared to one inside the liquid is [MP PMT 1993]

(a) Zero (b) Smaller
(c) The same (d) Greater

3. Two droplets merge with each other and forms a large droplet. In this process [CBSE PMT 1993; RPMT 1997, 2000; CPMT 2001; BHU 2001; AFMC 2002]

(a) Energy is liberated
(b) Energy is absorbed
(c) Neither liberated nor absorbed
(d) Some mass is converted into energy

4. A drop of liquid of diameter 2.8 *mm* breaks up into 125 identical drops. The change in energy is nearly (S.T. of liquid =75 *dynes/cm*)

(a) Zero (b) 19 *erg*
(c) 46 *erg* (d) 74 *erg*

5. Radius of a soap bubble is '*r*', surface tension of soap solution is *T*. Then without increasing the temperature, how much energy will be needed to double its radius [CPMT 1991; Pb. PMT 2000; RPET 2001]

(a) $4\pi r^2T$ (b) $2\pi r^2T$
(c) $12\pi r^2T$ (d) $24\pi r^2T$

6. Work done in splitting a drop of water of 1 mm radius into 10^6 droplets is (Surface tension of water $= 72\times10^{-3}\ J/m^2$) [MP PET/PMT 1988; CPMT 1989; RPET 2001]

(a) $9.58\times10^{-5}\ J$ (b) $8.95\times10^{-5}\ J$
(c) $5.89\times10^{-5}\ J$ (d) $5.98\times10^{-6}\ J$

7. A spherical liquid drop of radius *R* is divided into eight equal droplets. If surface tension is *T*, then the work done in this process will be [CPMT 1990]

(a) $2\pi R^2T$ (b) $3\pi R^2T$
(c) $4\pi R^2T$ (d) $2\pi RT^2$

8. The amount of work done in blowing a soap bubble such that its diameter increases from *d* to *D* is (*T*= surface tension of the solution) [MP PMT 1996]

(a) $4\pi(D^2 - d^2)T$ (b) $8\pi(D^2 - d^2)T$
(c) $\pi(D^2 - d^2)T$ (d) $2\pi(D^2 - d^2)T$

9. If *T* is the surface tension of soap solution, the amount of work done in blowing a soap bubble from a diameter *D* to 2*D* is

(a) $2\pi D^2T$ (b) $4\pi D^2T$
(c) $6\pi D^2T$ (d) $8\pi D^2T$

10. The radius of a soap bubble is increased from $\frac{1}{\sqrt{\pi}}$ *cm* to $\frac{2}{\sqrt{\pi}}$ *cm*. If the surface tension of water is 30 *dynes* per *cm*, then the work done will be [MP PMT 1986]

(a) 180 *ergs* (b) 360 *ergs*
(c) 720 *ergs* (d) 960 *ergs*

11. The surface tension of a liquid is 5 *N/m*. If a thin film of the area 0.02 *m* is formed on a loop, then its surface energy will be

(a) $5\times10^{2}\ J$ (b) $2.5\times10^{-2}\ J$

(c) $2\times10^{-1}\ J$ (d) $5\times10^{-1}\ J$

12. If work W is done in blowing a bubble of radius R from a soap solution, then the work done in blowing a bubble of radius $2R$ from the same solution is [MP PET 1990]

(a) W/2 (b) 2W

(c) 4W (d) $2\frac{1}{3}$W

13. A spherical drop of oil of radius 1 *cm* is broken into 1000 droplets of equal radii. If the surface tension of oil is 50 *dynes/cm*, the work done is [MP PET 1990]

(a) 18π *ergs* (b) 180π *ergs*

(c) 1800π *ergs* (d) 8000π *ergs*

14. The work done in blowing a soap bubble of radius r of the solution of surface tension T will be

[DPMT 1999; MP PMT 2003]

(a) $8\pi r^2T$ (b) $2\pi r^2T$

(c) $4\pi r^2T$ (d) $\frac{4}{3}\pi r^2T$

15. If two identical mercury drops are combined to form a single drop, then its temperature will [RPET 2000]

(a) Decrease (b) Increase

(c) Remains the same (d) None of the above

16. If the surface tension of a liquid is T, the gain in surface energy for an increase in liquid surface by A is

[MP PET 1991; RPMT 2002]

(a) AT^{-1} (b) AT

(c) A^2T (d) A^2T^2

17. The surface tension of a soap solution is $2\times10^{-2}\ N/m$. To blow a bubble of radius 1 *cm*, the work done is

[MP PMT 1989]

(a) $4\pi\times10^{-6}\ J$ (b) $8\pi\times10^{-6}\ J$

(c) $12\pi\times10^{-6}\ J$ (d) $16\pi\times10^{-6}\ J$

18. A mercury drop of 1 *cm* radius is broken into 10^6 small drops. The energy used will be (surface tension of mercury is $35\times10^{-3}\ N/cm$) [Roorkee 1984]

(a) $4.4\times10^{-3}\ J$ (b) $2.2\times10^{-4}\ J$

(c) $8.8\times10^{-4}\ J$ (d) $10^4\ J$

19. The surface tension of a liquid at its boiling point

[MP PMT 1980]

(a) Becomes zero

(b) Becomes infinity

(c) is equal to the value at room temperature

(d) is half to the value at the room temperature

20. Surface tension of a soap solution is $1.9\times10^{-2}\ N/m.$. Work done in blowing a bubble of 2.0 *cm* diameter will be

[MP PMT 1991]

(a) $7.6\times10^{-6}\pi$ *joule* (b) $15.2\times10^{-6}\pi$ *joule*

(c) $1.9\times10^{-6}\pi$ *joule* (d) 1×10^{-4} *joule*

21. The surface tension of liquid is 0.5 *N/m*. If a film is held on a ring of area 0.02 *m*, its surface energy is [CPMT 1977]

(a) 5×10^{-2} *joule* (b) 2.0×10^{-2} *joule*

(c) 4×10^{-4} *joule* (d) 0.8×10^{-1} *joule*

22. What is ratio of surface energy of 1 small drop and 1 large drop, if 1000 small drops combined to form 1 large drop

[CPMT 1990]

(a) 100 : 1 (b) 1000 : 1

(c) 10 : 1 (d) 1 : 100

23. The amount of work done in forming a soap film of size $10\,cm\times10\,cm$ is (Surface tension $T=3\times10^{-2}\ N/m$)

[MP PET 1994; MP PET 2000]

(a) $6\times10^{-4}\ J$ (b) $3\times10^{-4}\ J$

(c) $6\times10^{-3}\ J$ (d) $3\times10^{-4}\ J$

24. The work done in blowing a soap bubble of 10 *cm* radius is (Surface tension of the soap solution is $\frac{3}{100}\ N/m$)

[MP PMT 1995; MH CET 2002]

(a) 75.36×10^{-4} *joule* (b) 37.68×10^{-4} *joule*

(c) 150.72×10^{-4} *joule* (d) 75.36 *joule*

25. A liquid drop of diameter D breaks upto into 27 small drops of equal size. If the surface tension of the liquid is σ, then change in surface energy is [DCE 2005]

(a) $\pi D^2\sigma$ (b) $2\pi D^2\sigma$

(c) $3\pi D^2\sigma$ (d) $4\pi D^2\sigma$

26. One thousand small water drops of equal radii combine to form a big drop. The ratio of final surface energy to the total initial surface energy is [MP PET 1997; KCET 1999]

(a) 1000 : 1 (b) 1 : 1000

(c) 10 : 1 (d) 1 : 10

27. The work done in increasing the size of a soap film from 10 *cm* × 6 *cm* to 10 *cm* × 11 *cm* is 3×10^{-4} *joule*. The surface tension of the film is

[MP PET 1999; JIPMER 2001, 02; MP PMT 2000; AIIMS 2000]

(a) $1.5\times10^{-2}\ N/m$ (b) $3.0\times10^{-2}\ N/m$

(c) $6.0\times10^{-2}\ N/m$ (d) $11.0\times10^{-2}\ N/m$

28. If σ be the surface tension, the work done in breaking a big drop of radius R in n drops of equal radius is

[Bihar CEET 1995]

(a) $Rn^{2/3}\sigma$ (b) $(n^{2/3}-1)R\sigma$

(c) $(n^{1/3}-1)R\sigma$ (d) $4\pi R^2(n^{1/3}-1)\sigma$

(e) $\frac{1}{n^{1/3}-1}\sigma R$

29. A big drop of radius R is formed by 1000 small droplets of water, then the radius of small drop is

[AFMC 1998; Pb. PMT 2000]

(a) $R/2$ (b) $R/5$

(c) $R/6$ (d) $R/10$

30. When 10^6 small drops coalesce to make a new larger drop then the drop [RPMT 1999]

(a) Density increases

(b) Density decreases

(c) Temperature increases

(d) Temperature decreases

31. Which of the following statements are true in case when two water drops coalesce and make a bigger drop [Roorkee 1999]

(a) Energy is released

(b) Energy is absorbed

(c) The surface area of the bigger drop is greater than the sum of the surface areas of both the drops

(d) The surface area of the bigger drop is smaller than the sum of the surface areas of both the drops

32. 8000 identical water drops are combined to form a big drop. Then the ratio of the final surface energy to the initial surface energy of all the drops together is [EAMCET (Engg.) 2000]

(a) 1 : 10 (b) 1 : 15

(c) 1 : 20 (d) 1 : 25

33. The surface energy of liquid film on a ring of area $0.15\, m^2$ is (Surface tension of liquid $= 5 Nm^{-1}$) [EAMCET (Engg.) 2000]

(a) 0.75 *J* (b) 1.5 *J*

(c) 2.25 *J* (d) 3.0 *J*

34. 8 mercury drops coalesce to form one mercury drop, the energy changes by a factor of [DCE 2000]

(a) 1 (b) 2

(c) 4 (d) 6

35. If work done in increasing the size of a soap film from $10\, cm \times 6\, cm$ to $10\, cm \times 11\, cm$ is $2\times 10^{-4} J$, then the surface tension is [AIIMS 2000]

(a) $2\times 10^{-2} Nm^{-1}$ (b) $2\times 10^{-4} Nm^{-1}$

(c) $2\times 10^{-6} Nm^{-1}$ (d) $2\times 10^{-8} Nm^{-1}$

36. A mercury drop of radius 1*cm* is sprayed into 10^6 drops of equal size. The energy expended in joules is (surface tension of Mercury is $460\times 10^{-3} N/m$) [EAMCET 2001]

(a) 0.057 (b) 5.7

(c) 5.7×10^{-4} (d) 5.7×10^{-6}

37. When two small bubbles join to form a bigger one, energy is [BHU 2001]

(a) Released (b) Absorbed

(c) Both (a) and (b) (d) None of these

38. A film of water is formed between two straight parallel wires of length 10*cm* each separated by 0.5 *cm*. If their separation is increased by 1 *mm* while still maintaining their parallelism, how much work will have to be done (Surface tension of water = $7.2\times 10^{-2} N/m$)

(a) 7.22×10^{-6} *Joule* (b) 1.44×10^{-5} *Joule*

(c) 2.88×10^{-5} *Joule* (d) 5.76×10^{-5} *Joule*

39. A drop of mercury of radius 2 *mm* is split into 8 identical droplets. Find the increase in surface energy. (Surface tension of mercury is $0.465\, J/m^2$) [UPSEAT 2002]

(a) $23.4 \mu J$ (b) $18.5 \mu J$

(c) $26.8 \mu J$ (d) $16.8 \mu J$

40. Two small drops of mercury, each of radius *R*, coalesce to form a single large drop. The ratio of the total surface energies before and after the change is [AIIMS 2003; DCE 2003]

(a) $1 : 2^{1/3}$ (b) $2^{1/3} : 1$

(c) 2 : 1 (d) 1 : 2

41. Radius of a soap bubble is increased from *R* to 2*R* work done in this process in terms of surface tension is [BHU 2003, RPET 2001; CPMT 2004]

(a) $24\pi R^2 S$ (b) $48\pi R^2 S$

(c) $12\pi R^2 S$ (d) $36\pi R^2 S$

42. The work done in blowing a soap bubble of radius 0.2 *m* is (the surface tension of soap solution being 0.06 *N/m*) [Pb. PET 2002]

(a) $192\pi \times 10^{-4} J$ (b) $280\pi \times 10^{-4} J$

(c) $200\pi \times 10^{-3} J$ (d) None of these

43. A liquid film is formed in a loop of area 0.05 *m*. Increase in its potential energy will be (*T* = 0.2 *N/m*) [RPMT 2002]

(a) $5\times 10^{-2} J$ (b) $2\times 10^{-2} J$

(c) $3\times 10^{-2} J$ (d) None of these

44. In order to float a ring of area 0.04 *m* in a liquid of surface tension 75 *N/m*, the required surface energy will be [RPMT 2003]

(a) 3 *J* (b) 6.5 *J*

(c) 1.5 *J* (d) 4 *J*

45. If two soap bubbles of equal radii *r* coalesce then the radius of curvature of interface between two bubbles will be [J&K CET 2005]

(a) *r* (b) 0

(c) Infinity (d) 1/2*r*

Angle of Contact

1. A liquid does not wet the sides of a solid, if the angle of contact is [MP PAT 1990; AFMC 1988; MNR 1998; RPMT 1999, 2003; Pb. PMT 2002 KCET 2005]

(a) Zero (b) Obtuse (More than 90°)

(c) Acute (Less than 90°) (d) 90°

2. The meniscus of mercury in the capillary tube is [MP PET/PMT 1988]

(a) Convex (b) Concave

(c) Plane (d) Uncertain

3. When the temperature is increased the angle of contact of a liquid [MP PET 2001]

(a) Increases

(b) Decreases

(c) Remains the same

(d) First increases and then decreases

4. The angle of contact between glass and mercury is [MP PMT 1987]

(a) 0° (b) 30°

(c) 90° (d) 135°

5. A mercury drop does not spread on a glass plate because the angle of contact between glass and mercury is [MP PMT 1984]

(a) Acute (b) Obtuse

(c) Zero (d) 90°

6. A liquid is coming out from a vertical tube. The relation between the weight of the drop W, surface tension of the liquid T and radius of the tube r is given by, if the angle of contact is zero

(a) $W = \pi r^2 T$ (b) $W = 2\pi r T$

(c) $W = 2r^2 \pi T$ (d) $W = \frac{3}{4}\pi r^3 T$

7. The parts of motor cars are polished by chromium because the angle of contact between water and chromium is

(a) 0° (b) 90°

(c) Less than 90° (d) Greater than 90°

8. A glass plate is partly dipped vertically in the mercury and the angle of contact is measured. If the plate is inclined, then the angle of contact will

(a) Increase (b) Remain unchanged

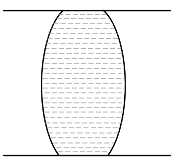
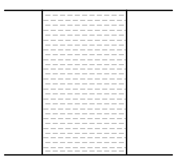
(c) Increase or decrease (d) Decrease

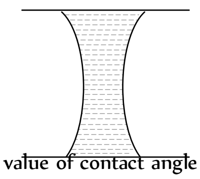
9. The liquid meniscus in capillary tube will be convex, if the angle of contact is [EAMCET (Med.) 1995; KCET 2001; Pb. PET 2000]

(a) Greater than 90° (b) Less than 90°

(c) Equal to 90° (d) Equal to 0°

10. If a water drop is kept between two glass plates, then its shape is

(a)  (b) 

(c)  (d) None of these

11. The value of contact angle for kerosene with solid surface. [RPMT 2000]

(a) 0° (b) 90^o

(c) 45^o (d) 33^o

12. Nature of meniscus for liquid of 0^o angle of contact [RPET 2001]

(a) Plane (b) Parabolic

(c) Semi-spherical (d) Cylindrical

13. A liquid wets a solid completely. The meniscus of the liquid in a sufficiently long tube is [Kerala (Engg.) 2002]

(a) Flat (b) Concave

(c) Convex (d) Cylindrical

14. What is the shape when a non-wetting liquid is placed in a capillary tube [AFMC 2004]

(a) Concave upward (b) Convex upward

(c) Concave downward (d) Convex downward

15. For which of the two pairs, the angle of contact is same [J & K CET 2004]

(a) Water and glass; glass and mercury

(b) Pure water and glass; glass and alcohol

(c) Silver and water; mercury and glass

(d) Silver and chromium; water and chromium

16. If the surface of a liquid is plane, then the angle of contact of the liquid with the walls of container is [MH CET 2004]

(a) Acute angle (b) Obtuse angle

(c) 90° (d) 0°

Pressure Difference

1. A soap bubble assumes a spherical surface. Which of the following statement is wrong [NCERT 1976]

(a) The soap film consists of two surface layers of molecules back to back

(b) The bubble encloses air inside it

(c) The pressure of air inside the bubble is less than the atmospheric pressure; that is why the atmospheric pressure has compressed it equally from all sides to give it a spherical shape

(d) Because of the elastic property of the film, it will tend to shrink to as small a surface area as possible for the volume it has enclosed

2. If two soap bubbles of different radii are in communication with each other [NCERT 1980; MP PMT/PET 1988; AIEEE 2004]

(a) Air flows from larger bubble into the smaller one

(b) The size of the bubbles remains the same

(c) Air flows from the smaller bubble into the large one and the larger bubble grows at the expense of the smaller one [CPMT 1997]

(d) The air flows from the larger

3. The surface tension of soap solution is $25 \times 10^{-3}\ Nm^{-1}$. The excess pressure inside a soap bubble of diameter 1 *cm* is

(a) 10 *Pa* (b) 20 *Pa*

(c) 5 *Pa* (d) None of the above

4. When two soap bubbles of radius r_1 and r_2 $(r_2 > r_1)$ coalesce, the radius of curvature of common surface is [MP PMT 1996]

(a) $r_2 - r_1$ (b) $\frac{r_2 - r_1}{r_1 r_2}$

(c) $\frac{r_1 r_2}{r_2 - r_1}$ (d) $r_2 + r_1$

5. The excess pressure due to surface tension in a spherical liquid drop of radius r is directly proportional to [MP PMT 1987; KCET 2000]

(a) r (b) r^2

(c) r^{-1} (d) r^{-2}

6. A long cylindrical glass vessel has a small hole of radius 'r' at its bottom. The depth to which the vessel can be lowered vertically in the deep water bath (surface tension T) without any water entering inside is [MP PMT 1990]

(a) $4T/\rho rg$ (b) $3T/\rho rg$

(c) $2T/\rho rg$ (d) $T/\rho rg$

7. If the surface tension of a soap solution is 0.03 *MKS* units, then the excess of pressure inside a soap bubble of diameter 6 mm over the atmospheric pressure will be

(a) Less than 40 *N/m* (b) Greater than 40 *N/m*

(c) Less than 20 *N/m* (d) Greater than 20 *N/m*

8. The excess of pressure inside a soap bubble than that of the outer pressure is

[MP PMT 1989; BHU 1995; MH CET 2002; RPET 2003; AMU (Engg.) 2000]

(a) $\frac{2T}{r}$ (b) $\frac{4T}{r}$

(c) $\frac{T}{2r}$ (d) $\frac{T}{r}$

9. The pressure of air in a soap bubble of 0.7*cm* diameter is 8 *mm* of water above the pressure outside. The surface tension of the soap solution is

[MP PET 1991; MP PMT 1997]

(a) $100 dyne/cm$ (b) $68.66 dyne/cm$

(c) $137 dyne/cm$ (d) $150 dyne/cm$

10. Pressure inside two soap bubbles are 1.01 and 1.02 atmospheres. Ratio between their volumes is

[MP PMT 1991]

(a) 102 : 101 (b) $(102)^3 : (101)^3$

(c) 8 : 1 (d) 2 : 1

11. A capillary tube of radius r is dipped in a liquid of density ρ and surface tension S. If the angle of contact is θ, the pressure difference between the two surfaces in the beaker and the capillary

(a) $\frac{S}{r}\cos\theta$ (b) $\frac{2S}{r}\cos\theta$

(c) $\frac{S}{r\cos\theta}$ (d) $\frac{2S}{r\cos\theta}$

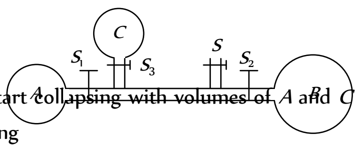
12. The radii of two soap bubbles are r_1 and r_2. In isothermal conditions, two meet together in vaccum. Then the radius of the resultant bubble is given by

[MP PMT 2001; RPET 1999; EAMCET 2003]

(a) $R=(r_1+r_2)/2$ (b) $R=r_1(r_1r_2+r_2)$

(c) $R^2=r_1^2+r_2^2$ (d) $R=r_1+r_2$

13. The adjoining diagram shows three soap bubbles *A*, *B* and *C* prepared by blowing the capillary tube fitted with stop cocks, S_1, S_2 and S_3. With stop cock *S* closed and stop cocks S_1, S_2 and S_3 opened



(a) *B* will start collapsing with volumes of *A* and *C* increasing

(b) *C* will start collapsing with volumes of *A* and *B* increasing

(c) *C* and *A* both will start collapsing with the volume of *B* increasing

(d) Volumes of *A*, *B* and *C* will become equal at equilibrium

14. When a large bubble rises from the bottom of a lake to the surface, its radius doubles. If atmospheric pressure is equal to that of column of water height *H*, then the depth of lake is

[AIIMS 1995; AFMC 1997]

(a) *H* (b) 2*H*

(c) 7*H* (d) 8*H*

15. A soap bubble in vacuum has a radius of 3 *cm* and another soap bubble in vacuum has a radius of 4 *cm*. If the two bubbles coalesce under isothermal condition, then the radius of the new bubble is [MP PMT/PE

(a) 2.3 *cm* (b) 4.5 *cm*

(c) 5 *cm* (d) 7 *cm*

16. The volume of an air bubble becomes three times as it rises from the bottom of a lake to its surface. Assuming atmospheric pressure to be 75 *cm* of *Hg* and the density of water to be 1/10 of the density of mercury, the depth of the lake is

(a) 5 *m* (b) 10 *m*

(c) 15 *m* (d) 20 *m*

17. Excess pressure of one soap bubble is four times more than the other. Then the ratio of volume of first bubble to another one is [CPMT 1997; M

(a) 1 : 64 (b) 1 : 4

(c) 64 : 1 (d) 1 : 2

18. There are two liquid drops of different radii. The excess pressure inside over the outside is [JIPMER 1999]

(a) More in the big drop

(b) More in the small drop

(c) Equal in both drops

(d) There is no excess pressure inside the drops

19. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake then what is the depth of the lake

[RPET 2000]

(a) 10*m* (b) 20*m*

(c) 60*m* (d) 30*m*

20. If the radius of a soap bubble is four times that of another, then the ratio of their pressures will be [AIIMS 2000]

(a) 1 : 4 (b) 4 : 1

(c) 16 : 1 (d) 1 : 16

21. A spherical drop of water has radius 1 *mm* If surface tension of water is 70×10^{-3} *N/m* difference of pressures between inside and out side of the spherical drop is

[CPMT 2000; AIIMS 2000]

(a) $35\ N/m^{-2}$ (b) $70\ N/m^2$

(c) $140\ N/m^2$ (d) Zero

[CPMT 1988]

22. The pressure at the bottom of a tank containing a liquid does not depend on [Kerala (Engg.) 2001]

(a) Acceleration due to gravity

(b) Height of the liquid column

(c) Area of the bottom surface

(d) Nature of the liquid

23. In capillary pressure below the curved surface of water will be

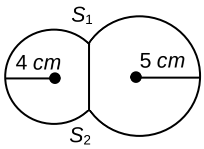
(a) Equal to atmospheric

(b) Equal to upper side pressure

(c) More than upper side pressure

(d) Lesser than upper side pressure

24. Two soap bubbles of radii r_1 and r_2 equal to 4 *cm* and 5 *cm* are touching each other over a common surface S_1S_2 (shown in figure). Its radius will be [MP PMT 2002]



(a) 4 *cm*

(b) 20 *cm*

(c) 5 *cm*

(d) 4.5 *cm*

25. The pressure inside a small air bubble of radius 0.1 *mm* situated just below the surface of water will be equal to

[Take surface tension of water $70 \times 10^{-3} Nm^{-1}$ and atmospheric pressure = $1.013 \times 10^5 Nm^{-2}$]

[AMU (Med.) 2002]

(a) $2.054 \times 10^3 Pa$ (b) $1.027 \times 10^3 Pa$

(c) $1.027 \times 10^5 Pa$ (d) $2.054 \times 10^5 Pa$

26. Two bubbles *A* and *B* $(A > B)$ are joined through a narrow tube. Then [UPSEAT 2001; Kerala (Med.) 2002]

(a) The size of *A* will increase

(b) The size of *B* will increase

(c) The size of *B* will increase until the pressure equals

(d) None of these

27. Two soap bubbles have different radii but their surface tension is the same. Mark the correct statement

[MP PMT 2004]

(a) Internal pressure of the smaller bubble is higher than the internal pressure of the larger bubble

(b) Pressure of the larger bubble is higher than the smaller bubble

(c) Both bubbles have the same internal pressure

(d) None of the above

28. If the excess pressure inside a soap bubble is balanced by oil column of height 2 *mm*, then the surface tension of soap solution will be (r = 1 *cm* and density d = 0.8 *gm/cc*)

[J & K CET 2004]

(a) 3.9 *N/m* (b) 3.9×10^{-2} *N/m*

(c) 3.9×10^{-3} *N/m* (d) 3.9 *dyne/m*

29. In Jager's method, at the time of bursting of the bubble

[RPET 2002]

(a) The internal pressure of the bubble is always greater than external pressure

(b) The internal pressure of the bubble is always equal to external pressure

(c) The internal pressure of the bubble is always less than external pressure

(d) The internal pressure of the bubble is always slightly greater than external pressure

30. The excess pressure in a soap bubble is thrice that in other one. Then the ratio of their volume is

[RPMT 2003; CPMT 2001]

(a) 1 : 3 (b) 1 : 9

(c) 27 : 1 (d) 1 : 27

Capillarity

1. When two capillary tubes of different diameters are dipped vertically, the rise of the liquid is [NCERT 1978]

(a) Same in both the tubes

(b) More in the tube of larger diameter

(c) Less in the tube of smaller diameter

(d) More in the tube of smaller diameter

2. Due to capillary action, a liquid will rise in a tube, if the angle of contact is [DPMT 1984; AFMC 1988; BHU 2001]

(a) Acute (b) Obtuse

(c) 90° (d) Zero

3. In the state of weightlessness, a capillary tube is dipped in water, then water

(a) Will not rise at all

(b) Will rise to same height as at atmospheric pressure

(c) Will rise to less height than at atmospheric pressure

(d) Will rise up to the upper end of the capillary tube of any length

4. Two parallel glass plates are dipped partly in the liquid of density '*d* keeping them vertical. If the distance between the plates is '*x*', surface tension for liquids is *T* and angle of contact is θ, then rise of liquid between the plates due to capillary will be

(a) $\frac{T\cos\theta}{xd}$ (b) $\frac{2T\cos\theta}{xdg}$

(c) $\frac{2T}{xdg\cos\theta}$ (d) $\frac{T\cos\theta}{xdg}$

5. Water rises in a capillary tube to a certain height such that the upward force due to surface tension is balanced by $75 \times 10^{-4} N$ force due to the weight of the liquid. If the surface tension of water is $6 \times 10^{-2}\ Nm^{-1}$, the inner circumference of the capillary must be [CPMT 19

(a) $1.25 \times 10^{-2} m$ (b) $0.50 \times 10^{-2} m$

(c) $6.5 \times 10^{-2} m$ (d) $12.5 \times 10^{-2} m$

6. It is not possible to write directly on blotting paper or newspaper with ink pen

(a) Because of viscosity (b) Because of inertia

(c) Because of friction (d) Because of capillarity

7. Two capillary tubes *P* and *Q* are dipped in water. The height of water level in capillary *P* is 2/3 to the height in *Q* capillary. The ratio of their diameters is [MP PMT 1985]

(a) 2 : 3 (b) 3 : 2

(c) 3 : 4 (d) 4 : 3

8. Two capillaries made of same material but of different radii are dipped in a liquid. The rise of liquid in one capillary is 2.2 *cm* and that in the other is 6.6 *cm*. The ratio of their radii is [MP PET 1990]

(a) 9 : 1 (b) 1 : 9

(c) 3 : 1 (d) 1 : 3

9. Two capillaries made of the same material with radii $r_1 = 1mm$ and $r_2 = 2mm$. The rise of the liquid in one capillary ($r_1 = mm$) is 30 *cm*, then the rise in the other will be [MP PET 1991]

(a) 7.5 *cm* (b) 60 *cm*

(c) 15 *cm* (d) 120 *cm*

10. When a capillary is dipped in water, water rises to a heig ht h. If the length of the capillary is made less than h, then

(a) The water will come out

(b) The water will not come out

(c) The water will not rise

(d) The water will rise but less than height of capillary

11. Water rises upto 10 *cm* height in a long capillary tube. If this tube is immersed in water so that the height above the water surface is only 8 *cm*, then [MP PMT 1991]

(a) Water flows out continuously from the upper end

(b) Water rises upto upper end and forms a spherical surface

(c) Water only rises upto 6 *cm* height

(d) Water does not rise at all

12. A vessel, whose bottom has round holes with diameter of 0.1*mm*, is filled with water. The maximum height to which the water can be filled without leakage is

(S.T. of water =75 *dyne/cm*, g =1000 *cm/s*)

[CPMT 1989; J&K CET 2004]

(a) 100 *cm* (b) 75 *cm*

(c) 50 *cm* (d) 30 *cm*

13. Water rises in a capillary tube when its one end is dipped vertically in it, is 3 *cm*. If the surface tension of water is 75 × 10 *N/m*, then the diameter of capillary will be

[MP PET 1989]

(a) 0.1 *mm* (b) 0.5 *mm*

(c) 1.0 *mm* (d) 2.0 *mm*

14. A capillary tube made of glass is dipped into mercury. Then

[MP PET 1996]

(a) Mercury rises in the capillary tube

(b) Mercury rises and flows out of the capillary tube

(c) Mercury descends in the capillary tube

(d) Mercury neither rises nor descends in the capillary tube

15. By inserting a capillary tube upto a depth *l* in water, the water rises to a height *h*. If the lower end of the capillary is closed inside water and the capillary is taken out and closed end opened, to what height the water will remain in the tube

[RPET 1996; DPMT 2000]

(a) Zero (b) $l + h$

(c) $2h$ (d) h

16. If the diameter of a capillary tube is doubled, then the height of the liquid that will rise is [CPMT 1997]

(a) Twice (b) Half

(c) Same as earlier (d) None of these

17. If the surface tension of water is 0.06 *Nm*, then the capillary rise in a tube of diameter 1 *mm* is (θ =0°)

[AFMC 1998]

(a) 1.22 *cm* (b) 2.44 *cm*

(c) 3.12 *cm* (d) 3.86 *cm*

18. Two capillary tubes of radii 0.2 *cm* and 0.4 *cm* are dipped in the same liquid. The ratio of heights through which liquid will rise in the tubes is [MNR 1998]

(a) 1 : 2 (b) 2 : 1

(c) 1 : 4 (d) 4 : 1

19. A capillary tube when immersed vertically in liquid records a rise of 3 *cm*. If the tube is immersed in the liquid at an angle of 60^0 with the vertical. The length of the liquid column along the tube is

(a) 9*cm* (b) 6*cm*

(c) 3*cm* (d) 2*cm*

20. The action of a nib split at the top is explained by

[JIPMER 1999]

(a) Gravity flow (b) Diffusion of fluid

(c) Capillary action (d) Osmosis of liquid

21. The correct relation is [RPMT 2002]

(a) $r = \frac{2T\cos\theta}{hdg}$ (b) $r = \frac{hdg}{2T\cos\theta}$

(c) $r = \frac{2T\,dgh}{\cos\theta}$ (d) $r = \frac{T\cos\theta}{2hdg}$

22. Water rises upto a height *h* in a capillary on the surface of earth in stationary condition. Value of h increases if this tube is taken

(a) On sun

(b) On poles

(c) In a lift going upward with acceleration

(d) In a lift going downward with acceleration

23. During capillary rise of a liquid in a capillary tube, the surface of contact that remains constant is of

[Pb. PMT 2000]

(a) Glass and liquid (b) Air and glass

(c) Air and liquid (d) All of these

24. A shell having a hole of radius *r* is dipped in water. It holds the water upto a depth of *h* then the value of *r* is

[RPMT 2000]

(a) $r = \frac{2T}{hdg}$ (b) $r = \frac{T}{hdg}$

(c) $r = \frac{Tg}{hd}$ (d) None of these

25. In a capillary tube, water rises by 1.2 *mm*. The height of water that will rise in another capillary tube having half the radius of the first, is [CPMT 2001; Pb. PET 2002]

(a) 1.2 *mm* (b) 2.4 *mm*

(c) 0.6 *mm* (d) 0.4 *mm*

26. If capillary experiment is performed in vacuum then for a liquid there [RPET 2001]

(a) It will rise (b) Will remain same
(c) It will fall (d) Rise to the top

27. If liquid level falls in a capillary then radius of capillary will [RPET 2001]
(a) Increase (b) Decrease
(c) Unchanged (d) None of these

28. Water rises to a height h in a capillary at the surface of earth. On the surface of the moon the height of water column in the same capillary will be [MP PMT 2001]
(a) $6h$ (b) $\frac{1}{6}h$
(c) h (d) Zero

29. Two capillary tubes of same diameter are put vertically one each in two liquids whose relative densities are 0.8 and 0.6 and surface tensions are 60 and 50 *dyne/cm* respectively Ratio of heights of liquids in the two tubes $\frac{h_1}{h_2}$ is [MP PMT 2002]
(a) $\frac{10}{9}$ (b) $\frac{3}{10}$
(c) $\frac{10}{3}$ (d) $\frac{9}{10}$

30. Water rises in a vertical capillary tube upto a height of 2.0 *cm* . If the tube is inclined at an angle of 60^o with the vertical, then upto what length the water will rise in the tube [UPSEAT 2002]
(a) 2.0 *cm* (b) 4.0 *cm*
(c) $\frac{4}{\sqrt{3}}cm$ (d) $2\sqrt{2}\,cm$

31. The surface tension for pure water in a capillary tube experiment is [MH CET 2002]
(a) $\frac{\rho g}{2hr}$ (b) $\frac{2}{hr\rho g}$
(c) $\frac{r\rho g}{2h}$ (d) $\frac{hr\rho g}{2}$

32. In a capillary tube experiment, a vertical 30 *cm* long capillary tube is dipped in water. The water rises up to a height of 10*cm* due to capillary action. If this experiment is conducted in a freely falling elevator, the length of the water column becomes [Orissa JEE 2003; AIEEE 2005]
(a) 10 *cm* (b) 20 *cm*
(c) 30 *cm* (d) Zero

33. Radius of a capillary is $2\times10^{-3}m$. A liquid of weight $6.28\times10^{-4}\,N$ may remain in the capillary then the surface tension of liquid will be [RPET 2003]
(a) $5\times10^{-3}\,N/m$ (b) $5\times10^{-2}\,N/m$
(c) $5\,N/m$ (d) $50\,N/m$

34. Two long capillary tubes A and B of radius $R_A > R_B$ dipped in same liquid. Then [Orissa PMT 2004]
(a) Water rise is more in A than B
(b) Water rises more in B than A
(c) Same water rise in both
(d) All of these according to the density of water

35. If water rises in a capillary tube upto 3 *cm*. What is the diameter of capillary tube (Surface tension of water = 7.2×10^{-2} *N/m*)
(a) 9.6×10^{-4} *m* (b) 9.6×10^{-3} *m*
(c) 9.6×10^{-2} *m* (d) 9.6×10^{-1} *m*

36. When a capillary is dipped in water, water rises 0.015 *m* in it. If the surface tension of water is 75×10^{-3} *N/m*, the radius of capillary is
(a) 0.1 *mm* (b) 0.5 *mm*
(c) 1 *mm* (d) 2 *mm*

37. In a capillary tube, water rises to 3 *mm*. The height of water that will rise in another capillary tube having one-third radius of the first is [BHU 2004]
(a) 1 *mm* (b) 3 *mm*
(c) 6 *mm* (d) 9 *mm*

38. Kerosene oil rises up the wick in a lantern [NCERT 1980; MNR 1985]
(a) Due to surface tension of the oil
(b) The wick attracts the kerosene oil
(c) Of the diffusion of the oil through the wick
(d) None of the above

39. Water rises against gravity in a capillary tube when its one end is dipped into water because
(a) Pressure below the meniscus is less than atmospheric pressure
(b) Pressure below the meniscus is more than atmospheric pressure
(c) Capillary attracts water
(d) Of viscosity

40. A capillary tube of radius R is immersed in water and water rises in it to a height H. Mass of water in the capillary tube is M. If the radius of the tube is doubled, mass of water that will rise in the capillary tube will now be [RPMT 1997; RPET 1999; CPMT 2002]
(a) M (b) $2M$
(c) $M/2$ (d) $4M$

41. Water rises up to a height h in a capillary tube of certain diameter. This capillary tube is replaced by a similar tube of half the diameter. Now the water will rise to the height of [Kerala PMT 2005]
(a) $4h$ (b) $3h$
(c) $2h$ (d) h

Critical Thinking
Objective Questions

1. There is a horizontal film of soap solution. On it a thread is placed in the form of a loop. The film is pierced inside the loop and the thread becomes a circular loop of radius R. If the surface tension of the loop be T, then what will be the tension in the thread
(a) $\pi R^2/T$ (b) $\pi R^2 T$
(c) $2\pi RT$ (d) $2RT$

2. A large number of water drops each of radius r combine to have a drop of radius R. If the surface tension is T and the mechanical equivalent of heat is J, then the rise in temperature will be [MP PET 1994; DPMT 2002]
(a) $\frac{2T}{rJ}$ (b) $\frac{3T}{RJ}$
(c) $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$ (d) $\frac{2T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

3. An air bubble in a water tank rises from the bottom to the top. Which of the following statements are true

[Roorkee 2000]

(a) Bubble rises upwards because pressure at the bottom is less than that at the top.

(b) Bubble rises upwards because pressure at the bottom is greater than that at the top.

(c) As the bubble rises, its size increases

(d) As the bubble rises, its size decreases

4. In a surface tension experiment with a capillary tube water rises upto 0.1 *m*. If the same experiment is repeated on an artificial satellite, which is revolving around the earth, water will rise in the capillary tube upto a height of

[Roorkee 1992]

(a) 0.1 *m*

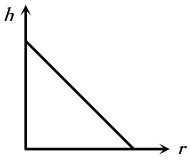
(b) 0.2 *m*

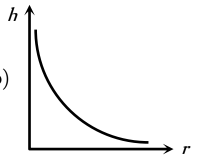
(c) 0.98 *m*

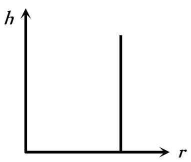
(d) Full length of the capillary tube

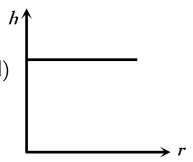
Graphical Questions

1. The correct curve between the height or depression h of liquid in a capillary tube and its radius is

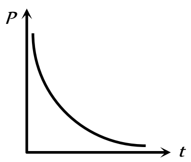
(a)


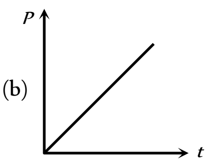
(b)


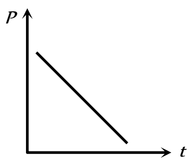
(c)


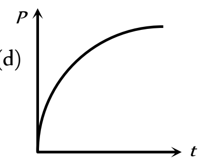
(d)


2. A soap bubble is blown with the help of a mechanical pump at the mouth of a tube. The pump produces a certain increase per minute in the volume of the bubble, irrespective of its internal pressure. The graph between the pressure inside the soap bubble and time t will be-

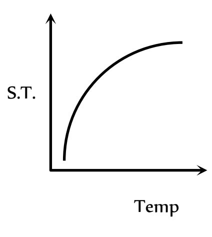
(a)


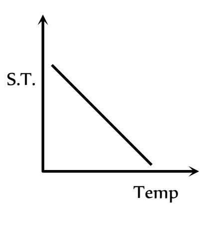
(b)


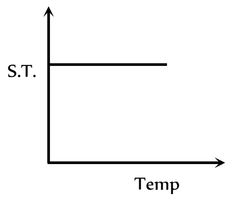
(c)


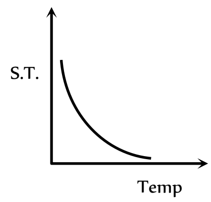
(d)


3. Which graph represents the variation of surface tension with temperature over small temperature ranges for water

(a)


(b)


(c)


(d)


Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : It is easier to spray water in which some soap is dissolved.

Reason : Soap is easier to spread.

2. Assertion : It is better to wash the clothes in cold soap solution.

Reason : The surface tension of cold solution is more than the surface tension of hot solution.

3. Assertion : When height of a tube is less than liquid rise in the capillary tube, the liquid does not overflow.

Reason : Product of radius of meniscus and height of liquid in capillary tube always remains constant.

4. Assertion : A needle placed carefully on the surface of water may float, whereas a ball of the same material will always sink.

Reason : The buoyancy of an object depends both on the material and shape of the object.

5. Assertion : A large force is required to draw apart normally two glass plates enclosing a thin water film.

Reason : Water works as glue and sticks two glass plates.

6. Assertion : The impurities always decrease the surface tension of a liquid.

Reason : The change in surface tension of the liquid depends upon the degree of contamination of the impurity.

7. Assertion : The angle of contact of a liquid decrease with increase in temperature.

Reason : With increase in temperature, the surface tension of liquid increase.

8. Assertion : The concept of surface tension is held only for liquids.

Reason : Surface tension does not hold for gases.

9. Assertion : At critical temperature, surface tension of a liquid becomes zero.

Reason : At this temperature, intermolecular forces for liquids and gases become equal. Liquid can expand without any restriction.

10. Assertion : A large soap bubble expands while a small bubble shrinks, when they are connected to each other by a capillary tube.

Reason : The excess pressure inside bubble (or drop) is inversely proportional to the radius.

11. Assertion : Tiny drops of liquid resist deforming forces better than bigger drops.

Reason : Excess pressure inside a drop is directly proportional to surface tension.

12. Assertion : The water rises higher in a capillary tube of small diameter than in the capillary tube of large diameter.

Reason : Height through which liquid rises in a capillary tube is inversely proportional to the diameter of the capillary tube.

13. Assertion : Hot soup tastes better than the cold soup.

Reason : Hot soup has high surface tension and it does not spread properly on our tongue.

14. Assertion : The shape of a liquid drop is spherical.

Reason : The pressure inside the drop is greater than that of outside.

Answers

Surface Tension

1	a	2	b	3	b	4	a	5	d
6	a	7	b	8	b	9	b	10	cd
11	d	12	a	13	b	14	b	15	c
16	d	17	a	18	c	19	c	20	d
21	b	22	d	23	a	24	a	25	c
26	d	27	d	28	b	29	b	30	d
31	d	32	c	33	d	34	c	35	a
36	b	37	b	38	a	39	a	40	c
41	d	42	c	43	d	44	a	45	a
46	a								

Surface Energy

1	a	2	d	3	a	4	d	5	d
6	b	7	c	8	d	9	c	10	c
11	c	12	c	13	c	14	a	15	b
16	b	17	d	18	a	19	a	20	b
21	b	22	d	23	a	24	a	25	b
26	d	27	b	28	d	29	d	30	c
31	ad	32	c	33	b	34	c	35	a
36	a	37	a	38	b	39	a	40	b
41	a	42	a	43	b	44	a	45	c

Angle of Contact

1	b	2	a	3	b	4	d	5	b
6	b	7	d	8	b	9	a	10	c
11	a	12	c	13	b	14	b	15	b
16	d								

Pressure Difference

1	c	2	c	3	b	4	c	5	c
6	c	7	b	8	b	9	b	10	c
11	b	12	c	13	c	14	c	15	c
16	c	17	a	18	b	19	b	20	a
21	c	22	c	23	d	24	b	25	c
26	a	27	a	28	b	29	a	30	d

Capillarity

1	d	2	a	3	d	4	b	5	d
6	d	7	b	8	c	9	c	10	b
11	b	12	d	13	c	14	c	15	d
16	b	17	b	18	b	19	b	20	c
21	a	22	d	23	c	24	a	25	b
26	a	27	a	28	a	29	d	30	b
31	d	32	c	33	b	34	a	35	a
36	c	37	d	38	a	39	a	40	b
41	c								

Critical Thinking Questions

1	d	2	c	3	bc	4	d		

Graphical Questions

1	b	2	a	3	b				

Assertion and Reason

1	c	2	e	3	a	4	c	5	c
6	e	7	c	8	b	9	a	10	a
11	b	12	a	13	c	14	b		

Answers and Solutions

Surface Tension

1. (a)
2. (b)
3. (b)
4. (a)
5. (d) Soap helps to lower the surface tension of solution, thus soap get stick to the dust particles and grease and these are removed by action of water.
6. (a)
7. (b)
8. (b)
9. (b)
10. (c,d) At critical temperature ($T_c = 370^o C = 643\ K$), the surface tension of water is zero.
11. (d)
12. (a) Weight of spiders or insects can be balanced by vertical component of force due to surface tension.
13. (b)
14. (b)
15. (c) Force on each side $= 2TL$ (due to two surfaces)

    $\therefore$ Force on the frame $= 4(2TL) = 8TL$
16. (d)
17. (a)
18. (c) This happens due to viscosity.
19. (c)
20. (d) The total length of the circular plate on which the force will act $= 2\pi R$

    Force to pull $= 2\pi RT = 2 \times \pi \times 5 \times 75 = 750\pi$ *dynes*

21. (b)

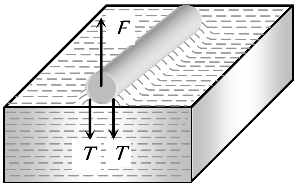
22. (d) $T = T_0(1 - \alpha t)$

23. (a) Due to force of attraction it is not easier to separate the two glass plates.

24. (a) Soluble impurities increases the surface tension.

25. (c) $T = \frac{F}{2l} = \frac{728}{2 \times 5}$

$\therefore T = 72.8\ dyne/cm$



26. (d) Cohesive force > Adhesive force, so shape of liquid surface near the solid would be convex.

For example mercury surface in glass capillary is convex.

27. (d) Surface tension decreases with increase in temperature.

28. (b)

29. (b)

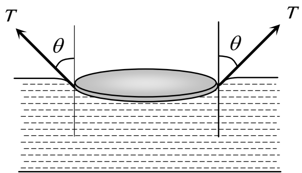
30. (d)

31. (d) Because surface tension of water > surface tension of oil

32. (c) Surface tension pulls the plates towards each other.

33. (d) Sphere has the minimum surface area for the given volume of the liquid.

34. (c)



Weight of metal disc = total upward force

= upthrust force + force due to surface tension

= weight of displaced water + $T\cos\theta\,(2\pi r)$

= $W + 2\pi rT\cos\theta$

35. (a) $T = \frac{F}{2l} = \frac{2 \times 10^{-2}}{2 \times 10 \times 10^{-2}} = 0.1\ N/m$

36. (b) Surface tension of water decrease with rise in temperature.

37. (b)

38. (a) Force required to separate the plates

$$F = \frac{2TA}{t} = \frac{2 \times 70 \times 10^{-3} \times 10^{-2}}{0.05 \times 10^{-3}} = 28N$$

39. (a)

40. (c) The cohesive force is the force of attraction between the molecules of same substance.

41. (d)

42. (c) $T = \frac{F}{l} = \frac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$

43. (d) Net force on stick $= F_1 - F_2 = (T_1 - T_2)l$

$= (0.07 - 0.06)l = 0.01 \times 2 = 0.02N$

44. (a) Because film tries to cover minimum surface area.

45. (a) Force required, $F = 2\pi rT = 2\pi \times 2 \times 70 = 280\pi.Dyne$

46. (a)

Surface Energy

1. (a) Energy needed = Increment in surface energy

= (surface energy of n small drops) – (surface energy of one big drop)

$= n4\pi r^2T - 4\pi R^2T = 4\pi T(nr^2 - R^2)$

2. (d)

3. (a) When two droplets merge with each other, their surface energy decreases.

$W = T(\Delta A) = (\text{negative})$ *i.e.* energy is released.

4. (d) $E = 4\pi R^2T(n^{1/3} - 1)$

$= 4 \times 3.14 \times (1.4 \times 10^{-1})^2 \times 75(125^{1/3} - 1) = 74\ erg$

5. (d) $W = 8\pi T(R_2^2 - R_1^2) = 8\pi T[(2r)^2 - (r)^2] = 24\pi r^2T$

6. (b) Work done in splitting a water drop of radius R into n drops of equal size $= 4\pi R^2T(n^{1/3} - 1)$

$= 4\pi \times (10^{-3})^2 \times 72 \times 10^{-3} \times (10^{6/3} - 1)$

$= 4\pi \times 10^{-6} \times 72 \times 10^{-3} \times 99 = 8.95 \times 10^{-5}\ J$

7. (c) $W = 4\pi R^2T(r^{1/3} - 1) = 4\pi R^2T(8^{1/3} - 1) = 4\pi R^2T$

8. (d) $W = T \times 8\pi(r_2^2 - r_1^2) = T \times 8\pi\left(\frac{D^2}{4} - \frac{d^2}{4}\right)$

$= 2\pi(D^2 - d^2)T$

9. (c) Work done to increase the diameter of bubble from d to D

$$W = 2\pi(D^2 - d^2)T = 2\pi\left[(2D)^2 - (D)^2\right]T = 6\pi D^2T$$

10. (c) $W = 8\pi T(r_2^2 - r_1^2) = 8\pi T\left[\left(\frac{2}{\sqrt{\pi}}\right)^2 - \left(\frac{1}{\sqrt{\pi}}\right)^2\right]$

$\therefore W = 8 \times \pi \times 30 \times \frac{3}{\pi} = 720\ erg$

11. (c) $W = T \times \Delta A = 5 \times 2 \times (0.02)$ (Film has two free surfaces)

$= 2 \times 10^{-1}\ J$

12. (c) $W = 8\pi R^2T\ \therefore\ W \propto R^2$ (T is constant)

If radius becomes double then work done will become four times.

13. (c) $W = 4\pi R^2T(n^{1/3} - 1) = 4\pi \times 1 \times 50(10^{3/3} - 1)$

$= 1800\pi\ erg$

14. (a)

15. (b) Surface energy of combined drop will be lowered, so excess surface energy will raise the temperature of the drop.

16. (b) Surface energy = surface tension × increment in area

$= T \times A$

17. (d) $W = 8\pi R^2 T = 8 \times \pi \times (10^{-2})^2 \times 2 \times 10^{-2} = 16\pi \times 10^{-6}\ J$

18. (a) $E = 4\pi R^2 T(n^{1/3} - 1)$

$= 4 \times 3.14 \times 10^{-4} \times 35 \times 10^{-1}(10^{6/3} - 1) = 4.4 \times 10^{-3}\ J$

19. (a)

20. (b) $W = 8\pi R^2 T = 8\pi \times (1 \times 10^{-2})^2 \times 1.9 \times 10^{-2} = 15.2 \times 10^{-6}\ \pi J$

21. (b) Surface energy = $T \times \Delta A = 0.5 \times 2 \times (0.02) = 2 \times 10^{-2}\ J$

22. (d) Volume of liquid remain same *i.e.* volume of 1000 small drops will be equal to volume of one big drop

$n\frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow 1000r^3 = R^3 \Rightarrow R = 10r \therefore \frac{r}{R} = \frac{1}{10}$

$\frac{\text{surface energy of one small drop}}{\text{surface energy of one big drop}} = \frac{4\pi r^2 T}{4\pi R^2 T} = \frac{1}{100}$

23. (a) $E = T \times \Delta A = 3 \times 10^{-2} \times 2(100 \times 10^{-4}) = 6 \times 10^{-4}\ J$

24. (a) $W = 8\pi R^2 T = 8 \times 3.14 \times (10 \times 10^{-2}) \times \frac{3}{100}$

$= 7.536 \times 10^{-3}\ J$

25. (b) Work done = $4\pi R^2 T(n^{1/3} - 1) = 4\pi\left(\frac{D}{2}\right)^2 \sigma(n^{1/3} - 1)$

$= \pi D^2 \sigma(27^{1/3} - 1) = 2\pi D^2 \sigma$

26. (d) As volume remain constant therefore $R = n^{1/3} r$

$\frac{\text{surface energy of one big drop}}{\text{surface energy of } n \text{ drop}} = \frac{4\pi R^2 T}{n \times 4\pi r^2 T}$

$\frac{R^2}{nr^2} = \frac{n^{2/3} r^2}{nr^2} = \frac{1}{n^{1/3}} = \frac{1}{(1000)^{1/3}} = \frac{1}{10}$

27. (b) $W = T \times \Delta A \ \therefore\ T = \frac{W}{\Delta A}$

$T = \frac{3 \times 10^{-4}}{2 \times (110 - 60) \times 10^{-4}}$ (Soap film has two surfaces)

$= 3 \times 10^{-2}\ N/m$

28. (d)

29. (d) $\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$ (As volume remains constant)

$R^3 = 1000r^3 \Rightarrow R = 10r \Rightarrow r = \frac{R}{10}$

30. (c) Because energy is liberated

31. (a,d)

32. (c) As volume remains constant $R^3 = 8000r^3 \ \therefore R = 20r$

$\frac{\text{Surface energy of one big drop}}{\text{Surface energy of 8000 small drop}} = \frac{4\pi R^2 T}{8000\ 4\pi r^2 T}$

$= \frac{R^2}{8000r^2} = \frac{(20r)^2}{8000r^2} = \frac{1}{20}$

33. (b) Surface energy = $T \times A = 5 \times 2 \times (0.15) = 1.5 J$

34. (c) As volume remains constant therefore $R = n^{1/3} r$

$\frac{\text{Energy of big drop}}{\text{Energy of small drop}} = \frac{4\pi R^2 T}{4\pi r^2 T} = \frac{R^2}{r^2} = (8)^{2/3} = 4$

35. (a) $T = \frac{W}{\Delta A} = \frac{2 \times 10^{-4}}{2 \times (50 \times 10^{-4})} = 2 \times 10^{-2}\ N/m$

36. (a) $W = T\Delta A = 4\pi R^2 T(n^{1/3} - 1)$

$= 4 \times 3.14 \times (10^{-2})^2 \times 460 \times 10^{-3} \times [(10^6)^{1/3} - 1] = 0.057$

37. (a)

38. (b) Increment in area of soap film = $A_2 - A_1$

$= 2 \times [(10 \times 0.6) - (10 \times 0.5)] \times 10^{-4} = 2 \times 10^{-4} m^2$

Work done = $T \times \Delta A$

$= 7.2 \times 10^{-2} \times 2 \times 10^{-4} = 1.44 \times 10^{-5}\ J$

39. (a) Increase in surface energy or work done in splitting a big drop $= 4\pi R^2 T(n^{1/3} - 1)$

$\Rightarrow W = 4\pi \times (2 \times 10^{-3})^2 \times 0.465(8^{1/3} - 1) = 23.4\ \mu J$

40. (b) The ratio of the total surface energies before and after the change $= n^{1/3} : 1 = 2^{1/3} : 1$

41. (a) $W = 8\pi S(R_2^2 - R_1^2) = 8\pi S[(2R)^2 - R^2] = 24\pi R^2 S$

42. (a) $W = 8\pi r^2 \times T = 8\pi \times (0.2)^2 \times 0.06 = 192\pi \times 10^{-4}\ J$

43. (b) Increment in Potential energy = $T \times \Delta A$

$= 0.02 \times 2 \times 0.05 = 2 \times 10^{-2}\ J$

44. (a) $E = T \times \Delta A = 75 \times 0.04 = 3\ J$

45. (c) $r = \frac{r_1 r_2}{r_2 - r_1} = \infty$ since $r_1 = r_2$

Angle of Contact

1. (b)

2. (a)

3. (b) Cohesive force decreases so angle of contact decreases.

4. (d)

5. (b)

6. (b)

7. (d)

8. (b)

9. (a)

10. (c) Angle of contact is acute.

11. (a)

12. (c)

13. (b)

14. (b) Since for such liquid (Non-wetting) angle of contact is obtuse.

15. (b) Both liquids water and alcohol have same nature (*i.e.* wet the solid). Hence angle of contact for both is acute.

16. (d) Tangent drawn at point of contact makes 0° with wall of container.

Pressure Difference

1. (c)

2. (c) Since $\Delta P \propto \frac{1}{R}$

3. (b) Excess pressure $\Delta P = \frac{4T}{r}$

$$= \frac{4\times 2\times 25\times 10^{-3}}{1\times 10^{-2}} = 20\ N/m^2 = 20\ Pa\ (\text{as } r = d/2)$$

4. (c)

5. (c)

6. (c) $hdg = \frac{2T}{r} \Rightarrow h = \frac{2T}{rdg}$

7. (b) $\Delta P = \frac{4T}{r} = 40\ N/m^2$

8. (b)

9. (b) $\Delta P = \frac{4T}{r} = hdg \Rightarrow T = \frac{rhdg}{4} = \frac{0.35\times 0.8\times 1\times 10^3}{4}$

$$= 70\ dyne/cm \equiv 68.66\ dyne/cm$$

10. (c) Outside pressure = 1 *atm*

Pressure inside first bubble = 1.01 *atm*

Pressure inside second bubble = 1.02 *atm*

Excess pressure $\Delta P_1 = 1.01 - 1 = 0.01\, atm$

Excess pressure $\Delta P_2 = 1.02 - 1 = 0.02\ atm$

$$\Delta P \propto \frac{1}{r} \Rightarrow r \propto \frac{1}{\Delta P} \Rightarrow \frac{r_1}{r_2} = \frac{\Delta P_2}{\Delta P_1} = \frac{0.02}{0.01} = \frac{2}{1}$$

Since $V = \frac{4}{3}\pi r^3\ \therefore\ \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$

11. (b) $S = \frac{rhdg}{2\cos\theta} \Rightarrow$ Pressure difference $= hdg = \frac{2S}{r}\cos\theta$

12. (c)

13. (c) Excess pressure inside soap bubble is inversely proportional to the radius of bubble *i.e.* $\Delta P \propto \frac{1}{r}$

This means that bubbles *A* and *C* posses greater pressure inside it than *B*. So the air will move from *A* and *C* towards *B*.

14. (c) $P_1V_1 = P_2V_2 \Rightarrow (H+h)\rho g \times \frac{4}{3}\pi r^3 = H \times \frac{4}{3}\pi (2r)^3$

$$\Rightarrow H + h = 8H\ \therefore\ h = 7H$$

15. (c) $r = \sqrt{r_1^2 + r_2^2} = \sqrt{9+16} = 5\ cm$

16. (c) $P_1V_1 = P_2V_2 \Rightarrow (H_{Hg}\rho_{Hg} + H_W\rho_W)V = H_{Hg}\rho_{Hg}\times 3V$

$$\Rightarrow H_{Hg}\rho_{Hg} + H_W\frac{\rho_{Hg}}{10} = 3H_{Hg}\rho_{Hg}$$

$$\Rightarrow H_W = 2H_{Hg}\times 10 = \frac{2\times 75\times 10}{100} = 15m$$

17. (a) $\Delta P = \frac{4T}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = 4\ \therefore \frac{r_2}{r_1} = 4$ and $\frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \frac{1}{64}$

18. (b) $\Delta P \propto \frac{1}{r}$

19. (b) Pressure at half the depth $= P_0 + \frac{h}{2}dg$

Pressure at the bottom $= P_0 + hdg$

According to given condition

$$P_0 + \frac{h}{2}dg = \frac{2}{3}(P_0 + hdg)$$

$$\Rightarrow 3P_0 + \frac{3h}{2}dg = 2P_0 + 2hdg$$

$$\Rightarrow h = \frac{2P_0}{dg} = \frac{2\times 10^5}{10^3\times 10} = 20\ m$$

20. (a) $\Delta P \propto \frac{1}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} = \frac{r}{4r} = \frac{1}{4}$

21. (c) $\Delta P = \frac{2T}{R} = \frac{2\times 70\times 10^{-3}}{1\times 10^{-3}} = 140\ N/m^2$

22. (c) $P = h\rho g$

23. (d)

24. (b) $r = \frac{r_1 r_2}{r_1 - r_2} = \frac{5\times 4}{5-4} = 20\ cm$

25. (c) Excess pressure inside the air bubble $= \frac{2T}{r}$

$\Rightarrow P_{in} - P_{out} = \frac{2T}{r} = \frac{2\times 70\times 10^{-3}}{0.1\times 10^{-3}} = 1400 Pa$

$\Rightarrow P_{in} = 1400 + 1.013\times 10^5 = 1.027\times 10^5\ Pa$

26. (a) $r_A > r_B$ and $P \propto \frac{1}{r}$ so $P_A < P_B$

So air will flow from *B* to *A* *i.e.* size of *A* will increase.

27. (a) $\Delta P = \frac{4T}{R}\ \therefore\ \Delta P \propto \frac{1}{R}$ (T = constant)

Hence, the internal pressure of smaller bubble is larger than that of larger bubble.

28. (b) $\frac{4T}{R} = hdg\ \therefore\ T = \frac{Rhdg}{4}$

$T = \frac{10^{-2}\times 2\times 10^{-3}\times 0.8\times 10^3\times 9.8}{4} = 3.9\times 10^{-2}\ N/m$

29. (a)

30. (d) $\Delta P \propto \frac{1}{r} \Rightarrow \frac{r_1}{r_2} = \frac{\Delta P_2}{\Delta P_1} = \frac{1}{3} \Rightarrow \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \frac{1}{27}$

Capillarity

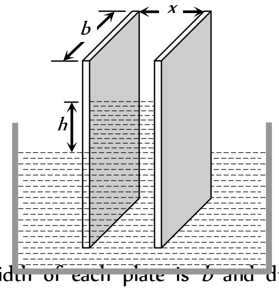
1. (d) $h = \frac{2T\cos\theta}{rdg}\ \therefore h \propto \frac{1}{r}$ (T, θ, d and g are constant)

If r is less then h will be more.

2. (a) $h = \frac{2T\cos\theta}{rdg}$. If θ is less than 90° then h will be positive

3. (d) In the state of weightlessness or in gravity free space, water will rise to the upper end of the tube of any length.

4. (b)



Let the width of each plate is *b* and due to surface tension liquid will rise upto height h then upward force due to surface tension

$= 2Tb\cos\theta$ ...(i)

Weight of the liquid rises in between the plates

$= Vdg = (bxh)dg$ ...(ii)

Equating (i) and (ii) we get, $2T\cos\theta = bxhdg$

$\therefore h = \frac{2T\cos\theta}{xdg}$

5. (d) $6\times 10^{-2}\times$ Circumference = Force

$\therefore$ Circumference $= \frac{75\times 10^{-4}}{6\times 10^{-2}} = 12.5\times 10^{-2} m$

6. (d) Due to capillarity it absorbs the ink.

7. (b) $r \propto \frac{1}{h} \Rightarrow \frac{r_P}{r_Q} = \frac{h_Q}{h_P} = \frac{h}{\frac{2}{3}h} = \frac{2}{3}$

8. (c) $r \propto \frac{1}{h} \Rightarrow \frac{r_1}{r_2} = \frac{h_2}{h_1} = \frac{6.6}{2.2} = \frac{3}{1}$

9. (c) $\frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{1}{2} \Rightarrow h_2 = \frac{30}{2} = 15cm$

10. (b)

11. (b)

12. (d) $h = \frac{2T}{rdg} = \frac{2\times 75}{0.005\times 1\times 10^3} = 30cm$

13. (c) $T = \frac{rh\rho g}{2} \Rightarrow 75\times 10^{-3} = \frac{3\times 10^{-2}\times r\times 10^3\times 9.8}{2}$

$\Rightarrow r = \frac{1}{2}mm\ \therefore D = 2r = 1\ mm$

14. (c) The angle of contact of mercury with glass is obtuse. So it gets depressed below the liquid level outside.

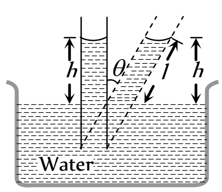
15. (d) The water rises to height h due to capilarity.

16. (b) $h \propto \frac{1}{r}$

17. (b) $h = \frac{2T}{rdg} = \frac{2\times 6\times 10^{-2}}{5\times 10^{-4}\times 10^3\times 10} = 2.4\times 10^{-2} m = 2.4cm$

18. (b) $h \propto \frac{1}{r}\ \therefore\ r_1 h_1 = r_2 h_2 \Rightarrow \frac{h_1}{h_2} = \frac{r_2}{r_1} = \frac{0.4}{0.2} = 2:1$

19. (b)



Vertical height of the water in the tube remains constant

So, $l = \frac{h}{\cos\theta} = \frac{3}{\cos 60^o} = 6\ cm$

20. (c)

21. (a)

22. (d) If lift moves downward with some acceleration then effective g decreases, so h increases.

As $h = \frac{2T\cos\theta}{rdg}$ $\therefore h \propto \frac{1}{g}$

23. (c)

24. (a) $\frac{2T}{r} = hdg \Rightarrow r = \frac{2T}{hdg}$

25. (b) $h \propto \frac{1}{r} \therefore r_1h_1 = r_2h_2 \Rightarrow h_2 = \frac{r_1h_1}{r_2} = 2.4\ mm$

26. (a)

27. (a) $h \propto \frac{1}{r} \therefore rh$ = constant

28. (a) $h = \frac{2T\cos\theta}{rdg} \therefore h \propto \frac{1}{g}$

As $g_m = \frac{g_e}{6} \therefore h_m = 6h_e$

29. (d) Ascent formula $h = \frac{2T\cos\theta}{rdg}$

$\Rightarrow \frac{h_1}{h_2} = \frac{T_1}{T_2} \times \frac{d_2}{d_1}$ (r, θ and g are constants)

$= \frac{60}{50} \times \frac{0.6}{0.8} = \frac{9}{10}$

30. (b) $l = \frac{h}{\cos\theta} = \frac{2}{\cos 60^o} = 4.0\ cm$

31. (d) $T = \frac{rhdg}{2\cos\theta}$. For pure water $\theta = 0^o$ so $T = \frac{rhdg}{2}$

32. (c) The length of the water column will be equal to full length of capillary tube.

33. (b) $T = \frac{F}{2\pi r} = \frac{6.28 \times 10^{-4}}{2 \times 3.14 \times 2 \times 10^{-3}} = 5 \times 10^{-2}\ N/m$

34. (a) $h \propto \frac{1}{R}$

35. (a) $h = \frac{2T\cos\theta}{rdg}$, for water $\theta = 0°$

$\Rightarrow r = \frac{2T}{hdg} = \frac{2 \times 7.2 \times 10^{-2}}{3 \times 10^{-2} \times 10^3 \times 10} = 4.8 \times 10^{-4}$

$\therefore d = 2r = 9.6 \times 10^{-4}\ m$

36. (c) $h = \frac{2T}{rdg} \Rightarrow r = \frac{2T}{hdg} = \frac{2 \times 75 \times 10^{-3}}{15 \times 10^{-3} \times 10^3 \times 10} = 1mm$

37. (d) $h \propto \frac{1}{r}$

38. (a)

39. (a)

40. (b) Mass of liquid in capillary tube

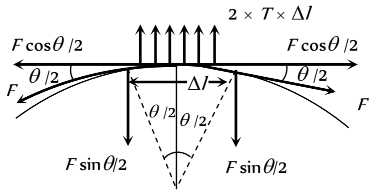
$M = \pi R^2 H \times \rho \therefore M \propto R^2 \times \left(\frac{1}{R}\right)$ (As $H \propto 1/R$)

$\therefore$ M $\propto R$. If radius becomes double then mass will becomes twice.

41. (c) $h \propto \frac{1}{r} \Rightarrow \frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{D_1}{D_2} = 2 \Rightarrow h_2 = 2h_1$

Critical Thinking Questions

1. (d) Suppose tension in thread is F, then for small part Δl of thread



$\Delta l = R\theta$ and $2F\sin\theta/2 = 2T\Delta l = 2TR\theta$

$\Rightarrow F = \frac{TR\theta}{\sin\theta/2} = \frac{TR\theta}{\theta/2} = 2TR(\sin\theta/2 \approx \theta/2)$

2. (c) Rise in temperature, $\Delta\theta = \frac{3T}{JSd}\left(\frac{1}{r} - \frac{1}{R}\right)$

$\therefore \Delta\theta = \frac{3T}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$ (For water $S = 1$ and $d = 1$)

3. (b,c) $P_{Bottom} > P_{Surface}$. So bubble rises upward.

At constant temperature $V \propto \frac{1}{P}$ (Boyle's law)

Since as the bubble rises upward, pressure decreases, then from above law volume of bubble will increase *i.e.* its size increases.

4. (d) In the satellite, the weight of the liquid column is zero. So the liquid will rise up to the top of the tube.

Graphical Questions

1. (b) $h = \frac{2T\cos\theta}{rdg} \therefore h \propto \frac{1}{r}$. So the graph between h and r will be rectangular hyperbola.

2. (a) $\Delta P = \frac{4T}{r} \therefore \Delta P \propto \frac{1}{r}$

As radius of soap bubble increases with time $\therefore \Delta P \propto \frac{1}{t}$

3. (b) $T_c = T_o(1 - \alpha t)$ *i.e.* surface tension decreases with increase in temperature.

Assertion and Reason

1. (c) When a liquid is sprayed, the surface area of the liquid increases. Therefore, work has to be done in spraying the liquid, which is directly proportional to the surface tension.

Because on adding soap, surface tension of water decreases, the spraying of water becomes easy.

2. (e) The soap solution, has less surface tension as compared to ordinary water and its surface tension decreases further on heating. The hot soap solution can, therefore spread over large surface area and also it has more wetting power. It is on account of this property that hot soap solution can penetrate and clean the clothes better than the ordinary water.

3. (a) $h = \frac{2T}{Rdg} \Rightarrow hR = \frac{2T}{Rdg}$ $\therefore$ $hR = \text{constant}$

Hence when the tube is of insufficient length, radius of curvature of the liquid meniscus increases, so as to maintain the product hR a finite constant.

i.e. as h decreases, R increases and the liquid meniscus becomes more and more flat, but the liquid does not overflow.

4. (c) Needle floats due to surface tension there is no role of buoyant force in its floating

Buoyant force = $V\sigma g$

Where V = volume of body submerged in liquid

σ = density of liquid.

i.e. the buoyancy of an object depends on the shape of the object.

5. (c) The two glass plates stick together due to surface tension.

6. (e) The presence of impurities either on the liquid surface or dissolved in it, considerably affect the force of surface tension, depending upon the degree of contamination. A highly soluble substance like sodium chloride when dissolved in water increase the surface tension. But the sparing soluble or substance like phenol when dissolved in water reduces the surface tension of water.

7. (c) With increase in temperature surface tension of the liquid decreases and angle of contact also decreases.

8. (b) We know that the intermolecular distance between the gas molecules is large as compared to that of liquid. Due to it the forces of cohesion in the gas molecules are very small and these are quite large for liquids. Therefore, the concept of surface tension is applicable to liquid but not to gases.

9. (a) Zero surface tension means no opposition to expansion.

10. (a) Since the excess pressure due to surface tension is inversely proportional to its radius, it follows that smaller the bubble, greater is the excess pressure. Thus, when the larger and the smaller bubbles are put in communication, air starts passing from the smaller into the large bubble because excess pressure inside the former is greater than inside the latter. As a result, the smaller bubble shrinks and the larger one swells.

11. (b) When a drop of liquid is poured on a glass plate, the shape of the drop is governed by two forces, the force of gravity. For very small drops, the potential energy due to gravity is insignificant compared to that due to surface tension. Hence, in this case the shape of the drop is determined by surface tension alone and drop becomes spherical.

12. (a) The height of capillary rise is inversely proportional to radius (or diameter) of capillary tube *i.e.* $h \propto \frac{1}{r}$

So for smaller r the value of h is higher.

13. (c) With increase in temperature of liquid its surface tension decreases so that it tends to acquire larger area. Hence hot soup having low value of surface tension spread properly on our tongue & provides better taste than cold soup.

14. (b) The free surface of liquid tries to acquire a minimum area due to surface tension, hence liquid drop is spherical because sphere has minimum area than other shape.

Surface Tension

SET Self Evaluation Test - 10

1. A soap film of surface tension $3\times10^{-2}\,Nm^{-1}$ formed in rectangular frame, can support a straw. The length of the film is 10 *cm*. Mass of the straw the film can support is

(a) 0.06 *gm* (b) 0.6 *gm*

(c) 6 *gm* (d) 60 *gm*

2. Energy required to form a soap bubble of diameter 20 *cm* will be (Surface tension for soap solution is 30 *dynes/cm*)

(a) 12000 π *ergs* (b) 1200 π *ergs*

(c) 2400 π *ergs* (d) 24000 π *ergs*

3. If the work done in blowing a bubble of volume V is W, then the work done in blowing the bubble of volume $2V$ from the same soap solution will be [MP PET 1989]

(a) $W/2$ (b) $\sqrt{2}\ W$

(c) $\sqrt[3]{2}\ W$ (d) $\sqrt[3]{4}\ W$

4. Surface tension of soap solution is 2×10^{-2} *N/m*. The work done in producing a soap bubble of radius 2 *cm* is

(a) $64\pi\times10^{-6}\,J$ (b) $32\pi\times10^{-6}\,J$

(c) $16\pi\times10^{-6}\,J$ (d) $8\pi\times10^{-6}\,J$

5. Excess pressure inside a soap bubble is three times that of the other bubble, then the ratio of their volumes will be

(a) 1 : 3 (b) 1 : 9

(c) 1 : 27 (d) 1 : 81

6. When a capillary tube is dipped in water it rises upto 8 *cm* in the tube. What happens when the tube is pushed down such that its end is only 5 *cm* above the outside water level

(a) The radius of the meniscus increases and therefore water does not overflow

(b) The radius of the meniscus decreases and therefore water does not overflow

(c) The water forms a droplet on top of the tube but does not overflow

(d) The water start overflowing

7. A bubble of 8 mm diameter is formed in the air. The surface tension of soap solution is 30 *dynes/cm*. The excess pressure inside the bubble is [MP PET 1990]

(a) 150 *dynes/cm* (b) 300 *dynes/cm*

(c) 3×10^{-3} *dynes/cm* (d) 12 *dynes/cm*

8. The height upto which water will rise in a capillary tube will be

(a) Maximum when water temperature is $4°C$

(b) Maximum when water temperature is $0°C$

(c) Minimum when water temperature is $4°C$

(d) Same at all temperatures

9. Water rises to a height of 10 *cm* in capillary tube and mercury falls to a depth of 3.112 *cm* in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the ratio of surface tension of water and mercury is

(a) 1 : 0.15 (b) 1 : 3

(c) 1 : 6 (d) 1.5 : 1

10. The angle of contact between glass and water is 0° and it rises in a capillary upto 6 *cm* when its surface tension is 70 *dynes/cm*. Another liquid of surface tension 140 *dynes/cm*, angle of contact 60° and relative density 2 will rise in the same capillary by

(a) 12 *cm* (b) 24 *cm*

(c) 3 *cm* (d) 6 *cm*

11. A drop of water breaks into two droplets of equal size. In this process, which of the following statement is correct [NCERT 1976]

(a) The sum of temperature of the two droplets together is equal to the original temperature of the drop

(b) The sum of masses of the two droplets is equal to the original mass of the drop

(c) The sum of the radii of two droplets is equal to the radius of the original drop

(d) The sum of the surface areas of the two droplets is equal to the surface area of the original drop

12. A soap bubble of radius R is blown. After heating the solution a second bubble of radius $2R$ is blown. The work required to blow the second bubble in comparison to that required for the first bubble is

(a) Double

(b) Slightly less than double

(c) Slightly less than four times

(d) Slightly more than four times

13. A false statement is

(a) Angle of contact $\theta < 90°$, if cohesive force < adhesive force

(b) Angle of contact $\theta > 90°$, , if cohesive force > adhesive force

(c) Angle of contact θ = 90°, if cohesive force = adhesive force

(d) If the radius of capillary is reduced to half, the rise of liquid column becomes four times

14. The diameter of rain-drop is 0.02 *cm*. If surface tension of water be 72×10^{-3} *newton* per *metre*, then the pressure difference of external and internal surfaces of the drop will be

(a) $1.44\times10^{4}\ dyne-cm^{-2}$

(b) $1.44\times10^{4}\ newton-m^{-2}$

(c) $1.44 \times 10^3\ dyne - cm^{-2}$

(d) $1.44 \times 10^5\ newton - m^{-2}$

15. Water rises to a height of 16.3 *cm* in a capillary of height 18 *cm* above the water level. If the tube is cut at a height of 12 *cm*

(a) Water will come as a fountain from the capillary tube

(b) Water will stay at a height of 12 *cm* in the capillary tube

(c) The height of the water in the capillary will be 10.3 *cm*

(d) Water will flow down the sides of the capillary tube

[CPMT 1974]

Answers and Solutions

(SET - 10)

1. (b) The weight of straw will be balanced by the force of surface tension $\therefore\ mg = 2Tl \Rightarrow m = \frac{2Tl}{g}$

$$= \frac{2 \times 3 \times 10^{-2} \times 10 \times 10^{-2}}{9.8} kg = 0.6 gm$$

2. (d) $E = 8\pi r^2 T = 8\pi (10)^2 \times 30 = 24000\ \pi\ erg$

3. (d) Work done to form a soap bubble

$W = 8\pi R^2 T$ (As $V \propto R^3\ \therefore\ R \propto V^{1/3}$)

$\therefore\ W \propto V^{2/3}$

$$\frac{W_2}{W_1} = \left(\frac{V_2}{V_1}\right)^{2/3} = (2)^{2/3} \Rightarrow W_2 = (4)^{1/3} W$$

4. (a) $W = 8\pi R^2 T = 8 \times \pi \times (2 \times 10^{-2})^2 \times 2 \times 10^{-2} = 64\pi \times 10^{-6}\ J$

5. (c) $\Delta P \propto \frac{1}{r} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{r_2}{r_1} \Rightarrow \frac{r_2}{r_1} = \frac{3}{1}$

$\therefore \frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{3}\right)^3 = \frac{1}{27}$

6. (a) $h = \frac{2T}{Rdg} \Rightarrow hR = \frac{2T}{dg} = \text{constant}$

When h decreases, R increases.

7. (b) $\Delta P = \frac{4T}{r} = \frac{4 \times 30}{0.4} = 300\ dyne/cm^2$.

8. (c) $h = \frac{2T\cos\theta}{rdg}$. For water, density is maximum at 4^oC, so the height is minimum at 4^oC.

***

9. (c) $h = \frac{2T\cos\theta}{rdg} \therefore T = \frac{hrdg}{2\cos\theta}$

$\Rightarrow \frac{T_1}{T_2} = \frac{h_1}{h_2} \times \frac{r_1}{r_2} \times \frac{d_1}{d_2} \times \frac{\cos\theta_2}{\cos\theta_1} = \frac{1}{6}$

10. (c) $h = \frac{2T\cos\theta}{rdg} \therefore \frac{h_2}{h_1} = \frac{T_2}{T_1} \times \frac{\cos\theta_2}{\cos\theta_1} \times \frac{d_1}{d_2} \times \frac{r_1}{r_2}$

$\frac{h_2}{h_1} = \frac{140}{70} \times \frac{\cos 60°}{\cos 0°} \times \frac{1}{2} \times 1 = \frac{1}{2} \Rightarrow h_2 = \frac{h_1}{2} = 3cm.$

11. (b)

12. (c) Work done to form a bubble of radius R

$W_1 = 8\pi R^2 T_1$

Work done to form a bubble of radius $2R$

$W_2 = 8\pi(2R)^2 T_2 = 32\pi R^2 T_2 \therefore \frac{W_1}{W_2} = \frac{T_1}{4T_2}$

If surface tension of soap solution is same then

$W_2 = 4W_1$

But in the problem temperature of solution is increased so its surface tension decreases.

$\therefore W_2 < 4W_1$

13. (d) If radius of capillary is reduced to half, the rise of liquid column will be two times. as $h \propto 1/r$

14. (a) $\Delta P = \frac{2T}{r} = \frac{2 \times 72 \times 10^{-3}}{0.01 \times 10^{-2}} = 1440\ N/m^2$

$= 1.44 \times 10^4\ dyne/cm^2$

15. (b) Because if the length available is less than required, then water will rise upto available height and adjust its radius of curvature.

Chapter
11
Fluid Mechanics

Fluid is the name given to a substance which begins to flow when external force is applied on it. Liquids and gases are fluids. Fluids do not have their own shape but take the shape of the containing vessel. The branch of physics which deals with the study of fluids at rest is called hydrostatics and the branch which deals with the study of fluids in motion is called hydrodynamics.

Pressure

The normal force exerted by liquid at rest on a given surface in contact with it is called thrust of liquid on that surface.

The normal force (or thrust) exerted by liquid at rest per unit area of the surface in contact with it, is called pressure of liquid or hydrostatic pressure.

If F be the normal force acting on a surface of area A in contact with liquid, then pressure exerted by liquid on this surface is $P = F/A$

(1) Units : N/m^2 or Pascal (S.I.) and Dyne/cm (C.G.S.)

(2) Dimension : $[P] = \frac{[F]}{[A]} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

(3) At a point pressure acts in all directions and a definite direction is not associated with it. So pressure is a tensor quantity.

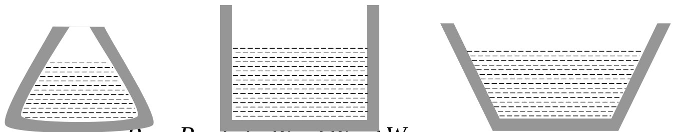
(4) Atmospheric pressure : The gaseous envelope surrounding the earth is called the earth's atmosphere and the pressure exerted by the atmosphere is called atmospheric pressure. Its value on the surface of the earth at sea level is nearly $1.013 \times 10^5 N/m^2$ or Pascal in S.I., other practical units of pressure are atmosphere, bar and torr (*mm* of *Hg*)

$$1atm = 1.01 \times 10^5 Pa = 1.01 \text{bar} = 760 \text{ torr}$$

The atmospheric pressure is maximum at the surface of earth and goes on decreasing as we move up into the earth's atmosphere.

(5) If P_0 is the atmospheric pressure then for a point at depth h below the surface of a liquid of density ρ, hydrostatic pressure P is given by $P = P_0 + h\rho g$

(6) Hydrostatic pressure depends on the depth of the point below the surface (h), nature of liquid (ρ) and acceleration due to gravity (g) while it is independent of the amount of liquid, shape of the container or cross-sectional area considered. So if a given liquid is filled in vessels of different shapes to same height, the pressure at the base in each vessel's will be the same, though the volume or weight of the liquid in different vessels will be different.



$P_A = P_B = P_C$ but $W_A < W_B < W_C$

Fig. 11.2

(7) In a liquid at same level, the pressure will be same at all points, if not, due to pressure difference the liquid cannot be at rest. This is why the height of liquid is the same in vessels of different shapes containing different amounts of the same liquid at rest when they are in communication with each other.

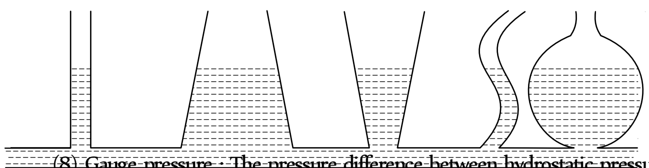


Fig. 11.3

(8) Gauge pressure : The pressure difference between hydrostatic pressure P and atmospheric pressure P_0 is called gauge pressure.

$$P - P_0 = h\rho g$$

Density

In a fluid, at a point, density ρ is defined as:

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V} = \frac{dm}{dV}$$

(1) In case of homogenous isotropic substance, it has no directional properties, so is a scalar.

(2) It has dimensions $[ML^{-3}]$ and S.I. unit *kg/m* while C.G.S. unit *g/cc* with $1 g/cc = 10^3 kg/m^3$

(3) Density of substance means the ratio of mass of substance to the volume occupied by the substance while density of a body means the ratio of mass of a body to the volume of the body. So for a solid body.

Density of body = Density of substance

While for a hollow body, density of body is lesser than that of substance $[\text{As } V_{\text{body}} > V_{\text{sub.}}]$

(4) When immiscible liquids of different densities are poured in a container, the liquid of highest density will be at the bottom while that of lowest density at the top and interfaces will be plane.

(5) Sometimes instead of density we use the term relative density or specific gravity which is defined as :

$$RD = \frac{\text{Density of body}}{\text{Density of water}}$$

(6) If m_1 mass of liquid of density ρ_1 and m_2 mass of density ρ_2 are mixed, then as

$$m = m_1 + m_2 \text{ and } V = (m_1/\rho_1) + (m_2/\rho_2)$$

$$[\text{As } V = m/\rho]$$

$$\rho = \frac{m}{V} = \frac{m_1 + m_2}{(m_1/\rho_1) + (m_2/\rho_2)} = \frac{\Sigma m_i}{\Sigma(m_i/\rho_i)}$$

If $m_1 = m_2$ $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ = Harmonic mean

(7) If V_1 volume of liquid of density ρ_1 and V_2 volume of liquid of density ρ_2 are mixed, then as:

$$m = \rho_1 V_1 + \rho_2 V_2 \text{ and } V = V_1 + V_2 \quad [\text{As } \rho = m/V]$$

If $V_1 = V_2 = V$ $\rho = (\rho_1 + \rho_2)/2$ = Arithmetic Mean

(8) With rise in temperature due to thermal expansion of a given body, volume will increase while mass will remain unchanged, so density will decrease, *i.e.*,

$$\frac{\rho}{\rho_0} = \frac{(m/V)}{(m/V_0)} = \frac{V_0}{V} = \frac{V_0}{V_0(1 + \gamma\Delta\theta)} \quad [\text{As } V = V_0(1 + \gamma\Delta\theta)]$$

or $\rho = \frac{\rho_0}{(1 + \gamma\Delta\theta)} \simeq \rho_0(1 - \gamma\Delta\theta)$

(9) With increase in pressure due to decrease in volume, density will increase, *i.e.,*

$$\frac{\rho}{\rho_0} = \frac{(m/V)}{(m/V_0)} = \frac{V_0}{V} \quad [\text{As } \rho = \frac{m}{V}]$$

But as by definition of bulk-modulus

$$B = -V_0 \frac{\Delta p}{\Delta V} \text{ i.e., } V = V_0\left[1 - \frac{\Delta p}{B}\right]$$

So $\rho = \rho_0\left(1 - \frac{\Delta p}{B}\right)^{-1} \simeq \rho_0\left(1 + \frac{\Delta p}{B}\right)$

Pascal's Law

It states that if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.

or

The increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of the liquid and also to the walls of the container, provided the effect of gravity is neglected.

Example : Hydraulic lift, hydraulic press and hydraulic brakes

Working of hydraulic lift : It is used to lift the heavy loads. If a small force *f* is applied on piston of *C* then the pressure exerted on the liquid

$P = f/a$ [*a* = Area of cross section of the piston in *C*]

This pressure is transmitted equally to piston of cylinder *D*.

Hence the upward force acting on piston of cylinder *D*.

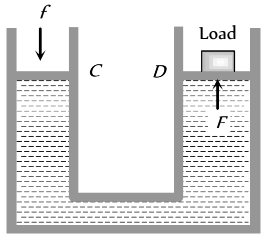


Fig. 11.4

$$F = PA = \frac{f}{a}A = f\left(\frac{A}{a}\right)$$

As $A >> a$, therefore $F >> f$. So heavy load placed on the larger piston is easily lifted upwards by applying a small force.

Archimedes Principle

Accidentally Archimedes discovered that when a body is immersed partly or wholly in a fluid, at rest, it is buoyed up with a force equal to the weight of the fluid displaced by the body. This principle is called Archimedes principle and is a necessary consequence of the laws of fluid statics.

When a body is partly or wholly dipped in a fluid, the fluid exerts force on the body due to hydrostatic pressure. At any small portion of the surface of the body, the force exerted by the fluid is perpendicular to the surface and is equal to the pressure at that point multiplied by the area. The resultant of all these constant forces is called upthrust or buoyancy.

To determine the magnitude and direction of this force consider a body immersed in a fluid of density σ as shown in figure. The forces on the vertical sides of the body will cancel each other. The top surface of the body will experience a downward force.

$$F_1 = AP_1 = A(h_1\sigma g + P_0) \quad [\text{As } P = h\sigma g + P_0]$$

While the lower face of the body will experience an upward force.

$$F_2 = AP_2 = A(h_2\sigma g + P_0)$$

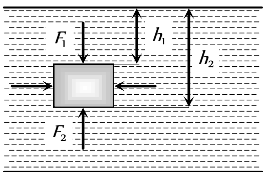


Fig. 11.5

As $h_2 > h_1$, F_2 will be greater than F_1, so the body will experience a net upward force

$$F = F_2 - F_1 = A\sigma g(h_2 - h_1)$$

If *L* is the vertical height of the body $F = A\sigma gL = V\sigma g$

$$[\text{As } V = AL = A(h_2 - h_1)]$$

i.e., *F* = Weight of fluid displaced by the body.

This force is called upthrust or buoyancy and acts vertically upwards (opposite to the weight of the body) through the centre of gravity of displaced fluid (called centre of buoyancy). Though we have derived this result for a body fully submerged in a fluid, it can be shown to hold good for partly submerged bodies or a body in more than one fluid also.

(1) Upthrust is independent of all factors of the body such as its mass, size, density etc. except the volume of the body inside the fluid.

(2) Upthrust depends upon the nature of displaced fluid. This is why upthrust on a fully submerged body is more in sea water than in fresh water because its density is more than fresh water.

(3) Apparent weight of the body of density (ρ) when immersed in a liquid of density (σ).

Apparent weight = Actual weight – Upthrust $= W - F_{up}$

$$= V\rho g - V\sigma g = V(\rho - \sigma)g = V\rho g\left(1 - \frac{\sigma}{\rho}\right)$$

$$\therefore \quad W_{APP} = W\left(1 - \frac{\sigma}{\rho}\right)$$

(4) If a body of volume V is immersed in a liquid of density σ then its weight reduces.

W_1 = Weight of the body in air, W_2 = Weight of the body in water

Then apparent (loss of weight) weight $W_1 - W_2 = V\sigma g$

$$\therefore \quad V = \frac{W_1 - W_2}{\sigma g}$$

(5) Relative density of a body

$$(\text{R.D.}) = \frac{\text{density of body}}{\text{density of water}}$$

$$= \frac{\text{Weight of body}}{\text{Weight of equal volume of water}} = \frac{\text{Weight of body}}{\text{Water thrust}}$$

$$= \frac{\text{Weight of body}}{\text{Loss of weight in water}}$$

$$= \frac{\text{Weight of body in air}}{\text{Weight in air} - \text{weight in water}} = \frac{W_1}{W_1 - W_2}$$

(6) If the loss of weight of a body in water is 'a' while in liquid is 'b'

$$\therefore \frac{\sigma_L}{\sigma_W} = \frac{\text{Upthrust on body in liquid}}{\text{Upthrust on body in water}}$$

$$= \frac{\text{Loss of weight in liquid}}{\text{Loss of weight in water}} = \frac{a}{b} = \frac{W_{\text{air}} - W_{\text{liquid}}}{W_{\text{air}} - W_{\text{water}}}$$

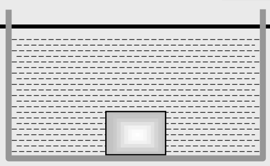
Floatation

(1) **Translatory equilibrium :** When a body of density ρ and volume V is immersed in a liquid of density σ, the forces acting on the body are

Weight of body $W = mg = V\rho g$, acting vertically downwards through centre of gravity of the body.

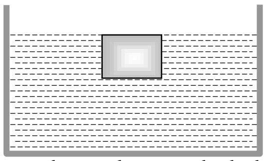
Upthrust force = $V\sigma g$ acting vertically upwards through the centre of gravity of the displaced liquid *i.e.*, centre of buoyancy.

If density of body is greater than that of liquid $\rho > \sigma$



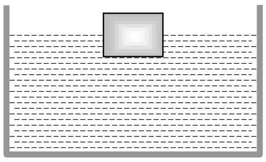
Weight will be more than upthrust so the body will sink

If density of body is equal to that of liquid $\rho = \sigma$



Weight will be equal to upthrust so the body will float fully submerged in neutral equilibrium with its top surface in it just at the top of liquid

If density of body is lesser than that of liquid $\rho < \sigma$



Weight will be less than upthrust so the body will, move upwards and in equilibrium will float and partially immersed in the liquid Such that, $W = V_{in}\sigma g \Rightarrow V\rho g = V_{in}\sigma g$

$V\rho = V_{in}\sigma$ Where V_{in} is the volume of body in the liquid

(i) A body will float in liquid only and only if $\rho \le \sigma$

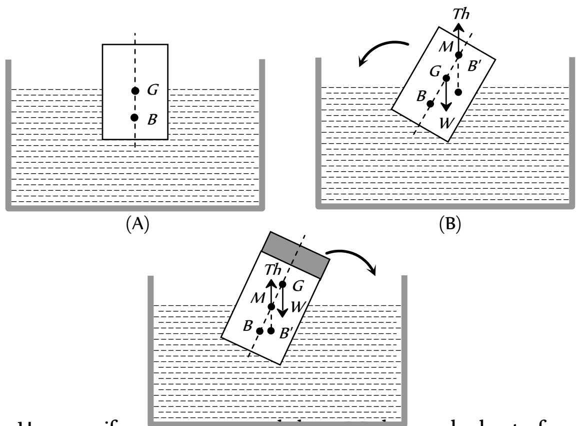
(ii) In case of floating as weight of body = upthrust

So W_{App} = Actual weight – upthrust = 0

(iii) In case of floating $V\rho g = V_{in}\sigma g$

So the equilibrium of floating bodies is unaffected by variations in g though both thrust and weight depend on g.

(2) **Rotatory Equilibrium :** When a floating body is slightly tilted from equilibrium position, the centre of buoyancy B shifts. The vertical line passing through the new centre of buoyancy B' and initial vertical line meet at a point M called meta-centre. If the meta-centre M is above the centre of gravity the couple due to forces at G (weight of body W) and at B' (upthrust) tends to bring the body back to its original position. So for rotational equilibrium of floating body the meta-centre must always be higher than the centre of gravity of the body.



(C)

Fig. 11.6

However, if meta-centre goes below CG, the couple due to forces at G and B' tends to topple the floating body.

That is why a wooden log cannot be made to float vertical in water or a boat is likely to capsize if the sitting passengers stand on it. In these situations *CG* becomes higher than *MG* and so the body will topple if slightly tilted.

(3) **Application of floatation**

(i) When a body floats then the weight of body = Upthrust

$$V\rho g = V_{in}\sigma g \Rightarrow V_{in} = \left(\frac{\rho}{\sigma}\right)V$$

$$\therefore \; V_{\text{out}} = V - V_{in} = \left(1 - \frac{\rho}{\sigma}\right)V$$

i.e., Fraction of volume outside the liquid $f_{\text{out}} = \frac{V_{\text{out}}}{V} = \left[1 - \frac{\rho}{\sigma}\right]$

(ii) For floatation $V\rho = V_{in}\sigma \Rightarrow \rho = \frac{V_{in}}{V}\sigma = f_{in}\sigma$

If two different bodies *A* and *B* are floating in the same liquid then $\frac{\rho_A}{\rho_B} = \frac{(f_{in})_A}{(f_{in})_B}$

(iii) If the same body is made to float in different liquids of densities σ_A and σ_B respectively.

$$V\rho = (V_{in})_A\sigma_A = (V_{in})_B\sigma_B \qquad \therefore \qquad \frac{\sigma_A}{\sigma_B} = \frac{(V_{in})_B}{(V_{in})_A}$$

(iv) If a platform of mass *M* and cross-section *A* is floating in a liquid of density σ with its height *h* inside the liquid

$$Mg = hA\sigma g \qquad \text{...(i)}$$

Now if a body of mass *m* is placed on it and the platform sinks by *y* then

$$(M + m)g = (y + h)A\sigma g \qquad \text{...(ii)}$$

Subtracting equation (i) from (ii),

$$mg = A\sigma y g, \; i.e., \; W \propto y \qquad \text{...(iii)}$$

So we can determine the weight of a body by placing it on a floating platform and noting the depression of the platform in the liquid by it.

Streamline, Laminar and Turbulent Flow

(1) **Stream line flow :** Stream line flow of a liquid is that flow in which each element of the liquid passing through a point travels along the same path and with the same velocity as the preceding element passes through that point.

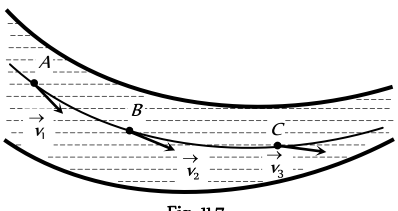


Fig. 11.7

A streamline may be defined as the path, straight or curved, the tangent to which at any point gives the direction of the flow of liquid at that point.

The two streamlines cannot cross each other and the greater is the crowding of streamlines at a place, the greater is the velocity of liquid particles at that place.

Path *ABC* is streamline as shown in the figure and v_1, v_2 and v_3 are the velocities of the liquid particles at *A*, *B* and *C* point respectively.

(2) **Laminar flow :** If a liquid is flowing over a horizontal surface with a steady flow and moves in the form of layers of different velocities which do not mix with each other, then the flow of liquid is called laminar flow.

In this flow, the velocity of liquid flow is always less than the critical velocity of the liquid. The laminar flow is generally used synonymously with streamlined flow.

(3) **Turbulent flow :** When a liquid moves with a velocity greater than its critical velocity, the motion of the particles of liquid becomes disordered or irregular. Such a flow is called a turbulent flow.

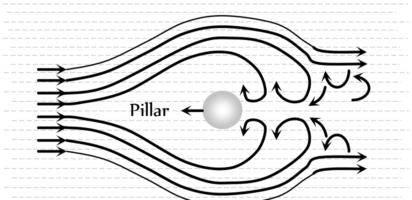


Fig. 11.8

In a turbulent flow, the path and the velocity of the particles of the liquid change continuously and haphazardly with time from point to point. In a turbulent flow, most of the external energy maintaining the flow is spent in producing eddies in the liquid and only a small fraction of energy is available for forward flow. For example, eddies are seen by the sides of the pillars of a river bridge.

Critical Velocity and Reynold's Number

The critical velocity is that velocity of liquid flow upto which its flow is streamlined and above which its flow becomes turbulent.

Reynold's number is a pure number which determines the nature of flow of liquid through a pipe.

It is defined as the ratio of the inertial force per unit area to the viscous force per unit area for a flowing fluid.

$$N_R = \frac{\text{Inertial force per unit area}}{\text{Viscous force per unit area}}$$

If a liquid of density ρ is flowing through a tube of radius *r* and cross section *A* then mass of liquid flowing through the tube per second $\frac{dm}{dt}$ = volume flowing per second × density = $Av \times \rho$

$\therefore$ Inertial force per unit area = $\frac{dp/dt}{A} = \frac{v(dm/dt)}{A} = \frac{v\,Av\,\rho}{A} = v^2\rho$

Viscous force per unit area $F/A = \frac{\eta v}{r}$

So by the definition of Reynolds number

$$N_R = \frac{\text{Inertial force per unit area}}{\text{Viscous force per unit area}} = \frac{v^2\rho}{\eta v / r} = \frac{v\rho r}{\eta}$$

If the value of Reynold's number

(i) Lies between 0 to 2000, the flow of liquid is streamline or laminar.

(ii) Lies between 2000 to 3000, the flow of liquid is unstable and changing from streamline to turbulent flow.

(iii) Above 3000, the flow of liquid is definitely turbulent.

Equation of Continuity

The equation of continuity is derived from the principle of conservation of mass.

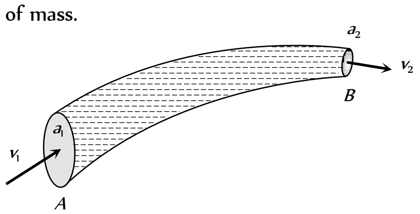


Fig. 11.9

A non-viscous liquid in streamline flow passes through a tube *AB* of varying cross section. Let the cross sectional area of the pipe at points *A* and *B* be a_1 and a_2 respectively. Let the liquid enter with normal velocity v_1 at *A* and leave with velocity v_2 at *B*. Let ρ_1 and ρ_2 be the densities of the liquid at point *A* and *B* respectively.

Mass of the liquid entering per second at *A* = Mass of the liquid leaving per second at *B*

$a_1 v_1 \rho_1 = a_2 v_2 \rho_2$ and $a_1 v_1 = a_2 v_2$

[If the liquid is incompressible $\rho_2 = \rho_1$]

or $av =$ constant or $a \propto \frac{1}{v}$

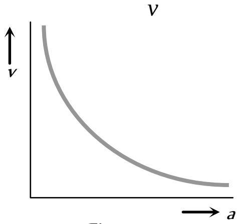


Fig. 11.10

This expression is called the equation of continuity for the steady flow of an incompressible and non-viscous liquid.

(1) The velocity of flow is independent of the liquid (assuming the liquid to be non-viscous)

(2) The velocity of flow will increase if cross-section decreases and vice-versa. That is why :

(a) In hilly region, where the river is narrow and shallow (*i.e.,* small cross-section) the water current will be faster, while in plains where the river is wide and deep (*i.e.*, large cross-section) the current will be slower, and so deep water will appear to be still.

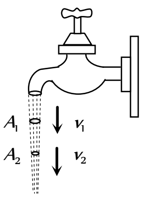


Fig. 11.11

(b) When water falls from a tap, the velocity of falling water under the action of gravity will increase with distance from the tap (*i.e,* $v_2 > v_1$). So in accordance with continuity equation the cross section of the water stream will decrease (*i.e.,* $A_2 < A_1$), *i.e.,* the falling stream of water becomes narrower.

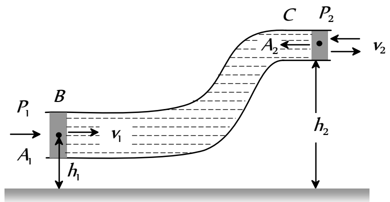
Energy of a Flowing Fluid

A flowing fluid in motion possesses the following three types of energy

Pressure Energy	Potential energy	Kinetic energy
It is the energy possessed by a liquid by virtue of its pressure. It is the measure of work done in pushing the liquid against pressure without imparting any velocity to it.	It is the energy possessed by liquid by virtue of its height or position above the surface of earth or any reference level taken as zero level.	It is the energy possessed by a liquid by virtue of its motion or velocity.
Pressure energy of the liquid PV	Potential energy of the liquid mgh	Kinetic energy of the liquid $\frac{1}{2}mv^2$
Pressure energy per unit mass of the liquid $\frac{P}{\rho}$	Potential energy per unit mass of the liquid gh	Kinetic energy per unit mass of the liquid $\frac{1}{2}v^2$
Pressure energy per unit volume of the liquid P	Potential energy per unit volume of the liquid ρgh	Kinetic energy per unit volume of the liquid $\frac{1}{2}\rho v^2$

Bernoulli's Theorem

According to this theorem the total energy (pressure energy, potential energy and kinetic energy) per unit volume or mass of an incompressible and non-viscous fluid in steady flow through a pipe remains constant throughout the flow, provided there is no source or sink of the fluid along the length of the pipe.



Mathematically for unit volume of liquid flowing through a pipe.

Fig. 11.12

$$P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$$

To prove it, consider a liquid flowing steadily through a tube of non-uniform area of cross-section as shown in fig. If P_1 and P_2 are the pressures at the two ends of the tube respectively, work done in pushing the volume *V* of incompressible fluid from point B to C through the tube will be

$$W = P_1 V - P_2 V = (P_1 - P_2)V \quad \text{...(i)}$$

This work is used by the fluid in two ways.

(a) In changing the potential energy of mass *m* (in the volume *V*) from mgh_1 to mgh_2

i.e., $\Delta U = mg(h_2 - h_1)$ ...(ii)

(b) In changing the kinetic energy from $\frac{1}{2}mv_1^2$ to $\frac{1}{2}mv_2^2$,

i.e., $\Delta K = \frac{1}{2}m(v_2^2 - v_1^2)$ ...(iii)

Now as the fluid is non-viscous, by conservation of mechanical energy

$W = \Delta U + \Delta K$

i.e., $(P_1 - P_2)V = mg(h_2 - h_1) + \frac{1}{2}m(v_2^2 - v_1^2)$

or $P_1 - P_2 = \rho g(h_2 - h_1) + \frac{1}{2}\rho(v_2^2 - v_1^2)$ [As $\rho = m/V$]

or $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

or $P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$

This equation is the so called Bernoulli's equation and represents conservation of mechanical energy in case of moving fluids.

(i) Bernoulli's theorem for unit mass of liquid flowing through a pipe can also be written as:

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = \text{constant}$$

(ii) Dividing above equation by g we get $\frac{P}{\rho g} + h + \frac{v^2}{2g}$ = constant

Here $\frac{P}{\rho g}$ is called pressure head, h is called gravitational head and $\frac{v^2}{2g}$ is called velocity head. From this equation Bernoulli's theorem can be stated as.

"In stream line flow of an ideal liquid, the sum of pressure head, gravitational head and velocity head of every cross section of the liquid is constant."

Applications of Bernoulli's Theorem

(i) **Attraction between two closely parallel moving boats (or buses)**

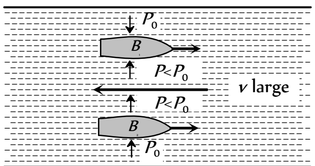


Fig. 11.13

When two boats or buses move side by side in the same direction, the water (or air) in the region between them moves faster than that on the remote sides. Consequently in accordance with *Bernoulli's principle* the pressure between them is reduced and hence due to pressure difference they are pulled towards each other creating the so called attraction.

(ii) **Working of an aeroplane**

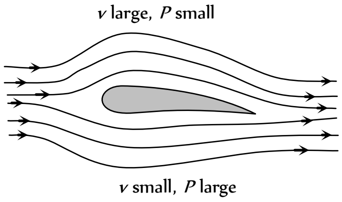


Fig. 11.14

This is also based on Bernoulli's principle. The wings of the aeroplane are of the shape as shown in fig. Due to this specific shape of wings when the aeroplane runs, air passes at higher speed over it as compared to its lower surface. This difference of air speeds above and below the wings, in accordance with Bernoulli's principle, creates a pressure difference, due to which an upward force called 'dynamic lift' (= pressure difference × area of wing) acts on the plane. If this force becomes greater than the weight of the plane, the plane will rise up.

(iii) **Action of atomiser**

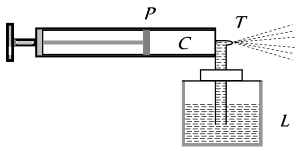


Fig. 11.15

The action of carburetor, paint-gun, scent-spray or insect-sprayer is based on Bernoulli's principle. In all these, by means of motion of a piston P in a cylinder C, high speed air is passed over a tube T dipped in liquid L to be sprayed. High speed air creates low pressure over the tube due to which liquid (paint, scent, insecticide or petrol) rises in it and is then blown off in very small droplets with expelled air.

(iv) **Blowing off roofs by wind storms**

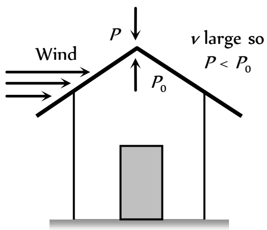


Fig. 11.16

During a tornado or hurricane, when a high speed wind blows over a straw or tin roof, it creates a low pressure (P) in accordance with Bernoulli's principle.

However, the pressure below the roof (*i.e.,* inside the room) is still atmospheric ($= P_0$). So due to this difference of pressure, the roof is lifted up and is then blown off by the wind.

(v) **Magnus effect :** When a spinning ball is thrown, it deviates from its usual path in flight. This effect is called Magnus effect and plays as important role in tennis, cricket and soccer, etc. as by applying appropriate spin the moving ball can be made to curve in any desired direction.

If a ball is moving from left to right and also spinning about a horizontal axis perpendicular to the direction of motion as shown in fig. then relative to the ball, air will be moving from right to left.

The resultant velocity of air above the ball will be $(v + r\omega)$ while below it $(v - r\omega)$. So in accordance with Bernoulli's principle pressure above the ball will be less than below it. Due to this difference of pressure an upward force will act on the ball and hence the ball will deviate from its usual path OA_0 and will hit the ground at A_1 following the path OA_1 *i.e.,* if a ball is thrown with back-spin, the pitch will curve less sharply prolonging the flight.

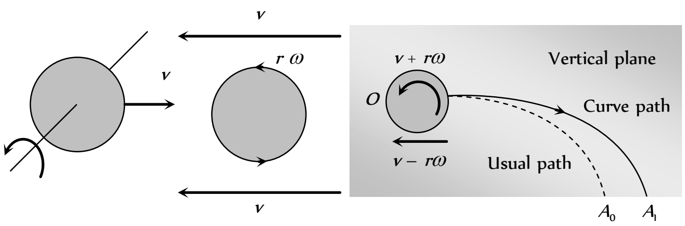


Fig. 11.17

Similarly if the spin is clockwise *i.e.,* the ball is thrown with top-spin, the force due to pressure difference will act in the direction of gravity and so the pitch will curve more sharply shortening the flight.

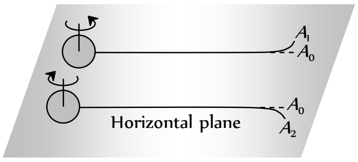


Fig. 11.18

Furthermore, if the ball is spinning about a vertical axis, the curving will be sideways as shown in producing the so called out swing or in swing.

(vi) **Venturimeter :** It is a device based on Bernoulli's theorem used for measuring the rate of flow of liquid through pipes.

It consists of two identical coaxial tubes *A* and *C* connected by a narrow co-axial tube *B*. Two vertical tubes *D* and *E* are mounted on the tubes *A* and *B* to measure the pressure of the flowing liquid.

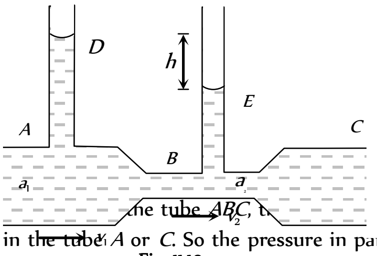


Fig. 11.19

When the ... the tube *ABC*, ... f flow in part *B* will be larger than in the tube *A* or *C*. So the pressure in part *B* will be less than that in tube *A* or *C*. By measuring the pressure difference between *A* and *B*, the rate of flow of the liquid in the tube can be calculated.

Let a_1 and a_2 are area of cross section of tube A and B respectively

v_1, v_2 = Velocity of flow of liquid through A and B respectively

P_1, P_2 = Liquid pressure at A and B respectively

$\therefore\ P_1 - P_2 = h\rho g$ ...(i)

[ρ = density of flowing liquid]

From Bernoulli's theorem for horizontal flow of liquid

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) \quad \text{...(ii)}$$

From (i) and (ii) $h\rho g = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2}\rho\left[\frac{V^2}{a_2^2} - \frac{V^2}{a_1^2}\right]$

[As $V = a_1 v_1 = a_2 v_2$]

$$\therefore\quad V^2 = \frac{2a_1^2 a_2^2 hg}{a_1^2 - a_2^2} \text{ or } V = a_1 a_2\sqrt{\frac{2hg}{a_1^2 - a_2^2}}$$

Velocity of Efflux

If a liquid is filled in a vessel up to height *H* and a hole is made at a depth *h* below the free surface of the liquid as shown in fig. then taking the level of hole as reference level (*i.e.,* zero point of potential energy) and applying Bernoulli's principle to the liquid just inside and outside the hole (assuming the liquid to be at rest inside) we get

$$\therefore\quad (P_0 + h\rho g) + 0 = P_0 + \frac{1}{2}\rho v^2 \text{ or } v = \sqrt{2gh}$$

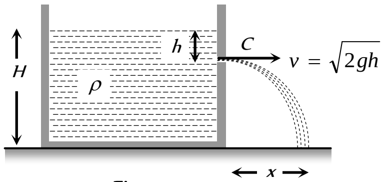


Fig. 11.20

Which is same as the speed that an object would acquire in falling from rest through a distance *h* and is called velocity of efflux or velocity of flow.

This result was first given by Torricelli, so this is known as Torricelli's theorem.

(i) The velocity of efflux is independent of the nature of liquid, quantity of liquid in the vessel and the area of orifice.

(ii) Greater is the distance of the hole from the free surface of liquid, greater will be the velocity of efflux [*i.e.,* $v \propto \sqrt{h}$]

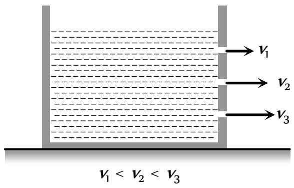


Fig. 11.21

(iii) As the vertical velocity of liquid at the orifice is zero and it is at a height $(H - h)$ from the base, the time taken by the liquid to reach the base-level $t = \sqrt{\frac{2(H-h)}{g}}$

(iv) Now during time *t* liquid is moving horizontally with constant velocity *v*, so it will hit the base level at a horizontal distance *x* (called range) as shown in figure.

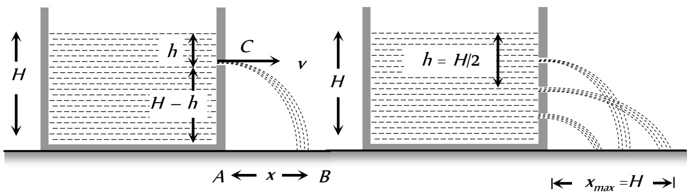


Fig. 11.22

Such that $x = vt = \sqrt{2gh} \times \sqrt{[2(H-h)/g]} = 2\sqrt{h(H-h)}$

For maximum range $\frac{dx}{dh} = 0$

$\therefore\quad h = \frac{H}{2}$

i.e., range *x* will be maximum when

$h = \frac{H}{2}$.

$\therefore$ Maximum range $x_{max} = 2\sqrt{\frac{H}{2}\left[H - \frac{H}{2}\right]} = H$

(v)

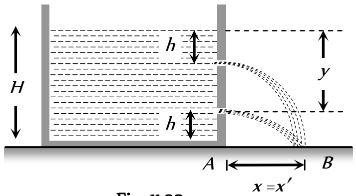


Fig. 11.23

If the level of free surface in a container is at height H from the base and there are two holes at depth h and y below the free surface, then

$$x = 2\sqrt{h(H-h)} \text{ and } x' = 2\sqrt{y(H-y)}$$

Now if $x = x'$, *i.e.*, $h(H-h) = y(H-y)$

i.e., $y^2 - Hy + h(H-h) = 0$

or $y = \frac{1}{2}[H \pm (H-2h)]$,

i.e., $y = h$ or $(H-h)$

i.e., the range will be same if the orifice is at a depth h or $(H-h)$ below the free surface. Now as the distance $(H-h)$ from top means $H-(H-h) = h$ from the bottom, so the range is same for liquid coming out of holes at same distance below the top and above the bottom.

(vi)

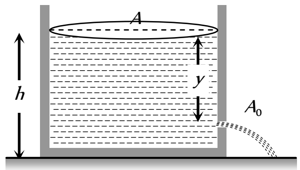


Fig. 11.24

If A_0 is the area of orifice at a depth y below the free surface and A is that of container, the volume of liquid coming out of the orifice per second will be $(dV/dt) = vA_0 = A_0\sqrt{2gy}$ [As $v = \sqrt{2gy}$]

Due to this, the level of liquid in the container will decrease and so if the level of liquid in the container above the hole changes from y to $y - dy$ in time t to $t + dt$ then $-dV = A\,dy$

So substituting this value of dV in the above equation

$$-A\frac{dy}{dt} = A_0\sqrt{2gy}$$

i.e., $\int dt = -\frac{A}{A_0}\frac{1}{\sqrt{2g}}\int y^{-1/2}dy$

So the time taken for the level to fall from H *to* H'

$$t = -\frac{A}{A_0}\frac{1}{\sqrt{2g}}\int_H^{H'} y^{-1/2}dy = \frac{A}{A_0}\sqrt{\frac{2}{g}}[\sqrt{H} - \sqrt{H'}]$$

If the hole is at the bottom of the tank, time t to make the tank empty :

$$t = \frac{A}{A_0}\sqrt{\frac{2H}{g}}$$ [As here $H' = 0$]

Viscosity and Newton's law of Viscous Force

In case of steady flow of a fluid when a layer of fluid slips or tends to slip on adjacent layers in contact, the two layer exert tangential force on each other which tries to destroy the relative motion between them. The property of a fluid due to which it opposes the relative motion between its different layers is called viscosity (or fluid friction or internal friction) and the force between the layers opposing the relative motion is called viscous force.

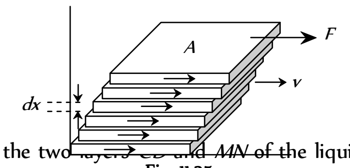


Fig. 11.25

Consider the two layers CD and MN of the liquid at distances x and $x + dx$ from the fixed surface AB, having the velocities v and $v + dv$ respectively. Then $\frac{dv}{dx}$ denotes the rate of change of velocity with distance and is known as velocity gradient.

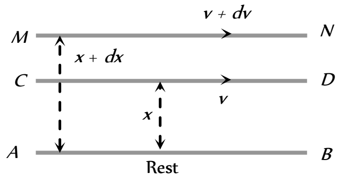


Fig. 11.26

According to Newton's hypothesis, the tangential force F acting on a plane parallel layer is proportional to the area of the plane A and the velocity gradient $\frac{dv}{dx}$ in a direction normal to the layer, *i.e.*,

$$F \propto A \quad \text{and} \quad F \propto \frac{dv}{dx}$$

$$\therefore \quad F \propto A\frac{dv}{dx}$$

or $F = -\eta A\frac{dv}{dx}$

Where η is a constant called the coefficient of viscosity. Negative sign is employed because viscous force acts in a direction opposite to the flow of liquid.

If $A = 1, \frac{dv}{dx} = 1$ then $\eta = F$.

Hence the coefficient of viscosity is defined as the viscous force acting per unit area between two layers moving with unit velocity gradient.

(1) Units : dyne-s-cm^{-2} or Poise (C.G.S. system); Newton-s-m^{-2} or Poiseuille or decapoise (S.I. system)

1 Poiseuille = 1 decapoise = 10 Poise

(2) Dimension : $[ML^{-1}T^{-1}]$

(3) Viscosity of liquid is much greater (about 100 times more) than that of gases i.e. $\eta_L > \eta_G$

Example : Viscosity of water = 0.01 Poise.

While of air = 200 μ Poise

(4) With increase in pressure, the viscosity of liquids (except water) increases while that of gases is practically independent of pressure. The viscosity of water decreases with increase in pressure.

(5) Difference between viscosity and solid friction : Viscosity differs from the solid friction in the respect that the viscous force acting between two layers of the liquid depends upon the area of the layers, the relative velocity of two layers and distance between two layers, but the friction between two solid surfaces is independent of the area of surfaces in contact and the relative velocity between them.

(6) From kinetic theory point of view viscosity represents transport of momentum, while diffusion and conduction represents transport of mass and energy respectively.

(7) The viscosity of thick liquids like honey, glycerin, coaltar *etc.* is more than that of thin liquids like water.

(8) The cause of viscosity in liquids is cohesive forces among molecules where as in gases, it is due to diffusion.

(9) The viscosity of gases increases with increase of temperature, because on increasing temperature the rate of diffusion increases.

(10) The viscosity of liquid decreases with increase of temperature, because the cohesive force between the liquid molecules decreases with increase of temperature

Relation between coefficient of viscosity and temperature; Andrade formula $\eta = \dfrac{A e^{C\rho/T}}{\rho^{-1/3}}$

Where T= Absolute temperature of liquid, ρ = density of liquid, A and C are constants.

Stoke's Law and Terminal Velocity

When a body moves through a fluid, the fluid in contact with the body is dragged with it. This establishes relative motion in fluid layers near the body, due to which viscous force starts operating. The fluid exerts viscous force on the body to oppose its motion. The magnitude of the viscous force depends on the shape and size of the body, its speed and the viscosity of the fluid. Stokes established that if a sphere of radius r moves with velocity v through a fluid of viscosity η, the viscous force opposing the motion of the sphere is

$F = 6\pi\eta r v$

This law is called Stokes law.

If a spherical body of radius r is dropped in a viscous fluid, it is first accelerated and then it's acceleration becomes zero and it attains a constant velocity called terminal velocity.

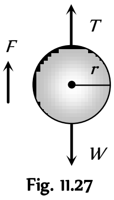


Fig. 11.27

Force on the body

(i) Weight of the body (W) = mg

= (*volume* × *density*) × $g = \frac{4}{3}\pi r^3 \rho g$

(ii) Upward thrust (T) = weight of the fluid displaced

= (*volume* × *density*) of the fluid × $g = \frac{4}{3}\pi r^3 \sigma g$

(iii) Viscous force (F) = $6\pi\eta r v$

When the body attains terminal velocity the net force acting on the body is zero. ∴ $W - T - F = 0$ or $F = W - T$

$$\Rightarrow 6\pi\eta r v = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

$$\therefore \text{ Terminal velocity } v = \frac{2}{9}\frac{r^2(\rho - \sigma) g}{\eta}$$

(i) Terminal velocity depend on the radius of the sphere so if radius is made n - fold, terminal velocity will become n times.

(ii) Greater the density of solid greater will be the terminal velocity

(iii) Greater the density and viscosity of the fluid lesser will be the terminal velocity.

(iv) If $\rho > \sigma$ then terminal velocity will be positive and hence the spherical body will attain constant velocity in downward direction.

(v) If $\rho < \sigma$ then terminal velocity will be negative and hence the spherical body will attain constant velocity in upward direction. Example : Air bubble in a liquid and clouds in sky.

(vi) Terminal velocity graph :

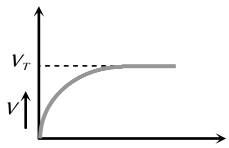


Fig. 11.28

Poiseuille's Formula

Poiseuille studied the stream-line flow of liquid in capillary tubes. He found that if a pressure difference (P) is maintained across the two ends of a capillary tube of length 'l' and radius r, then the volume of liquid coming out of the tube per second is

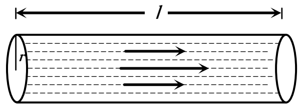


Fig. 11.29

(i) Directly proportional to the pressure difference (P).

(ii) Directly proportional to the fourth power of radius (r) of the capillary tube

(iii) Inversely proportional to the coefficient of viscosity (η) of the liquid.

(iv) Inversely proportional to the length (l) of the capillary tube.

i.e. $V \propto \dfrac{P r^4}{\eta l}$ or $V = \dfrac{K P r^4}{\eta l}$

$$\therefore V = \frac{\pi P r^4}{8\eta l}$$

[Where $K = \dfrac{\pi}{8}$ is the constant of proportionality]

This is known as Poiseuille's equation.

This equation also can be written as,

$$V = \frac{P}{R} \text{ where } R = \frac{8\eta l}{\pi r^4}$$

R is called as liquid resistance.

(1) **Series combination of tubes**

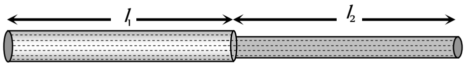


Fig. 11.30

(i) When two tubes of length l_1, l_2 and radii r_1 r_2 are connected in series across a pressure difference P,

Then $\quad P = P_1 + P_2 \quad$ ...(i)

Where P_1 and P_2 are the pressure difference across the first and second tube respectively

(ii) The volume of liquid flowing through both the tubes *i.e.* rate of flow of liquid is same.

Therefore $V = V_1 = V_2$

i.e., $$V = \frac{\pi P_1 r_1^4}{8\eta l_1} = \frac{\pi P_2 r_2^4}{8\eta l_2} \quad \text{...(ii)}$$

Substituting the value of P_1 and P_2 from equation (ii) to equation (i) we get

$$P = P_1 + P_2 = V\left[\frac{8\eta l_1}{\pi r_1^4} + \frac{8\eta l_2}{\pi r_2^4}\right]$$

$$\therefore \; V = \frac{P}{\left[\frac{8\eta l_1}{\pi r_1^4} + \frac{8\eta l_2}{\pi r_2^4}\right]} = \frac{P}{R_1 + R_2} = \frac{P}{R_{eff}}$$

Where R_1 and R_2 are the liquid resistance in tubes

(iii) Effective liquid resistance in series combination $R_{eff} = R_1 + R_2$

(2) **Parallel combination of tubes**

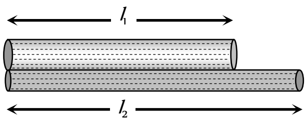


Fig. 11.31

(i) $P = P_1 = P_2$

(ii) $V = V_1 + V_2 = \dfrac{P\pi r_1^4}{8\eta l_1} + \dfrac{P\pi r_2^4}{8\eta l_2}$

$$= P\left[\frac{\pi r_1^4}{8\eta l_1} + \frac{\pi r_2^4}{8\eta l_2}\right]$$

$$\therefore \; V = P\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \frac{P}{R_{eff}}$$

(iii) Effective liquid resistance in parallel combination

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{or} \quad R_{eff} = \frac{R_1 R_2}{R_1 + R_2}$$

Tips & Tricks

✍ When a liquid is in equilibrium, the force acting on its surface is perpendicular everywhere.

✍ In a liquid, the pressure is same at the same horizontal level.

✍ Pressure at any point is same in all directions.

✍ The pressure is perpendicular to the surface of the fluid.

✍ The pressure at any point in the liquid depends on depth (h) below the surface, density of liquid and acceleration due to gravity.

It is independent of the shape of the containing vessel, or total mass of the liquid.

✍ Force is a vector quantity but pressure is a tensor quantity

✍ Pressure and density play the same role in case of fluids as force and mass play in case of solids.

✍ Bar and millibar are commonly used units for pressure in meteorology.

✍ Sudden fall in atmospheric pressure predicts possibility of a storm.

✍ Water barometer was constructed in 17th century by Von Guericke and fixed on the outside wall of his house. With the help of this barometer Von Guericke made the first recorded scientific weather forecast. He correctly predicted the severe storm after noting a sudden fall in the height of the water column.

✍ The specific gravity is also known as relative density. Thus, S.G. of a substance $= \dfrac{\text{densityof the substance}}{\text{densityof water (at } 4°C)}$

✍ If the specific gravity of the material of a body is x, then its density is

(I) $x\ g\ cm^{3}$ in C.G.S.

(Ii) $x \times 10^{3}\ kg\ m^{3}$ in SI.

✍ The number of moles in a sample of any substance containing N molecules is given by

$$\mu = \frac{N}{N_A}$$

✍ The force between atoms and molecules is electrical in nature. However, it does not obey inverse square law.

✍ If two liquids of masses m_1, m_2 and densities ρ_1, ρ_2 are mixed together, then the density of the mixture is given by

$$\rho = \frac{m_1 + m_2}{\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}}$$

✍ If two liquids of same mass but different densities are mixed together, then the density of the mixture is harmonic mean of the densities. That is

$$\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} \quad \text{or} \quad \frac{1}{\rho} = \frac{1}{2}\left[\frac{1}{\rho_1} + \frac{1}{\rho_2}\right]$$

✍ It two drops of same volume but different densities are mixed together, then the density of the mixture is arithmetic mean of the densities. That is $\rho = \dfrac{\rho_1 + \rho_2}{2}$

✍ The density of the liquid changes with pressure as follows : $\rho = \rho_0 \left[1 + \dfrac{\Delta p}{B}\right]$ where $\Delta p =$ change in pressure and B is the bulk modulus.

✍ The density of a liquid of bulk modules B at depth h is given $\rho_d = \rho_0 \left[1 + \dfrac{h\rho g}{B}\right]$

Where ρ is the average density of the liquid.

✍ The hydrometer can be used to measure density of the liquid or fluid.

✍ If a vessel contains liquid upto a height H and it has a hole in the side at a height h, then the velocity of efflux is $v = \sqrt{2g(H-h)}$. The time taken by the liquid to reach the ground level is $t = \sqrt{2h/g}$. Horizontal range of the liquid $R = 2[h(H-h)]^{1/2}$. The range is same for the hole at a height h above the bottom or at the depth h below the surface of the liquid.

The range is maximum for $h = H/2$. It is given by :

$$R_{max} = 2\left[\left(\frac{H}{2}\right)\left(H - \frac{H}{2}\right)\right]^{1/2} = H$$

✍ The cross-section of the water stream from a tap decreases as it goes down in accordance with the equation of continuity.

✍ The upthrust on body immersed in a liquid does not depend on the mass, density or shape of the body. It only depends on the volume of the body.

✍ The weight of the plastic bag full of air is same as that of the empty bag because the upthrust is equal to the weight of the air enclosed.

✍ Upthrust depends on the density of the fluid, not the density of the body.

✍ If two bodies have equal upthrust in a liquid, both have the same volume.

✍ When air blows over a roof, the force on the roof is upwards.

✍ If one floats one's back on the surface of water, the apparent weight is zero.

✍ If a body just floats in liquid (density of the body is equal to the density of liquid) then the body sinks if it is pushed downwards.

✍ The line joining the centre of gravity and centre of buoyancy is called central line.

✍ The point where the vertical line through centre of huoyancy intersects the central line is called metacentre.

✍ The floating body is in stable equilibrium where the metacentre is above the centre of gravity. (Centre of gravity is below the centre of buoyancy)

✍ The floating body is in unstable equilibrium when the metancetre lies below the centre of gravity. (Centre of gravity is above the centre of buoyancy).

✍ The floating body is in the neutral equilibrium when centre of gravity coincides with the metacentre. (Centre of gravity coincides with the centre of buoyancy).

✍ The wooden rod cannot float vertically in a pond of water because centre of gravity lies above the metacentre.

✍ Air bubble in water always goes up. It is because density of air (ρ) is less than the density of water (σ). So the terminal velocity for air bubble is negative, which implies that the air bubble will go up. Positive terminal velocity means the body will fall down.

✍ The faster the air, the lower the pressure.

✍ Wings of an aeroplane are shaped to make air travel further and faster over their top surfaces.

✍ The lift force on a wing or aerofoil is proportional to the square of the speed of flow.

✍ Viscous force between the layers of a liquid is analogous to friction between two solid surfaces.

✍ With increase in temperature, the coefficient of viscosity of liquids decreases but that of gases increases. The reason is that as temperature rises, the atoms of the liquid become more mobile, whereas in case of a gas, the collision frequency of atoms increases as their motion becomes more random.

✍ We cannot sip a drink with a straw on the moon because there is no atmosphere on the moon.

Ordinary Thinking

Objective Questions

Pressure and Density

1. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake then what is the depth of the lake

[RPET 2000]

(a) 10 *m* (b) 20 *m*

(c) 60 *m* (d) 30 *m*

2. Two bodies are in equilibrium when suspended in water from the arms of a balance. The mass of one body is 36 *g* and its density is 9 g/cm^3. If the mass of the other is 48 *g*, its density in g/cm^3 is

(a) $\frac{4}{3}$ (b) $\frac{3}{2}$

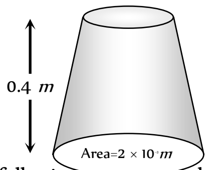
(c) 3 (d) 5

3. An inverted bell lying at the bottom of a lake 47.6 *m* deep has 50 cm^3 of air trapped in it. The bell is brought to the surface of the lake. The volume of the trapped air will be (atmospheric pressure = 70 *cm* of *Hg* and density of *Hg* = 13.6 g/cm^3)

(a) 350 cm^3 (b) 300 cm^3

(c) 250 cm^3 (d) 22 cm^3

4. A uniformly tapering vessel is filled with a liquid of density 900 kg/m^3. The force that acts on the base of the vessel due to the liquid is $(g = 10\, ms^{-2})$



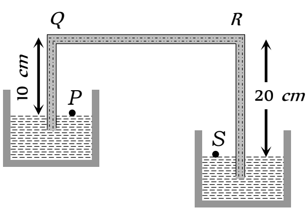
(a) 3.6 *N*

(b) 7.2 *N*

(c) 9.0 *N*

(d) 14.4 *N*

5. A siphon in use is demonstrated in the following figure. The density of the liquid flowing in siphon is 1.5 *gm/cc*. The pressure difference between the point *P* and *S* will be



(a) 10^5 N/m^2

(b) 2×10^5 N/m^2

(c) Zero

(d) Infinity

6. The height of a mercury barometer is 75 *cm* at sea level and 50 *cm* at the top of a hill. Ratio of density of mercury to that of air is 10^4. The height of the hill is

(a) 250 *m* (b) 2.5 *km*

(c) 1.25 *km* (d) 750 *m*

7. Density of ice is ρ and that of water is σ. What will be the decrease in volume when a mass *M* of ice melts

(a) $\frac{M}{\sigma - \rho}$ (b) $\frac{\sigma - \rho}{M}$

(c) $M\left[\frac{1}{\rho} - \frac{1}{\sigma}\right]$ (d) $\frac{1}{M}\left[\frac{1}{\rho} - \frac{1}{\sigma}\right]$

8. Equal masses of water and a liquid of density 2 are mixed together, then the mixture has a density of

(a) 2/3 (b) 4/3

(c) 3/2 (d) 3

9. A body of density d_1 is counterpoised by Mg of weights of density d_2 in air of density *d*. Then the true mass of the body is

(a) M (b) $M\left(1 - \frac{d}{d_2}\right)$

(c) $M\left(1 - \frac{d}{d_1}\right)$ (d) $\frac{M(1 - d/d_2)}{(1 - d/d_1)}$

10. The pressure at the bottom of a tank containing a liquid does not depend on [Kerala (Engg.) 2002]

[CBSE PMT 1994]

(a) Acceleration due to gravity

(b) Height of the liquid column

(c) Area of the bottom surface

(d) Nature of the liquid

11. When a large bubble rises from the bottom of a lake to the surface. Its radius doubles. If atmospheric pressure is equal to that of column of water height *H*, then the depth of lake is

[AIIMS 1995; AFMC 1997]

[CPMT 1989]

(a) *H* (b) 2*H*

(c) 7*H* (d) 8*H*

12. The volume of an air bubble becomes three times as it rises from the bottom of a lake to its surface. Assuming atmospheric pressure to be 75 *cm* of *Hg* and the density of water to be 1/10 of the density of mercury, the depth of the lake is

(a) 5 *m* (b) 10 *m*

(c) 15 *m* (d) 20 *m*

13. The value of *g* at a place decreases by 2%. The barometric height of mercury

(a) Increases by 2%

(b) Decreases by 2%

(c) Remains unchanged

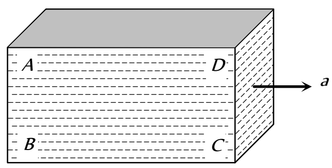
(d) Sometimes increases and sometimes decreases

14. A barometer kept in a stationary elevator reads 76 *cm*. If the elevator starts accelerating up the reading will be

(a) Zero (b) Equal to 76 *cm*

(c) More than 76 *cm* (d) Less than 76 *cm*

15. A closed rectangular tank is completely filled with water and is accelerated horizontally with an acceleration *a* towards right. Pressure is (i) maximum at, and (ii) minimum at



(a) (i) B (ii) D

(b) (i) C (ii) D

(c) (i) B (ii) C

(d) (i) *B* (ii) *A*

16. A beaker containing a liquid is kept inside a big closed jar. If the air inside the jar is continuously pumped out, the pressure in the liquid near the bottom of the liquid will

(a) Increases

(b) Decreases

(c) Remain constant

(d) First decrease and then increase

17. A barometer tube reads 76 *cm* of mercury. If the tube is gradually inclined at an angle of 60° with vertical, keeping the open end immersed in the mercury reservoir, the length of the mercury column will be

(a) 152 *cm* (b) 76 *cm*

(c) 38 *cm* (d) $38\sqrt{3}cm$

18. The height to which a cylindrical vessel be filled with a homogeneous liquid, to make the average force with which the liquid presses the side of the vessel equal to the force exerted by the liquid on the bottom of the vessel, is equal to

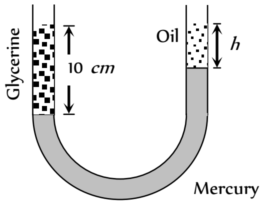
(a) Half of the radius of the vessel

(b) Radius of the vessel

(c) One-fourth of the radius of the vessel

(d) Three-fourth of the radius of the vessel

19. A vertical U-tube of uniform inner cross section contains mercury in both sides of its arms. A glycerin (density = 1.3 *g/cm*) column of length 10 *cm* is introduced into one of its arms. Oil of density 0.8 *gm/cm* is poured into the other arm until the upper surfaces of the oil and glycerin are in the same horizontal level. Find the length of the oil column, Density of mercury = 13.6 *g/cm*



(a) 10.4 cm

(b) 8.2 cm

(c) 7.2 cm

(d) 9.6 cm

20. A triangular lamina of area A and height h is immersed in a liquid of density ρ in a vertical plane with its base on the surface of the liquid. The thrust on the lamina is

(a) $\frac{1}{2}A\rho gh$ (b) $\frac{1}{3}A\rho gh$

(c) $\frac{1}{6}A\rho gh$ (d) $\frac{2}{3}A\rho gh$

21. If two liquids of same masses but densities ρ_1 and ρ_2 respectively are mixed, then density of mixture is given by

(a) $\rho = \frac{\rho_1+\rho_2}{2}$ (b) $\rho = \frac{\rho_1+\rho_2}{2\rho_1\rho_2}$

(c) $\rho = \frac{2\rho_1\rho_2}{\rho_1+\rho_2}$ (d) $\rho = \frac{\rho_1\rho_2}{\rho_1+\rho_2}$

22. If two liquids of same volume but different densities ρ_1 and ρ_2 are mixed, then density of mixture is given by

(a) $\rho = \frac{\rho_1+\rho_2}{2}$ (b) $\rho = \frac{\rho_1+\rho_2}{2\rho_1\rho_2}$

(c) $\rho = \frac{2\rho_1\rho_2}{\rho_1+\rho_2}$ (d) $\rho = \frac{\rho_1\rho_2}{\rho_1+\rho_2}$

23. The density ρ of water of bulk modulus B at a depth y in the ocean is related to the density at surface ρ_0 by the relation

(a) $\rho = \rho_0\left[1-\frac{\rho_0 gy}{B}\right]$ (b) $\rho = \rho_0\left[1+\frac{\rho_0 gy}{B}\right]$

(c) $\rho = \rho_0\left[1+\frac{B}{\rho_0 hgy}\right]$ (d) $\rho = \rho_0\left[1-\frac{B}{\rho_0 gy}\right]$

24. With rise in temperature, density of a given body changes according to one of the following relations

(a) $\rho = \rho_0[1+\gamma\, d\theta]$ (b) $\rho = \rho_0[1-\gamma\, d\theta]$

(c) $\rho = \rho_0\gamma d\theta$ (d) $\rho = \rho_0/\gamma d\theta$

25. Three liquids of densities $d, 2d$ and $3d$ are mixed in equal volumes. Then the density of the mixture is

(a) d (b) $2d$

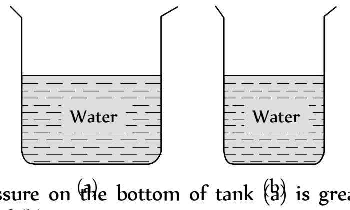
(c) $3d$ (d) $5d$

26. Three liquids of densities $d, 2d$ and $3d$ are mixed in equal proportions of weights. The relative density of the mixture is

(a) $\frac{11d}{7}$ (b) $\frac{18d}{11}$

(c) $\frac{13d}{9}$ (d) $\frac{23d}{18}$

27. From the adjacent figure, the correct observation is **[KCET 2005]**



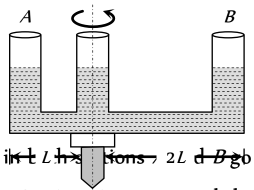
(a) The pressure on the bottom of tank (a) is greater than at the bottom of (b).

(b) The pressure on the bottom of the tank (a) is smaller than at the bottom of (b)

(c) The pressure depend on the shape of the container

(d) The pressure on the bottom of (a) and (b) is the same

28. A given shaped glass tube having uniform cross section is filled with water and is mounted on a rotatable shaft as shown in figure. If the tube is rotated with a constant angular velocity ω then



(a) Water levels in both sections A and B go up

(b) Water level in Section A goes up and that in B comes down

(c) Water level in Section A comes down and that in B it goes up

(d) Water levels remains same in both sections

29. Why the dam of water reservoir is thick at the bottom **[AFMC 2005]**

(a) Quantity of water increases with depth

(b) Density of water increases with depth

(c) Pressure of water increases with depth

(d) Temperature of water increases with depth

30. Air is blown through a hole on a closed pipe containing liquid. Then the pressure will **[AFMC 2005]**

(a) Increase on sides

(b) Increase downwards

(c) Increase in all directions

(d) Never increases

31. Radius of an air bubble at the bottom of the lake is r and it becomes $2r$ when the air bubbles rises to the top surface of the lake. If P *cm* of water be the atmospheric pressure, then the depth of the lake is

(a) $2p$ (b) $8p$

(c) $4p$ (d) $7p$

Pascal's Law and Archmidies Principle

1. An ice berg of density 900 *Kg/m* is floating in water of density 1000 *Kg/m*. The percentage of volume of ice-cube outside the water is

(a) 20% (b) 35%

(c) 10% (d) 25%

2. A log of wood of mass 120 *Kg* floats in water. The weight that can be put on the raft to make it just sink, should be (density of wood = 600 *Kg/m*) [CPMT 2004]

(a) 80 *Kg* (b) 50 *Kg*

(c) 60 *Kg* (d) 30 *Kg*

3. A hemispherical bowl just floats without sinking in a liquid of density 1.2 × 10 *kg/m*. If outer diameter and the density of the bowl are 1 *m* and 2 × 10 *kg/m* respectively, then the inner diameter of the bowl will be [SCRA 1998]

(a) 0.94 *m* (b) 0.97 *m*

(c) 0.98 *m* (d) 0.99 *m*

4. In making an alloy, a substance of specific gravity s_1 and mass m_1 is mixed with another substance of specific gravity s_2 and mass m_2 ; then the specific gravity of the alloy is [CPMT 1995]

(a) $\left(\frac{m_1+m_2}{s_1+s_2}\right)$ (b) $\left(\frac{s_1 s_2}{m_1+m_2}\right)$

(c) $\frac{m_1+m_2}{\left(\frac{m_1}{s_1}+\frac{m_2}{s_2}\right)}$ (d) $\frac{\left(\frac{m_1}{s_1}+\frac{m_2}{s_2}\right)}{m_1+m_2}$

5. A concrete sphere of radius R has a cavity of radius r which is packed with sawdust. The specific gravities of concrete and sawdust are respectively 2.4 and 0.3 for this sphere to float with its entire volume submerged under water. Ratio of mass of concrete to mass of sawdust will be [AIIMS 1995]

(a) 8 (b) 4

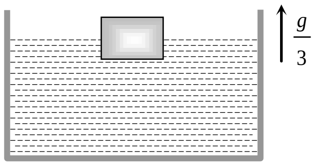
(c) 3 (d) Zero

6. A metallic block of density 5 *gm* cm and having dimensions 5 *cm* × 5 *cm* × 5 *cm* is weighed in water. Its apparent weight will be

(a) 5 × 5 × 5 × 5 *gf* (b) 4 × 4 × 4 × 4 gf

(c) 5 × 4 × 4 × 4 gf (d) 4 × 5 × 5 × 5 gf

7. A cubical block is floating in a liquid with half of its volume immersed in the liquid. When the whole system accelerates upwards with acceleration of *g/3*, the fraction of volume immersed in the liquid will be



(a) $\frac{1}{2}$

(b) $\frac{3}{8}$ [Kerla PET 2005]

(c) $\frac{2}{3}$

(d) $\frac{3}{4}$

8. A silver ingot weighing 2.1 *kg* is held by a string so as to be completely immersed in a liquid of relative density 0.8. The relative density of silver is 10.5. The tension in the string in *kg-wt* is [CPMT 2004]

(a) 1.6 (b) 1.94

(c) 3.1 (d) 5.25

9. A sample of metal weighs 210 *gm* in air, 180 *gm* in water and 120 *gm* in liquid. Then relative density (RD) of

(a) Metal is 3 (b) Metal is 7

(c) Liquid is 3 (d) Liquid is $\frac{1}{3}$

10. Two solids A and B float in water. It is observed that A floats with half its volume immersed and B floats with 2/3 of its volume immersed. Compare the densities of A and B

(a) 4 : 3 (b) 2 : 3

(c) 3 : 4 (d) 1 : 3

11. The fraction of a floating object of volume V_0 and density d_0 above the surface of a liquid of density d will be

(a) $\frac{d_0}{d}$ (b) $\frac{dd_0}{d+d_0}$

(c) $\frac{d-d_0}{d}$ (d) $\frac{dd_0}{d-d_0}$

12. Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel. This law was first formulated by

(a) Bernoulli (b) Archimedes

(c) Boyle (d) Pascal

13. A block of steel of size 5 *cm* × 5 *cm* × 5 *cm* is weighed in water. If the relative density of steel is 7, its apparent weight is

(a) 6 × 5 × 5 × 5 *gf* (b) 4 × 4 × 4 × 7 *gf*

(c) 5 × 5 × 5 × 7 *gf* (d) 4 × 4 × 4 × 6 *gf*

14. A body is just floating on the surface of a liquid. The density of the body is same as that of the liquid. The body is slightly pushed down. What will happen to the body [AIIMS 1980]

(a) It will slowly come back to its earlier position

(b) It will remain submerged, where it is left

(c) It will sink

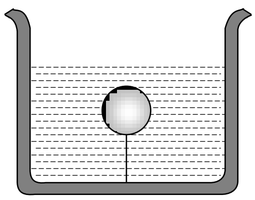
(d) It will come out violently

15. A cork is submerged in water by a spring attached to the bottom of a bowl. When the bowl is kept in an elevator moving with acceleration downwards, the length of spring

(a) Increases (b) Decreases

(c) Remains unchanged (d) None of these

16. A solid sphere of density η (> 1) times lighter than water is suspended in a water tank by a string tied to its base as shown in fig. If the mass of the sphere is m then the tension in the string is given by



(a) $\left(\frac{\eta-1}{\eta}\right)mg$

(b) ηmg

(c) $\frac{mg}{\eta-1}$

(d) $(\eta-1)mg$

17. A hollow sphere of volume V is floating on water surface with *half* immersed in it. What should be the minimum volume of water poured inside the sphere so that the sphere now sinks into the water

(a) $V/2$ (b) $V/3$

(c) $V/4$ (d) V

18. A rectangular block is 5 cm × 5 cm × 10cm in size. The block is floating in water with 5 cm side vertical. If it floats with 10 cm side vertical, what change will occur in the level of water?

(a) No change

(b) It will rise

(c) It will fall

(d) It may rise or fall depending on the density of block

19. A ball whose density is 0.4×10^3 kg/m^3 falls into water from a height of 9 cm . To what depth does the ball sink

(a) 9 cm (b) 6 cm

(c) 4.5 cm (d) 2.25 cm

20. Two solids A and B float in water. It is observed that A floats with $\frac{1}{2}$ of its body immersed in water and B floats with $\frac{1}{4}$ of its volume above the water level. The ratio of the density of A to that of B is

(a) 4 : 3 (b) 2 : 3

(c) 3 : 4 (d) 1 : 2

21. A boat carrying steel balls is floating on the surface of water in a tank. If the balls are thrown into the tank one by one, how will it affect the level of water **[J&K CET 2005]**

(a) It will remain unchanged

(b) It will rise

(c) It will fall

(d) First it will first rise and then fall

22. Two pieces of metal when immersed in a liquid have equal upthrust on them; then

(a) Both pieces must have equal weights

(b) Both pieces must have equal densities

(c) Both pieces must have equal volumes

(d) Both are floating to the same depth

23. A wooden cylinder floats vertically in water with half of its length immersed. The density of wood is

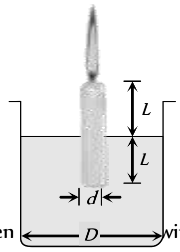
(a) Equal of that of water

(b) Half the density of water

(c) Double the density of water

(d) The question is incomplete

24. A candle of diameter d is floating on a liquid in a cylindrical container of diameter D (D>>d) as shown in figure. If it is burning at the rate of 2$cm/hour$ then the top of the candle will



(a) Remain at the same height

(b) Fall at the rate of 1 $cm/hour$

(c) Fall at the rate of 2 $cm/hour$

(d) Go up the rate of 1$cm/hour$

25. An ice block contains a glass ball when within the water containing vessel, the level of water **[AFMC 2005]**

(a) Rises (b) Falls

(c) Unchanged (d) First rises and then falls

26. A large ship can float but a steel needle sinks because of **[AFMC 2005]**

(a) Viscosity (b) Surface tension

(c) Density (d) None of these

27. Construction of submarines is based on **[Kerala PMT 2005]**

(a) Archimedes' principle (b) Bernoulli's theorem

(c) Pascal's law (d) Newton's laws

Fluid Flow

1. In which one of the following cases will the liquid flow in a pipe be most streamlined **[Pb. CET 2005]**

(a) Liquid of high viscosity and high density flowing through a pipe of small radius

(b) Liquid of high viscosity and low density flowing through a pipe of small radius

(c) Liquid of low viscosity and low density flowing through a pipe of large radius

(d) Liquid of low viscosity and high density flowing through a pipe of large radius

2. Two water pipes of diameters 2 cm and 4 cm are connected with the main supply line. The velocity of flow of water in the pipe of 2 cm diameter is **[MNR 1980]**

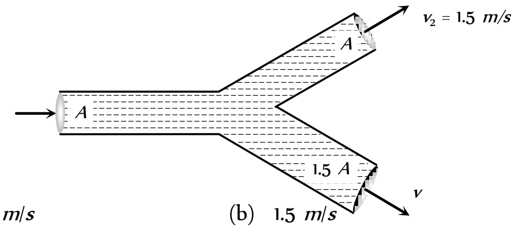
(a) 4 times that in the other pipe

(b) $\frac{1}{4}$ times that in the other pipe

(c) 2 times that in the other pipe

(d) $\frac{1}{2}$ times that in the other pipe

3. An incompressible liquid flows through a horizontal tube as shown in the following fig. Then the velocity v of the fluid is



(a) 3.0 m/s (b) 1.5 m/s
(c) 1.0 m/s (d) 2.25 m/s

4. Water enters through end A with speed v_1 and leaves through end B with speed v_2 of a cylindrical tube AB. The tube is always completely filled with water. In case I tube is horizontal and in case II it is vertical with end A upwards and in case III it is vertical with end B upwards. We have $v_1 = v_2$ for

(a) Case I (b) Case II
(c) Case III (d) Each case

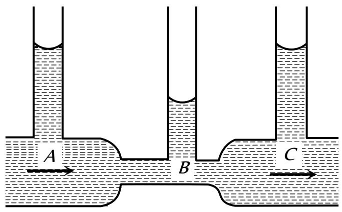
5. Water is moving with a speed of 5.18 ms through a pipe with a cross-sectional area of 4.20 cm. The water gradually descends 9.66 m as the pipe increase in area to 7.60 cm. The speed of flow at the lower level is

(a) 3.0 ms (b) 5.7 ms
(c) 3.82 ms (d) 2.86 ms

6. The velocity of kerosene oil in a horizontal pipe is 5 m/s. If $g = 10 m/s^2$ then the velocity head of oil will be

(a) 1.25 m (b) 12.5 m
(c) 0.125 m (d) 125 m

7. In the following fig. is shown the flow of liquid through a horizontal pipe. Three tubes A, B and C are connected to the pipe. The radii of the tubes A, B and C at the junction are respectively 2 cm, 1 cm and 2 cm. It can be said that the



(a) Height of the liquid in the tube A is maximum
(b) Height of the liquid in the tubes A and B is the same
(c) Height of the liquid in all the three tubes is the same
(d) Height of the liquid in the tubes A and C is the same

8. A manometer connected to a closed tap reads 3.5 × 10 N/m. When the valve is opened, the reading of manometer falls to 3.0 × 10 N/m, then velocity of flow of water is

(a) 100 m/s (b) 10 m/s
(c) 1 m/s (d) $10\sqrt{10}$ m/s

9. Air is streaming past a horizontal air plane wing such that its speed in 120 m/s over the upper surface and 90 m/s at the lower surface. If the density of air is 1.3 kg per metre and the wing is 10 m long and has an average width of 2 m, then the difference of the pressure on the two sides of the wing of

(a) 4095.0 Pascal (b) 409.50 Pascal
(c) 40.950 Pascal (d) 4.0950 Pascal

10. A large tank filled with water to a height 'h' is to be emptied through a small hole at the bottom. The ratio of time taken for the level of water to fall from h to $\frac{h}{2}$ and from $\frac{h}{2}$ to zero is

(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$
(c) $\sqrt{2}-1$ (d) $\frac{1}{\sqrt{2}-1}$

11. A cylinder of height 20 m is completely filled with water. The velocity of efflux of water (in m/s) through a small hole on the side wall of the cylinder near its bottom is

[AIEEE 2002]

(a) 10 (b) 20
(c) 25.5 (d) 5

12. There is a hole in the bottom of tank having water. If total pressure at bottom is 3 atm (1 atm = 10 N/m) then the velocity of water flowing from hole is [CPMT 2002]

(a) $\sqrt{400}$ m/s (b) $\sqrt{600}$ m/s
(c) $\sqrt{60}$ m/s (d) None of these

13. There is a hole of area A at the bottom of cylindrical vessel. Water is filled up to a height h and water flows out in t second. If water is filled to a height $4h$, it will flow out in time equal to

(a) t (b) $4t$
(c) $2t$ (d) $t/4$

14. A cylindrical tank has a hole of 1 cm in its bottom. If the water is allowed to flow into the tank from a tube above it at the rate of 70 cm/sec. then the maximum height up to which water can rise in the tank is

(a) 2.5 cm (b) 5 cm
(c) 10 cm (d) 0.25 cm

15. A square plate of 0.1 m side moves parallel to a second plate with a velocity of 0.1 m/s, both plates being immersed in water. If the viscous force is 0.002 N and the coefficient of viscosity is 0.01 poise, distance between the plates in m is

[EAMCET (Med.) 2003]

(a) 0.1 (b) 0.05
(c) 0.005 (d) 0.0005

16. Spherical balls of radius 'r' are falling in a viscous fluid of viscosity 'η' with a velocity 'v'. The retarding viscous force acting on the spherical ball is [AIEEE 2004]

(a) Inversely proportional to 'r' but directly proportional to velocity 'v'
(b) Directly proportional to both radius 'r' and velocity 'v'
(c) Inversely proportional to both radius 'r' and velocity 'v'
(d) Directly proportional to 'r' but inversely proportional to 'v'

17. A small sphere of mass m is dropped from a great height. After it has fallen 100 m, it has attained its terminal velocity and continues to fall at that speed. The work done by air friction against the sphere during the first 100 m of fall is

[MP PMT 1990]

(a) Greater than the work done by air friction in the second 100 m

(b) Less than the work done by air friction in the second 100 *m*

(c) Equal to 100 *mg*

(d) Greater than 100 *mg*

18. Two drops of the same radius are falling through air with a steady velocity of 5 *cm* per *sec*. If the two drops coalesce, the terminal velocity would be [MP PMT 1990]

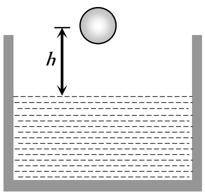
(a) 10 *cm* per *sec* (b) 2.5 *cm* per *sec*

(c) $5 \times (4)^{1/3} cm$ per *sec* (d) $5 \times \sqrt{2}\, cm$ per sec

19. A ball of radius *r* and density ρ falls freely under gravity through a distance *h* before entering water. Velocity of ball does not change even on entering water. If viscosity of water is η, the value of *h* is given by

(a) $\frac{2}{9} r^2 \left(\frac{1-\rho}{\eta}\right) g$

(b) $\frac{2}{81} r^2 \left(\frac{\rho-1}{\eta}\right) g$



(c) $\frac{2}{81} r^4 \left(\frac{\rho-1}{\eta}\right)^2 g$

(d) $\frac{2}{9} r^4 \left(\frac{\rho-1}{\eta}\right)^2 g$

20. The rate of steady volume flow of water through a capillary tube of length '*l*' and radius '*r*' under a pressure difference of *P* is *V*. This tube is connected with another tube of the same length but half the radius in series. Then the rate of steady volume flow through them is (The pressure difference across the combination is *P*)

(a) $\frac{V}{16}$ (b) $\frac{V}{17}$

(c) $\frac{16V}{17}$ (d) $\frac{17V}{16}$

21. A liquid is flowing in a horizontal uniform capillary tube under a constant pressure difference *P*. The value of pressure for which the rate of flow of the liquid is doubled when the radius and length both are doubled is

[EAMCET 2001]

(a) *P* (b) $\frac{3P}{4}$

(c) $\frac{P}{2}$ (d) $\frac{P}{4}$

22. We have two (narrow) capillary tubes T_1 and T_2. Their lengths are l_1 and l_2 and radii of cross-section are r_1 and r_2 respectively. The rate of flow of water under a pressure difference *P* through tube T_1 is 8*cm/sec*. If $l_2 = 2l_1$ and $r_2 = r_1$, what will be the rate of flow when the two tubes are connected in series and pressure difference across the combination is same as before (= *P*)

(a) 4 *cm/sec* (b) (16/3) *cm/sec*

(c) (8/17) *cm/sec* (d) None of these

23. In a laminar flow the velocity of the liquid in contact with the walls of the tube is

(a) Zero

(b) Maximum

(c) In between zero and maximum

(d) Equal to critical velocity

24. In a turbulent flow, the velocity of the liquid molecules in contact with the walls of the tube is

(a) Zero

(b) Maximum

(c) Equal to critical velocity

(d) May have any value

25. The Reynolds number of a flow is the ratio of

(a) Gravity to viscous force

(b) Gravity force to pressure force

(c) Inertia forces to viscous force

(d) Viscous forces to pressure forces

26. Water is flowing through a tube of non-uniform cross-section ratio of the radius at entry and exit end of the pipe is 3 : 2. Then the ratio of velocities at entry and exit of liquid is

[RPMT 2001]

(a) 4 : 9 (b) 9 : 4

(c) 8 : 27 (d) 1 : 1

27. Water is flowing through a horizontal pipe of non-uniform cross-section. At the extreme narrow portion of the pipe, the water will have [MP PMT 1992]

(a) Maximum speed and least pressure

(b) Maximum pressure and least speed

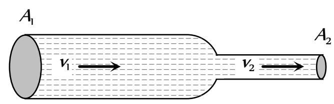
(c) Both pressure and speed maximum

(d) Both pressure and speed least

28. A liquid flows in a tube from left to right as shown in figure. A_1 and A_2 are the cross-sections of the portions of the tube as shown. Then the ratio of speeds v_1 / v_2 will be [EAMCET (Engg.) 2003]

(a) A_1 / A_2

(b) A_2 / A_1



(c) $\sqrt{A_2} / \sqrt{A_1}$

(d) $\sqrt{A_1} / \sqrt{A_2}$

29. In a streamline flow

(a) The speed of a particle always remains same

(b) The velocity of a particle always remains same

(c) The kinetic energies of all the particles arriving at a given point are the same

(d) The moments of all the particles arriving at a given point are the same

30. An application of Bernoulli's equation for fluid flow is found in

(a) Dynamic lift of an aeroplane

(b) Viscosity meter

(c) Capillary rise

(d) Hydraulic press

31. The Working of an atomizer depends upon

[MP PMT 1992; AFMC 2005]

(a) Bernoulli's theorem (b) Boyle's law

(c) Archimedes principle (d) Newton's law of motion

32. The pans of a physical balance are in equilibrium. Air is blown under the right hand pan; then the right hand pan will

(a) Move up

(b) Move down

(c) Move erratically

(d) Remain at the same level

33. According to Bernoulli's equation

$$\frac{P}{\rho g}+h+\frac{1}{2}\frac{v^2}{g}=\text{constant}$$

The terms *A*, *B* and *C* are generally called respectively:

(a) Gravitational head, pressure head and velocity head

(b) Gravity, gravitational head and velocity head

(c) Pressure head, gravitational head and velocity head

(d) Gravity, pressure and velocity head

34. At what speed the velocity head of a stream of water be equal to 40 *cm* of *Hg*

(a) 282.8 *cm/sec* (b) 432.6 *cm/sec*

(c) 632.6 *cm/sec* (d) 832.6 *cm/sec*

35. The weight of an aeroplane flying in air is balanced by

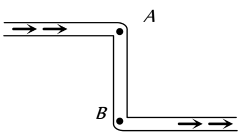
(a) Upthrust of the air which will be equal to the weight of the air having the same volume as the plane

(b) Force due to the pressure difference between the upper and lower surfaces of the wings, created by different air speeds on the surface

(c) Vertical component of the thrust created by air currents striking the lower surface of the wings

(d) Force due to the reaction of gases ejected by the revolving propeller

36. In this figure, an ideal liquid flows through the tube, which is of uniform cross-section. The liquid has velocities v_A and v_B, and pressure P_A and P_B at points *A* and *B* respectively



(a) $v_A = v_B$

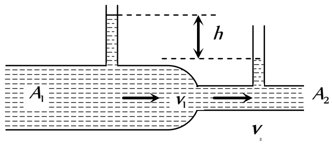
(b) $v_B > v_A$

(c) $P_A = P_B$

(d) $P_A > P_B$

37. A liquid flows through a horizontal tube. The velocities of the liquid in the two sections, which have areas of cross-section A_1 and A_2, are v_1 and v_2 respectively. The difference in the levels of the liquid in the two vertical tubes is h

(a) The volume of the liquid flowing through the tube in unit time is A_1v_1



(b) $v_2 - v_1 = \sqrt{2gh}$

(c) $v_2^2 - v_1^2 = 2gh$

(d) The energy per unit mass of the liquid is the same in both sections of the tube

38. A sniper fires a rifle bullet into a gasoline tank making a hole 53.0 *m* below the surface of gasoline. The tank was sealed at 3.10 *atm*. The stored gasoline has a density of 660 kgm^{-3}. The velocity with which gasoline begins to shoot out of the hole is

(a) $27.8\,ms^{-1}$ (b) $41.0\,ms^{-1}$

(c) $9.6\,ms^{-1}$ (d) $19.7\,ms^{-1}$

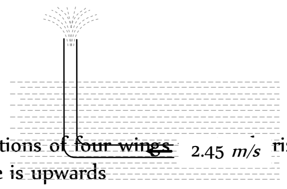
39. An L-shaped tube with a small orifice is held in a water stream as shown in fig. The upper end of the tube is 10.6 *cm* above the surface of water. What will be the height of the jet of water coming from the orifice? Velocity of water stream is 2.45 *m/s*

(a) Zero

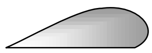
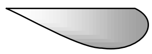
(b) 20.0 *cm*

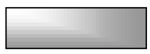
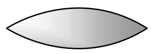
(c) 10.6 *cm*

(d) 40.0 *cm*

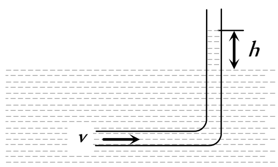


40. Fig. represents vertical sections of four wings [...] rizontally in air. In which case the force is upwards

(a)  (b) 

(c)  (d) 

41. An L-shaped glass tube is just immersed in flowing water such that its opening is pointing against flowing water. If the speed of water current is *v*, then



(a) The water in the tube rises to height $\frac{v^2}{2g}$

(b) The water in the tube rises to height $\frac{g}{2v^2}$

(c) The water in the tube does not rise at all

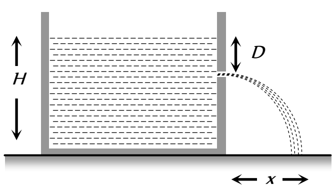
(d) None of these

42. A tank is filled with water up to a height *H*. Water is allowed to come out of a hole *P* in one of the walls at a depth *D* below the surface of water. Express the horizontal distance *x* in terms of *H* and *D* [MNR 1992; CPMT 2004]

(a) $x = \sqrt{D(H-D)}$

(b) $x = \sqrt{\frac{D(H-D)}{2}}$

(c) $x = 2\sqrt{D(H-D)}$

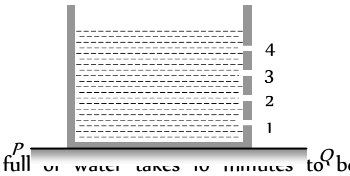


(d) $x = 4\sqrt{D(H-D)}$

43. A cylindrical vessel of 90 *cm* height is kept filled upto the brim. It has four holes 1, 2, 3, 4 which are respectively at heights of 20 *cm*, 30 *cm*, 45 *cm* and 50 *cm* from the horizontal floor *PQ*. The water falling at the maximum horizontal distance from the vessel comes from

[CPMT 1989]

(a) Hole number 4
(b) Hole number 3
(c) Hole number 2
(d) Hole number 1



44. A rectangular vessel when full of water takes 10 minutes to be emptied through an orifice in its bottom. How much time will it take to be emptied when half filled with water

(a) 9 *minute* (b) 7 *minute*
(c) 5 *minute* (d) 3 *minute*

45. A streamlined body falls through air from a height h on the surface of a liquid. If d and $D(D > d)$ represents the densities of the material of the body and liquid respectively, then the time after which the body will be instantaneously at rest, is

(a) $\sqrt{\frac{2h}{g}}$ (b) $\sqrt{\frac{2h}{g}\cdot\frac{D}{d}}$

(c) $\sqrt{\frac{2h}{g}\cdot\frac{d}{D}}$ (d) $\sqrt{\frac{2h}{g}}\left(\frac{d}{D-d}\right)$

46. A large tank is filled with water to a height H. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to $\frac{H}{\eta}(\eta > 1)$; and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is

(a) 2 (b) 3
(c) 4 (d) $2\sqrt{2}$

47. Velocity of water in a river is [CBSE PMT 1988]

(a) Same everywhere
(b) More in the middle and less near its banks
(c) Less in the middle and more near its banks
(d) Increase from one bank to other bank

48. As the temperature of water increases, its viscosity

(a) Remains unchanged
(b) Decreases
(c) Increases
(d) Increases or decreases depending on the external pressure

49. The coefficient of viscosity for hot air is

(a) Greater than the coefficient of viscosity for cold air
(b) Smaller than the coefficient of viscosity for cold air
(c) Same as the coefficient of viscosity for cold air
(d) Increases or decreases depending on the external pressure

50. A good lubricant should have

(a) High viscosity (b) Low viscosity
(c) Moderate viscosity (d) High density

51. We have three beakers *A*, *B* and *C* containing glycerine, water and kerosene respectively. They are stirred vigorously and placed on a table. The liquid which comes to rest at the earliest is

(a) Glycerine
(b) Water
(c) Kerosene
(d) All of them at the same time

52. A small drop of water falls from rest through a large height h in air; the final velocity is

(a) $\propto \sqrt{h}$

(b) $\propto h$

(c) $\propto (1/h)$

(d) Almost independent of h

53. The rate of flow of liquid in a tube of radius *r*, length *l*, whose ends are maintained at a pressure difference P is $V = \frac{\pi Q P r^4}{\eta l}$ where η is coefficient of the viscosity and Q is

[DCE 2002]

(a) 8 (b) $\frac{1}{8}$

(c) 16 (d) $\frac{1}{16}$

54. In Poiseuilli's method of determination of coefficient of viscosity, the physical quantity that requires greater accuracy in measurement is

(a) Pressure difference
(b) Volume of the liquid collected
(c) Length of the capillary tube
(d) Inner radius of the capillary tube

55. Two capillary tubes of the same length but different radii r_1 and r_2 are fitted in parallel to the bottom of a vessel. The pressure head is *P*. What should be the radius of a single tube that can replace the two tubes so that the rate of flow is same as before

(a) $r_1 + r_2$ (b) $r_1^2 + r_2^2$

(c) $r_1^4 + r_2^4$ (d) None of these

56. Two capillaries of same length and radii in the ratio 1 : 2 are connected in series. A liquid flows through them in streamlined condition. If the pressure across the two extreme ends of the combination is 1 *m* of water, the pressure difference across first capillary is

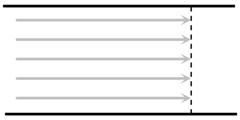
(a) 9.4 *m* (b) 4.9 *m*
(c) 0.49 *m* (d) 0.94 *m*

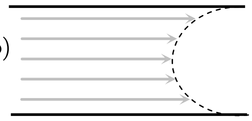
57. Water flows in a streamlined manner through a capillary tube of radius *a*, the pressure difference being *P* and the rate of flow *Q*. If the radius is reduced to *a*/2 and the pressure increased to 2*P*, the rate of flow becomes

(a) $4Q$ (b) Q

(c) $\frac{Q}{4}$ (d) $\frac{Q}{8}$

58. A viscous fluid is flowing through a cylindrical tube. The velocity distribution of the fluid is best represented by the diagram

(a) 

(b) 

(c) 

(d) None of these

59. Water is flowing in a pipe of diameter 4 *cm* with a velocity 3 *m/s*. The water then enters into a tube of diameter 2 *cm*. The velocity of water in the other pipe is **[BCECE 2005]**

(a) 3 *m/s* (b) 6 *m/s*

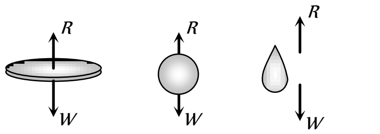
(c) 12 *m/s* (d) 8 *m/s*

60. Two capillary of length L and $2L$ and of radius R and $2R$ are connected in series. The net rate of flow of fluid through them will be (given rate of the flow through single capillary, $X = \pi PR^4 / 8\eta L$) **[DCE 2005]**

(a) $\frac{8}{9}X$ (b) $\frac{9}{8}X$

(c) $\frac{5}{7}X$ (d) $\frac{7}{5}X$

61. When a body falls in air, the resistance of air depends to a great extent on the shape of the body, 3 different shapes are given. Identify the combination of air resistances which truly represents the physical situation. (The cross sectional areas are the same).



(1) Disc (2) Ball (3) Cigar shaped

(a) 1 < 2 < 3 (b) 2 < 3 < 1

(c) 3 < 2 < 1 (d) 3 < 1 < 2

62. Water falls from a tap, down the streamline **[Orissa JEE 2005]**

(a) Area decreases (b) Area increases

(c) Velocity remains same (d) Area remains same

63. A manometer connected to a closed tap reads 4.5×10^5 *pascal*. When the tap is opened the reading of the manometer falls to 4×10^5 *pascal*. Then the velocity of flow of water is

(a) 7 ms^{-1} (b) 8 ms^{-1}

(c) 9 ms^{-1} (d) 10 ms^{-1}

64. What is the velocity v of a metallic ball of radius r falling in a tank of liquid at the instant when its acceleration is one-half that of a freely falling body ? (The densities of metal and of liquid are ρ and σ respectively, and the viscosity of the liquid is η).

(a) $\frac{r^2 g}{9\eta}(\rho - 2\sigma)$ (b) $\frac{r^2 g}{9\eta}(2\rho - \sigma)$

(c) $\frac{r^2 g}{9\eta}(\rho - \sigma)$ (d) $\frac{2r^2 g}{9\eta}(\rho - \sigma)$

65. Consider the following equation of Bernouilli's theorem.

$P + \frac{1}{2}\rho V^2 + \rho gh = K$ (constant)

The dimensions of *K/P* are same as that of which of the following [AFMC 2005

(a) Thrust (b) Pressure

(c) Angle (d) Viscosity

66. An incompressible fluid flows steadily through a cylindrical pipe which has radius $2r$ at point A and radius r at B further along the flow direction. If the velocity at point A is v, its velocity at point B is **[Kerala PMT 2005]**

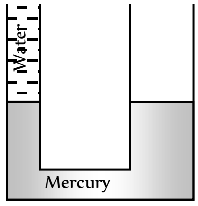
(a) $2v$ (b) v

(c) $v/2$ (d) $4v$

Critical Thinking

Objective Questions

1. A U-tube in which the cross-sectional area of the limb on the left is one quarter, the limb on the right contains mercury (density 13.6 *g/cm*). The level of mercury in the narrow limb is at a distance of 36 *cm* from the upper end of the tube. What will be the rise in the level of mercury in the right limb if the left limb is filled to the top with water **[KCET 2005]**



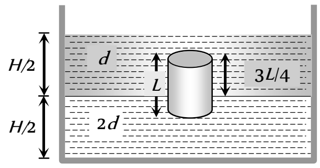
(a) 1.2 *cm*

(b) 2.35 *cm*

(c) 0.56 *cm*

(d) 0.8 *cm*

2. A homogeneous solid cylinder of length $L(L < H/2)$. Cross-sectional area $A/5$ is immersed such that it floats with its axis vertical at the liquid-liquid interface with length $L/4$ in the denser liquid as shown in the fig. The lower density liquid is open to atmosphere having pressure P_0. Then density D of solid is given by



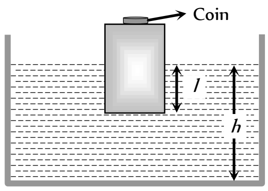
(a) $\frac{5}{4}d$

(b) $\frac{4}{5}d$

(c) d

(d) $\frac{d}{5}$

3. A wooden block, with a coin placed on its top, floats in water as shown in fig. the distance l and h are shown there. After some time the coin falls into the water. Then **[Kerala PET 2005]** **[IIT-JEE (Screening) 2002]**



(a) l decreases and h increases

(b) l increases and h decreases

(c) Both l and h increase

(d) Both l and h decrease

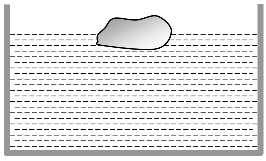
4. A vessel contains oil (density = 0.8 *gm/cm*) over mercury (density = 13.6 *gm/cm*). A homogeneous sphere floats with half of its volume immersed in mercury and the other half in oil. The density of the material of the sphere in *gm/cm* is

(a) 3.3 (b) 6.4

(c) 7.2 (d) 12.8

5. A body floats in a liquid contained in a beaker. The whole system as shown falls freely under gravity. The upthrust on the body due to the liquid is

[IIT-JEE 1982]



(a) Zero

(b) Equal to the weight of the liquid displaced

(c) Equal to the weight of the body in air

(d) Equal to the weight of the immersed position of the body

6. A liquid is kept in a cylindrical vessel which is being rotated about a vertical axis through the centre of the circular base. If the radius of the vessel is r and angular velocity of rotation is ω, then the difference in the heights of the liquid at the centre of the vessel and the edge is

(a) $\frac{r\omega}{2g}$ (b) $\frac{r^2\omega^2}{2g}$

(c) $\sqrt{2gr\omega}$ (d) $\frac{\omega^2}{2gr^2}$

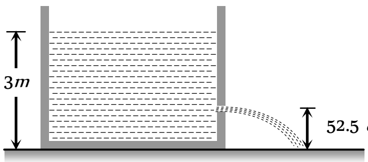
7. Water is filled in a cylindrical container to a height of 3*m*. The ratio of the cross-sectional area of the orifice and the beaker is 0.1. The square of the speed of the liquid coming out from the orifice is (g = 10 *m/s*) [IIT JEE 2004]

(a) 50 *m/s*

(b) 50.5 *m/s*

(c) 51 *m/s*

(d) 52 *m/s*



8. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth $4y$ from the top. When the tank is completely filled with water the quantities of water flowing out per second from both the holes are the same. Then R is equal to

(a) $2\pi L$ (b) $\frac{L}{\sqrt{2\pi}}$

(c) L (d) $\frac{L}{2\pi}$

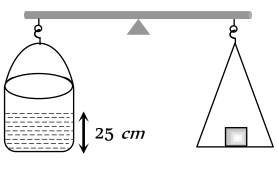
9. A cylinder containing water up to a height of 25 *cm* has a hole of cross-section $\frac{1}{4}cm^2$ in its bottom. It is counterpoised in a balance. What is the initial change in the balancing weight when water begins to flow out

(a) Increase of 12.5 *gm-wt*

(b) Increase of 6.25 *gm-wt*

(c) Decrease of 12.5 *gm-wt*

(d) Decrease of 6.25 *gm-wt*



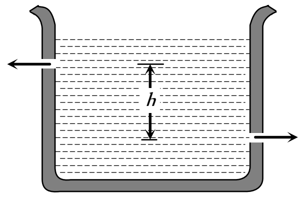
10. There are two identical small holes of area of cross-section a on the opposite sides of a tank containing a liquid of density ρ. The difference in height between the holes is h. Tank is resting on a smooth horizontal surface. Horizontal force which will has to be applied on the tank to keep it in equilibrium is

(a) $gh\rho a$

(b) $\frac{2gh}{\rho a}$

(c) $2\rho agh$

(d) $\frac{\rho gh}{a}$



11. Two communicating vessels contain mercury. The diameter of one vessel is n times larger than the diameter of the other. A column of water of height h is poured into the left vessel. The mercury level will rise in the right-hand vessel (s = relative density of mercury and ρ = density of water) by

(a)

(c) $\frac{h}{(n+1)^2 s}$ (d) $\frac{h}{n^2 s}$

12. A uniform rod of density ρ is placed in a wide tank containing a liquid of density $\rho_0(\rho_0 > \rho)$. The depth of liquid in the tank is half the length of the rod. The rod is in equilibrium, with its lower end resting on the bottom of the tank. In this position the rod makes an angle θ with the horizontal

(a) $\sin\theta = \frac{1}{2}\sqrt{\rho_0 / \rho}$ (b) $\sin\theta = \frac{1}{2}.\frac{\rho_0}{\rho}$

(c) $\sin\theta = \sqrt{\rho / \rho_0}$ (d) $\sin\theta = \rho_0 / \rho$

[IIT-JEE (Screening) 2000]

13. A block of ice floats on a liquid of density 1.2in a beaker then level of liquid when ice completely melt

[IIT-JEE 1994]

(a) Remains same (b) Rises

(c) Lowers (d) (a), (b) or (c)

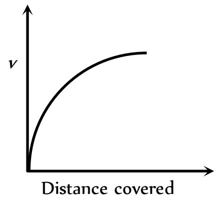
14. A vessel of area of cross-section A has liquid to a height H. There is a hole at the bottom of vessel having area of cross-section a. The time taken to decrease the level from H_1 to H_2 will be

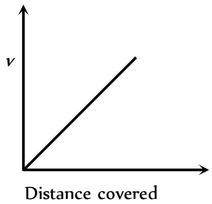
(a) $\frac{A}{a}\sqrt{\frac{2}{g}}[\sqrt{H_1} - \sqrt{H_2}]$ (b) $\sqrt{2gh}$

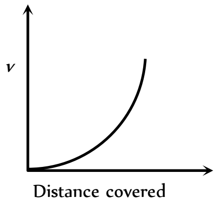
(c) $\sqrt{2gh(H_1 - H_2)}$ (d) $\frac{A}{a}\sqrt{\frac{g}{2}}[\sqrt{H_1} - \sqrt{H_2}]$

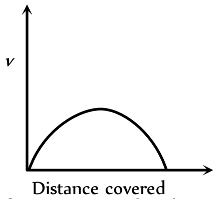
GQ Graphical Questions

1. A lead shot of 1mm diameter falls through a long column of glycerine. The variation of its velocity v. with distance covered is represented by [AIIMS 2003]

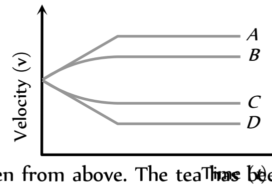
(a) 

(b) 

(c) 

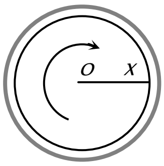
(d) 

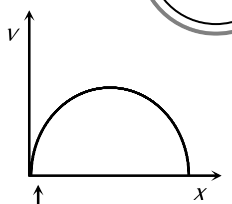
2. A small spherical solid ball is dropped from a great height in a viscous liquid. Its journey in the liquid is best described in the diagram given below by the [CPMT 1988]

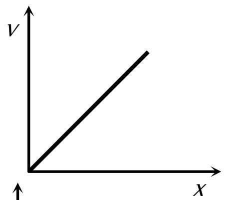


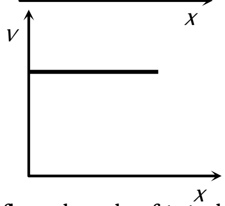
(a) Curve A
(b) Curve B
(c) Curve C
(d) Curve D

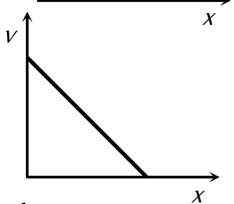
3. The diagram shows a cup of tea seen from above. The tea has been stirred and is now rotating without turbulence. A graph showing the speed v with which the liquid is crossing points at a distance X from O along a radius XO would look like



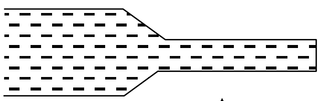
(a) 

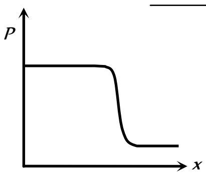
(b) 

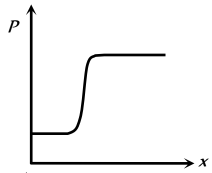
(c) 

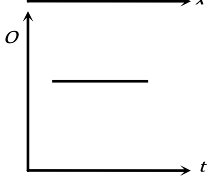
(d) 

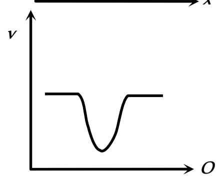
4. Water flows through a frictionless duct with a cross-section varying as shown in fig. Pressure p at points along the axis is represented by



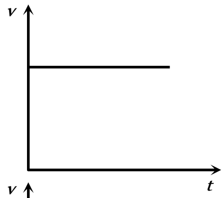
(a) 

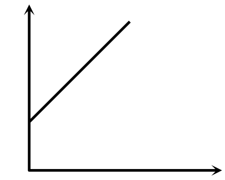
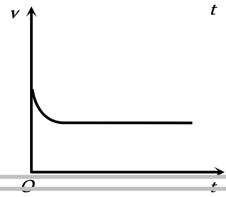
(b) 

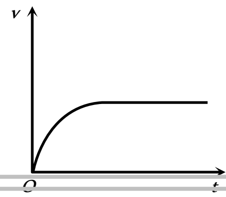
(c) 

(d) 

5. From amongst the following curves, which one shows the variation of the velocity v with time t for a small sized spherical body falling vertically in a long column of a viscous liquid

(a) 

(b) 
(c) 

(d) 

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Pascal law is the working principle of a hydraulic lift.
   Reason : Pressure is equal to thrust per area.
2. Assertion : The blood pressure in humans is greater at the feet than at the brain.
   Reason : Pressure of liquid at any point is proportional to height, density of liquid and acceleration due to gravity.
3. Assertion : Hydrostatic pressure is a vector quantity.
   Reason : Pressure is force divided by area, and force is a vector quantity.
4. Assertion : To float, a body must displace liquid whose weight is greater than the actual weight of the body.
   Reason : The body will experiences no net downward force, in the case of floating.
5. Assertion : A man sitting in a boat which is floating on a pond. If the man drinks some water from the pond, the level of the water in the pond decreases.
   Reason : According to Archimede's principle the weight displaced by body is equal to the weight of the body.
6. Assertion : A piece of ice floats in water, the level of water remains unchanged when the ice melts completely.
   Reason : According to Archimede's principle, the loss in weight of the body in the liquid is equal to the weight of the liquid displaced by the immersed part of the body.
7. Assertion : The velocity increases, when water flowing in broader pipe enter a narrow pipe.

Reason : According to equation of continuity, product of area and velocity is constant.

8. Assertion : The velocity of fall of a man jumping with a parachute first increases and then becomes constant.

Reason : The constant velocity of fall of man is called terminal velocity.

9. Assertion : The velocity of flow of a liquid is smaller when pressure is larger and viceversa.

Reason : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

10. Assertion : The shape of an automobile is so designed that its front resembles the stream line pattern of the fluid through which it moves.

Reason : The resistance offered by the fluid is maximum.

11. Assertion : The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.

Reason : Flow rate is independent of pressure exerted by the thumb of the doctor.

12. Assertion : A fluid flowing out of a small hole in a vessel apply a backward thrust on the vessel.

Reason : According to equation of continuity, the product of area and velocity remain constant.

13. Assertion : For a floating body to be in stable equilibrium, its centre of buoyancy must be located above the centre of gravity.

Reason : The torque produced by the weight of the body and the upthrust will restore body back to its normal position, after the body is disturbed.

14. Assertion : Water flows faster than honey.

Reason : The coefficient of viscosity of water is less than honey.

15. Assertion : The viscosity of liquid increases rapidly with rise of temperature.

Reason : Viscosity of a liquid is the property of the liquid by virtue of which it opposes the relative motion amongst its different layers.

16. Assertion : Aeroplanes are made to run on the runway before take off, so that they acquire the necessary lift.

Reason : According to Bernoulli's theorem, as velocity increases pressure decreases and viceversa.

17. Assertion : Sudden fall of pressure at a place indicates strom.

Reason : Air flows from higher pressure to lower pressure.

18. Assertion : Machine parts are jammed in winter.

Reason : The viscosity of lubricant used in machine parts increase at low temperature.

19. Assertion : A block of wood is floating in a tank containing water. The apparent weight of the floating block is equal to zero.

Reason : Because the entire weight of the block is supported by the buoyant force (the upward thrust) due to water.

20. Assertion : A rain drop after falling through some height attains a constant velocity.

Reason : At constant velocity, the viscous drag is just equal to its weight.

21. Assertion : paper pins are made to have pointed end.

Reason : Because pointed pins have very smalll area due to which even for small applied force it exert large pressure on the surface.

22. Assertion : Railways tracks are laid on small sized wooden sleepers.

Reason : Small sized wooden sleepers are used so that rails exert more pressure on the railway track. Due to which rail does not leave the track

23. Assertion : It is difficult to stop bleeding from a cut in the body at high altitudes.

Reason : The atmospheric pressure at high altitude is lesser than the blood pressure.

24. Assertion : To empty an oil tank, two holes are made.

Reason : Oil will come out two holes so it will emptied faster.

25. Assertion : Terminal velocity is same as the critical velocity.

Reason : The constant velocity of fall of a body through a viscous fluid is called terminal velocity.

26. Assertion : When two boats sails parallel in the same direction and close to each other, they are pulled towards each other.

Reason : The viscous drag on a spherical body moving with speed v is proportional to v.

27. Assertion : Cars and aeroplanes are streamlined.

Reason : This is done to reduce the backward drag due to atmosphere.

28. Assertion : Bernoulli's theorem holds for incompressible, non-viscous fluids.

Reason : The factor $\frac{v^2}{2g}$ is called velocity head.

Answers

Pressure and Density

1	b	2	c	3	b	4	b	5	c
6	b	7	c	8	b	9	d	10	c
11	c	12	c	13	a	14	d	15	a
16	b	17	a	18	b	19	d	20	b
21	c	22	a	23	b	24	b	25	b
26	b	27	d	28	a	29	c	30	c
31	d								

Pascal's Law and Archmidies Principle

1	c	2	a	3	c	4	c	5	b
6	d	7	a	8	b	9	bc	10	c
11	c	12	d	13	a	14	b	15	b
16	d	17	a	18	a	19	b	20	b
21	c	22	c	23	b	24	b	25	b
26	d	27	a						

Fluid Flow

1	b	2	a	3	c	4	d	5	d
6	a	7	d	8	b	9	a	10	c
11	b	12	a	13	c	14	a	15	d
16	b	17	b	18	c	19	c	20	b
21	d	22	b	23	a	24	d	25	c
26	a	27	a	28	b	29	a	30	a
31	a	32	b	33	c	34	a	35	b
36	ad	37	acd	38	b	39	b	40	a
41	a	42	c	43	b	44	b	45	d
46	c	47	b	48	b	49	a	50	a
51	a	52	d	53	b	54	d	55	d
56	d	57	d	58	c	59	c	60	a
61	c	62	a	63	d	64	c	65	c
66	d								

Critical Thinking Questions

1	c	2	a	3	d	4	c	5	a
6	b	7	a	8	b	9	c	10	c
11	b	12	a	13	b	14	a		

Graphical Questions

1	a	2	b	3	d	4	a	5	d

Assertion and Reason

1	b	2	a	3	e	4	c	5	e
6	a	7	a	8	b	9	a	10	c
11	c	12	a	13	a	14	a	15	e
16	a	17	a	18	a	19	a	20	a
21	a	22	d	23	a	24	c	25	e
26	b	27	a	28	b				

Answers and Solutions

Pressure and Density

1. (b) Pressure at bottom of the lake = $P_0 + h\rho g$

Pressure at half the depth of a lake $= P_0 + \frac{h}{2}\rho g$

According to given condition

$P_0 + \frac{1}{2}h\rho g = \frac{2}{3}(P_0 + h\rho g) \Rightarrow \frac{1}{3}P_0 = \frac{1}{6}h\rho g$

$\Rightarrow h = \frac{2P_0}{\rho g} = \frac{2\times 10^5}{10^3 \times 10} = 20m$.

2. (c) Apparent weight $= V(\rho - \sigma)g = \frac{m}{\rho}(\rho - \sigma)g$

where $m =$ mass of the body,

$\rho =$ density of the body

$\sigma =$ density of water

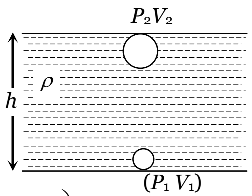
If two bodies are in equilibrium then their apparent weight must be equal.

$\therefore \frac{m_1}{\rho_1}(\rho_1 - \sigma) = \frac{m_2}{\rho_2}(\rho_2 - \sigma)$

$\Rightarrow \frac{36}{9}(9-1) = \frac{48}{\rho_2}(\rho_2 - 1)$

By solving we get $\rho_2 = 3$.

3. (b) According to Boyle's law, pressure and volume are inversely proportional to each other *i.e.* $P \propto \frac{1}{V}$



$\Rightarrow P_1V_1 = P_2V_2$

$\Rightarrow (P_0 + h\rho_w g)V_1 = P_0V_2$

$\Rightarrow V_2 = \left(1 + \frac{h\rho_w g}{P_0}\right)V_1$

$\Rightarrow V_2 = \left(1 + \frac{47.6 \times 10^2 \times 1 \times 1000}{70 \times 13.6 \times 1000}\right)V_1$

$\Rightarrow V_2 = (1+5)50\,cm^3 = 300\,cm^3$.

[As $P_2 = P_0 = 70\,cm$ of $Hg = 70 \times 13.6 \times 1000$]

4. (b) Force acting on the base

$F = P \times A = hdgA = 0.4 \times 900 \times 10 \times 2 \times 10^{-3} = 7.2N$

5. (c) As the both points are at the surface of liquid and these points are in the open atmosphere. So both point possess similar pressure and equal to 1 *atm*. Hence the pressure difference will be zero.

6. (b) Difference of pressure between sea level and the top of hill

$\Delta P = (h_1 - h_2) \times \rho_{Hg} \times g = (75-50)\times 10^{-2} \times \rho_{Hg} \times g$ ...(i)

and pressure difference due to h meter of air

$\Delta P = h \times \rho_{air} \times g$ ...(ii)

By equating (i) and (ii) we get

$h \times \rho_{air} \times g = (75-50)\times 10^{-2} \times \rho_{Hg} \times g$

$\therefore h = 25 \times 10^{-2}\left(\frac{\rho_{Hg}}{\rho_{air}}\right) = 25 \times 10^{-2} \times 10^4 = 2500\,m$

$\therefore$ Height of the hill = 2.5 *km*.

7. (c) Volume of ice $= \frac{M}{\rho}$, volume of water $= \frac{M}{\sigma}$.

$\therefore$ Change in volume $= \frac{M}{\rho} - \frac{M}{\sigma} = M\left(\frac{1}{\rho} - \frac{1}{\sigma}\right)$

8. (b) If two liquid of equal masses and different densities are mixed together then density of mixture

$\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} = \frac{2\times 1 \times 2}{1+2} = \frac{4}{3}$

9. (d) Let M_0 = mass of body in vacuum.

Apparent weight of the body in air = Apparent weight of standard weights in air

$\Rightarrow$ Actual weight – upthrust due to displaced air

= Actual weight – upthrust due to displaced air

$\Rightarrow M_0 g - \left(\frac{M_0}{d_1}\right)dg = Mg - \left(\frac{M}{d_2}\right)dg \Rightarrow M_0 = \frac{M\left[1 - \frac{d}{d_2}\right]}{\left[1 - \frac{d}{d_1}\right]}$

10. (c) $P = h\rho g$ *i.e.* pressure does not depend upon the area of bottom surface.

11. (c) $P_1V_1 = P_2V_2 \Rightarrow (P_0 + h\rho g)\times \frac{4}{3}\pi r^3 = P_0 \times \frac{4}{3}\pi(2r)^3$

Where, h = depth of lake

$\Rightarrow h\rho g = 7P_0 \Rightarrow h = 7 \times \frac{H\rho g}{\rho g} = 7H$.

12. (c) $P_1V_1 = P_2V_2 \Rightarrow (P_0 + h\rho g)V = P_0 \times 3V$

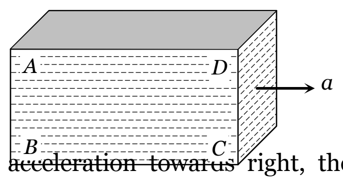
$\Rightarrow h\rho g = 2P_0 \Rightarrow h = \frac{2 \times 75 \times 13.6 \times g}{\frac{13.6}{10} \times g} = 15\,m$

13. (a) $h = \frac{P}{\rho g}$ $\therefore h \propto \frac{1}{g}$ (P and ρ are constant)

If value of g decreased by 2% then h will increase by 2%.

14. (d) $h = \frac{P}{\rho g}$ $\therefore h \propto \frac{1}{g}$. If lift moves upward with some acceleration then effective g increases. So the value of h decreases *i.e.* reading will be less than 76 *cm*.

15. (a)



Due to acceleration towards right, there will be a pseudo force in a left direction. So the pressure will be more on rear side (Points A and B) in comparison with front side (Point D and C).

Also due to height of liquid column pressure will be more at the bottom (points B and C) in comparison with top (point A and D).

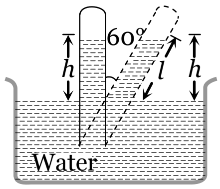
So overall maximum pressure will be at point B and minimum pressure will be at point D.

16. (b) Total pressure at (near) bottom of the liquid

$P = P_0 + h\rho g$

As air is continuously pumped out from jar (container), P_0 decreases and hence P decreases.

17. (a) $\cos 60° = \frac{h}{l}$



$\Rightarrow l = \frac{h}{\cos 60°} = \frac{76}{1/2}$

$\therefore\ l = 152\ cm$

18. (b) Pressure at the bottom = $h\rho g$

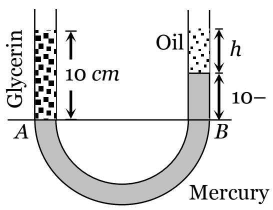
and pressure on the vertical surface = $\frac{1}{2}h\rho g$

Now, according to problem

Force at the bottom = Force on the vertical surface

$\Rightarrow\ h\rho g \times \pi r^2 = \frac{1}{2}h\rho g \times 2\pi r h \Rightarrow h = r$

19. (d)



At the condition of equilibrium

Pressure at point A = Pressure at point B

$P_A = P_B \Rightarrow\ 10 \times 1.3 \times g = h \times 0.8 \times g + (10 - h) \times 13.6 \times g$

By solving we get $h = 9.7\ cm$

20. (b) Thrust on lamina = pressure at centroid × Area

$= \frac{h\rho g}{3} \times A = \frac{1}{3}A\rho g h.$

21. (c) $\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{2m}{V_1 + V_2} = \frac{2m}{m\left(\frac{1}{\rho_1} + \frac{1}{\rho_2}\right)}$

$\therefore\ \rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$

22. (a) $\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{m_1 + m_2}{2V} = \frac{V(\rho_1 + \rho_2)}{2V} = \frac{\rho_1 + \rho_2}{2}$

23. (b) Bulk modulus, $B = -V_0\frac{\Delta p}{\Delta V} \Rightarrow \Delta V = -V_0\frac{\Delta p}{B}$

$\Rightarrow\ V = V_0\left[1 - \frac{\Delta p}{B}\right]$

$\therefore$ Density, $\rho = \rho_0\left[1 - \frac{\Delta p}{B}\right]^{-1} = \rho_0\left[1 + \frac{\Delta p}{B}\right]$

where, $\Delta p = p - p_0 = h\rho_0 g$

= pressure difference between depth and surface of ocean

$\therefore\ \rho = \rho_0\left[1 + \frac{\rho_0 g y}{B}\right]$ (As $h = y$)

24. (b) Since, with increase in temperature, volume of given body increases, while mass remains constant so that density will decrease.

i.e. $\frac{\rho}{\rho_0} = \frac{m/V}{m/V_0} = \frac{V_0}{V} = \frac{V_0}{V_0(1 + r\Delta\theta)} = (1 - \gamma\Delta\theta)$

$\therefore\ \rho = \rho_0(1 - \gamma\Delta\theta)$

25. (b) $\rho_{mix} = \frac{m_1 + m_2 + m_3}{3V} = \frac{V(d + 2d + 3d)}{3V} = 2d.$

26. (b) $\rho_{mix} = \frac{3m}{V_1 + V_2 + V_3} = \frac{3m}{\frac{m}{d} + \frac{m}{2d} + \frac{m}{3d}} = \frac{3 \times 6}{11}d = \frac{18}{11}d$

27. (d) Pressure = $h\rho g$ *i.e.* pressure at the bottom is independent of the area of the bottom of the tank. It depends on the height of water upto which the tank is filled with water. As in both the tanks, the levels of water are the same, pressure at the bottom is also the same.

28. (a)

29. (c) A torque is acting on the wall of the dam trying to make it topple. The bottom is made very broad so that the dam will be stable.

30. (c)

31. (d)

Pascal's Law and Archmidies Principle

1. (c) Let the total volume of ice-berg is V and its density is ρ. If this ice-berg floats in water with volume V_{in} inside it then $V_{in}\sigma g = V\rho g \Rightarrow V_{in} = \left(\frac{\rho}{\sigma}\right)V$

or $V_{out} = V - V_{in} = \left(\frac{\sigma - \rho}{\sigma}\right)V$

$\Rightarrow \frac{V_{out}}{V} = \left(\frac{\sigma - \rho}{\sigma}\right) = \frac{1000 - 900}{1000} = \frac{1}{10}$

$\therefore\ V_{out} = 10\%$ of V

2. (a) Volume of log of wood $V = \frac{\text{mass}}{\text{density}} = \frac{120}{600} = 0.2\ m^3$

Let x weight that can be put on the log of wood.

So weight of the body = $(120 + x) \times 10\ N$

Weight of displaced liquid = $V\sigma g = 0.2 \times 10^3 \times 10\ N$

The body will just sink in liquid if the weight of the body will be equal to the weight of displaced liquid.

$\therefore\ (120+x)\times 10 = 0.2\times 10^3\times 10$

$\Rightarrow 120 + x = 200\ \therefore\ x = 80\ kg$

3. (c) Weight of the bowl = mg

$= V\rho g = \frac{4}{3}\pi\left[\left(\frac{D}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right]\rho g$

where D = Outer diameter ,
d = Inner diameter
ρ = Density of bowl

Weight of the liquid displaced by the bowl

$= V\sigma g = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3\sigma g$

where σ is the density of the liquid.

For the flotation $\frac{4}{3}\pi\left(\frac{D}{2}\right)^3\sigma g = \frac{4}{3}\pi\left[\left(\frac{D}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right]\rho g$

$\Rightarrow \left(\frac{1}{2}\right)^3\times 1.2\times 10^3 = \left[\left(\frac{1}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right]2\times 10^4$

By solving we get $d = 0.98\ m$.

4. (c) Specific gravity of alloy $= \frac{\text{Density of alloy}}{\text{Density of water}}$

$= \frac{\text{Mass of alloy}}{\text{Volume of alloy}\times\text{density of water}}$

$= \frac{m_1+m_2}{\left(\frac{m_1}{\rho_1}+\frac{m_2}{\rho_2}\right)\times\rho_w} = \frac{m_1+m_2}{\frac{m_1}{\rho_1/\rho_w}+\frac{m_2}{\rho_2/\rho_w}} = \frac{m_1+m_2}{\frac{m_1}{s_1}+\frac{m_2}{s_2}}$

$\left[\text{As specific gravity of substance} = \frac{\text{density of substance}}{\text{density of water}}\right]$

5. (b) Let specific gravities of concrete and saw dust are ρ_1 and ρ_2 respectively.

According to principle of floatation weight of whole sphere = upthrust on the sphere

$\frac{4}{3}\pi(R^3 - r^3)\rho_1 g + \frac{4}{3}\pi r^3\rho_2 g = \frac{4}{3}\pi R^3\times 1\times g$

$\Rightarrow R^3\rho_1 - r^3\rho_1 + r^3\rho_2 = R^3$

$\Rightarrow R^3(\rho_1 - 1) = r^3(\rho_1 - \rho_2) \Rightarrow \frac{R^3}{r^3} = \frac{\rho_1-\rho_2}{\rho_1 - 1}$

$\Rightarrow \frac{R^3 - r^3}{r^3} = \frac{\rho_1 - \rho_2 - \rho_1 + 1}{\rho_1 - 1}$

$\Rightarrow \frac{(R^3 - r^3)\rho_1}{r^3\rho_2} = \left(\frac{1-\rho_2}{\rho_1 - 1}\right)\frac{\rho_1}{\rho_2}$

$\Rightarrow \frac{\text{Mass of concrete}}{\text{Mass of saw dust}} = \left(\frac{1-0.3}{2.4-1}\right)\times\frac{2.4}{0.3} = 4$

6. (d) Apparent weight

$= V(\rho - \sigma)g = l\times b\times h\times(5-1)\times g$

$= 5\times 5\times 5\times 4\times g\ Dyne = 4\times 5\times 5\times 5\ gf.$

7. (a) Fraction of volume immersed in the liquid $V_{in} = \left(\frac{\rho}{\sigma}\right)V$

i.e. it depends upon the densities of the block and liquid.

So there will be no change in it if system moves upward or downward with constant velocity or some acceleration.

8. (b) Apparent weight $= V(\rho - \sigma)g = \frac{M}{\rho}(\rho - \sigma)g$

$= M\left(1 - \frac{\sigma}{\rho}\right)g = 2.1\left(1 - \frac{0.8}{10.5}\right)g = 1.94\ g\ N$

$= 1.94\ Kg\text{-}wt$

9. (b, c) Density of metal = ρ , Density of liquid = σ

If V is the volume of sample then according to problem

$210 = V\rho g$ ...(i)

$180 = V(\rho - 1)g$ ...(ii)

$120 = V(\rho - \sigma)g$ ...(iii)

By solving (i), (ii) and (iii) we get $\rho = 7$ and $\sigma = 3$.

10. (c) If two different bodies A and B are floating in the same liquid then $\frac{\rho_A}{\rho_B} = \frac{(f_{in})_A}{(f_{in})_B} = \frac{1/2}{2/3} = \frac{3}{4}$

11. (c) For the floatation $V_0 d_0 g = V_{in}\ d\ g \Rightarrow V_{in} = V_0\frac{d_0}{d}$

$\therefore\ V_{out} = V_0 - V_{in} = V_0 - V_0\frac{d_0}{d} = V_0\left[\frac{d - d_0}{d}\right]$

$\Rightarrow \frac{V_{out}}{V_0} = \frac{d - d_0}{d}.$

12. (d)

13. (a) Apparent weight = $V(\rho - \sigma)g$

$= 5\times 5\times 5(7-1)g = 6\times 5\times 5\times 5\ gf$

14. (b)

15. (b) Effective weight $W' = m(g - a)$ which is less than actual weight mg, so the length of spring decreases.

16. (d) Tension in spring T = upthrust – weight of sphere

$= V\sigma g - V\rho g = V\eta\rho g - V\rho g$ (As $\sigma = \eta\rho$)

$= (\eta - 1)V\rho g = (\eta - 1)mg.$

17. (a) When body (sphere) is half immersed, then upthrust = weight of sphere

$\Rightarrow \frac{V}{2}\times\rho_{\text{liq}}\times g = V\times\rho\times g\ \therefore\ \rho = \frac{\rho_{\text{liq}}}{2}$

When body (sphere) is fully immersed then,
Upthrust = wt. of sphere + wt. of water poured in sphere

$\Rightarrow V\times\rho_{\text{liq}}\times g = V\times\rho\times g + V'\times\rho_{\text{liq}}\times g$

$\Rightarrow V\times\rho_{\text{liq}} = \frac{V\times\rho_{\text{liq}}}{2} + V'\times\rho_{\text{liq}} \Rightarrow V' = \frac{V}{2}$

18. (a) Since no change in volume of displaced water takes place, hence level of water remains same.

19. (b) The velocity of ball before entering the water surface

$v = \sqrt{2gh} = \sqrt{2g \times 9}$

When ball enters into water, due to upthrust of water the velocity of ball decreases (or retarded)

The retardation, $a = \frac{\text{apparent weight}}{\text{mass of ball}}$

$= \frac{V(\rho - \sigma)g}{V\rho} = \left(\frac{\rho - \sigma}{\rho}\right)g = \left(\frac{0.4 - 1}{0.4}\right) \times g = -\frac{3}{2}g$

If h be the depth upto which ball sink, then,

$0 - v^2 = 2 \times \left(-\frac{3}{2}g\right) \times h \Rightarrow 2g \times 9 = 3gh \therefore h = 6\ cm.$

20. (b) Upthrust = weight of body

For A, $\frac{V_A}{2} \times \rho_W \times g = V_A \times \rho_A \times g \Rightarrow \rho_A = \frac{\rho_W}{2}$

For B, $\frac{3}{4} V_B \times \rho_W \times g = V_B \times \rho_B \times g \Rightarrow \rho_B = \frac{3}{4}\rho_W$

(Since 1/4 of volume of B is above the water surface)

$\therefore \frac{\rho_A}{\rho_B} = \frac{\rho_W/2}{3/4\ \rho_W} = \frac{2}{3}$

21. (c)

22. (c) Since, up thrust (F) = $V\sigma g$ *i.e.* $F \propto V$

23. (b) $V\rho g = \frac{V}{2}\sigma g \therefore \rho = \frac{\sigma}{2}$ (σ = density of water)

24. (b)

25. (b)

26. (d)

27. (a)

Fluid Flow

1. (b) For streamline flow, Reynold's number $N_R \propto \frac{r\rho}{\eta}$ should be less. For less value of N_R, radius and density should be small and viscosity should be high.

2. (a) $d_A = 2cm$ and $d_B = 4\ cm$ $\therefore r_A = 1\ cm$ and $r_B = 2\ cm$

From equation of continuity, av = constant

$\therefore \frac{v_A}{v_B} = \frac{a_B}{a_A} = \frac{\pi(r_B)^2}{\pi(r_A)^2} = \left(\frac{2}{1}\right)^2 \Rightarrow v_A = 4v_B$

3. (c) If the liquid is incompressible then mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end.

$\therefore M = m_1 + m_2 \Rightarrow Av_1 = Av_2 + 1.5A.v$

$\Rightarrow A \times 3 = A \times 1.5 + 1.5A.v \Rightarrow v = 1\ m/s$

4. (d) This happens in accordance with equation of continuity and this equation was derived on the principle of conservation of mass and it is true in every case, either tube remain horizontal or vertical.

5. (d) $a_1v_1 = a_2v_2$

$\Rightarrow 4.20 \times 5.18 = 7.60 \times v_2 \Rightarrow v_2 = 2.86\ m/s$

6. (a) Velocity head $h = \frac{v^2}{2g} = \frac{(5)^2}{2 \times 10} = 1.25\ m$

7. (d) As cross-section areas of both the tubes A and C are same and tube is horizontal. Hence according to equation of continuity $v_A = v_C$ and therefore according to Bernoulli's theorem $P_A = P_C$ *i.e.* height of liquid is same in both the tubes A and C.

8. (b) Bernoulli's theorem for unit mass of liquid

$\frac{P}{\rho} + \frac{1}{2}v^2 = \text{constant}$

As the liquid starts flowing, it pressure energy decreases

$\frac{1}{2}v^2 = \frac{P_1 - P_2}{\rho} \Rightarrow \frac{1}{2}v^2 = \frac{3.5 \times 10^5 - 3 \times 10^5}{10^3} \Rightarrow v^2$

$= \frac{2 \times 0.5 \times 10^5}{10^3} \Rightarrow v^2 = 100 \Rightarrow v = 10\ m/s$

9. (a) From the Bernoulli's theorem

$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2} \times 1.3 \times [(120)^2 - (90)^2]$

$= 4095\ N/m^2$ or *Pascal*

10. (c) Time taken for the level to fall from H to H'

$t = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{H} - \sqrt{H'}\right]$

According to problem- the time taken for the level to fall from h to $\frac{h}{2}$ $t_1 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{h} - \sqrt{\frac{h}{2}}\right]$

and similarly time taken for the level to fall from $\frac{h}{2}$ to zero $t_2 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{h}{2}} - 0\right]$

$\therefore \frac{t_1}{t_2} = \frac{1 - \frac{1}{\sqrt{2}}}{\frac{1}{\sqrt{2}} - 0} = \sqrt{2} - 1.$

11. (b) $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20\ m/s$

12. (a) Pressure at the bottom of tank $P = h\rho g = 3 \times 10^5 \frac{N}{m^2}$

Pressure due to liquid column

$P_l = 3 \times 10^5 - 1 \times 10^5 = 2 \times 10^5$

and velocity of water $v = \sqrt{2gh}$

$\therefore v = \sqrt{\frac{2P_l}{\rho}} = \sqrt{\frac{2 \times 2 \times 10^5}{10^3}} = \sqrt{400}\ m/s$

13. (c) Time required to emptied the tank $t = \frac{A}{A_0}\sqrt{\frac{2H}{g}}$

$\therefore \frac{t_2}{t_1} = \sqrt{\frac{H_2}{H_1}} = \sqrt{\frac{4h}{h}} = 2 \therefore t_2 = 2t$

14. (a) The height of water in the tank becomes maximum when the volume of water flowing into the tank per second becomes equal to the volume flowing out per second.

Volume of water flowing out per second

$= Av = A\sqrt{2gh}$ ...(i)

Volume of water flowing in per second

$= 70\, cm^3/sec$ ...(ii)

From (i) and (ii) we get

$A\sqrt{2gh} = 70 \Rightarrow 1 \times \sqrt{2gh} = 70$

$\Rightarrow 1 \times \sqrt{2 \times 980 \times h} = 70$

$\therefore\ h = \frac{4900}{1960} = 2.5\, cm.$

15. (d) $A = (0.1)^2 = 0.01 m^2$,

$\eta = 0.01\ Poise = 0.001\ decapoise$ (M.K.S. unit),

dv = 0.1 m/s and F = 0.002 N

$F = \eta A \frac{dv}{dx}$

$\therefore\ dx = \frac{\eta A dv}{F} = \frac{0.001 \times 0.01 \times 0.1}{0.002} = 0.0005 m$.

16. (b) $F = 6\pi \eta r v$

17. (b) In the first 100 m body starts from rest and its velocity goes on increasing and after 100 m it acquire maximum velocity (terminal velocity). Further, air friction *i.e.* viscous force which is proportional to velocity is low in the beginning and maximum at $v = v_T$.

Hence work done against air friction in the first 100 m is less than the work done in next 100 m.

18. (c) If two drops of same radius r coalesce then radius of new drop is given by R

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r^3 + \frac{4}{3}\pi r^3 \Rightarrow R^3 = 2r^3 \Rightarrow R = 2^{1/3} r$

If drop of radius r is falling in viscous medium then it acquire a critical velocity v and $v \propto r^2$

$\frac{v_2}{v_1} = \left(\frac{R}{r}\right)^2 = \left(\frac{2^{1/3} r}{r}\right)^2$

$\Rightarrow v_2 = 2^{2/3} \times v_1 = 2^{2/3} \times (5) = 5 \times (4)^{1/3} m/s$

19. (c) Velocity of ball when it strikes the water surface $v = \sqrt{2gh}$ ...(i)

Terminal velocity of ball inside the water $v = \frac{2}{9} r^2 g \frac{(\rho - 1)}{\eta}$ ...(ii)

Equating (i) and (ii) we get $\sqrt{2gh} = \frac{2}{9} \frac{r^2 g}{\eta} (\rho - 1)$

$\Rightarrow h = \frac{2}{81} r^4 \left(\frac{\rho - 1}{\eta}\right)^2 g$

20. (b) Rate of flow of liquid $V = \frac{P}{R}$

where liquid resistance $R = \frac{8\eta l}{\pi r^4}$

For another tube liquid resistance

$R' = \frac{8\eta l}{\pi \left(\frac{r}{2}\right)^4} = \frac{8\eta l}{\pi r^4}.16 = 16R$

For the series combination

$V_{New} = \frac{P}{R + R'} = \frac{P}{R + 16R} = \frac{P}{17R} = \frac{V}{17}$.

21. (d) From $V = \frac{P\pi r^4}{8\eta l} \Rightarrow P = \frac{V 8\eta l}{\pi r^4}$

$\Rightarrow \frac{P_2}{P_1} = \frac{V_2}{V_1} \times \frac{l_2}{l_1} \times \left(\frac{r_1}{r_2}\right)^4 = 2 \times 2 \times \left(\frac{1}{2}\right)^4 = \frac{1}{4}$

$\Rightarrow P_2 = \frac{P_1}{4} = \frac{P}{4}$.

22. (b) $V = \frac{\pi P r^4}{8\eta l} = \frac{8 cm^3}{\text{sec}}$

For composite tube

$V_1 = \frac{P\pi r^4}{8\eta\left(l + \frac{l}{2}\right)} = \frac{2}{3}\frac{\pi P r^4}{8\eta l} = \frac{2}{3} \times 8 = \frac{16}{3}\frac{cm^3}{\text{sec}}$

$\left[\because\ l_1 = l = 2l_2 \text{ or } l_2 = \frac{l}{2}\right]$

23. (a)

24. (d)

25. (c)

26. (a) If velocities of water at entry and exit points are v_1 and v_2, then according to equation of continuity,

$A_1 v_1 = A_2 v_2 \Rightarrow \frac{v_1}{v_2} = \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$

27. (a)

28. (b)

29. (a)

30. (a)

31. (a)

32. (b) According to Bernoulli's theorem.

33. (c)

34. (a) $\frac{v^2}{2g} = h \Rightarrow v = \sqrt{2gh}$

$= \sqrt{2 \times 10^3 \times 40} = 2\sqrt{2} \times 10^2 = 282.8\ cm/s$

35. (b)

36. (a,d)

37. (a,c,d) According to equation of continuity the volume of liquid flowing through the tube in unit time remains constant *i.e.* $A_1 v_1 = A_2 v_2$, hence option (a) is correct

According to Bernoulli's theorem,

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

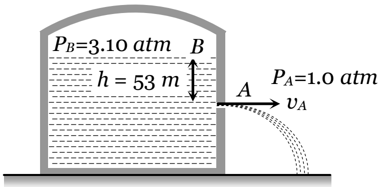
$\Rightarrow P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) \Rightarrow h\rho g = \frac{1}{2}\rho(v_2^2 - v_1^2)$

$\therefore v_2^2 - v_1^2 = 2gh$

Hence option (c) is correct.

Also, according to Bernoulli's theorem option (d) is correct

38. (b)



According to Bernoulli's theorem,

$P_B + h\rho g = P_A + \frac{1}{2}\rho v_A^2$ (As $v_A >> v_B$)

$3.10P + 53 \times 660 \times 10 = P + \frac{1}{2} \times 660 v_A^2$

$\Rightarrow 2.1 \times 1.01 \times 10^5 + 3.498 \times 10^5 = \frac{1}{2} \times 660 \times v_A^2$

$\Rightarrow 5.619 \times 10^5 = \frac{1}{2} \times 660 \times v_A^2$

$\therefore v_A = \sqrt{\frac{2 \times 5.619 \times 10^5}{660}} = 41\ m/s$

39. (b) According to Bernoulli's theorem, $h = \frac{v^2}{2g}$

$\Rightarrow h = \frac{(2.45)^2}{2 \times 10} = 0.314 = 31.4\ cm$

$\therefore$ Height of jet coming from orifice

$= 31.4 - 10.6 = 20.8\ cm$

40. (a)

41. (a)

42. (c) Time taken by water to reach the bottom

$= t = \sqrt{\frac{2(H-D)}{g}}$

and velocity of water coming out of hole, $v = \sqrt{2gD}$

$\therefore$ Horizontal distance covered $x = v \times t$

$= \sqrt{2gD} \times \sqrt{\frac{2(H-D)}{g}} = 2\sqrt{D(H-D)}$

43. (b) Horizontal range will be maximum when $h = \frac{H}{2} = \frac{90}{2}$

$= 45\ cm$ *i.e.* hole 3.

44. (b) Time taken to be emptied for h height, $t = \sqrt{\frac{2h}{g}}$

and for $\frac{h}{2}$ height, $t' = \sqrt{\frac{2h/2}{g}} = \sqrt{\frac{h}{g}}$

$\therefore \frac{t'}{t} = \frac{1}{\sqrt{2}} \Rightarrow t' = \frac{t}{\sqrt{2}} = \frac{10}{\sqrt{2}} = 7\ minute$

45. (d) Upthrust – weight of body = apparent weight

$VDg - Vdg = Vda,$

Where a = retardation of body $\therefore a = \left(\frac{D-d}{d}\right)g$

The velocity gained after fall from h height in air, $v = \sqrt{2gh}$

Hence, time to come in rest,

$t = \frac{v}{a} = \frac{\sqrt{2gh} \times d}{(D-d)g} = \sqrt{\frac{2h}{g}} \times \frac{d}{(D-d)}$

46. (c) $t = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H_1} - \sqrt{H_2}\right]$

Now, $T_1 = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H} - \sqrt{\frac{H}{\eta}}\right]$

and $T_2 = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{H}{\eta}} - \sqrt{0}\right]$

According to problem $T_1 = T_2$

$\therefore \sqrt{H} - \sqrt{\frac{H}{\eta}} = \sqrt{\frac{H}{\eta}} - 0 \Rightarrow \sqrt{H} = 2\sqrt{\frac{H}{\eta}} \Rightarrow \eta = 4$

47. (b)

48. (b)

49. (a)

50. (a)

51. (a)

52. (d)

53. (b)

54. (d)

55. (d) $V = V_1 + V_2$

$\Rightarrow \frac{\pi P r^4}{8\eta l} = \frac{\pi P r_1^4}{8\eta l} + \frac{\pi P r_2^4}{8\eta l} \Rightarrow r^4 = r_1^4 + r_2^4$

$\therefore r = (r_1^4 + r_2^4)^{1/4}$

56. (d) Given, $l_1 = l_2 = 1$, and $\frac{r_1}{r_2} = \frac{1}{2}$

$V = \frac{\pi P_1 r_1^4}{8\eta l} = \frac{\pi P_2 r_2^4}{8\eta l} \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_2}{r_1}\right)^4 = 16$

$\Rightarrow P_1 = 16P_2$

Since both tubes are connected in series, hence pressure difference across combination,

$P = P_1 + P_2 \Rightarrow 1 = P_1 + \frac{P_1}{16} \Rightarrow P_1 = \frac{16}{17} = 0.94m$

57. (d) $V = \frac{\pi p r^4}{8\eta l}$ $\therefore V \propto P r^4$ (η and l are constants)

$\therefore \frac{V_2}{V_1} = \left(\frac{P_2}{P_1}\right)\left(\frac{r_2}{r_1}\right)^4 = 2 \times \left(\frac{1}{2}\right)^4 = \frac{1}{8} \therefore V_2 = \frac{Q}{8}$

58. (c)

59. (c) $a_1v_1 = a_2v_2 \Rightarrow \frac{v_2}{v_1} = \frac{a_1}{a_2} = \left(\frac{r_1}{r_2}\right)^2$

$\Rightarrow v_2 = 3\times(2)^2 = 12\ m/s$

60. (a) Fluid resistance is given by $R = \frac{8\eta l}{\pi r^4}$.

When two capillary tubes of same size are joined in parallel, then equivalent fluid resistance is

$$R_e = R_1 + R_2 = \frac{8\eta L}{\pi r^4} + \frac{8\eta \times 2L}{\pi(2R)^4} = \left(\frac{8\eta L}{\pi r^4}\right)\times\frac{9}{8}$$

Equivalent resistance becomes $\frac{9}{8}$ times so rate of flow will be $\frac{8}{9}X$

61. (c) A stream lined body has less resistance due to air.

62. (a)

63. (d) $\frac{P_1 - P_2}{\rho g} = \frac{v^2}{2g} \Rightarrow \frac{4.5\times10^5 - 4\times10^5}{10^3\times g} = \frac{v^2}{2g}\ \therefore\ v = 10m/s$

64. (c)

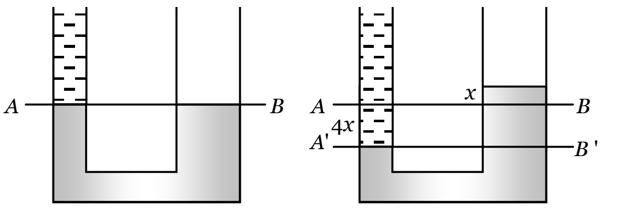
65. (c)

66. (d)

Critical Thinking Questions

1. (c) If the rise of level in the right limb be $x\ cm$. the fall of level of mercury in left limb be $4x\ cm$ because the area of cross section of right limb is 4 times as that of left limb.

$\therefore$ Level of water in left limb is $(36 + 4x)\ cm$.



Now equating pressure at interface of Hg and water (at $A'B'$)

$(36 + 4x)\times1\times g = 5x\times13.6\times g$

By solving we get $x = 0.56\ cm$.

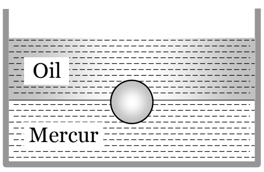
2. (a) Weight of cylinder = upthrust due to both liquids

$$V\times D\times g = \left(\frac{A}{5}\times\frac{3}{4}L\right)\times d\times g + \left(\frac{A}{5}\times\frac{L}{4}\right)\times 2d\times g$$

$$\Rightarrow \left(\frac{A}{5}\times L\right)\times D\times g = \frac{A\times L\times d\times g}{4} \Rightarrow \frac{D}{5} = \frac{d}{4}\ \ \therefore D = \frac{5}{4}d$$

3. (d) As the block moves up with the fall of coin, l decreases, similarly h will also decrease because when the coin is in water, it displaces water equal to its own volume only.

4. (c)



As the sphere floats in the liquid. Therefore its weight will be equal to the upthrust force on it

Weight of sphere

$= \frac{4}{3}\pi R^3\rho g$ ...(i)

Upthrust due to oil and mercury

$= \frac{2}{3}\pi R^3\times\sigma_{oil}g + \frac{2}{3}\pi R^3\sigma_{Hg}g$ ...(ii)

Equating (i) and (ii)

$\frac{4}{3}\pi R^3\rho g = \frac{2}{3}\pi R^3 0.8g + \frac{2}{3}\pi R^3\times13.6g$

$\Rightarrow 2\rho = 0.8 + 13.6 = 14.4 \Rightarrow \rho = 7.2$

5. (a) Upthrust $= V\rho_{\text{liquid}}(g - a)$

where, a = downward acceleration,

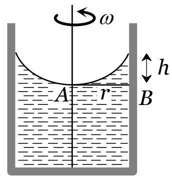
V = volume of liquid displaced

But for free fall $a = g\ \therefore$ Upthrust = 0

6. (b) From Bernoulli's theorem,

$P_A + \frac{1}{2}dv_A^2 + dgh_A = P_B + \frac{1}{2}dv_B^2 + dgh_B$

Here, $h_A = h_B$



$\therefore P_A + \frac{1}{2}dv_A^2 = P_B + \frac{1}{2}dv_B^2$

$\Rightarrow P_A - P_B = \frac{1}{2}d[v_B^2 - v_A^2]$

Now, $v_A = 0, v_B = r\omega$ and $P_A - P_B = hdg$

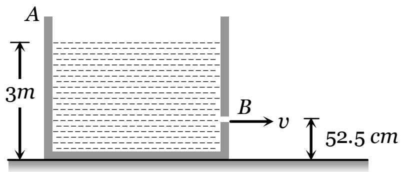
$\therefore\ hdg = \frac{1}{2}dr^2\omega^2$ or $h = \frac{r^2\omega^2}{2g}$

7. (a) Let A = cross-section of tank

a = cross-section hole

V = velocity with which level decreases

v = velocity of efflux



From equation of continuity $av = AV \Rightarrow V = \frac{av}{A}$

By using Bernoulli's theorem for energy per unit volume

Energy per unit volume at point A

= Energy per unit volume at point B

$P + \rho gh + \frac{1}{2}\rho V^2 = P + 0 + \frac{1}{2}\rho v^2$

$$\Rightarrow v^2 = \frac{2gh}{1 - \left(\frac{a}{A}\right)^2} = \frac{2\times10\times(3 - 0.525)}{1 - (0.1)^2} = 50(m/\sec)^2$$

8. (b) Velocity of efflux when the hole is at depth h, $v = \sqrt{2gh}$

Rate of flow of water from square hole

$Q_1 = a_1 v_1 = L^2\sqrt{2gy}$

Rate of flow of water from circular hole

$Q_2 = a_2 v_2 = \pi R^2\sqrt{2g(4y)}$

According to problem $Q_1 = Q_2$

$\Rightarrow L^2\sqrt{2gy} = \pi R^2\sqrt{2g(4y)} \Rightarrow R = \frac{L}{\sqrt{2\pi}}$

9. (c) Let A = The area of cross section of the hole

v = Initial velocity of efflux

d = Density of water,

Initial volume of water flowing out per second = Av

Initial mass of water flowing out per second = Avd

Rate of change of momentum = Adv^2

Initial downward force on the flowing out water = Adv^2

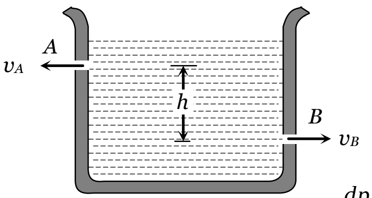
So equal amount of reaction acts upwards on the cylinder.

$\therefore$ Initial upward reaction = Adv^2 [As $v = \sqrt{2gh}$]

$\therefore$ Initial decrease in weight $= Ad(2gh)$

$= 2Adgh = 2\times\left(\frac{1}{4}\right)\times 1\times 980\times 25 = 12.5$ *gm-wt.*

10. (c)



Net force (reaction) = $F = F_B - F_A = \frac{dp_B}{dt} - \frac{dp_A}{dt}$

$= av_B\rho\times v_B - av_A\rho\times v_A$

$\therefore \quad F = a\rho\left(v_B^2 - v_A^2\right)$ ...(i)

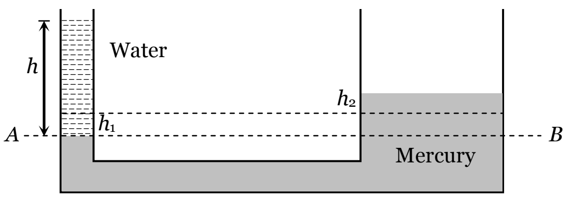
According to Bernoulli's theorem

$p_A + \frac{1}{2}\rho v_A^2 + \rho gh = p_B + \frac{1}{2}\rho v_B^2 + 0$

$\Rightarrow \frac{1}{2}\rho\left(v_B^2 - v_A^2\right) = \rho gh \Rightarrow v_B^2 - v_A^2 = 2gh$

From equation (i), $F = 2a\rho gh$.

11. (b)



If the level in narrow tube goes down by h_1 then in wider tube goes up to h_2,

Now, $\pi r^2 h_1 = \pi(nr)^2 h_2 \Rightarrow h_1 = n^2 h_2$

Now, pressure at point A = pressure at point B

$h\rho g = (h_1 + h_2)\rho' g$

$\Rightarrow h = (n^2 h_2 + h_2)sg \left(\text{As } s = \frac{\rho'}{\rho}\right) \Rightarrow h_2 = \frac{h}{(n^2+1)s}$

12. (a) Let $L = PQ$ = length of rod

$\therefore SP = SQ = \frac{L}{2}$

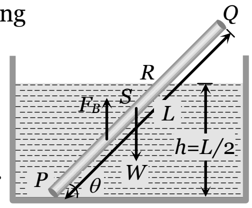
Weight of rod, $W = Al\rho g$, acting

At point S

And force of buoyancy,

$F_B = Al\rho_0 g$, $[l = PR]$

which acts at mid-point of PR.



For rotational equilibrium,

$Al\rho_0 g\times\frac{l}{2}\cos\theta = AL\rho g\times\frac{L}{2}\cos\theta$

$\Rightarrow \frac{l^2}{L^2} = \frac{\rho}{\rho_0} \Rightarrow \frac{l}{L} = \sqrt{\frac{\rho}{\rho_0}}$

From figure, $\sin\theta = \frac{h}{l} = \frac{L}{2l} = \frac{1}{2}\sqrt{\frac{\rho_0}{\rho}}$

13. (b) The volume of liquid displaced by floating ice $V_D = \frac{M}{\sigma_L}$

Volume of water formed by melting ice, $V_F = \frac{M}{\sigma_W}$

If $\sigma_1 > \sigma_W$, then, $\frac{M}{\sigma_L} < \frac{M}{\sigma_W}$ *i.e.* $V_D < V_F$

i.e. volume of liquid displaced by floating ice will be lesser than water formed and so the level if liquid will rise.

14. (a)

Graphical Questions

1. (a)

2. (b)

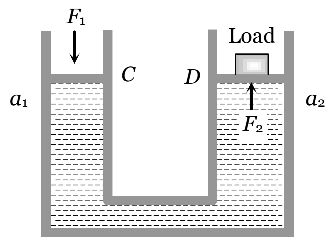
3. (d) When we move from centre to circumference, the velocity of liquid goes on decreasing and finally becomes zero.

4. (a) When cross-section of duct is decreased, the velocity of water increased and in accordance with Bernoulli's theorem, the pressure P decreased at that place.

5. (d)

Assertion and Reason

1 (b) According to Pascal's law, if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.



$P_1 = P_2$ *i.e.* $\frac{F_1}{a_1} = \frac{F_2}{a_2}$ or $F_2 = \frac{a_2}{a_1} F_1$

As $a_2 >> a_1$ $\therefore F_2 >> F_1$

This shows that small force (F_1) applied on the smaller piston (of area a_1) will be appearing as a very large force on the larger piston.

2 (a) Height of the blood column in the human body is more at feet than at the brain. As $P = h\rho g$, therefore the blood exerts more pressure at the feet than at the brain.

3 (e) Since due to applied force on liquid, the pressure is transmitted equally in all directions inside the liquid. That is why there is no fixed direction for the pressure due to liquid. Hence hydrostatic pressure is a scalar quantity.

4 (c) Net force = actual weight – upthrust force

= Actual weight – Weight of liquid displaced.

The body will rise above the surface of liquid to such an extent that the weight of the liquid displaced by the immersed part of the body (*i.e.* upward thrust) becomes equal to the weight of the body. Thus the body will float when upward thrust is more than its actual weight. In this special case the density of solid body is less than the density of liquid.

5 (e) The level of water does not change. The reason is that on drinking the water (say *m gm*), the weight of man increases by *m gm* and hence water displaced by man increases by *m gm*, tending to raise the level. However, this much amount of water has already been consumed by the man. Therefore the level of pond remain same.

6 (a)

7 (a) In a stream line flow of a liquid, according to equation of continuity $av =$ constant.

Where *a* is the area of cross section and *v* is the velocity of liquid flow. When water flowing in a broader pipe enters a narrow pipe, the area of cross-section of water decreases therefore the velocity of water increases.

8 (b) As a man jumps-out from a height in air with a parachute, its velocity increases first, because the gravity pull dominates the viscous drag and buoyancy of air which opposes the motion. As the velocity increases, the viscous drag of air also increases and soon a stage is reached where viscous drag and buoyancy of air balances the gravity pull. Then the man with a parachute falls with a constant velocity, called terminal velocity.

9 (a) According to Bernoulli's theorem, $P + \frac{1}{2}\rho v^2 =$ a constant

i.e. when velocity is large, the pressure is less in a stream line flow of an ideal liquid through a horizontal tube.

10 (c) When a body moves through a fluid, its motion is opposed by the force of fluid friction, which increases with the speed of the body. When cars and planes move through air, their motion is opposed by the air friction, which in turn, depend upon the shape of the body. It is due to this reason that the cars or planes are given such shape (known as stream lined shaped) so that air friction is minimum. Rather the movement of air layers on the upper and lower side of stream line shape provides a lift which helps in increasing the speed of the car.

11 (c) According to Bernoulli's equation,

$\frac{P}{\rho} + hg + \frac{1}{2}v^2 =$ constant

Thus, total energy of the injectable medicine depends upon second power of the velocity and first power of the pressure. It implies that total energy of the injectable medicine has greater dependence on its velocity. Therefore, a doctor adjust the flow of the medicine with the help of the size of the needle of the syringe $a_1v_1 = a_2v_2$) rather than the thumb pressure.

12 (a) Due to small area of cross-section of the hole, fluid flows out of the vessel with a large speed and thus the fluid possesses a large linear momentum. As no external forces acts on the system, in order to conserve linear momentum, the vessel acquires a velocity in backward direction or in other words a backward thrust results on the vessel.

13 (a) The stability of a floating body depends on the relative position of centre of gravity of a body, through which its weight acts and centre of gravity of the displaced water called centre of buoyancy through which the upthrust act.

14 (a)

15 (e) The viscosity of liquid decreases rapidly with rise of temperature. The variation of viscosity of liquid with temperature is given by $\eta_t = \eta_0(1 + \alpha t + \beta t^2)$

Where η_t and η_0 are the coefficient of viscosities at $t°C$ and $0°C$ respectively and α and β are constant.

16 (a) According to Bernoulli's theorem, when wind velocity over the wings is larger than the wind velocity under the wings, pressure of wind over the wings becomes less than the pressure of wind under the wing's. This provides the necessary lift to the aeroplane.

17 (a)

18 (a) Viscosities of fluids are markedly dependent on temperature, increasing for gases and decreasing for liquids as the temperature is increased. Thus important consideration in the design of oils for engine lubrication is to reduce the temperature variation of viscosity as much as possible.

19 (a)

20 (a) When a body falls through a viscous medium, finally, it attains terminal velocity. At this velocity, viscous force on rain drop balances the weight of the body.

21 (a) Smaller the area, larger the pressure exerted by a force

22 (d) Railways tracks are laided on large sized wooden sleepers. Due to large sized sleepers the weight of rail act on the large area. Hence, the pressure exerted is reduced appreciably.

23 (a)

24 (c) When two holes are made in the tin, air keeps on entering through the other hole. Due to this the pressure inside the tin does not become less than atmospheric pressure which happen only one hole is made.

25 (e) Terminal velocity and critical velocity are not same. Critical velocity is the velocity below which the flow of liquid is streamline.

26 (b)

27 (a)

28 (b)

Fluid Mechanics

SET Self Evaluation Test - 11

1. A tank 5 *m* high is half filled with water and then is filled to the top with oil of density 0.85 *g/cm*. The pressure at the bottom of the tank, due to these liquids is

   (a) 1.85 *g/cm* (b) 89.25 *g/cm*

   (c) 462.5 *g/cm* (d) 500 *g/cm*

2. Two substances of densities ρ_1 and ρ_2 are mixed in equal volume and the relative density of mixture is 4. When they are mixed in equal masses, the relative density of the mixture is 3. The values of ρ_1 and ρ_2 are

   (a) $\rho_1 = 6$ and $\rho_2 = 2$ (b) $\rho_1 = 3$ and $\rho_2 = 5$

   (c) $\rho_1 = 12$ and $\rho_2 = 4$ (d) None of these

3. A wooden block of volume 1000 *cm* is suspended from a spring balance. It weighs 12 *N* in air. It is suspended in water such that half of the block is below the surface of water. The reading of the spring balance is

   (a) 10 *N* (b) 9 *N*

   (c) 8 *N* (d) 7 *N*

4. Two different liquids are flowing in two tubes of equal radius. The ratio of coefficients of viscosity of liquids is 52:49 and the ratio of their densities is 13:1, then the ratio of their critical velocities will be

   (a) 4 : 49 (b) 49 : 4

   (c) 2 : 7 (d) 7 : 2

5. Two capillary tubes of same radius *r* but of lengths l_1 and l_2 are fitted in parallel to the bottom of a vessel. The pressure head is *P*. What should be the length of a single tube that can replace the two tubes so that the rate of flow is same as before

   (a) $l_1 + l_2$ (b) $\frac{1}{l_1} + \frac{1}{l_2}$

   (c) $\frac{l_1 l_2}{l_1 + l_2}$ (d) $\frac{1}{l_1 + l_2}$

6. A capillary tube is attached horizontally to a constant head arrangement. If the radius of the capillary tube is increased by 10% then the rate of flow of liquid will change nearly by

   (a) + 10% (b) + 46%

   (c) – 10% (d) – 40%

7. Two stretched membranes of area 2 *cm* and 3 *cm* are placed in a liquid at the same depth. The ratio of pressures on them is

   (a) 1 : 1 (b) 2 : 3

   (c) 3 : 2 (d) 2 : 3

8. Three identical vessels are filled to the same height with three different liquids *A*, *B* and $C (\rho_A > \rho_B > \rho_C)$. The pressure at the base will be

   (a) Equal in all vessels (b) Maximum in vessel *A*

   (c) Maximum in vessel *B* (d) Maximum in vessel *C*

9. Three identical vessels are filled with equal masses of three different liquids *A*, *B* and C $(\rho_A > \rho_B > \rho_C)$. The pressure at the base will be

   (a) Equal in all vessels (b) Maximum in vessel *A*

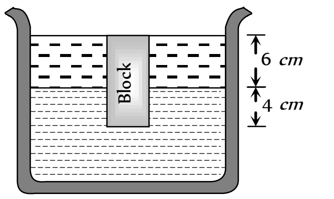
   (c) Maximum in vessel *B* (d) Maximum in vessel *C*

10. A piston of cross-section area 100 cm^2 is used in a hydraulic press to exert a force of 10^7 dynes on the water. The cross-sectional area of the other piston which supports an object having a mass 2000 kg. is

    (a) 100 cm^2 (b) 10^9 cm^2

    (c) 2×10^4 cm^2 (d) 2×10^{10} cm^2

11. A cubical block of wood 10 cm on a side floats at the interface between oil and water with its lower surface horizontal and 4 cm below the interface. The density of oil is $0.6 gcm^{-3}$. The mass of block is

    (a) 706 *g*

    (b) 607 *g*

    (c) 760 *g*

    (d) 670 *g*

12. A spherical ball of radius *r* and relative density 0.5 is floating in equilibrium in water with half of it immersed in water. The work done in pushing the ball down so that whole of it is just immersed in water is : (where ρ is the density of water)

    (a) $\frac{5}{12}\pi r^4 \rho g$ (b) $0.5 \rho r g$

    (c) $\frac{4}{3}\pi r^3 \rho g$ (d) $\frac{2}{3}\pi r^4 \rho g$

13. If *W* be the weight of a body of density ρ in vacuum then its apparent weight in air of density σ is

    (a) $\frac{W\rho}{\sigma}$ (b) $W\left(\frac{\rho}{\sigma} - 1\right)$

    (c) $\frac{W}{\rho}\sigma$ (d) $W\left(1 - \frac{\sigma}{\rho}\right)$

14. Which of the following is not the characteristic of turbulent flow

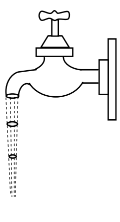
    (a) Velocity more than the critical velocity

    (b) Velocity less than the critical velocity

    (c) Irregular flow

    (d) Molecules crossing from one layer to another

15. Water coming out of the mouth of a tap and falling vertically in streamline flow forms a tapering column, *i.e.,* the area of cross-section of the liquid column decreases as it moves

down. Which of the following is the most accurate explanation for this

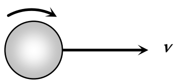
(a) As the water moves down, its speed increases and hence its pressure decreases. It is then compressed by the atmosphere

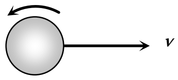
(b) Falling water tries to reach a terminal velocity and hence reduces the area of cross-section to balance upward and downward forces

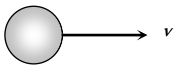
(c) The mass of water flowing past any cross-section must remain constant. Also, water is almost incompressible. Hence, the rate of volume flow must remain constant. As this is equal to velocity × area, the area decreases as velocity increases

(d) The surface tension causes the exposed surface area of the liquid to decrease continuously

16. To get the maximum flight, a ball must be thrown as

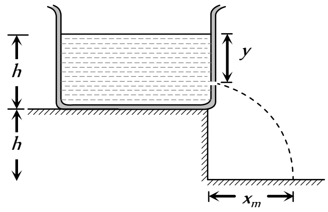
(a) 

(b) 

(c) 

(d) Any of (a), (b) and (c)

17. A tank is filled upto a height h with a liquid and is placed on a platform of height h from the ground. To get maximum range x_m a small hole is punched at a distance of y from the free surface of the liquid. Then



(a) $x_m = 2h$

(b) $x_m = 1.5h$

(c) $y = h$

(d) $y = 0.75h$

18. The relative velocity of two consecutive layers is 8 *cm/s*. If the perpendicular distance between the layers is 0.1 *cm*, then the velocity gradient will be

(a) $8 sec^{-1}$ (b) $80\ sec^{-1}$

(c) $0.8\ sec^{-1}$ (d) $0.08\ sec^{-1}$

19. Under a constant pressure head, the rate of flow of liquid through a capillary tube is V. If the length of the capillary is doubled and the diameter of the bore is halved, the rate of flow would become

(a) $V/4$ (b) $16\ V$

(c) $V/8$ (d) $V/32$

Answers and Solutions

(SET - 11)

1. (c) Pressure at the bottom $P = (h_1 d_1 + h_2 d_2)\frac{g}{cm^2}$

$= [250 \times 1 + 250 \times 0.85] = 250\ [1.85]\frac{g}{cm^2}$

$= 462.5\frac{g}{cm^2}$

2. (a) When substances are mixed in equal volume then density $= \frac{\rho_1 + \rho_2}{2} = 4 \Rightarrow \rho_1 + \rho_2 = 8$ ....(i)

When substances are mixed in equal masses then density $= \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} = 3$

$\Rightarrow 2\rho_1\rho_2 = 3(\rho_1 + \rho_2)$ ....(ii)

By solving (i) and (ii) we get $\rho_1 = 6$ and $\rho_2 = 2$.

3. (d) Reading of the spring balance
= Apparent weight of the block
= Actual weight – upthrust

$= 12 - V_{in}\sigma g$

$= 12 - 500\times 10^{-6}\times 10^3 \times 10 = 12 - 5 = 7N.$

4. (a) Critical velocity $v = N_R \dfrac{\eta}{\rho r}$

$\Rightarrow \dfrac{v_1}{v_2} = \dfrac{\eta_1}{\eta_2}\times\dfrac{\rho_2}{\rho_1} = \dfrac{52}{49}\times\dfrac{1}{13} = \dfrac{4}{49}.$

5. (c) For parallel combination $\dfrac{1}{R_{eff}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

$\Rightarrow \dfrac{\pi r^4}{8\eta l} = \dfrac{\pi r^4}{8\eta l_1} + \dfrac{\pi r^4}{8\eta l_2} \Rightarrow \dfrac{1}{l} = \dfrac{1}{l_1} + \dfrac{1}{l_2} \quad \therefore l = \dfrac{l_1 l_2}{l_1 + l_2}$

6. (b) $V = \dfrac{P\pi r^4}{8\eta l} \Rightarrow \dfrac{V_2}{V_1} = \left(\dfrac{r_2}{r_1}\right)^4$

$\Rightarrow V_2 = V_1\left(\dfrac{110}{100}\right)^4 = V_1(1.1)^4 = 1.4641V$

$\dfrac{\Delta V}{V} = \dfrac{V_2 - V_1}{V} = \dfrac{1.4641V - V}{V} = 0.46$ or 46%.

7. (a) Pressure is independent of area of cross section

8. (b) $P \propto \rho$

9. (a) $P = \dfrac{F}{A} = \dfrac{mg}{A}$

***

10. (c) $P_1 = P_2 \Rightarrow \dfrac{F_1}{A_1} = \dfrac{F_2}{A_2} \Rightarrow \dfrac{10^7}{10^2} = \dfrac{2000\times 10^3\times 10^3}{A_2}$

$\therefore A_2 = 2\times 10^4 cm^2 \qquad (g = 980 \approx 10^3 cm/s^2)$

11. (c) Weight of block
= Weight of displaced oil + Weight of displaced water

$\Rightarrow mg = V_1\rho_0 g + V_2\rho_W g$

$\Rightarrow m = (10\times 10\times 6)\times 0.6 + (10\times 10\times 4)\times 1 = 760$ *gm.*

12. (a)

13. (d) Apparent weight in air = W – upthrust = $V\rho g - V\sigma g$

$= V\rho g\left(1 - \dfrac{\sigma}{\rho}\right) = W\left(1 - \dfrac{\sigma}{\rho}\right)$

14. (b)

15. (c)

16. (b)

17. (a,c) Velocity of liquid through orifice, $v = \sqrt{2gy}$

and time taken by liquid to reach the ground

$t = \sqrt{\dfrac{2(h + h - y)}{g}} = \sqrt{\dfrac{2(2h - y)}{g}}$

$\therefore$ Horizontal distance covered by liquid

$x = v.t. = \sqrt{2gy}\times\sqrt{\dfrac{2(2h - y)}{g}} = \sqrt{4y(2h - y)}$

$\Rightarrow x^2 = 4y(2h - y)$

$\Rightarrow \dfrac{d(x)^2}{dy} = 8h - 8y$

for x to be maximum, $\dfrac{d}{dy}(x^2) = 0$

$\therefore 8h - 8y = 0$ or $h = y$

So $x_m = \sqrt{4h(2h - h)} = 2h$

18. (b) $\dfrac{dv}{dx} = \dfrac{8}{0.1} = 80 s^{-1}$

19. (d) Rate of flow under a constant pressure head,

$V = \dfrac{\pi p r^4}{8\eta l} \Rightarrow V \propto \dfrac{r^4}{l} \Rightarrow \dfrac{V_2}{V_1} = \left(\dfrac{r_2}{r_1}\right)^4 \times \dfrac{l_1}{l_2} = \left(\dfrac{1}{2}\right)^4 \times \dfrac{1}{2}$

$\Rightarrow V_2 = \dfrac{V_1}{32} = \dfrac{V}{32}$

Chapter

12

Thermometry, Thermal Expansion and Calorimetry

Temperature

Temperature is defined as the degree of hotness or coldness of a body. The natural flow of heat is from higher temperature to lower temperature.

Two bodies are said to be in thermal equilibrium with each other, when no heat flows from one body to the other. That is when both the bodies are at the same temperature.

(1) Temperature is one of the seven fundamental quantities with dimension $[\theta]$. It is a scalar physical quantity with S.I. unit kelvin.

(2) When heat is given to a body and its state does not change, the temperature of the body rises and if heat is taken from a body its temperature falls *i.e.* temperature can be regarded as the effect of cause "heat".

(3) According to kinetic theory of gases, temperature (macroscopic physical quantity) is a measure of average translational kinetic energy of a molecule (microscopic physical quantity).

(4) Although the temperature of a body can to be raised without limit, it cannot be lowered without limit and theoretically limiting low temperature is taken to be zero of the kelvin scale.

(5) Highest possible temperature achieved in laboratory is about $10^8 K$ while lowest possible temperature attained is $10^{-8} K$.

(6) Temperature of the core of the sun is $10^7 K$ while that of its surface is 6000 K.

(7) Normal temperature of human body is 310. 15 K ($37°C = 98.6°F$).

(8) NTP or STP implies 273.15K ($0°C = 32°F$)

Scales of Temperature

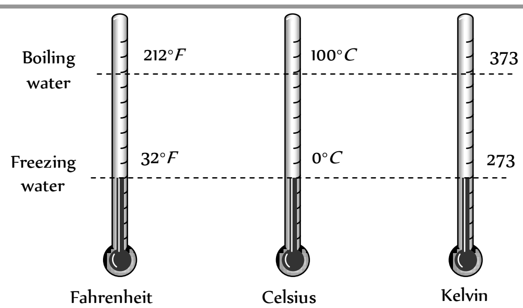


Fig. 12.1

The centigrade (°C), Farenheite (°F), Kelvin (K), Reaumer (R), Rankine (Ra) are commonly used temperature scales.

(1) To construct a scale of temperature, two fixed points are taken. First fixed point is the freezing point (ice point) of water, it is called lower fixed point (LFP). The second fixed point is the boiling point (steam point) of water, it is called upper fixed point (UFP).

(2) **Celsius scale :** In this scale LFP (ice point) is taken 0° and UFP (steam point) is taken 100°. The temperature measured on this scale all in degree Celsius (°C).

(3) **Farenheite scale :** This scale of temperature has LFP as 32°F and UFP as 212°F. The change in temperature of 1°F corresponds to a change of less than 1° on Celsius scale.

(4) **Kelvin scale :** The Kelvin temperature scale is also known as thermodynamic scale. The triple point of water is also selected to be the zero of scale of temperature. The temperature measured on this scale are in Kelvin (K).

The triple point of water is that point on a P-T diagram where the three phases of water, the solid, the liquid and the gas, can coexist in equilibrium.

Table 12.1 : Different measuring scales

Scale	Symbol for each degree	LFP	UFP	Number of divisions on the scale
Celsius	$°C$	$0°C$	$100°C$	100
Fahrenheit	$°F$	$32°F$	$212°F$	180
Reaumer	$°R$	$0°R$	$80°R$	80
Rankine	$°Ra$	460 Ra	672 Ra	212
Kelvin	K	273.15 K	373.15 K	100

(5) Temperature on one scale can be converted into other scale by using the following identity.

$$\frac{\text{Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}} = \text{Constant for all scales}$$

(6) All these temperatures are related to each other by the following relationship

$$\frac{C-0}{100} = \frac{F-32}{212-32} = \frac{K-273.15}{373.15-273.15} = \frac{R-0}{80-0} = \frac{Ra-460}{672-460}$$

or $$\frac{C}{5} = \frac{F-32}{9} = \frac{K-273}{5} = \frac{R}{4} = \frac{Ra-460}{10.6}$$

(7) The Celsius and Kelvin scales have different zero points but the same size degrees. Therefore any temperature difference is the same on the Celsius and Kelvin scales $(T_2 - T_1)°C = (T_2 - T_1)\,K$.

Thermometry

A branch of science which deals with the measurement of temperature of a substance is known as thermometry.

(1) The linear variation in some physical properties of a substance with change of temperature is the basic principle of thermometry and these properties are defined as thermometric property (x) of the substance.

(2) Thermometric properties (x) may be as follows

(i) Length of liquid in capillary

(ii) Pressure of gas at constant volume.

(iii) Volume of gas at constant pressure.

(iv) Resistance of a given platinum wire.

(3) In old thermometry, freezing point ($0°C$) and steam point ($100°C$) are taken to define the temperature scale. So if the thermometric property at temperature $0°C$, $100°C$ and $t°C$ are x_0, x_{100} and x respectively then

$$\frac{t-0}{100-0} = \frac{x - x_0}{x_{100} - x_0} \Rightarrow t°C = \frac{x - x_0}{x_{100} - x_0} \times 100°C$$

(4) In modern thermometry instead of two fixed points only one reference point is chosen (triple point of water 273.16 K) the other is itself 0 K where the value of thermometric property is assumed to be zero.

So if the value of thermometric property at 0 K, 273.16 K and TK are 0, x_{Tr} and x respectively then

$$\frac{T}{273.16} = \frac{x}{x_{Tr}} \Rightarrow T = 273.16\left[\frac{x}{x_{Tr}}\right]K$$

Thermometers

An instrument used to measure the temperature of a body is called a thermometer

It works by absorbing some heat from the body, so the temperature recorded by it is lesser than the actual value unless the body is at constant temperature. Some common types of thermometers are as follows

(1) **Liquid (mercury) thermometers :** In liquid thermometers mercury is preferred over other liquids as its expansion is large and uniform and it has high thermal conductivity and low specific heat.

(i) Range of temperature : $\underset{\text{(freezingpoint)}}{-50°C}$ to $\underset{\text{(boiling point)}}{350°C}$

(ii) Upper limit of range of mercury thermometer can be raised upto $550°C$ by filling nitrogen in space over mercury under pressure (which elevates boiling point of mercury).

(iii) Mercury thermometer with cylindrical bulbs are more sensitive than those with spherical bulbs.

(iv) If alcohol is used instead of mercury then range of temperature measurement becomes – $80°C$ to $350°C$

(v) Formula : $t = \dfrac{l - l_0}{l_{100} - l_0} \times 100°C$

(2) **Gas thermometers :** These are more sensitive and accurate than liquid thermometers as expansion of gases is more than that of liquids. The thermometers using a gas as thermoelectric substance are called ideal gas thermometers. These are of two types

(i) **Constant pressure gas thermometers**

(a) Principle $V \propto T$ (if P = constant)

(b) Formula : $t = \dfrac{V - V_0}{V_{100} - V_0} \times 100°C$ or $T = 273.16 \dfrac{V}{V_{Tr}} K$

(ii) **Constant volume gas thermometers**

(a) Principle $P \propto T$ (if V = constant)

(b) Formula : $t = \dfrac{P - P_0}{P_{100} - P_0} \times 100°C$ or $T = 273.16 \dfrac{P}{P_{Tr}} K$

(c) Range of temperature :

Hydrogen gas thermometer : – $200°C$ to $500°C$

Nitrogen gas thermometer : – $200°C$ to $1600°C$

Helium gas thermometer : – $268°C$ to $500°C$

(3) **Resistance thermometers :** Usually platinum is used in resistance thermometers due to high melting point and large value of temperature coefficient of resistance.

Resistance of metals varies with temperature according to relation. $R = R_0(1 + \alpha t)$ where α is the temperature coefficient of resistance and t is change in temperature.

(i) Formula : $t = \dfrac{R - R_0}{R_{100} - R_0} \times 100°C$ or $T = 273.16 \dfrac{R}{R_{Tr}} K$

(ii) Temperature range : For Platinum resistance thermometer it is – $200°C$ to $1200°C$

For Germanium resistance thermometer it is 4 to 77 K.

(4) **Thermoelectric thermometers :** These are based on "Seebeck effect" according to which when two distinct metals are joined to form a closed circuit called thermocouple and the difference in temperature is maintained between their junctions, an emf is developed. The emf is called thermo-emf and if one junction is at $0°C$, thermoelectric emf varies with temperature of hot junction (t) according to $e = at + bt$; where a and b are constants.

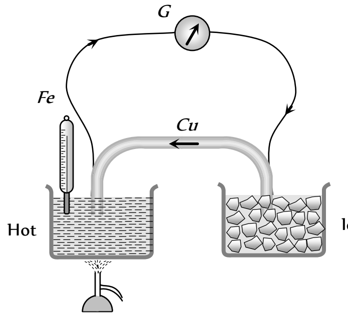


Fig. 12.2

Thermoelectric thermometers have low thermal capacity and high thermal conductivity, so can be used to measure quickly changing temperature

Table 12.2 : Different temperature range

Thermo couple	Temperature range
Copper-iron thermocouple	$0°C$ to $260°C$
Iron-constantan thermocouple	$0°C$ to $800°C$
Tungsten-molybdenum thermocouple	$2000°C$ to $3000°C$

(5) **Pyrometers :** These are the devices used to measure the temperature by measuring the intensity of radiations received from the body. They are based on the fact that the amount of radiations emitted from a body per unit area per second is directly proportional to the fourth power of temperature (Stefan's law).

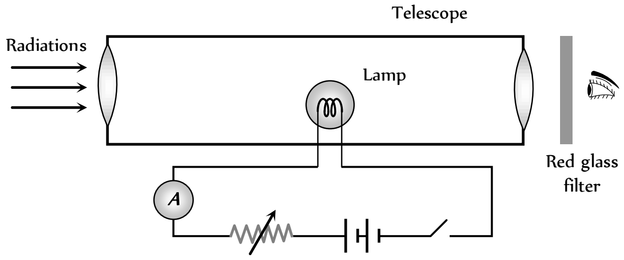


Fig. 12.3

(i) These can be used to measure temperatures ranging from $800°C$ to $6000°C$.

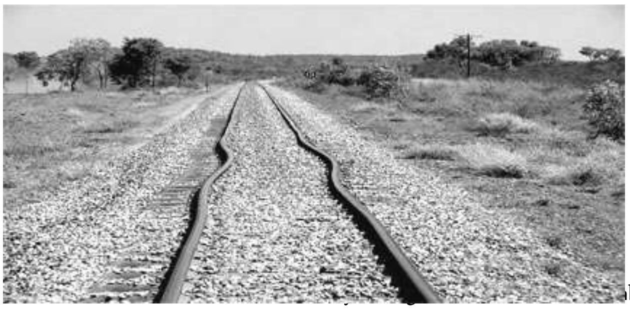
(ii) They cannot measure temperature below $800°C$ because the amount of radiations is too small to be measured.

(6) **Vapour pressure thermometer :** These are used to measure very low temperatures. They are based on the fact that saturated vapour pressure P of a liquid depends on the temperature according to the relation

$$\log P = a + bT + \frac{c}{T}$$

The range of these thermometers varies from 0.71 K to 120 K for different liquid vapours.

Thermal Expansion



lly expands. According to atomic theory of matter, a symmetry in potential energy curve is responsible for thermal expansion. As with rise in temperature the amplitude of vibration and hence energy of atoms increases, hence the average distance between the atoms increases. So the matter as a whole expands.

(1) Thermal expansion is minimum in case of solids but maximum in case of gases because intermolecular force is maximum in solids but minimum in gases.

(2) Solids can expand in one dimension (linear expansion), two dimension (superficial expansion) and three dimension (volume expansion) while liquids and gases usually suffers change in volume only.

(3) **Linear expansion :** When a solid is heated and it's length increases, then the expansion is called linear expansion.

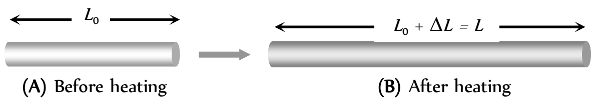


Fig. 12.4

(i) Change in length $\Delta L = L_0 \alpha \Delta T$

(L_0 = Original length, ΔT = Temperature change)

(ii) Final length $L = L_0 (1 + \alpha \Delta T)$

(iii) Co-efficient of linear expansion $\alpha = \dfrac{\Delta L}{L_0 \Delta T}$

(iv) Unit of α is $°C^{-1}$ or K^{-1}. It's dimension is $[\theta^{-1}]$

(4) **Superficial (areal) expansion :** When the temperature of a $2D$ object is changed, it's area changes, then the expansion is called superficial expansion.

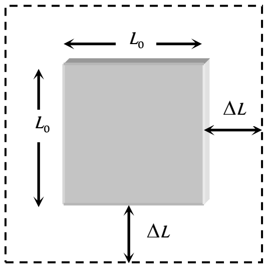


Fig. 12.5

(i) Change in area is $\Delta A = A_0 \beta \Delta T$

(A_0 = Original area, ΔT = Temperature change)

(ii) Final area $A = A_0 (1 + \beta \Delta T)$

(iii) Co-efficient of superficial expansion $\beta = \dfrac{\Delta A}{A_0 \Delta T}$

(iv) Unit of β is $°C^{-1}$ or K^{-1}.

(5) **Volume or cubical expansion :** When a solid is heated and it's volume increases, then the expansion is called volume or cubical expansion.

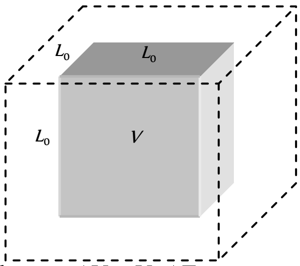


Fig. 12.6

(i) Change in volume is $\Delta V = V_0 \gamma \Delta T$

(V_0 = Original volume, ΔT = change in temperature)

(ii) Final volume $V = V_0(1 + \gamma \Delta T)$

(iii) Volume co-efficient of expansion $\gamma = \dfrac{\Delta V}{V_0 \Delta T}$

(iv) Unit of γ is $°C$ or K.

(6) **More about α, β and γ :** The co-efficient α, β and γ for a solid are related to each other as follows

$$\alpha = \frac{\beta}{2} = \frac{\gamma}{3} \Rightarrow \alpha : \beta : \gamma = 1 : 2 : 3$$

(i) Hence for the same rise in temperature

Percentage change in area = 2 × percentage change in length.

Percentage change in volume = 3 × percentage change in length.

(ii) The three coefficients of expansion are not constant for a given solid. Their values depend on the temperature range in which they are measured.

(iii) The values of α, β, γ are independent of the units of length, area and volume respectively.

(iv) For anisotropic solids $\gamma = \alpha_x + \alpha_y + \alpha_z$ where α_x, α_y and α_z represent the mean coefficients of linear expansion along three mutually perpendicular directions.

(7) **Contraction on heating :** Some rubber like substances contract with rising temperature, because transverse vibration of atoms of substance dominate over longitudinal vibration which is responsible for expansion.

Table 12.3 : α and γ for some materials

Material	$\alpha[K^{-1}$ or $(°C)^{-1}]$	$\gamma[K^{-1}$ or $(°C)^{-1}]$
Steel	1.2×10^{-5}	3.6×10^{-5}
Copper	1.7×10^{-5}	5.1×10^{-5}
Brass	2.0×10^{-5}	6.0×10^{-5}
Aluminium	2.4×10^{-5}	7.2×10^{-5}

Application of Thermal Expansion in Solids

(1) **Bi-metallic strip :** Two strips of equal lengths but of different materials (different coefficient of linear expansion) when join together, it is called "bi-metallic strip", and can be used in thermostat to break or make electrical contact. This strip has the characteristic property of bending on heating due to unequal linear expansion of the two metal. The strip will bend with metal of greater α on outer side *i.e.* convex side.

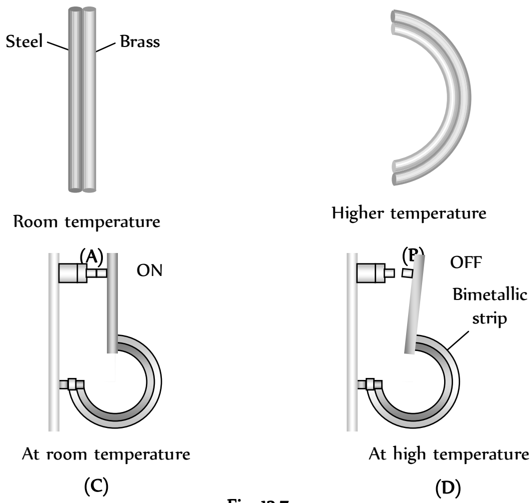


Fig. 12.7

(2) **Effect of temperature on the time period of a simple pendulum :** A pendulum clock keeps proper time at temperature θ. If temperature is increased to $\theta'(>\theta)$ then due to linear expansion, length of pendulum and hence its time period will increase.

Fractional change in time period $\dfrac{\Delta T}{T} = \dfrac{1}{2}\alpha \Delta\theta$

(i) Due to increment in its time period, a pendulum clock becomes slow in summer and will lose time.

Loss of time in a time period $\Delta T = \dfrac{1}{2}\alpha\ \Delta\theta\ T$

(ii) Time lost by the clock in a day (t = 86400 *sec*)

$$\Delta t = \frac{1}{2}\alpha\ \Delta\theta\ t = \frac{1}{2}\alpha\ \Delta\theta\ (86400) = 43200\,\alpha\ \Delta\theta\ sec$$

(iii) The clock will lose time *i.e.* will become slow if $\theta' > \theta$ (in summer)

and will gain time *i.e.* will become fast if $\theta' < \theta$ (in winter).

(iv) The gain or loss in time is independent of time period T and depends on the time interval t.

(v) Since coefficient of linear expansion (α) is very small for invar, hence pendulums are made of invar to show the correct time in all seasons.

(3) **Thermal stress in a rigidly fixed rod :** When a rod whose ends are rigidly fixed such as to prevent expansion or contraction, undergoes a change in temperature, due to thermal expansion or contraction, a compressive or tensile stress is developed in it. Due to this thermal stress the rod will exert a large force on the supports. If the change in temperature of a rod of length L is $\Delta\theta$ then

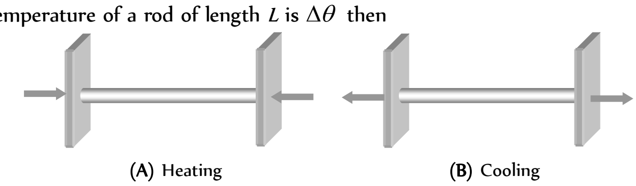


Fig. 12.8

Thermal strain $= \dfrac{\Delta L}{L} = \alpha\Delta\theta$ $\left[\text{As}\,\alpha = \dfrac{\Delta L}{L} \times \dfrac{1}{\Delta\theta}\right]$

So Thermal stress $= Y\alpha\Delta\theta$ $\left[\text{As}\, Y = \dfrac{\text{stress}}{\text{strain}}\right]$

or Force on the supports $F = YA\,\alpha\,\Delta\theta$

(4) **Error in scale reading due to expansion or contraction :** If a scale gives correct reading at temperature θ, at temperature $\theta'(>\theta)$ due to linear expansion of scale, the scale will expand and scale reading will be lesser than true value so that,

True value = Scale reading $[1+\alpha(\theta'-\theta)]$

i.e. $\text{TV} = SR\,[1+\alpha\,\Delta\theta]$ with $\Delta\theta = (\theta'-\theta)$

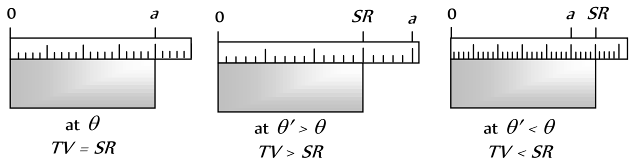
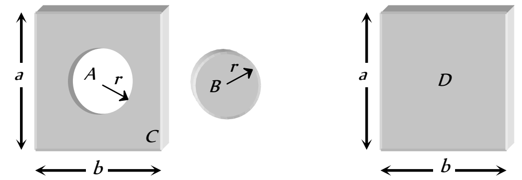


Fig. 12.9

However, if $\theta' < \theta$, due to contraction of scale, scale reading will be more than true value, so true value will be lesser than scale reading and will still be given by above equation with $\Delta\theta = (\theta'-\theta)$ negative.

(5) **Expansion of cavity :** Thermal expansion of an isotropic object may be imagined as a photographic enlargement. So if there is a hole A in a plate C (or cavity A inside a body C), the area of hole (or volume of cavity) will increase when body expands on heating, just as if the hole (or cavity) were solid B of the same material. Also the expansion of area (or volume) of the body C will be independent of shape and size of hole (or cavity), *i.e.*, will be equal to that of D.



Expansion of A = Expansion of B Expansion of C = Expansion of D

Fig. 12.10

(6) **Some other application**

(i) When rails are laid down on the ground, space is left between the ends of two rails.

(ii) The transmission cable are not tightly fixed to the poles.

(iii) Test tubes, beakers and crucibles are made of pyrex-glass or silica because they have very low value of coefficient of linear expansion.

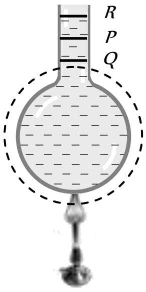
(iv) The iron rim to be put on a cart wheel is always of slightly smaller diameter than that of wheel.

(v) A glass stopper jammed in the neck of a glass bottle can be taken out by warming the neck of the bottle

Thermal Expansion in Liquids

(1) Liquids do not have linear and superficial expansion but these only have volume expansion.

(2) Since liquids are always to be heated along with a vessel which contains them so initially on heating the system (liquid + vessel), the level of liquid in vessel falls (as vessel expands more since it absorbs heat and liquid expands less) but later on, it starts rising due to faster expansion of the liquid.



$PQ \rightarrow$ represents expansion of vessel

$QR \rightarrow$ represents the real expansion of liquid

$PR \rightarrow$ Represent the apparent expansion of liquid

Fig. 12.11

(3) The actual increase in the volume of the liquid = The apparent increase in the volume of liquid + the increase in the volume of the vessel.

(4) Liquids have two coefficients of volume expansion.

(i) **Co-efficient of apparent expansion (γ) :** It is due to apparent (that appears to be, but is not) increase in the volume of liquid if expansion of vessel containing the liquid is not taken into account.

$$\gamma_a = \frac{\text{Apparent expansion in volume}}{\text{Initial vdume} \times \Delta\theta} = \frac{(\Delta V)_a}{V\times\Delta\theta}$$

(ii) **Co-efficient of real expansion (γ) :** It is due to the actual increase in volume of liquid due to heating.

$$\gamma_r = \frac{\text{Real increase in volume}}{\text{Initial vdume}\times\Delta\theta} = \frac{(\Delta V)_r}{V\times\Delta\theta}$$

(iii) Also coefficient of expansion of flask $\gamma_{Vessel} = \dfrac{(\Delta V)_{Vessel}}{V\times\Delta\theta}$

(iv) $\gamma_{Real} = \gamma_{Apparent} + \gamma_{Vessel}$

(v) Change (apparent change) in volume in liquid relative to vessel is

$$\Delta V_{app} = V\,\gamma_{app}\,\Delta\theta = V(\gamma_{Real} - \gamma_{Vessel})\Delta\theta = V(\gamma_r - 3\alpha)\Delta\theta$$

α = Coefficient of linear expansion of the vessel.

Table 12.4 : Different level of liquid in vessel

γ	ΔV	Level
$\gamma_{Real} > \gamma_{Vessel}\,(=3\alpha) \Rightarrow \gamma_{app} > 0$	ΔV_{app} is positive	Level of liquid in vessel will rise on heating.
$\gamma_{Real} < \gamma_{Vessel}\,(=3\alpha) \Rightarrow \gamma_{app} < 0$	ΔV_{app} is negative	Level of liquid in vessel will fall on heating.
$\gamma_{Real} = \gamma_{Vessel}\,(=3\alpha) \Rightarrow \gamma_{app} = 0$	$\Delta V_{app} = 0$	level of liquid in vessel will remain same.

(5) **Anomalous expansion of water :** Generally matter expands on heating and contracts on cooling. In case of water, it expands on heating if its temperature is greater than $4°C$. In the range $0°C$ to $4°C$, water contracts on heating and expands on cooling, *i.e.* γ is negative. This behaviour of water in the range from $0°C$ to $4°C$ is called anomalous expansion.

This anomalous behaviour of water causes ice to form first at the surface of a lake in cold weather. As winter approaches, the water temperature increases initially at the surface. The water there sinks because of its increased density. Consequently, the surface reaches $0°C$ first and the lake becomes covered with ice. Aquatic life is able to survive the cold winter as the lake bottom remains unfrozen at a temperature of about $4°C$.

At $4°C$, density of water is maximum while its specific volume is minimum.

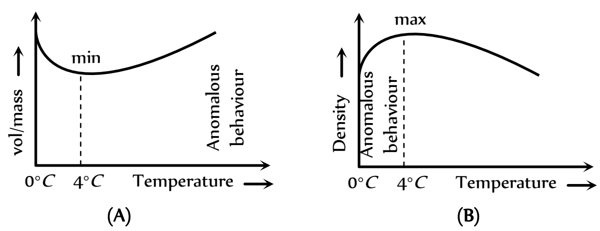


Fig. 12.12

(6) **Effect of temperature on upthrust :** The thrust on V volume of a body in a liquid of density σ is given by $Th = V\sigma g$

Now with rise in temperature by $\Delta\theta\,°C$, due to expansion, volume of the body will increase while density of liquid will decrease according to the relations $V' = V(1+\gamma_S\Delta\theta)$ and $\sigma' = \sigma/(1+\gamma_L\Delta\theta)$

So the thrust $Th' = V'\sigma' g \Rightarrow \dfrac{Th'}{Th} = \dfrac{V'\sigma' g}{V\sigma g} = \dfrac{(1+\gamma_S\Delta\theta)}{(1+\gamma_L\Delta\theta)}$

and apparent weight of the body W_{app} = Actual weight – Thrust

As $\gamma_S < \gamma_L \;\therefore\; Th' < Th$ with rise in temperature thrust also decreases and apparent weight of body increases.

Variation of Density with Temperature

Most substances (solid and liquid) expand when they are heated, *i.e.*, volume of a given mass of a substance increases on heating, so the density should decrease $\left(\text{as } \rho \propto \dfrac{1}{V}\right)$. For a given mass $\rho \propto \dfrac{1}{V} \Rightarrow$

$$\frac{\rho'}{\rho} = \frac{V}{V'} = \frac{V}{V+\Delta V} = \frac{V}{V+\gamma V\Delta\theta} = \frac{1}{1+\gamma\,\Delta\theta}$$

$$\Rightarrow \rho' = \frac{\rho}{1+\gamma\,\Delta\theta} = \rho(1+\gamma\,\Delta\theta)^{-1} = \rho(1-\gamma\,\Delta\theta)$$

Expansion of Gases

Gases have no definite shape, therefore gases have only volume expansion. Since the expansion of container is negligible in comparison to the gases, therefore gases have only real expansion.

(1) **Coefficient of volume expansion :** At constant pressure, the unit volume of a given mass of a gas, increases with 1°C rise of temperature, is called coefficient of volume expansion.

$$\alpha = \frac{\Delta V}{V_0}\times\frac{1}{\Delta\theta} \Rightarrow \text{Final volume } V' = V(1+\alpha\Delta\theta)$$

(2) **Coefficient of pressure expansion :** $\beta = \dfrac{\Delta P}{P}\times\dfrac{1}{\Delta\theta}$

$\therefore$ Final pressure $P' = P(1+\beta\Delta\theta)$

For an ideal gas, coefficient of volume expansion is equal to the coefficient of pressure expansion *i.e.* $\alpha = \beta = \dfrac{1}{273}\,°C^{-1}$

Heat

(1) The form of energy which is exchanged among various bodies or system on account of temperature difference is defined as heat.

(2) We can change the temperature of a body by giving heat (temperature rises) or by removing heat (temperature falls) from body.

(3) The amount of heat (Q) is given to a body depends upon it's mass (m), change in it's temperature ($\Delta\theta° = \Delta\theta$) and nature of material *i.e.* $Q = m.c.\Delta\theta$; where c = specific heat of material.

(4) Heat is a scalar quantity. It's units are *joule, erg, cal, kcal etc.*

(5) The calorie (*cal*) is defined as the amount of heat required to raise the temperature of 1 *gm* of water from 14.5°C to 15.5°C.

Also 1 *kcal* = 1000 *cal* = 4186 *J* and 1 *cal* = 4.18 *J*

(6) **British Thermal Unit (BTU) :** One BTU is the quantity of heat required to raise the temperature of one pound (1 *lb*) of water from 63°F to 64°F

1 *BTU* = 778 *ft. lb* = 252 *cal* = 1055 *J*

(7) In solids thermal energy is present in the form of kinetic energy, in liquids, in the form of translatory energy of molecules. In gas it is due to the random motion of molecules.

(8) Heat always flows from a body of higher temperature to lower temperature till their temperature becomes equal (Thermal equilibrium).

(9) The heat required for a given temperature increase depends only on how many atoms the sample contains, not on the mass of an individual atom.

Specific Heat

When a body is heated it's temperature rises (except during a change in phase).

(1) **Gram specific heat :** The amount of heat energy required to raise the temperature of unit mass of a body through 1°C (or K) is called specific heat of the material of the body.

If Q heat changes the temperature of mass m by $\Delta\theta$ then specific heat $c = \dfrac{Q}{m\Delta\theta}$

(i) Units : *Calorie/gm* × °C (practical), *J/kg* × K (S.I.) Dimension : $[L^2T^{-2}\theta^{-1}]$

(ii) For an infinitesimal temperature change $d\theta$ and corresponding quantity of heat dQ.

Specific heat $c = \dfrac{1}{m}.\dfrac{dQ}{d\theta}$

(2) **Molar specific heat :** Molar specific heat of a substance is defined as the amount of heat required to raise the temperature of one gram mole of the substance through a unit degree it is represented by (capital) C.

Molar specific heat (C) $= M \times \text{Gram specific heat } (c)$

(M = Molecular mass of substance)

$$C = M\frac{Q}{m\Delta\theta} = \frac{1}{\mu}\frac{Q}{\Delta\theta} \quad \left(\text{where, Number of moles } \mu = \frac{m}{M}\right)$$

Units : *calorie/mole* × °C (practical); *J/mole* × *kelvin* (S.I.) Dimension : $[ML^2T^{-2}\theta^{-1}]$

Specific Heat of Solids

When a solid is heated through a small range of temperature, its volume remains more or less constant. Therefore specific heat of a solid may be called its specific heat at constant volume C_v.

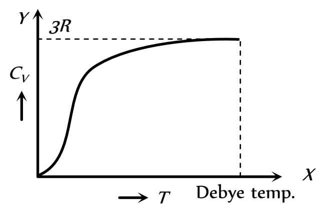


Fig. 12.13

(1) From the graph it is clear that at T = 0, C_v tends to zero

(2) With rise in temperature, C_v increases and at a particular temperature (called Debey's temperature) it becomes constant = $3R$ = 6 *cal/mole* × *kelvin* = 25 *J/mole* × *kelvin*

(3) For most of the solids, Debye temperature is close to room temperature.

(4) **Dulong and Petit law :** Average molar specific heat of all metals at room temperature is constant, being nearly equal to $3R$ = 6 *cal. mole*$^{-1}$ *K*$^{-1}$ = 25 *J mole*$^{-1}$ *K*$^{-1}$, where *R* is gas constant for one mole of the gas. This statement is known as Dulong and Petit law.

(5) **Debey's law :** It was observed that at very low temperature molar specific heat $\propto T^3$ (exception are *Sn*, *Pb* and *Pt*)

(6) **Specific heat of ice :** In C.G.S. $c_{\text{ice}} = 0.5 \dfrac{cal}{gm \times °C}$

In S.I. $c = 500 \dfrac{cal}{kg \times °C} = 2100 \dfrac{Joule}{kg \times °C}$.

Table 12.5 : Specific heat of some solids at room temperature and atmospheric pressure

Substance	Specific heat (J-kg^{-1} K^{-1})	Molar specific heat (J-g $mole^{-1}$ K^{-1})
Aluminium	900.0	24.4
Copper	386.4	24.5
Silver	236.1	25.5
Lead	127.7	26.5
Tungsten	134.4	24.9

Specific Heat of Liquid (Water)

(1) Among all known solids and liquids specific heat of water is maximum *i.e.* water takes more time to heat and more time to cool *w.r.t.* other solids and liquids.

(2) It is observed that by increasing temperature, initially specific heat of water goes on decreasing, becomes minimum at 37°*C* and then it start increasing. Specific heat of water is –

$$\frac{1\,cal}{gm \times °C} = 1000 \frac{cal}{kg \times °C} = 4200 \frac{J}{kg \times °C}$$

(This value is obtained between the temperature 14.5°*C* to 15.5°*C*)

(3) The variation of specific heat with temperature for water is shown in the figure. Usually this temperature dependence of specific heat is neglected.

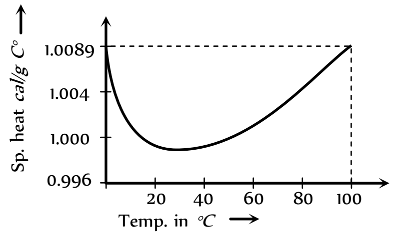


Fig. 12.14

(4) As specific heat of water is very large; by absorbing or releasing large amount of heat its temperature changes by small amount. This is why, it is used in hot water bottles or as coolant in radiators.

Specific Heat of Gases

(1) In case of gases, heat energy supplied to a gas is spent not only in raising the temperature of the gas but also in expansion of gas against atmospheric pressure.

(2) Hence specific heat of a gas, which is the amount of heat energy required to raise the temperature of one gram of gas through a unit degree shall not have a single or unique value.

(3) If the gas is compressed suddenly and no heat is supplied from outside *i.e.* ΔQ = 0, but the temperature of the gas raises on the account of compression.

$$\Rightarrow \quad c = \frac{Q}{m(\Delta\theta)} = \frac{0}{m\Delta\theta} = 0$$

(4) If the gas is heated and allowed to expand at such a rate that rise in temperature due to heat supplied is exactly equal to fall in temperature due to expansion of the gas. *i.e.* $\Delta\theta$ = 0

$$\Rightarrow \quad c = \frac{Q}{m(\Delta\theta)} = \frac{Q}{0} = \infty$$

(5) If rate of expansion of the gas were slow, the fall in temperature of the gas due to expansion would be smaller than the rise in temperature of the gas due to heat supplied. Therefore, there will be some net rise in temperature of the gas *i.e.* ΔT will be positive.

$$\Rightarrow \quad c = \frac{Q}{m(\Delta\theta)} = \text{ Positive}$$

(6) If the gas were to expand very fast, fall of temperature of gas due to expansion would be greater than rise in temperature due to heat supplied. Therefore, there will be some net fall in temperature of the gas *i.e.* $\Delta\theta$ will be negative.

$$\Rightarrow \quad c = \frac{Q}{m(-\Delta\theta)} = \text{Negative}$$

Hence the specific heat of gas can have any positive value ranging from zero to infinity. Further it can even be negative. The exact value depends upon the mode of heating the gas. Out of many values of specific heat of a gas, two are of special significance, namely C_v and C_p, in the chapter "Kinetic theory of gases" we will discussed this topic in detail.

Specific heat of steam : $c_{\text{steam}} = 0.47\, cal/gm \times °C$

Phase Change and Latent Heat

(1) **Phase :** We use the term phase to describe a specific state of matter, such as solid, liquid or gas. A transition from one phase to another is called a phase change.

(i) For any given pressure a phase change takes place at a definite temperature, usually accompanied by absorption or emission of heat and a change of volume and density.

(ii) In phase change ice at $0°C$ melts into water at $0°C$. Water at $100°C$ boils to form steam at $100°C$.

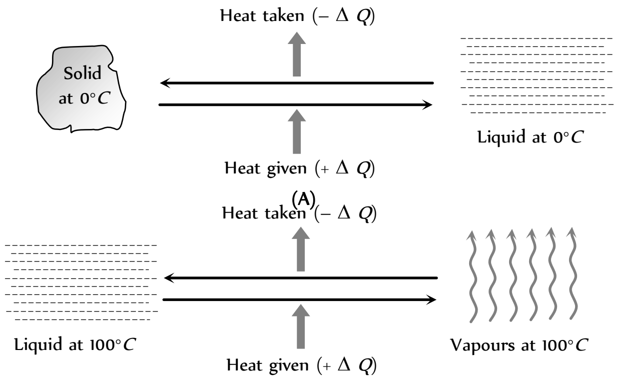


Fig. 12.15

(iii) In solids, the forces between the molecules are large and the molecules are almost fixed in their positions inside the solid. In a liquid, the forces between the molecules are weaker and the molecules may move freely inside the volume of the liquid. However, they are not able to come out of the surface. In vapours or gases, the intermolecular forces are almost negligible and the molecules may move freely anywhere in the container. When a solid melts, its molecules move apart against the strong molecular attraction. This needs energy which must be supplied from outside. Thus, the internal energy of a given body is larger in liquid phase than in solid phase. Similarly, the internal energy of a given body in vapour phase is larger than that in liquid phase.

(iv) In case of change of state if the molecules come closer, energy is released and if the molecules move apart, energy is absorbed.

(2) **Latent heat :** The amount of heat required to change the state of the mass m of the substance is written as : $Q = mL$, where L is the latent heat. Latent heat is also called as Heat of Transformation. It's unit is *cal/gm* or *J/kg* and Dimension: $[L^2T^{-2}]$

(i) **Latent heat of fusion :** The latent heat of fusion is the heat energy required to change 1 *kg* of the material in its solid state at its melting point to 1 *kg* of the material in its liquid state. It is also the amount of heat energy released when at melting point 1 *kg* of liquid changes to 1 *kg* of solid. For water at its normal freezing temperature or melting point ($0°C$), the latent heat of fusion (or latent heat of ice) is

$$L_F = L_{\text{ice}} \approx 80\, cal/gm \approx 60\, kJ/mol \approx 336\, kilo\, joule/kg$$

(ii) **Latent heat of vaporisation :** The latent heat of vaporisation is the heat energy required to change 1 *kg* of the material in its liquid state at its boiling point to 1 *kg* of the material in its gaseous state. It is also the amount of heat energy released when 1 *kg* of vapour changes into 1 *kg* of liquid. For water at its normal boiling point or condensation temperature ($100°C$), the latent heat of vaporisation (latent heat of steam) is

$$L_V = L_{\text{steam}} \approx 540\, cal/gm \approx 40.8\, kJ/mol \approx 2260\, kilo\, joule/kg$$

(iii) Latent heat of vaporisation is more than the latent heat of fusion. This is because when a substance gets converted from liquid to vapour, there is a large increase in volume. Hence more amount of heat is required. But when a solid gets converted to a liquid, then the increase in volume is negligible. Hence very less amount of heat is required. So, latent heat of vaporisation is more than the latent heat of fusion.

Thermal Capacity and Water Equivalent

(1) **Thermal capacity :** It is defined as the amount of heat required to raise the temperature of the whole body (mass m) through $0°C$ or $1K$.

Thermal capacity $= mc = \mu C = \dfrac{Q}{\Delta\theta}$

The value of thermal capacity of a body depends upon the nature of the body and its mass.

Dimension : $[ML^2T^{-2}\theta^{-1}]$, Unit : *cal/°C* (practical) *Joule/k* (S.I.)

(2) **Water Equivalent :** Water equivalent of a body is defined as the mass of water which would absorb or evolve the same amount of heat as is done by the body in rising or falling through the same range of temperature. It is represented by W.

If m = Mass of the body, c = Specific heat of body, $\Delta\theta$ = Rise in temperature.

Then heat given to body $\Delta Q = mc\Delta\theta$ ..... (i)

If same amount of heat is given to W *gm* of water and its temperature also rises by $\Delta\theta$. Then

heat given to water $Q = W \times 1 \times \Delta\theta$ ... (ii) [As $c_{\text{water}} = 1$]

From equation (i) and (ii) $\Delta Q = mc\Delta\theta = W \times 1 \times \Delta\theta$

$\Rightarrow$ Water equivalent (W) = *mc gm*

(i) Unit : *Kg* (S.I.) Dimension : $[ML^0T^0]$

(ii) Unit of thermal capacity is *J/kg* while unit of water equivalent is *kg*.

(iii) Thermal capacity of the body and its water equivalent are numerically equal.

(iv) If thermal capacity of a body is expressed in terms of mass of water it is called water-equivalent of the body.

Some Important Terms

(1) **Evaporation :** Vaporisation occurring from the free surface of a liquid is called evaporation. Evaporation is the escape of molecules from the surface of a liquid. This process takes place at all temperatures and increases with the increase of temperature. Evaporation leads to cooling because the faster molecules escape and, therefore, the average kinetic energy of the molecules of the liquid (and hence the temperature) decreases.

Evaporation cools hot water produced by power plants

Fig. 12.16

(2) **Melting (or fusion)/freezing (or solidification) :** The phase change of solid to liquid is called melting or fusion. The reverse phenomenon is called freezing or solidification.

Fig. 12.17

When pressure is applied on ice, it melts. As soon as the pressure is removed, it freezes again. This phenomenon is called **regelation**.

(3) **Vaporisation/liquefication (condensation) :** The phase change from liquid to vapour is called vaporisation. The reverse transition is called liquefication or condensation.

(4) **Sublimation :** Sublimation is the conversion of a solid directly into vapours. Sublimation takes place when boiling point is less than the melting point. A block of ice sublimates into vapours on the surface of moon because of very very low pressure on its surface. Heat required to change unit mass of solid directly into vapours at a given temperature is called heat of sublimation at that temperature.

(5) **Hoar frost :** Direct conversion of vapours into solid is called hoar frost. This process is just reverse of the process of sublimation, *e.g.*, formation of snow by freezing of clouds.

Fig. 12.18

(6) **Vapour pressure :** When the space above a liquid is closed, it soon becomes saturated with vapour and a dynamic equilibrium is established. The pressure exerted by this vapour is called Saturated Vapour Pressure (S.V.P.) whose value depends only on the temperature – it is independent of any external pressure. If the volume of the space is reduced, some vapour liquefies, but the pressure is unchanged.

A saturated vapour does not obey the gas law whereas the unsaturated vapour obeys them fairly well. However, a vapour differs from a gas in that the former can be liquefied by pressure alone, whereas the latter cannot be liquefied unless it is first cooled.

(7) **Boiling :** As the temperature of a liquid is increased, the rate of evaporation also increases. A stage is reached when bubbles of vapour start forming in the body of the liquid which rise to the surface and escape. A liquid boils at a temperature at which the S.V.P. is equal to the external pressure.

Fig. 12.19

It is a fast process. The boiling point changes on mixing impurities.

(8) **Dew point :** It is that temperature at which the mass of water vapour present in a given volume of air is just sufficient to saturate it, *i.e.* the temperature at which the actual vapour pressure becomes equal to the saturated vapuor pressure.

(9) **Humidity :** Atmospheric air always contains some water vapour. The mass of water vapour per unit volume is called absolute humidity.

The ratio of the mass of water vapour (m) actually present in a given volume of air to the mass of water vapour (M) required to saturate the same volume at the same temperature is called the relative humidity (R.H.).

Generally, it is expressed as a percentage, *i.e.*, $\text{R.H.}(\%) = \frac{m}{M} \times 100(\%)$

R.H. May also be defined as the ratio of the actual vapour pressure (p) of water at the same temperature, *i.e.* $\text{R.H.}(\%) = \frac{p}{P} \times 100(\%)$

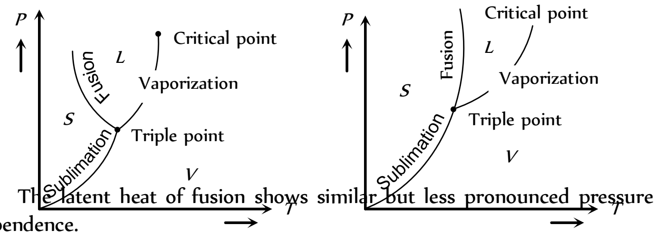
Thus R.H. may also be defined as

$$\text{R.H.}(\%) = \frac{\text{S.V.P. at dew point}}{\text{S.V. P. at given temperature}} \times 100$$

(10) **Variation of melting point with pressure :** For those substances with contract on melting (*e.g.* water and rubber), the melting point decreases with pressure. The reason is the pressure helps shrinking and hence melting. Most substances expand on melting. (*e.g.* max, sulpher *etc.*)

An increase of pressure opposes the melting of such substances and their melting point is raised.

(11) **Variation of latent heat with temperature and pressure :** The latent heat of vapourization of a substance varies with temperature and hence pressure because the boiling point depends on pressure. It increases as the temperature is decreased. For example, water at 1 *atm* boils at 100°*C* and has latent heat 2259 Jg^{-1} but at 0.5 *atm* it boils at 82°*C* and has latent heat 2310 Jg^{-1}



The latent heat of fusion shows similar but less pronounced pressure dependence.

Fig. 12.20

The figures show the *P*-*T* graphs for (*a*) a substance (*e.g.*, water) which contracts on melting an (*b*) a substance (*e.g.* wax) which expands on melting. The *P*-*T* graph consists of three curves.

(i) Sublimation curve which connects points at which vapour (*V*) and solid (*S*) exist in equilibrium.

(ii) Vapourization curve which shows vapour and liquid (*L*) existing in equilibrium.

(iii) Fusion curve which shows liquid and solid existing in equilibrium.

The three curves meet at a single point which is called the triple point. It is that unique temperature-pressure point for a substance at which all the three phases exist in equilibrium.

(12) **Freezing mixture :** If salt is added to ice, then the temperature of mixture drops down to less than 0°*C*. This is so because, some ice melts down to cool the salt to 0°*C*. As a result, salt gets dissolved in the water formed and saturated solution of salt is obtained; but the ice point (freeing point) of the solution formed is always less than that of pure water. So, ice cannot be in the solid state with the salt solution at 0°*C*. The ice which is in contact with the solution, starts melting and it absorbs the required latent heat from the mixture, so the temperature of mixture falls down.

Joule's Law (Heat and Mechanical Work)

Whenever heat is converted into mechanical work or mechanical work is converted into heat, then the ratio of work done to heat produced always remains constant. *i.e.* $W \propto Q$ or $\frac{W}{Q} = J$

This is Joule's law and J is called mechanical equivalent of heat.

(1) From $W = JQ$ if $Q = 1$ then $J = W$. Hence the amount of work done necessary to produce unit amount of heat is defined as the mechanical equivalent of heat.

(2) J is neither a constant, nor a physical quantity rather it is a conversion factor which used to convert *Joule* or *erg* into *calorie* or *kilo calories* vice-versa.

(3) Value of $J = 4.2\,\frac{Joule}{cal} = 4.2 \times 10^7\,\frac{erg}{cal}$

$$= 4.2 \times 10^3\,\frac{Joule}{kcal}.$$

(4) When water in a stream falls from height h, then its potential energy is converted into heat and temperature of water rises slightly.

From $W = JQ \Rightarrow mgh = J\,(mc\,\Delta\theta)$

[where m = Mass of water, c = Specific heat of water, $\Delta\theta$ = temperature rise]

$\Rightarrow$ Rise in temperature $\Delta\theta = \frac{gh}{Jc}\,°C$

(5) The kinetic energy of a bullet fired from a gun gets converted into heat on striking the target. By this heat the temperature of bullet increases by $\Delta\theta$.

From $W = JQ \Rightarrow \frac{1}{2}mv^2 = J(m\,s\,\Delta\theta)$

[where m = Mass of the bullet, v = Velocity of the bullet, c = Specific heat of the bullet]

$\Rightarrow$ Rise in temperature $\Delta t = \frac{v^2}{2Jc}\,°C$

If the temperature of bullet rises upto the melting point of the bullet and bullet melts then.

From $W = J(Q_{\text{Temperature change}} + Q_{\text{Phase change}})$

$\Rightarrow \frac{1}{2}mv^2 = J(mc\,\Delta\theta + mL)$; L = Latent heat of bullet

$\Rightarrow$ Rise in temperature $\Delta\theta = \left[\frac{\left(\frac{v^2}{2J} - L\right)}{c}\right]°C$

(6) If m kg ice-block falls down through some height (h) and melts partially (m' kg) then its potential energy gets converted into heat of melting.

From $W = JQ \Rightarrow mgh = J\,m'\,L \Rightarrow h = \frac{m'}{m}\left(\frac{JL}{g}\right)$

If ice-block melts completely then $m' = m \Rightarrow h = \frac{JL}{g}\,meter$

Principle of Calorimetry

Calorimetry means 'measuring heat'.

When two bodies (one being solid and other liquid or both being liquid) at different temperatures are mixed, heat will be transferred from body at higher temperature to a body at lower temperature till both acquire same temperature. The body at higher temperature releases heat while body at lower temperature absorbs it, so that

Heat lost = Heat gained

i.e. principle of calorimetry represents the law of conservation of heat energy.

(1) Temperature of mixture (θ_{mix}) is always ≥ lower temperature (θ_L) and ≤ higher temperature (θ_H), *i.e.,* $\theta_L \le \theta_{mix} \le \theta_H$.

It means the temperature of mixture can never be lesser than lower temperatures (as a body cannot be cooled below the temperature of cooling body) and greater than higher temperature (as a body cannot be heated above the temperature of heating body). Furthermore usually rise in temperature of one body is not equal to the fall in temperature of the other body though heat gained by one body is equal to the heat lost by the other.

(2) **Mixing of two substances when temperature changes only** : It means no phase change. Suppose two substances having masses m_1 and m_2, gram specific heat c_1 and c_2, temperatures θ_1 and θ_2 $(\theta_1 > \theta_2)$ are mixed together such that temperature of mixture at equilibrium is θ_{mix}

Hence, Heat lost = Heat gained

$$\Rightarrow m_1c_1(\theta_1 - \theta_{mix}) = m_2c_2(\theta_{mix} - \theta_2) \Rightarrow$$

$$\theta_{mix} = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2}$$

Table 12.6 : Temperature of mixture in different cases

Condition	Temperature of mixture
If bodies are of same material *i.e.* $c_1 = c_2$	$\theta_{mix} = \frac{m_1\theta_1 + m_2\theta_2}{m_1 + m_2}$
If bodies are of same mass $m_1 = m_2$	$\theta_{mix} = \frac{\theta_1c_1 + \theta_2c_2}{c_1 + c_2}$
If $m_1 = m_2$ and $c_1 = c_2$	$\theta_{mix} = \frac{\theta_1 + \theta_2}{2}$

(3) **Mixing of two substances when temperature and phase both changes or only phase changes:** A very common example for this category is ice-water mixing.

Suppose water at temperature $\theta_w°C$ is mixed with ice at $0°C$, first ice will melt and then it's temperature rises to attain thermal equilibrium. Hence; Heat given = Heat taken

$$\Rightarrow m_WC_W(\theta_W - \theta_{mix}) = m_iL_i + m_iC_W(\theta_{mix} - 0°)$$

$$\Rightarrow \theta_{mix} = \frac{m_W\theta_W - \frac{m_iL_i}{C_W}}{m_W + m_i}$$

(i) If $m_W = m_i$ then $\theta_{mix} = \frac{\theta_W - \frac{L_i}{C_W}}{2}$

(ii) By using this formulae if $\theta_{mix} < \theta_i$ then take $\theta_{mix} = 0°C$

Heating Curve

If to a given mass (m) of a solid, heat is supplied at constant rate P and a graph is plotted between temperature and time, the graph is as shown in figure and is called heating curve. From this curve it is clear that

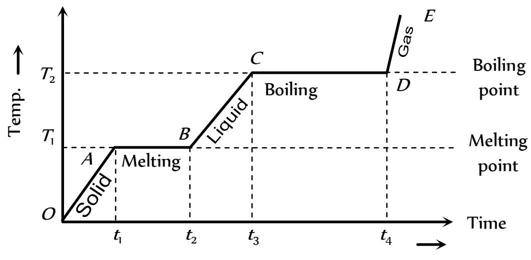


Fig. 12.21

(1) In the region OA temperature of solid is changing with time so, $Q = mc_S \Delta T \Rightarrow P\,\Delta t = mc_S \Delta T$ [as $Q = P\Delta t$]

But as $(\Delta T/\Delta t)$ is the slope of temperature-time curve

$$c_s \propto \frac{1}{\text{Slope of line } OA}$$

i.e. specific heat (or thermal capacity) is inversely proportional to the slope of temperature-time curve.

(2) In the region AB temperature is constant, so it represents change of state, *i.e.*, melting of solid with melting point T. At A melting starts and at B all solid is converted into liquid. So between A and B substance is partly solid and partly liquid. If L_F is the latent heat of fusion. $Q = mL_F$ or

$$L_F = \frac{P(t_2 - t_1)}{m} \quad [\text{as } Q = P(t_2 - t_1)]$$

or $L_F \propto$ length of line AB

i.e. Latent heat of fusion is proportional to the length of line of zero slope. [In this region specific heat $\propto \frac{1}{\tan 0} = \infty$]

(3) In the region BC temperature of liquid increases so specific heat (or thermal capacity) of liquid will be inversely proportional to the slope of line BC

i.e., $c_L \propto \frac{1}{\text{Slope of line } BC}$

(4) In the region CD temperature is constant, so it represents the change of state, *i.e.*, boiling with boiling point T. At C all substance is in liquid state while at D in vapour state and between C and D partly liquid and partly gas. The length of line CD is proportional to latent heat of vaporisation

i.e., $L_V \propto$ Length of line CD [In this region specific heat $\propto \frac{1}{\tan 0} = \infty$]

(5) The line DE represents gaseous state of substance with its temperature increasing linearly with time. The reciprocal of slope of line will be proportional to specific heat or thermal capacity of substance in vapour state.

Tips & Tricks

✍ After snow falls, the temperature of the atmosphere becomes very low. This is because the snow absorbs the heat from the atmosphere to melt down. So, in the mountains, when snow falls, one does not feel too cold, but when ice melts, he feels too cold.

✍ There is more shivering effect of **ice-cream** on teeth as compared to that of water (obtained from ice). This is because, when ice-cream melts down, it absorbs large amount of heat from teeth.

✍ Branch of physics dealing with production and measurement of temperatures close to $0K$ is known as cryogenics while that dealing with the measurement of very high temperature is called as pyrometry.

✍ It is more painful to get burnt by steam rather than by boiling water at same temperature. This is so because when steam at 100°C gets converted to water at 100°C, then it gives out 536 *calories* of heat. So, it is clear that steam at 100°C has more heat than water at 100°C (*i.e.*, boiling of water).

✍ A solid and hollow sphere of same radius and material, heated to the same temperature then expansion of both will be equal because thermal expansion of isotropic solids is similar to true photographic enlargement. It means the expansion of cavity is same as if it has been a solid body of the same material. But if same heat is given to the two spheres, due to lesser mass, rise in temperature of hollow sphere will be more $\left\{\text{As}\left(\Delta\theta = \frac{\Delta Q}{mc}\right)\right\}$.

Hence its expansion will be more.

✍ Specific heat of a substance can also be negative. Negative specific heat means that in order to raise the temperature, a certain quantity of heat is to be withdrawn from the body.

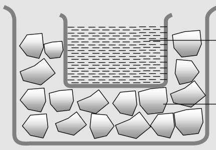
e.g. Specific heat of saturated vapours.

✍ Specific heat for hydrogen is maximum $(3.5\ cal/gm \times {}^oC)$ and it is minimum for radon and actinium $(\simeq 0.022\,cal/gm \times {}^\circ C)$.

✍ The minimum possible temperature is 0 K.

✍ Amount of steam at 100°C required to just melt m gm of ice at 0°C is $m/8$ gm.

✍ If we put the beaker containing water in melting ice, the water in the beaker will cool to 0°C but will never freeze.



✍ A pressure in excess of 25 *atm* is required to make helium solidfy. At 1 *atm* pressure, helium remains a liquid down to absolute zero.

✍ Boiling temperature of water, if pressure is different from normal pressure is $t_{boiling}$ = [100°C – (760 – P in mm) × 0.037]°C

✍ **Confusing S.I. and C.G.S. units**

It is advised to do questions on calorimetry in C.G.S. as calculations becomes simple. If the final answer is in joules, then convert cal into joules.

✍ Invar and quartz have very small values of co-efficient of linear expansion.

✍ In S.I. nomenclature " degree" is not used with the kelvin scale; *e.g.* 273°*K* is wrong while 273 *K* is correct to write.

✍ Magnetic thermometer is recommended for measuring very low temperature (2*K*).

✍ The most sensitive thermometer is gas thermometer.

✍ Dew formation is more probable on a cloudiness calm night.

✍ In winters, generally fog disappear before noon. Because, the atmosphere warms up and tends to be unsaturated. The condensed vapours reevaporates and the fog disappears.

✍ Standardisation of thermometer is obtained with gas thermometer. Because coefficient of expansion of gas is very large.

✍ Dogs hang their tongues in order to expose a surface to the air for evaporation and hence, cooling. They do not sweat.

Ordinary Thinking

Objective Questions

Thermometry

1. On the Celsius scale the absolute zero of temperature is at [CBSE PMT 1994]

(a) $0°C$ (b) $-32°C$
(c) $100°C$ (d) $-273.15°C$

2. Oxygen boils at $-183°C$. This temperature is approximately [CPMT 1992]

(a) $215°F$ (b) $-297°F$
(c) $329°F$ (d) $361°F$

3. Recently, the phenomenon of superconductivity has been observed at 95 K. This temperature is nearly equal to [CPMT 1990]

(a) $-288°F$ (b) $-146°F$
(c) $-368°F$ (d) $+178°F$

4. The temperature of a substance increases by $27°C$. On the Kelvin scale this increase is equal to [CPMT 1993]

(a) 300 K (b) 2.46 K
(c) 27 K (d) 7 K

5. The resistance of a resistance thermometer has values 2.71 and 3.70 *ohm* at $10°C$ and $100°C$. The temperature at which the resistance is 3.26 *ohm* is [CPMT 1994]

(a) $40°C$ (b) $50°C$
(c) $60°C$ (d) $70°C$

6. No other thermometer is as suitable as a platinum resistance thermometer to measure temperature in the entire range of [MNR 1993]

(a) $0°C$ to $100°C$ (b) $100°C$ to $1500°C$
(c) $-50°C$ to $+350°C$ (d) $-200°C$ to $600°C$

7. The temperature of the sun is measured with [Pb. PMT 1998; CPMT 1998; Pb. PET 1997, 2001]
(a) Platinum thermometer
(b) Gas thermometer
(c) Pyrometer
(d) Vapour pressure thermometer

8. Absolute temperature can be calculated by [AFMC 1994]
(a) Mean square velocity (b) Motion of the molecule
(c) Both (a) and (b) (d) None of the above

9. Thermoelectric thermometer is based on [CPMT 1993, 95; AFMC 1998]
(a) Photoelectric effect (b) Seeback effect
(c) Compton effect (d) Joule effect

10. Maximum density of H_2O is at the temperature [CPMT 1996; Pb. PMT 1996]
(a) $32°F$ (b) $39.2°F$
(c) $42°F$ (d) $4°F$

11. The study of physical phenomenon at low temperatures (below liquid nitrogen temperature) is called [CPMT 1992]
(a) Refrigeration (b) Radiation
(c) Cryogenics (d) Pyrometry

12. 'Stem Correction' in platinum resistance thermometers are eliminated by the use of [AIIMS 1998]
(a) Cells (b) Electrodes
(c) Compensating leads (d) None of the above

13. The absolute zero is the temperature at which [AIIMS 1998]
(a) Water freezes
(b) All substances exist in solid state
(c) Molecular motion ceases
(d) None of the above

14. Absolute scale of temperature is reproduced in the laboratory by making use of a [SCRA 1998]
(a) Radiation pyrometer
(b) Platinum resistance thermometer
(c) Constant volume helium gas thermometer
(d) Constant pressure ideal gas thermometer

15. Absolute zero (0 K) is that temperature at which [AFMC 1993]
(a) Matter ceases to exist
(b) Ice melts and water freezes
(c) Volume and pressure of a gas becomes zero
(d) None of these

16. On which of the following scales of temperature, the temperature is never negative [EAMCET 1997]
(a) Celsius (b) Fahrenheit
(c) Reaumur (d) Kelvin

17. The temperature on Celsius scale is $25°C$. What is the corresponding temperature on the Fahrenheit scale [AFMC 2001]
(a) $40°F$ (b) $77°F$
(c) $50°F$ (d) $45°F$

18. One quality of a thermometer is that its heat capacity should be small. If P is a mercury thermometer, Q is a resistance thermometer and R thermocouple type then [CPMT 1997]
(a) P is best, R worst (b) R is best, P worst
(c) R is best, Q worst (d) P is best, Q worst

19. Two thermometers are used to record the temperature of a room. If the bulb of one is wrapped in wet hanky [AFMC 1997]
(a) The temperature recorded by both will be same
(b) The temperature recorded by wet-bulb thermometer will be greater than that recorded by the other
(c) The temperature recorded by dry-bulb thermometer will be greater than that recorded by the other
(d) None of the above

20. The temperature of a body on Kelvin scale is found to be x K. When it is measured by Fahrenheit thermometer, it is found to be $x°F$, then the value of x is [UPSEAT 2000; Pb. CET 2004]
(a) 40 (b) 313
(c) 574.25 (d) 301.25

21. A centigrade and a Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers 140°. What is the fall in temperature as registered by the Centigrade thermometer [CBSE PMT 1992; AIIMS 1998]
(a) 30° (b) 40°
(c) 60° (d) 80°

22. At what temperature the centigrade (Celsius) and Fahrenheit, readings are the same [RPMT 1997, 99, 2003; BHU 1997; MNR 1992; DPMT 1998; CPMT 1995; UPSEAT 1999; KCET 2000]
(a) – 40° (b) + 40°
(c) 36.6° (d) – 37°

23. Standardisation of thermometers is obtained with [CPMT 1996]
(a) Jolly's thermometer
(b) Platinum resistance thermometer
(c) Thermocouple thermometer
(d) Gas thermometer

24. The gas thermometers are more sensitive than liquid thermometers because [CPMT 1993]
(a) Gases expand more than liquids
(b) Gases are easily obtained
(c) Gases are much lighter
(d) Gases do not easily change their states

25. Mercury thermometers can be used to measure temperatures upto [CBSE PMT 1992, 96; BHU 1998; UPSEAT 1998]
(a) $100°C$ (b) $212°C$
(c) $360°C$ (d) $500°C$

26. A constant volume gas thermometer shows pressure reading of $50 cm$ and $90 cm$ of mercury at $0°C$ and $100°C$ respectively. When the pressure reading is 60 cm of mercury, the temperature is [MNR 1991; UPSEAT 2000; Pb. CET 2004]
(a) $25°C$ (b) $40°C$

(c) $15°C$ (d) $12.5°C$

27. Mercury boils at $367°C$. However, mercury thermometers are made such that they can measure temperature up to $500°C$. This is done by [CPMT 2004]

(a) Maintaining vacuum above mercury column in the stem of the thermometer

(b) Filling nitrogen gas at high pressure above the mercury column

(c) Filling nitrogen gas at low pressure above the mercury level

(d) Filling oxygen gas at high pressure above the mercury column

28. A device used to measure very high temperature is [KCET 1998]

(a) Pyrometer (b) Thermometer

(c) Bolometer (d) Calorimeter

29. The absolute zero temperature in Fahrenheit scale is [DCE 1996]

(a) $-273°F$ (b) $-32°F$

(c) $-460°F$ (d) $-132°F$

30. A constant pressure air thermometer gave a reading of 47.5 units of volume when immersed in ice cold water, and 67 units in a boiling liquids. The boiling point of the liquid will be

(a) $135°C$ (b) $125°C$

(c) $112°C$ (d) $100°C$

31. If a thermometer reads freezing point of water as $20°C$ and boiling point as $150°C$, how much thermometer read when the actual temperature is $60°C$ [AFMC 2004]

(a) $98°C$ (b) $110°C$

(c) $40°C$ (d) $60°C$

32. If temperature of an object is $140°F$, then its temperature in centigrade is [RPMT 1999]

(a) $105°C$ (b) $32°C$

(c) $140°C$ (d) $60°C$

33. Of the following thermometers, the one which can be used for measuring a rapidly changing temperature is a [CPMT 1992]

(a) Thermocouple thermometer

(b) Gas thermometer

(c) Maximum resistance thermometer

(d) Vapour pressure thermometer

34. On centigrade scale the temperature of a body increases by 30 degrees. The increase in temperature on Fahrenheit scale is

(a) 50° (b) 40°

(c) 30° (d) 54°

35. The correct value of $0°C$ on Kelvin scale will be [RPMT 1999]

(a) $273.15\ K$ (b) $273.00\ K$

(c) $273.05\ K$ (d) $273.63\ K$

Thermal Expansion

1. When a copper ball is heated, the largest percentage increase will occur in its [EAMCET 1992]

(a) Diameter (b) Area

(c) Volume (d) Density

2. A vertical column 50 *cm* long at $50°C$ balances another column of same liquid 60 *cm* long at $100°C$. The coefficient of absolute expansion of the liquid is [EAMCET 1990]

(a) $0.005/°C$ (b) $0.0005/°C$

(c) $0.002/°C$ (d) $0.0002/°C$

3. The apparent coefficient of expansion of a liquid when heated in a copper vessel is C and when heated in a silver vessel is S. If A is the linear coefficient of expansion of copper, then the linear coefficient of expansion of silver is [EAMCET 1991]

(a) $\frac{C+S-3A}{3}$ (b) $\frac{C+3A-S}{3}$

(c) $\frac{S+3A-C}{3}$ (d) $\frac{C+S+3A}{3}$

4. A uniform metal rod is used as a bar pendulum. If the room temperature rises by $10°C$, and the coefficient of linear expansion of the metal of the rod is 2×10^{-6} per °C, the period of the pendulum will have percentage increase of [NSEP 1992]

(a) -2×10^{-3} [AIIMS 1994] (b) -1×10^{-3}

(c) 2×10^{-3} (d) 1×10^{-3}

5. A bar of iron is 10 *cm* at $20°C$. At $19°C$ it will be (α of iron $= 11 \times 10^{-6}/°C$) [EAMCET 1997]

(a) 11×10^{-6} *cm* longer (b) 11×10^{-6} *cm* shorter

(c) 11×10^{-5} *cm* shorter (d) 11×10^{-5} *cm* longer

6. When a rod is heated but prevented from expanding, the stress developed is independent of [EAMCET 1997]

(a) Material of the rod (b) Rise in temperature

(c) Length of rod (d) None of above

7. Expansion during heating [CBSE PMT 1994]

(a) Occurs only in solids

(b) Increases the weight of a material

(c) Decreases the density of a material

(d) Occurs at the same rate for all liquids and solids

8. On heating a liquid of coefficient of cubical expansion γ in a container having coefficient of linear expansion $\gamma / 3$, the level of liquid in the container will [EAMCET 1993] [UPSEAT 2005]

(a) Rise

(b) Fall

(c) Will remain almost stationary

(d) It is difficult to say

9. A pendulum clock keeps correct time at $0°C$. Its mean coefficient of linear expansions is $\alpha / °C$, then the loss in seconds per day by the clock if the temperature rises by $t°C$ is

(a) $\frac{\frac{1}{2}\alpha t \times 864000}{1-\frac{\alpha t}{2}}$ (b) $\frac{1}{2}\alpha t \times 86400$

(c) $\dfrac{\frac{1}{2}\alpha t \times 86400}{\left(1-\frac{\alpha t}{2}\right)^2}$ (d) $\dfrac{\frac{1}{2}\alpha t \times 86400}{1+\frac{\alpha t}{2}}$

10. When a bimetallic strip is heated, it [CBSE PMT 1990]

(a) Does not bend at all

(b) Gets twisted in the form of an helix

(c) Bend in the form of an arc with the more expandable metal outside

(d) Bends in the form of an arc with the more expandable metal inside

11. A solid ball of metal has a concentric spherical cavity within it. If the ball is heated, the volume of the cavity will

[AFMC 1997; Orissa PMT 2004]

(a) Increase (b) Decrease

(c) Remain unaffected (d) None of these

12. A *litre* of alcohol weighs [AFMC 1994]

(a) Less in winter than in summer

(b) Less in summer than in winter

(c) Some both in summer and winter

(d) None of the above

13. 5 *litre* of benzene weighs [MNR 1996]

(a) More in summer than in winter

(b) More in winter than in summer

(c) Equal in winter and summer

(d) None of the above

14. Water has maximum density at [Pb. PMT 1997]

(a) $0°C$ (b) $32°F$

(c) $-4°C$ (d) $4°C$

15. At some temperature T, a bronze pin is a little large to fit into a hole drilled in a steel block. The change in temperature required for an exact fit is minimum when

[SCRA 1998]

(a) Only the block is heated

(b) Both block and pin are heated together

(c) Both block and pin are cooled together

(d) Only the pin is cooled

16. If the length of a cylinder on heating increases by 2%, the area of its base will increase by [CPMT 1993; BHU 1997]

(a) 0.5% (b) 2%

(c) 1% (d) 4%

17. The volume of a gas at $20°C$ is 100 cm^3 at normal pressure. If it is heated to $100°C$, its volume becomes 125 cm^3 at the same pressure, then volume coefficient of the gas at normal pressure is

(a) $0.0015/°C$ (b) $0.0045/°C$

(c) $0.0025/°C$ (d) $0.0033/°C$

18. The coefficient of superficial expansion of a solid is 2×10^{-5} /°C. It's coefficient of linear expansion is [KCET 1999]

(a) $4 \times 10^{-5}/°C$ (b) $3 \times 10^{-5}/°C$

(c) $2 \times 10^{-5}/°C$ (d) $1 \times 10^{-5}/°C$

19. Density of substance at $0°C$ is 10 *gm/cc* and at $100°C$, its density is 9.7 *gm/cc*. The coefficient of linear expansion of the substance will be

[BHU 1996; Pb. PMT 1999; DPMT 1998, 2003]

(a) 10^{2} (b) 10^{-2}

(c) 10^{-3} (d) 10^{-4}

20. Coefficient of real expansion of mercury is $0.18 \times 10^{-3}/°C$. If the density of mercury at $0°C$ is 13.6 *gm/cc*. its density at $473K$ is

(a) 13.11 *gm/cc* (b) 26.22 *gm/cc*

(c) 52.11 *gm/cc* (d) None of these

21. The real coefficient of volume expansion of glycerine is 0.000597 per$°C$ and linear coefficient of expansion of glass is 0.000009 per$°C$. Then the apparent volume coefficient of expansion of glycerine is

(a) 0.000558 per$°C$ (b) 0.00057 per$°C$

(c) 0.00027 per$°C$ (d) 0.00066 per$°C$

22. A beaker is completely filled with water at $4°C$. It will overflow if [EAMCET 199

(a) Heated above $4°C$

(b) Cooled below $4°C$

(c) Both heated and cooled above and below $4°C$ respectively

(d) None of the above

23. The volume of a metal sphere increases by 0.24% when its temperature is raised by $40°C$. The coefficient of linear expansion of the metal is .... $°C$ [Kerala PMT 2005]

(a) 2×10^{-5} (b) 6×10^{-5}

(c) 2.1×10^{-5} (d) 1.2×10^{-5}

24. Ratio among linear expansion coefficient (α), areal expansion coefficient (β) and volume expansion coefficient (γ) is

(a) 1 : 2 : 3 (b) 3 : 2 : 1

(c) 4 : 3 : 2 (d) None of these

25. If on heating liquid through $80°C$, the mass expelled is (1/100)th of mass still remaining, the coefficient of apparent expansion of liquid is [RPMT 2004]

(a) $1.25 \times 10^{-4}/°C$ (b) $12.5 \times 10^{-4}/°C$

(c) $1.25 \times 10^{-5}/°C$ (b) None of these

26. In cold countries, water pipes sometimes burst, because

(a) Pipe contracts

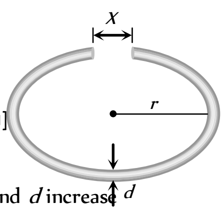
(b) Water expands on freezing

(c) When water freezes, pressure increases

(d) When water freezes, it takes heat from pipes

27. A cylindrical metal rod of length L_0 is shaped into a ring with a small gap as shown. On heating the system

[Pb. PET 2002; DPMT 2001]



(a) x decreases, r and d increase

(b) x and r increase, d decreases

(c) x, r and d all increase

(d) Data insufficient to arrive at a conclusion

28. The length of a metallic rod is $5m$ at $0°C$ and becomes 5.01 m, on heating upto $100°C$. The linear expansion of the metal will be

(a) 2.33×10^{-5} /°C (b) 6.0×10^{-5} /°C

(c) 4.0×10^{-5} /°C (d) 2.0×10^{-5} /°C

29. A metal rod of silver at 0°C is heated to 100°C. It's length is increased by 0.19 *cm*. Coefficient of cubical expansion of the silver rod is [UPSEAT 2001]

(a) 5.7×10^{-5}/°C (b) 0.63×10^{-5}/°C

(c) 1.9×10^{-5}/°C (d) 16.1×10^{-5}/°C

30. A brass disc fits simply in a hole of a steel plate. The disc from the hole can be loosened if the system [UPSEAT 2001]

(a) First heated then cooled (b) First cooled then heated

(c) Is heated (d) Is cooled

31. An iron bar of length 10 *m* is heated from 0°C to 100°C. If the coefficient of linear thermal expansion of iron is 10×10^{-6} /°C, the increase in the length of bar is [UPSEAT 2005]

(a) 0.5 *cm* (b) 1.0 *cm*

(c) 1.5 *cm* (d) 2.0 *cm*

32. If a cylinder of diameter 1.0 *cm* at 30°C is to be solid into a hole of diameter 0.9997 *cm* in a steel plate at the same temperature, then minimum required rise in the temperature of the plate is : (Coefficient of linear expansion of steel $= 12 \times 10^{-6} / °C$)

(a) 25°C (b) 35°C

(c) 45°C (d) 55°C

33. Surface of the lake is at 2°C. Find the temperature of the bottom of the lake [Orissa JEE 2002]

(a) 2°C (b) 3°C

(c) 4°C (d) 1°C

34. Two rods, one of aluminum and the other made of steel, having initial length l_1 and l_2 are connected together to form a single rod of length $l_1 + l_2$. The coefficients of linear expansion for aluminum and steel are α_a and α_s respectively. If the length of each rod increases by the same amount when their temperature are raised by $t^o C$, then find the ratio $\frac{l_1}{(l_1 + l_2)}$

(a) $\frac{\alpha_s}{\alpha_a}$ (b) $\frac{\alpha_a}{\alpha_s}$

(c) $\frac{\alpha_s}{(\alpha_a + \alpha_s)}$ (d) $\frac{\alpha_a}{(\alpha_a + \alpha_s)}$

Calorimetry

1. When vapour condenses into liquid [CPMT 1990]

(a) It absorbs heat (b) It liberates heat

(c) Its temperature increases (d) Its temperature decreases

2. At NTP water boils at 100°C. Deep down the mine, water will boil at a temperature [CPMT 1996]

(a) 100°C (b) > 100°C

(c) < 100°C (d) Will not boil at all

3. If specific heat of a substance is infinite, it means [AIIMS 1997]

(a) Heat is given out

(b) Heat is taken in

(c) No change in temperature takes place whether heat is taken in or given out

(d) All of the above

4. A gas in an airtight container is heated from 25°C to 90°C. The density of the gas will [BCECE 1997]

(a) Increase slightly (b) Increase considerably

(c) Remain the same (d) Decrease slightly

5. A quantity of heat required to change the unit mass of a solid substance, from solid state to liquid state, while the temperature remains constant, is known as [AIIMS 1998]

(a) Latent heat (b) Sublimation

(c) Hoar frost (d) Latent heat of fusion

6. The latent heat of vaporization of a substance is always [SCRA 1998]

(a) Greater than its latent heat of fusion

(b) Greater than its latent heat of sublimation

(c) Equal to its latent heat of sublimation

(d) Less than its latent heat of fusion

7. The factor not needed to calculate heat lost or gained when there is no change of state is [AFMC 1997; BHU 1997]

(a) Weight (b) Specific heat

(c) Relative density [EAMCET 2001] (d) Temperature change

8. 540 *g* of ice at 0°C is mixed with 540 *g* of water at 80°C. The final temperature of the mixture is [AFMC 1994]

(a) 0°C (b) 40°C

(c) 80°C (d) Less than 0°C

9. Water is used to cool radiators of engines, because [AFMC 2001]

(a) Of its lower density (b) It is easily available

(c) It is cheap (d) It has high specific heat

10. How much heat energy is gained when 5 *kg* of water at 20°C is brought to its boiling point

(Specific heat of water = 4.2 $kJ\ kg^{-1} c^{-1}$) [BHU 2001]

(a) 1680 *kJ* (b) 1700 *kJ*

[IIT-JEE (Screening) 2003] (c) 1720 *kJ* (d) 1740 *kJ*

11. Melting point of ice [CBSE PMT 1993]

(a) Increases with increasing pressure

(b) Decreases with increasing pressure

(c) Is independent of pressure

(d) Is proportional to pressure

12. Heat required to convert one gram of ice at 0°C into steam at 100°C is (given L_{steam} = 536 *cal/gm*) [Pb. PMT 1990]

(a) 100 *calorie* (b) 0.01 *kilocalorie*

(c) 716 *calorie* (d) 1 *kilocalorie*

13. 80 *gm* of water at 30°C are poured on a large block of ice at 0°C. The mass of ice that melts is [CBSE PMT 1989]

(a) 30 *gm* (b) 80 *gm*

(c) 1600 *gm* (d) 150 *gm*

14. The saturation vapour pressure of water at 100°C is [EAMCET 1997]

(a) 739 *mm* of mercury (b) 750 *mm* of mercury

(c) 760 *mm* of mercury (d) 712 *mm* of mercury

15. Two spheres made of same substance have diameters in the ratio 1 : 2. Their thermal capacities are in the ratio of [JIPMER 1999]

(a) 1 : 2 (b) 1 : 8

(c) 1 : 4 (d) 2 : 1

16. Work done in converting one gram of ice at –10°*C* into steam at 100°*C* is

[MP PET/PMT 1988; EAMCET (Med.) 1995; MP PMT 2003]

(a) 3045 *J* (b) 6056 *J*

(c) 721 *J* (d) 616 *J*

17. If mass energy equivalence is taken into account, when water is cooled to form ice, the mass of water should

[AIEEE 2002]

(a) Increase (b) Remain unchanged

(c) Decrease (d) First increase then decrease

18. Compared to a burn due to water at 100°*C*, a burn due to steam at 100°*C* is [KCET 1999; UPSEAT 1999]

(a) More dangerous (b) Less dangerous

(c) Equally dangerous (d) None of these

19. 50 *gm* of copper is heated to increase its temperature by 10°*C*. If the same quantity of heat is given to 10 *gm* of water, the rise in its temperature is (Specific heat of copper = 420 *Joule-kg*$^{-1}$°*C*$^{-1}$)

(a) 5°*C* (b) 6°*C*

(c) 7°*C* (d) 8°*C*

20. Two liquids *A* and *B* are at 32°*C* and 24°*C*. When mixed in equal masses the temperature of the mixture is found to be 28°*C*. Their specific heats are in the ratio of [DPMT 1996]

(a) 3 : 2 (b) 2 : 3

(c) 1 : 1 (d) 4 : 3

21. A beaker contains 200 *gm* of water. The heat capacity of the beaker is equal to that of 20 *gm* of water. The initial temperature of water in the beaker is 20°*C*. If 440 *gm* of hot water at 92°*C* is poured in it, the final temperature (neglecting radiation loss) will be nearest to [NSEP 1994]

(a) 58°*C* (b) 68°*C*

(c) 73°*C* (d) 78°*C*

22. Amount of heat required to raise the temperature of a body through 1*K* is called its

[KCET 1996; MH CET 2001; AIEEE 2002]

(a) Water equivalent (b) Thermal capacity

(c) Entropy (d) Specific heat

23. A metallic ball and highly stretched spring are made of the same material and have the same mass. They are heated so that they melt, the latent heat required [AIIMS 2002]

(a) Are the same for both

(b) Is greater for the ball

(c) Is greater for the spring

(d) For the two may or may not be the same depending upon the metal

24. A liquid of mass *m* and specific heat *c* is heated to a temperature 2*T*. Another liquid of mass *m*/2 and specific heat 2*c* is heated to a temperature *T*. If these two liquids are mixed, the resulting temperature of the mixture is

[EAMCET 1992]

(a) (2/3)*T* (b) (8/5)*T*

(c) (3/5)*T* (d) (3/2)*T*

25. Calorie is defined as the amount of heat required to raise temperature of 1*g* of water by 1°*C* and it is defined under which of the following conditions

[IIT-JEE (Screening) 2005]

(a) From 14.5°*C* to 15.5°*C* at 760 *mm* of *Hg*

(b) From 98.5°*C* to 99.5°*C* at 760 *mm* of *Hg*

(c) From 13.5°*C* to 14.5°*C* at 76 *mm* of *Hg*

(d) From 3.5°*C* to 4.5°*C* at 76 *mm* of *Hg*

26. 100 *gm* of ice at 0°*C* is mixed with 100 *g* of water at 100°*C*. What will be the final temperature of the mixture

[SCRA 1996; AMU 1999]

(a) 10°*C* (b) 20°*C*

(c) 30°*C* (d) 40°*C*

27. At atmospheric pressure, the water boils at 100°*C*. If pressure is reduced, it will boil at [MP PMT 1984]

(a) Higher temperature (b) Lower temperature

(c) At the same temperature (d) At critical temperature

28. A closed bottle containing water at 30°*C* is carried to the moon in a space-ship. If it is placed on the surface of the moon, what will happen to the water as soon as the lid is opened

[EAMCET (Med.) 2000]

(a) Water will boil

(b) Water will freeze

(c) Nothing will happen on it

(d) It will decompose into H_2 and O_2

29. The thermal capacity of 40 *gm* of aluminium (specific heat = 0.2 *cal*/*gm*/°*C*) is [CBSE PMT 1990]

(a) 40 *cal*/°*C* (b) 160 *cal*/°*C*

(c) 200 *cal*/°*C* (d) 8 *cal*/°*C*

30. If temperature scale is changed from °*C* to °*F*, the numerical value of specific heat will [CPMT 1984]

(a) Increases (b) Decreased

(c) Remains unchanged (d) None of the above

31. By exerting a certain amount of pressure on an ice block, you

(a) Lower its melting point

(b) Make it melt at 0°*C* only

(c) Make it melt at a faster rate

(d) Raise its melting point

32. When we rub our palms they gets heated but to a maximum temperature because

(a) Heat is absorbed by our palm

(b) Heat is lost in the environment

(c) Produced of heat is stopped

(d) None of the above

33. A bullet moving with a uniform velocity *v*, stops suddenly after hitting the target and the whole mass melts be *m*, specific heat *S*, initial temperature 25°*C*, melting point 475°*C* and the latent heat *L*. Then *v* is given by

[NCERT 1972]

(a) $mL = mS\,(475-25)+\frac{1}{2}\cdot\frac{mv^2}{J}$

(b) $mS(475-25)+mL=\frac{mv^2}{2J}$

(c) $mS\,(475-25)+mL=\frac{mv^2}{J}$

(d) $mS(475-25)-mL=\dfrac{mv^2}{2J}$

34. A water fall is 84 *metres* high. If half of the potential energy of the falling water gets converted to heat, the rise in temperature of water will be [JIPMER 2002]

(a) $0.098°C$ (b) $0.98°C$

(c) $9.8°C$ (d) $0.0098°C$

35. A body of mass 5 *kg* falls from a height of 30 *metre*. If its all mechanical energy is changed into heat, then heat produced will be

(a) 350 *cal* (b) 150 *cal*

(c) 60 *cal* (d) 6 *cal*

36. In supplying 400 calories of heat to a system, the work done will be

(a) 400 *joules* (b) 1672 *joules*

(c) 1672 *watts* (d) 1672 *ergs*

37. 0.93 *watt-hour* of energy is supplied to a block of ice weighing 10 *gm*. It is found that [NCERT 1973; DPMT 1999]

(a) Half of the block melts

(b) The entire block melts and the water attains a temperature of $4°C$

(c) The entire block just melts

(d) The block remains unchanged

38. The weight of a person is 60 *kg*. If he gets 10^5 calories heat through food and the efficiency of his body is 28%, then upto how much height he can climb (approximately) [AFMC 1997]

(a) 100 *m* (b) 200 *m*

(c) 400 *m* (d) 1000 *m*

39. The temperature of *Bhakhra dam* water at the ground level with respect to the temperature at high level should be

(a) Greater (b) Less

(c) Equal (d) $0°C$

40. The height of a waterfall is 84 *metre*. Assuming that the entire kinetic energy of falling water is converted into heat, the rise in temperature of the water will be

$(g=9.8\,m/s^2,\ J=4.2\ joule/cal)$ [MP PET 1994]

(a) $0.196°C$ (b) $1.960°C$

(c) $0.96°C$ (d) $0.0196°C$

41. Hailstone at $0°C$ falls from a height of 1 *km* on an insulating surface converting whole of its kinetic energy into heat. What part of it will melt $(g=10\,m/s^2)$ [MP PMT 1994]

(a) $\dfrac{1}{33}$ (b) $\dfrac{1}{8}$

(c) $\dfrac{1}{33}\times 10^{-4}$ (d) All of it will melt

42. The *SI* unit of mechanical equivalent of heat is [MP PMT/PET 1998]

(a) *Joule* × *Calorie* (b) *Joule*/*Calorie*

(c) *Calorie* × *Erg* (d) *Erg*/*Calorie*

43. Of two masses of 5 *kg* each falling from height of 10 *m*, by which 2*kg* water is stirred. The rise in temperature of water will be

(a) $2.6°C$ (b) $1.2°C$

(c) $0.32°C$ (d) $0.12°C$

44. A lead ball moving with a velocity *V* strikes a wall and stops. If 50% of its energy is converted into heat, then what will be the increase in temperature (Specific heat of lead is *S*) [CPMT 1975] [RPMT 1996] [MP PMT 1989]

(a) $\dfrac{2V^2}{JS}$ (b) $\dfrac{V^2}{4JS}$

(c) $\dfrac{V^2}{J}$ (d) $\dfrac{V^2S}{2J}$

45. The mechanical equivalent of heat *J* is [MP PET 2000]

(a) A constant (b) A physical quantity

(c) A conversion factor (d) None of the above

46. Water falls from a height of 210*m*. Assuming whole of energy due to fall is converted into heat the rise in temperature of water would be (*J* = 4.3 *Joule*/*cal*) [Pb. PMT 2002]

(a) $42°C$ (b) $49°C$

(c) $0.49°C$ (d) $4.9°C$

47. A block of mass 100 *gm* slides on a rough horizontal surface. If the speed of the block decreases from 10 *m*/*s* to 5 *m*/*s*, the thermal energy developed in the process is [UPSEAT 2002]

(a) 3.75 *J* (b) 37.5 *J*

(c) 0.375 *J* (d) 0.75 *J*

48. 4200 *J* of work is required for [MP PMT 1986]

(a) Increasing the temperature of 10 *gm* of water through $10°C$

(b) Increasing the temperature of 100 *gm* of water through $10°C$

(c) Increasing the temperature of 1 *kg* of water through $10°C$

(d) Increasing the temperature of 10 *kg* of water through $10°C$

49. At $100°C$, the substance that causes the most severe burn, is [KCET 1999; UPSEAT 1999]

(a) Oil (b) Steam

(c) Water (d) Hot air

50. In a water-fall the water falls from a height of 100 *m*. If the entire K.E. of water is converted into heat, the rise in temperature of water will be [MP PMT 2001]

(a) $0.23°C$ (b) $0.46°C$

(c) $2.3°C$ (d) $0.023°C$

51. A lead bullet of 10 *g* travelling at 300 *m*/*s* strikes against a block of wood and comes to rest. Assuming 50% of heat is absorbed by the bullet, the increase in its temperature is

(Specific heat of lead = 150*J*/*kg*, *K*) [EAMCET 2001]

(a) $100°C$ (b) $125°C$

(c) $150°C$ (d) $200°C$

52. The temperature at which the vapour pressure of a liquid becomes equals to the external (atmospheric) pressure is its [Kerala (Engg.) 2001]

(a) Melting point (b) Sublimation point
(c) Critical temperature (d) Boiling point

53. When the pressure on water is increased the boiling temperature of water as compared to $100°C$ will be [RPET 1999]

(a) Lower
(b) The same
(c) Higher
(d) On the critical temperature

54. Calorimeters are made of which of the following [AFMC 2000]

(a) Glass (b) Metal
(c) Wood (d) Either (a) or (c)

55. Triple point of water is [CPMT 2002]

(a) $273.16°F$ (b) $273.16\ K$
(c) $273.16°C$ (d) $273.16\ R$

56. A liquid boils when its vapour pressure equals [MP PET 2002]

(a) The atmospheric pressure
(b) Pressure of 76.0 *cm* column of mercury
(c) The critical pressure
(d) The dew point of the surroundings

57. The amount of work, which can be obtained by supplying 200 *cal* of heat, is [Pb. PET 2001, 03; BHU 2004]

(a) 840 *dyne* (b) 840 *W*
(c) 840 *erg* (d) 840 *J*

58. How many grams of a liquid of specific heat 0.2 at a temperature $40°C$ must be mixed with 100 *gm* of a liquid of specific heat of 0.5 at a temperature $20°C$, so that the final temperature of the mixture becomes $32°C$ [Pb. PET 1999]

(a) 175 *gm* (b) 300 *g*
(c) 295 *gm* (d) 375 *g*

59. 1 *g* of a steam at $100°C$ melt how much ice at $0°C$? (Latent heat of ice = 80 *cal/gm* and latent heat of steam = 540 *cal/gm*)

(a) 1 *gm* (b) 2 *gm*
(c) 4 *gm* (d) 8 *gm*

60. 5 *g* of ice at $0°C$ is dropped in a beaker containing 20 *g* of water at $40°C$. The final temperature will be [Pb. PET 2003]

(a) $32°C$ (b) $16°C$
(c) $8°C$ (d) $24°C$

61. One kilogram of ice at $0°C$ is mixed with one kilogram of water at $80°C$. The final temperature of the mixture is

(Take : specific heat of water $= 4200\ J\ kg^{-1}\ K^{-1}$, latent heat of ice $= 336\ kJ\ kg^{-1}$) [KCET 2002]

(a) $40°C$ (b) $60°C$
(c) $0°C$ (d) $50°C$

62. During constant temperature, we feel colder on a day when the relative humidity will be [Pb. PMT 1996]

(a) 25% (b) 12.5%
(c) 50% (d) 75%

63. Which of the following is the unit of specific heat [MH CET 2004]

(a) $J\ kg\ °C^{-1}$ (b) $J / kg\ °C$
(c) $kg\ °C / J$ (d) $J / kg\ °C^{-2}$

64. 50 *gm* of ice at $0°C$ is mixed with 50 *gm* of water at $80°C$, final temperature of mixture will be [DCE 2002]

(a) $0°C$ (b) $40°C$
(c) $40°C$ (d) $4°C$

65. The freezing point of the liquid decreases when pressure is increased, if the liquid [DCE 1995]

(a) Expands while freezing
(b) Contracts while freezing
(c) Does not change in volume while freezing
(d) None of these

66. The relative humidity on a day, when partial pressure of water vapour is $0.012 \times 10^5\ Pa$ at $12°C$ is (take vapour pressure of water at this temperature as $0.016 \times 10^5\ Pa$) [AIIMS 1998]

(a) 70% (b) 40%
(c) 75% (d) 25%

67. A hammer of mass 1*kg* having speed of 50 *m/s*, hit a iron nail of mass 200 *gm*. If specific heat of iron is 0.105 *cal/gm°C* and half the energy is converted into heat, the raise in temperature of nail is

(a) $7.1°C$ (b) $9.2°C$
(c) $10.5°C$ (d) $12.1°C$

68. Latent heat of 1*gm* of steam is 536 *cal/gm*, then its value in *joule/kg* is [RPMT 1999]

(a) 2.25×10^6 (b) 2.25×10^3
(c) 2.25 (d) None

69. Which of the following has maximum specific heat [RPMT 1999]

(a) Water (b) Alcohol
(c) Glycerine [Pb. PET 2000] (d) Oil

70. 50 *gm* ice at $0°C$ in insulator vessel, 50*g* water of $100°C$ is mixed in it, then final temperature of the mixture is (neglect the heat loss)

(a) $10°C$ (b) $0° << T_m < 20°C$
(c) $20°C$ (d) Above $20°C$

71. A stationary object at $4°C$ and weighing 3.5 *kg* falls from a height of 2000 *m* on a snow mountain at $0°C$. If the temperature of the object just before hitting the snow is $0°C$ and the object comes to rest immediately $(g = 10\ m/s^2)$ and (latent heat of ice $= 3.5 \times 10^5\ joule/\sec$), then the object will melt

(a) 2 *kg* of ice (b) 200 *gm* of ice
(c) 20 *gm* ice (d) 2 *gm* of ice

72. 300 *gm* of water at 25°*C* is added to 100 *gm* of ice at 0°*C*. The final temperature of the mixture is [MP PET 2004]

(a) $-\frac{5}{3}°C$ (b) $-\frac{5}{2}°C$

(c) – 5°*C* (d) 0°*C*

73. Calculate the amount of heat (in calories) required to convert 5 *gm* of ice at 0°*C* to steam at 100°*C* [DPMT 2005]

(a) 3100 (b) 3200

(c) 3600 (d) 4200

74. 2*gm* of steam condenses when passed through 40*gm* of water initially at 25°*C*. The condensation of steam raises the temperature of water to 54.3°*C*. What is the latent heat of steam

(a) 540 *cal/g* (b) 536 *cal/g*

(c) 270 *cal/g* (d) 480 *cal/g*

75. 10 *gm* of ice at 0°*C* is mixed with 100 *gm* of water at 50°*C*. What is the resultant temperature of mixture [AFMC 2005]

(a) 31.2°*C* (b) 32.8°*C*

(c) 36.7°*C* (d) 38.2°*C*

76. Three liquids with masses m_1, m_2, m_3 are thoroughly mixed. If their specific heats are c_1, c_2, c_3 and their temperatures T_1, T_2, T_3 respectively, then the temperature of the mixture is

(a) $\frac{c_1T_1 + c_2T_2 + c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$

(b) $\frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$

(c) $\frac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1T_1 + m_2T_2 + m_3T_3}$

(d) $\frac{m_1T_1 + m_2T_2 + m_3T_3}{c_1T_1 + c_2T_2 + c_3T_3}$

77. The point on the pressure temperature phase diagram where all the phases co-exist is called [MH CET 2005]

(a) Sublimation (b) Fusion point

(c) Triple point (d) Vaporisation point

78. Boiling water is changing into steam. At this stage the specific heat of water is [UPSEAT 1998]

(a) < 1 (b) ∞

(c) 1 (d) 0

79. A vessel contains 110 *g* of water. The heat capacity of the vessel is equal to 10 *g* of water. The initial temperature of water in vessel is 10°*C*. If 220 *g* of hot water at 70°*C* is poured in the vessel, the final temperature neglecting radiation loss, will be

(a) 70°*C* (b) 80°*C*

(c) 60°*C* (d) 50°*C*

80. The thermal capacity of a body is 80 *cal*, then its water equivalent is [UPSEAT 2001]

(a) 80 *cal / gm* (b) 8 *gm*

(c) 80 *gm* (d) 80 *kg*

81. A liquid of mass *M* and specific heat *S* is at a temperature 2*t*. If another liquid of thermal capacity 1.5 times, at a temperature of $\frac{t}{3}$ is added to it, the resultant temperature will be

(a) $\frac{4}{3}t$ (b) t

(c) $\frac{t}{2}$ (d) $\frac{2}{3}t$

82. Dry ice is [CPMT 2000]

(a) Ice cube (b) Sodium chloride

(c) Liquid nitrogen [J & K CET 2005] (d) Solid carbon dioxide

Critical Thinking

Objective Questions

1. A glass flask is filled up to a mark with 50 *cc* of mercury at 18°*C*. If the flask and contents are heated to 38°*C*, how much mercury will be above the mark ? (α for glass is $9 \times 10^{-6}/°C$ and coefficient of real expansion of mercury is $180 \times 10^{-6}/°C$)

(a) 0.85 *cc* (b) 0.46 *cc*

(c) 0.153 *cc* (d) 0.05 *cc*

2. The coefficient of apparent expansion of mercury in a glass vessel is $153 \times 10^{-6}/°C$ and in a steel vessel is $144 \times 10^{-6}/°C$. If α for steel is $12 \times 10^{-6}/°C$, then that of glass is [EAMCET 1997]

(a) $9 \times 10^{-6}/°C$ (b) $6 \times 10^{-6}/°C$

(c) $36 \times 10^{-6}/°C$ (d) $27 \times 10^{-6}/°C$

3. Solids expand on heating because [CPMT 1990]

(a) Kinetic energy of the atoms increases

(b) Potential energy of the atoms increases

(c) Total energy of the atoms increases

(d) The potential energy curve is asymmetric about the equilibrium distance between neighbouring atoms

4. An iron tyre is to be fitted on to a wooden wheel 1*m* in diameter. The diameter of tyre is 6 *mm* smaller than that of wheel. The tyre should be heated so that its temperature increases by a minimum of (the coefficient of cubical expansion of iron is $3.6 \times 10^{-5}/°C$)[CPMT 1989]

(a) 167°*C* (b) 334°*C*

(c) 500°*C* (d) 1000°*C*

5. A glass flask of volume one *litre* at 0°*C* is filled, level full of mercury at this temperature. The flask and mercury are now heated to 100°*C*. How much mercury will spill out, if coefficient of volume expansion of mercury is $1.82 \times 10^{-4}/°C$ and linear expansion of glass is $0.1 \times 10^{-4}/°C$ respectively [UPSEAT 2000] [MNR 1994]

(a) 21.2 *cc* (b) 15.2 *cc*

(c) 1.52 *cc* (d) 2.12 *cc*

6. A steel scale measures the length of a copper wire as $80.0\,cm$, when both are at $20°C$ (the calibration temperature for scale). What would be the scale read for the length of the wire when both are at $40°C$? (Given $\alpha_{steel} = 11 \times 10^{-6}$ per°C and $\alpha_{copper} = 17 \times 10^{-6}\ per\ °C$) **[CPMT 2004]**

(a) $80.0096\,cm$ (b) $80.0272\,cm$

(c) $1\,cm$ (d) $25.2\,cm$

7. A bimetallic strip is formed out of two identical strips, one of copper and other of brass. The coefficients of linear expansion of the two metals are α_C and α_B. On heating, the temperature of the strip goes up by ΔT and the strip bends to form an arc of radius of curvature *R*. Then *R* is **[IIT-JEE (Screening) 1999]**

(a) Proportional to ΔT

(b) Inversely proportional to ΔT

(c) Proportional to $|\alpha_B - \alpha_C|$

(d) Inversely proportional to $|\alpha_B - \alpha_C|$

8. Two metal strips that constitute a thermostat must necessarily differ in their **[IIT-JEE 1992]**

(a) Mass

(b) Length

(c) Resistivity

(d) Coefficient of linear expansion

9. A metal ball immersed in alcohol weighs W_1 at 0°C and W_2 at 59°C. The coefficient of cubical expansion of the metal is less than that of alcohol. Assuming that the density of metal is large compared to that of alcohol, it can be shown that **[CPMT 1998]**

(a) $W_1 > W_2$ (b) $W_1 = W_2$

(c) $W_1 < W_2$ (d) $W_2 = (W_1 / 2)$

10. The coefficient of volumetric expansion of mercury is 18 × 10^{-5}/°C. A thermometer bulb has a volume 10^{-6} m^3 and cross section of stem is 0.004 cm^2. Assuming that bulb is filled with mercury at 0°C then the length of the mercury column at 100°C is **[Pb. PMT 1998, DPMT 1997, 2001]**

(a) 18.8 *mm* (b) 9.2 *mm*

(c) 7.4 *cm* (d) 4.5 *cm*

11. A piece of metal weight 46 *gm* in air, when it is immersed in the liquid of specific gravity 1.24 at 27°C it weighs 30 *gm*. When the temperature of liquid is raised to 42°C the metal piece weight 30.5 *gm*, specific gravity of the liquid at 42°C is 1.20, then the linear expansion of the metal will be **[BHU 1995]**

(a) 3.316 × 10^{-5}/°C (b) 2.316 × 10^{-5}/°C

(c) 4.316 × 10^{-5}/°C (d) None of these

12. It is known that wax contracts on solidification. If molten wax is taken in a large vessel and it is allowed to cool slowly, then

(a) It will start solidifying from the top downward

(b) It will start solidifying from the bottom upward

(c) It will start solidifying from the middle, upward and downward at equal rates

(d) The whole mass will solidify simultaneously

13. A substance of mass *m* kg requires a power input of *P* watts to remain in the molten state at its melting point. When the power is turned off, the sample completely solidifies in time *t* sec. What is the latent heat of fusion of the substance **[IIT JEE 1992]**

(a) $\frac{Pm}{t}$ (b) $\frac{Pt}{m}$

(c) $\frac{m}{Pt}$ (d) $\frac{t}{Pm}$

14. Steam at 100°C is passed into 1.1 *kg* of water contained in a calorimeter of water equivalent 0.02 *kg* at 15°C till the temperature of the calorimeter and its contents rises to 80°C. The mass of the steam condensed in *kg* is **[IIT 1995]**

(a) 0.130 (b) 0.065

(c) 0.260 (d) 0.135

15. 2 *kg* of ice at – 20°C is mixed with 5 *kg* of water at 20°C in an insulating vessel having a negligible heat capacity. Calculate the final mass of water remaining in the container. It is given that the specific heats of water and ice are 1 *kcal/kg per* °C and 0.5 *kcal/kg/*°C while the latent heat of fusion of ice is 80 *kcal/kg* **[IIT-JEE (Screening) 2003]**

(a) 7 *kg* (b) 6 *kg*

(c) 4 *kg* (d) 2 *kg*

16. Water of volume 2 *litre* in a container is heated with a coil of $1\,kW$ at $27\,°C$. The lid of the container is open and energy dissipates at rate of $160\,J/s$. In how much time temperature will rise from $27\,°C$ to $77\,°C$ [Given specific heat of water is $4.2\,kJ/kg$]

(a) 8 *min* 20 *s* (b) 6 *min* 2 *s*

(c) 7 *min* (d) 14 *min*

17. A lead bullet at 27°C just melts when stopped by an obstacle. Assuming that 25% of heat is absorbed by the obstacle, then the velocity of the bullet at the time of striking (M.P. of lead = 327°C, specific heat of lead = 0.03 *cal/gm*°C, latent heat of fusion of lead = 6 *cal/gm* and *J* = 4.2 *joule/cal*) **[IIT 1981]**

(a) 410 *m/sec* (b) 1230 *m/sec*

(c) 307.5 *m/sec* (d) None of the above

18. If two balls of same metal weighing 5 *gm* and 10 *gm* strike with a target with the same velocity. The heat energy so developed is used for raising their temperature alone, then the temperature will be higher

(a) For bigger ball

(b) For smaller ball

(c) Equal for both the balls

(d) None is correct from the above three

[CBSE PMT 1994]

19. The temperature of equal masses of three different liquids *A*, *B* and *C* are 12°C, 19°C and 28°C respectively. The temperature when *A* and *B* are mixed is 16°C and when *B* and *C* are mixed is 23°C. The temperature when *A* and *C* are mixed is

(a) 18.2°C (b) 22°C

(c) 20.2°C (d) 25.2°C

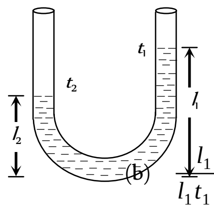
20. In an industrial process 10 *kg* of water per hour is to be heated from 20°C to 80°C. To do this steam at 150°C is passed from a boiler into a copper coil immersed in water. The steam condenses in the coil and is returned to the boiler as water at 90°C. how many *kg* of steam is required per hour.

(Specific heat of steam = 1 *calorie* per *gm*°C, Latent heat of vaporisation = 540 *cal/gm*)

(a) 1 *gm* (b) 1 *kg*

(c) 10 *gm* (d) 10 *kg*

21. In a vertical U-tube containing a liquid, the two arms are maintained at different temperatures t_1 and t_2. The liquid columns in the two arms have heights l_1 and l_2 respectively. The coefficient of volume expansion of the liquid is equal to



(a) $\frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$ (b) $\frac{l_1 - l_2}{l_1 t_1 - l_2 t_2}$

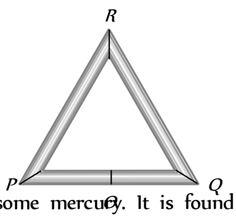
(c) $\frac{l_1 + l_2}{l_2 t_1 + l_1 t_2}$ (d) $\frac{l_1 + l_2}{l_1 t_1 + l_2 t_2}$

22. The coefficient of linear expansion of crystal in one direction is α_1 and that in every direction perpendicular to it is α_2. The coefficient of cubical expansion is

(a) $\alpha_1 + \alpha_2$ (b) $2\alpha_1 + \alpha_2$

(c) $\alpha_1 + 2\alpha_2$ (d) None of these

23. Three rods of equal length l are joined to form an equilateral triangle PQR. O is the mid point of PQ. Distance OR remains same for small change in temperature. Coefficient of linear expansion for PR and RQ is same *i.e.* α_2 but that for PQ is α_1. Then



(a) $\alpha_2 = 3\alpha_1$

(b) $\alpha_2 = 4\alpha_1$

(c) $\alpha_1 = 3\alpha_2$

(d) $\alpha_1 = 4\alpha_2$

24. A one *litre* glass flask contains some mercury. It is found that at different temperatures the volume of air inside the flak remains the same. What is the volume of mercury in this flask if coefficient of linear expansion of glass is $9 \times 10^{-6}/°C$ while of volume expansion of mercury is $1.8 \times 10^{-4}/°C$

(a) 50 *cc* (b) 100 *cc*

(c) 150 *cc* (d) 200 *cc*

25. 10 *gm* of ice at – 20°C is dropped into a calorimeter containing 10 *gm* of water at 10°C; the specific heat of water is twice that of ice. When equilibrium is reached, the calorimeter will contain

(a) 20 *gm* of water

(b) 20 *gm* of ice

(c) 10 *gm* ice and 10 *gm* water

(d) 5 *gm* ice and 15 *gm* water

26. A rod of length 20 *cm* is made of metal. It expands by 0.075*cm* when its temperature is raised from 0°C to 100°C. Another rod of a different metal B having the same length expands by 0.045 *cm* for the same change in temperature. A third rod of the same length is composed of two parts, one of metal A and the other of metal B. This rod expands by 0.060 *cm* for the same change in temperature. The portion made of metal A has the length

(a) 20 *cm* (b) 10 *cm*

(c) 15 *cm* (d) 18 *cm*

27. Steam is passed into 22 *gm* of water at 20°C. The mass of water that will be present when the water acquires a temperature of 90°C (Latent heat of steam is 540 *cal/gm*) is

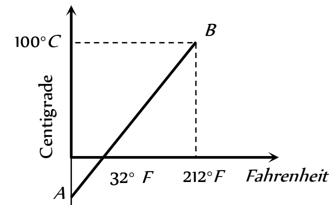
[SCRA 1994]

(a) 24.8 *gm* (b) 24 *gm*

(c) 36.6 *gm* (d) 30 *gm*

GQ Graphical Questions

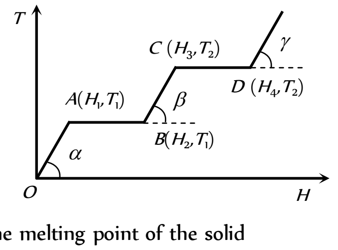
1. The graph AB shown in figure is a plot of temperature of a body in degree celsius and degree Fahrenheit. Then



(a) Slope of line AB is 9/5 (b) Slope of line AB is 5/9

(c) Slope of line AB is 1/9 (d) Slope of line AB is 3/9

2. The graph shows the variation of temperature (T) of one *kilogram* of a material with the heat (H) supplied to it. At O, the substance is in the solid state. From the graph, we can conclude that



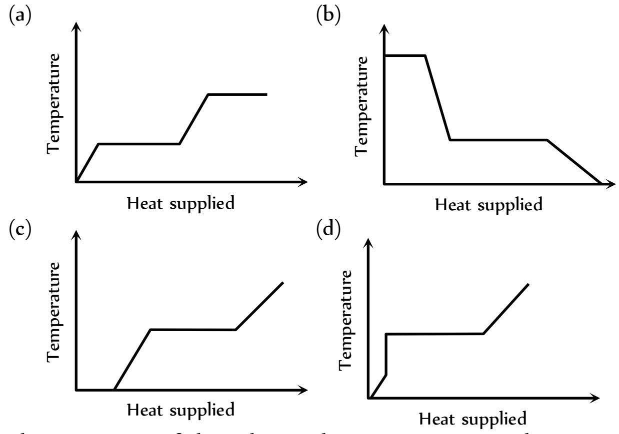
(a) T_2 is the melting point of the solid

(b) BC represents the change of state from solid to liquid

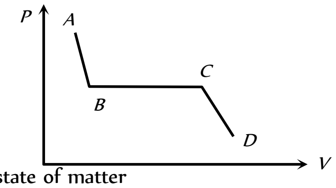
(c) $(H_2 - H_1)$ represents the latent heat of fusion of the substance

(d) $(H_3 - H_1)$ represents the latent heat of vaporization of the liquid

3. A block of ice at $-10°C$ is slowly heated and converted to steam at $100°C$. Which of the following curves represents the phenomenon qualitatively [IIT-JEE (Screening) 2000]



4. The portion AB of the indicator diagram representing the state of matter denotes



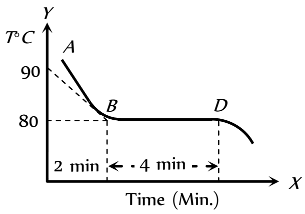
(a) The liquid state of matter

(b) Gaseous state of matter

(c) Change from liquid to gaseous state

(d) Change from gaseous state to liquid state

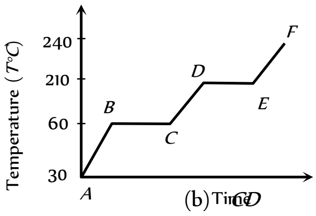
5. The figure given below shows the cooling curve of pure wax material after heating. It cools from A to B and solidifies along BD. If L and C are respective values of latent heat and the specific heat of the liquid wax, the ratio L/C is



(a) 40 (b) 80

(c) 100 (d) 20

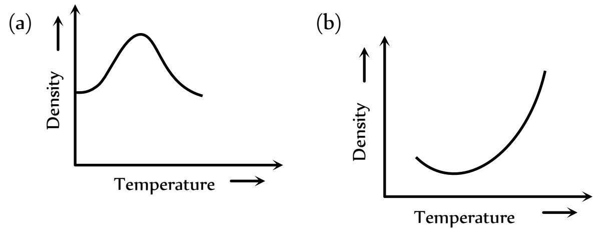
6. A solid substance is at $30°C$. To this substance heat energy is supplied at a constant rate. Then temperature versus time graph is as shown in the figure. The substance is in liquid state for the portion (of the graph) [RPET 1990, 94]

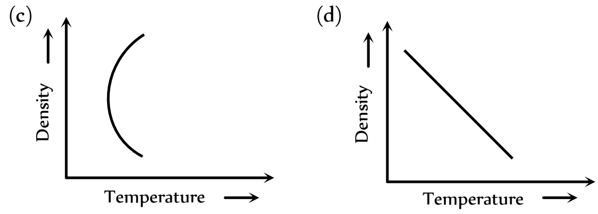


(a) BC (b) CD

(c) ED (d) EF

7. The variation of density of water with temperature is represented by the





8. If a graph is plotted taking the temperature in Fahrenheit along Y-axis and the corresponding temperature in Celsius along the X-axis, it will be a straight line [AIIMS 1997]

(a) Having a $+ve$ intercept on Y-axis

(b) Having a $+ve$ intercept on X-axis

(c) Passing through the origin

(d) Having $a - ve$ intercepts on both the axis

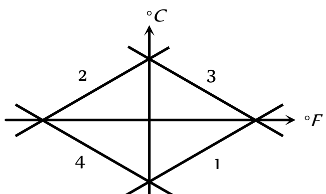
9. Which of the curves in figure represents the relation between Celsius and Fahrenheit temperatures

(a) 1

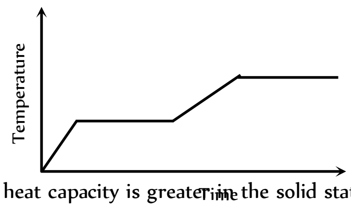
(b) 2

(c) 3

(d) 4



10. Heat is supplied to a certain homogenous sample of matter, at a uniform rate. Its temperature is plotted against time, as shown. Which of the following conclusions can be drawn



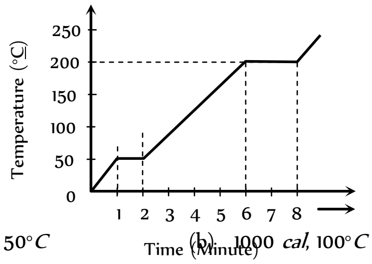
(a) Its specific heat capacity is greater in the solid state than in the liquid state

(b) Its specific heat capacity is greater in the liquid state than in the solid state

(c) Its latent heat of vaporization is greater than its latent heat of fusion

(d) Its latent heat of vaporization is smaller than its latent heat of fusion

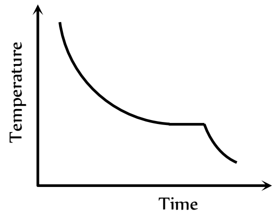
11. A student takes $50gm$ wax (specific heat = 0.6 $kcal/kg°C$) and heats it till it boils. The graph between temperature and time is as follows. Heat supplied to the wax per minute and boiling point are respectively [BHU 1994]



(a) 500 cal, $50°C$ (b) 1000 cal, $100°C$

(c) 1500 cal, $200°C$ (d) $200°C$

12. The graph signifies [JIPMER 1999]



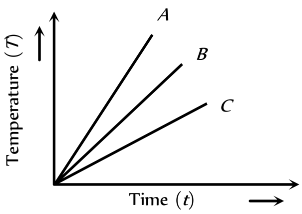
(a) Adiabatic expansion of a gas

(b) Isothermal expansion of a gas

(c) Change of state from liquid to solid

(d) Cooling of a heated solid

13. Which of the substances A, B or C has the highest specific heat ? The temperature *vs* time graph is shown



(a) A (b) B

(c) C (d) All have equal specific heat

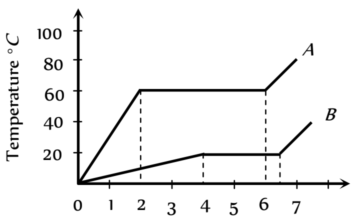
14. Two substances A and B of equal mass m are heated at uniform rate of 6 $cal\ s^{-1}$ under similar conditions. A graph between temperature and time is shown in figure. Ratio of heat absorbed H_A / H_B by them for complete fusion is

(a) $\frac{9}{4}$

(b) $\frac{4}{9}$

(c) $\frac{8}{5}$

(d) $\frac{5}{8}$



Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : The melting point of ice decreases with increase of pressure.

Reason : Ice contracts on melting. [AIIMS 2004]

2. Assertion : Fahrenheit is the smallest unit measuring temperature.

Reason : Fahrenheit was the first temperature scale used for measuring temperature.

[AIIMS 1999]

3. Assertion : Melting of solid causes no change in internal energy.

Reason : Latent heat is the heat required to melt a unit mass of solid. [AIIMS 1998]

4. Assertion : Specific heat capacity is the cause of formation of land and sea breeze.

Reason : The specific heat of water is more than land.

[AIIMS 1995]

5. Assertion : A brass disc is just fitted in a hole in a steel plate. The system must be cooled to loosen the disc from the hole.

Reason : The coefficient of linear expansion for brass is greater than the coefficient of linear expansion for steel.

6. Assertion : The coefficient of volume expansion has dimension K^{-1}.

Reason : The coefficient of volume expansion is defined as the change in volume per unit volume per unit change in temperature.

7. Assertion : The temperature at which Centigrade and Fahrenheit thermometers read the same is $-40°$.

Reason : There is no relation between Fahrenheit and Centigrade temperature.

8. Assertion : When a solid iron ball is heated, percentage increase is its volume is largest.

Reason : Coefficient of superficial expansion is twice that of linear expansion where as coefficient of volume expansion is three time of linear expansion.

9. Assertion : A beaker is completely filled with water at $4°C$. It will overflow, both when heated or cooled.

Reason : There is expansion of water below and above $4°C$.

10. Assertion : Latent heat of fusion of ice is 336000 J/kg.

Reason : Latent heat refers to change of state without any change in temperature

11. Assertion : Two bodies at different temperatures, if brought in thermal contact do not necessary settle to the mean temperature.

Reason : The two bodies may have different thermal capacities.

12. Assertion : Specific heat of a body is always greater than its thermal capacity.

Reason : Thermal capacity is the required for raising temperature of unit mass of the body through unit degree.

13. Assertion : Water kept in an open vessel will quickly evaporate on the surface of the moon.

Reason : The temperature at the surface of the moon is much higher than boiling point of the water.

14. Assertion : The molecules at $0°C$ ice and $0°C$ water will have same potential energy.

Reason : Potential energy depends only on temperature of the system.

Answers

Thermometry

1	d	2	b	3	a	4	c	5	b
6	d	7	c	8	a	9	b	10	b
11	c	12	c	13	c	14	c	15	c
16	d	17	b	18	c	19	c	20	c
21	c	22	a	23	d	24	a	25	c
26	a	27	b	28	a	29	c	30	c
31	a	32	d	33	a	34	d	35	a

Thermal Expansion

1	c	2	a	3	b	4	d	5	c
6	c	7	c	8	c	9	b	10	c
11	a	12	b	13	b	14	d	15	a
16	d	17	d	18	d	19	d	20	a
21	b	22	c	23	a	24	a	25	a
26	b	27	c	28	d	29	a	30	d
31	b	32	a	33	a	34	c		

Calorimetry

1	b	2	b	3	c	4	c	5	d
6	a	7	c	8	a	9	d	10	a
11	b	12	c	13	a	14	c	15	b
16	a	17	b	18	a	19	a	20	c
21	b	22	b	23	a	24	d	25	a
26	a	27	b	28	a	29	d	30	b
31	a	32	b	33	b	34	a	35	a
36	b	37	c	38	b	39	a	40	a
41	a	42	b	43	d	44	b	45	c
46	c	47	a	48	b	49	b	50	a
51	c	52	d	53	c	54	b	55	b
56	a	57	d	58	d	59	d	60	b
61	c	62	a	63	a	64	a	65	a
66	c	67	a	68	a	69	a	70	a
71	b	72	d	73	c	74	a	75	d
76	b	77	c	78	b	79	d	80	c
81	b	82	d						

Critical Thinking Questions

1	c	2	a	3	d	4	c	5	b
6	a	7	bd	8	d	9	c	10	d
11	b	12	b	13	b	14	a	15	b
16	a	17	a	18	c	19	c	20	b
21	a	22	c	23	d	24	c	25	c
26	b	27	a						

Graphical Questions

1	b	2	c	3	a	4	a	5	d
6	b	7	a	8	a	9	a	10	bc
11	c	12	c	13	c	14	c		

Assertion and Reason

1	a	2	c	3	e	4	a	5	a
6	a	7	c	8	a	9	a	10	b
11	a	12	d	13	a	14	d		

Answers and Solutions

Thermometry

1. (d) $T = 273.15 + t°C \Rightarrow 0 = 273.15 + t°C$
$\Rightarrow t = -273.15°C$

2. (b) $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{-183}{5} = \frac{F-32}{9} \Rightarrow F = -297°F$

3. (a) $\frac{F-32}{9} = \frac{K-273}{5} \Rightarrow \frac{F-32}{9} = \frac{95-273}{5} \Rightarrow F = -288°F$

4. (c) Temperature change in Celsius scale = Temperature change in Kelvin scale = 27 K

5. (b) Change in resistance $3.70 - 2.71 = 0.99\,\Omega$ corresponds to interval of temperature $90°C$.

So change in resistance $3.26 - 2.71 = 0.55\,\Omega$ Corresponds to change in temperature

$$= \frac{90}{0.99} \times 0.55 = 50°C$$

6. (d) – $200°C$ to $600°C$ can be measured by platinum resistance thermometer.

7. (c) Pyrometer can measure temperature from $800°C$ to $6000°C$. Hence temperature of sun is measured with pyrometer.

8. (a) $\overline{v^2} \propto T$

9. (b) Thermoelectric thermometer is based on Seeback Effect.

10. (b) Maximum density of water is at $4°C$

Also $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{4}{5} = \frac{F-32}{9} \Rightarrow F = 39.2°F$

11. (c) Production and measurement of temperature close to $0\,K$ is done in cryogenics

12. (c)

13. (c) At absolute zero (*i.e.* 0 K) v_{rms} becomes zero.

14. (c)

15. (c) We know that $P = P_0(1 + \gamma t)$ and $V = V_0(1 + \gamma t)$

and $\gamma = (1/273)/°C$ for $t = -273°C$, we have $P = 0$ and $V = 0$

Hence, at absolute zero, the volume and pressure of the gas become zero.

16. (d) Zero kelvin $= -273°C$ (absolute temperature). As no matter can attain this temperature, hence temperature can never be negative on Kelvin scale.

17. (b) $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{25}{5} = \frac{F-32}{9} \Rightarrow F = 77°F$.

18. (c) Thermoelectric thermometer is used for finding rapidly varying temperature.

19. (c) Due to evaporation cooling is caused which lowers the temperature of bulb wrapped in wet hanky.

20. (c) $\frac{F-32}{9} = \frac{K-273}{5} \Rightarrow \frac{x-32}{9} = \frac{x-273}{5} \Rightarrow x = 574.25$

21. (c) $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{C}{5} = \frac{(140-32)}{9} \Rightarrow C = 60°$

22. (a) $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{t}{5} = \frac{t-32}{9} \Rightarrow t = -40°$

23. (d) Standardisation of thermometers is done with gas thermometer.

24. (a) For gases γ is more.

25. (c) The boiling point of mercury is 400°C. Therefore, the mercury thermometer can be used to measure the temperature upto 360°C.

26. (a) $t = \frac{(P_t - P_0)}{(P_{100} - P_0)} \times 100°C = \frac{(60-50)}{(90-50)} \times 100 = 25°C$

27. (b) By filling nitrogen gas at high pressure, the boiling point of mercury is increased which extend the range upto 500°C.

28. (a) Pyrometer is used to measure very high temperature.

29. (c) $\frac{F-32}{9} = \frac{K-273}{5} \Rightarrow \frac{F-32}{9} = \frac{0-273}{5}$

$\Rightarrow F = -459.4°F \approx -460°F$

30. (c) Initial volume $V_1 = 47.5$ units

Temperature of ice cold water $T_1 = 0°C = 273\,K$

Final volume of $V_2 = 67$ units

Applying Charle's law, we have $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

(where temperature T_2 is the boiling point)

or $T_2 = \frac{V_2}{V_1} \times T_1 = \frac{67 \times 273}{47.5} = 385\,K = 112°C$

31. (a) Temperature on any scale can be converted into other scale by $\frac{x - LFP}{UFP - LFP}$ = Constant for all scales $\frac{x-20}{150-20} = \frac{60}{100} \Rightarrow$ $x = 98°C$

32. (d) $\frac{C}{5} = \frac{F-32}{9} \Rightarrow \frac{C}{5} = \frac{140-32}{9} \Rightarrow C = 60°C$

33. (a) Rapidly changing temperature is measured by thermocouple thermometers.

34. (d) Difference of $100°C$ = difference of $180°F$

$\therefore$ Difference of $30° = \frac{180}{100} \times 30 = 54°$

35. (a)

Thermal Expansion

1. (c) When a copper ball is heated, it's size increases. As Volume $\propto (\text{radius})^3$ and Area $\propto ((\text{radius})^2$, so percentage increase will be largest in it's volume. Density will decrease with rise in temperature.

2. (a) $\frac{h_1}{h_2} = \frac{\rho_1}{\rho_2} = \frac{(1+\gamma\theta_1)}{(1+\gamma\theta_2)}$ $\left[\because \rho = \frac{\rho_0}{(1+\gamma\theta)}\right]$

$\Rightarrow \frac{50}{60} = \frac{1+\gamma \times 50}{1+\gamma \times 100} \Rightarrow \gamma = 0.005/°C$

3. (b) $\gamma_r = \gamma_a + \gamma_v$; where γ_r = coefficient of real expansion, γ_a = coefficient of apparent expansion and γ_v = coefficient of expansion of vessel.

For copper $\gamma_r = C + 3\alpha_{Cu} = C + 3A$

For silver $\gamma_r = S + 3\alpha_{Ag}$

$\Rightarrow C + 3A = S + 3\alpha_{Ag} \Rightarrow \alpha_{Ag} = \frac{C - S + 3A}{3}$

4. (d) Fractional change in period

$\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta = \frac{1}{2} \times 2 \times 10^{-6} \times 10 = 10^{-5}$

% change $= \frac{\Delta T}{T} \times 100 = 10^{-5} \times 100 = 10^{-3}$ %

5. (c) $L = L_0(1+\alpha\Delta\theta) \Rightarrow \frac{L_1}{L_2} = \frac{1+\alpha(\Delta\theta)_1}{1+\alpha(\Delta\theta)_2}$

$\Rightarrow \frac{10}{L_2} = \frac{1 + 11 \times 10^{-6} \times 20}{1 + 11 \times 10^{-6} \times 19} \Rightarrow L_2 = 9.99989$

$\Rightarrow$ Length is shorten by

$10 - 9.99989 = 0.00011 = 11 \times 10^{-5}\,cm$

6. (c) Stress $= Y\alpha\Delta\theta$; hence it is independent of length.

7. (c) Solids, liquids and gases all expand on being heated as result density (= mass/volume) decreases.

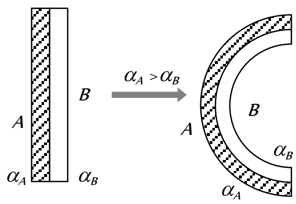
8. (c) As coefficient of cubical expansion of liquid equals coefficient of cubical expansion of vessel, the level of liquid will not change on heating.

9. (b) Loss in time per second $\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta = \frac{1}{2}\alpha(t-0)$

$\Rightarrow$ loss in time per day

$\Delta t = \left(\frac{1}{2}\alpha t\right)t = \frac{1}{2}\alpha t \times (24 \times 60 \times 60) = \frac{1}{2}\alpha t \times 86400$

10. (c) A bimetallic strip on being heated bends in the form of an arc with more expandable metal (A) outside (as shown) correct.



11. (a) When the ball is heated, expansion of ball and cavity both occurs, hence volume of cavity increases.

12. (b) In summer alcohol expands, density decreases, so 1 litre of alcohol will weigh less in summer than in winter.

13. (b) Similar to previous question, benzene contracts in winter. So 5 litre of benzene will weigh more in winter than in summer.

14. (d) Water has maximum density at $4°C$.

15. (a) Since coefficient of expansion of steel is greater than that of bronze. Hence with small increase in it's temperature the hole expand sufficiently.

16. (d) $A \propto L^2 \Rightarrow \frac{\Delta A}{A} = 2 \cdot \frac{\Delta L}{L} \Rightarrow \frac{\Delta A}{A} = 2 \times 2 = 4\%$.

17. (d) $\frac{V_1}{V_2} = \frac{1+\gamma t_1}{1+\gamma t_2} \Rightarrow \frac{100}{125} = \frac{1+\gamma \times 20}{1+\gamma \times 100} \Rightarrow \gamma = 0.0033/°C$

18. (d) $\alpha = \frac{\beta}{2} = \frac{2 \times 10^{-5}}{2} = 10^{-5}\,/°C$

19. (d) Coefficient of volume expansion

$\gamma = \frac{\Delta\rho}{\rho.\Delta T} = \frac{(\rho_1 - \rho_2)}{\rho.(\Delta\theta)} = \frac{(10-9.7)}{10 \times (100-0)} = 3 \times 10^{-4}$

Hence, coefficient of linear expansion

$\alpha = \frac{\gamma}{3} = 10^{-4}\,/°C$

20. (a) $\rho = \rho_0(1 - \gamma.\Delta\theta) = 13.6[1 - 0.18 \times 10^{-3}(473 - 273)]$

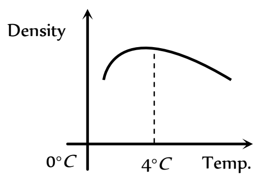
$= 13.6[1 - 0.036] = 13.11\,gm/cc$.

21. (b) As we know $\gamma_{\text{real}} = \gamma_{\text{app.}} + \gamma_{\text{vessel}}$

$\Rightarrow \gamma_{\text{app.}} = \gamma_{\text{glycerine}} - \gamma_{\text{glass}}$

$= 0.000597 - 0.000027 = 0.00057/°C$

22. (c) Water has maximum density at $4°C$, so if the water is heated above $4°C$ or cooled below $4°C$ density decreases *i.e.* volume increases. In other words, it expands so it overflows in both the cases.



23. (a)

$$\gamma = \frac{\Delta V}{V.\Delta T} = \frac{0.24}{100 \times 40} = 6 \times 10^{-5} / °C$$

$$\Rightarrow \alpha = \frac{\gamma}{3} = 2 \times 10^{-5} / °C$$

24. (a) As $\alpha = \frac{\beta}{2} = \frac{\gamma}{3} \Rightarrow \alpha : \beta : \gamma = 1 : 2 : 3$

25. (a) $\gamma_{app.} = \frac{\text{Mass expelled}}{\text{Mass remained } \times \Delta T}$

$$= \frac{x/100}{x \times 80} = \frac{1}{8000} = 1.25 \times 10^{-4} / °C$$

26. (b) In anomalous expansion, water contracts on heating and expands on cooling in the range 0°*C* to 4°*C*. Therefore water pipes sometimes burst, in cold countries.

27. (c) On heating the system; *x, r, d* all increases, since the expansion of isotropic solids is similar to true photographic enlargement.

28. (d) $\alpha = \frac{\Delta L}{L_0 \times \Delta\theta} = \frac{0.01}{5 \times 100} = 2 \times 10^{-5} / °C$

29. (a) $\alpha = \frac{\Delta L}{L_0(\Delta\theta)} = \frac{0.19}{100(100-0)} = 1.9 \times 10^{-5} / °C$

Now $\gamma = 3\alpha = 3 \times 1.9 \times 10^{-5}/°C = 5.7 \times 10^{-5}/°C$

30. (d) Since, the coefficient of linear expansion of brass is greater than that of steel. On cooling, the brass contracts more, so, it get loosened.

31. (b) Increase in length $\Delta L = L_0 \alpha \Delta\theta$

$= 10 \times 10 \times 10^{-6} \times (100 - 0) = 10^{-2}\ m = 1\ cm$

32. (a) $\alpha = \frac{\Delta L}{L_0 \Delta\theta} = \frac{(1-0.9997)}{0.9997 \times 12 \times 10^{-6}} = 25°C$

33. (c) The densest layer of water will be at bottom. The density of water is maximum at 4°*C*. So the temperature of bottom of lake will be 4°*C*.

34. (c) Given $\Delta l_1 = \Delta l_2$ or $l_1 \alpha_a t = l_2 \alpha_s t$

$\therefore \frac{l_1}{l_2} = \frac{\alpha_s}{\alpha_a}$ or $\frac{l_1}{l_1 + l_2} = \frac{\alpha_s}{\alpha_a + \alpha_s}$.

Calorimetry

1. (b) In vapor to liquid phase transition, heat liberates.

2. (b) Pressure inside the mines is greater than that of normal. Pressure. Also we know that boiling point increases with increase in pressure.

3. (c) $Q = m.c.\Delta\theta \Rightarrow c = \frac{Q}{m.\Delta\theta}$; when $\Delta\theta = 0 \Rightarrow c = \infty$

4. (c) Mass and volume of the gas will remain same, so density will also remain same.

5. (d)

6. (a) The latent heat of vaporization is always greater than latent heat of fusion because in liquid to vapour phase change there is a large increase in volume. Hence more heat is required as compared to solid to liquid phase change.

7. (c) When state is not changing $\Delta Q = mc\Delta\theta$.

8. (a) Heat taken by ice to melt at 0°*C* is

$$Q_1 = mL = 540 \times 80 = 43200\,cal$$

Heat given by water to cool upto 0°*C* is

$$Q_2 = ms\Delta\theta = 540 \times 1 \times (80 - 0) = 43200\,cal$$

Hence heat given by water is just sufficient to melt the whole ice and final temperature of mixture is 0°*C*.

Short trick : For these type of frequently asked questions you can remember the following formula

$$\theta_{mix} = \frac{m_W \theta_W - \frac{m_i L_i}{c_W}}{m_i + m_W}$$ (See theory for more details)

If $m_W = m_i$ then $\theta_{mix} = \frac{\theta_W - \frac{L_i}{c_W}}{2} = \frac{80 - \frac{80}{1}}{2} = 0°C$

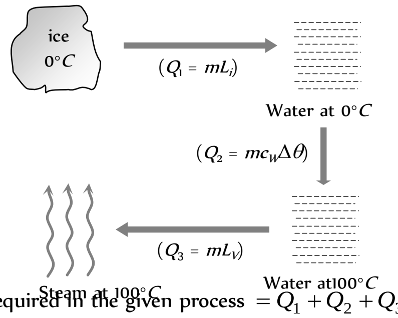
9. (d) Due to large specific heat of water, it releases large heat with very small temperature change.

10. (a) $Q = m.c.\Delta\theta = 5 \times (1000 \times 4.2) \times (100 - 20)$

$$= 1680 \times 10^3\ J = 1680\,kJ$$

11. (b) Melting point of ice decreases with increase in pressure (as ice expands on solidification).

12. (c) Conversion of ice (0°*C*) into steam (100°*C*) is as follows



Heat required in the given process $= Q_1 + Q_2 + Q_3$

$$= 1 \times 80 + 1 \times 1 \times (100 - 0) + 1 \times 536 = 716\,cal$$

13. (a) If *m gm* ice melts then

Heat lost = Heat gain

$$80 \times 1 \times (30 - 0) = m \times 80 \Rightarrow m = 30\,gm$$

14. (c) At boiling point saturation vapour pressure becomes equal to atmospheric pressure. Therefore, at 100°*C* for water. S.V.P. = 760 *mm* of *Hg* (atm pressure).

15. (b) Thermal capacity = Mass × Specific heat

Due to same material both spheres will have same specific heat.

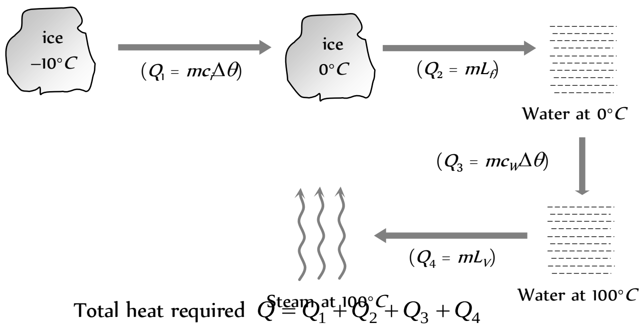
Also mass = Volume (*V*) × Density (ρ)

∴ Ratio of thermal capacity

$$= \frac{m_1}{m_2} = \frac{V_1 \rho}{V_2 \rho} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{2}\right)^3 = 1 : 8$$

16. (a) Ice (–10°*C*) converts into steam as follows

(c_i = Specific heat of ice, c_w = Specific heat of water)



Total heat required $Q = Q_1 + Q_2 + Q_3 + Q_4$

$$\Rightarrow Q = 1 \times 0.5(10) + 1 \times 80 + 1 \times 1 \times (100 - 0) + 1 \times 540$$

$$= 725\,cal$$

Hence work done $W = JQ = 4.2 \times 725 = 3045\ J$

17. (b) When water is cooled at 0°C to form ice then 80 *calorie/gm* (latent heat) energy is released. Because potential energy of the molecules decreases. Mass will remain constant in the process of freezing of water.

18. (a) Steam at 100°C contains extra 540 *calorie/gm* energy as compare to water at 100°C. So it's more dangerous to burn with steam then water.

19. (a) Same amount of heat is supplied to copper and water so $m_c c_c \Delta\theta_c = m_W c_W \Delta\theta_W$

$$\Rightarrow \Delta\theta_W = \frac{m_c c_c (\Delta\theta)_c}{m_W c_W} = \frac{50 \times 10^{-3} \times 420 \times 10}{10 \times 10^{-3} \times 4200} = 5°C$$

20. (c) Temperature of mixture $\theta_{mix} = \frac{\theta_A c_A + \theta_B c_B}{c_A + c_B}$

$$\Rightarrow 28 = \frac{32 \times c_A + 24 \times c_B}{c_A + c_B}$$

$$\Rightarrow 28\, c_A + 28 c_B = 32\, c_A + 24\, c_B \Rightarrow \frac{c_A}{c_B} = \frac{1}{1}$$

21. (b) Heat lost by hot water = Heat gained by cold water in beaker + Heat absorbed by beaker

$\Rightarrow 440(92 - \theta) = 200 \times (\theta - 20) + 20 \times (\theta - 20)$

$\Rightarrow \theta = 68°C$

22. (b) $Q = m.c.\Delta\theta$; if $\Delta\theta = 1\,K$ then $Q = mc =$ Thermal capacity.

23. (a) Latent heat is independent of configuration. Ordered energy spent in stretching the spring will not contribute to heat which is disordered kinetic energy of molecules of substance.

24. (d) Temperature of mixture

$$\theta_{mix} = \frac{m_1 c_1 \theta_1 + m_2 c_2 \theta_2}{m_1 c_1 + m_2 c_2} = \frac{m \times c \times 2T + \frac{m}{2}(2c)T}{m.c + \frac{m}{2}(2c)} = \frac{3}{2}T$$

25. (a)

26. (a) $\theta_{mix} = \dfrac{\theta_W - \frac{L_i}{c_W}}{2} = \dfrac{100 - \frac{80}{1}}{2} = 10°C$

27. (b) When pressure decreases, boiling point also decreases.

28. (a) Boiling occurs when the vapour pressure of liquid becomes equal to the atmospheric pressure. At the surface of moon, atmospheric pressure is zero, hence boiling point decreases and water begins to boil at 30°C.

29. (d) Thermal capacity $= mc = 40 \times 0.2 = 8\ cal/°C$.

30. (b) $Q = m.c.\Delta\theta \Rightarrow c = \frac{Q}{m.\Delta\theta}$

In temperature measurement scale $\Delta\theta°F > \Delta\theta°C$ so $(c)_{°F} < (c)_{°C}$.

31. (a) Increasing pressure lowers melting point of ice.

32. (b) Work done changes into heat energy, when the temperature of palm becomes above the atmosphere so it starts losing heat to the surroundings.

33. (b) Firstly the temperature of bullet rises up to melting point, then it melts. Hence according to $W = JQ$.

$$\Rightarrow \frac{1}{2}mv^2 = J.[m.c.\Delta\theta + mL] = J[m\,S\,(475 - 25) + mL]$$

$$\Rightarrow mS(475 - 25) + mL = \frac{mv^2}{2J}$$

34. (a) As $W = JQ \Rightarrow \frac{1}{2}(mgh) = J \times mc\Delta\theta \Rightarrow \Delta\theta = \frac{gh}{2Jc}$

$$\Delta\theta = \frac{9.8 \times 84}{2 \times 4.2 \times 1000} = 0.098°C$$

$$(\because c_{water} = 1000 \frac{cal}{kg \times °C})$$

Short trick : Remember the value of $\frac{g}{Jc_W} = 0.0023$, here

$$\Delta\theta = \frac{1}{2} \times (0.0023)h = \frac{1}{2} \times 0.0023 \times 84 = 0.098°C$$

35. (a) $W = JQ \Rightarrow mgh = J \times Q$

$$\Rightarrow Q = \frac{mgh}{J} = \frac{5 \times 9.8 \times 30}{4.2} = 350\ cal$$

36. (b) $W = JQ = 4.18 \times 400 = 1672\ joule$

37. (c) Energy supplied $= 0.93 \times 3600\ joules = 3348\ joules$

Heat required to melt 10 *gms* of ice

$= 10 \times 80 \times 4.18 = 3344\ joules$

Hence block of ice just melts.

38. (b) Suppose person climbs upto height *h*, then by using

$W = JQ \Rightarrow mgh = JQ$

$$\Rightarrow 60 \times 9.8 \times h = 4.2 \times \left(10^5 \times \frac{28}{100}\right) \Rightarrow h = 200\,m$$

39. (a) When water falls from a height, loss of potential energy causes rise in temperature.

40. (a) $W = JQ \Rightarrow mg\,h = J(m.c.\Delta\theta)$

$$\Rightarrow \Delta\theta = \frac{g\,h}{Jc} = 0.0023\,h = 0.0023 \times 84 = 0.196°C$$

41. (a) Suppose m' *kg* ice melts out of m *kg* then by using

$W = JQ \Rightarrow mgh = J(m'L)$. Hence fraction of ice melts

$$= \frac{m'}{m} = \frac{gh}{JL} = \frac{9.8 \times 1000}{4.18 \times 80} = \frac{1}{33}$$

42. (b) $J = \frac{W}{Q} = \frac{Joule}{cal}$

43. (d) $W = JQ \Rightarrow (2m)gh = J \times m'c\Delta\theta$

$\Rightarrow 2 \times 5 \times 10 \times 10 = 4.2(2 \times 1000 \times \Delta\theta)$

$\Rightarrow \Delta\theta = 0.1190°C = 0.12°C$

44. (b) $W = JQ \Rightarrow \frac{1}{2}\left(\frac{1}{2}mV^2\right) = J \times mS\Delta\theta \Rightarrow \Delta\theta = \frac{V^2}{4\,JS}$

45. (c) 'J' is a conversion

46. (c) $\Delta\theta = 0.0023h = 0.0023 \times 210 = 0.483°C \approx 0.49°C$.

47. (a) According to energy conservation, change in kinetic energy appears in the form of heat (thermal energy).

$\Rightarrow$ *i.e.* Thermal energy $= \frac{1}{2}m(v_1^2 - v_2^2)$ $\left[\because \underset{(\text{Joule})}{W} = \underset{(\text{Joule})}{Q}\right]$

$= \frac{1}{2}(100 \times 10^{-3})(10^2 - 5^2) = 3.75\ J$

48. (b) Work done to raise the temperature of 100 gm water through $10°C$ is

$W = JQ = 4.2 \times (100 \times 10^{-3} \times 1000 \times 10) = 4200\ J$

49. (b) Among all the option, latent heat of steam is highest.

50. (a) $\Delta\theta = 0.0023h = 0.0023 \times 100 = 0.23°C$

51. (c) Since specific heat of lead is given in *Joules*, hence use $W = Q$ instead of $W = JQ$.

$\Rightarrow \frac{1}{2} \times \left(\frac{1}{2}mv^2\right) = m.c.\Delta\theta \Rightarrow \Delta\theta = \frac{v^2}{4c} = \frac{(300)^2}{4 \times 150} = 150°C$.

52. (d) At boiling point, vapour pressure becomes equal to the external pressure.

53. (c) When pressure increases boiling point also increases.

54. (b) Calorimeters are made by conducting materials.

55. (b) Triple point of water is 273.16 K.

56. (a)

57. (d) $W = JQ \Rightarrow W = 4.2 \times 200 = 840\ J$.

58. (d) Temperature of mixture $\theta = \frac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2\theta_2}$

$\Rightarrow 32 = \frac{m_1 \times 0.2 \times 40 + 100 \times 0.5 \times 20}{m_1 \times 0.2 + 100 \times 0.5} \Rightarrow m_1 = 375\ gm$

59. (d) Suppose $m\ gm$ ice melted, then heat required for its melting $= mL = m \times 80\ cal$

Heat available with steam for being condensed and then brought to $0°C$

$= 1 \times 540 + 1 \times 1 \times (100 - 0) = 640\ cal$

$\Rightarrow$ Heat lost = Heat taken

$\Rightarrow 640 = m \times 80 \Rightarrow m = 8\ gm$

Short trick: You can remember that amount of steam (m') at $100°C$ required to melt $m\ gm$ ice at $0°C$ is $m' = \frac{m}{8}$.

Here, $m = 8 \times m' = 8 \times 1 = 8\ gm$

60. (b) For water and ice mixing $\theta_{\text{mix}} = \frac{m_W\theta_W - \frac{m_iL_i}{c_W}}{m_i + m_W}$

$= \frac{20 \times 40 - \frac{5 \times 80}{1}}{5 + 20} = 16°C$

61. (c) $\theta_{\text{mix}} = \frac{m_W\theta_W - \frac{m_iL_i}{c_W}}{m_i + m_W}$

$\because m_i = m_W \Rightarrow \theta_{mix} = \frac{\theta_W - \frac{L_i}{c_W}}{2} = \frac{80 - \frac{336}{4.2}}{2} = 0°C$

62. (a) When the relative humidity is low (approx. 25%), the evaporation from our body is faster. Thus we feel colder.

63. (a) $c = \frac{Q}{m.\Delta\theta} \to \frac{J}{kg \times °C}$

64. (a) $\theta_{\text{mix}} = \frac{\theta_W - \frac{L_i}{c_W}}{2} = \frac{80 - \frac{80}{1}}{2} = 0$

65. (a) Freezing point of water decreases when pressure increases, because water expands on solidification while "except water" for other liquid freezing point increases with increase in pressure.

Since the liquid in question is water. Hence, it expands on freezing.

66. (c) Partial pressure of water vapour $P_W = 0.012 \times 10^5\ Pa$,

Vapour pressure of water $P_V = 0.016 \times 10^5\ Pa$.

The relative humidity at a given temperature is given by

$= \frac{\text{Partial pressure of water vapour}}{\text{Vapour pressure of water}}$

$= \frac{0.012 \times 10^5}{0.016 \times 10^5} = 0.75 = 75\%$

67. (a) $W = JQ \Rightarrow \frac{1}{2}\left(\frac{1}{2}Mv^2\right) = J(m.c.\Delta\theta)$

$\Rightarrow \frac{1}{4} \times 1 \times (50)^2 = 4.2[200 \times 0.105 \times \Delta\theta] \Rightarrow \Delta\theta = 7.1°C$

68. (a) $536\frac{cal}{gm} = \frac{536 \times 4.2\ J}{10^{-3}\ kg} = 2.25 \times 10^6\ J/kg$

69. (a) Water has maximum specific heat.

70. (a) $\theta_{\text{mix}} = \frac{\theta_W - \frac{L_i}{C_W}}{2} = \frac{100 - \frac{80}{1}}{2} = 10°C$

71. (b) Suppose $m\ kg$ of ice melts then by using $\underset{(\text{Joules})}{W} = \underset{(\text{Joules})}{H}$

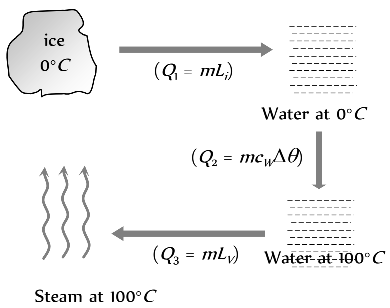
$\Rightarrow Mgh = mL \Rightarrow 3.5 \times 10 \times 2000 = m \times 3.5 \times 10^5$

$\Rightarrow m = 0.2\ kg = 200\ gm$

72. (d) $\theta_{\text{mix}} = \frac{m_W\theta_W - \frac{m_iL_i}{S_W}}{m_i + m_W} = \frac{300 \times 25 - \frac{100 \times 80}{1}}{100 + 300} = -1.25°C$

Which is not possible. Hence $\theta_{mix} = 0°C$

73. (c) Ice ($0°C$) converts into steam ($100°C$) in following three steps.



Total heat required $Q = Q_1 + Q_2 + Q_3$

$= 5 \times 80 + 5 \times 1 \times (100 - 0) + 5 \times 540 = 3600\, cal$

74. (a) Let L be the latent heat and using principle of calorimetry.

$2L + 2\,(100 - 54.3) = 40 \times (54.3 - 25.3)$

$\Rightarrow L = 540.3$ *cal/gm.*

75. (d) $\theta_{\text{mix}} = \dfrac{m_W\theta_W - \dfrac{m_i L_i}{c_W}}{m_i + m_W} = \dfrac{100 \times 50 - 10 \times \dfrac{80}{1}}{10 + 100} \approx 38.2°C$

76. (b) Let the final temperature be $T°C$.

Total heat supplied by the three liquids in coming down to $0°C$ =

$m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$ ..... (i)

Total heat used by three liquids in raising temperature from $0°C$ to $T°C$

$= m_1c_1T + m_2c_2T + m_3c_3T$ .....(ii)

By equating (i) and (ii) we get

$(m_1c_1 + m_2c_2 + m_3c_3)T$

$= m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3$

$\Rightarrow T = \dfrac{m_1c_1T_1 + m_2c_2T_2 + m_3c_3T_3}{m_1c_1 + m_2c_2 + m_3c_3}$.

77. (c) At triple point all the phases co-exist

78. (b) $c = \dfrac{Q}{m.\Delta\theta}$; as $\Delta\theta = 0$, hence c becomes ∞.

79. (d) Let final temperature of water be θ

Heat taken = Heat given

$110 \times 1\,(\theta - 10) + 10\,(\theta - 10) = 220 \times 1\,(70 - \theta)$

$\Rightarrow \theta = 48.8°C \approx 50°C$.

80. (c) We know that thermal capacity of a body expressed in calories is equal to water equivalent of the body expressed in grams.

81. (b) $\theta_{mix} = \dfrac{m_1c_1\theta_1 + m_2c_2\theta_2}{m_1c_1 + m_2c_2} = \dfrac{m\,s\,(2t) + 1.5\,(m\,s) \times \dfrac{t}{3}}{m\,s + 1.5\,(m\,s)} = t$

82. (d) We know that when solid carbondioxide is heated, it becomes vapour directly without passing through its liquid phase. Therefore it is called dry ice.

Critical Thinking Questions

1. (c) Due to volume expansion of both mercury and flask, the change in volume of mercury relative to flask is given by $\Delta V = V_0[\gamma_L - \gamma_g]\Delta\theta = V[\gamma_m - 3\alpha_g]\Delta\theta$

$= 50\,[180 \times 10^{-6} - 3 \times 9 \times 10^{-6}](38 - 18) = 0.153\, cc$

2. (a) $\gamma_{real} = \gamma_{app.} + \gamma_{vessel}$

So $(\gamma_{app.} + \gamma_{vessel})_{glass} = (\gamma_{app.} + \gamma_{vessel})_{steel}$

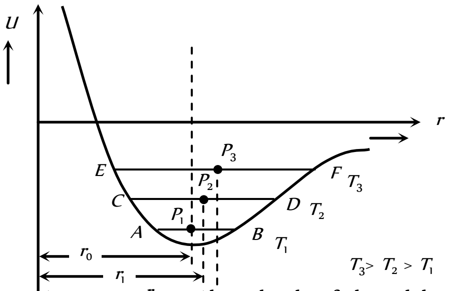
$\Rightarrow 153 \times 10^{-6} + (\gamma_{vessel})_{glass} = (144 \times 10^{-6} + \gamma_{vessel})_{steel}$

Further, $(\gamma_{vessel})_{steel} = 3\alpha = 3 \times (12 \times 10^{-6}) = 36 \times 10^{-6}/°C$

$\Rightarrow 153 \times 10^{-6} + (\gamma_{vessel})_{glass} = 144 \times 10^{-6} + 36 \times 10^{-6}$

$\Rightarrow (\gamma_{vessel})_{glass} = 3\alpha = 27 \times 10^{-6}/°C \Rightarrow \alpha = 9 \times 10^{-6}/°C$

3. (d) The expansion of solids can be well understood by potential energy curve for two adjacent atoms in a crystalline solid as a function of their internuclear separation (r).



At ordinary temperature : Each molecule of the solid vibrate about it' s equilibrium position P_1 between A and B (r_0 is the equilibrium distance of it from some other molecule)

At high temperature : Amplitude of vibration increase ($C \leftrightarrow D$ and $E \leftrightarrow F$). Due to asymmetry of the curve, the equilibrium positions (P_2 and P_3) of molecule displaced. Hence it's distance from other molecule increases ($r_2 > r_1 > r_0$).

Thus, on raising the temperature, the average equilibrium distance between the molecules increases and the solid as a whole expands.

4. (c) Initial diameter of tyre = (1000 – 6) *mm* = 994 *mm*, so initial radius of tyre $R = \dfrac{994}{2} = 497\, mm$

and change in diameter $\Delta D = 6$ *mm* so $\Delta R = \dfrac{6}{2} = 3\, mm$

After increasing temperature by $\Delta\theta$ tyre will fit onto wheel

Increment in the length (circumference) of the iron tyre

$\Delta L = L \times \alpha \times \Delta\theta = L \times \dfrac{\gamma}{3} \times \Delta\theta$ [As $\alpha = \dfrac{\gamma}{3}$]

$2\pi\,\Delta R = 2\pi R\left(\dfrac{\gamma}{3}\right)\Delta\theta \Rightarrow \Delta\theta = \dfrac{3}{\gamma}\dfrac{\Delta R}{R} = \dfrac{3 \times 3}{3.6 \times 10^{-5} \times 497}$

$\Rightarrow \Delta\theta = 500^o C$

5. (b) Due to volume expansion of both liquid and vessel, the change in volume of liquid relative to container is given by $\Delta V = V_0[\gamma_L - \gamma_g]\Delta\theta$

Given $V_0 = 1000$ *cc*, $\alpha_g = 0.1 \times 10^{-4}/°C$

$\therefore \gamma_g = 3\alpha_g = 3 \times 0.1 \times 10^{-4}\,/°C = 0.3 \times 10^{-4}\,/°C$

$\therefore \Delta V = 1000\,[1.82 \times 10^{-4} - 0.3 \times 10^{-4}] \times 100 = 15.2$ *cc*

6. (a) With temperature rise (same $25°C$ for both), steel scale and copper wire both expand. Hence length of copper wire *w.r.t.* steel scale or apparent length of copper wire after rise in temperature

$L_{app} = L'_{cu} - L'_{steel} = [L_0(1 + \alpha_{Cu}\Delta\theta) - L_0(1 + \alpha_s\Delta\theta)$

$\Rightarrow L_{app} = L_0(\alpha_{Cu} - \alpha_s)\Delta\theta$

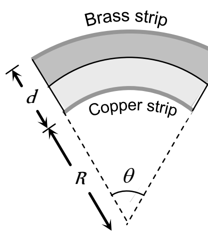
$= 80(17 \times 10^{-6} - 11 \times 10^{-6}) \times 20 = 80.0096$ *cm*

7. (b, d) Let L_0 be the initial length of each strip before heating.

Length after heating will be

$L_B = L_0(1 + \alpha_B\Delta T) = (R + d)\theta$

$L_C = L_0(1 + \alpha_C\Delta T) = R\theta$



$$\Rightarrow \frac{R+d}{R} = \frac{1+\alpha_B \Delta T}{1+\alpha_C \Delta T}$$

$$\Rightarrow 1+\frac{d}{R} = 1+(\alpha_B-\alpha_C)\Delta T$$

$$\Rightarrow R = \frac{d}{(\alpha_B-\alpha_C)\Delta T} \Rightarrow R \propto \frac{1}{\Delta T} \text{ and } R \propto \frac{1}{(\alpha_B-\alpha_C)}$$

8. (d) Thermostat is used in electric apparatus like refrigerator, Iron *etc* for automatic cut off. Therefore for metallic strips to bend on heating their coefficient of linear expansion should be different.

9. (c) As the coefficient of cubical expansion of metal is less as compared to the coefficient of cubical expansion of liquid, we may neglect the expansion of metal ball. So when the ball is immersed in alcohol at 0°C, it displaces some volume V of alcohol at 0°C and has weight W_1.

$\therefore \quad W_1 = W_0 - V\rho_0 g$

where W_0 = weight of ball in air

Similarly, $W_2 = W_0 - V\rho_{50} g$

where ρ_0 = density of alcohol at 0°C

and ρ_{50} = density of alcohol at 50°C

As $\rho_{50} < \rho_0$, $\Rightarrow W_2 > W_1$ or $W_1 < W_2$

10. (d) $V = V_0(1 + \gamma\,\Delta\theta) \Rightarrow$ Change in volume

$$V - V_0 = \Delta V = A.\Delta l = V_0 \gamma \Delta\theta$$

$$\Rightarrow \Delta l = \frac{V_0.\Delta\theta}{A} = \frac{10^{-6}\times 18\times 10^{-5}\times(100-0)}{0.004\times 10^{-4}}$$

$= 45 \times 10^{-3}\ m = 4.5\ cm$

11. (b) Loss of weight at 27°C is

$= 46 - 30 = 16 = V_1 \times 1.24\ \rho_l \times g \quad$ ...(i)

Loss of weight at 42°C is

$= 46 - 30.5 = 15.5 = V_2 \times 1.2\ \rho_l \times g \quad$ ...(ii)

Now dividing (i) by (ii), we get $\frac{16}{15.5} = \frac{V_1}{V_2}\times\frac{1.24}{1.2}$

But $\frac{V_2}{V_1} = 1 + 3\alpha\,(t_2 - t_1) = \frac{15.5\times 1.24}{16\times 1.2} = 1.001042$

$\Rightarrow 3\alpha\,(42° - 27°) = 0.001042 \Rightarrow \alpha = 2.316 \times 10^{-5}/°C.$

12. (b) Substances are classified into two categories

(i) water like substances which expand on solidification.

(ii) CO_2 like (Wax, Ghee *etc.*) which contract on solidification.

Their behaviour regarding solidification is opposite.

Melting point of ice decreases with rise of temp but that of wax etc increases with increase in temperature. Similarly ice starts forming from top downwards whereas wax starts its formation from bottom.

13. (b) Heat lost in t sec = mL or heat lost per sec = $\frac{mL}{t}$. This must be the heat supplied for keeping the substance in molten state per sec.

$\therefore \quad \frac{mL}{t} = P$ or $L = \frac{Pt}{m}$

14. (a) Heat is lost by steam in two stages (i) for change of state from steam at 100°C to water at 100°C is m × 540 (ii) to change water at 100°C to water at 80°C is m × 1 × (100 – 80), where m is the mass of steam condensed.

Total heat lost by steam is m × 540 + m × 20 = 560 m (*cals*)

Heat gained by calorimeter and its contents is

= (1.1 + 0.02) × (80 – 15) = 1.12 × 65 *cals.*

using Principle of calorimetery, Heat gained = heat lost

$\therefore$ 560 m = 1.12 × 65, m = 0.130 *gm*

15. (b) Initially ice will absorb heat to raise it's temperature to 0°C then it's melting takes place

If m_i = Initial mass of ice, m_i' = Mass of ice that melts and m_W = Initial mass of water

By Law of mixture Heat gained by ice = Heat lost by water $\Rightarrow$ $m_i \times c\times(20) + m_i'\times L = m_W c_W[20]$

$\Rightarrow 2\times 0.5(20) + m_i'\times 80 = 5\times 1\times 20 \Rightarrow m_i' = 1kg$

So final mass of water = Initial mass of water + Mass of ice that melts = 5 + 1= 6 *kg.*

16. (a) Heat gained by the water = (Heat supplied by the coil) – (Heat dissipated to environment)

$\Rightarrow mc\ \Delta\theta = P_{Coil}\ t - P_{Loss}\ t$

$\Rightarrow 2\times 4.2\times 10^3\times(77-27) = 1000\,t - 160\,t$

$\Rightarrow t = \frac{4.2\times 10^5}{840} = 500\ sec = 8\ min\ 20\ sec$

17. (a) If mass of the bullet is *m gm,*

then total heat required for bullet to just melt down

$Q_1 = m\ c\ \Delta\theta + m\ L = m \times 0.03\ (327 - 27) + m \times 6$

$= 15\ m\ cal = (15m\times 4.2)J$

Now when bullet is stopped by the obstacle, the loss in its mechanical energy $= \frac{1}{2}(m\times 10^{-3})v^2 J$

(As $m\ gm = m\times 10^{-3} kg$)

As 25% of this energy is absorbed by the obstacle,

The energy absorbed by the bullet

$$Q_2 = \frac{75}{100}\times\frac{1}{2}mv^2\times 10^{-3} = \frac{3}{8}mv^2\times 10^{-3}\ J$$

Now the bullet will melt if $Q_2 \geq Q_1$

i.e. $\frac{3}{8}mv^2\times 10^{-3} \geq 15m\times 4.2 \Rightarrow v_{min} = 410\ m/s$

18. (c) Energy = $\frac{1}{2}mv^2 = mc\,\Delta\theta; \Rightarrow \Delta\theta \propto v^2$

Temperature does not depend upon the mass of the balls.

19. (c) Heat gain = heat lost

$C_A(16 - 12) = C_B\ (19 - 16) \Rightarrow \frac{C_A}{C_B} = \frac{3}{4}$

and $C_B(23 - 19) = C_C\ (28 - 23) \Rightarrow \frac{C_B}{C_C} = \frac{5}{4}$

$\Rightarrow \frac{C_A}{C_C} = \frac{15}{16}$ ...(i)

If θ is the temperature when A and C are mixed then,

$C_A(\theta - 12) = C_C(28 - \theta) \Rightarrow \frac{C_A}{C_C} = \frac{28-\theta}{\theta - 12}$ ...(ii)

On solving equation (i) and (ii) $\theta = 20.2°C$.

20. (b) Suppose m kg steam required per hour

Heat released by steam in following three steps

(i) When 150°C steam $\xrightarrow[Q_1]{} 100°C$ steam

$Q_1 = mc_{steam}\Delta\theta = m \times 1\ (150 - 100) = 50\ m\ cal$

(ii) When 150°C steam $\xrightarrow[Q_2]{} 100°C$ water

$Q_2 = mL_v = m \times 540 = 540\ m\ cal$

(iii) When 100°C water $\xrightarrow[Q_2]{} 90°C$ water

$Q_3 = mc_w\Delta\theta = m \times 1 \times (100 - 90) = 10\ m\ cal$

Hence total heat given by the steam $Q = Q_1 + Q_2 + Q_3 = 600\ mcal$ ... (i)

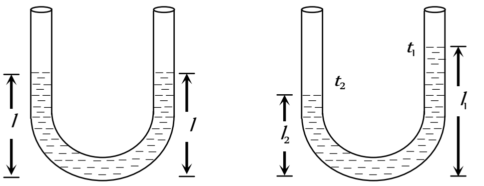
Heat taken by 10 kg water

$Q' = mc_W\Delta\theta = 10 \times 10^3 \times 1 \times (80 - 20) = 600 \times 10^3\ cal$

Hence $Q = Q' \Rightarrow 600\ m = 600 \times 10^3$

$\Rightarrow m = 10^3\ gm = 1 kg.$

21. (a) Suppose, height of liquid in each arm before rising the temperature is l.



With temperature rise height of liquid in each arm increases i.e. $l_1 > l$ and $l_2 > l$

Also $l = \frac{l_1}{1 + \gamma t_1} = \frac{l_2}{1 + \gamma t_2}$

$\Rightarrow l_1 + \gamma l_1 t_2 = l_2 + \gamma l_2 t_1 \Rightarrow \gamma = \frac{l_1 - l_2}{l_2 t_1 - l_1 t_2}$

22. (c) $V = V_0(1 + \gamma\Delta\theta)$

$L^3 = L_0(1 + \alpha_1\Delta\theta)L_0^2(1 + \alpha_2\Delta\theta)^2 = L_0^3(1 + \alpha_1\Delta\theta)(1 + \alpha_2\Delta\theta)^2$

Since $L_0^3 = V_0$ and $L^3 = V$

Hence $1 + \gamma\Delta\theta = (1 + \alpha_1\Delta\theta)(1 + \alpha_2\Delta\theta)^2$

$\cong (1 + \alpha_1\Delta\theta)(1 + 2\alpha_2\Delta\theta) \cong (1 + \alpha_1\Delta\theta + 2\alpha_2\Delta\theta)$

$\Rightarrow \gamma = \alpha_1 + 2\alpha_2$

23. (d) $(OR)^2 = (PR)^2 - (PO)^2 = l^2 - \left(\frac{l}{2}\right)^2$

$= [l(1 + \alpha_2 t)]^2 - \left[\frac{l}{2}(1 + \alpha_1 t)\right]^2$

$l^2 - \frac{l^2}{4} = l^2(1 + \alpha_2^2 t^2 + 2\alpha_2 t) - \frac{l^2}{4}(1 + \alpha_1^2 t^2 + 2\alpha_1 t)$

Neglecting $\alpha_2^2 t^2$ and $\alpha_1^2 t^2$

$0 = l^2(2\alpha_2 t) - \frac{l^2}{4}(2\alpha_1 t) \Rightarrow 2\alpha_2 = \frac{2\alpha_1}{4} \Rightarrow; \alpha_1 = 4\alpha_2$

24. (c) It is given that the volume of air in the flask remains the same. This means that the expansion in volume of the vessel is exactly equal to the volume expansion of mercury.

i.e., $\Delta V_g = \Delta V_L$ or $V_g\gamma_g\Delta\theta = V_L\gamma_L\Delta\theta$

$\therefore V_L = \frac{V_g\gamma_g}{\gamma_L} = \frac{1000 \times (3 \times 9 \times 10^{-6})}{1.8 \times 10^{-4}} = 150\ cc$

25. (c) Heat given by water $Q_1 = 10 \times 10 = 100\ cal.$

Heat taken by ice to melt

$Q_2 = 10 \times 0.5 \times [0 - (-20)] + 10 \times 80 = 900\ cal$

As $Q_1 < Q_2$, so ice will not completely melt and final temperature = 0°C.

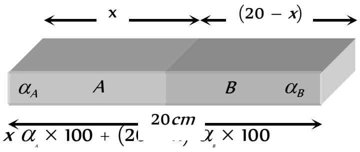
As heat given by water in cooling up to 0°C is only just sufficient to increase the temperature of ice from – 20°C to 0°C, hence mixture in equilibrium will consist of 10 gm ice and 10 gm water at 0°C.

26. (b) $\Delta L = L_0\ \alpha\Delta\theta$

Rod A : 0.075 = 20 × α_A × 100 $\Rightarrow \alpha_A = \frac{75}{2} \times 10^{-6} / °C$

rod B : 0.045 = 20 × α_B × 100 $\Rightarrow \alpha_B = \frac{45}{2} \times 10^{-6} / °C$

For composite rod : x cm of A and (20 – x) cm of B we have

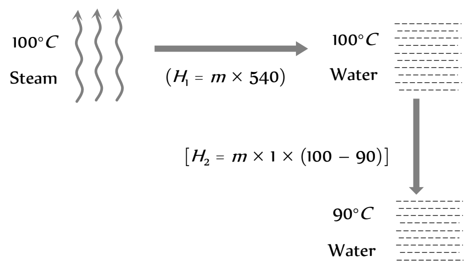


0.060 = $x\ \alpha_A \times 100 + (20 - x)\ \alpha_B \times 100$

$= x\left[\frac{75}{2} \times 10^{-6} \times 100 + (20 - x) \times \frac{45}{2} \times 10^{-6} \times 100\right]$

On solving we get x = 10 cm.

27. (a) Let m gm of steam get condensed into water (By heat loss). This happens in following two steps.



Heat gained by water (20°C) to raise it's temperature upto 90° $= 22 \times 1 \times (90 - 20)$

Hence, in equilibrium heat lost = Heat gain

$\Rightarrow m \times 540 + m \times 1 \times (100 - 90) = 22 \times 1 \times (90 - 20)$

$\Rightarrow m = 2.8\ gm$

The net mass of the water present in the mixture $= 22 + 2.8 = 24.8\ gm$.

Graphical Questions

1. (b) Relation between Celsius and Fahrenheit scale of temperature is $\frac{C}{5} = \frac{F-32}{9} \Rightarrow C = \frac{5}{9}F - \frac{160}{9}$

Equating above equation with standard equation of line

$y = mx + c$ we get slope of the line *AB* is $m = \frac{5}{9}$

2. (c) Since in the region *AB* temperature is constant therefore at this temperature phase of the material changes from solid to liquid and $(H_2 - H_1)$ heat will be absorb by the material. This heat is known as the heat of melting of the solid.

Similarly in the region *CD* temperature is constant therefore at this temperature phase of the material changes from liquid to gas and $(H_4 - H_3)$ heat will be absorb by the material. This heat as known as the heat of vaporisation of the liquid.

3. (a) Initially, on heating temperature rises from $-10°C$ to $0°C$. Then ice melts and temperature does not rise. After the whole ice has melted, temperature begins to rise until it reaches $100°C$. Then it becomes constant, as at the boiling point will not rise.

4. (a) The volume of matter in portion *AB* of the curve is almost constant and pressure is decreasing. These are the characteristics of liquid state.

5. (d) Let the quantity of heat supplied per minute be *Q*. Then quantity of heat supplied in 2 *min* $= mC(90-80)$

In 4 *min*, heat supplied $= 2m\,C(90-80)$

$\therefore\ 2m\,C(90-80) = m\,L \Rightarrow \frac{L}{C} = 20$

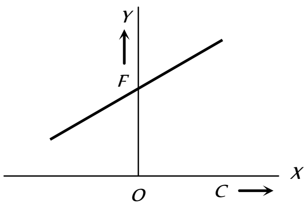
6. (b) In the given graph *CD* represents liquid state.

7. (a) Density of water is maximum at $4°C$ and is less on either side of this temperature.

8. (a) We know that, $\frac{C}{100} = \frac{F-32}{180}$ or $F = \frac{9}{5}C + 32$

Equation of straight line is, $y = mx + c$

Hence, $m = (9/5)$, positive and $c = 32$ positive. The graph is shown in figure.



9. (a)

$$\frac{C}{5} = \frac{F-32}{9} \Rightarrow$$

$C = \left(\frac{5}{9}\right)F - \frac{20}{3}$. Hence graph between $°C$ and $°F$ will be a straight line with positive slope and negative intercept.

10. (bc) The horizontal parts of the curve, where the system absorbs heat at constant temperature must depict changes of state. Here the latent heats are proportional to lengths of the horizontal parts. In the sloping parts, specific heat capacity is inversely proportional to the slopes.

11. (c) Since specific heat = 0.6 $kcal/gm \times °C$ = 0.6 $cal/gm \times °C$

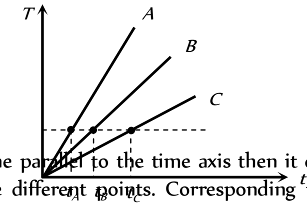
From graph it is clear that in a minute, the temperature is raised from $0°C$ to $50°C$.

$\Rightarrow$ Heat required for a minute = 50 × 0.6 × 50 = 1500 *cal.*

Also from graph, Boiling point of wax is $200°C$.

12. (c)

13. (c) Substances having more specific heat take longer time to get heated to a higher temperature and longer time to get cooled.



If we draw a line parallel to the time axis then it cuts the given graphs at three different points. Corresponding points on the times axis shows that

$t_C > t_B > t_A \Rightarrow C_C > C_B > C_A$

14. (c) From given curve,

Melting point for $A = 60°C$

and melting point for $B = 20°C$

Time taken by *A* for fusion $= (6-2) = 4$ minute

Time taken by *B* for fusion $= (6.5-4) = 2.5$ minute

Then $\frac{H_A}{H_B} = \frac{6 \times 4 \times 60}{6 \times 2.5 \times 60} = \frac{8}{5}$.

Assertion and Reason

1. (a) With rise in pressure melting point of ice decreases. Also ice contracts on melting

2. (c) Celsius scale was the first temperature scale and Fahrenheit is the smallest unit measuring temperature.

3. (e) Melting is associated with increasing of internal energy without change in temperature. In view of the reason being correct the amount of heat absorbed or given out during change of state is expressed $Q = mL$, where *m* is the mass of the substance and *L* is the latent heat of the substance.

4. (a) The temperature of land rises rapidly as compared to sea because of specific heat of land is five times less than that of sea water. Thus, the air above the land become hot and light so rises up so because of pressure drops over land. To compensate the drop of pressure, the cooler air starts from sea starts blowing towards lands, so, setting up sea breeze. During night land as well sea radiate heat energy. The temperature of land falls more rapidly as compared to sea water, as sea water consists of higher specific heat capacity. The air above sea water being warm and light rises up and to take its place the cold air from land starts blowing towards sea and so et up breeze.

5. (a) Linear expansion for brass $(19 \times 10^{-4}) >$ linear expansion for steel (11×10^{-4}). On cooling the disk shrinks to a greater extent than the hole and hence it will get loose.

6. (a) As, $\gamma = \frac{\Delta V}{V \Delta T}$ *i.e.*, units of coefficient of volume expansion is K.

7. (c) The relation between *F* and *C* scale is, $\frac{C}{5} = \frac{F-32}{9}$. If $F = C$

$\Rightarrow C = -40°C$ *i.e.*, at $-40°$ the Centigrade and Fahrenheit thermometers reads the same.

8. (a) As $\beta = 2\alpha$ and $\gamma = 3\alpha$, *i.e.*, coefficient of volume expansion of solid is three time coefficient of linear expansion and 1.5 times the coefficient of superficial expansion, on heating a solid iron ball, percentage increase in its volume is largest.

9. (a) Water has maximum density at $4°C$. On heating above $4°C$ or cooling below $4°C$, density of water decreases and its volume increases. Therefore, water overflows in both the cases.

10. (b) The Latent heat of fusion of ice is amount of heat required to convert unit mass of ice at $0°C$ into water at $0°C$. For fusion of ice

$$L = 80\, cal/gm = 80000\, cal/gm = 8000 \times 4.2\ J/kg$$

$$= 336000\ J/kg\ .$$

11. (a) When two bodies at temperature T_1 and T_2 are brought in thermal contact, they do settle to the mean temperature $(T_1 + T_2)/2$. They will do so, in case the two bodies were of same mass and material *i.e.*, same thermal capacities. In other words, the two bodies may be having different thermal capacities, that's why they do not settle to the mean temperature, when brought together.

12. (d) Specific heat of a body is the amount of heat required to raise the temperature of unit mass of the body through unit degree. When mass of a body is less than unity, then its thermal capacity is less than its specific heat and vice-versa.

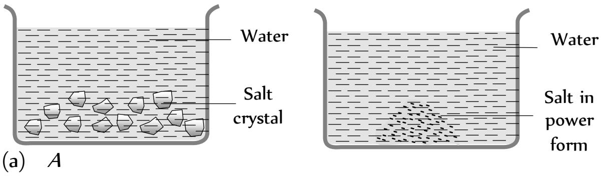
13. (a) Water would evaporate quickly because there is no atmosphere on moon, due to which surface temperature of moon is much higher than earth (Maximum surface temperature of moon is $123°C$).

14. (d) The potential energy of water molecules is more. The heat given to melt the ice at $0°C$ is used up in increasing the potential energy of water molecules formed at $0°C$.

Thermometry, Thermal Expansion and Calorimetry

SET Self Evaluation Test -12

1. Out of the following, in which vessel will the temperature of the solution be higher after the salt is completely dissolved.



(a) A
(b) B
(c) Equal in both
(d) Information is not sufficient

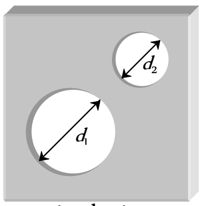
2. Fire is extinguished more effectively by
(a) Hot water (b) Cold water
(c) Equally by both (d) Ice

3. An ideal thermometer should have
(a) Large heat capacity (b) Medium heat capacity
(c) Small heat capacity (d) Variable heat capacity

4. A steel meter scale is to be ruled so that millimeter intervals are accurate within about 5×10^{-5} *mm* at a certain temperature. The maximum temperature variation allowable during the ruling is (Coefficient of linear expansion of steel $= 10 \times 10^{-6} K^{-1}$)
(a) $2°C$ (b) $5°C$
(c) $7°C$ (d) $10°C$

5. During illness an 80 *kg* man ran a fever of $102.2°F$ instead of normal body temperature of $98.6°F$. Assuming that human body is mostly water, how much heat is required to raise his temperature by that amount
(a) 100 *kcal* (b) 160 *kcal*
(c) 50 *kcal* (d) 92 *kcal*

6. Two holes of unequal diameters d_1 and d_2 $(d_1 > d_2)$ are cut in a metal sheet. If the sheet is heated
(a) Both d_1 and d_2 will decrease
(b) Both d_1 and d_2 will increase
(c) d_1 will increase, d_2 will decrease
(d) d_1 will decrease, d_2 will increase



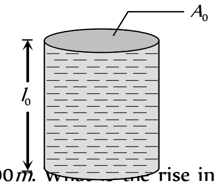
7. If earth suddenly stops rotating about its own axis, the increase in it's temperature will be
(a) $\frac{R^2\omega^2}{5Js}$ (b) $\frac{R^2\omega^2}{Js}$
(c) $\frac{Rm\omega^2}{5Js}$ (d) None of these

8. Latent heat of ice is 80 *cal/gm*. A man melts 60 *g* of ice by chewing in 1 *minute*. His power is
(a) 4800 W (b) 336 W
(c) 1.33 W (d) 0.75 W

9. A faulty thermometer has its lower fixed point marked as $-10°C$ and upper fixed point marked as 110° and upper fixed point marked as 110°. If the temperature of the body shown in this scale is 62°, the temperature shown on the Celsius scale is
(a) 72° C (b) 82° C
(c) 60° C (d) 42° C

10. If there are no heat losses, the heat released by the condensation of x *gm* of steam at $100°C$ into water at $100°C$ can be used to convert y *gm* of ice at $0°C$ into water at $100°C$. Then the ratio $y : x$ is nearly
(a) 1 : 1 (b) 2.5 : 1
(c) 2 : 1 (d) 3 : 1

11. The figure shows a glass tube (linear co-efficient of expansion is α) completely filled with a liquid of volume expansion co-efficient γ. On heating length of the liquid column does not change. Choose the correct relation between γ and α
(a) $\gamma = \alpha$
(b) $\gamma = 2\alpha$
(c) $\gamma = 3\alpha$ **[EAMCET 2001]**
(d) $\gamma = \frac{\alpha}{3}$



12. Water falls from a height 500 m. What is the rise in temperature of water at bottom if whole energy remains in the water
(a) $0.96°C$ (b) $1.02°C$
(c) $1.16°C$ (d) $0.23°C$

13. A steel ball of mass 0.1 *kg* falls freely from a height of 10 *m* and bounces to a height of 5.4 m from the ground. If the dissipated energy in this process is absorbed by the ball, the rise in its temperature is
(Specific heat of steel $= 460\ Joule - kg^{-1}°C^{-1}$, $g = 10\ ms^{-2}$)
[EAMCET (Med.) 2000]
(a) $0.01°C$ (b) $0.1°C$
(c) $1°C$ (d) $1.1°C$

14. 1 *gm* of ice at $0°C$ is mixed with 1 *gm* of water at $100°C$ the resulting temperature will be **[AIIMS 1994]**
(a) $5°C$ (b) $0°C$
(c) $10°C$ (d) ∞

15. The amount of heat required to change 1 *gm* ($0°C$) of ice into water of $100°C$, is **[RPMT 1999]**
(a) 716 *cal* (b) 500 *cal*
(c) 180 *cal* (d) 100 *cal*

AS Answers and Solutions

(SET -12)

1. (b) When salt crystals dissolves, crystal lattice is destroyed. The process requires a certain amount of energy (latent heat) which is taken from the water.

In vessel (B), a part of intermolecular bonds has already been destroyed in crushing the crystal. Hence less energy is require to dissolve the powder and the water will be at higher temperature.

2. (a) Fire is extinguished by the vaporisation do water which lowers the temperature of the burning body. Further, the water vapour envelops the body, keeping oxygen away. Hot water evaporates more than cold water as

3. (c) The thermometer has to attain the temperature of the body. To do this, it should draw as little heat from the body as possible, so that the existing temperature of the body is not disturbed.

4. (b) As we know $\alpha = \frac{\Delta L}{L_0 \Delta\theta} \Rightarrow \Delta\theta = \frac{\Delta L}{\alpha L_0} = \frac{5\times10^{-5}}{10\times10^{-6}\times1} = 5°C$

5. (b) Since $102.2°F \rightarrow 39°C$ and $98.6°F \rightarrow 39°C$

Hence ΔQ = m. s. ΔQ = 80 × 1000 × (39 − 37)

= 16 × 10^4 cal = 160 $kcal$.

6. (b) If the sheet is heated then both d_1 and d_2 will increase since the thermal expansion of isotropic solid is similar to true photographic enlargement.

7. (a) $W = JQ \Rightarrow \frac{1}{2} I\omega^2 = J(MS\Delta\theta) \Rightarrow \frac{1}{2}\left(\frac{2}{5}MR^2\right)\omega^2$

$= J(MS\Delta\theta) \Rightarrow \Delta\theta = \frac{R^2\omega^2}{5Js}$

8. (b) $W = JQ = J(mL) \Rightarrow P\times t = J(mL) \Rightarrow P = J\left(\frac{m}{t}\right)L$;

where $\frac{m}{t}$ = rate of melting of ice by chewing

$= \frac{60\,gm}{min} = \frac{1\,gm}{sec} \Rightarrow P$ = 4.2 × 1 × 80 = 336 W.

9. (c) $\frac{X-L}{U-L} = \frac{C}{100} \Rightarrow \frac{62-(10)}{110-(-10)} = \frac{C}{100}$ (C = 60°C)

***

10. (d) Heat released to convert x gm of steam at 100°C to water at 100°C is x × 540 $cals$.

If y gm of ice is converted from 0°C to water at 100°C it requires heat y × 80 + y × 1 × 100 = 180 y

$\therefore\; x\times540 = 180y$ or $\frac{y}{x} = \frac{540}{180} = \frac{3}{1}$

11. (b) When length of the liquid column remains constant, then the level of liquid moves down with respect to the container, thus γ must be less than 3α.

Now we can write $V = V_0(1+\gamma\Delta T)$

Since $V = Al = [A_0(1+2\alpha\Delta T)]l = V_0(1+2\alpha\Delta T)$

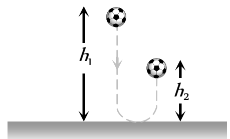
Hence $V_0(1+\gamma\Delta T) = V_0(1+2\alpha\Delta T) \Rightarrow \gamma = 2\alpha$.

12. (c) By using

$\Delta\theta = 0.0023h = 0.0023\times500 = 1.15°C \approx 1.16°C$

13. (b) According to energy conservation, change in potential energy of the ball, appears in the form of heat which raises the temperature of the ball.

i.e. $mg(h_1 - h_2) = m.c.\Delta\theta$

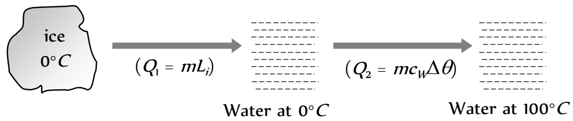


$\Rightarrow \Delta\theta = \frac{g(h_1-h_2)}{c}$

$= \frac{10(10-5.4)}{460} = 0.1°C$

14. (c) $\theta_{mix} = \frac{\theta_w - \frac{L_i}{C_W}}{2} = \frac{100-\frac{80}{1}}{2} = 10°C$

15. (c) Ice (0°C) converts into water (100°C) in following two steps.



Total heat required

$Q = Q_1 + Q_2 = 1\times80 + 1\times1\times(100-0) = 180\,cal$

Chapter 13
Kinetic Theory of Gases

Gas

In gases the intermolecular forces are very weak and its molecule may fly apart in all directions. So the gas is characterized by the following properties.

(i) It has no shape and size and can be obtained in a vessel of any shape or size.

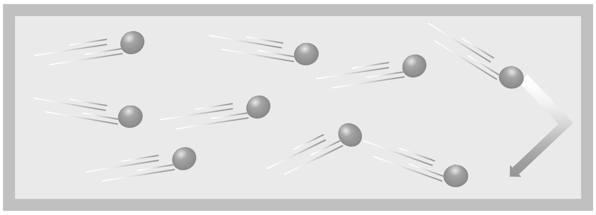
(ii) It expands indefinitely and uniformly to fill the available space.

(iii) It exerts pressure on its surroundings.

(iv) Intermolecular forces in a gas are minimum.

(v) They can easily compressed and expand.

Assumption of Ideal Gases (or Kinetic Theory of Gases)



Kinetic theory of gases relates the macroscopic properties of gases (such as pressure, temperature *etc.*) to the microscopic properties of the gas molecules (such as speed, momentum, kinetic energy of molecule *etc.*)

Actually it attempts to develop a model of the molecular behaviour which should result in the observed behaviour of an ideal gas. It is based on following assumptions :

(1) Every gas consists of extremely small particles known as molecules. The molecules of a given gas are all identical but are different than those of another gas.

(2) The molecules of a gas are identical, spherical, rigid and perfectly elastic point masses.

(3) Their size is negligible in comparison to intermolecular distance (10^{-9} *m*)

(4) The volume of molecules is negligible in comparison to the volume of gas. (The volume of molecules is only 0.014% of the volume of the gas).

(5) Molecules of a gas keep on moving randomly in all possible direction with all possible velocities.

(6) The speed of gas molecules lie between zero and infinity

(7) The gas molecules keep on colliding among themselves as well as with the walls of containing vessel. These collisions are perfectly elastic.

(8) The time spent in a collision between two molecules is negligible in comparison to time between two successive collisions.

(9) The number of collisions per unit volume in a gas remains constant.

(10) No attractive or repulsive force acts between gas molecules.

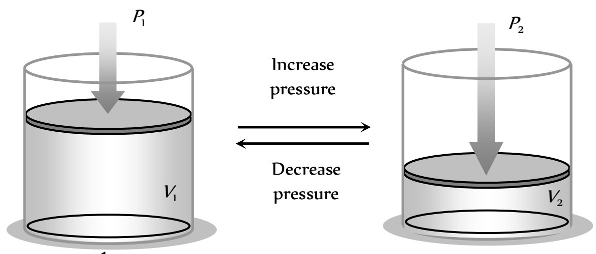
(11) Gravitational attraction among the molecules is ineffective due to extremely small masses and very high speed of molecules.

(12) Molecules constantly collide with the walls of container due to which their momentum changes. The change in momentum is transferred to the walls of the container. Consequently pressure is exerted by gas molecules on the walls of container.

(13) The density of gas is constant at all points of the container.

Gas Laws

(1) **Boyle's law :** For a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure.



i.e. $V \propto \frac{1}{P}$ or PV = constant $\Rightarrow P_1V_1 = P_2V_2$

Fig. 13.1

(i) $PV = P\left(\frac{m}{\rho}\right)$ = constant $\Rightarrow$ $\frac{P}{\rho}$ = constant or $\frac{P_1}{\rho_1} = \frac{P_2}{\rho_2}$

(As volume $= \frac{m}{\rho(\text{Density of the gas})}$ and m = constant)

(ii) $PV = P\left(\frac{N}{n}\right)$ = constant $\Rightarrow \frac{P}{n}$ = constant or $\frac{P_1}{n_1} = \frac{P_2}{n_2}$

(iii) As number of molecules per unit volume $n = \frac{N}{V}$

$\Rightarrow V = \frac{N}{n}$ also N = constant

(iv) Graphical representation : If m and T are constant

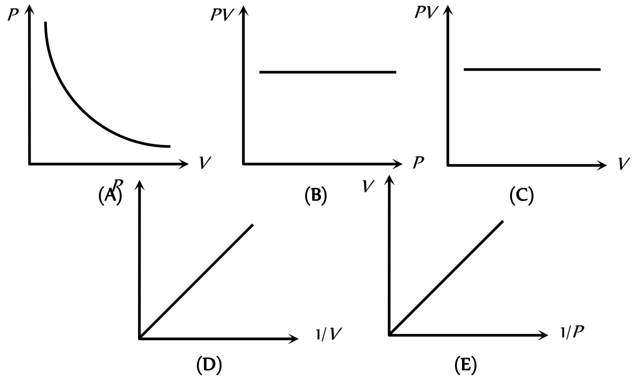


Fig. 13.2

(2) **Charle's law :** If the pressure remaining constant, the volume of the given mass of a gas is directly proportional to its absolute temperature.

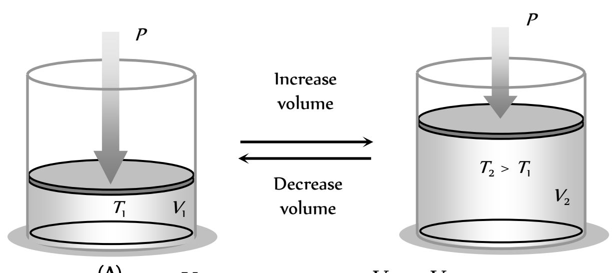


Fig. 13.3

i.e., $V \propto T$ $\Rightarrow \frac{V}{T}$ = constant $\Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

(i) $\frac{V}{T} = \frac{m}{\rho T}$ = constant (As volume $V = \frac{m}{\rho}$)

or ρT = constant $\Rightarrow \rho_1 T_1 = \rho_2 T_2$

(ii) If the pressure remains constant, the volume of the given mass of a gas increases or decreases by $\frac{1}{273.15}$ of its volume at 0°C for each 1°C rise or fall in temperature.

$$V_t = V_0\left(1 + \frac{1}{273.15}t\right).$$

This is Charle's law for centigrade scale.

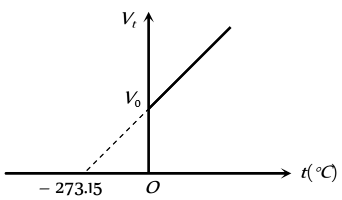
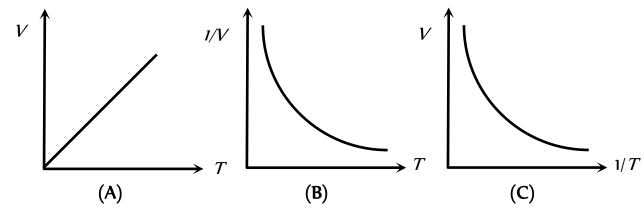


Fig. 13.4

(v) Graphical representation: If m and P are constant



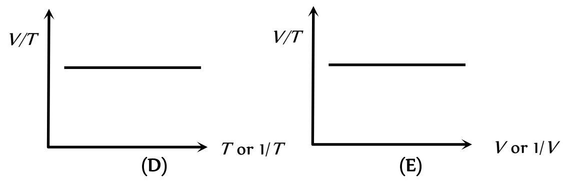


Fig. 13.5

(3) **Gay-Lussac's law or pressure law :** The volume remaining constant, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

$P \propto T$ or $\frac{P}{T}$ = constant $\Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2}$

(i) The volume remaining constant, the pressure of a given mass of a gas increases or decreases by $\frac{1}{273.15}$ of its pressure at 0°C for each 1°C rise or fall in temperature.

$$P_t = P_0\left[1 + \frac{1}{273.15}t\right]$$

This is pressure law for centigrade scale.

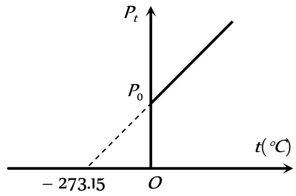


Fig. 13.5

(ii) **Graphical representation :** If m and V are constants

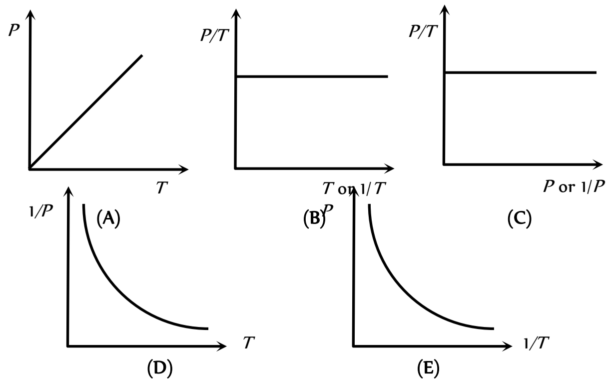


Fig. 13.6

(4) **Avogadro's law :** Equal volume of all the gases under similar conditions of temperature and pressure contain equal number of molecules *i.e.* $N_1 = N_2$.

(5) **Grahm's law of diffusion :** When two gases at the same pressure and temperature are allowed to diffuse into each other, the rate of diffusion of each gas is inversely proportional to the square root of the density of the gas *i.e.* $r \propto \frac{1}{\sqrt{\rho}} \propto \frac{1}{\sqrt{M}}$ (M is the molecular weight of the gas) $\Rightarrow$

$$\frac{r_1}{r_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{M_2}{M_1}}$$

If V is the volume of gas diffused in t *sec* then

$$r = \frac{V}{t} \Rightarrow \frac{r_1}{r_2} = \frac{V_1}{V_2} \times \frac{t_2}{t_1}$$

(6) **Dalton's law of partial pressure :** The total pressure exerted by a mixture of non-reacting gases occupying a vessel is equal to the sum of the

individual pressures which each gases exert if it alone occupied the same volume at a given temperature.

For n gases $P = P_1 + P_2 + P_3 + ... P_n$

where P = Pressure exerted by mixture and $P_1, P_2, P_3, ... P_n$ = Partial pressure of component gases.

Equation of State or Ideal Gas Equation

The equation which relates the pressure (P) volume (V) and temperature (T) of the given state of an ideal gas is known as ideal gas equation or equation of state.

For 1 mole of gas $\frac{PV}{T} = R$ (constant) $\Rightarrow PV = RT$

where R = universal gas constant.

Table 13.1 : Different forms of gas equation

Quantity of gas	Equation	Constant
1 mole gas	$PV = RT$	R = universal gas constant
μ mole gas	$PV = \mu RT$	
1 molecule of gas	$PV = \left(\frac{R}{N_A}\right)T = kT$	k = Boltzmann's constant
N molecules of gas	$PV = NkT$	
1 *gm* of gas	$PV = \left(\frac{R}{M}\right)T = rT$	r = Specific gas constant
m gm of gas	$PV = mrT$	

(1) **Universal gas constant (R) :** Universal gas constant signifies the work done by (or on) a gas per mole per kelvin.

$$R = \frac{PV}{\mu T} = \frac{\text{Pressure} \times \text{Volume}}{\mu \times \text{Temperature}} = \frac{\text{Work done}}{\mu \times \text{Temperature}}$$

(i) At S.T.P. the value of universal gas constant is same for all gases $R = 8.31 \frac{J}{mole \times kelvin} = 1.98 \frac{cal}{mole \times kelvin} \simeq 2 \frac{cal}{mol \times kelvin}$

$$= 0.8221 \frac{litre \times atm}{mole \times kelvin}.$$

(ii) Dimension : $[ML^2T^{-2}\theta^{-1}]$

(2) **Boltzman's constant (k) :** It is represented by per mole gas constant *i.e.,* $k = \frac{R}{N} = \frac{8.31}{6.023 \times 10^{23}} = 1.38 \times 10^{-23}\ J/K$

It's dimension : $[ML^2T^{-2}\theta^{-1}]$

(3) **Specific gas constant (r) :** It is represented by per gram gas constant *i.e.,* $r = \frac{R}{M}$. It's unit is $\frac{Joule}{gm \times kelvin}$ and dimension $[L^2T^{-2}\theta^{-1}]$

Since the value of M is different for different gases. Hence the value of r is different for different gases. *e.g.* It is maximum for hydrogen $r_{H_2} = \frac{R}{2}$

Real Gases

(1) The gases actually found in nature are called real gases.

(2) They do not obeys gas Laws.

(3) For exactly one mole of an ideal gas $\frac{PV}{RT} = 1$. Plotting the experimentally determined value of $\frac{PV}{RT}$ for exactly one mole of various real gases as a function of pressure P, shows a deviation from identity.

(4) The quantity $\frac{PV}{RT}$ is called the compressibility factor and should be unit for an ideal gas.

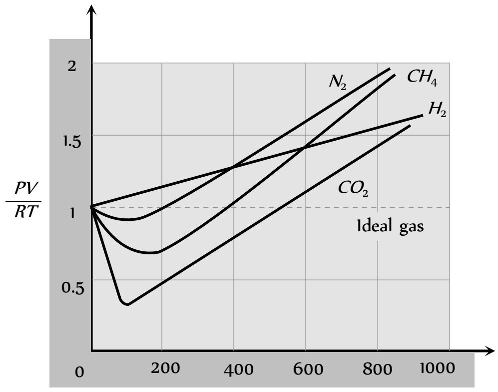


Fig. 13.7

(5) Deviation from ideal behaviour as a function of temperature

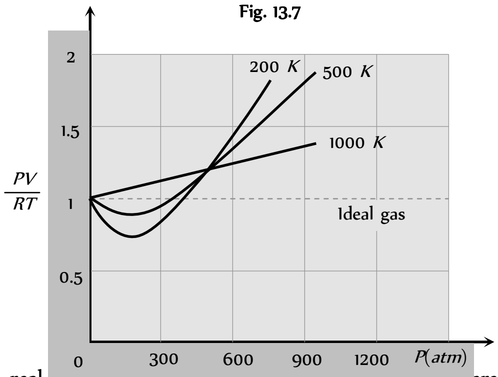


Fig. 13.8

(6) A real gas behaves as ideal gas most closely at low pressure and high temperature. Also can actual gas can be liquefied most easily which deviates most from ideal gas behaviour at low temperature and high pressure.

(7) **Equation of state for real gases :** It is given by Vander Waal's with two correction in ideal gas equation. The it know as Vander Waal's gas equation.

(i) **Volume correction :** Due to finite size of molecule, a certain portion of volume of a gas is covered by the molecules themselves. Therefore the space available for the free motion of molecules of gas will be slightly less than the volume V of a gas. Hence the effective volume becomes ($V - b$).

(ii) **Pressure correction :** Due to intermolecular force in real gases, molecule do not exert that force on the wall which they would have exerted in the absence of intermolecular force. Therefore the observed pressure P of the gas will be less than that present in the absence of intermolecular force. Hence the effective pressure becomes $\left(P + \frac{a}{V^2}\right)$.

(iii) **Vander Waal's gas equations**

For 1 *mole* of gas $\left(P + \frac{a}{V^2}\right)(V - b) = RT$

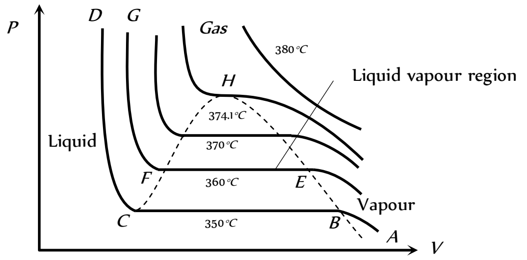
For μ *moles* of gas $\left(P+\frac{a\mu^2}{V^2}\right)(V-\mu b)=\mu RT$

Here a and b are constant called Vander Waal's constant.

Dimension : $[a]$ = $[ML^5T^{-2}]$ and $[b]$ = $[L]$

Units : $a = N \times m$ and $b = m$.

(8) **Andrews curves** : The pressure (P) versus volume (V) curves for actual gases are called Andrews curves.



Andrews curve for water

Fig. 13.9

(i) At 350°C, part AB represents vapour phase of water, in this part Boyle's law is obeyed $\left(P \propto \frac{1}{V}\right)$. Part BC represents the co-existence of vapour and liquid phases. At point C, vapours completely change to liquid phase. Part CD is parallel to pressure axis which shows that compressibility of the water is negligible.

(ii) At 360°C portion representing the co-existence of liquid vapour phase is shorter.

(iii) At 370°C this portion is further decreased.

(iv) At 374.1°C, it reduces to point (H) called critical point and the temperature 374.1°C is called critical temperature (T) of water.

(v) The phase of water (at 380°C) above the critical temperature is called gaseous phase.

(9) **Critical temperature, pressure and volume :** The point on the P-V curve at which the matter gets converted from gaseous state to liquid state is known as critical point. At this point the difference between the liquid and vapour vanishes *i.e.* the densities of liquid and vapour become equal.

(i) **Critical temperature (T_c) :** The maximum temperature below which a gas can be liquefied by pressure alone is called critical temperature and is characteristic of the gas. A gas cannot be liquefied if its temperature is more than critical temperature.

CO_2 (31.1°C), O_2(–118°C), N_2 (–147.1°C) and H_2O (374.1°C)

(ii) **Critical pressure (P_c) :** The minimum pressure necessary to liquify a gas at critical temperature is defined as critical pressure CO_2 (73.87 *bar*) and O_2 (49.7*atm*)

(iii) **Critical volume (V_c) :** The volume of 1 mole of gas at critical pressure and critical temperature is defined as critical volume CO_2 (95 ×10 *m*)

(iv) **Relation between Vander Waal's constants and T_c, P_c, V_c**

$$T_c=\frac{8a}{27Rb},\ P_c=\frac{a}{27b^2},\ V_c=3b,$$

$$a=\frac{27R^2}{64}\frac{T_c^2}{P_c},\ b=\frac{R}{8}\left(\frac{T_c}{P_c}\right) \text{ and } \frac{P_cV_c}{T_c}=\frac{3}{8}R$$

Pressure of an Ideal Gas

Consider an ideal gas (consisting of N molecules each of mass m) enclosed in a cubical box of side L.

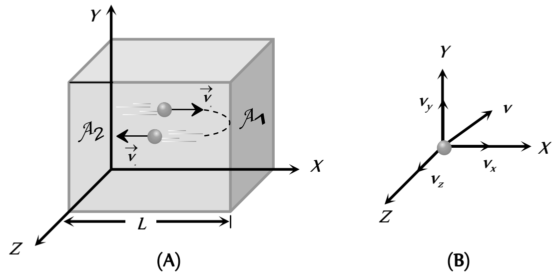


Fig. 13.10

(1) **Instantaneous velocity :** Any molecule of gas moves with velocity $\vec{v}$ in any direction

where $\vec{v}=v_x\hat{i}+v_y\hat{j}+v_z\hat{k} \Rightarrow v=\sqrt{v_x^2+v_y^2+v_z^2}$. Due to random motion of molecule $v_x=v_y=v_z \Rightarrow v^2=3v_x^2=3v_y^2=3v_z^2$

(2) **Time during collision :** Time between two successive collision with the wall A_1.

$$\Delta t=\frac{\text{Distance travelled by molecule between two successive collision}}{\text{Velocity of molecule}}$$

$$=\frac{2L}{v_x}$$

(3) **Collision frequency (n) :** It means the number of collision per second. Hence $n=\frac{1}{\Delta t}=\frac{v_x}{2L}$

(4) **Change in momentum :** This molecule collides with the shaded wall (A_1) with velocity v_x and rebounds with velocity $-v_x$.

The change in momentum of the molecule

$$\Delta p=(-mv_x)-(mv_x)=-2mv_x$$

As the momentum remains conserved in a collision, the change in momentum of the wall A_1 is $\Delta p=2mv_x$

After rebound this molecule travel toward opposite wall A_2 with velocity $-v_x$, collide to it and again rebound with velocity v_x towards wall A_1.

(5) **Force on wall :** Force exerted by a single molecule on shaded wall is equal to rate at which the momentum is transferred to the wall by this molecule.

i.e. $F_{\text{Single molecule}}=\frac{\Delta p}{\Delta t}=\frac{2mv_x}{(2L/v_x)}=\frac{mv_x^2}{L}$

The total force on the wall A_1 due to all the molecules

$$F_x=\frac{m}{L}\sum v_x^2=\frac{m}{M}(v_{x_1}^2+v_{x_2}^2+v_{x_3}^2+...)=\frac{mN}{L}\overline{v_x^2}$$

$\overline{v_x^2}$ = mean square of x component of the velocity.

(6) **Pressure :** Now pressure is defined as force per unit area, hence pressure on shaded wall $P_x=\frac{F_x}{A}=\frac{mN}{AL}\overline{v_x^2}=\frac{mN}{V}\overline{v_x^2}$

For any molecule, the mean square velocity $\overline{v^2}=\overline{v_x^2}+\overline{v_y^2}+\overline{v_z^2}$; by symmetry $\overline{v_x^2}=\overline{v_y^2}=\overline{v_z^2} \Rightarrow \overline{v_x^2}=\overline{v_y^2}=\overline{v_z^2}=\frac{\overline{v^2}}{3}$

Total pressure inside the container

$$P=\frac{1}{3}\frac{mN}{V}\overline{v^2}=\frac{1}{3}\frac{mN}{V}v_{rms}^2 \qquad \text{(where } v_{rms}=\sqrt{\overline{v^2}}\text{)}$$

(7) **Relation between pressure and kinetic energy :** As we know $P=\frac{1}{3}\frac{mN}{V}v_{rms}^2=\frac{1}{3}\frac{M}{V}v_{rms}^2 \Rightarrow P=\frac{1}{3}\rho v_{rms}^2$ ... (i)

[As $M = mN$ = Total mass of the gas and $\rho=\frac{M}{V}$]

$\therefore$ K.E. per unit volume $E=\frac{1}{2}\left(\frac{M}{V}\right)v_{rms}^2=\frac{1}{2}\rho v_{rms}^2$ ...(ii)

From (i) and (ii), we get $P=\frac{2}{3}E$

i.e. the pressure exerted by an ideal gas is numerically equal to the two third of the mean kinetic energy of translation per unit volume of the gas.

(8) **Effect of mass, volume and temperature on pressure :** $P=\frac{1}{3}\frac{mN}{V}v_{rms}^2$ or $P\propto\frac{(mN)T}{V}$ [As $v_{rms}^2\propto T$]

(i) If volume and temperature of a gas are constant $P\propto mN$ *i.e.* Pressure $\propto$ (Mass of gas).

i.e. if mass of gas is increased, number of molecules and hence number of collision per second increases *i.e.* pressure will increase.

(ii) If mass and temperature of a gas are constant. $P\propto(1/V)$, *i.e.*, if volume decreases, number of collisions per second will increase due to lesser effective distance between the walls resulting in greater pressure.

(iii) If mass and volume of gas are constant, $P\propto(v_{rms})^2\propto T$

i.e., if temperature increases, the mean square speed of gas molecules will increase and as gas molecules are moving faster, they will collide with the walls more often with greater momentum resulting in greater pressure.

Various Speeds of Gas Molecules

The motion of molecules in a gas is characterised by any of the following three speeds.

(1) **Root mean square speed :** It is defined as the square root of mean of squares of the speed of different molecules

i.e. $v_{rms}=\sqrt{\frac{v_1^2+v_2^2+v_3^2+v_4^2+....}{N}}=\sqrt{\overline{v^2}}$

(i) From the expression of pressure $P=\frac{1}{3}\rho v_{rms}^2$

$\Rightarrow v_{rms}=\sqrt{\frac{3P}{\rho}}=\sqrt{\frac{3PV}{\text{Mass of gas}}}=\sqrt{\frac{3RT}{M}}=\sqrt{\frac{3kT}{m}}$

where $\rho=\frac{\text{Mass of gas}}{V}$ = Density of the gas, $M=\mu\times$ (mass of gas), $pV=\mu RT$, $R=kN_A$, $k=$ Boltzmann's constant,

$m=\frac{M}{N_A}$ = mass of each molecule.

(ii) With rise in temperature *rms* speed of gas molecules increases as $v_{rms}\propto\sqrt{T}$.

(iii) With increase in molecular weight *rms* speed of gas molecule decreases as $v_{rms}\propto\frac{1}{\sqrt{M}}$. *e.g.*, *rms* speed of hydrogen molecules is four times that of oxygen molecules at the same temperature.

(iv) *rms* speed of gas molecules is of the order of *km/s* *e.g.*, at NTP for hydrogen gas

$(v_{rms})=\sqrt{\frac{3RT}{M}}=\sqrt{\frac{3\times8.31\times273}{2\times10^3}}=1840\ m/s$.

(v) *rms* speed of gas molecules is $\sqrt{\frac{3}{\gamma}}$ times that of speed of sound in gas, as $v_{rms}=\sqrt{\frac{3RT}{M}}$ and $v_s=\sqrt{\frac{\gamma RT}{M}} \Rightarrow v_{rms}=\sqrt{\frac{3}{\gamma}}v_s$

(vi) *rms* speed of gas molecules does not depends on the pressure of gas (if temperature remains constant) because $P\propto\rho$ (Boyle's law) if pressure is increased *n* times then density will also increases by *n* times but v_{rms} remains constant.

(vii) Moon has no atmosphere because v_{rms} of gas molecules is more than escape velocity (v_e).

A planet or satellite will have atmosphere only if $v_{rms}<v_e$

(viii) At $T=0$; $v_{rms}=0$ *i.e.* the *rms* speed of molecules of a gas is zero at 0 *K*. This temperature is called absolute zero.

(2) **Most probable speed :** The particles of a gas have a range of speeds. This is defined as the speed which is possessed by maximum fraction of total number of molecules of the gas. *e.g.*, if speeds of 10 molecules of a gas are 1, 2, 2, 3, 3, 3, 4, 5, 6, 6 *km/s*, then the most probable speed is 3 *km/s*, as maximum fraction of total molecules possess this speed.

Most probable speed $v_{mp}=\sqrt{\frac{2P}{\rho}}=\sqrt{\frac{2RT}{M}}=\sqrt{\frac{2kT}{m}}$

(3) **Average speed :** It is the arithmetic mean of the speeds of molecules in a gas at given temperature.

$$v_{av}=\frac{v_1+v_2+v_3+v_4+.....}{N}$$

and according to kinetic theory of gases

Average speed $v_{av}=\sqrt{\frac{8P}{\pi\rho}}=\sqrt{\frac{8}{\pi}\frac{RT}{M}}=\sqrt{\frac{8}{\pi}\frac{kT}{m}}$

Maxwell's Law (or the Distribution of Molecular Speeds

(1) The v_{rms} gives us a general idea of molecular speeds in a gas at a given temperature. This doesn't mean that the speed of each molecule is v_{rms}. Many of the molecules have speed less than v_{rms} and many have speeds greater than v_{rms}.

(2) Maxwell derived as equation given the distribution of molecules in different speed as follow

$$dN=4\pi N\left(\frac{m}{2\pi kT}\right)^{3/2}v^2e^{-\frac{mv^2}{2kT}}dv$$

where dN = Number of molecules with speeds between v and $v+dv$.

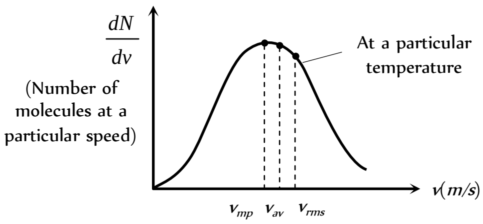


Fig. 13.11

(3) Graph between $\frac{dN}{dv}$ (number of molecules at a particular speed) and v (speed of these molecules). From the graph it is seen that $\frac{dN}{dv}$ is maximum at most probable speed.

This graph also represent that $v_{rms} > v_{av} > v_{mp}$

(Order remember trick RAM)

$$\Rightarrow \sqrt{\frac{3RT}{M}} > \sqrt{\frac{8RT}{\pi M}} > \sqrt{\frac{2RT}{M}} \Rightarrow$$

$$1.77\sqrt{\frac{RT}{M}} > 1.6\sqrt{\frac{RT}{M}} > 1.41\sqrt{\frac{RT}{M}}$$

Area bonded by this curve with speed axis represents the number of molecules corresponds to that velocity range. This curve is asymmetric curve.

Effect of temperature on velocity distribution : With temperature rise the $\frac{dN}{dv}$ vs v. Curve shift towards right and becomes broader.

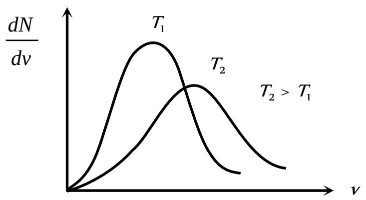


Fig. 13.12

(Because with temperature rise average molecular speed increases).

Mean Free Path

(1) The distance travelled by a gas molecule between two successive collisions is known as free path.

$$\lambda = \frac{\text{Total distance travelled by a gas molecule between successive collisions}}{\text{Total number of collisions}}$$

During two successive collisions, a molecule of a gas moves in a straight line with constant velocity and

Let $\lambda_1, \lambda_2, \lambda_3.....$ be the distance travelled by a gas molecule during n collisions respectively, then the mean free path of a gas molecule is given by

$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 + ... + \lambda_n}{n}$$

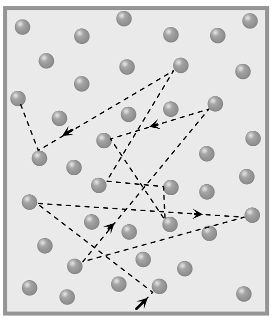


Fig. 13.13

(2) $\lambda = \frac{1}{\sqrt{2}\pi n d^2}$

where d = Diameter of the molecule,

n = Number of molecules per unit volume

(3) As $PV = \mu RT = \mu NkT \Rightarrow \frac{N}{V} = \frac{P}{kT} = n =$ Number of molecule per unit volume so $\lambda = \frac{1}{\sqrt{2}} \frac{kT}{\pi d^2 P}$.

(4) From $\lambda = \frac{1}{\sqrt{2}\pi n d^2} = \frac{m}{\sqrt{2}\pi (mn) d^2} = \frac{m}{\sqrt{2}\pi d^2 \rho}$

[As m = Mass each molecule, mn = Mass per unit volume = Density = ρ]

(5) If average speed of molecule is v then $\lambda = v \times \frac{t}{N} = v \times T$

[As N = Number of collision in time t, T = time interval between two collisions].

(i) As $\lambda \propto \frac{1}{\rho}$ and $\lambda \propto m$ *i.e.* the mean free path is inversely proportional to the density of a gas and directly proportional to the mass of each molecule.

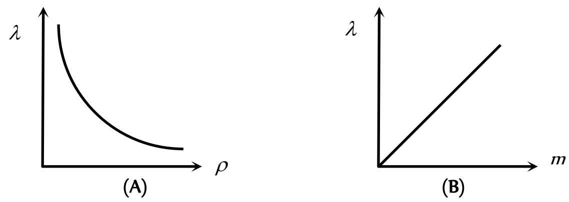


Fig. 13.14

(ii) As $\lambda = \frac{1}{\sqrt{2}} \frac{kT}{\pi d^2 P}$. For constant volume and hence constant number density n of gas molecules, $\frac{P}{T}$ is constant so that λ will not depend on P and T. But if volume of given mass of a gas is allowed to change with P or T then $\lambda \propto T$ at constant pressure and $\lambda \propto \frac{1}{P}$ at constant temperature.

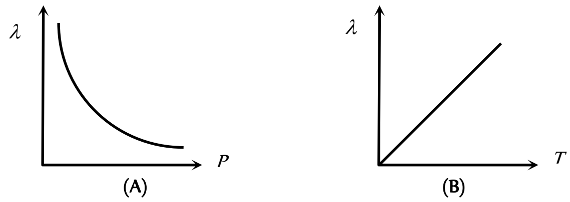


Fig. 13.15

Degree of Freedom

The term degree of freedom of a system refers to the possible independent motions, systems can have. or

The total number of independent modes (ways) in which a system can possess energy is called the degree of freedom (f).

The independent motions can be translational, rotational or vibrational or any combination of these.

So the degree of freedom are of three types :

(i) Translational degree of freedom

(ii) Rotational degree of freedom

(iii) Vibrational degree of freedom

General expression for degree of freedom

$f = 3A - B$; where A = Number of independent particles,

B = Number of independent restriction

(1) **Monoatomic gas :** Molecule of monoatomic gas can move in any direction in space so it can have three independent motions and hence 3 degrees of freedom (all translational)

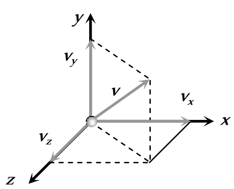


Fig. 13.16

(2) **Diatomic gas :** Molecules of diatomic gas are made up of two atoms joined rigidly to one another through a bond. This cannot only move bodily, but also rotate about one of the three co-ordinate axes. However its moment of inertia about the axis joining the two atoms is negligible compared to that about the other two axes.

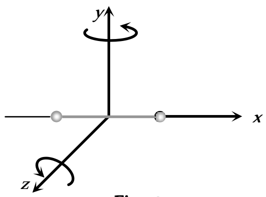


Fig. 13.17

Hence it can have only two rotational motion. Thus a diatomic molecule has 5 degree of freedom : 3 translational and 2 rotational.

(3) **Triatomic gas (Non-linear) :** A non-linear molecule can rotate about any of three co-ordinate axes. Hence it has 6 degrees of freedom : 3 translational and 3 rotational.

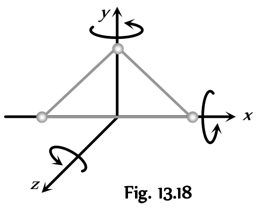
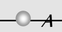
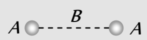
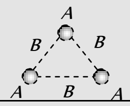
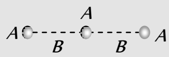


Fig. 13.18

Table 13.2 ; Degree of freedom for different gases

Atomicity of gas	Example	A	*B*	*f* = 3 *A* – *B*	Figure
Monoatomic	*He, Ne, Ar*	1	0	*f* = 3	
Diatomic	H_2, O_2, N_2, Cl_2 *etc.*	2	1	*f* = 5	
Triatomic non linear	H_2O	3	3	*f* = 6	
Triatomic linear	CO_2, $BeCl_2$	3	2	*f* = 7	

The above degrees of freedom are shown at room temperature. Further at high temperature, in case of diatomic or polyatomic molecules, the atoms with in the molecule may also vibrate with respect to each other. In such cases, the molecule will have an additional degrees of freedom, due to vibrational motion.

An object which vibrates in one dimension has two additional degree of freedom. One for the potential energy and one for the kinetic energy of vibration.

A diatomic molecule that is free to vibrate (in addition to translation and rotation) will have $7\,(2+3+2)$ degrees of freedom.

Kinetic Energy of Ideal Gas

In ideal gases, the molecules are considered as point particles. For point particles, there is no internal excitation, no vibration and no rotation. The point particles can have only translational motion and thus only translational energy. For an ideal gas the internal energy can only be tranlational kinetic energy.

Hence kinetic energy (or internal energy) of 1 mole ideal gas

$$E = \frac{1}{2}Mv_{rms}^2 = \frac{1}{2}M \times \frac{3RT}{M} = \frac{3}{2}RT$$

Table 13.3 : Various Translational kinetic energies

Quantity of gas	Kinetic energy
1 mole gas	$\frac{3}{2}RT$; R = Universal gas constant
μ mole gas	$\frac{3}{2}\mu RT$
1 molecule	$\frac{3}{2}kT$; k = Boltzmann's constant
N molecule	$\frac{3}{2}NkT$
1 *gm* gas	$\frac{3}{2}rT$; r = Specific gas constant
m gm gas	$\frac{3}{2}mrT$

(1) Kinetic energy per molecule of gas does not depends upon the mass of the molecule but only depends upon the temperature of the gas. As $E = \frac{3}{2}kT$ or $E \propto T$ *i.e.* molecules of different gases say *He*, H_2 and O_2 *etc.* at same temperature will have same translational kinetic energy though their *r.m.s.* speed are different.

(2) For two gases at the same temperature $m_1(v_{rms})_1^2 = m_2(v_{rms})_2^2$

(3) Kinetic energy per mole of gas depends only upon the temperature of gas.

(4) Kinetic energy per *gram* of gas depend upon the temperature as well as molecular weight (or mass of one molecule) of the gas. $E_{gram} = \frac{3}{2}\frac{k}{m}T \Rightarrow E_{gram} \propto \frac{T}{m}$

(5) From the above expressions it is clear that higher the temperature of the gas, more will be the average kinetic energy possessed by the gas molecules at *T* = 0, *E* = 0 *i.e.* at absolute zero the molecular motion stops.

Law of Equipartition of Energy

According to this law, for any system in thermal equilibrium, the total energy is equally distributed among its various degree of freedom. And each degree of freedom is associated with energy $\frac{1}{2}kT$ (where $k = 1.38 \times 10^{-23}\ J/K$, *T* = absolute temperature of the system).

(1) At a given temperature *T*, all ideal gas molecules no matter what their mass have the same average translational kinetic energy; namely, $\frac{3}{2}kT$. When measure the temperature of a gas, we are also measuring the average translational kinetic energy of it' s molecules.

(2) At same temperature gases with different degrees of freedom (*e.g.*, *He* and H_2) will have different average energy or internal energy namely $\frac{f}{2}kT$. (*f* is different for different gases)

(3) Different energies of a system of degree of freedom *f* are as follows

(i) Total energy associated with each molecule = $\frac{f}{2}kT$

(ii) Total energy associated with *N* molecules = $\frac{f}{2}NkT$

(iii) Total energy associated with μ mole = $\frac{f}{2}RT$

(iv) Total energy associated with μ molen = $\frac{f}{2}\mu RT$

(v) Total energy associated with each gram = $\frac{f}{2}rT$

(iv) Total energy associated with m gram = $\frac{f}{2}mrT$

Specific Heat (C_P and C_V) of a Gas

The specific heat of gas can have many values, but out of them following two values are very important

(1) **Specific heat at constant volume (c_V) :** The specific heat of a gas at constant volume is defined as the quantity of heat required to raise the temperature of unit mass of gas through 1°C or 1 K when its volume is kept constant, *i.e.*, $c_V = \frac{(\Delta Q)_V}{m\Delta T}$

If instead of unit mass, 1 mole of gas is considered, the specific heat is called molar specific heat at constant volume and is represented by capital C_V.

$$C_V = Mc_V = \frac{M(\Delta Q)_V}{m\Delta T} = \frac{1}{\mu}\frac{(\Delta Q)_V}{\Delta T} \qquad \left[\text{As}\,\mu = \frac{m}{M}\right]$$

(2) **Specific heat at constant from (c_P) :** The specific heat of a gas at constant pressure is defined as the quantity of heat required to raise the temperature of unit mass of gas through 1 K when its pressure is kept constant, *i.e.*, $c_P = \frac{(\Delta Q)_p}{m\Delta T}$

If instead of unit mass, 1 mole of gas is considered, the specific heat is called molar specific heat at constant pressure and is represented by C_P.

$$C_p = MC_p = \frac{M(\Delta Q)_p}{m\Delta T} = \frac{1}{\mu}\frac{(\Delta Q)_p}{\Delta T} \qquad \left[\text{As}\,\mu = \frac{m}{M}\right]$$

Mayer's Formula

(1) Out of two principle specific heats of a gas, C_P is more than C_V because in case of C_V volume of gas is kept constant and heat is required only for raising the temperature of one gram mole of the gas through 1°C or 1 K. Hence no heat, what so ever, is spent in expansion of the gas.

It means that heat supplied to the gas increases its internal energy only *i.e.* $(\Delta Q)_V = \Delta U = \mu C_V \Delta T$ .....(i)

(2) While in case of C_P the heat is used in two ways

(i) In increasing the temperature of the gas by ΔT

(ii) In doing work, due to expansion at constant pressure (ΔW)

So $(\Delta Q)_P = \Delta U + \Delta W = \mu C_P \Delta T$ .....(ii)

From equation (i) and (ii) $\mu C_P \Delta T - \mu C_V \Delta T = \Delta W$

$$\Rightarrow \quad \mu \Delta T(C_P - C_V) = P\Delta V \Rightarrow \quad C_P - C_V = \frac{P\Delta V}{\mu \Delta T} = R$$

[For constant pressure, $\Delta W = P\Delta V$ also from $PV = \mu RT$, $P\Delta V = \mu R\Delta T$]

This relation is called Mayer's formula and shows that $C_P > C_V$ *i.e.* molar specific heat at constant pressure is greater than that at constant volume.

Specific Heat in Terms of Degree of Freedom

(1) C_V **:** For a gas at temperature T, the internal energy $U = \frac{f}{2}\mu RT \Rightarrow$ Change in energy $\Delta U = \frac{f}{2}\mu R\Delta T$ ... (i)

Also, as we know for any gas heat supplied at constant volume $(\Delta Q)_V = \mu C_V \Delta T = \Delta U$ ... (ii)

From equation (i) and (ii) $C_V = \frac{1}{2}fR$

(2) C_P **:** From the Mayer's formula $C_p - C_v = R$

$$\Rightarrow \quad C_P = C_V + R = \frac{f}{2}R + R = \left(\frac{f}{2} + 1\right)R$$

(3) **Ratio of C_P and C_V (γ) :** $\gamma = \frac{C_P}{C_V} = \frac{\left(\frac{f}{2}+1\right)R}{\frac{f}{2}R} = 1 + \frac{2}{f}$

(i) Value of γ is different for monoatomic, diatomic and triatomic gases. $\gamma_{mono} = \frac{5}{3} = 1.6, \gamma_{di} = \frac{7}{5} = 1.4, \gamma_{tri} = \frac{4}{3} = 1.33$

(ii) Value of γ is always more than 1. So we can say that always $C_P > C_V$.

Gaseous Mixture

If two non-reactive gases are enclosed in a vessel of volume V. In the mixture μ_1 moles of one gas are mixed with μ_2 moles of another gas. If N_A is Avogadro's number then

Number of molecules of first gas $N_1 = \mu_1 N_A$

and number of molecules of second gas $N_2 = \mu_2 N_A$

(1) Total mole fraction $\mu = (\mu_1 + \mu_2)$.

(2) If M_1 is the molecular weight of first gas and M_2 that of second gas.

Then molecular weight of mixture $M = \frac{\mu_1 M_1 + \mu_2 M_2}{\mu_1 + \mu_2}$

(3) Specific heat of the mixture at constant volume will be

$$C_{V_{mix}} = \frac{\mu_1 C_{V_1} + \mu_2 C_{V_2}}{\mu_1 + \mu_2} = \frac{\frac{m_1}{M_1}C_{V_1} + \frac{m_2}{M_2}C_{V_2}}{\frac{m_1}{M_1} + \frac{m_2}{M_2}}$$

(4) Specific heat of the mixture at constant pressure will be

$$C_{P_{mix}} = \frac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 + \mu_2} = \frac{\mu_1\left(\frac{\gamma_1}{\gamma_1 - 1}\right)R + \mu_2\left(\frac{\gamma_2}{\gamma_2 - 1}\right)R}{\mu_1 + \mu_2}$$

$$= \frac{R}{\mu_1 + \mu_2}\left[\mu_1\left(\frac{\gamma_1}{\gamma_1 - 1}\right) + \mu_2\left(\frac{\gamma_2}{\gamma_2 - 1}\right)\right]$$

$$= \frac{R}{\frac{m_1}{M_1} + \frac{m_2}{M_2}}\left[\frac{m_1}{M_1}\left(\frac{\gamma_1}{\gamma_1 - 1}\right) + \frac{m_2}{M_2}\left(\frac{\gamma_2}{\gamma_2 - 1}\right)\right]$$

(5) $$\gamma_{\text{mixture}} = \frac{C_{P_{mix}}}{C_{V_{mix}}} = \frac{\frac{(\mu_1 C_{P_1} + \mu_2 C_{P_2})}{\mu_1 + \mu_2}}{\frac{(\mu_1 C_{V_1} + \mu_2 C_{V_2})}{\mu_1 + \mu_2}}$$

$$= \frac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 C_{V_1} + \mu_2 C_{V_2}} = \frac{\left\{\mu_1\left(\frac{\gamma_1}{\gamma_1 - 1}\right)R + \mu_2\left(\frac{\gamma_2}{\gamma_2 - 1}\right)R\right\}}{\left\{\mu_1\left(\frac{R}{\gamma_1 - 1}\right) + \mu_2\left(\frac{R}{\gamma_2 - 1}\right)\right\}}$$

$$\therefore\ \gamma_{\text{mixture}} = \frac{\frac{\mu_1\gamma_1}{\gamma_1 - 1} + \frac{\mu_2\gamma_2}{\gamma_2 - 1}}{\frac{\mu_1}{\gamma_1 - 1} + \frac{\mu_2}{\gamma_2 - 1}} = \frac{\mu_1\gamma_1(\gamma_2 - 1) + \mu_2\gamma_2(\gamma_1 - 1)}{\mu_1(\gamma_2 - 1) + \mu_2(\gamma_1 - 1)}$$

Tips & Tricks

✍ The cooking gas cylinder contains L.P.G. (Liquid Petroleum gas) which is saturated. And as pressure of saturated vapours is independent of volume (at constant temperature). the pressure of gas coming out of the cylinder remains constant till the cylinder becomes empty.

✍ If the number of molecules in a gas increases, then the temperature, kinetic energy and pressure of the gas increases because $P \propto n$, $T \propto n$ and kinetic energy $\propto T \propto n$.

✍ At constant volume if T increases then $\overline{v}$, v_{rms}, P and collision frequency increases.

✍ If two gases are filled in vessel then nothing can be predicted about the pressure of gases. However their mean molecular energies will be same but their *rms* velocities will be different.

✍ The average distance between two gas molecules at NTP is 10^{-9} *m*.

✍ The space available for a single gas molecule at NTP is 37.2×10^{-2} *m*.

✍ The molecules of gases will escape out from a planet if the temperature of planet $T \le \frac{Mv_e^2}{3R}$; where v_e = escape velocity from the planet, R = universal, gas constant and M = Molecular mass of the gas.

✍ As f (degree of freedom) increases then $C_p\uparrow$, $C_v\uparrow$ and $\gamma\uparrow$.

✍ The number of molecules present in 1 *gm mole* of a gas is defined as Avogadro number (N).

$$N_A = 6.023\times10^{23} \text{ per } gm\ mole = 6.023\times10^{26} \text{ per } kg\ mole.$$

At S.T.P. or N.T.P. (T = 273 *K* and P = 1 *atm*) 22.4 *litre* of each gas has 6.023×10^{23} molecule

✍ One mole of any gas at S.T.P. occupy 22.4 *litre* of volume

e.g. 32 *gm* oxygen, 28 *gm* nitrogen and 2*gm* hydrogen occupy the same volume at S.T.P.

✍ For any gas 1 *mole* = *M gram* = 22.4 *litre* = 6.023×10^{23} molecule.

✍ $v_{rms} : v_{av} : v_{mp} = \sqrt{3} : \sqrt{\frac{8}{\pi}} : \sqrt{2} = \sqrt{3} : \sqrt{2.5} : \sqrt{2}$

✍ For oxygen gas molecules v_{rms} = 461 *m/s*, v_{av} = 424.7 *m/s* and v_{rms} = 376.4 *m/s*

✍ An atom in a solid though has no degree of freedom for translational and rotational motion, due to vibration along 3 axes has 3 × 2 = 6 degrees of freedom (and not like an ideal gas molecule). When a diatomic or polyatomic gas dissociates into atoms it behaves as monoatomic gas whose degree of freedom are changed accordingly

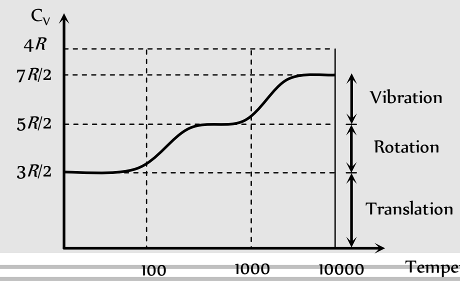
✍ In General a polyatmic molecule has 3 translational, 3 rotational degree of freedom and a certain number of vibration mode f_{vib}. Hence $\gamma_{poly} = \frac{4 + f_{vib}}{3 + f_{vib}}$.

✍ Only average translational kinetic energy of a gas contributes to its temperature. Two gases with the same average translational kinetic energy have the same temperature even if one has grater rotational energy and thus greater internal energy.

✍ Unsaturated vapours obey gas laws while saturated vapours don't.

✍ For real gases effective volume is considered as $(V - \mu b)$ where $b = 4N_A\left(\frac{4}{3}\pi r^3\right)$; r = radius of each molecule and N_A = avogrado number.

✍ Variation of degree of freedom of a diatomic gas (H) with temperature. At very low temperature only translation is possible. as the temperature increases rotational motion can begin. At still higher temperatures vibratory motion can begin.



Ordinary Thinking

Objective Questions

Gas Laws

1. The temperature of a gas at pressure P and volume V is 27°*C*. Keeping its volume constant if its temperature is raised to 927°*C*, then its pressure will be [MP PMT 1985]
   (a) 2 *P* (b) 3 *P*
   (c) 4 *P* (d) 6 *P*

2. 4 moles of an ideal gas is at 0°*C*. At constant pressure it is heated to double its volume, then its final temperature will be
   (a) 0°*C* (b) 273°*C*
   (c) 546°*C* (d) 136.5°*C*

3. Every gas (real gas) behaves as an ideal gas
   [CPMT 1997; RPMT 2000; MP PET 2001]

(a) At high temperature and low pressure
(b) At low temperature and high pressure
(c) At normal temperature and pressure
(d) None of the above

4. Boyle's law holds for an ideal gas during [AFMC 1994; KCET 1999]
(a) Isobaric changes (b) Isothermal changes
(c) Isochoric changes (d) Isotonic changes

5. S.I. unit of universal gas constant is [MNR 1988; MP PMT 1994; UPSEAT 1999]
(a) $cal/°C$ (b) J/mol
(c) $J\,mol^{-1}\,K^{-1}$ (d) J/kg

6. Molecules of a gas behave like [J & K CET 2000]
(a) Inelastic rigid sphere
(b) Perfectly elastic non-rigid sphere
(c) Perfectly elastic rigid sphere
(d) Inelastic non-rigid sphere

Ordinary Thinking

Objective Questions

Communication

1. In short wave communication waves of which of the following frequencies will be reflected back by the ionospheric layer, having electron density 10^{11} per m

[AIIMS 2003]

(a) 2 *MHz* (b) 10 *MHz*

(c) 12 *MHz* (d) 18 *MHz*

2. In an amplitude modulated wave for audio frequency of 500 *cycle/second*, the appropriate carrier frequency will be

[AMU 1996]

(a) 50 *cycles/sec* (b) 100 *cycles/sec*

(c) 500 *cycles/sec* (d) 50,000 *cycles/sec*

3. AM is used for broadcasting because

(a) It is more noise immune than other modulation systems

(b) It requires less transmitting power compared with other systems

(c) Its use avoids receiver complexity

(d) No other modulation system can provide the necessary bandwidth faithful transmission

4. Range of frequencies allotted for commercial FM radio broadcast is

(a) 88 to 108 *MHz* (b) 88 to 108 *kHz*

(c) 8 to 88 *MHz* (d) 88 to 108 *GHz*

5. The velocity factor of a transmission line *x*. If dielectric constant of the medium is 2.6, the value of *x* is

[AFMC 1995]

(a) 0.26 (b) 0.62

(c) 2.6 (d) 6.2

6. The process of superimposing signal frequency (*i.e.* audio wave) on the carrier wave is known as [AIIMS 1987]

(a) Transmission (b) Reception

(c) Modulation (d) Detection

7. Long distance short-wave radio broadcasting uses

[AFMC 1996]

(a) Ground wave (b) Ionospheric wave

(c) Direct wave (d) Sky wave

8. A step index fibre has a relative refractive index of 0.88%. What is the critical angle at the corecladding interface

[Manipal 2003]

(a) 60° (b) 75°

(c) 45° (d) None of these

9. The characteristic impedance of a coaxial cable is of the order of

(a) 50 Ω (b) 200 Ω

(c) 270 Ω (d) None of these

10. In which frequency range, space waves are normally propagated

(a) HF (b) VHF

(c) UHF (d) SHF

11. If μ_1 and μ_2 are the refractive indices of the materials of core and cladding of an optical fibre, then the loss of light due to its leakage can be minimised by having [BVP 2003]

(a) $\mu_1 > \mu_2$ (b) $\mu_1 < \mu_2$

(c) $\mu_1 = \mu_2$ (d) None of these

12. Through which mode of propagation, the radio waves can be sent from one place to another [JIPMER 2003]

(a) Ground wave propagation

(b) Sky wave propagation

(c) Space wave propagation

(d) All of them

13. A laser beam of pulse power 10^{12} *watt* is focussed on an object are 10^{-4} cm^2. The energy flux in *watt*/ cm^2 at the point of focus is

(a) 10^{20} (b) 10^{16}

(c) 10^{8} (d) 10^{4}

14. The carrier frequency generated by a tank circuit containing 1 *nF* capacitor and 10 μH inductor is [AFMC 2003]

(a) 1592 *Hz* (b) 1592 *MHz*

(c) 1592 *kHz* (d) 159.2 *Hz*

15. Broadcasting antennas are generally [AFMC 2003]

(a) Omnidirectional type (b) Vertical type

(c) Horizontal type (d) None of these

16. For television broadcasting, the frequency employed is normally

(a) 30-300 *MHz* (b) 30-300 *GHz*

(c) 30-300 *KHz* (d) 30-300 *Hz*

17. The radio waves of frequency 300 *MHz* to 3000 *MHz* belong to [MNR 1997]

(a) High frequency band

(b) Very high frequency band

(c) Ultra high frequency band

(d) Super high frequency band

18. An antenna behaves as resonant circuit only when its length is

(a) $\frac{\lambda}{2}$

(b) $\frac{\lambda}{4}$

(c) λ

(d) $\frac{\lambda}{2}$ or integral multiple of $\frac{\lambda}{2}$

19. Maximum useable frequency (MUF) in *F*-region layer is *x*, when the critical frequency is 60 *MHz* and the angle of incidence is 70°. Then *x* is [Himachal PMT 2003]

(a) 150 *MHz* (b) 170 *MHz*

(c) 175 *MHz* (d) 190 *MHz*

20. The electromagnetic waves of frequency 2 *MHz* to 30 *MHz* are [CPMT 2003]

(a) In ground wave propagation

(b) In sky wave propagation

(c) In microwave propagation

(d) In satellite communication

21. A laser is a coherent source because it contains

[JIPMER 2003] [EAMCET 2002]

(a) Many wavelengths

(b) Uncoordinated wave of a particular wavelength

(c) Coordinated wave of many wavelengths

(d) Coordinated waves of a particular wavelength

22. The attenuation in optical fibre is mainly due to [AFMC 2003]

(a) Absorption

(b) Scattering

(c) Neither absorption nor scattering

(d) Both (a) and (b)

23. The maximum distance upto which TV transmission from a TV tower of height h can be received is proportional to [AIIMS 2003]

(a) $h^{1/2}$ (b) h

(c) $h^{3/2}$ (d) h^2

24. A laser beam is used for carrying out surgery because it [AIIMS 2003]

(a) Is highly monochromatic (b) Is highly coherent

(c) Is highly directional (d) Can be sharply focussed

25. Laser beams are used to measure long distances because [DCE 2002, 03]

(a) They are monochromatic

(b) They are highly polarised

(c) They are coherent

(d) They have high degree of parallelism

26. An oscillator is producing FM waves of frequency 2 *kHz* with a variation of 10 *kHz*. What is the modulating index [DCE 2004]

(a) 0.20 (b) 5.0

(c) 0.67 (d) 1.5

27. The maximum peak to peak voltage of an AM wire is 24 *mV* and the minimum peak to peak voltage is 8 *mV*. The modulation factor is

(a) 10% (b) 20%

(c) 25% (d) 50%

28. Sinusoidal carrier voltage of frequency 1.5 *MHz* and amplitude 50 *V* is amplitude modulated by sinusoidal voltage of frequency 10 *kHz* producing 50% modulation. The lower and upper side-band frequencies in *kHz* are

(a) 1490, 1510 (b) 1510, 1490

(c) $\frac{1}{1490}, \frac{1}{1510}$ (d) $\frac{1}{1510}, \frac{1}{1490}$

29. What is the modulation index of an over modulated wave

(a) 1 (b) Zero

(c) < 1 (d) > 1

30. Basically, the product modulator is

(a) An amplifier (b) A mixer

(c) A frequency separator (d) A phase separator

31. If f_a and f_f represent the carrier wave frequencies for amplitude and frequency modulations respectively, then

(a) $f_a > f_f$ (b) $f_a < f_f$

(c) $f_a \approx f_f$ (d) $f_a \geq f_f$

32. Which of the following is the disadvantage of FM over AM

(a) Larger band width requirement

(b) Larger noise

(c) Higher modulation power

(d) Low efficiency

33. If a number of sine waves with modulation indices n_1, n_2, n_3 .... modulate a carrier wave, then total modulation index (n) of the wave is

(a) $n_1 + n_2 .... + 2(n_1 + n_2.....)$

(b) $\sqrt{n_1 - n_2 + n_3..........}$

(c) $\sqrt{n_1^2 + n_2^2 + n_3^2.........}$

(d) None of these

34. An AM wave has 1800 *watt* of total power content, For 100% modulation the carrier should have power content equal to

(a) 1000 *watt* (b) 1200 *watt*

(c) 1500 *watt* (d) 1600 *watt*

35. The frequency of a FM transmitter without signal input is called

(a) Lower side band frequency

(b) Upper side band frequency

(c) Resting frequency

(d) None of these

36. What type of modulation is employed in India for radio transmission

(a) Amplitude modulation (b) Frequency modulation

(c) Pulse modulation (d) None of these

37. When the modulating frequency is doubled, the modulation index is halved and the modulating voltage remains constant, the modulation system is

(a) Amplitude modulation (b) Phase modulation

(c) Frequency modulation (d) All of the above

38. An antenna is a device

(a) That converts electromagnetic energy into radio frequency signal

(b) That converts radio frequency signal into electromagnetic energy

(c) That converts guided electromagnetic waves into free space electromagnetic waves and vice-versa

(d) None of these

39. While tuning in a certain broadcast station with a receiver, we are actually

(a) Varying the local oscillator frequency

(b) Varying the frequency of the radio signal to be picked up

(c) Tuning the antenna

(d) None of these

40. Indicate which one of the following system is digital

(a) Pulse position modulation

(b) Pulse code modulation

(c) Pulse width modulation

(d) Pulse amplitude modulation

41. In a communication system, noise is most likely to affect the signal

(a) At the transmitter

(b) In the channel or in the transmission line

(c) In the information source

(d) At the receiver

42. The waves used in telecommunication are

(a) IR (b) UV

(c) Microwave (d) Cosmic rays

43. In an FM system a 7 *kHz* signal modulates 108 *MHz* carrier so that frequency deviation is 50 *kHz*. The carrier swing is

(a) 7.143 (b) 8

(c) 0.71 (d) 350

44. Consider telecommunication through optical fibres. Which of the following statements is not true [AIEEE 2003]

(a) Optical fibres may have homogeneous core with a suitable cladding

(b) Optical fibres can be of graded refractive index

(c) Optical fibres are subject to electromagnetic interference from outside

(d) Optical fibres have extremely low transmission loss

45. The phenomenon by which light travels in an optical fibres is

(a) Reflection (b) Refraction

(c) Total internal reflection (d) Transmission

46. Television signals on earth cannot be received at distances greater than 100 *km* from the transmission station. The reason behind this is that [DCE 1995]

(a) The receiver antenna is unable to detect the signal at a distance greater than 100 *km*

(b) The TV programme consists of both audio and video signals

(c) The TV signals are less powerful than radio signals

(d) The surface of earth is curved like a sphere

47. Advantage of optical fibre [DCE 2005]

(a) High bandwidth and EM interference

(b) Low bandwidth and EM interference

(c) High band width, low transmission capacity and no EM interference

(d) High bandwidth, high data transmission capacity and no EM interference

48. In frequency modulation [Kerala PMT 2005]

(a) The amplitude of modulated wave varies as frequency of carrier wave

(b) The frequency of modulated wave varies as amplitude of modulating wave

(c) The amplitude of modulated wave varies as amplitude of carrier wave

(d) The frequency of modulated wave varies as frequency of modulating wave

(e) The frequency of modulated wave varies as frequency of carrier wave

49. Audio signal cannot be transmitted because

[Kerala PMT 2005]

(a) The signal has more noise

(b) The signal cannot be amplified for distance communication

(c) The transmitting antenna length is very small to design

(d) The transmitting antenna length is very large and impracticable

(e) The signal is not a radio signal

50. In which of the following remote sensing technique is not used

(a) Forest density (b) Pollution

(c) Wetland mapping (d) Medical treatment

51. For sky wave propagation of a 10 *MHz* signal, what should be the minimum electron density in ionosphere

[AIIMS 2005]

(a) $\sim 1.2 \times 10^{12}\ m^{-3}$ (b) $\sim 10^{6}\ m^{-3}$

(c) $\sim 10^{14}\ m^{-3}$ (d) $\sim 10^{22}\ m^{-3}$

52. What should be the maximum acceptance angle at the aircore interface of an optical fibre if n_1 and n_2 are the refractive indices of the core and the cladding, respectively

[AIIMS 2005]

(a) $\sin^{-1}(n_2 / n_1)$ (b) $\sin^{-1}\sqrt{n_1^2 - n_2^2}$

(c) $\left[\tan^{-1}\frac{n_2}{n_1}\right]$ (d) $\left[\tan^{-1}\frac{n_1}{n_2}\right]$

[DCE 2001]

Critical Thinking

Objective Questions

1. A sky wave with a frequency 55 *MHz* is incident on *D*-region of earth's atmosphere at 45°. The angle of refraction is (electron density for *D*-region is 400 $electron/cm^3$)

[Haryana PMT 2003]

(a) 60° (b) 45°

(c) 30° (d) 15°

2. In a diode AM-detector, the output circuit consist of $R = 1k\Omega$ and $C = 10\ pF$. A carrier signal of 100 *kHz* is to be detected. Is it good

(a) Yes

(b) No

(c) Information is not sufficient

(d) None of these

3. Consider an optical communication system operating at $\lambda \sim 800\ nm$. Suppose, only 1% of the optical source frequency is the available channel bandwidth for optical communication. How many channels can be accommodated for transmitting audio signals requiring a bandwidth of 8 *kHz*

(a) 4.8×10^{8} (b) 48

(c) 6.2×10^{8} (d) 4.8×10^{5}

4. A photodetector is made from a semiconductor $In_{0.53}Ga_{0.47}As$ with E_g = 0.73 *eV*. What is the maximum wavelength, which it can detect

(a) 1000 *nm* (b) 1703 *nm*

(c) 500 *nm* (d) 173 *nm*

5. A transmitter supplies 9 kW to the aerial when unmodulated. The power radiated when modulated to 40% is

(a) 5 kW (b) 9.72 kW

(c) 10 kW (d) 12 kW

6. The antenna current of an AM transmitter is 8 A when only carrier is sent but increases to 8.96 A when the carrier is sinusoidally modulated. The percentage modulation is

(a) 50% (b) 60%

(c) 65% (d) 71%

7. The total power content of an AM wave is 1500 W. For 100% modulation, the power transmitted by the carrier is

(a) 500 W (b) 700 W

(c) 750 W (d) 1000 W

8. The total power content of an AM wave is 900 W. For 100% modulation, the power transmitted by each side band is

(a) 50 W (b) 100 W

(c) 150 W (d) 200 W

9. The modulation index of an FM carrier having a carrier swing of 200 kHz and a modulating signal 10 kHz is

(a) 5 (b) 10

(c) 20 (d) 25

10. A 500 Hz modulating voltage fed into an FM generator produces a frequency deviation of 2.25 kHz. If amplitude of the voltage is kept constant but frequency is raised to 6 kHz then the new deviation will be

(a) 4.5 kHz (b) 54 kHz

(c) 27 kHz (d) 15 kHz

11. The audio signal used to modulate 60 sin $(2\pi \times 10^6 \; t)$ is $15 \sin 300\pi t$. The depth of modulation is

(a) 50% (b) 40%

(c) 25% (d) 15%

12. The bit rate for a signal, which has a sampling rate of 8 kHz and where 16 quantisation levels have been used is

(a) 32000 *bits/sec* (b) 16000 *bits/sec*

(c) 64000 *bits/sec* (d) 72000 *bits/sec*

13. An amplitude modulated wave is modulated to 50%. What is the saving in power if carrier as well as one of the side bands are suppressed

(a) 70% (b) 65.4%

(c) 94.4% (d) 25.5%

14. In AM, the centpercent modulation is achieved when

(a) Carrier amplitude = signal amplitude

(b) Carrier amplitude ≠ signal amplitude

(c) Carrier frequency = signal frequency

(d) Carrier frequency ≠ signal frequency

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Diode lasers are used as optical sources in optical communication.

Reason : Diode lasers consume less energy. [AIIMS 2005]

2. Assertion : Television signals are received through sky-wave propagation.

Reason : The ionosphere reflects electromagnetic waves of frequencies greater than a certain critical frequency. [AIIMS 2005]

3. Assertion : In high latitude one sees colourful curtains of light hanging down from high altitudes.

Reason : The high energy charged particles from the sun are deflected to polar regions by the magnetic field of the earth. [AIIMS 2003]

4. Assertion : Short wave bands are used for transmission of radio waves to a large distance.

Reason : Short waves are reflected by ionosphere [AIIMS 1994]

5. Assertion : The electrical conductivity of earth's atmosphere decreases with altitude.

Reason : The high energy particles (*i.e.* γ-rays and cosmic rays) coming from outer space and entering our earth's atmosphere cause ionisation of the atoms of the gases present there and the pressure of gases decreases with increase in altitude.

6. Assertion : The electromagnetic waves of shorter wavelength can travel longer distances on earth's surface than those of longer wavelengths.

Reason : Shorter the wavelength, the larger is the velocity of wave propagation.

7. Assertion : The surface wave propagation is used for medium wave band and for television broadcasting.

Reason : The surface waves travel directly from transmitting antenna to receiver antenna through atmosphere.

8. Assertion : The television broadcasting becomes weaker with increasing distance.

Reason : The power transmitted from TV transmitter varies inversely as the distance of the receiver

9. Assertion : Microwave propagation is better than the sky wave propagation.

Reason : Microwaves have frequencies 100 to 300 GHz, which have very good directional properties.

10. Assertion : Satellite is an ideal platform for remote sensing.

Reason : Satellite in polar orbit can provide global coverage or continuous coverage of the fixed area in geostationary configuration.

11. Assertion : Fax is a modulating and demodulating device.

Reason : It is necessary for exact reproduction of a document.

12. Assertion : A dish antenna is highly directional.

Reason : This is because a dipole antenna is omni directional.

Answers

Communication

1	a	2	d	3	c	4	a	5	b
6	c	7	c	8	d	9	c	10	c
11	a	12	d	13	b	14	c	15	b
16	a	17	c	18	d	19	c	20	b
21	d	22	d	23	a	24	d	25	d
26	b	27	d	28	a	29	d	30	b
31	b	32	a	33	c	34	b	35	c
36	a	37	c	38	c	39	a	40	b
41	b	42	c	43	a	44	c	45	c
46	d	47	d	48	b	49	d	50	d
51	a	52	b						

Critical Thinking Questions

1	b	2	b	3	a	4	b	5	b
6	d	7	d	8	c	9	b	10	b
11	c	12	a	13	c	14	a		

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : In pressure-temperature (*P-T*) phase diagram of water, the slope of the melting curve is found to be negative.
Reason : Ice contracts on melting to water. [AIIMS 2005]

2. Assertion : For gas atom the number of degrees of freedom is 3.
Reason : $\frac{C_P}{C_V} = \gamma$ [AIIMS 2000]

3. Assertion : A gas have a unique value of specific heat.
Reason : Specific heat is defined as the amount of heat required to raise the temperature of unit mass of the substance through unit degree.

4. Assertion : A gas can be liquified at any temperature by increase of pressure alone.
Reason : On increasing pressure the temperature of gas decreases.

5. Assertion : Equal masses of helium and oxygen gases are given equal quantities of heat. There will be a greater rise in the temperature of helium compared to that of oxygen.
Reason : The molecular weight of oxygen is more than the molecular weight of helium.

6. Assertion : Absolute zero is the temperature corresponding to zero energy.
Reason : The temperature at which no molecular motion cease is called absolute zero temperature.

7. Assertion : The ratio of specific heat gas at constant pressure and specific heat at constant volume for a diatomic gas is more than that for a monatomic gas.
Reason : The molecules of a monatomic gas have more degree of freedom than those of a diatomic gas.

8. Assertion : At room temperature, water does not sublimate from water to steam.
Reason : The critical point of water is much above the room temperature.

9. Assertion : Specific heat of a gas at constant pressure (*C*) is greater than its specific heat at constant volume (*C*).
Reason : At constant pressure, some heat is spent in expansion of the gas.

10. Assertion : The internal energy of a real gas is function of both, temperature and volume.
Reason : Internal kinetic energy depends on temperature and internal potential energy depends on volume.

11. Assertion : For an ideal gas, at constant temperature, the product of the pressure and volume is constant.
Reason : The mean square velocity of the molecules is inversely proportional to mass. [AIIMS 1998]

12. Assertion : If a gas container in motion is suddenly stopped, the temperature of the gas rises.
Reason : The kinetic energy of ordered mechanical motion is converted in to the kinetic energy of random motion of gas molecules.

13. Assertion : Internal energy of an ideal gas does not depend upon volume of the gas
Reason : Internal energy of ideal gas depends on temperature of gas.

14. Assertion : At low density, variables of gases *P, V* and *T* follows the equation $PV = \mu RT$
Reason : At low density real gases are more closely to ideal gases

15. Assertion : Maxwell speed distribution graph is symmetric about most probable speed
Reason : *rms* speed of ideal gas, depends upon it's type (monoatomic, diatomic and polyatomic)

Answers

Gas Laws

1	c	2	b	3	a	4	b	5	c
6	c	7	c	8	c	9	a	10	d
11	a	12	d	13	b	14	d	15	c
16	b	17	c	18	a	19	a	20	d
21	c	22	b	23	a	24	a	25	a
26	a	27	c	28	a	29	c	30	c
31	d	32	c	33	a	34	d	35	a
36	a	37	c	38	a	39	a	40	c
41	d	42	b	43	a	44	c	45	a
46	a	47	d	48	d	49	c	50	d
51	c	52	c	53	c	54	b	55	d
56	c	57	c	58	a	59	d	60	a
61	d	62	c	63	d	64	d	65	c
66	b	67	a	68	d	69	d	70	c
71	c	72	c	73	d	74	b	75	c
76	c	77	c	78	a	79	c	80	c
81	b	82	a	83	c	84	b	85	c
86	d	87	c	88	c	89	b	90	a
91	b	92	a	93	a	94	d	95	a
96	c	97	a	98	a	99	c	100	c

Speed of Gas

1	b	2	a	3	c	4	c	5	a
6	a	7	d	8	d	9	a	10	a
11	c	12	d	13	b	14	c	15	a

16	a	17	a	18	d	19	c	20	a
21	d	22	c	23	c	24	a	25	d
26	a	27	b	28	d	29	a	30	b
31	c	32	b	33	d	34	c	35	a
36	b	37	a	38	c	39	d	40	a
41	d	42	a	43	c	44	b	45	b
46	c	47	c	48	b	49	b	50	a
51	b	52	b	53	b	54	d	55	a
56	a	57	c	58	b	59	d	60	a
61	c	62	b	63	b	64	d	65	a
66	b	67	b	68	a				

Degree of Freedom and Specific Heat

1	a	2	c	3	a	4	a	5	c
6	d	7	c	8	b	9	d	10	d
11	c	12	a	13	b	14	d	15	a
16	a	17	a	18	a	19	b	20	a
21	c	22	b	23	c	24	d	25	b
26	d	27	d	28	a	29	b	30	d
31	a	32	c	33	a	34	c	35	a
36	d	37	a	38	a	39	b	40	c
41	b	42	b	43	b	44	d	45	b
46	c	47	c	48	d				

Pressure and Energy

1	c	2	b	3	c	4	d	5	d
6	d	7	d	8	a	9	a	10	b
11	d	12	c	13	c	14	a	15	d
16	d	17	b	18	b	19	c	20	a
21	c	22	b	23	b	24	c	25	a
26	b	27	d	28	d	29	c	30	d
31	a	32	a	33	c	34	c	35	d
36	c	37	a	38	b	39	ac	40	d
41	d	42	b	43	a	44	a	45	a
46	b	47	a	48	a	49	d	50	a
51	c	52	c	53	d	54	c	55	b
56	c	57	d	58	d	59	c	60	c
61	a	62	c	63	c	64	a		

Critical Thinking Questions

1	d	2	d	3	a	4	b	5	a
6	acd	7	b	8	b	9	cd	10	b
11	b	12	bc	13	d	14	d	15	a
16	c	17	d	18	b	19	d	20	d
21	a	22	c	23	b	24	a	25	c
26	c	27	c	28	c	29	d	30	d
31	d	32	b	33	a	34	a	35	d
36	c	37	c	38	d				

Graphical Questions

1	d	2	b	3	c	4	c	5	c
6	c	7	a	8	b	9	a	10	c
11	b	12	c	13	c	14	a	15	b
16	b	17	a	18	a	19	b	20	c
21	a	22	c	23	b	24	b	25	a

Assertion and Reason

1	a	2	b	3	e	4	d	5	b
6	e	7	d	8	a	9	a	10	a
11	b	12	a	13	b	14	a	15	d

Answers and Solutions

Gas Laws

1. (c) Using Charle's law $\frac{P_1}{P_2} = \frac{T_1}{T_2}$

or $P_2 = \frac{P_1 T_2}{T_1} = \frac{P(273+927)}{(273+27)} = 4P.$

2. (b) $\frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow T_2 = 2 \times T_1 = 2 \times (273+0) = 546K$

$\Rightarrow T_2 = 273 \times 2 = 546K \Rightarrow 273°C \Rightarrow 273° C$

Kinetic Theory of Gases

SET Self Evaluation Test -13

1. An ideal gas has an initial pressure of 3 pressure units and an initial volume of 4 volume units. The table gives the final pressure and volume of the gas (in those same units) in four, processes. Which processes start and end on the same isotherm

(a) A

(b) B

(c) C

(d) D

	A	B	C	D
P	5	4	12	6
V	7	6	1	3

2. Suppose ideal gas equation follows VP^3 = constant. Initial temperature and volume of the gas are T and V respectively. If gas expand to $27V$ then its temperature will be come

(a) T (b) $9T$

(c) $27T$ (d) $T/9$

3. One mole of a monoatomic ideal gas is mixed with one mole of a diatomic ideal gas. The molar specific heat of the mixture at constant volume is

(a) 8 (b) $\frac{3}{2}R$

(c) $2R$ (d) $2.5\ R$

4. When the temperature of a gas is raised from 27°C to 90°C, the percentage increase in the *r.m.s.* velocity of the molecules will be

(a) 10% (b) 15%

(c) 20% (d) 17.5%

5. A gas is enclosed in a closed pot. On keeping this pot in a train moving with high speed, the temperature of the gas

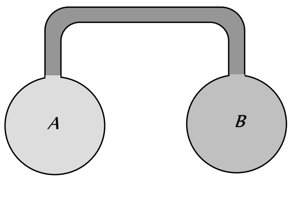
(a) Will increase

(b) Will decrease

(c) Will remain the same

(d) Will change according to the nature of the gas

6. Two spherical vessel of equal volume, are connected by *a n* arrow tube. The apparatus contains an ideal gas at one atmosphere and 300K. Now if one vessel is immersed in a bath of constant temperature 600K and the other in a bath of constant temperature 300K. Then the common pressure will be



(a) 1 *atm*

(b) $\frac{4}{5}$ *atm*

(c) $\frac{4}{3}$ *atm*

(d) $\frac{3}{4}$ *atm*

7. The *r.m.s.* velocity of a gas at a certain temperature is $\sqrt{2}$ times than that of the oxygen molecules at that temperature. The gas can be

(a) H_2 (b) *He*

(c) CH_4 (d) SO_2

8. At what temperature, the mean kinetic energy of O_2 will be the same for H_2 molecules at – 73°C

(a) 127°C (b) 527°C

(c) – 73°C (d) – 173°C

9. The volume of a gas at pressure $21\times10^4\ N/m^2$ and temperature 27°C is 83 *litres*. If R = 8.3 *J/mol/K*, then the quantity of gas in *gm-mole* will be

(a) 15 (b) 42

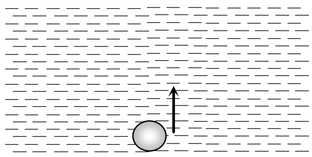
(c) 7 (d) 14

10. The pressure and temperature of an ideal gas in a closed vessel are 720 *kPa* and 40°C respectively. If $\frac{1}{4}$ th of the gas is released from the vessel and the temperature of the remaining gas is raised to 353°C, the final pressure of the gas is **[EAMCET (Med.) 2000]**

(a) 1440 *kPa* (b) 1080 *kPa*

(c) 720 *kPa* (d) 540 *kPa*

11. An air bubble doubles its radius on raising from the bottom of water reservoir to be the surface of water in it. If the atmospheric pressure is equal to 10 m of water, the height of water in the reservoir is **[EAMCET Med.1999]**



(a) 10 m

(b) 20 m

(c) 70 m

(d) 80 m

12. If the *r.m.s.* velocity of a gas at a given temperature (Kelvin scale) is 300 *m/sec*. What will be the *r.m.s.* velocity of a gas having twice the molecular weight and half the temperature on Kelvin scale =

(a) 300 *m/sec* (b) 600 *m/sec*

(c) 75 *m/sec* (d) 150 *m/sec*

13. The ratio of two specific heats $\frac{C_P}{C_V}$ of CO is

(a) 1.33 (b) 1.40

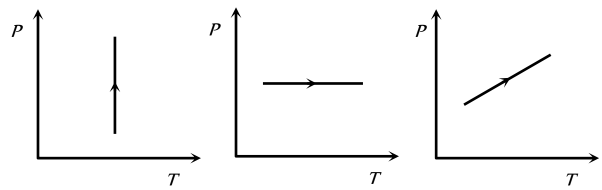
(c) 1.29 (d) 1.66

14. The energy of a *gas/litre* is 300 joules, then its pressure will be

(a) $3\times10^5\ N/m^2$ (b) $6\times10^5\ N/m^2$

(c) $10^5\ N/m^2$ (d) $2\times10^5\ N/m^2$

15. Pressure versus temperature graphs of an ideal gas are as shown in figure. Choose the wrong statement



(i) (ii) (iii)

(a) Density of gas is increasing in graph (i)

(b) Density of gas is decreasing in graph (ii)

(c) Density of gas is constant in graph (iii)

(d) None of these

16. If pressure of CO_2 (real gas) in a container is given by $P = \frac{RT}{2V-b} - \frac{a}{4b^2}$ then mass of the gas in container is

(a) 11 *gm* (b) 22 *gm*

(c) 33 *gm* (d) 44 *gm*

17. A cylinder of fixed capacity 44.8 *litre*. contains a monatomic gas at standard temperature and pressure. The amount of heat required to cylinder by 10°*C* will be.

(*R*= universal gas constant)

(a) *R* (b) 10*R*

(c) 20*R* (d) 30*R*

18. A pressure cooker contains air at 1 *atm* and 30°*C*. If the safety value of the cooler blows when the inside pressure ≥ 3 *atm*, then the maximum temperature of the air, inside the cooker can be

(a) 90°*C* (b) 636°*C*

(c) 909°*C* (d) 363°*C*

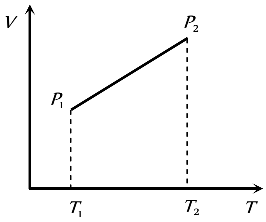
19. One mole of an ideal monatomic gas requires 210 *J* heat to raise the temperature by 10 *K*, when heated at constant temperature. If the same gas is heated at constant volume to raise the temperature by 10 *K* then heat required is

[Pb. PET 2000]

(a) 238 *J* (b) 126 *J*

(c) 210 *J* (d) 350 *J*

20. From the following *V-T* diagram we can conclude



(a) $P_1 = P_2$

(b) $P_1 > P_2$

(c) $P_1 < P_2$

(d) None of these

21. A cylinder contains 10 *kg* of gas at pressure of $10^7\ N/m^2$. The quantity of gas taken out of the cylinder, if final pressure is $2.5 \times 10^6\ N/m^2$, will be (Temperature of gas is constant)

[EAMCET 1998; Pb. PMT 1999; 2003; DPMT 199, 2003]

(a) 15.2 *kg* (b) 3.7 *kg*

(c) Zero (d) 7.5 *kg*

22. Certain amount of an ideal gas are contained in a closed vessel. The vessel is moving with a constant velocity *v*. The molecular mass of gas is *M*. The rise in temperature of the gas when the vessel is suddenly stopped is $(\gamma = C_P / C_V)$

(a) $\frac{Mv^2}{2R(\gamma+1)}$ (b) $\frac{Mv^2(\gamma-1)}{2R}$

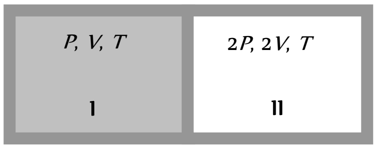
(c) $\frac{Mv^2}{2R(\gamma+1)}$ (d) $\frac{Mv^2}{2R(\gamma+1)}$

23. Air is filled at 60°*C* in a vessel of open mouth. The vessel is heated to a temperature *T* so that 1/4th part of air escapes. Assuming the volume of the vessel remaining constant, the value of *T* is

(a) 80°*C* (b) 444°*C*

(c) 333°*C* (d) 171°*C*

24. A partition divides a container having insulated walls into two compartments I and II. the same gas fills the two compartments. The ratio of the number of molecules in compartments I and II is



(a) 1 : 6

(b) 6 : 1

(c) 4 : 1

(d) 1 : 4

25. Considering the gases to be ideal, the value of $\gamma = \frac{C_P}{C_V}$ for a gaseous mixture consisting of = 3 moles of carbon dioxide and 2 moles of oxygen will be $(\gamma_{O_2} = 1.4, \gamma_{CO_2} = 1.3)$

[UPSEAT 2000; Pb. PET 2004]

(a) 1.37 (b) 1.34

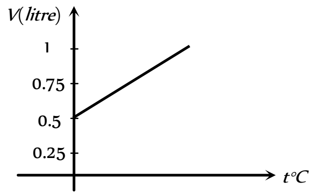
(c) 1.55 (d) 1.63

26. A jar has a mixture of hydrogen and oxygen gas in the ratio of 1 : 5. The ratio of mean kinetic energies of hydrogen and oxygen molecules is [CPMT 1977]

(a) 1 : 16 (b) 1 : 4

(c) 1 : 5 (d) 1 : 1

27. Graph between volume and temperature for a gas is shown in figure. If α = volume coefficient of gas = $\frac{1}{273}$ *per °C*, then what is the volume of gas at a temperature of 819°*C*



(a) $1 \times 10^{-3}\ m^3$

(b) $2 \times 10^{-3}\ m^3$

(c) $3 \times 10^{-3}\ m^3$

(d) $4 \times 10^{-3}\ m^3$

Answers and Solutions

(SET -13)

1. (c) For same isotherm ; $T \to$ constant

$\therefore\ P \propto \frac{1}{V} \Rightarrow P_1V_1 = P_2V_2$

2. (b) VP^3 = constant = $k \Rightarrow P = \frac{k}{V^{1/3}}$

Also $PV = \mu RT \Rightarrow \frac{k}{V^{1/3}}.V = \mu RT \Rightarrow V^{2/3} = \frac{\mu RT}{k}$

Hence $\left(\frac{V_1}{V_2}\right)^{2/3} = \frac{T_1}{T_2} \Rightarrow \left(\frac{V}{27V}\right)^{2/3} = \frac{T}{T_2} \Rightarrow T_2 = 9T$

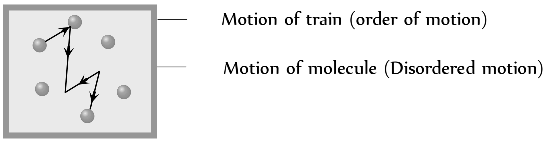
3. (c) $(C_V)_{mix} = \frac{\mu_1 C_{V_1} + \mu_2 C_{V_2}}{\mu_1 + \mu_2} = \frac{1 \times \frac{3}{2}R + 1 \times \frac{5}{2}R}{1+1} = 2R$

$\left((C_V)_{mono} = \frac{3}{2}R,\ (C_V)_{di} = \frac{5}{2}R\right)$

4. (a) $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{(273+90)}{(273+30)}} = 1.1$

% increase $= \left(\frac{v_2}{v_1} - 1\right) \times 100 = 0.1 \times 100 = 10\%$

5. (c) Temperature of the gas is concerned only with it's disordered motion. It is no way concerned with it's ordered motion.



6. (c) $\mu = \mu_1 + \mu_2$

$$\frac{P(2V)}{RT_1} = \frac{P'v}{RT_1} + \frac{P'V}{RT_2} \Rightarrow \frac{2P}{RT_1} = \frac{P'}{R}\left[\frac{T_2 + T_1}{T_1 T_2}\right]$$

$$P' = \frac{2PT_2}{(T_1 + T_2)} = \frac{2 \times 1 \times 600}{(300 + 600)} = \frac{4}{3} atm$$

7. (c) $v_{rms} \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{M_2}{M_1}}$

$\therefore \frac{1}{\sqrt{2}} = \sqrt{\frac{M_2}{32}} \Rightarrow M_2 = 16$. Hence the gas is CH_4.

8. (c) Mean kinetic energy of molecule depends upon temperature only. For O_2 it is same as that of H_2 at the same temperature of $-73°C$.

9. (c) $PV = \mu RT \Rightarrow \mu = \frac{PV}{RT} = \frac{21 \times 10^4 \times 83 \times 10^{-3}}{8.3 \times 300} = 7$

10. (b) $P_1 = 720 kpa, \ T_1 = 40°C = 273 + 40 = 313K$

$$P \propto mT \Rightarrow \frac{P_2}{P_1} = \frac{m_2}{m_1}\frac{T_2}{T_1} = \frac{3}{4} \times \frac{626}{313} = 1.5$$

$$\Rightarrow P_2 = 1.5P_1 = 1.5 \times 720 = 1080 kPa$$

11. (c) According to Boyle's law $(P_1V_1)_{\text{bottom}} = (P_2V_2)_{\text{top}}$

$(10 + h) \times \frac{4}{3}\pi r_1^3 = 10 \times \frac{4}{3}\pi r_2^3$ but $r_2 = 2r_1$

$\therefore (10 + h)r_1^3 = 10 \times 8r_1^3 \Rightarrow 10 + h = 80 \ \therefore h = 70m$

12. (d) $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms} \propto \sqrt{\frac{T}{M}}$

$$\frac{v_2}{v_1} = \sqrt{\frac{M_1}{M_2} \times \frac{T_2}{T_1}} = \sqrt{\frac{1}{2} \times \frac{1}{2}} \Rightarrow v_2 = \frac{v_1}{2} = \frac{300}{2} = 150 \text{ m/sec}$$

13. (bc) *Co* is diatomic gas, for diatomic gas

$$C_P = \frac{7}{2}R \text{ and } C_V = \frac{5}{2}R \Rightarrow \gamma_{di} = \frac{C_P}{C_V} = \frac{7R/2}{5R/2} = 1.4$$

14. (d) Energy $= 300 J/litre = 300 \times 10^3 J/m^3$

$$P = \frac{2}{3}E = \frac{2 \times 300 \times 10^3}{3} = 2 \times 10^5 N/m^2$$

15. (c) $\rho = \frac{PM}{RT}$

Density ρ remains constant when P/T or volume remains constant.

In graph (i) Pressure is increasing at constant temperature hence volume is decreasing so density is increasing. Graphs (ii) and (iii) volume is increasing hence, density is decreasing. Note that volume would had been constant in case the straight line in graph (iii) had passed through origin.

16. (b) Vander wall's gas equation for μ mole of real gas

$$\left(P + \frac{\mu^2 a}{V^2}\right)(V - \mu b) = \mu RT \Rightarrow P = \frac{\mu RT}{V - \mu b} - \frac{\mu^2 a}{V^2}$$

on comparing the given equation with this standard equation we get $\mu = \frac{1}{2}$. Hence $\mu = \frac{m}{M} \Rightarrow$ mass of gas

$$m = \mu m = \frac{1}{2} \times 44 = 22gm.$$

17. (d) As we know 1 *mol* of any ideal gas at *STP* occupies a volume of 22.4 *litres*.

Hence number of moles of gas $\mu = \frac{44.8}{22.4} = 2$

Since the volume of cylinder is fixed,

Hence $(\Delta Q)_V = \mu \omega \Delta T$

$$= 2 \times \frac{3}{2}R \times 10 = 30R \qquad \left(\because (C_V)_{mono} = \frac{3}{2}R\right)$$

18. (b) Since volume is constant,

Hence $\frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{1}{3} = \frac{(273+30)}{T_2}$

$$\Rightarrow T_2 = 909K = 636°C$$

19. (b) $(\Delta Q)_P = \mu C_P \Delta T$ and $(\Delta Q)_V = \mu C_V \Delta T$

$$\Rightarrow \frac{(\Delta Q)_V}{(\Delta Q)_P} = \frac{C_V}{C_P} = \frac{\frac{3}{2}R}{\frac{5}{2}R} = \frac{3}{5}$$

$$\left[\because (C_V)_{mono} = \frac{3}{2}R, (C_P)_{mono} = \frac{5}{2}R\right]$$

$$\Rightarrow (\Delta Q)_V = \frac{3}{5} \times (\Delta Q)_P = \frac{3}{5} \times 210 = 126 J$$

20. (b) In case of given graph, V and T are related as $V = aT - b$, where a and b are constants.

From ideal gas equation, $PV = \mu RT$

We find $P = \frac{\mu RT}{aT - b} = \frac{\mu R}{a - b/T}$

Since $T_2 > T_1$, therefore $P_2 < P_1$.

21. (d) $PV = mrT \Rightarrow P \propto m \qquad [\because V, r, T \rightarrow \text{constant}]$

$$\Rightarrow \frac{m_1}{m_2} = \frac{P_1}{P_2} \Rightarrow \frac{10}{m_2} = \frac{10^7}{2.5 \times 10^6} \Rightarrow m_2 = 2.5 \ kg.$$

Hence mass of the gas taken out of the cylinder

$$= 10 - 2.5 = 7.5kg.$$

22. (b) If m is the total mass of the gas then its kinetic energy $= \frac{1}{2}mv^2$

When the vessel is suddenly stopped then total kinetic energy will increase the temperature of the gas. Hence

$$\frac{1}{2}mv^2 = \mu C_v \Delta T = \frac{m}{M}C_v\Delta T \qquad \left[\text{As } C_v = \frac{R}{\gamma - 1}\right]$$

$$\Rightarrow \frac{m}{M}\frac{R}{\gamma-1}\Delta T = \frac{1}{2}mv^2 \Rightarrow \Delta T = \frac{Mv^2(\gamma-1)}{2R}.$$

23. (d) For open mouth vessel, pressure is constant.
Volume is also given constant

Hence from $PV = \mu RT = \left(\frac{m}{M}\right)RT \Rightarrow T \propto \frac{1}{m} \Rightarrow \frac{T_1}{T_2} = \frac{m_2}{m_1}$

$\because$ $\frac{1}{4}th$ part escapes, so remaining mass in the vessel

$$m_2 = \frac{3}{4}m_1 \Rightarrow \frac{(273+60)}{T} = \frac{3/4\, m_1}{m_1}$$

$\Rightarrow T = 444K = 171°C$

24. (d) $n = \frac{PV}{kT}$ Now, $n' = \frac{(2P)(2V)}{kT} = 4\frac{PV}{kT} = 4n$ or $\frac{n}{n'} = \frac{1}{4}$.

25. (b) $$\gamma_{\text{mix}} = \frac{\frac{\mu_1\gamma_1}{\gamma_1 - 1} + \frac{\mu_2\gamma_2}{\gamma_2 - 1}}{\frac{\mu_1}{\gamma_1 - 1} + \frac{\mu_2}{\gamma_2 - 1}} = \frac{\frac{3\times 1.3}{(1.3-1)} + \frac{2\times 1.4}{(1.4-1)}}{\frac{3}{(1.3-1)} + \frac{2}{(1.4-1)}} = 1.33$$

26. (d) In mixture gases will acquire thermal equilibrium (*i.e.*, same temperature) so their kinetic energies will also be same.

27. (b) $V_t = V_0(1+\alpha t) = 0.5\left(1 + \frac{1}{273}\times 819\right) = 2$ *litre* $= 2\times 10^{-3}\ m^3$

Chapter

14

Thermodynamics

Thermodynamics is a branch of science which deals with exchange of heat energy between bodies and conversion of the heat energy into mechanical energy and vice-versa.

Some Definitions

(1) **Thermodynamic system**

(i) It is a collection of an extremely large number of atoms or molecules

(ii) It is confined with in certain boundaries.

(iii) Anything outside the thermodynamic system to which energy or matter is exchanged is called its surroundings.

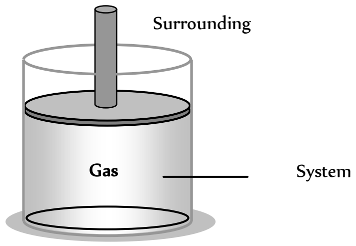


Fig. 14.1

(iv) Thermodynamic system may be of three types

(a) Open system : It exchange both energy and matter with the surrounding.

(b) Closed system : It exchange only energy (not matter) with the surroundings.

(c) Isolated system : It exchange neither energy nor matter with the surrounding.

(2) **Thermodynamic variables and equation of state :** A thermodynamic system can be described by specifying its pressure, volume, temperature, internal energy and the number of moles. These parameters are called thermodynamic variables. The relation between the thermodynamic variables (P, V, T) of the system is called equation of state.

For μ moles of an ideal gas, equation of state is $PV = \mu RT$ and for 1 mole of an it ideal gas is $PV = RT$

(3) **Thermodynamic equilibrium :** In steady state thermodynamic variables are independent of time and the system is said to be in the state of thermodynamic equilibrium. For a system to be in thermodynamic equilibrium, the following conditions must be fulfilled.

(i) Mechanical equilibrium : There is no unbalanced force between the system and its surroundings.

(ii) Thermal equilibrium : There is a uniform temperature in all parts of the system and is same as that of surrounding.

(iii) Chemical equilibrium : There is a uniform chemical composition through out the system and the surrounding.

(4) **Thermodynamic process :** The process of change of state of a system involves change of thermodynamic variables such as pressure P, volume V and temperature T of the system. The process is known as thermodynamic process. Some important processes are

(i) Isothermal process : Temperature remain constant

(ii) Adiabatic process : No transfer of heat

(iii) Isobaric process : Pressure remains constant

(iv) Isochoric (isovolumic process) : Volume remains constant

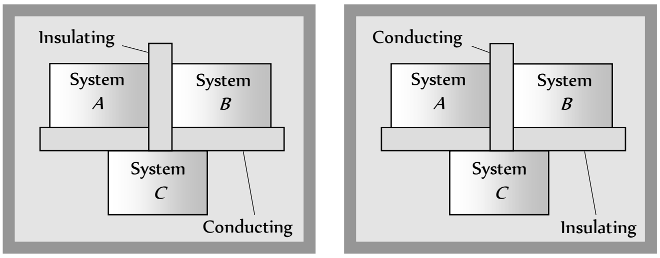
(v) Cyclic and non-cyclic process : Incyclic process Initial and final states are same while in non-cyclic process these states are different.

(vi) Reversible and irreversible process :

(5) **Indicator diagram :** Whenever the state of a gas (*P*, *V*, *T*) is changed, we say the gaseous system is undergone a thermodynamic process. The graphical representation of the change in state of a gas by a thermodynamic process is called indicator diagram. Indicator diagram is plotted generally in pressure and volume of gas.

Zeroth Law of Thermodynamics

If systems *A* and *B* are each in thermal equilibrium with a third system *C*, then *A* and *B* are in thermal equilibrium with each other.



(A) (B)

Fig. 14.3

(1) The zeroth law leads to the concept of temperature. All bodies in thermal equilibrium must have a common property which has the same value for all of them. This property is called the temperature.

(2) The zeroth law came to light long after the first and seconds laws of thermodynamics had been discovered and numbered. It is so named because it logically precedes the first and second laws of thermodynamics.

Heat, Internal Energy and Work in Thermodynamics

(1) **Heat (ΔQ) :** It is the energy that is transferred between a system and its environment because of the temperature difference between them.

(i) Heat is a path dependent quantity *e.g.* Heat required to change the temperature of a given gas at a constant pressure is different from that required to change the temperature of same gas through same amount at constant volume.

(ii) For gases when heat is absorbed and temperature changes $\Rightarrow$ $\Delta Q = \mu C \Delta T$

At constant pressure $(\Delta Q)_P = \mu C_P \Delta T$

At constant volume $(\Delta Q)_V = \mu C_V \Delta T$

(2) **Internal energy (U) :** Internal energy of a system is the energy possessed by the system due to molecular motion and molecular configuration.

The energy due to molecular motion is called internal kinetic energy U_K and that due to molecular configuration is called internal potential energy U_P *i.e.* Total internal energy $U = U_K + U_P$

(i) For an ideal gas, as there is no molecular attraction $U_p = 0$

i.e. internal energy of an ideal gas is totally kinetic and is given by $U = U_K = \frac{3}{2}\mu RT$ and change in internal energy $\Delta U = \frac{3}{2}\mu R\,\Delta T$

(ii) In case of gases whatever be the process

$$\Delta U = \mu\frac{f}{2}R\Delta T = \mu C_V \Delta T = \mu\frac{R}{(\gamma-1)}\Delta T = \frac{\mu R(T_f - T_i)}{\gamma - 1}$$

$$= \frac{\mu RT_f - \mu RT_i}{\gamma - 1} = \frac{(P_f V_f - P_i V_i)}{\gamma - 1}$$

(iii) Change in internal energy does not depend on the path of the process. So it is called *a* point function *i.e.* it depends only on the initial and final states of the system, *i.e.* $\Delta U = U_f - U_i$

(3) **Work (ΔW) :** Suppose a gas is confined in a cylinder that has a movable piston at one end. If *P* be the pressure of the gas in the cylinder, then force exerted by the gas on the piston of the cylinder *F* = *PA* (*A* = Area of cross-section of piston)

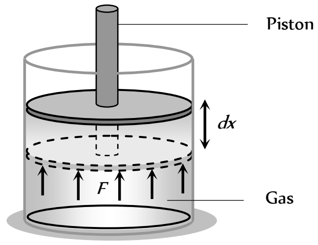


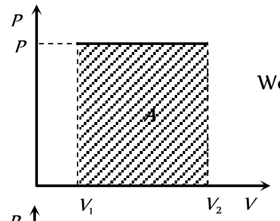
Fig. 14.4

When the piston is pushed outward an infinitesimal distance *dx*, the work done by the gas $dW = F.dx = P(A\,dx) = P\,dV$

For a finite change in volume from V_i to V_f

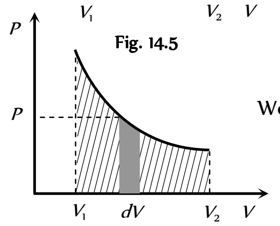
Total amount of work done $W = \int_{Vi}^{V_f} P\,dV = P(V_f - V_i)$

(i) If we draw indicator diagram, the area bounded by *PV*-graph and volume axis represents the work done



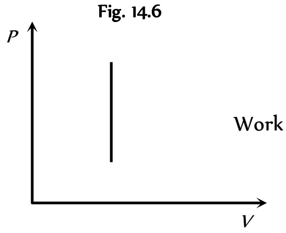
Work = Area = $P(V_2 - V_1)$

Fig. 14.5



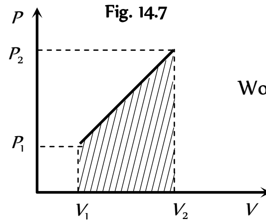
Work $= \int_{V_1}^{V_2} PdV = P(V_2 - V_1)$

Fig. 14.6



Work = 0

Fig. 14.7



Work = Area of the shown trapezium

$= \frac{1}{2}(P_1 + P_2)(V_2 - V_1)$

Fig. 14.8

(ii) From $\Delta W = P\Delta V = P(V_f - V_i)$

If system expands against some external force then $V_f > V_i$

$\Rightarrow$ ΔW = positive

If system contracts because of external force then $V_f < V_i$

$\Rightarrow$ ΔW = negative

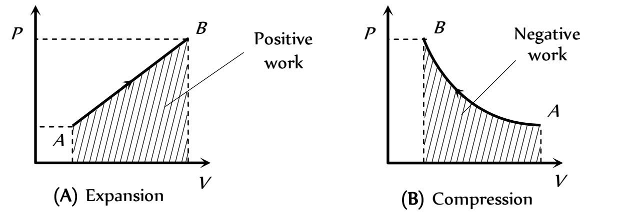
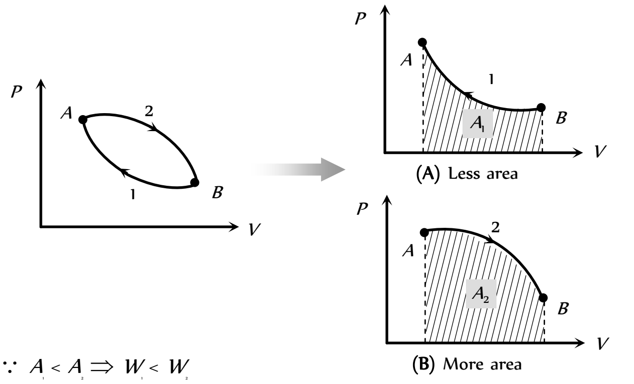


Fig. 14.9

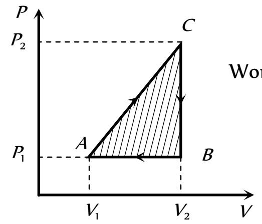
(iii) Like heat, work done is also depends upon initial and final state of the system and path adopted for the process



$\because$ $A_1 < A_2 \Rightarrow W_1 < W_2$

Fig. 14.10

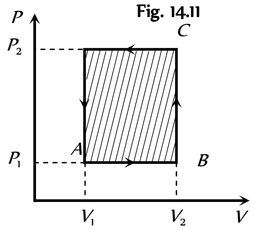
(iv) In cyclic process, work done is equal to the area of closed curve. It is positive if the cycle is clockwise and it is negative if the cycle is anticlockwise.



Work = Area of triangle *ABC*

$$= \frac{1}{2} \times (V_2 - V_1) \times (P_2 - P_1)$$

Fig. 14.11

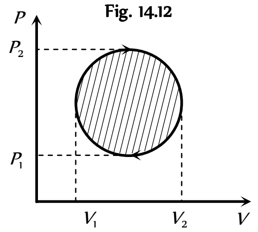


Work = Area of rectangle *ABCD*

= $AB \times AD$

= $(V_2 - V_1)\,(P_2 - P_1)$

Fig. 14.12



Work = $\frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$

Fig. 14.13

First Law of Thermodynamics (FLOT)

(1) It is a statement of conservation of energy in thermodynamical process.

(2) According to it heat given to a system (ΔQ) is equal to the sum of increase in its internal energy (ΔU) and the work done (ΔW) by the system against the surroundings.

$$\Delta Q = \Delta U + \Delta W$$

(3) It makes no distinction between work and heat as according to it the internal energy (and hence temperature) of a system may be increased either by adding heat to it or doing work on it or both.

(4) ΔQ and ΔW are the path functions but ΔU is the point function.

(5) In the above equation all three quantities ΔQ, ΔU and ΔW must be expressed either in *Joule* or in *calorie*.

(6) The first law introduces the concept of internal energy.

(7) Limitation : First law of thermodynamics does not indicate the direction of heat transfer. It does not tell anything about the conditions, under which heat can be transformed into work and also it does not indicate as to why the whole of heat energy cannot be converted into mechanical work continuously.

Table 14.1 : Useful sign convention in thermodynamics

Quantity	Sign	Condition
ΔQ	+	When heat is supplied to a system
	–	When heat is drawn from the system
ΔW	+	When work done by the gas (expansion)
	–	When work done on the gas (compression)
ΔU	+	With temperature rise, internal energy increases
	–	With temperature fall, internal energy decreases

Isobaric Process

When a thermodynamic system undergoes a physical change in such a way that its pressure remains constant, then the change is known as isobaric process.

(1) **Equation of state :** In this process V and T changes but P remains constant. Hence Charle's law is obeyed in this process.

Hence if pressure remains constant $V \propto T \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

(2) **Indicator diagram :** Graph 1 represent isobaric expansion, graph 2 represent isobaric compression.

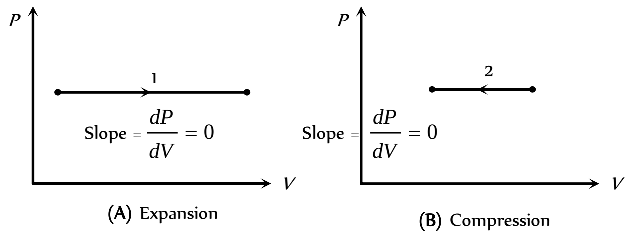


Fig. 14.14

(i) In isobaric expansion (Heating)

Temperature $\longrightarrow$ increases so ΔU is positive

Volume $\longrightarrow$ increases so ΔW is positive

Heat $\longrightarrow$ flows into the system so ΔQ is positive

(ii) In isobaric compression (Cooling)

Temperature $\longrightarrow$ decreases so ΔU is negative

Volume $\longrightarrow$ decreases so ΔW is negative

Heat $\longrightarrow$ flows out from the system so ΔQ is negative

(3) **Specific heat :** Specific heat of gas during isobaric process $C_P = \left(\frac{f}{2}+1\right)R$

(4) **Bulk modulus of elasticity :** $K = \frac{\Delta P}{-\Delta V / V} = 0$ [As $\Delta P = 0$]

(5) **Work done in isobaric process**

$$\Delta W = \int_{V_i}^{V_f} P\,dV = P\int_{V_i}^{V_f} dV = P[V_f - V_i] \qquad \text{[As } P = \text{constant]}$$

$$\Rightarrow \Delta W = P(V_f - V_i) = \mu R[T_f - T_i] = \mu R\,\Delta T$$

(6) **FLOT in isobaric process :** From $\Delta Q = \Delta U + \Delta W$

$$\because \Delta U = \mu C_V\,\Delta T = \mu\frac{R}{(\gamma-1)}\Delta T \text{ and } \Delta W = \mu R\,\Delta T$$

$$\Rightarrow (\Delta Q)_P = \mu\frac{R}{(\gamma-1)}\Delta T + \mu R\,\Delta T = \mu\left(\frac{\gamma}{\gamma-1}\right)R\,\Delta T = \mu C_P\,\Delta T$$

(7) **Examples of isobaric process :** All state changes occurs at constant temperature and pressure.

Boiling of water

(i) Water $\longrightarrow$ vapours

(ii) Temperature $\longrightarrow$ constant

(iii) Volume $\longrightarrow$ increases

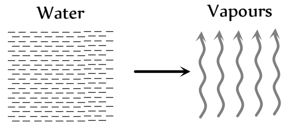


Fig. 14.15

(iv) A part of heat supplied is used to change volume (expansion) against external pressure and remaining part is used to increase it's potential energy (kinetic energy remains constant)

(v) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow mL = \Delta U + P(V_f - V_i)$

Freezing of water

(i) Water $\longrightarrow$ ice

(ii) Temperature $\longrightarrow$ constant

(iii) Volume $\longrightarrow$ increases

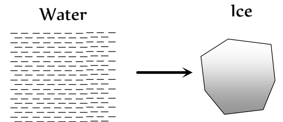


Fig. 14.16

(iv) Heat is given by water it self. It is used to do work against external atmospheric pressure and to decreases the internal potential energy.

(v) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow -mL = \Delta U + P(V_f - V_i)$

Isochoric or Isometric Process

When a thermodynamic process undergoes a physical change in such a way that its volume remains constant, then the change is known as isochoric process.

(1) **Equation of state :** In this process P and T changes but V = constant. Hence Gay-Lussac's law is obeyed in this process *i.e.* $P \propto T \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$

(2) **Indicator diagram :** Graph 1 and 2 represent isometric increase in pressure at volume V_1 and isometric decrease in pressure at volume V_2 respectively and slope of indicator diagram $\frac{dP}{dV} = \infty$

(i) Isometric heating

(a) Pressure $\longrightarrow$ increases

(b) Temperature $\longrightarrow$ increases

(c) $\Delta Q \longrightarrow$ positive

(d) $\Delta U \longrightarrow$ positive

(ii) Isometric cooling

(a) Pressure $\longrightarrow$ decreases

(b) Temperature $\longrightarrow$ decreases

(c) $\Delta Q \longrightarrow$ negative

(d) $\Delta U \longrightarrow$ negative

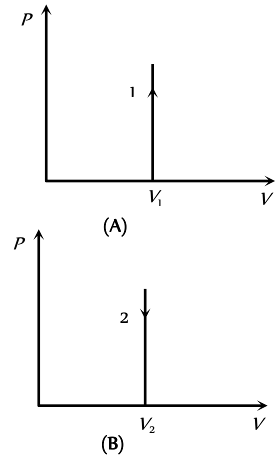


Fig. 14.17

(3) **Specific heat :** Specific heat of gas during isochoric process $C_V = \frac{f}{2}R$

(4) **Bulk modulus of elasticity :** $K = \frac{\Delta P}{-\Delta V / V} = \frac{\Delta P}{0} = \infty$

(5) **Work done in isochoric process**

$\Delta W = P\Delta V = P[V_f - V_i] = 0$ [As V = constant]

(6) **FLOT in isochoric process :** From $\Delta Q = \Delta U + \Delta W$

$$\because \Delta W = 0 \Rightarrow (\Delta Q)_V = \Delta U = \mu C_V\,\Delta T = \mu\frac{R}{\gamma-1}\Delta T = \frac{P_fV_f - P_iV_i}{\gamma-1}$$

Isothermal Process

When a thermodynamic system undergoes a physical change in such a way that its temperature remains constant, then the change is known as isothermal changes.

(1) **Essential condition for isothermal process**

(i) The walls of the container must be perfectly conducting to allow free exchange of heat between the gas and its surrounding.

(ii) The process of compression or expansion should be so slow so as to provide time for the exchange of heat.

Since these two conditions are not fully realised in practice, therefore, no process is perfectly isothermal.

(2) **Equation of state :** In this process, P and V change but T = constant *i.e.* change in temperature $\Delta T = 0$.

Boyle's law is obeyed *i.e.* PV = constant $\Rightarrow P_1V_1 = P_2V_2$

(3) **Example of isothermal process :** Melting of ice (at 0°*C*) and boiling of water (at 100°*C*) are common example of this process.

(4) **Indicator diagram :** According to PV = constant, graph between P and V is a part of rectangular hyperbola. The graphs at different temperature are parallel to each other are called isotherms.

$T_1 < T_2 < T_3$

Two isotherms never intersect

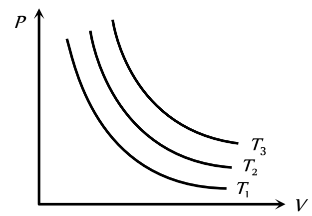


Fig. 14.18

(i) Slope of isothermal curve : By differentiating PV = constant. We get

$$P\,dV + V\,dP = 0$$

$$\Rightarrow PdV = -VdP$$

$$\Rightarrow \text{Slope} = \tan\theta = \frac{dP}{dV} = -\frac{P}{V}$$

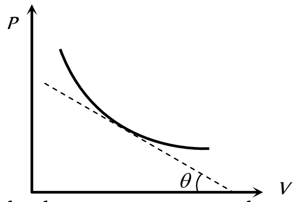


Fig. 14.19

(ii) Area between the isotherm and volume axis represents the work done in isothermal process.

If volume increases ΔW = + (Area under curve) and if volume decreases ΔW = – (Area under curve)

(5) **Specific heat :** Specific heat of gas during isothermal change is infinite. As $C = \frac{Q}{m\Delta T} = \frac{Q}{m \times 0} = \infty$ [As ΔT = 0]

(6) **Isothermal elasticity (E_θ) :** For this process PV = constant.

$$\Rightarrow P\,dV = -V\,dP \Rightarrow P = \frac{dP}{-dV/V} = \frac{\text{Stress}}{\text{Strain}} = E_\theta$$

$\Rightarrow E_\theta = P$ *i.e.* isothermal elasticity is equal to pressure

At N.T.P., E_θ = Atmospheric pressure = $1.01 \times 10^5\ N/m^2$

(7) **Work done in isothermal process**

$$W = \int_{V_i}^{V_f} P\,dV = \int_{V_i}^{V_f} \frac{\mu RT}{V}\,dV \qquad [\text{As } PV = \mu RT]$$

$$W = \mu RT \log_e\left(\frac{V_f}{V_i}\right) = 2.303\ \mu RT \log_{10}\left(\frac{V_f}{V_i}\right)$$

or $$W = \mu RT \log_e\left(\frac{P_i}{P_f}\right) = 2.303 \mu RT \log_{10}\left(\frac{P_i}{P_f}\right)$$

(8) **FLOT in isothermal process :** From $\Delta Q = \Delta U + \Delta W$

$\because\ \Delta U = 0$ [As ΔT = 0] $\Rightarrow \Delta Q = \Delta W$

i.e. heat supplied in an isothermal change is used to do work against external surrounding.

or if the work is done on the system than equal amount of heat energy will be liberated by the system.

Adiabatic Process

When a thermodynamic system undergoes a change in such a way that no exchange of heat takes place between System and surroundings, the process is known as adiabatic process.

In this process P, V and T changes but ΔQ = 0.

(1) **Essential conditions for adiabatic process**

(i) There should not be any exchange of heat between the system and its surroundings. All walls of the container and the piston must be perfectly insulating.

(ii) The system should be compressed or allowed to expand suddenly so that there is no time for the exchange of heat between the system and its surroundings.

Since, these two conditions are not fully realised in practice, so no process is perfectly adiabatic.

(2) **Some examples of adiabatic process**

(i) Sudden compression or expansion of a gas in a container with perfectly non-conducting walls.

(ii) Sudden bursting of the tube of bicycle tyre.

(iii) Propagation of sound waves in air and other gases.

(iv) Expansion of steam in the cylinder of steam engine.

(3) **FLOT in adiabatic process :** From $\Delta Q = \Delta U + \Delta W$

For adiabatic process $\Delta Q = 0 \Rightarrow \Delta U = -\Delta W$

If ΔW = positive then ΔU = negative so temperature decreases *i.e.* adiabatic expansion produce cooling.

If ΔW = negative then ΔU = positive so temperature increases *i.e.* adiabatic compression produce heating.

(4) **Equation of state :** In adiabatic change ideal gases do not obeys Boyle's law but obeys Poisson's law. According to it

PV^γ **= constant**; where $\gamma = \frac{C_P}{C_V}$

(i) For temperature and volume

$TV^{\gamma-1}$ = constant $\Rightarrow T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$ or $T \propto V^{1-\gamma}$

(ii) For temperature and pressure

$\frac{T^\gamma}{P^{\gamma-1}}$ = const. $\Rightarrow T_1^\gamma P_1^{1-\gamma} = T_2^\gamma P_2^{1-\gamma}$ or $T \propto P^{\frac{\gamma-1}{\gamma}}$ or $P \propto T^{\frac{\gamma}{\gamma-1}}$

Table 14.2 : Special cases of adiabatic process

Type of gas	$P \propto \frac{1}{V^\gamma}$	$P \propto T^{\frac{\gamma}{\gamma-1}}$	$T \propto \frac{1}{V^{\gamma-1}}$
Monoatomic γ = 5/3	$P \propto \frac{1}{V^{5/3}}$	$P \propto T^{5/2}$	$T \propto \frac{1}{V^{2/3}}$
Diatomic γ = 7/5	$P \propto \frac{1}{V^{7/5}}$	$P \propto T^{7/2}$	$T \propto \frac{1}{V^{2/5}}$
Polyatomic γ = 4/3	$P \propto \frac{1}{V^{4/3}}$	$P \propto T^4$	$T \propto \frac{1}{V^{1/3}}$

(5) **Indicator diagram**

(i) Curve obtained on PV graph are called adiabatic curve.

(ii) Slope of adiabatic curve : From PV^γ = constant

By differentiating, we get

$$dP\,V^\gamma + P\gamma V^{\gamma-1}\,dV = 0$$

$$\frac{dP}{dV} = -\gamma \frac{PV^{\gamma-1}}{V^\gamma} = -\gamma\left(\frac{P}{V}\right)$$

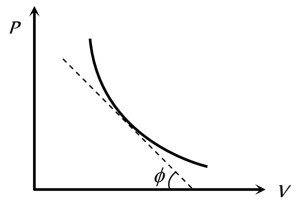


Fig. 14.20

$\therefore$ Slope of adiabatic curve $\tan\phi = -\gamma\left(\frac{P}{V}\right)$

(iii) But we also know that slope of isothermal curve $\tan\theta = \frac{-P}{V}$

Hence $(\text{Slope})_{Adi} = \gamma \times (\text{Slope})_{Iso}$ or $\frac{(\text{Slope})_{Adi}}{(\text{Slope})_{Iso}} > 1$

(6) **Specific heat :** Specific heat of a gas during adiabatic change is zero As $C = \frac{Q}{m\Delta T} = \frac{0}{m\Delta T} = 0$ [As $Q = 0$]

(7) **Adiabatic elasticity (E_ϕ) :** PV^γ = constant

Differentiating both sides $d\,PV^\gamma + P\gamma V^{\gamma-1}dV = 0$

$$\gamma P = \frac{dP}{-dV/V} = \frac{\text{Stress}}{\text{Strain}} = E_\phi \Rightarrow E_\phi = \gamma P$$

i.e. adiabatic elasticity is γ times that of pressure

Also isothermal elasticity $E_\theta = P \Rightarrow \frac{E_\phi}{E_\theta} = \gamma = \frac{C_P}{C_V}$

i.e. the ratio of two elasticity of gases is equal to the ratio of two specific heats.

(8) **Work done in adiabatic process**

$$W = \int_{V_i}^{V_f} P\,dV = \int_{V_i}^{V_f} \frac{K}{V^\gamma}dV \Rightarrow W = \frac{[P_iV_i - P_fV_f]}{(\gamma-1)} = \frac{\mu R(T_i - T_f)}{(\gamma-1)}$$

(As $PV^\gamma = K$, $P_iV_i = \mu RT_i$ and $P_fV_f = \mu RT_f$)

(i) $W \propto$ quantity of gas (either M or μ)

(ii) $W \propto$ temperature difference $(T_i - T_f)$

(iii) $W \propto \frac{1}{\gamma - 1}$ $\because \gamma_{mono} > \gamma_{di} > \gamma_{tri} \Rightarrow W_{mono} < W_{di} < W_{tri}$

(9) **Comparison between isothermal and adiabatic indicator diagrams :** Always remember that adiabatic curves are more steeper than isothermal curves

(i) Equal expansion : Graph 1 represent isothermal process and 2 represent adiabatic process

$W_{isothermal} > W_{adiabatic}$

$P_{isothermal} > P_{adiabatic}$

$T_{isothermal} > T_{adiabatic}$

$(\text{Slope})_{isothermal} < (\text{Slope})_{Adiabatic}$

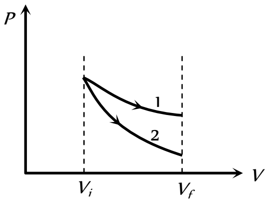


Fig. 14.21

(ii) Compression : Graph 1 represent adiabatic process and 2 represent isothermal process

$W_{Adiabatic} > W_{Isothermal}$

$P_{Adiabatic} > P_{Isothermal}$

$T_{Adiabatic} > T_{Isothermal}$

$(\text{Slope})_{Isothermal} < (\text{Slope})_{Adiabatic}$

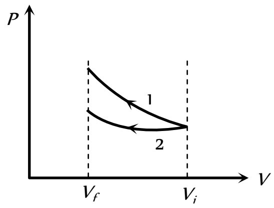


Fig. 14.22

(10) **Free expansion :** Free expansion is adiabatic process in which no work is performed on or by the system. Consider two vessels placed in a system which is enclosed with thermal insulation (asbestos-covered). One vessel contains a gas and the other is evacuated. When suddenly the stopcock is opened, the gas rushes into the evacuated vessel and expands freely.

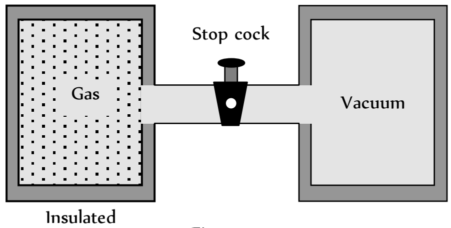


Fig. 14.23

$\Delta W = 0$ (Because walls are rigid)

$\Delta Q = 0$ (Because walls are insulated)

$\Delta U = U_f - U_i = 0$ (Because ΔQ and ΔW are zero. Thus the final and initial energies are equal in free expansion.

Cyclic and Non-cyclic Process

A cyclic process consists of a series of changes which return the system back to its initial state.

In non-cyclic process the series of changes involved do not return the system back to its initial state.

(1) In case of cyclic process as $U_f = U_i \Rightarrow \Delta U = U_f - U_i = 0$

i.e. change in internal energy for cyclic process is zero and also $\Delta U \propto \Delta T \Rightarrow \Delta T = 0$ *i.e.* temperature of system remains constant.

(2) From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$

i.e. heat supplied is equal to the work done by the system.

(3) For cyclic process *P-V* graph is a closed curve and area enclosed by the closed path represents the work done.

If the cycle is clockwise work done is positive and if the cycle is anticlockwise work done is negative.

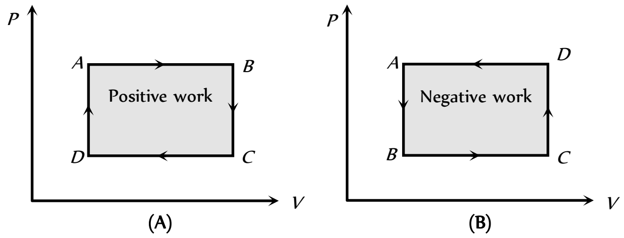


Fig. 14.24

(4) Work done in non cyclic process depends upon the path chosen or the series of changes involved and can be calculated by the area covered between the curve and volume axis on *PV* diagram.

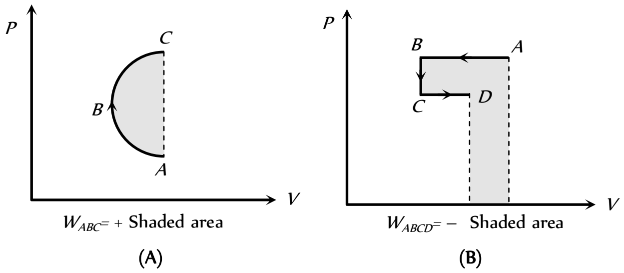


Fig. 14.25

Quasi Static Process

When we perform a process on a given system, its state is, in general, changed. Suppose the initial state of the system is described by the values P_1, V_1, T_1 and the final state by P_2, V_2, T_2. If the process is performed in such a way that at any instant during the process, the system is very nearly in thermodynamic equilibrium, the process is called quasi-static. This means, we can specify the parameters *P*, *V*, *T* uniquely at any instant during such a process.

Actual processes are not quasi-static. To change the pressure of a gas, we can move a piston inside the enclosure. The gas near the piston is acted upon by piston. The pressure of the gas may not be uniform everywhere while the piston is moving. However, we can move the piston very slowly to make the process as close to quasi-static as we wish. Thus, a quasi-static process is an idealised process in which all changes take place infinitely slowly.

Reversible and Irreversible Process

(1) **Reversible process :** A reversible process is one which can be reversed in such a way that all changes occurring in the direct process are exactly repeated in the opposite order and inverse sense and no change is left in any of the bodies taking part in the process or in the surroundings. For example if heat is absorbed in the direct process, the same amount of heat should be given out in the reverse process, if work is done on the working substance in the direct process then the same amount of work should be done by the working substance in the reverse process. The conditions for reversibility are

(i) There must be complete absence of dissipative forces such as friction, viscosity, electric resistance etc.

(ii) The direct and reverse processes must take place infinitely slowly.

(iii) The temperature of the system must not differ appreciably from its surroundings.

Some examples of reversible process are

(a) All isothermal and adiabatic changes are reversible if they are performed very slowly.

(b) When a certain amount of heat is absorbed by ice, it melts. If the same amount of heat is removed from it, the water formed in the direct process will be converted into ice.

(c) An extremely slow extension or contraction of a spring without setting up oscillations.

(d) When a perfectly elastic ball falls from some height on a perfectly elastic horizontal plane, the ball rises to the initial height.

(e) If the resistance of a thermocouple is negligible there will be no heat produced due to Joule's heating effect. In such a case heating or cooling is reversible. At a junction where a cooling effect is produced due to Peltier effect when current flows in one direction and equal heating effect is produced when the current is reversed.

(f) Very slow evaporation or condensation.

It should be remembered that the conditions mentioned for a reversible process can never be realised in practice. Hence, a reversible process is only an ideal concept. In actual process, there is always loss of heat due to friction, conduction, radiation *etc.*

(2) **Irreversible process :** Any process which is not reversible exactly is an irreversible process. All natural processes such as conduction, radiation, radioactive decay *etc.* are irreversible. All practical processes such as free expansion, Joule-Thomson expansion, electrical heating of a wire are also irreversible. Some examples of irreversible processes are given below

(i) When a steel ball is allowed to fall on an inelastic lead sheet, its kinetic energy changes into heat energy by friction. The heat energy raises the temperature of lead sheet. No reverse transformation of heat energy occurs.

(ii) The sudden and fast stretching of a spring may produce vibrations in it. Now a part of the energy is dissipated. This is the case of irreversible process.

(iii) Sudden expansion or contraction and rapid evaporation or condensation are examples of irreversible processes.

(iv) Produced by the passage of an electric current through a resistance is irreversible.

(v) Heat transfer between bodies at different temperatures is also irreversible.

(vi) Joule-Thomson effect is irreversible because on reversing the flow of gas a similar cooling or heating effect is not observed.

Mixed Graphical Representation

(1) ***PV*-graphs**

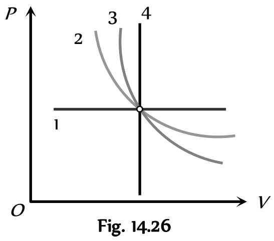


Fig. 14.26

1 ⟶ Isobaric (*P*-constant)

2 ⟶ Isothermal (Because $P \propto \frac{1}{V}$)

3 ⟶ Adiabatic (Because $P \propto \frac{1}{V^{\gamma}}$)

4 ⟶ Isochoric (*V*-constant)

(2) ***PT*-graphs**

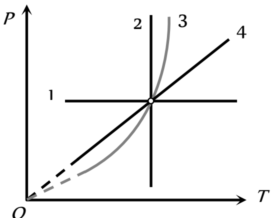


Fig. 14.27

1 ⟶ Isobaric (*P*-constant)

2 ⟶ Isothermal (*T*-constant)

3 ⟶ Adiabatic (Because $P \propto T^{\frac{\gamma}{\gamma-1}}$)

4 ⟶ Isochoric (In isochoric $P \propto T$)

(3) ***VT*-graphs**

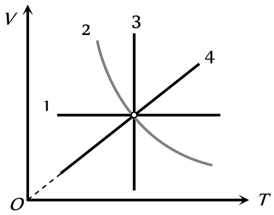


Fig. 14.28

1 ⟶ Isochoric (*V*-constant)

2 ⟶ Adiabatic (Because $V \propto T^{\frac{1}{1-\gamma}}$)

3 ⟶ Isothermal (*T*-constant)

4 ⟶ Isobaric (In isobaric $V \propto T$)

Heat Engine

Heat engine is a device which converts heat into work continuously through a cyclic process.

The essential parts of a heat engine are

(1) **Source :** It is a reservoir of heat at high temperature and infinite thermal capacity. Any amount of heat can be extracted from it.

(2) **Working substance :** Steam, petrol *etc.*

(3) **Sink :** It is a reservoir of heat at low temperature and infinite thermal capacity. Any amount of heat can be given to the sink.

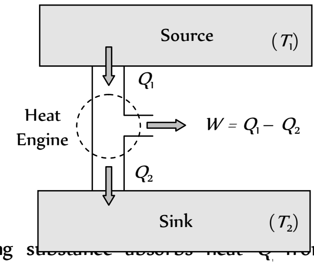


Fig. 14.29

The working substance absorbs heat Q_1 from the source, does an amount of work *W*, returns the remaining amount of heat to the sink and comes back to its original state and there occurs no change in its internal energy.

By repeating the same cycle over and over again, work is continuously obtained.

The performance of heat engine is expressed by means of "efficiency" η which is defined as the ratio of useful work obtained from the engine to the heat supplied to it.

$$\eta = \frac{\text{Work done}}{\text{Heat input}} = \frac{W}{Q_1}$$

For cyclic process $\Delta U = 0$ hence from FLOT $\Delta Q = \Delta W$

So $W = Q_1 - Q_2 \Rightarrow \eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

A perfect heat engine is one which converts all heat into work *i.e.* $W = Q_1$ so that $Q_2 = 0$ and hence $\eta = 1$.

But practically efficiency of an engine is always less than 1.

Refrigerator or Heat Pump

A refrigerator or heat pump is basically a heat engine run in reverse direction.

It essentially consists of three parts

(1) **Source :** At higher temperature T_1

(2) **Working substance :** It is called refrigerant liquid ammonia and freon works as a working substance.

(3) **Sink :** At lower temperature T_2

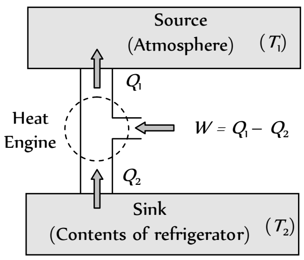


Fig. 14.30

The working substance takes heat Q_2 from a sink (contents of refrigerator) at lower temperature, has a net amount of work done W on it by an external agent (usually compressor of refrigerator) and gives out a larger amount of heat Q_1 to a hot body at temperature T_1 (usually atmosphere). Thus, it transfers heat from a cold to a hot body at the expense of mechanical energy supplied to it by an external agent. The cold body is thus cooled more and more.

The performance of a refrigerator is expressed by means of "coefficient of performance" β which is defined as the ratio of the heat extracted from the cold body to the work needed to transfer it to the hot body.

i.e. $\beta = \frac{\text{Heat extracted}}{\text{Work done}} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$

A perfect refrigerator is one which transfers heat from cold to hot body without doing work

i.e. $W = 0$ so that $Q_1 = Q_2$ and hence $\beta = \infty$

(1) **Carnot refrigerator :** For Carnot refrigerator $\frac{Q_1}{Q_2} = \frac{T_1}{T_2}$

$$\Rightarrow \frac{Q_1 - Q_2}{Q_2} = \frac{T_1 - T_2}{T_2} \text{ or } \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

So coefficient of performance $\beta = \frac{T_2}{T_1 - T_2}$

where T_1 = temperature of surrounding, T_2 = temperature of cold body. It is clear that $\beta = 0$ when $T_2 = 0$

i.e. the coefficient of performance will be zero if the cold body is at the temperature equal to absolute zero.

(2) **Relation between coefficient of performance and efficiency of refrigerator**

We know $\beta = \frac{Q_2}{Q_1 - Q_2} = \frac{Q_2 / Q_1}{1 - Q_2 / Q_1}$ ..... (i)

But the efficiency $\eta = 1 - \frac{Q_2}{Q_1}$ or $\frac{Q_2}{Q_1} = 1 - \eta$ .....(ii)

From (i) and (ii) we get, $\beta = \frac{1 - \eta}{\eta}$

Second Law of Thermodynamics

First law of thermodynamics merely explains the equivalence of work and heat. It does not explain why heat flows from bodies at higher temperatures to those at lower temperatures. It cannot tell us why the converse is possible. It cannot explain why the efficiency of a heat engine is always less than unity. It is also unable to explain why cool water on stirring gets hotter whereas there is no such effect on stirring warm water in a beaker. Second law of thermodynamics provides answers to these questions. Statement of this law is as follows

(1) **Clausius statement :** It is impossible for a self acting machine to transfer heat from a colder body to a hotter one without the aid of an external agency.

From Clausius statement it is clear that heat cannot flow from a body at low temperature to one at higher temperature unless work is done by an external agency. This statement is in fair agreement with our experiences in different branches of physics. For example, electrical current cannot flow from a conductor at lower electrostatic potential to that at higher potential unless an external work is done. Similarly, a body at a lower gravitational potential level cannot move up to higher level without work done by an external agency.

(2) **Kelvin's statement :** It is impossible for a body or system to perform continuous work by cooling it to a temperature lower than the temperature of the coldest one of its surroundings. A Carnot engine cannot work if the source and sink are at the same temperature because work done by the engine will result into cooling the source and heating the surroundings more and more.

(3) **Kelvin-Planck's statement :** It is impossible to design an engine that extracts heat and fully utilises into work without producing any other effect.

From this statement it is clear that any amount of heat can never be converted completely into work. It is essential for an engine to return some amount of heat to the sink. An engine essentially requires a source as well as sink. The efficiency of an engine is always less than unity because heat cannot be fully converted into work.

Carnot Engine

(1) Carnot designed a theoretical engine which is free from all the defects of a practical engine. This engine cannot be realised in actual practice, however, this can be taken as a standard against which the performance of an actual engine can be judged.

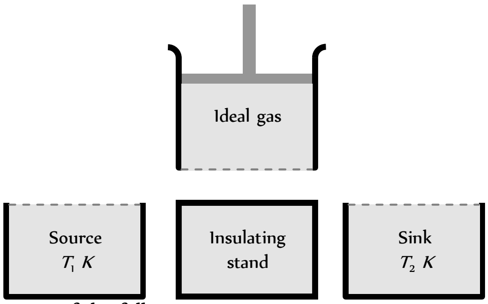


Fig. 14.31

It consists of the following parts

(i) A cylinder with perfectly non-conducting walls and a perfectly conducting base containing a perfect gas as working substance and fitted with a non-conducting frictionless piston

(ii) A source of infinite thermal capacity maintained at constant higher temperature T_1

(iii) A sink of infinite thermal capacity maintained at constant lower temperature T_2.

(iv) A perfectly non-conducting stand for the cylinder.

(2) **Carnot cycle :** As the engine works, the working substance of the engine undergoes a cycle known as Carnot cycle. The Carnot cycle consists of the following four strokes

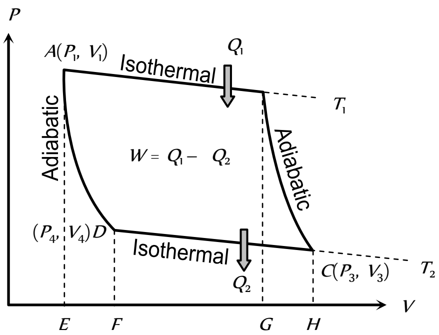


Fig. 14.32

(i) First stroke (Isothermal expansion) (curve AB) :

The cylinder containing ideal gas as working substance allowed to expand slowly at this constant temperature T_1.

Work done = Heat absorbed by the system

$$W_1 = Q_1 = \int_{V_1}^{V_2} P\,dV = RT_1 \log_e\left(\frac{V_2}{V_1}\right) = \text{Area } ABGE$$

(ii) Second stroke (Adiabatic expansion) (curve BC) :

The cylinder is then placed on the non conducting stand and the gas is allowed to expand adiabatically till the temperature falls from T_1 to T_2.

$$W_2 = \int_{V_2}^{V_3} P\,dV = \frac{R}{(\gamma-1)}[T_1 - T_2] = \text{Area } BCHG$$

(iii) Third stroke (Isothermal compression) (curve CD) :

The cylinder is placed on the sink and the gas is compressed at constant temperature T_2.

Work done = Heat released by the system

$$W_3 = Q_2 = -\int_{V_3}^{V_4} P\,dV = -RT_2 \log_e \frac{V_4}{V_3}$$

$$= RT_2 \log_e \frac{V_3}{V_4} = \text{Area } CDFH$$

(iv) Fourth stroke (adiabatic compression) (curve DA) : Finally the cylinder is again placed on non-conducting stand and the compression is continued so that gas returns to its initial stage.

$$W_4 = -\int_{V_4}^{V_1} P\,dV = -\frac{R}{\gamma-1}(T_2 - T_1) = \frac{R}{\gamma-1}(T_1 - T_2) = \text{Area } ADFE$$

(3) **Efficiency of Carnot cycle :** The efficiency of engine is defined as the ratio of work done to the heat supplied *i.e.*

$$\eta = \frac{\text{Work done}}{\text{Heat input}} = \frac{W}{Q_1}$$

Net work done during the complete cycle

$$W = W_1 + W_2 + (-W_3) + (-W_4) = W_1 - W_3 = \text{Area } ABCD$$

[As $W_2 = W_4$]

$$\therefore \quad \eta = \frac{W}{Q_1} = \frac{W_1 - W_3}{W_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{W_3}{W_1} = 1 - \frac{Q_2}{Q_1}$$

or $$\eta = 1 - \frac{RT_2 \log_e(V_3/V_4)}{RT_1 \log_e(V_2/V_1)}$$

Since points B and C lie on same adiabatic curve

$$\therefore \quad T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1} \text{ or } \frac{T_1}{T_2} = \left(\frac{V_3}{V_2}\right)^{\gamma-1} \qquad \text{.....(i)}$$

Also point D and A lie on the same adiabatic curve

$$\therefore \quad T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1} \text{ or } \frac{T_1}{T_2} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \qquad \text{.....(ii)}$$

From (i) and (ii), $\dfrac{V_3}{V_2} = \dfrac{V_4}{V_1}$ or $\dfrac{V_3}{V_4} = \dfrac{V_2}{V_1} \Rightarrow \log_e\left(\dfrac{V_3}{V_4}\right) = \log_e\left(\dfrac{V_2}{V_1}\right)$

So efficiency of Carnot engine $\eta = 1 - \dfrac{T_2}{T_1}$

(i) Efficiency of a heat engine depends only on temperatures of source and sink and is independent of all other factors.

(ii) All reversible heat engines working between same temperatures are equally efficient and no heat engine can be more efficient than Carnot engine (as it is ideal).

(iii) As on Kelvin scale, temperature can never be negative (as 0 K is defined as the lowest possible temperature) and T_1 and T_2 are finite, efficiency of a heat engine is always lesser than unity, *i.e.*, whole of heat can never be converted into work which is in accordance with second law.

(4) **Carnot theorem :** The efficiency of Carnot's heat engine depends only on the temperature of source (T_1) and temperature of sink (T_2), *i.e.*, $\eta = 1 - \dfrac{T_2}{T_1}$.

Carnot stated that no heat engine working between two given temperatures of source and sink can be more efficient than a perfectly reversible engine (Carnot engine) working between the same two temperatures. Carnot's reversible engine working between two given temperatures is considered to be the most efficient engine.

Table 14.3 : Difference Between Petrol Engine and Diesel Engine

Petrol engine	Diesel engine
Working substance is a mixture of petrol vapour and air.	Working substance in this engine is a mixture of diesel vapour and air.
Efficiency is smaller (~47%).	Efficiency is larger (~55%).
It works with a spark plug.	It works with an oil plug.
It is associated with the risk of explosion, because petrol vapour and air is compressed. So, low compression ratio is kept.	No risk of explosion, because only air is compressed. Hence compression ratio is kept large.
Petrol vapour and air is created with spark plug.	Spray of diesel is obtained through the jet.

Entropy

Entropy is a measure of disorder of molecular motion of a system. Greater is the disorder, greater is the entropy.

The change in entropy *i.e.*

$$dS = \frac{\text{Heat absorbed by system}}{\text{Absolute temperature}} \text{ or } dS = \frac{dQ}{T}$$

The relation is called the mathematical form of Second Law of Thermodynamics.

(1) **For solids and liquids**

(i) When heat given to a substance changes its state at constant temperature, then change in entropy $dS = \frac{dQ}{T} = \pm\frac{mL}{T}$

where positive sign refers to heat absorption and negative sign to heat evolution.

(ii) When heat given to a substance raises its temperature from T_1 to T_2, then change in entropy

$$dS = \int\frac{dQ}{T} = \int_{T_1}^{T_2} mc\frac{dT}{T} = mc\log_e\left(\frac{T_2}{T_1}\right)$$

$$\Rightarrow \Delta S = 2.303\, mc\log_{10}\left(\frac{T_2}{T_1}\right).$$

(2) **For a perfect gas :** Perfect gas equation for n moles is $PV = nRT$

$$\Delta S = \int\frac{dQ}{T} = \int\frac{\mu C_V dT + P\,dV}{T} \qquad [\text{As } dQ = dU + dW]$$

$$\Rightarrow \Delta S = \int\frac{\mu C_V dT + \frac{\mu RT}{V}dV}{T}$$

$$= \mu C_V\int_{T_1}^{T_2}\frac{dT}{T} + \mu R\int_{V_1}^{V_2}\frac{dV}{V} \qquad [\text{As } PV = \mu RT]$$

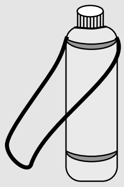
$$\therefore \quad \Delta S = \mu C_V\log_e\left(\frac{T_2}{T_1}\right) + \mu R\log_e\left(\frac{V_2}{V_1}\right)$$

In terms of T and P, $\Delta S = \mu C_P\log_e\left(\frac{T_2}{T_1}\right) - \mu R\log_e\left(\frac{P_2}{P_1}\right)$

and in terms of P and V $\Delta S = \mu C_V\log_e\left(\frac{P_2}{P_1}\right) + \mu C_P\log_e\left(\frac{V_2}{V_1}\right)$

Tips & Tricks

✍ When a thermos bottle is vigorously shaken :



Heat transferred to the coffee $\Rightarrow \Delta Q = 0$

[As thermos flask is insulated from the surrounding]

Work is done on the coffee against viscous force

$\Delta W = (-)$

Internal energy of the coffee increases $\Delta U = (+)$

and temperature of the coffee also increases $\Delta T = (+)$

✍ **Work done without the volume limits**

$$W = \int_{V_i}^{V_f} P\,dV$$

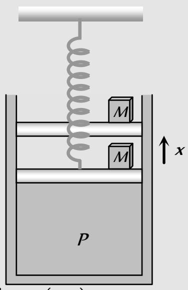
From this equation it seems as if work done can be calculated only when P-V equation is known and limits V_i and V_f are known to us. But it is not so. We can calculate work done if we know the limits of temperature.

For μ moles of an ideal gas if $P = \frac{\alpha}{T}$ with temperature limits T_0 and $2T_0$.

From $PV = \mu RT \Rightarrow V = \frac{\mu RT}{P} = \frac{\mu RT^2}{\alpha} \Rightarrow dV = \frac{2\mu RT}{\alpha}dT$

$$\therefore \quad W = \int_{V_i}^{V_f} P\,dV = \int_{T_0}^{2T_0}\left(\frac{\alpha}{T}\right)\left(\frac{2\mu RT}{\alpha}\right)dT = 2\mu RT_0$$

✍ **Work done with spring :** If mass less piston is attached to a spring of force constant K and a mass m is placed over the piston. If the external pressure is P_0 and due to expansion of gas the piston moves up through a distance x then



Total work done by the gas

$W = W_1 + W_2 + W_3$

where W_1 = Work done against external pressure (P_0)

W_2 = Work done against spring force (Kx)

W_3 = Work done against gravitational force (mg)

$$\therefore \quad W = P_0V + \frac{1}{2}Kx^2 + mgx$$

✍ The efficiency of an actual engine is much lesser than that of an ideal engine. Actually the practical efficiency of a steam engine is about (8-15)% while that of a petrol engine is 40%. The efficiency of a diesel engine is maximum and is about (50-55)%.

✍ When P and V bear the relation PV^x = constant, where $x \neq 1$ or γ the process is called a polytropic one. In this process the molar heat capacity is, $C = C_V + \frac{R}{1-x} = \frac{R}{\gamma-1} + \frac{R}{1-x}$

✍ **Enthalpy :** Four quantities called "thermodynamic potentials" are useful in the chemical thermodynamics of reactions and non-cyclic processes. They are internal energy, the enthalpy, the Helmoltz free energy and the Gibbs free energy. Enthalpy is defined by

$$H = U + PV$$

where P and V are the pressure and volume, and U is internal energy, Enthalpy is somewhat parallel to the first law of thermodynamics for a constant pressure system $Q = \Delta U + P\Delta V$ since in this case $Q = \Delta H$.

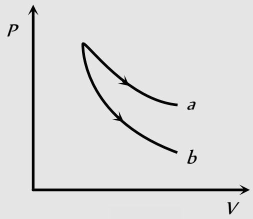
✍ **Confusion about FLOT**

It is typical for chemistry texts to write the first law as

$$\Delta U = \Delta Q + \Delta W$$

It is the same law, of course the thermodynamic expression of the conservation of energy principle. It is just that W is defined as the work done on the system instead of work done by the system. In the context of physics, the common scenario is one of adding heat to a volume of gas and using the expansion of that gas to do work, as in the pushing down of a piston in an internal combustion engine. In the context of chemical reactions and process, it may be more common to deal with situations where work is done on the system rather than by it.

✍ **Possibilities**



If $a \longrightarrow$ Isothermal then $b \longrightarrow$ Must be adiabatic

But If $b \longrightarrow$ adiabatic then it is not compulsory that a must be isothermal, it may be adiabatic also.

Ordinary Thinking

Objective Questions

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1. First law of thermnodynamics is given by [CPMT 1977, 91]

(a) $dQ = dU + PdV$ (b) $dQ = dU \times PdV$

(c) $dQ = (dU + dV)P$ (d) $dQ = PdU + dV$

2. The internal energy of an ideal gas depends upon [RPMT 1997; MP PMT 1999; CPMT 2003]

(a) Specific volume (b) Pressure

(c) Temperature (d) Density

3. In changing the state of thermodynamics from A to B state, the heat required is Q and the work done by the system is W. The change in its internal energy is [MP PMT 1986; AMU (Med.) 2001]

(a) $Q + W$ (b) $Q - W$

(c) Q (d) $\frac{Q-W}{2}$

4. Heat given to a system is 35 joules and work done by the system is 15 *joules*. The change in the internal energy of the system will be

(a) – 50 J (b) 20 J

(c) 30 J (d) 50 J

5. The temperature of an ideal gas is kept constant as it expands. The gas does external work. During this process, the internal energy of the gas [MP PMT 1990]

(a) Decreases

(b) Increases

(c) Remains constant

(d) Depends on the molecular motion

6. The first law of thermodynamics is concerned with the conservation of [MP PMT 1987; CBSE PMT 1990, 92; AFMC 1997; CPMT 1999; BHU 1999; DCE 2000; BCECE 2003]

(a) Momentum (b) Energy

(c) Mass (d) Temperature

7. A thermodynamic system goes from states (i) P_1, V to $2P_1$, V (ii) P, V to P, $2V$. Then work done in the two cases is [MP PMT 1990]

(a) Zero, Zero (b) Zero, PV_1

(c) PV_1, Zero (d) PV_1, P_1V_1

8. If the amount of heat given to a system be 35 *joules* and the amount of work done by the system be -15 *joules*, then the change in the internal energy of the system is [MP PMT 1989]

(a) -50 *joules* (b) 20 *joules*

(c) 30 *joules* (d) 50 *joules*

9. A system is given 300 calories of heat and it does 600 *joules* of work. How much does the internal energy of the system change in this process

(J = 4.18 *joules/cal*) [MP PET 1991]

(a) 654 *Joule* (b) 156.5 *Joule*

(c) – 300 *Joule* (d) – 528.2 *Joule*

10. Work done on or by a gas, in general depends upon the

(a) Initial state only

(b) Final state only

(c) Both initial and final states only

(d) Initial state, final state and the path

11. If R = universal gas constant, the amount of heat needed to raise the temperature of 2 mole of an ideal monoatomic gas from 273K to 373K when no work is done [MP PET 1990]

(a) 100 R (b) 150 R

(c) 300 R (d) 500 R

12. Find the change in internal energy of the system when a system absorbs 2 *kilocalorie* of heat and at the same time does 500 *joule* of work [EAMCET 1984]

(a) 7900 J (b) 8200 J

(c) 5600 J (d) 6400 J

[MP PET/PMT 1988]

13. A system performs work ΔW when an amount of heat is ΔQ added to the system, the corresponding change in the internal energy is ΔU. A unique function of the initial and final states (irrespective of the mode of change) is

[CPMT 1981; J & KCET 2004]

(a) ΔQ (b) ΔW

(c) ΔU and ΔQ (d) ΔU

14. A container of volume $1m^3$ is divided into two equal compartments by a partition. One of these compartments contains an ideal gas at 300 *K*. The other compartment is vacuum. The whole system is thermally isolated from its surroundings. The partition is removed and the gas expands to occupy the whole volume of the container. Its temperature now would be [Manipal MEE 1995]

(a) 300 *K* (b) 239 *K*

(c) 200 *K* (d) 100 *K*

15. 110 *J* of heat is added to a gaseous system, whose internal energy change is 40 *J*, then the amount of external work done is [CBSE PMT 1993; DPMT 1996, 03; AFMC 1999; JIPMER 2000; MH CET 2000; Pb. PMT 2003]

(a) 150 *J* (b) 70 *J*

(c) 110 *J* (d) 40 *J*

16. Which of the following is not thermodynamical function

[CBSE PMT 1993; CPMT 2001; DCE 1996; 2001]

(a) Enthalpy (b) Work done

(c) Gibb's energy (d) Internal energy

17. When the amount of work done is 333 *cal* and change in internal energy is 167 *cal*, then the heat supplied is

[AFMC 1998]

(a) 166 *cal* (b) 333 *cal*

(c) 500 *cal* (d) 400 *cal*

18. First law thermodynamics states that [KCET 1999]

(a) System can do work

(b) System has temperature

(c) System has pressure

(d) Heat is a form of energy

19. A thermo-dynamical system is changed from state (P_1, V_1) to (P_2, V_2) by two different process. The quantity which will remain same will be [RPET 1999]

(a) ΔQ (b) ΔW

(c) $\Delta Q + \Delta W$ (d) $\Delta Q - \Delta W$

20. In thermodynamic process, 200 *Joules* of heat is given to a gas and 100 *Joules* of work is also done on it. The change in internal energy of the gas is [AMU (Engg.) 1999]

(a) 100 *J* (b) 300 *J*

(c) 419 *J* (d) 24 *J*

21. A perfect gas contained in a cylinder is kept in vacuum. If the cylinder suddenly bursts, then the temperature of the gas

[MH CET 1999]

(a) Remains constant (b) Becomes zero

(c) Increases (d) Decreases

22. If 150 *J* of heat is added to a system and the work done by the system is 110 *J*, then change in internal energy will be

[AMU (Engg.) 1999; BHU 2000]

(a) 260 *J* (b) 150 *J*

(c) 110 *J* (d) 40 *J*

23. If ΔQ and ΔW represent the heat supplied to the system and the work done on the system respectively, then the first law of thermodynamics can be written as [Roorkee 2000]

(a) $\Delta Q = \Delta U + \Delta W$ (b) $\Delta Q = \Delta U - \Delta W$

(c) $\Delta Q = \Delta W - \Delta U$ (d) $\Delta Q = -\Delta W - \Delta U$

where ΔU is the internal energy

24. For free expansion of the gas which of the following is true

[AMU (Med.) 2000]

(a) $Q = W = 0$ and $\Delta E_{int} = 0$

(b) $Q = 0, W > 0$ and $\Delta E_{int} = -W$

(c) $W = 0, Q > 0,$ and $\Delta E_{int} = Q$

(d) $W > 0, Q < 0$ and $\Delta E_{int} = 0$

25. Which of the following can not determine the state of a thermodynamic system [AFMC 2001]

(a) Pressure and volume

(b) Volume and temperature

(c) Temperature and pressure

(d) Any one of pressure, volume or temperature

26. Which of the following is not a thermodynamics co-ordinate

[AIIMS 2001]

(a) *P* (b) *T*

(c) *V* (d) *R*

27. In a given process for an ideal gas, $dW = 0$ and $dQ < 0$. Then for the gas [IIT-JEE (Screening) 2001]

(a) The temperature will decrease

(b) The volume will increase

(c) The pressure will remain constant

(d) The temperature will increase

28. The specific heat of hydrogen gas at constant pressure is $C_P = 3.4 \times 10^3 cal/kg\ ^oC$ and at constant volume is $C_V = 2.4 \times 10^3 cal/kg\ ^oC$. If one kilogram hydrogen gas is heated from 10^oC to 20^oC at constant pressure, the external work done on the gas to maintain it at constant pressure is

(a) 10^5 *cal* (b) 10^4 *cal*

(c) 10^3 *cal* (d) 5×10^3 *cal*

29. Which of the following parameters does not characterize the thermodynamic state of matter [CPMT 2001; AIEEE 2003]

(a) Volume (b) Temperature

(c) Pressure (d) Work

30. In a thermodynamic system working substance is ideal gas, its internal energy is in the form of **[MP PMT 2003]**

(a) Kinetic energy only

(b) Kinetic and potential energy

(c) Potential energy

(d) None of these

31. Which of the following statements is correct for any thermodynamic system **[AIEEE 2004]**

(a) The internal energy changes in all processes

(b) Internal energy and entropy are state functions

(c) The change in entropy can never be zero

(d) The work done in an adiabatic process is always zero

32. A system is provided with 200 cal of heat and the work done by the system on the surrounding is 40 *J*. Then its internal energy

(a) Increases by 600 *J* (b) Decreases by 800 *J*

(c) Increases by 800 *J* (d) Decreases by 50 *J*

33. In a thermodynamic process, pressure of a fixed mass of a gas is changed in such a manner that the gas molecules gives out 20 *J* of heat and 10 *J* of work is done on the gas. If the initial internal energy of the gas was 40 *J*, then the final internal energy will be

(a) 30 *J* (b) 20 *J*

(c) 60 *J* (d) 40 *J*

34. Heat is not being exchanged in a body. If its internal energy is increased, then **[RPMT 2002]**

(a) Its temperature will increase

(b) Its temperature will decrease

(c) Its temperature will remain constant

(d) None of these

35. Out of the following which quantity does not depend on path

(a) Temperature (b) Energy

(c) Work (d) None of these

36. First law of thermodynamics is a special case of **[CPMT 1985; RPET 2000; DCE 2000; CBSE PMT 2000; AIEEE 2002; AFMC 2002]**

(a) Newton's law

(b) Law of conservation of energy

(c) Charle's law

(d) Law of heat exchange

37. One mole of an ideal monoatomic gas is heated at a constant pressure of one atmosphere from 0^oC to 100^oC. Then the change in the internal energy is **[Pb. PMT 2001]**

(a) 6.56 *joules* (b) 8.32×10^2 *joules*

(c) 12.48×10^2 *joules* (d) 20.80 *joules*

38. If the ratio of specific heat of a gas at constant pressure to that at constant volume is γ, the change in internal energy of a mass of gas, when the volume changes from *V* to 2V constant pressure *p*, is

(a) $R/(\gamma-1)$ (b) pV

(c) $pV/(\gamma-1)$ (d) $\gamma pV/(\gamma-1)$

39. If $C_V = 4.96 cal/mole$ *K*, then increase in internal energy when temperature of 2 moles of this gas is increased from 340 *K* to 342 *K* **[RPET 1997]**

(a) 27.80 *cal* (b) 19.84 *cal*

(c) 13.90 *cal* (d) 9.92 *cal*

40. Temperature is a measurement of coldness or hotness of an object. This definition is based on **[RPET 2003]**

(a) Zeroth law of thermodynamics

(b) First law of thermodynamics

(c) Second law of thermodynamics

(d) Newton's law of cooling

41. When heat energy of 1500 *Joules*, is supplied to a gas at constant pressure $2.1\times10^5 N/m^2$, there was an increase in its volume equal to $2.5\times10^{-3} m^3$. The increase in internal energy of the gas in Joules is **[EAMCET (Engg.) 1999]**

[Orissa PMT 2004]

(a) 450 (b) 525

(c) 975 (d) 2025

42. If heat given to a system is 6 *kcal* and work done is 6 k*J*. Then change in internal energy is **[BHU Med. 2000]**

[DPMT 2004]

(a) 19.1 *kJ* (b) 12.5 *kJ*

(c) 25 *kJ* (d) Zero

43. In a thermodynamics process, pressure of a fixed mass of a gas is changed in such a manner that the gas releases 20 *J* of heat and 8*J* of work is done on the gas. If the initial internal energy of the gas was 30*J*. The final internal energy will be

(a) 18*J* (b) 9*J*

(c) 4.5*J* (d) 36*J*

44. A monoatomic gas of *n*-moles is heated from temperature *T* to *T* under two different conditions (i) at constant volume and (ii) at constant pressure. The change in internal energy of the gas is

[RPET 2002]

(a) More for (i)

(b) More for (ii)

(c) Same in both cases

(d) Independent of number of moles

45. The state of a thermodynamic system is represented by **[MH CET 2004]**

(a) Pressure only

(b) Volume only

(c) Pressure, volume and temperature

(d) Number of moles

46. A perfect gas goes from state *A* to another state *B* by absorbing $8\times10^5 J$ of heat and doing $6.5\times10^5 J$ of external work. It is now transferred between the same two states in another process in which it absorbs $10^5 J$ of heat. Then in the second process

[CBSE PMT 1998]

(a) Work done on the gas is $0.5\times10^5 J$

(b) Work done by gas is $0.5\times10^5 J$

(c) Work done on gas is $10^5 J$

(d) Work done by gas is $10^5 J$

47. If a system undergoes contraction of volume then the work done by the system will be **[BHU 1999]**

(a) Zero (b) Negligible

(c) Negative (d) Positive

48. Which of the following is *incorrect* regarding the first law of thermodynamics [AIEEE 2005]

(a) It introduces the concept of the internal energy

(b) It introduces the concept of the entropy

(c) It is not applicable to any cyclic process

(d) None of the above

Isothermal Process

1. For an ideal gas, in an isothermal process [BHU 1998]

(a) Heat content remains constant

(b) Heat content and temperature remain constant

(c) Temperature remains constant

(d) None of the above

2. Can two isothermal curves cut each other

(a) Never

(b) Yes

(c) They will cut when temperature is $0°C$

(d) Yes, when the pressure is critical pressure

3. In an isothermal expansion [KCET 2000; AFMC 2001]

(a) Internal energy of the gas increases

(b) Internal energy of the gas decreases

(c) Internal energy remains unchanged

(d) Average kinetic energy of gas molecule decreases

4. In an isothermal reversible expansion, if the volume of 96 *gm* of oxygen at $27°C$ is increased from 70 *litres* to 140 *litres*, then the work done by the gas will be

(a) $300\,R\log_{10}2$ (b) $81\,R\log_e 2$

(c) $900\,R\log_{10}2$ (d) $2.3\times900\,R\log_{10}2$

5. A vessel containing 5 *litres* of a gas at 0.8 *m* pressure is connected to an evacuated vessel of volume 3 *litres*. The resultant pressure inside will be (assuming whole system to be isolated)

(a) 4/3 *m* (b) 0.5 *m*

(c) 2.0 *m* (d) 3/4 *m*

6. For an isothermal expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal [CPMT 1980]

(a) $-\gamma^{1/2}\frac{\Delta V}{V}$ (b) $-\frac{\Delta V}{V}$

(c) $-\gamma\frac{\Delta V}{V}$ (d) $-\gamma^2\frac{\Delta V}{V}$

7. The gas law $\frac{PV}{T}=$ constant is true for

[MNR 1974; MP PMT 1984; BHU 1995, 98, 2000]

(a) Isothermal changes only

(b) Adiabatic changes only

(c) Both isothermal and adiabatic changes

(d) Neither isothermal nor adiabatic changes

8. One mole of O_2 gas having a volume equal to 22.4 *litres* at 0^oC and 1 atmospheric pressure in compressed isothermally so that its volume reduces to 11.2 *litres*. The work done in this process is

(a) $1672.5\,J$ (b) 1728 J

(c) $-1728J$ (d) $-1572.5\,J$

9. If a gas is heated at constant pressure, its isothermal compressibility

(a) Remains constant

(b) Increases linearly with temperature

(c) Decreases linearly with temperature

(d) Decreases inversely with temperature

10. Work done per mol in an isothermal change is

[RPMT 2004; BCECE 2005]

(a) $RT\log_{10}\frac{V_2}{V_1}$ (b) $RT\log_{10}\frac{V_1}{V_2}$

(c) $RT\log_e\frac{V_2}{V_1}$ (d) $RT\log_e\frac{V_1}{V_2}$

11. The isothermal Bulk modulus of an ideal gas at pressure P is

[CPMT 1974, 81; UPSEAT 1998; IIT 1998]

(a) P (b) γP

(c) $P/2$ (d) P/γ

12. In isothermal expansion, the pressure is determined by

[AFMC 1995]

(a) Temperature only

(b) Compressibility only

(c) Both temperature and compressibility

(d) None of these

13. The isothermal bulk modulus of a perfect gas at normal pressure is

(a) $1.013\times10^5\,N/m^2$ (b) $1.013\times10^6\,N/m^2$

(c) $1.,013\times10^{-11}\,N/m^2$ (d) $1.013\times10^{11}\,N/m^2$

14. In an isothermal change, an ideal gas obeys

[MP PMT 1993] [EAMCET 1994; CPMT 1999]

(a) Boyle's law (b) Charle's law

(c) Gaylussac law (d) None of the above

15. In isothermic process, which statement is wrong

[RPMT 1997]

(a) Temperature is constant

(b) Internal energy is constant

(c) No exchange of energy

(d) (a) and (b) are correct

16. An ideal gas A and a real gas B have their volumes increased from V to 2 V under isothermal conditions. The increase in internal energy

[CBSE PMT 1993; JIPMER 2001, 02]

(a) Will be same in both A and B

(b) Will be zero in both the gases

(c) Of B will be more than that of A

(d) Of A will be more than that of B

17. The specific heat of a gas in an isothermal process is

[AFMC 1998]

(a) Infinite (b) Zero

(c) Negative (d) Remains constant

18. A thermally insulated container is divided into two parts by a screen. In one part the pressure and temperature are P and T for an ideal gas filled. In the second part it is vacuum. If now a small hole is created in the screen, then the temperature of the gas will

(a) Decrease (b) Increase
(c) Remain same (d) None of the above

19. A container that suits the occurrence of an isothermal process should be made of [Pb. PMT 2000]

(a) Copper (b) Glass
(c) Wood (d) Cloth

20. In an isothermal process the volume of an ideal gas is halved. One can say that [MP PMT 2004]

(a) Internal energy of the system decreases
(b) Work done by the gas is positive
(c) Work done by the gas is negative
(d) Internal energy of the system increases

21. A thermodynamic process in which temperature T of the system remains constant though other variable P and V may change, is called [Pb. PMT 2004]

(a) Isochoric process (b) Isothermal process
(c) Isobaric process (d) None of these

22. If an ideal gas is compressed isothermally then [RPMT 2003]

(a) No work is done against gas
(b) Heat is relased by the gas
(c) The internal energy of gas will increase
(d) Pressure does not change

23. When an ideal gas in a cylinder was compressed isothermally by a piston, the work done on the gas was found to be 1.5×10^4 *joules*. During this process about

[MP PMT 1987]

(a) 3.6×10^3 *cal* of heat flowed out from the gas
(b) 3.6×10^3 *cal* of heat flowed into the gas
(c) 1.5×10^4 *cal* of heat flowed into the gas
(d) 1.5×10^4 *cal* of heat flowed out from the gas

24. When heat is given to a gas in an isothermal change, the result will be [MP PET 1995; RPMT 1997]

(a) External work done
(b) Rise in temperature
(c) Increase in internal energy
(d) External work done and also rise in temp.

25. When 1 *gm* of water at 0^oC and $1 \times 10^5\ N/m^2$ pressure is converted into ice of volume $1.091\ cm^2$, the external work done will be

(a) 0.0091 *joule* (b) 0.0182 *joule*
(c) – 0.0091 *joule* (d) – 0.0182 *joule*

26. The latent heat of vaporisation of water is 2240 *J/gm*. If the work done in the process of expansion of 1 *g* is 168 *J*, then increase in internal energy is [Pb. PET 1998; CPMT 2000]

(a) 2408 *J* (b) 2240 *J*
(c) 2072 *J* (d) 1904 *J*

27. 540 *calories* of heat convert 1 cubic centimeter of water at 100^oC into 1671 cubic centimeter of steam at 100^oC at a pressure of one atmosphere. Then the work done against the atmospheric pressure is nearly [RPET 1999]

(a) 540 *cal* (b) 40 *cal*
(c) Zero *cal* (d) 500 *cal*

28. One mole of an ideal gas expands at a constant temperature of 300 *K* from an initial volume of 10 *litres* to a final volume of 20 *litres*. The work done in expanding the gas is

(R = 8.31 *J/mole-K*) [MP PMT 1995; UPSEAT 2000]

(a) 750 *joules* (b) 1728 *joules*
(c) 1500 *joules* (d) 3456 *joules*

29. A cylinder fitted with a piston contains 0.2 *moles* of air at temperature 27°*C*. The piston is pushed so slowly that the air within the cylinder remains in thermal equilibrium with the surroundings. Find the approximate work done by the system if the final volume is twice the initial volume

[BHU (Med.) 2000]

(a) 543 *J* (b) 345 *J*
(c) 453 *J* (d) 600 *J*

30. The volume of an ideal gas is 1 litre and its pressure is equal to 72*cm* of mercury column. The volume of gas is made 900 *cm* by compressing it isothermally. The stress of the gas will be

(a) 8 *cm* (mercury) (b) 7 *cm* (mercury)
(c) 6 *cm* (mercury) (d) 4 *cm* (mercury)

31. During an isothermal expansion of an ideal gas

[UPSEAT 2005]

(a) Its internal energy decreases
(b) Its internal energy does not change
(c) The work done by the gas is equal to the quantity of heat absorbed by it
(d) Both (b) and (c) are correct

Adiabatic Process

1. If a cylinder containing a gas at high pressure explodes, the gas undergoes [MP PET/PMT 1988]

(a) Reversible adiabatic change and fall of temperature
(b) Reversible adiabatic change and rise of temperature
(c) Irreversible adiabatic change and fall of temperature
(d) Irreversible adiabatic change and rise of temperature

2. The work done in an adiabatic change in a gas depends only on [CPMT 1971; MP

(a) Change is pressure (b) Change is volume
(c) Change in temperature (d) None of the above

3. In adiabatic expansion [DPMT 1999]

(a) $\Delta U = 0$ (b) $\Delta U =$ negative
(c) $\Delta U =$ positive (d) $\Delta W =$ zero

4. The pressure in the tyre of a car is four times the atmospheric pressure at 300 *K*. If this tyre suddenly bursts, its new temperature will be $(\gamma = 1.4)$

[RPMT 1996; MP PMT 1990]

(a) $300\,(4)^{1.4/0.4}$ (b) $300\left(\frac{1}{4}\right)^{-0.4/1.4}$
(c) $300\,(2)^{-0.4/1.4}$ (d) $300\,(4)^{-0.4/1.4}$

5. A gas at NTP is suddenly compressed to one-fourth of its original volume. If γ is supposed to be $\frac{3}{2}$, then the final pressure is

(a) 4 atmosphere (b) $\frac{3}{2}$ atmosphere

(c) 8 atmosphere (d) $\frac{1}{4}$ atmosphere

6. A monoatomic gas $(\gamma = 5/3)$ is suddenly compressed to $\frac{1}{8}$ of its original volume adiabatically, then the pressure of the gas will change to [CPMT 1976, 83; MP PMT 1994; DPMT 1996; Roorkee 2000; KCET 2000; Pb. PMT 1999, 2001]

(a) $\frac{24}{5}$

(b) 8

(c) $\frac{40}{3}$

(d) 32 times its initial pressure

7. The pressure and density of a diatomic gas $(\gamma = 7/5)$ change adiabatically from (P, d) to (P', d'). If $\frac{d'}{d} = 32$, then $\frac{P'}{P}$ should be [CPMT 1982; EAMCET 2001]

(a) 1/128 (b) 32

(c) 128 (d) None of the above

8. An ideal gas at 27^oC is compressed adiabatically to $\frac{8}{27}$ of its original volume. If $\gamma = \frac{5}{3}$, then the rise in temperature is [CPMT 1984; CBSE PMT 1999; DPMT 2000; BHU 2001; Pb. PET 2001; UPSEAT 2002, 03; KCET 2003;]

(a) 450 K (b) 375 K

(c) 225 K (d) 405 K

9. Two identical samples of a gas are allowed to expand (i) isothermally (ii) adiabatically. Work done is [MNR 1998]

(a) More in the isothermal process

(b) More in the adiabatic process

(c) Neither of them

(d) Equal in both processes

10. Which is the correct statement [MP PMT 1993]

(a) For an isothermal change PV = constant

(b) In an isothermal process the change in internal energy must be equal to the work done

(c) For an adiabatic change $\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^\gamma$, where γ is the ratio of specific heats

(d) In an adiabatic process work done must be equal to the heat entering the system

11. The slopes of isothermal and adiabatic curves are related as [CPMT 1971; BHU 1996; MH CET 1999; UPSEAT 2000; RPET 2003]

(a) Isothermal curve slope = adiabatic curve slope

(b) Isothermal curve slope = $\gamma \times$ adiabatic curve slope

(c) Adiabatic curve slope = $\gamma \times$ isothermal curve slope

(d) Adiabatic curve slope = $\frac{1}{2} \times$ isothermal curve slope [BHU 1995]

12. Pressure-temperature relationship for an ideal gas undergoing adiabatic change is $(\gamma = C_p / C_v)$

[CPMT 1992; MP PMT 1986, 87, 94, 97; Pb. PET 1998; DCE 2001; MP PET 2001; UPSEAT 1999, 2001; AFMC 2002]

(a) PT^γ = constant (b) $PT^{-1+\gamma}$ = constant

(c) $P^{\gamma-1}T^\gamma$ = constant (d) $P^{1-\gamma}T^\gamma$ = constant

13. The amount of work done in an adiabatic expansion from temperature T to T_1 is [MP PMT 1989]

(a) $R(T - T_1)$ (b) $\frac{R}{\gamma - 1}(T - T_1)$

(c) RT (d) $R(T - T_1)(\gamma - 1)$

14. During the adiabatic expansion of 2 moles of a gas, the internal energy of the gas is found to decrease by 2 *joules*, the work done during the process on the gas will be equal to

[CPMT 1988]

(a) $+1\ J$ (b) $-1\ J$

(c) $2\ J$ (d) $-2\ J$

15. The adiabatic elasticity of hydrogen gas $(\gamma = 1.4)$ at NTP is

[MP PMT 1990]

(a) $1 \times 10^5\ N/m^2$ (b) $1 \times 10^{-8}\ N/m2$

(c) $1.4\ N/m^2$ (d) $1.4 \times 10^5\ N/m^2$

16. If γ denotes the ratio of two specific heats of a gas, the ratio of slopes of adiabatic and isothermal PV curves at their point of intersection is

[NCERT 1990; MH CET 1999; MP PMT 2000]

(a) $1/\gamma$ (b) γ

(c) $\gamma - 1$ (d) $\gamma + 1$

17. Air in a cylinder is suddenly compressed by a piston, which is then maintained at the same position. With the passage of time [NCERT 1971; DPMT 1

KCET 2000; AIIMS 2000; MH CET 2001]

(a) The pressure decreases

(b) The pressure increases

(c) The pressure remains the same

(d) The pressure may increase or decrease depending upon the nature of the gas

18. When a gas expands adiabatically [CPMT 1990]

(a) No energy is required for expansion

(b) Energy is required and it comes from the wall of the container of the gas

(c) Internal energy of the gas is used in doing work

(d) Law of conservation of energy does not hold

19. One *gm* mol of a diatomic gas $(\gamma = 1.4)$ is compressed adiabatically so that its temperature rises from 27^oC to 127^oC. The work done will be

(a) 2077.5 *joules* (b) 207.5 *joules*

(c) 207.5 *ergs* (d) None of the above

20. Compressed air in the tube of a wheel of a cycle at normal temperature suddenly starts coming out from a puncture. The air inside [NCERT 1970]

(a) Starts becoming hotter
(b) Remains at the same temperature
(c) Starts becoming cooler
(d) May become hotter or cooler depending upon the amount of water vapour present

21. The adiabatic Bulk modulus of a perfect gas at pressure is given by [CPMT 1982; MH CET 2001]

(a) P (b) $2P$
(c) $P/2$ (d) γP

22. An adiabatic process occurs at constant [MNR 1985; AFMC 1996; AIIMS 1999; UPSEAT 1999, 2000; Pb. PET 2004]

(a) Temperature
(b) Pressure
(c) Heat
(d) Temperature and pressure

23. A polyatomic gas $\left(\gamma = \frac{4}{3}\right)$ is compressed to $\frac{1}{8}$ of its volume adiabatically. If its initial pressure is P_o, its new pressure will be [MP PET 1994; BHU 1995]

(a) $8P_o$ (b) $16P_0$
(c) $6P_o$ (d) $2P_o$

24. For adiabatic processes $\left(\gamma = \frac{C_p}{C_v}\right)$ [KCET 1999; MP PET 1995; CPMT 2003]

(a) $P^{\gamma}V$ = constant (b) $T^{\gamma}V$ = constant
(c) $TV^{\gamma-1}$ =constant (d) TV^{γ} = constant

25. An ideal gas is expanded adiabatically at an initial temperature of 300 *K* so that its volume is doubled. The final temperature of the hydrogen gas is $(\gamma = 1.40)$ [MP PMT 1995; DPMT 1999]

(a) 227.36 *K* (b) 500.30 *K*
(c) 454.76 *K* (d) $-47^o C$

26. A given system undergoes a change in which the work done by the system equals the decrease in its internal energy. The system must have undergone an [Haryana CEE 1996; UPSEAT 2003]

(a) Isothermal change (b) Adiabatic change
(c) Isobaric change (d) Isochoric change

27. During the adiabatic expansion of 2 moles of a gas, the internal energy was found to have decreased by 100 *J*. The work done by the gas in this process is [MP PET 1996, 97]

(a) Zero (b) –100 *J*
(c) 200 *J* (d) 100 *J*

28. In an adiabatic expansion of a gas initial and final temperatures are T_1 and T_2 respectively, then the change in internal energy of the gas is [MP PET 1997]

(a) $\frac{R}{\gamma-1}(T_2 - T_1)$ (b) $\frac{R}{\gamma-1}(T_1 - T_2)$
(c) $R(T_1 - T_2)$ (d) Zero

29. Helium at $27^o C$ has a volume of 8 *litres*. It is suddenly compressed to a volume of 1 *litre*. The temperature of the gas will be $[\gamma = 5/3]$ [CBSE PMT 1993; MP PMT 1999; Pb. PMT 2002]

(a) $108^o C$ (b) $9327^o C$
(c) $1200^o C$ (d) $927^o C$

30. A cycle tyre bursts suddenly. This represents an [SCRA 1994]

(a) Isothermal process (b) Isobaric process
(c) Isochoric process (d) Adiabatic process

31. One mole of helium is adiabatically expanded from its initial state (P_i, V_i, T_i) to its final state (P_f, V_f, T_f). The decrease in the internal energy associated with this expansion is equal to [SCRA 1994; BHU 2002]

(a) $C_V(T_i - T_f)$ (b) $C_P(T_i - T_f)$
(c) $\frac{1}{2}(C_P + C_V)(Ti - T_f)$ (d) $(C_P - C_V)(T_i - T_f)$

32. At N.T.P. one mole of diatomic gas is compressed adiabatically to half of its volume $\gamma = 1.41$. The work done on gas will be

(a) 1280 *J* (b) 1610 *J*
(c) 1815 *J* (d) 2025 *J*

33. For adiabatic process, wrong statement is [RPMT 1997]

(a) $dQ = 0$ (b) $dU = -dW$
(c) Q = constant (d) Entropy is not constant

34. A diatomic gas initially at 18°*C* is compressed adiabatically to one-eighth of its original volume. The temperature after compression will be [Pb. PET 1995; CBSE PMT 1996; CPMT 1999]

(a) $10^o C$ (b) $887^o C$
(c) $668K$ (d) $144^o C$

35. A gas is being compressed adiabatically. The specific heat of the gas during compression is [SCRA 1996]

(a) Zero (b) Infinite
(c) Finite but non-zero (d) Undefined

36. The process in which no heat enters or leaves the system is termed as [Pb. PET 1996; BHU 1998; BCECE 2003]

(a) Isochoric (b) Isobaric
(c) Isothermal (d) Adiabatic

37. Two moles of an ideal monoatomic gas at $27^o C$ occupies a volume of *V*. If the gas is expanded adiabatically to the volume $2V$, then the work done by the gas will be $[\gamma = 5/3, R = 8.31 J/mol\,K]$ [RPET 1999]

(a) $-2767.23J$ (b) $2767.23J$
(c) $2500J$ (d) $-2500J$

38. At $27^o C$ a gas is suddenly compressed such that its pressure becomes $\frac{1}{8}th$ of original pressure. Temperature of the gas will be $(\gamma = 5/3)$ [BHU 2000]

(a) $420K$ (b) $327^o C$

(c) $300K$ (d) $-142^o C$

39. $\Delta U + \Delta W = 0$ is valid for [RPMT 2000]

(a) Adiabatic process (b) Isothermal process

(c) Isobaric process (d) Isochoric process

40. An ideal gas at a pressures of 1 atmosphere and temperature of $27^o C$ is compressed adiabatically until its pressure becomes 8 times the initial pressure, then the final temperature is (γ = 3/2) [EAMCET (Engg.)2000]

(a) $627^o C$ (b) $527^o C$

(c) $427^o C$ (d) $327^o C$

41. Air is filled in a motor tube at $27^o C$ and at a pressure of 8 atmospheres. The tube suddenly bursts, then temperature of air is [Given γ of air $= 1.5$] [MP PMT 2002]

(a) $27.5^o C$ (b) $75^o K$

(c) $150 K$ (d) $150^o C$

42. If $\gamma = 2.5$ and volume is equal to $\frac{1}{8}$ times to the initial volume then pressure P' is equal to (Initial pressure = P) [RPET 2003]

(a) $P' = P$ (b) $P' = 2P$

(c) $P' = P \times (2)^{15/2}$ (d) $P' = 7P$

43. In an adiabatic process, the state of a gas is changed from $P_1, V_1, T_1,$ to P_2, V_2, T_2. Which of the following relation is correct [Orissa JEE 2003]

(a) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$ (b) $P_1 V_1^{\gamma-1} = P_2 V_2^{\gamma-1}$

(c) $T_1 P_1^{\gamma} = T_2 P_2^{\gamma}$ (d) $T_1 V_1^{\gamma} = T_2 V_2^{\gamma}$

44. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio C_p / C_v for the gas is [AIEEE 2003]

(a) $\frac{3}{2}$ (b) $\frac{4}{3}$

(c) 2 (d) $\frac{5}{3}$

45. In adiabatic expansion of a gas [BCECE 2001; MP PET 2003]

(a) Its pressure increases

(b) Its temperature falls

(c) Its density increases

(d) Its thermal energy increases

46. One mole of an ideal gas at an initial temperature of T K does 6 R joules of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be [CBSE PMT 2004]

(a) $(T + 2.4)K$ (b) $(T - 2.4)K$

(c) $(T + 4)K$ (d) $(T - 4)K$

47. A gas is suddenly compressed to 1/4 th of its original volume at normal temperature. The increase in its temperature is $(\gamma = 1.5)$

(a) 273 K (b) 573 K

(c) 373 K (d) 473 K

48. A gas $(\gamma = 1.3)$ is enclosed in an insulated vessel fitted with insulating piston at a pressure of $10^5 \, N/m^2$. On suddenly pressing the piston the volume is reduced to half the initial volume. The final pressure of the gas is [RPET 2002]

(a) $2^{0.7} \times 10^5$ (b) $2^{1.3} \times 10^5$

(c) $2^{1.4} \times 10^5$ (d) None of these

49. The internal energy of the gas increases In [MP PMT 1989; RPMT 2001]

(a) Adiabatic expansion (b) Adiabatic compression

(c) Isothermal expansion (d) Isothermal compression

50. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true [CBSE PMT 1998]

(a) $\Delta U = -W$ in an adiabatic process

(b) $\Delta U = W$ in an isothermal process

(c) $\Delta U = -W$ in an isothermal process

(d) $\Delta U = W$ in an adiabatic process

51. A gas is suddenly compressed to one fourth of its original volume. What will be its final pressure, if its initial pressure is P [Pb. PET 2002]

(a) Lesss than P (b) More than P

(c) P (d) Either (a) or (c)

52. A gas for which $\gamma = 1.5$ is suddenly compressed to $\frac{1}{4}th$ of the initial volume. Then the ratio of the final to the initial pressure is [EAMCET 200

(a) 1 : 16 (b) 1 : 8

(c) 1 : 4 (d) 8 : 1

53. One mole of an ideal gas with $\gamma = 1.4$, is adiabatically compressed so that its temperature rises from 27°C to 35°C. The change in the internal energy of the gas is $(R = 8.3 \, J/mol.K)$ [EAMCET 2001]

(a) –166 J (b) 166 J

(c) –168 J (d) 168 J

54. The volume of a gas is reduced adiabatically to $\frac{1}{4}$ of its volume at 27°C, if the value of $\gamma = 1.4$, then the new temperature will be

(a) $350 \times 4^{0.4} K$ (b) $300 \times 4^{0.4} K$

(c) $150 \times 4^{0.4} K$ (d) None of these

55. During an adiabatic expansion of 2 moles of a gas, the change in internal energy was found –50J. The work done during the process is [Pb. PET 1996]

(a) Zero (b) 100J

(c) – 50J (d) 50J

56. Adiabatic modulus of elasticity of a gas is $2.1 \times 10^5 \, N/m^2$. What will be its isothermal modulus of elasticity $\left(\frac{C_p}{C_v} = 1.4\right)$

[UPSEAT 1999]

(a) $1.8\times10^5\,N/m^2$ (b) $1.5\times10^5\,N/m^2$

(c) $1.4\times10^5\,N/m^2$ (d) $1.2\times10^5\,N/m^2$

57. For an adiabatic expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal to [CPMT 1983; MP PMT 1990]

(a) $-\sqrt{\gamma}\,\frac{\Delta V}{V}$ (b) $-\frac{\Delta V}{V}$

(c) $-\gamma\,\frac{\Delta V}{V}$ (d) $-\gamma^2\,\frac{\Delta V}{V}$

Isobaric and Isochoric Processes

1. A gas expands under constant pressure P from volume V_1 to V_2. The work done by the gas is

[CBSE PMT 1990; RPMT 2003]

(a) $P(V_2-V_1)$ (b) $P(V_1-V_2)$

(c) $P(V_1^\gamma-V_2^\gamma)$ (d) $P\,\frac{V_1V_2}{V_2-V_1}$

2. When heat in given to a gas in an isobaric process, then

[DPMT 2001]

(a) The work is done by the gas

(b) Internal energy of the gas increases

(c) Both (a) and (b)

(d) None from (a) and (b)

3. One mole of a perfect gas in a cylinder fitted with a piston has a pressure *P*, volume *V* and temperature *T*. If the temperature is increased by 1 *K* keeping pressure constant, the increase in volume is

(a) $\frac{2V}{273}$ (b) $\frac{V}{91}$

(c) $\frac{V}{273}$ (d) V

4. A gas is compressed at a constant pressure of $50N/m^2$ from a volume of $10m^3$ to a volume of $4m^3$. Energy of 100 *J* then added to the gas by heating. Its internal energy is

[MNR 1994]

(a) Increased by 400 *J* (b) Increased by 200 *J*

(c) Increased by 100 *J* (d) Decreased by 200 *J*

5. Work done by air when it expands from 50 *litres* to 150 *litres* at a constant pressure of 2 atmosphere is

(a) 2×10^4 *joules* (b) 2×100 *joules*

(c) $2\times10^5\times100$ *joules* (d) $2\times10^{-5}\times100$ joules

6. Work done by 0.1 mole of a gas at 27^oC to double its volume at constant pressure is (R = 2 *cal mol*$^{-1}$ *C*$^{-1}$)

[EAMCET 1994]

(a) 54 *cal* (b) 600 *cal*

(c) 60 *cal* (d) 546 *cal*

7. Unit mass of a liquid with volume V_1 is completely changed into a gas of volume V_2 at a constant external pressure P and temperature *T*. If the latent heat of evaporation for the given mass is *L*, then the increase in the internal energy of the system is

(a) Zero (b) $P(V_2-V_1)$

(c) $L-P(V_2-V_1)$ (d) L

8. A gas expands $0.25m^3$ at constant pressure $10^3\,N/m^2$, the work done is

[CPMT 1997; UPSEAT 1999; JIPMER 2001, 02]

(a) 2.5 *ergs* (b) 250 *J*

(c) 250 *W* (d) 250 *N*

9. Two kg of water is converted into steam by boiling at atmospheric pressure. The volume changes from $2\times10^{-3}\,m^3$ to $3.34m^3$. The work done by the system is about

(a) – 340 *kJ* (b) – 170 *kJ*

(c) 170 *kJ* (d) 340 *kJ*

10. An ideal gas has volume V_0 at 27^oC. It is heated at constant pressure so that its volume becomes $2V_0$. The final temperature is

[BCECE 2003]

(a) 54^oC (b) 32.6^oC

(c) $327\,°C$ (d) 150 *K*

11. If 300 *ml* of a gas at 27^oC is cooled to 7^oC at constant pressure, then its final volume will be

[Pb. PET 1999; BHU 2003; CPMT 2004]

(a) 540 *ml* (b) 350 *ml*

(c) 280 *ml* (d) 135 *ml*

12. Which of the following is correct in terms of increasing work done for the same initial and final state [RPMT 1996]

(a) Adiabatic < Isothermal < Isobaric

(b) Isobaric < Adiabatic < Isothermal

(c) Adiabatic < Isobaric < Isothermal

(d) None of these

13. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is

[CBSE PMT 1997; AIIMS 1998; JIPMER 2000]

(a) Isothermal (b) Isobaric

(c) Adiabatic (d) Equal in all cases

14. Which of the following is a slow process [J & K CET 2000]

(a) Isothermal (b) Adiabatic

(c) Isobaric (d) None of these

15. How much work to be done in decreasing the volume of and ideal gas by an amount of $2.4\times10^{-4}m^3$ at normal temperature and constant normal pressure of $1\times10^5\,N/m^2$

[UPSEAT 1999]

(a) 28 *joule* (b) 27 *joule*

(c) 25 *joule* (d) 24 *joule*

16. A Container having 1 mole of a gas at a temperature 27°*C* has a movable piston which maintains at constant pressure in container of 1 *atm*. The gas is compressed until temperature becomes 127°*C*. The work done is (C_p for gas is 7.03 *cal/mol K*)

(a) 703 *J* (b) 814 *J*

(c) 121 *J* (d) 2035 *J*

17. In a reversible isochoric change [NCERT 1990]

[Roorkee 1999]

(a) $\Delta W = 0$ (b) $\Delta Q = 0$

(c) $\Delta T = 0$ (d) $\Delta U = 0$

18. Entropy of a thermodynamic system does not change when this system is used for [AIIMS 1995]

(a) Conduction of heat from a hot reservoir to a cold reservoir

(b) Conversion of heat into work isobarically

(c) Conversion of heat into internal energy isochorically

(d) Conversion of work into heat isochorically

19. The work done in which of the following processes is zero [UPSEAT 2003]

(a) Isothermal process (b) Adiabatic process

(c) Isochoric process (d) None of these

20. In which thermodynamic process, volume remains same [Orissa PMT 2004]

(a) Isobaric (b) Isothermal

(c) Adiabatic (d) Isochoric

21. In an isochoric process if $T_1 = 27^o C$ and $T_2 = 127^o C$, then P_1 / P_2 will be equal to [RPMT 2003]

(a) 9 / 59 (b) 2 / 3

(c) 3 / 4 (d) None of these

22. Which is incorrect [DCE 2001]

(a) In an isobaric process, $\Delta p = 0$

(b) In an isochoric process, $\Delta W = 0$

(c) In an isothermal process, $\Delta T = 0$

(d) In an isothermal process, $\Delta Q = 0$

23. Which relation is correct for isometric process [RPMT 2001; BCECE 2003]

(a) $\Delta Q = \Delta U$ (b) $\Delta W = \Delta U$

(c) $\Delta Q = \Delta W$ (d) None of these

Heat Engine, Refrigerator and Second Law of Thermodynamics

1. A Carnot engine working between $300\ K$ and 600*K* has work output of 800 *J* per cycle. What is amount of heat energy supplied to the engine from source per cycle [DPMT 1999; Pb. PMT 2002, 05; Kerala PMT 2004]

(a) 1800 *J/cycle* (b) 1000 *J/cycle*

(c) 2000 *J/cycle* (d) 1600 *J/cycle*

2. The coefficient of performance of a Carnot refrigerator working between $30^o C$ and $0^o C$ is [UPSEAT 2002]

(a) 10 (b) 1

(c) 9 (d) 0

3. If the door of a refrigerator is kept open, then which of the following is true [DPMT 2001; BHU 2001; JIPMER 2002; AIEEE 2002; CPMT 2003]

(a) Room is cooled

(b) Room is heated

(c) Room is either cooled or heated

(d) Room is neither cooled nor heated

4. In a cyclic process, the internal energy of the gas

(a) Increases (b) Decreases

(c) Remains constant (d) Becomes zero

5. Irreversible process is

(a) Adiabatic process

(b) Joule-Thomson expansion

(c) Ideal isothermal process

(d) None of the above

6. For a reversible process, necessary condition is

(a) In the whole cycle of the system, the loss of any type of heat energy should be zero

(b) That the process should be too fast

(c) That the process should be slow so that the working substance should remain in thermal and mechanical equilibrium with the surroundings

(d) The loss of energy should be zero and it should be *quasistatic*

7. In a cyclic process, work done by the system is [BHU 2002]

(a) Zero

(b) Equal to heat given to the system

(c) More than the heat given to system

(d) Independent of heat given to the system

8. An ideal gas heat engine operates in a Carnot's cycle between $227^o C$ and $127^o C$. It absorbs 6×10^4 *J* at high temperature. The amount of heat converted into work is .... [KCET 2004]

(a) $4.8 \times 10^4\ J$ (b) $3.5 \times 10^4\ J$

(c) $1.6 \times 10^4\ J$ (d) $1.2 \times 10^4\ J$

9. An ideal heat engine exhausting heat at $77^o C$ is to have a 30% efficiency. It must take heat at [BCECE 2004]

(a) $127^o C$ (b) $227^o C$

(c) $327^o C$ (d) $673^o C$

10. Efficiency of Carnot engine is 100% if [Pb. PET 2000]

(a) $T_2 = 273\ K$ (b) $T_2 = 0\ K$

(c) $T_1 = 273\ K$ (d) $T_1 = 0\ K$

11. A Carnot's engine used first an ideal monoatomic gas then an ideal diatomic gas. If the source and sink temperature are $411^o C$ and $69^o C$ respectively and the engine extracts 1000 *J* of heat in each cycle, then area enclosed by the *PV* diagram is

(a) 100 *J* (b) 300 *J*

(c) 500 *J* (d) 700 *J*

12. A Carnot engine absorbs an amount Q of heat from a reservoir at an absolute temperature T and rejects heat to a sink at a temperature of *T*/3. The amount of heat rejected is [UPSEAT 2004]

(a) $Q / 4$ (b) $Q / 3$

(c) $Q / 2$ (d) $2Q / 3$

13. The temperature of sink of Carnot engine is $27^o C$. Efficiency of engine is 25%. Then temperature of source is

[DCE 2002; CPMT 2002]

(a) $227^o C$ (b) $327^o C$

(c) $127^o C$ (d) $27^o C$

14. The temperature of reservoir of Carnot's engine operating with an efficiency of 70% is 1000*K*. The temperature of its sink is

(a) 300 *K* (b) 400 *K*

(c) 500 *K* (d) 700 *K*

15. In a Carnot engine, when $T_2 = 0^o C$ and $T_1 = 200^o C$, its efficiency is η_1 and when $T_1 = 0\ ^o C$ and $T_2 = -200\ ^o C$, Its efficiency is η_2, then what is η_1 / η_2 [DCE 2004]

(a) 0.577 (b) 0.733

(c) 0.638 (d) Can not be calculated

16. The efficiency of Carnot's engine operating between reservoirs, maintained at temperatures $27^o C$ and $-123^o C$, is

(a) 50% (b) 24%

(c) 0.75% (d) 0.4%

17. A Carnot engine operates between $227^o C$ and $27^o C$. Efficiency of the engine will be [DCE 1999; BHU 2004]

(a) $\frac{1}{3}$ (b) $\frac{2}{5}$

(c) $\frac{3}{4}$ (d) $\frac{3}{5}$

18. A measure of the degree of disorder of a system is known as

[Pb. PET 1997; MH CET 1999]

(a) Isobaric (b) Isotropy

(c) Enthalpy (d) Entropy

19. A carnot engine has the same efficiency between 800 *K* to 500 *K* and *x K* to 600 *K*. The value of *x* is

[Pb. PMT 1996; CPMT 1996]

(a) 1000 *K* (b) 960 *K*

(c) 846 *K* (d) 754 *K*

20. A scientist says that the efficiency of his heat engine which operates at source temperature 127°*C* and sink temperature 27°*C* is 26%, then [CBSE PMT 2001]

(a) It is impossible

(b) It is possible but less probable

(c) It is quite probable

(d) Data are incomplete

21. A Carnot's engine is made to work between 200°*C* and 0°*C* first and then between 0°*C* and –200°*C*. The ratio of efficiencies of the engine in the two cases is [KCET 2002]

(a) 1.73 : 1 (b) 1 : 1.73

(c) 1 : 1 (d) 1 : 2

22. Efficiency of a Carnot engine is 50% when temperature of outlet is 500 *K*. In order to increase efficiency up to 60% keeping temperature of intake the same what is temperature of outlet [CBSE PMT 2002]

(a) 200 *K* (b) 400 *K*

(c) 600 *K* (d) 800 *K*

23. Even Carnot engine cannot give 100% efficiency because we cannot[AIEEE 2002]

(a) Prevent radiation

(b) Find ideal sources

(c) Reach absolute zero temperature

(d) Eliminate friction

24. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of [AIEEE 2003, EAM

(a) Second law of thermodynamics

(b) Conservation of momentum [DCE 2003]

(c) Conservation of mass

(d) First law of thermodynamics

25. A Carnot engine takes $3 \times 10^6\ cal.$ of heat from a reservoir at 627°*C*, and gives it to a sink at 27°*C*. The work done by the engine is [AIEEE 2003]

(a) $4.2 \times 10^6\ J$ (b) $8.4 \times 10^6\ J$

(c) $16.8 \times 10^6\ J$ (d) Zero

26. The first operation involved in a Carnot cycle is

[AFMC 1998]

[DPMT 2002, 03; BVP 2004]

(a) Isothermal expansion (b) Adiabatic expansion

(c) Isothermal compression (d) Adiabatic compression

27. For which combination of working temperatures the efficiency of Carnot's engine is highest [KCET 2000]

(a) 80 *K*, 60 *K* (b) 100 *K*, 80 *K*

(c) 60 *K*, 40 *K* (d) 40 *K*, 20 *K*

28. The efficiency of Carnot engine when source temperature is *T* and sink temperature is *T* will be [DCE 2000]

(a) $\frac{T_1 - T_2}{T_1}$ (b) $\frac{T_2 - T_1}{T_2}$

(c) $\frac{T_1 - T_2}{T_2}$ (d) $\frac{T_1}{T_2}$

29. An ideal heat engine working between temperature *T* and *T* has an efficiency η, the new efficiency if both the source and sink temperature are doubled, will be [DPMT 2000]

(a) $\frac{\eta}{2}$ (b) η

(c) 2η (d) 3η

30. An ideal refrigerator has a freezer at a temperature of $-13°C$. The coefficient of performance of the engine is 5. The temperature of the air (to which heat is rejected) will be

[BHU 2000; CPMT 2002]

(a) 325°*C* (b) 325*K*

(c) 39°*C* (d) 320°*C*

31. In a mechanical refrigerator, the low temperature coils are at a temperature of – 23°*C* and the compressed gas in the condenser has a temperature of 27°*C*. The theoretical coefficient of performance is [UPSEAT 2001]

(a) 5 (b) 8

(c) 6 (d) 6.5

32. An engine is supposed to operate between two reservoirs at temperature 727°*C* and 227°*C*. The maximum possible efficiency of such an engine is [UPSEAT 2005]

(a) 1/2 (b) 1/4

(c) 3/4 (d) 1

33. An ideal gas heat engine operates in Carnot cycle between 227°*C* and 127°*C*. It absorbs 6×10^4 *cals* of heat at higher temperature. Amount of heat converted to work is

[CBSE PMT 2005]

(a) 2.4×10^4 *cal* (b) 6×10^4 *cal*

(c) 1.2×10^4 *cal* (d) 4.8×10^4 *cal*

34. Which of the following processes is reversible

[CBSE PMT 2005]

(a) Transfer of heat by radiation
(b) Electrical heating of a nichrome wire
(c) Transfer of heat by conduction
(d) Isothermal compression

Critical Thinking
Objective Questions

1. When an ideal diatomic gas is heated at constant pressure, the fraction of the heat energy supplied which increases the internal energy of the gas, is

[IIT 1990; UPSEAT 1998; RPET 2000]

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$

(c) $\frac{3}{7}$ (d) $\frac{5}{7}$

2. $1cm^3$ of water at its boiling point absorbs 540 calories of heat to become steam with a volume of $1671cm^3$.If the atmospheric pressure = $1.013x10^5 N/m^2$ and the mechanical equivalent of heat = $4.19 J/calorie$, the energy spent in this process in overcoming intermolecular forces is

[MP PET 1999, 2001; Orissa JEE 2002]

(a) 540 *cal* (b) 40 *cal*
(c) 500 *cal* (d) Zero

3. During the melting of a slab of ice at 273 *K* at atmospheric pressure

(a) Positive work is done by ice-water system on the atmosphere
(b) Positive work is done on the ice-water system by the atmosphere
(c) The internal energy of the ice-water system increases
(d) The internal energy of the ice-water system decreases

4. Two identical containers *A* and *B* with frictionless pistons contain the same ideal gas at the same temperature and the same volume *V*. The mass of the gas in *A* is m_A and that in *B* is m_B. The gas in each cylinder is now allowed to expand isothermally to the same final volume 2*V*. The changes in the pressure in *A* and *B* are found to be ΔP and 1.5 ΔP respectively. Then

(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$

(c) $3m_A = 2m_B$ (d) $9m_A = 3m_B$

5. A monoatomic ideal gas, initially at temperature T_1, is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature. T_2 by releasing the piston suddenly. If L_1 and L_2 are the lengths of the gas column before and after expansion respectively, then T_1/T_2 is given by

[IIT-JEE (Screening) 2000]

(a) $\left(\frac{L_1}{L_2}\right)^{2/3}$ (b) $\frac{L_1}{L_2}$

(c) $\frac{L_2}{L_1}$ (d) $\left(\frac{L_2}{L_1}\right)^{2/3}$

6. A closed hollow insulated cylinder is filled with gas at $0^o C$ and also contains an insulated piston of negligible weight and negligible thickness at the middle point. The gas on one side of the piston is heated to $100^o C$. If the piston moves $5\,cm$, the length of the hollow cylinder is [EAMCET 2001]

(a) 13.65 *cm* (b) 27.3 *cm*
(c) 38.6 *cm* (d) 64.6 *cm*

7. A mono atomic gas is supplied the heat *Q* very slowly keeping the pressure constant. The work done by the gas will be

(a) $\frac{2}{3}Q$ (b) $\frac{3}{5}Q$

(c) $\frac{2}{5}Q$ (d) $\frac{1}{5}Q$

8. A gas mixture consists of 2 moles of oxygen and 4 moles argon at temperature *T*. Neglecting all vibrational modes, the total internal energy of the system is

[IIT 1999; UPSEAT 2003]

(a) 4 *RT* (b) 15 *RT*
(c) 9 *RT* (d) 11 *RT*

9. An ideal gas expands isothermally from a volume V_1 to V_2 and then compressed to original volume V_1 adiabatically. Initial pressure is P_1 and final pressure is P_3. The total work done is *W*. Then

(a) $P_3 > P_1, W > 0$ (b) $P_3 < P_1, W < 0$

(c) $P_3 > P_1, W < 0$ [IIT 1998] (d) $P_3 = P_1, W = 0$

10. Work done by a system under isothermal change from a volume V_1 to V_2 for a gas which obeys Vander Waal's equation $(V - \beta n)\left(P + \frac{\alpha n^2}{V}\right) = nRT$

[IIT 1998]

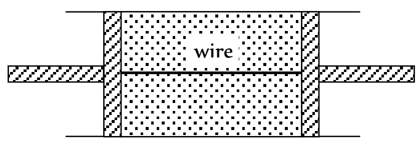
(a) $nRT \log_e\left(\frac{V_2 - n\beta}{V_1 - n\beta}\right) + \alpha n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

(b) $nRT \log_{10}\left(\frac{V_2 - \alpha\beta}{V_1 - \alpha\beta}\right) + \alpha n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

(c) $nRT \log_e\left(\frac{V_2 - n\alpha}{V_1 - n\alpha}\right) + \beta n^2 \left(\frac{V_1 - V_2}{V_1 V_2}\right)$

(d) $nRT \log_e\left(\frac{V_1 - n\beta}{V_2 - n\beta}\right) + \alpha n^2 \left(\frac{V_1 V_2}{V_1 - V_2}\right)$

11. A cylindrical tube of uniform cross-sectional area *A* is fitted with two air tight frictionless pistons. The pistons are connected to each other by a metallic wire. Initially the pressure of the gas is P_0 and temperature is T_0, atmospheric pressure is also P_0. Now the temperature of the gas is increased to $2T_0$, the tension in the wire will be



(a) $2P_0A$ (b) P_0A

(c) $\frac{P_0A}{2}$ (d) $4P_0A$

12. The molar heat capacity in a process of a diatomic gas if it does a work of $\frac{Q}{4}$ when a heat of Q is supplied to it is

(a) $\frac{2}{5}R$ (b) $\frac{5}{2}R$

(c) $\frac{10}{3}R$ (d) $\frac{6}{7}R$

13. An insulator container contains 4 moles of an ideal diatomic gas at temperature *T*. Heat *Q* is supplied to this gas, due to which 2 moles of the gas are dissociated into atoms but temperature of the gas remains constant. Then

(a) $Q = 2RT$ (b) $Q = RT$

(c) $Q = 3RT$ (d) $Q = 4RT$

14. The volume of air increases by 5% in its adiabatic expansion. The percentage decrease in its pressure will be

(a) 5% (b) 6%

(c) 7% (d) 8%

15. The temperature of a hypothetical gas increases to $\sqrt{2}$ times when compressed adiabatically to half the volume. Its equation can be written as

(a) $PV^{3/2}$ = constant (b) $PV^{5/2}$ = constant

(c) $PV^{7/3}$ = constant (d) $PV^{4/3}$ = constant

16. Two Carnot engines *A* and *B* are operated in succession. The first one, *A* receives heat from a source at $T_1 = 800K$ and rejects to sink at T_2K. The second engine *B* receives heat rejected by the first engine and rejects to another sink at $T_3 = 300K$. If the work outputs of two engines are equal, then the value of T_2 is

(a) 100*K* (b) 300*K*

(c) 550*K* (d) 700*K*

17. When an ideal monoatomic gas is heated at constant pressure, fraction of heat energy supplied which increases the internal energy of gas, is [AIIMS 1995]

(a) $\frac{2}{5}$ (b) $\frac{3}{5}$

(c) $\frac{3}{7}$ (d) $\frac{3}{4}$

18. When an ideal gas ($\gamma = 5/3$) is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work [RPET 1999]

(a) 40 % (b) 30 %

(c) 60 % (d) 20 %

19. Which one of the following gases possesses the largest internal energy [SCRA 1998]

(a) 2 moles of helium occupying $1m^3$ at 300 *K*

(b) 56 *kg* of nitrogen at $107 Nm^{-2}$ and 300 *K*

(c) 8 grams of oxygen at 8 atm and 300 *K*

(d) 6×10^{26} molecules of argon occupying $40m^3$ at 900 *K*

20. Two samples *A* and *B* of a gas initially at the same pressure and temperature are compressed from volume *V* to *V/2* (A isothermally and adiabatically). The final pressure of *A* is

[MP PET 1996, 99; MP PMT 1997, 99]

(a) Greater than the final pressure of *B*

(b) Equal to the final pressure of *B*

(c) Less than the final pressure of *B*

(d) Twice the final pressure of *B*

21. Initial pressure and volume of a gas are *P* and *V* respectively. First it is expanded isothermally to volume $4V$ and then compressed adiabatically to volume *V*. The final pressure of gas will be [CBSE PMT 1999]

(a) 1*P* (b) 2*P*

(c) 4*P* (d) 8*P*

22. A thermally insulated rigid container contains an ideal gas heated by a filament of resistance 100 Ω through a current of 1*A* for 5 min then change in internal energy is

[IIT-JEE (Screening) 2005]

(a) 0 *kJ* (b) 10 *kJ*

(c) 20 *kJ* (d) 30 *kJ*

23. A reversible engine converts one-sixth of the heat input into work. When the temperature of the sink is reduced by 62°*C*, the efficiency of the engine is doubled. The temperatures of the source and sink are [CBSE PMT 2000]

(a) 80°*C*, 37°*C* (b) 95°*C*, 28°*C*

(c) 90°*C*, 37°*C* (d) 99°*C*, 37°*C*

24. An engineer claims to have made an engine delivering 10 *kW* power with fuel consumption of 1 *g/sec*. The calorific value of the fuel is 2 *kcal/g*. Is the claim of the engineer

[J & K CET 2000]

(a) Valid

(b) Invalid

(c) Depends on engine design

(d) Depends of the load

25. Find the change in the entropy in the following process 100 *gm* of ice at 0°*C* melts when dropped in a bucket of water at 50°*C* (Assume temperature of water does not change) [BHU (Med.) 2000]

(a) – 4.5 *cal/K* (b) + 4.5 *cal/K*

(c) +5.4 *cal/K* (d) – 5.4 *cal/K*

26. An ideal gas expands in such a manner that its pressure and volume can be related by equation PV^2 = constant. During this process, the gas is [UPSEAT 2002]

(a) Heated

(b) Cooled

(c) Neither heated nor cooled

(d) First heated and then cooled

27. A Carnot engine whose low temperature reservoir is at 7°C has an efficiency of 50%. It is desired to increase the efficiency to 70%. By how many degrees should the temperature of the high temperature reservoir be increased

[UPSEAT 2005]

(a) 840 K (b) 280 K

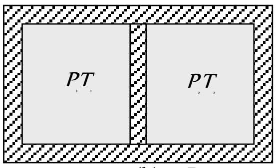
(c) 560 K (d) 380 K

28. P-V diagram of a diatomic gas is a straight line passing through origin. The molar heat capacity of the gas in the process will be

(a) 4 R (b) 2.5 R

(c) 3 R (d) $\frac{4R}{3}$

29. Following figure shows on adiabatic cylindrical container of volume V_0 divided by an adiabatic smooth piston (area of cross-section = A) in two equal parts. An ideal gas $(C_P / C_V = \gamma)$ is at pressure P_1 and temperature T_1 in left part and gas at pressure P_2 and temperature T_2 in right part. The piston is slowly displaced and released at a position where it can stay in equilibrium. The final pressure of the two parts will be (Suppose x = displacement of the piston)



(a) P_2 (b) P_1

(c) $\frac{P_1\left(\frac{V_0}{2}\right)^{\gamma}}{\left(\frac{V_0}{2}+Ax\right)^{\gamma}}$ (d) $\frac{P_2\left(\frac{V_0}{2}\right)^{\gamma}}{\left(\frac{V_0}{2}+Ax\right)^{\gamma}}$

30. Two cylinders A and B fitted with pistons contain equal amounts of an ideal diatomic gas at 300 K. The piston of A is free to move while that of B is held fixed. The same amount of heat is given to the gas in each cylinder. If the rise in temperature of the gas in A is 30 K, then the rise in temperature of the gas in B is

[IIT 1998]

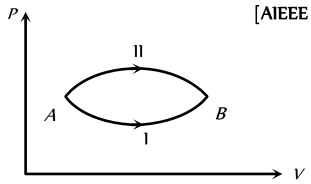
(a) 30 K (b) 18 K

(c) 50 K (d) 42 K

GQ Graphical Questions

1. A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then

[AIEEE 2005]



(a) $\Delta U_{II} > \Delta U_I$

(b) $\Delta U_{II} < \Delta U_I$

(c) $\Delta U_I = \Delta U_{II}$

(d) Relation between ΔU_I and ΔU_{II} can not be determined

2. A thermodynamic system is taken through the cycle $PQRSP$ process. The net work done by the system is

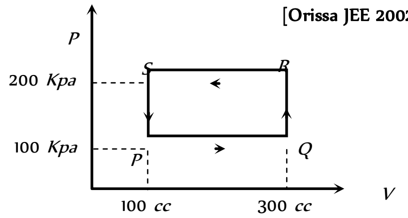
[Orissa JEE 2002]

(a) 20 J

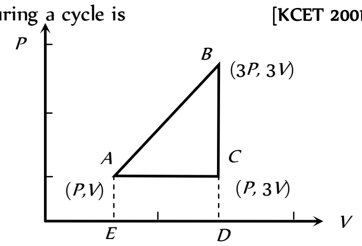
(b) – 20 J

(c) 400 J

(d) – 374 J



3. An ideal gas is taken around *ABCA* as shown in the above *P-V* diagram. The work done during a cycle is [KCET 2001]



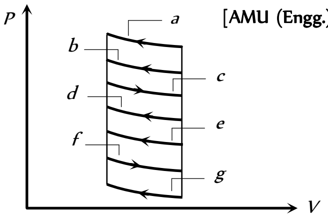
(a) $2PV$

(b) PV

(c) $1/2PV$

(d) Zero

4. The *P-V* diagram shows seven curved paths (connected by vertical paths) that can be followed by a gas. Which two of them should be parts of a closed cycle if the net work done by the gas is to be at its maximum value [AMU (Engg.) 2000]



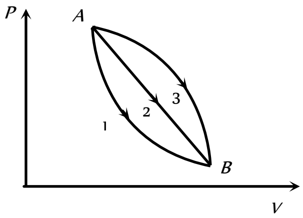
(a) *ac*

(b) *cg*

(c) *af*

(d) *cd*

5. An ideal gas of mass *m* in a state *A* goes to another state *B* via three different processes as shown in figure. If Q_1, Q_2 and Q_3 denote the heat absorbed by the gas along the three paths, then



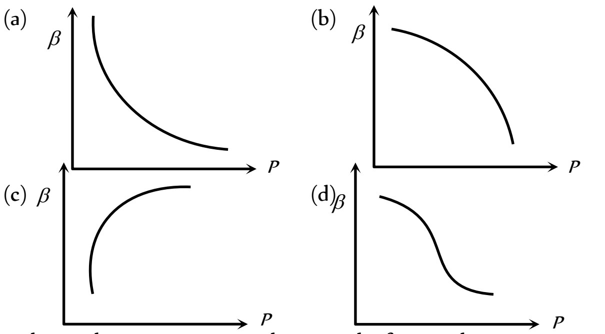
(a) $Q_1 < Q_2 < Q_3$

(b) $Q_1 < Q_2 = Q_3$

(c) $Q_1 = Q_2 > Q_3$

(d) $Q_1 > Q_2 > Q_3$

6. Which of the following graphs correctly represents the variation of $\beta = -(dV/dP)/V$ with P for an ideal gas at constant temperature [IIT-JEE (Screening) 2002]

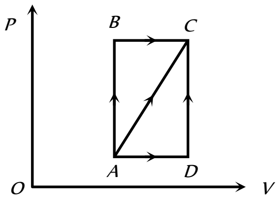


7. A thermodynamic process is shown in the figure. The pressures and volumes corresponding to some points in the figure are :

$P_A = 3\times 10^4\ Pa, P_B = 8\times 10^4\ Pa$ and

$V_A = 2\times 10^{-3} m^3, V_D = 5\times 10^{-3} m^3$

In process *AB*, 600 *J* of heat is added to the system and in process *BC*, 200 *J* of heat is added to the system. The change in internal energy of the system in process *AC* would be



(a) 560 *J*

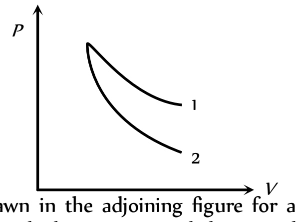
(b) 800 *J*

(c) 600 *J*

(d) 640 *J*

8. *P-V* plots for two gases during adiabatic process are shown in the figure. Plots 1 and 2 should correspond respectively to

[IIT-JEE (Screening) 2001]



(a) *He* and O_2

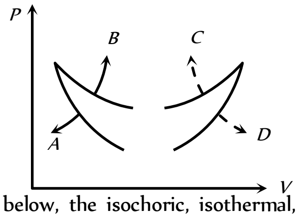
(b) O_2 and *He*

(c) *He* and *Ar*

(d) O_2 and N_2

9. Four curves *A*, *B*, *C* and *D* are drawn in the adjoining figure for a given amount of gas. The curves which represent adiabatic and isothermal changes are

[CPMT 1986; UPSEAT 1999]



(a) *C* and *D* respectively

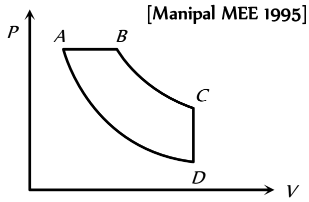
(b) *D* and *C* respectively

(c) *A* and *B* respectively

(d) *B* and *A* respectively

10. In pressure-volume diagram given below, the isochoric, isothermal, and isobaric parts respectively, are

[Manipal MEE 1995]



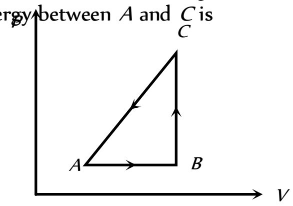
(a) *BA, AD, DC* [MP PET 1992]

(b) *DC, CB, BA*

(c) *AB, BC, CD*

(d) *CD, DA, AB*

11. The *P-V* diagram of a system undergoing thermodynamic transformation is shown in figure. The work done on the system in going from $A \to B \to C$ is 50 *J* and 20 *cal* heat is given to the system. The change in internal energy between *A* and *C* is



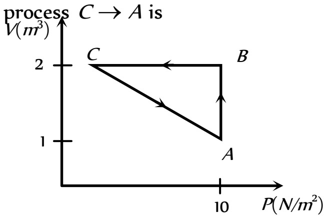
(a) 34 *J*

(b) 70 *J*

(c) 84 *J*

(d) 134 *J*

12. An ideal gas is taken through the cycle $A \to B \to C \to A$, as shown in the figure. If the net heat supplied to the gas in the cycle is 5 *J*, the work done by the gas in the process $C \to A$ is



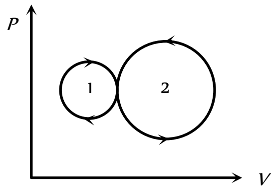
(a) – 5 *J*

(b) – 10 *J*

(c) – 15 *J*

(d) – 20 *J*

13. In the following indicator diagram, the net amount of work done will be



(a) Positive

(b) Negative [CBSE PMT 1992]

(c) Zero

(d) Infinity

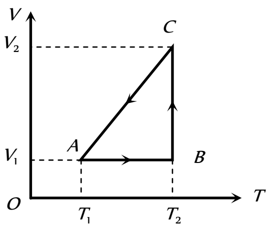
14. A cyclic process for 1 mole of an ideal gas is shown in figure in the *V-T*, diagram. The work done in *AB*, *BC* and *CA* respectively

(a) $0, RT_2 \ln\left(\frac{V_1}{V_2}\right), R(T_1 - T_2)$

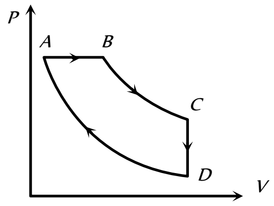
(b) $R(T_1 - T_2), 0, RT_1 \ln\frac{V_1}{V_2}$

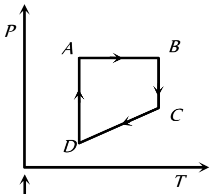
(c) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_1 - T_2)$

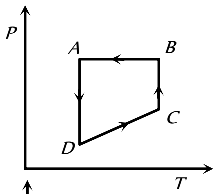
(d) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_2 - T_1)$

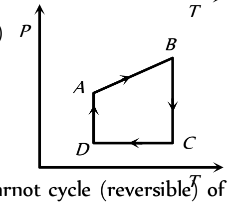


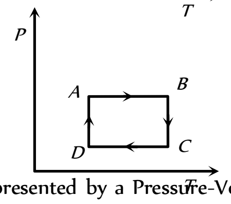
15. A cyclic process *ABCD* is shown in the figure *P-V* diagram. Which of the following curves represent the same process



(a)


(b)


(c)


(d)


16. Carnot cycle (reversible) of a gas represented by a Pressure-Volume curve is shown in the diagram

Consider the following statements

I. Area *ABCD* = Work done on the gas

II. Area *ABCD* = Net heat absorbed

III. Change in the internal energy in cycle = 0

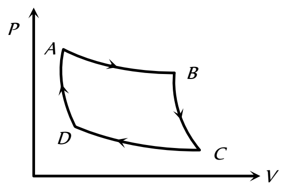
Which of these are correct [AMU (Med.) 2001]

(a) I only

(b) II only

(c) II and III

(d) I, II and III



17. The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is

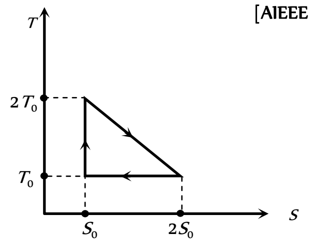
[AIEEE 2005]

(a) $1/3$

(b) $2/3$

(c) $1/2$

(d) $1/4$



18. Work done in the given *P-V* diagram in the cyclic process is

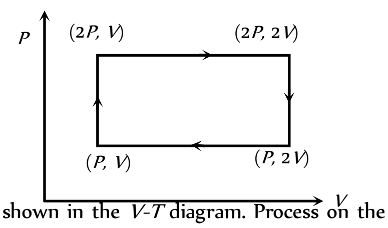
[UPSEAT 1998; RPET 2000; Kerala PMT 2002]

(a) *PV*

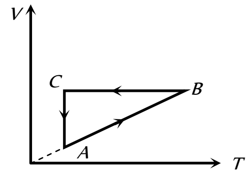
(b) 2*PV*

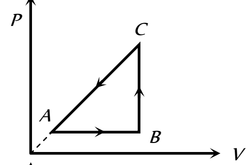
(c) *PV*/2

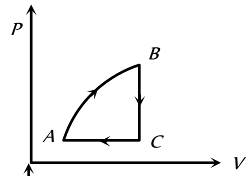
(d) 3*PV*

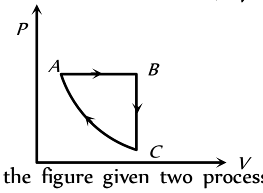


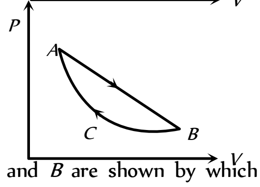
19. A cyclic process *ABCA* is shown in the *V-T* diagram. Process on the *P-V* diagram is



(a)


(b)


(c)


(d)


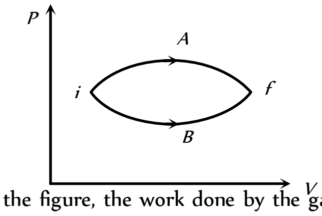
20. In the figure given two processes *A* and *B* are shown by which a thermo-dynamical system goes from initial to final state *F*. If ΔQ_A and ΔQ_B are respectively the heats supplied to the systems then

(a) $\Delta Q_A = \Delta Q_B$

(b) $\Delta Q_A \geq \Delta Q_B$

(c) $\Delta Q_A < \Delta Q_B$

(d) $\Delta Q_A > \Delta Q_B$



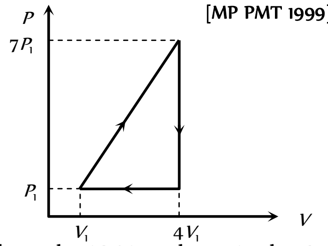
21. In the cyclic process shown in the figure, the work done by the gas in one cycle is [MP PMT 1999]

(a) $28\ P_1V_1$

(b) $14\ P_1V_1$

(c) $18\ P_1V_1$

(d) $9\ P_1V_1$



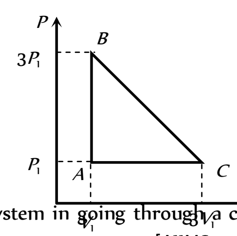
22. An ideal gas is taken around the cycle *ABCA* as shown in the *P-V* diagram. The net work done by the gas during the cycle is equal to

(a) $12\ P_1V_1$

(b) $6\ P_1V_1$

(c) $3\ P_1V_1$

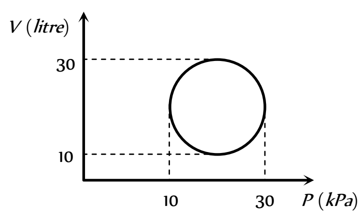
(d) $2P_1V_1$



23. Heat energy absorbed by a system in going through a cyclic process shown in figure is [AIIMS 1995; BHU 2002]

(a) $10^7\ \pi J$

(b) $10^4\ \pi J$



(c) $10\pi\, J$

(d) $10^{-3}\,\pi J$

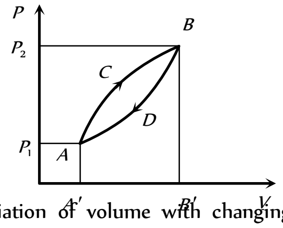
24. A thermodynamic system is taken from state A to B along ACB and is brought back to A along BDA as shown in the PV diagram. The net work done during the complete cycle is given by the area

(a) $P_1ACBP_2P_1$

(b) $ACBB'A'A$

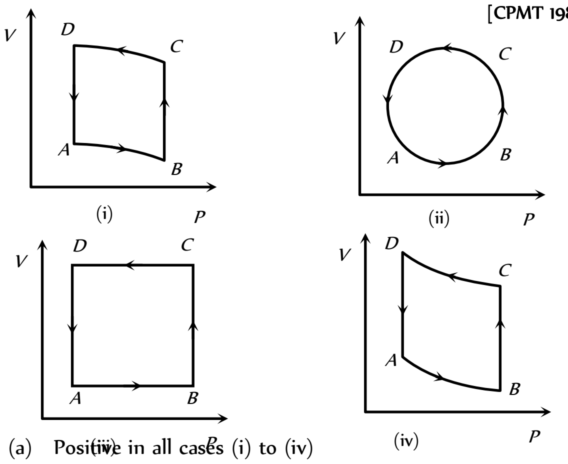
(c) $ACBDA$

(d) $ADBB'A'A$



25. In the diagrams (i) to (iv) of variation of volume with changing pressure is shown. A gas is taken along the path $ABCD$. The change in internal energy of the gas will be

[CPMT 1986, 88]



(a) Positive in all cases (i) to (iv)

(b) Positive in cases (i), (ii) and (iii) but zero in (iv) case

(c) Negative in cases (i), (ii) and (iii) but zero in (iv) case

(d) Zero in all four cases

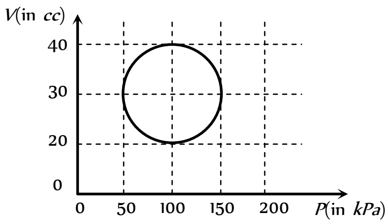
26. A system is taken through a cyclic process represented by a circle as shown. The heat absorbed by the system is

(a) $\pi \times 10^3\, J$

(b) $\frac{\pi}{2}\, J$

(c) $4\pi \times 10^2\, J$

(d) $\pi\, J$



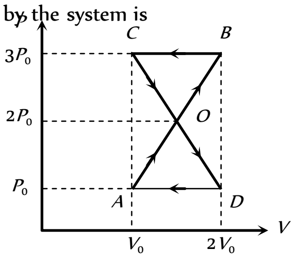
27. A thermodynamic system undergoes cyclic process $ABCDA$ as shown in figure. The work done by the system is

(a) P_0V_0

(b) $2P_0V_0$

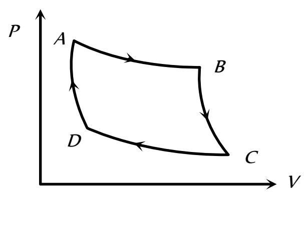
(c) $\frac{P_0V_0}{2}$

(d) Zero



28. The P-V graph of an ideal gas cycle is shown here as below. The adiabatic process is described by

[CPMT 1985; UPSEAT 2003]



(a) AB and BC

(b) AB and CD

(c) BC and DA

(d) BC and CD

[CBSE PMT 1992]

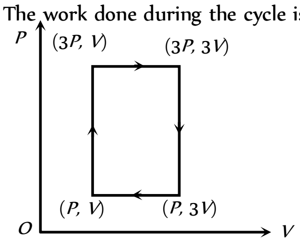
29. An ideal monoatomic gas is taken round the cycle ABCDA as shown in following P-V diagram. The work done during the cycle is [IIT 1983; CPMT 19

(a) PV

(b) $2\ PV$

(c) $4\ PV$

(d) Zero



30. A system changes from the state (P_1, V_1) to (P_2V_2) as shown in the figure. What is the work done by the system

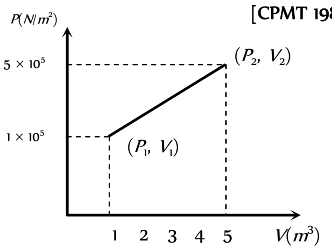
[CPMT 1981]

(a) 7.5×10^5 *joule*

(b) 7.5×10^5 *erg*

(c) 12×10^5 *joule*

(d) 6×10^5 *joule*



31. Carbon monoxide is carried around a closed cycle abc in which bc is an isothermal process as shown in the figure. The gas absorbs 7000 J of heat as its temperature increases from 300 K to 1000 K in going from a to b. The quantity of heat rejected by the gas during the process ca is

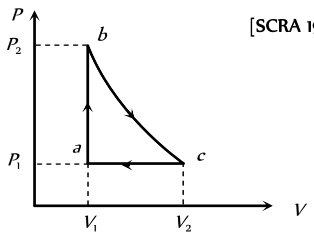
[SCRA 1994]

(a) 4200 J

(b) 5000 J

(c) 9000 J

(d) 9800 J



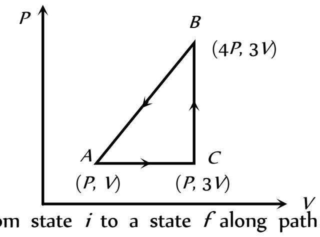
32. A sample of ideal monoatomic gas is taken round the cycle $ABCA$ as shown in the figure. The work done during the cycle is

(a) Zero

(b) $3\ PV$

(c) $6\ PV$

(d) $9PV$



33. When a system is taken from state i to a state f along path iaf, $Q = 50\ J$ and $W = 20 J$. Along path ibf, $Q = 35 J$. If $W = -13 J$ for the curved return path fi, Q for this path is

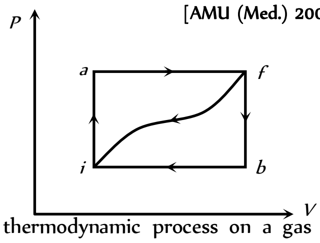
[AMU (Med.) 2000]

(a) 33 J

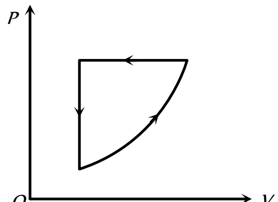
(b) 23 J

(c) – 7 J

(d) – 43 J



34. For one complete cycle of a thermodynamic process on a gas as shown in the P-V diagram, Which of following is correct



(a) $\Delta E_{\text{int}} = 0, Q < O$

(b) $\Delta E_{\text{int}} = 0, Q > 0$

(c) $\Delta E_{\text{int}} > 0, Q < 0$

(d) $\Delta E_{\text{int}} < 0, Q > 0$

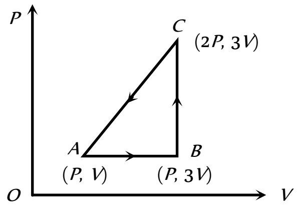
35. An ideal gas is taken around *ABCA* as shown in the above *P-V* diagram. The work done during a cycle is **[UPSEAT 2001]**

(a) Zero

(b) $\frac{1}{2}PV$

(c) 2 *PV*

(d) *PV*



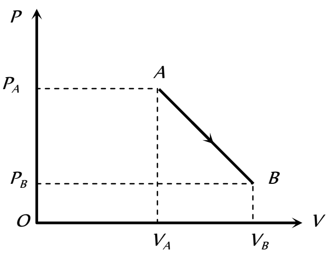
36. An ideal gas is taken from point *A* to the point *B*, as shown in the *P-V* diagram, keeping the temperature constant. The work done in the process is **[UPSEAT 2005]**

(a) $(P_A - P_B)(V_B - V_A)$

(b) $\frac{1}{2}(P_B - P_A)(V_B + V_A)$

(c) $\frac{1}{2}(P_B - P_A)(V_B - V_A)$

(d) $\frac{1}{2}(P_B + P_A)(V_B - V_A)$



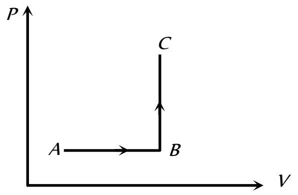
37. The *P-V* diagram of a system undergoing thermodynamic transformation is shown in figure. The work done by the system in going from $A \to B \to C$ is 30*J* and 40*J* heat is given to the system. The change in internal energy between *A* and *C* is

(a) 10 *J*

(b) 70 *J*

(c) 84 *J*

(d) 134 *J*



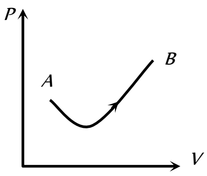
38. Consider a process shown in the figure. During this process the work done by the system

(a) Continuously increases

(b) Continuously decreases

(c) First increases, then decreases

(d) First decreases, then increases



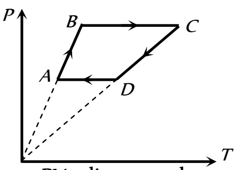
39. Six moles of an ideal gas perfomrs a cycle shown in figure. If the temperature are T_A = 600 *K*, T_B = 800 *K*, T_C = 2200 *K* and T_D = 1200 *K*, the work done per cycle is **[BCECE 2005]**

(a) 20 *kJ*

(b) 30 *kJ*

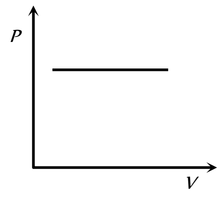
(c) 40 *kJ*

(d) 60 *kJ*

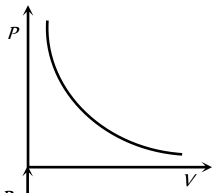


40. Which of the accompanying *PV*, diagrams best represents an isothermal process **[MP PET 2005]**

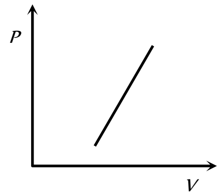
(a)



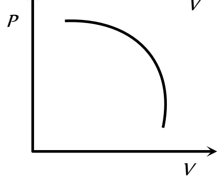
(b)



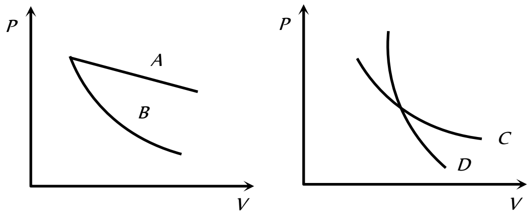
(c)



(d)



41. In the following figure, four curves *A*, *B*, *C* and *D* are shown. The curves are **[DCE 2003]**



(a) Isothermal for *A* and *D* while adiabatic for *B* and *C*

(b) Adiabatic for *A* and *C* while isothermal for *B* and *D*

(c) Isothermal for *A* and *B* while adiabatic for *C* and *D*

(d) Isothermal for *A* and *C* while adiabatic for *B* and *D*

42. *P-V* diagram of a cyclic process *ABCA* is as shown in figure. Choose the correct statement

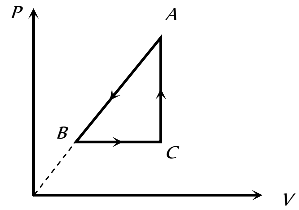
(a) $\Delta Q_{A \to B}$ = negative

(b) $\Delta U_{B \to C}$ = positive

[BCECE 2005]

(c) ΔW_{CAB} = negative

(d) All of these



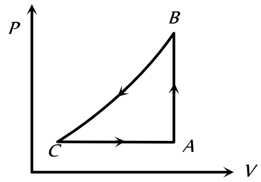
43. A sample of an ideal gas is taken through a cycle a shown in figure. It absorbs 50*J* of energy during the process *AB*, no heat during *BC*, rejects 70*J* during *CA*. 40*J* of work is done on the gas during *BC*. Internal energy of gas at *A* is 1500*J*, the internal energy at *C* would be

(a) 1590 *J*

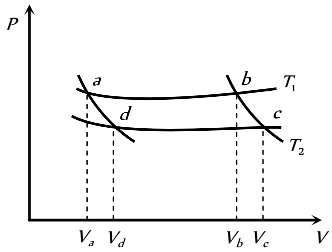
(b) 1620 *J*

(c) 1540 *J*

(d) 1570 *J*



44. In the following *P-V* diagram two adiabatics cut two isothermals at temperatures T_1 and T_2 (fig.). The value of $\frac{V_a}{V_d}$ will be



(a) $\frac{V_b}{V_c}$ (b) $\frac{V_c}{V_b}$

(c) $\frac{V_d}{V_a}$ (d) $V_b V_c$

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Reversible systems are difficult to find in real world.
Reason : Most processes are dissipative in nature [AIIMS 2005]

2. Assertion : Air quickly leaking out of a balloon becomes coolers
Reason : The leaking air undergoes adiabatic expansion.[AIIMS 2005]

3. Assertion : Thermodynamic process in nature are irreversible.
Reason : Dissipative effects can not be eliminated. [AIIMS 2004]

4. Assertion : When a bottle of cold carbonated drink is opened, a slight fog forms around the opening.
Reason : Adiabatic expansion of the gas causes lowering of temperature and condensation of water vapours.[AIIMS 2003]

5. Assertion : The isothermal curves intersect each other at a certain point.
Reason : The isothermal change takes place slowly, so the isothermal curves have very little slope. [AIIMS 2001]

6. Assertion : In adiabatic compression, the internal energy and temperature of the system get decreased.
Reason : The adiabatic compression is a slow process [AIIMS 2001]

7. Assertion : In isothermal process whole of the heat energy supplied to the body is converted into internal energy.
Reason : According to the first law of thermodynamics $\Delta Q = \Delta U + p\Delta V$. [AIIMS 1997]

8. Assertion : We can not change the temperature of a body without giving (or taking) heat to (or from) it.
Reason : According to principle of conservation of energy, total energy of a system should remains conserved.

9. Assertion : The specific heat of a gas is an adiabatic process is zero and in an isothermal process is infinite.
Reason : Specific heat of a gas in directly proportional to change of heat in system and inversely proportional to change in temperature.

10. Assertion : Work and heat are two equivalent form of energy.
Reason : Work is the transfer of mechanical energy irrespective of temperature difference, whereas heat is the transfer of thermal energy because of temperature difference only.

11. Assertion : The heat supplied to a system is always equal to the increase in its internal energy.
Reason : When a system changes from one thermal equilibrium to another, some heat is absorbed by it.

12. Assertion : A room can be cooled by opening the door of a refrigerator in a closed room.
Reason : Heat flows from lower temperature (refrigerator) to higher temperature (room).

13. Assertion : It is not possible for a system, unaided by an external agency to transfer heat from a body at lower temperature to another body at higher temperature.
Reason : According to Clausius statement, " No process is possible whose sole result is the transfer of heat from a cooled object to a hotter object.

14. Assertion : If an electric fan be switched on in a closed room, the air of the room will be cooled.
Reason : Fan air decrease the temperature of the room.

15. Assertion : The internal energy of an isothermal process does not change.
Reason : The internal energy of a system depends only on pressure of the system.

16. Assertion : In an adiabatic process, change in internal energy of a gas is equal to work done on or by the gas in the process.
Reason : Temperature of gas remains constant in a adiabatic process.

17. Assertion : An adiabatic process is an isoentropic process.
Reason : Change in entropy is zero in case of adiabatic process.

18. Assertion : Work done by a gas in isothermal expansion is more than the work done by the gas in the same expansion, adiabatically.
Reason : Temperature remains constant in isothermal expansion and not in adiabatic expansion.

19. Assertion : First law of thermodynamics is a restatement of the principle of conservation
Reason : Energy is fundamental quantity.

20. Assertion : Zeroth law of thermodynamic explain the concept of energy.
Reason : Energy is dependent on temperature.

21. Assertion : Efficiency of a Carnot engine increase on reducing the temperature of sink.
Reason : The efficiency of a Carnot engine is defined as ratio of net mechanical work done per cycle by the gas to the amount of heat energy absorbed per cycle from the source.

22. Assertion : The entropy of the solids is the highest
Reason : Atoms of the solids are arranged in orderly manner.

Answers

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1	a	2	c	3	b	4	b	5	c

6	b	7	b	8	d	9	a	10	d
11	c	12	a	13	d	14	a	15	b
16	b	17	c	18	d	19	d	20	b
21	a	22	d	23	b	24	a	25	d
26	d	27	a	28	b	29	d	30	a
31	b	32	c	33	c	34	a	35	a
36	b	37	c	38	c	39	b	40	a
41	c	42	a	43	a	44	c	45	c
46	a	47	c	48	b				

Isothermal Process

1	c	2	a	3	c	4	d	5	b
6	b	7	c	8	d	9	a	10	c
11	a	12	b	13	a	14	a	15	c
16	c	17	a	18	c	19	a	20	c
21	b	22	b	23	a	24	a	25	a
26	c	27	b	28	b	29	b	30	a
31	d								

Adiabatic Process

1	c	2	c	3	b	4	d	5	c
6	d	7	c	8	b	9	a	10	a
11	c	12	d	13	b	14	d	15	d
16	b	17	a	18	c	19	a	20	c
21	d	22	c	23	b	24	c	25	a
26	b	27	d	28	a	29	d	30	d
31	a	32	c	33	d	34	c	35	a
36	d	37	b	38	d	39	a	40	d
41	c	42	c	43	a	44	a	45	b
46	d	47	a	48	b	49	b	50	a
51	b	52	d	53	b	54	b	55	d
56	b	57	c						

Isobaric and Isochoric Processes

1	a	2	c	3	c	4	a	5	a
6	c	7	c	8	b	9	d	10	c
11	c	12	a	13	b	14	a	15	d
16	b	17	a	18	d	19	c	20	d
21	d	22	d	23	a				

Heat Engine, Refrigerator and Second Law of Thermodynamics

1	d	2	c	3	b	4	c	5	b
6	d	7	b	8	d	9	b	10	b
11	c	12	b	13	c	14	a	15	a
16	a	17	b	18	d	19	b	20	a
21	b	22	b	23	c	24	a	25	b
26	a	27	d	28	a	29	b	30	c
31	a	32	a	33	c	34	d		

Critical Thinking Questions

1	d	2	c	3	bc	4	c	5	d
6	d	7	c	8	d	9	c	10	a
11	b	12	c	13	b	14	c	15	a
16	c	17	b	18	a	19	b	20	c
21	b	22	d	23	d	24	b	25	b
26	b	27	d	28	c	29	c	30	d

Graphical Questions

1	c	2	b	3	a	4	c	5	a
6	a	7	a	8	b	9	c	10	d
11	d	12	a	13	b	14	c	15	a
16	c	17	a	18	a	19	c	20	d
21	d	22	d	23	c	24	c	25	d
26	b	27	d	28	c	29	c	30	c
31	d	32	b	33	d	34	a	35	d
36	d	37	a	38	a	39	c	40	b
41	d	42	d	43	a	44	a		

Assertion & Reason

1	a	2	a	3	a	4	a	5	e
6	d	7	e	8	d	9	a	10	a
11	d	12	d	13	a	14	d	15	c
16	c	17	a	18	b	19	c	20	e
21	b	22	a						

Answers and Solutions

First Law of Thermodynamics ($\Delta Q = \Delta U + \Delta W$)

1. (a) $\Delta Q = \Delta U + \Delta W$ and $\Delta W = P\Delta V$
2. (c)
3. (b) $\Delta Q = \Delta U + \Delta W$

   $\Rightarrow \Delta U = \Delta Q - \Delta W = Q - W$ (using proper sign)
4. (b) $\Delta U = \Delta Q - W = 35 - 15 = 20\ J$
5. (c) Internal energy depends only on the temperature of the gas.
6. (b)

7. (b) (i) Case $\rightarrow$ Volume = constant $\Rightarrow \int PdV = 0$

(ii) Case $\rightarrow P$ = constant $\Rightarrow \int_{V_1}^{2V_1} PdV = P\int_{V_1}^{2V_1} dV = PV_1$

8. (d) $\Delta Q = \Delta W + \Delta U \Rightarrow 35 = -15 + \Delta U \Rightarrow \Delta U = 50J$

9. (a) $J\Delta Q = \Delta U + \Delta W,\ \Delta U = J\Delta Q - \Delta W$

$\Delta U = 4.18 \times 300 - 600 = 654\ Joule$

10. (d) Work done $= \int_1^2 PdV$, which is state dependent as well as path dependent.

11. (c) $\Delta Q = \Delta U + \Delta W \because \Delta W = 0 \Rightarrow \Delta Q = \Delta U = \frac{f}{2}\mu R\Delta T$

$= \frac{3}{2} \times 2R(373 - 273) = 300R.$

12. (a) $\Delta Q = 2k\,cal = 2 \times 10^3 \times 4.2J = 8400J$ and $\Delta W = 500J$.

Hence from $\Delta Q = \Delta U + \Delta W,\ \Delta W = \Delta Q - \Delta U$ = 8400 – 500 = 7900 J

13. (d) Change in internal energy (ΔU) depends upon initial an find state of the function while ΔQ and ΔW are path dependent also.

14. (a) This is the case of free expansion and in this case $\Delta W = 0$, $\Delta U = 0$ so temperature remains same *i.e.* 300 K.

15. (b) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = \Delta Q - \Delta U = 100 - 40 = 70J$

16. (b) Work done is not a thermodynamical function.

17. (c) $\Delta Q = \Delta U + \Delta W = 167 + 333 = 500\ cal$

18. (d) Heat always refers to energy in transit from one body to another because of temperature difference.

19. (d) Change in internal energy does not depend upon path so $\Delta U = \Delta Q - \Delta W$ remain constant.

20. (b) $\Delta Q = \Delta U + \Delta W$; $\Delta Q = 200J$ and $\Delta W = -100J$

$\Rightarrow \Delta U = \Delta Q - \Delta W = 200 - (-100) = 300J$

21. (a) During free expansion of a perfect gas no, work is done and also no heat is supplied from outside. Therefore, no change in internal energy. Hence, temperature remain constant.

22. (d) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 150 - 110 = 40\ J$

23. (b) From FLOT $\Delta Q = \Delta U + \Delta W$

$\because$ Heat supplied to the system so $\Delta Q \rightarrow$ Positive

and work is done on the system so $\Delta W \rightarrow$ Negative

Hence $+\Delta Q = \Delta U - \Delta W$

24. (a)

25. (d) State of a thermodynamic state cannot determine by a single variable (P or V or T)

26. (d) R is the universal gas constant.

27. (a) From FLOT

$\Rightarrow dU = dQ - dW \Rightarrow dU = dQ (< 0)$ $(\because dW = 0)$

$\Rightarrow dU < 0$ So temperature will decrease.

28. (b) From FLOT $\Delta Q = \Delta U + \Delta W$

Work done at constant pressure $(\Delta W)_P = (\Delta Q)_P - \Delta U$

$(\Delta Q)_P - (\Delta Q)_V$ (As we know $(\Delta Q)_V = \Delta U$)

Also $(\Delta Q)_P = mc_P \Delta T$ and $(\Delta Q)_V = mc_V \Delta T$

$\Rightarrow (\Delta W)_P = m(c_P - c_V)\Delta T$

$\Rightarrow (\Delta W)_P = 1 \times (3.4 \times 10^3 - 2.4 \times 10^3) \times 10 = 10^4\, cal$

29. (d)

30. (a) Ideal gas possess only kinetic energy.

31. (b) The internal energy and entropy depend only on the initial and final states of the system and not on the path followed to attain that state.

32. (c) $\Delta Q = \Delta U + \Delta W$

$\because \Delta Q = 200 cal = 200 \times 4.2 = 840J$ and $\Delta W = 40J$

$\Rightarrow \Delta U = \Delta Q - \Delta W = 840 - 40 = 800J$

33. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$

$\Rightarrow 30 = (U_f - 40) + 10 \Rightarrow U_f = 60J$

34. (a) With rise in temperature, internal energy also increases.

35. (a)

36. (b) Heat supplied to a gas raise its internal energy and does some work against expansion, so it is a special case of law of conservation of energy.

37. (c) Change in internal energy is always equal to the heat supplied at constant volume.

i.e. $\Delta U = (\Delta Q)_V = \mu C_V \Delta T.$

For monoatomic gas $C_V = \frac{3}{2}R$

$\Rightarrow \Delta U = \mu\left(\frac{3}{2}R\right)\Delta T = 1 \times \frac{3}{2} \times 8.31 \times (100 - 0)$

$= 12.48 \times 10^2\, J$

38. (c) $\Delta U = \mu C_V \Delta T = n\left(\frac{R}{\gamma - 1}\right)\Delta T$

$\Rightarrow \Delta U = \frac{P\Delta V}{(\gamma - 1)} = \frac{P(2V - V)}{\gamma - 1} = \frac{PV}{(\gamma - 1)}$

39. (b) $\Delta U = \mu C_V \Delta T = 2 \times 4.96 \times (342 - 340) = 19.84\ cal$

40. (a)

41. (c) According to FLOT

$\Delta Q = \Delta U + P(\Delta V) \Rightarrow \Delta U = \Delta Q - P(\Delta V)$

$= 1500 - (2.1 \times 10^5)(2.5 \times 10^{-3}) = 975$ *Joule*

42. (a) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W$

$= 6 \times 4.18 - 6 = 19.08 kJ \approx 19.1\, kJ$

43. (a) Given $\Delta Q = -20J$, $\Delta W = -8J$ and $U_i = 30J$

$\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = (\Delta Q - \Delta W)$

$\Rightarrow (U_f - U_i) = (U_f - 30) = -20 - (-8) \Rightarrow U_f = 18J$

44. (c) Change in internal energy $\Delta U = \mu C_V \Delta T$

it doesn't depend upon type of process. Actually it is a state function

45. (c)

46. (a) In first process using $\Delta Q = \Delta U + \Delta W$

$\Rightarrow 8 \times 10^5 = \Delta U + 6.5 \times 10^5 \Rightarrow \Delta U = 1.5 \times 10 J$

Since final and initial states are same in both process

So ΔU will be same in both process

For second process using $\Delta Q = \Delta U + \Delta W$

$\Rightarrow 10^5 = 1.5 \times 10^5 + \Delta W \Rightarrow \Delta W = -0.5 \times 10^5\ J$

47. (c) $\Delta W = P\Delta V$; here ΔV is negative so ΔW will be negative

48. (b) Entropy is related to second law of thermodynamics.

Isothermal Process

1. (c) In isothermal process temperature remains constant.

2. (a) If isothermal curves cut each other then at equilibrium two temperature will be there which is impossible.

3. (c) In isothermal expansion temperature remains constant, hence no change in internal energy.

4. (d) $W = \mu RT \log_e \frac{V_2}{V_1}$

$= \left(\frac{m}{M}\right) RT \log_e \frac{V_2}{V_1} = 2.3 \times \frac{m}{M} RT \log_{10} \frac{V_2}{V_1}$

$= 2.3 \times \frac{96}{32} R\ (273 + 27) \log_{10} \frac{140}{70} = 2.3 \times 900 R \log_{10} 2$

5. (b) $0.8 \times 5 = P \times (3 + 5) \Rightarrow P = 0.5\ m$

6. (b) Differentiate $PV =$ constant *w.r.t* V

$\Rightarrow P\Delta V + V\Delta P = 0 \Rightarrow \frac{\Delta P}{P} = -\frac{\Delta V}{V}$

7. (c)

8. (d) $W = -\mu RT \log_e \frac{V_2}{V_1} = -1 \times 8.31 \times (273+0) \log_e \left(\frac{22.4}{11.2}\right)$

$= -8.31 \times 273 \times \log_e 2 = -1572.5J$ [$\because \log_e 2 = 0.693$]

9. (a) $E_\theta = P$, if $P =$ constant, $E_\theta =$ constant

10. (c) For isothermal process $PV = RT \Rightarrow P = \frac{RT}{V}$

$\therefore W = PdV = \int_{V_1}^{V_2} \frac{RT}{V} dV = RT \log_e \frac{V_2}{V_1}$

11. (a) $E_\theta = P$

12. (b) For such a case, pressure $= \frac{1}{\text{Compressibility}}$

13. (a) $E_\theta = P = 1.013 \times 10^5 \, N/m^2$

14. (a) In isothermal process, compressibility $E_\theta = \rho$.

15. (c) In isothermal process, exchange of energy takes place between system and surrounding to maintain the system temperature constant.

16. (c) No change in the internal energy of ideal gas but for real gas internal energy increases because work is done against intermolecular forces.

17. (a) In isothermal process temperature remains constant. *i.e.*, $\Delta T = 0$. Hence according to $C = \frac{Q}{m\Delta T} \Rightarrow C_{iso} = \infty$

18. (c) This is the case of free expansion of gas. In free expansion $\Delta U = 0 \Rightarrow$ Temp. remains same.

19. (a) An isothermal process takes place at constant temperature, must be carried out in a vessel with conducting wall so that heat generated should go out at once.

20. (c) For isothermal process

$dU = 0$ and work done $= dW = P(V_2 - V_1)$

$\because V_2 = \frac{V_1}{2} = \frac{V}{2} \; \therefore \; dW = -\frac{PV}{2}$

21. (b) In isothermal process, temperature remains constant.

22. (b) In isothermal process, heat is released by the gas to maintain the constant temperature.

23. (a) In isothermal compression, there is always an increase of heat. which must flow out the gas.

$\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W \;\; (\because \Delta U = 0)$

$\Rightarrow \Delta Q = -1.5 \times 10^4 J = \frac{1.5 \times 10^4}{4.18} cal = -3.6 \times 10^3 cal$

24. (a) In isothermal change, temperature remains constant, Hence $\Delta U = 0$.

Also from $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$

25. (a) It is an isothermal process. Hence work done $= P(V_2 - V_1)$

$= 1 \times 10^5 \times (1.091 - 1) \times 10^{-6} = 0.0091 \, J$

26. (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = \Delta Q - \Delta W = 2240 - 168 = 2072 \, J$.

27. (b) Amount of heat given $= 540 \, calories$

Change in volume $\Delta V = 1670 \, c.c$

Atmospheric pressure $P = 1.01 \times 10^6 \, dyne/cm^2$

Work done against atmospheric pressure

$W = P\Delta V = \frac{1.01 \times 10^6 \times 1670}{4.2 \times 10^7} \approx 40 \, cal$

28. (b) $W_{iso} = \mu RT \log_e \frac{V_2}{V_1} = 1 \times 8.31 \times 300 \log_e \frac{20}{10} = 1728 J$

29. (b) $W = \mu RT \log_e \left(\frac{V_2}{V_1}\right) = 0.2 \times 8.3 \times \log_e 2 \times (27 + 273)$

$= 0.2 \times 8.3 \times 300 \times 0.693 = 345 J$

30. (a) For isothermal process $P_1 V_1 = P_2 V_2$

$\Rightarrow P_2 = \frac{P_1 V_1}{V_2} = \frac{72 \times 1000}{900} = 80 \, cm$

Stress $\Delta P = P_2 - P_1 = 80 - 72 = 8 cm$

31. (d) During isothermal change $T =$ constant $\Rightarrow \Delta U = 0$

also from FLOT, $\Delta Q = \Delta W$.

Adiabatic Process

1. (c) Gas cylinder suddenly explodes is an irreversible adiabatic change and work done against expansion reduces the temperature.

2. (c) Work done in adiabatic change $= \frac{\mu R(T_1 - T_2)}{\gamma - 1}$

3. (b) In case of adiabatic expansion $\Delta W =$ positive and $\Delta Q = 0$

from FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = -\Delta W$ *i.e.*, ΔU will be negative.

4. (d) For adiabatic process $\frac{T^\gamma}{P^{\gamma-1}} =$ constant

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_1}{P_2}\right)^{\frac{1-\gamma}{\gamma}} \Rightarrow \frac{T_2}{300} = \left(\frac{4}{1}\right)^{\frac{(1-1.4)}{1.4}} \Rightarrow T_2 = 300(4)^{-\frac{0.4}{1.4}}$

5. (c) $PV^\gamma =$ constant $\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow \frac{P_2}{1} = \left(\frac{V_1}{V_1/4}\right)^{3/2} = 8$

$\Rightarrow P_2 = 8 \, atm.$

6. (d) $PV^\gamma =$ constant $\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow P_2 = (8)^{5/3} P_1 = 32 \, P_1$

7. (c) Volume of the gas $V = \frac{m}{d}$ and using $PV^\gamma =$ constant

We get $\frac{P'}{P} = \left(\frac{V}{V'}\right)^\gamma = \left(\frac{d'}{d}\right)^\gamma = (32)^{7/5} = 128$

8. (b) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} \Rightarrow T_2 = 300\left(\frac{27}{8}\right)^{\frac{5}{3}-1} = 300\left(\frac{27}{8}\right)^{\frac{2}{3}}$

$= 300\left\{\left(\frac{27}{8}\right)^{1/3}\right\}^2 = 800\left(\frac{3}{2}\right)^2 = 675K$

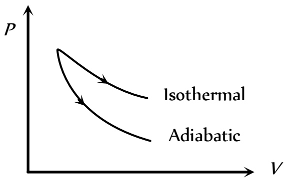
$\Rightarrow \Delta T = 675 - 300 = 375 \, K$

9. (a) In thermodynamic processes.

Work done = Area covered by PV diagram with V-axis

From graph it is clear that $(\text{Area})_{iso} > (\text{Area})_{adi}$

$\Rightarrow W_{iso} > W_{adi}$



10. (a) Since $PV = RT$ and $T =$ constant; $\therefore PV =$ constant.

11. (c) For Isothermal process $PV =$ constant

$\Rightarrow \left(\frac{dP}{dV}\right) = \frac{-P}{V} =$ Slope of Isothermal curve

For adiabatic $PV^\gamma =$ constant

$\Rightarrow \frac{dP}{dV} = \frac{-\gamma P}{V} =$ Slop of adiabatic curve slope

Clearly, $\left(\frac{dP}{dV}\right)_{\text{adiabatic}} = \gamma\left(\frac{dP}{dV}\right)_{\text{Isothermal}}$

12. (d) $PV^\gamma =$ constant $\Rightarrow P\left(\frac{RT}{P}\right)^\gamma =$ constant

$\Rightarrow P^{1-\gamma}T^\gamma =$ constant.

13. (b) $W_{adi} = \frac{R}{\gamma-1}(T_i - T_f) = \frac{R}{\gamma-1}(T - T_1)$

14. (d) $dQ = 0 = -2 + dW \Rightarrow dW = 2\ J$

$\Rightarrow$ Work done by the gas $= 2\ J$

$\Rightarrow$ Work done on the gas $= -2\ J$

15. (d) $E_\phi = \gamma P = 1.4 \times (1\times10^5) = 1.4\times10^5\ N/m^2$

16. (b) Slope of adiabatic curve = $\gamma \times$ (Slope of isothermal curve)

17. (a) Due to compression the temperature of the system increases to a very high value. This causes the flow of heat from system to the surroundings, thus decreasing the temperature. This decrease in temperature results in decrease in pressure.

18. (c) $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta W = -\Delta U$

if ΔW is positive *i.e.,* gas does work then ΔU should be negative meaning internal energy is used in doing work.

19. (a) $W = \frac{R}{\gamma-1}(T_1 - T_2)$

$= \frac{8.31\times\{(273+27)-(273+127)\}}{1.4-1} = -2077.5\ joules$

20. (c) Pressure is reduced, so the temperature falls.

21. (d) Adiabatic Bulk modulus $E_\phi = \gamma P$

22. (c) In adiabatic process, no heat transfers between system and surrounding.

23. (b) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = P_0(8)^{4/3} = 16P_0$.

24. (c) In adiabatic process $PV^\gamma =$ constant

$\Rightarrow \left(\frac{RT}{V}\right).V^\gamma =$ constant $\Rightarrow TV^{\gamma-1} =$ constant

25. (a) $TV^{\gamma-1} =$ constant $\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^\gamma$

$\Rightarrow T_2 = 300\left(\frac{1}{2}\right)^{0.4} = 227.36\ K$

26. (b) In adiabatic change $Q =$ constant $\Rightarrow \Delta Q = 0$

So $\Delta W = -\Delta U$ ($\because \Delta Q = \Delta U + \Delta W$)

27. (d) For adiabatic process from FLOT

$\Delta W = -\Delta U$ $(\because \Delta Q = 0)$

$\Rightarrow \Delta W = -(-100) = +100\,J$

28. (a) $\Delta U = -\Delta W = -\frac{R(T_1 - T_2)}{(\gamma-1)} = \frac{R(T_2 - T_1)}{\gamma-1}$

29. (d) $TV^{\gamma-1} =$ constant $\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 927^o C$

30. (d) The process is very fast, so the gas fails to gain or lose heat. Hence this process in adiabatic

31. (a) $\Delta U = \mu C_V \Delta T = 1\times C_V(T_f - T_i) = -C_V(T_i - T_f)$

$\Rightarrow |\Delta U| = C_V(T_i - T_f)$

32. (c) $T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 273(2)^{0.41} = 273\times1.328 = 363K$

$W = \frac{R(T_1 - T_2)}{\gamma-1} = \frac{8.31(273-363)}{1.41-1} = -1824$

$\Rightarrow |W| \approx 1815\ J$

33. (d)

34. (c) $TV^{\gamma-1} =$ constant

$\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = (273+18)\left(\frac{V}{V/8}\right)^{0.4} = 668K$

35. (a) $\Delta Q = mc\Delta\theta$. Here $\Delta Q = 0$, hence $c = 0$

36. (d) In adiabatic process, no transfer of heat takes place between system and surrounding.

37. (b) $W = \frac{\mu R(T_1 - T_2)}{(\gamma-1)} = \frac{\mu RT_1}{(\gamma-1)}\left[1 - \frac{T_2}{T_1}\right]$

$= \frac{\mu RT_1}{(\gamma-1)}\left[1 - \left(\frac{V_1}{V_2}\right)^{\gamma-1}\right]$

$= \frac{2\times8.31\times300}{\left(\frac{5}{3}-1\right)}\left[1 - \left(\frac{1}{2}\right)^{\frac{5}{3}-1}\right] = +2767.23\ J$

38. (d) $T^\gamma P^{1-\gamma} =$ constant $\Rightarrow T \propto P^{\frac{\gamma-1}{\gamma}}$

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{8}\right)^{\frac{5/3-1}{5/3}}$

$$T_2 = 300 \times \left(\frac{1}{8}\right)^{0.4} = 131K = -142°C$$

39. (a) In adiabatic process $\Delta Q = 0 \Rightarrow \Delta U + \Delta W = 0$
$(\because \Delta Q = \Delta U + \Delta W)$

40. (d) Using relation $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (8)^{\frac{3/2-1}{3/2}} = 2$.

$\Rightarrow T_2 = 2T_1 \Rightarrow T_2 = 2(273+27) = 600K = 327°C$

41. (c) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{T_1} = \left(\frac{1}{8}\right)^{\frac{1.5-1}{1.5}} = \left(\frac{1}{8}\right)^{\frac{1}{3}} = \frac{1}{2}$

$\Rightarrow T_2 = \frac{T_1}{2} = \frac{300}{2} = 150K$.

42. (c) $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} \Rightarrow \frac{P'}{P} = (8)^{5/2} \Rightarrow P' = P \times (2)^{15/2}$

43. (a)

44. (a) Given $P \propto T^3$, but we know for an adiabatic process, the pressure $P \propto T^{\gamma/\gamma-1}$

So $\frac{\gamma}{\gamma-1} = 3 \Rightarrow \gamma = \frac{3}{2} \Rightarrow \frac{C_P}{C_V} = \frac{3}{2}$

45. (b)

46. (d) $W = \frac{R(T_i - T_f)}{\gamma - 1} \Rightarrow 6R = \frac{R(T-T_f)}{\left(\frac{5}{3}-1\right)} \Rightarrow T_f = (T-4)K.$

47. (a) $\because TV^{\gamma-1} =$ constant $\Rightarrow T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$\Rightarrow T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = T_1(4)^{1.5-1} = 2T_1$

$\therefore$ change in temperature

$= T_2 - T_1 = 2T_1 - T_1 = T_1 = 273\,K$

48. (b) $\because PV^{\gamma} = k$ (constant) $\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 10^5 \times (2)^{1.3}$ $\quad (\because V_2 = \frac{V_1}{2})$

49. (b) In adiabatic process $\Delta U = -\Delta W$. In compression ΔW is negative, so ΔU is positive *i.e.* internal energy increases.

50. (a) According to the first law of thermodynamics

$\Delta Q = \Delta U + \Delta W$

In adiabatic process $\Delta Q = 0$, hence $\Delta U = -\Delta W$

51. (b) $PV^{\gamma} =$ constant $\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{\gamma} = \left(\frac{V_1}{V_1/4}\right)^{\gamma} = 4^{\gamma}$

$\Rightarrow P_2 = 4^{\gamma}P$

As γ is always greater than one so $4^{\gamma} > 4 \Rightarrow P_2 > 4P$

52. (d) $P_1V_1^{\gamma} = P_2V_2^{\gamma} \Rightarrow \frac{P_2}{P_1} = \left[\frac{V_1}{V_2}\right]^{\gamma} = \left[\frac{4}{1}\right]^{3/2} = \frac{8}{1}$

53. (b) Change in internal energy of the gas

$\Delta U = -\Delta W \frac{R}{\gamma-1}[T_2 - T_1] = \frac{8.3}{(1.4-1)}[308-300] = 166J$

54. (b) For adiabatic change $TV^{\gamma-1} =$ constant

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \times T_1$

$\Rightarrow T_2 = \left(\frac{V}{V/4}\right)^{1.4-1} \times 300 = 300 \times (4)^{0.4}K$

55. (d) For adiabatic forces $\Delta W = -\Delta U$ $\quad (\because \Delta Q = 0)$

$\Rightarrow \Delta W = -(-50) = +50J$

56. (b) $\frac{\text{Adiabatic elasticicty}(E_\phi)}{\text{Isothermal elasticicty}(E_\theta)} = \gamma \Rightarrow E_\theta = \frac{E_\phi}{\gamma}$

$\Rightarrow E_\theta = \frac{2.1 \times 10^5}{1.4} = 1.5 \times 10^5\,N/m^2$

57. (c) $PV^{\gamma} =$ constant : Differentiating both sides

$P\gamma V^{\gamma-1}dV + V^{\gamma}dP = 0 \Rightarrow \frac{dP}{P} = -\gamma\frac{dV}{V}$

Isobaric and Isochoric Processes

1. (a) Work done $= P\Delta V = P(V_2 - V_1)$

2. (c) When heat is supplied at constant pressure, a part of it goes in the expansion of gas and remaining part is used to increase the temperature of the gas which in turn increases the internal energy.

3. (c) For isobaric process $\frac{V_2}{V_1} = \frac{T_2}{T_1} \Rightarrow V_2 = V \times \frac{274}{273}$

Increase $= \frac{274\,V}{273} - V = \frac{V}{273}$

4. (a) From FLOT $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$

$\Rightarrow 100 = \Delta U + 50 \times (4-10) \Rightarrow \Delta U = 400\,J$

5. (a) $W = P \times \Delta V = 2 \times 10^5(150-50) \times 10^{-3} = 2 \times 10^4\,J$

6. (c) $W = P\Delta V = nR\Delta T = 0.1 \times 2 \times 300 = 60\,cal$

7. (c) $\Delta Q = \Delta V + P\Delta V \Rightarrow mL = \Delta U + P(V_2 - V_1)$

$\Rightarrow \Delta U = L - P(V_2 - V_1)$ $\quad (\because m = 1)$

8. (b) $\Delta W = P\Delta V = 10^3 \times 0.25 = 250\,J$

9. (d) $W = P\Delta V = 1.01 \times 10^5(3.34 - 2 \times 10^{-3})$

$= 337 \times 10^3\,J \approx 340\,KJ$

10. (c) $\frac{T_2}{T_1} = \frac{V_2}{V_1} = 2 \Rightarrow T_2 = 2 \times T_1 = 2 \times 300 = 600\,K = 327^o C$

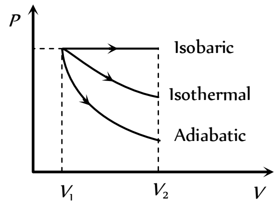
11. (c) $V \propto T$ at constant pressure

$\Rightarrow \frac{V_1}{V_2} = \frac{T_1}{T_2} \Rightarrow V_2 = \frac{V_1T_2}{T_1} = \frac{300 \times 280}{300} = 280\,ml.$

12. (a) In thermodynamic process, work done is equal to the area covered by the PV curve with volume axis.

Hence, according to graph shown

$W_{adiabatic} < W_{isothermal} < W_{isobaric}$



13. (b) (Similar to previous question)

14. (a)

15. (d) $W = P\Delta V = 2.4\times10^{-4}\times1\times10^{5} = 24 J$

16. (b) At constant pressure

$W = P\Delta V = \mu R\Delta T = 1\times8.31\times100 = 831 \approx 814 J$

17. (a) $\Delta V = 0 \Rightarrow P\Delta V = 0 \Rightarrow \Delta W = 0$

18. (d) Entropy of a reversible process does not change.

19. (c) $W = P\Delta V = 0$ (As $\Delta V = 0$)

20. (d)

21. (d) At constant volume $P \propto T \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{P_1}{P_2} = \frac{300}{400} = \frac{3}{4}$

22. (d) In isothermal process $\Delta Q \neq 0$.

23. (a) For isochoric process $\Delta V = 0 \Rightarrow \Delta W = 0$

From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta U$

Heat Engine, Refrigerator and Second Law of Thermodynamics

1. (d) $\eta = \frac{T_1 - T_2}{T_1} - \frac{W}{Q} \Rightarrow Q = \left(\frac{T_1}{T_1 - T_2}\right)W$

$= \frac{600}{(600-300)}\times800 = 1600 J$

2. (c) Coefficient of performance

$K = \frac{T_2}{T_1 - T_2} = \frac{273}{303-273} = \frac{273}{30} = 9$

3. (b) In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated if the door of a refrigerator is kept open.

4. (c) Internal energy is a state function.

5. (b)

6. (d) For a reversible process $\int \frac{dQ}{T} = 0$

7. (b) For cyclic forces $\Delta U = 0$ So, $\Delta Q = \Delta W$

8. (d) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{400}{500} = \frac{1}{5}$ $\because \eta = \frac{W}{Q} \Rightarrow \frac{1}{5} = \frac{W}{Q}$

$\Rightarrow W = \frac{Q}{5} = \frac{6}{5}\times10^4 = 1.2\times10^4 J$

9. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{30}{100} = 1 - \frac{350}{T_1}$

$\Rightarrow \frac{350}{T_1} = 1 - \frac{50}{100} = \frac{70}{100} = \frac{7}{10} \Rightarrow T_1 = 500 K = 227°C$

10. (b) $\eta = 1 - \frac{T_2}{T_1}$ for 100% efficiency $\eta = 1$ which gives $T_2 = 0 K$

11. (c) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273+69)}{(273+411)} = 0.5$

$\Rightarrow$ Work done $= \eta\times Q = 0.5\times1000 = 500 J$

12. (b) $\because \eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

where $Q_1 =$ heat absorbed, $Q_2 =$ heat rejected

$\Rightarrow 1 - \frac{T/3}{T} = \frac{W}{Q_1} \Rightarrow \frac{2}{3} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

$\Rightarrow \frac{2}{3} = 1 - \frac{Q_2}{Q_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{1}{3} \Rightarrow Q_2 = \frac{Q_1}{3} = \frac{Q}{3}$

13. (c) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{25}{100} = 1 - \frac{300}{T_1} \Rightarrow \frac{1}{4} = 1 - \frac{300}{T_1}$

$T_1 = 400 K = 127°C$

14. (a) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{70}{100} = 1 - \frac{T_2}{1000} \Rightarrow T_2 = 300 K$

15. (a) $\eta = 1 - \frac{T_2}{T_1} = \frac{T_1 - T_2}{T_1} \Rightarrow \eta_1 = \frac{(473-273)}{473} = \frac{200}{473}$

and $\eta_2 = \frac{273-73}{273} = \frac{200}{273}$

So required ratio $\frac{\eta_1}{\eta_2} = \frac{273}{473} = 0.577$

16. (a) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{(273+123)}{(273+27)} = 1 - \frac{150}{300} = \frac{1}{2} = 50\%$

17. (b) $\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{500} = \frac{2}{5}$

18. (d)

19. (b) In first case, $(\eta_1) = 1 - \frac{500}{800} = \frac{3}{8}$

and in second case, $(\eta_2) = 1 - \frac{600}{x}$

Since $\eta_1 = \eta_2$, therefore $\frac{3}{8} = 1 - \frac{600}{x}$

or $\frac{600}{x} = 1 - \frac{3}{8} = \frac{5}{8}$ or $x = \frac{600\times8}{5} = 960K$

20. (a) $\eta_{max} = 1 - \frac{T_2}{T_1} = 1 - \frac{300}{400} = \frac{1}{4} = 25\%$

So 26% efficiency is impossible

21. (b) In first case $\eta_1 = 1 - \frac{T_2}{T_1} = 1 - \frac{(273+0)}{(273+200)} = \frac{200}{473}$

In second case $\eta_2 = 1 - \frac{(273-200)}{(273+0)} = \frac{200}{273}$

$\Rightarrow \frac{\eta_1}{\eta_2} = \frac{1}{\left(\frac{473}{273}\right)} = 1:1.73$

22. (b) $\eta = 1 - \frac{T_2}{T_1} \Rightarrow \frac{1}{2} = 1 - \frac{500}{T_1} \Rightarrow \frac{500}{T_1} = \frac{1}{2}$ .....(i)

$\frac{60}{100} = 1 - \frac{T_2'}{T_1} \Rightarrow \frac{T_2'}{T_1} = \frac{2}{5}$ .....(ii)

Dividing equation (i) by (ii), $\frac{500}{T_2'} = \frac{5}{4} \Rightarrow T_2' = 400K$

23. (c)

24. (a)

25. (b) $\eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q} \Rightarrow W = \left(1 - \frac{T_1}{T_2}\right) Q = \left\{1 - \frac{(273+27)}{(273+627)}\right\}$

$\Rightarrow W = \left(1 - \frac{300}{900}\right) \times 3 \times 10^6 = 2 \times 10^6 \times 4.2\ J = 8.4 \times 10^6\ J$

26. (a)

27. (d) $\eta = 1 - \frac{T_2}{T_1}$; for η to be max. ratio $\frac{T_2}{T_1}$ should be min.

28. (a)

29. (b) In first case $\eta_1 = \frac{T_1 - T_2}{T_1}$

In second case $\eta_2 = \frac{2T_1 - 2T_2}{2T_1} = \frac{T_1 - T_2}{T_1} = \eta$

30. (c) Coefficient of performance

$K = \frac{T_2}{T_1 - T_2} \Rightarrow 5 = \frac{(273-13)}{T_1 - (273-13)} = \frac{260}{T_1 - 260}$

$\Rightarrow 5T_1 - 1300 = 260 \Rightarrow 5T_1 = 1560$

$\Rightarrow T_1 = 312K \to 39°C$

31. (a) Coefficient of performance $K = \frac{T_2}{T_1 - T_2}$

$= \frac{(273-23)}{(273+27)-(273-23)} = \frac{250}{300-250} = \frac{250}{20} = 5$

32. (a) $\eta = \frac{T_1 - T_2}{T_1} = \frac{(273+727)-(273+227)}{273+727} = \frac{1000-500}{1000} = \frac{1}{2}$

33. (c) $\eta = \frac{T_1 - T_2}{T_1} = \frac{W}{Q} \Rightarrow W = \frac{Q(T_1 - T_2)}{T_1}$

$= \frac{6 \times 10^4 [(227+273)-(273+127)]}{(227+273)}$

$= \frac{6 \times 10^4 \times 100}{500} = 1.2 \times 10^4\ cal$

34. (d) Slow isothermal expansion or compression of an ideal gas is reversible process, while the other given process are irreversible in nature.

Critical Thinking Questions

1. (d) Fraction of supplied energy which in creases the internal energy is given by

$$f = \frac{\Delta U}{(\Delta Q)_P} = \frac{(\Delta Q)_V}{(\Delta Q)_P} = \frac{\mu C_V \Delta T}{\mu C_P \Delta T} = \frac{1}{\gamma}$$

For diatomic gas $\gamma = \frac{7}{5} \Rightarrow f = \frac{5}{7}$

2. (c) $\Delta Q = \Delta U + \Delta W$

$\therefore \Delta U = \Delta Q - \Delta W = 540 - \frac{P(V_2 / V_1)}{J}$

$= 540 - \frac{1.013 \times 10^5 \times [(1671-1) \times 10^{-6}]}{4.2}$

$= 540 - 39.7 = 500\ calories$

3. (b,c) There is a decrease in volume during melting on an ice slab at $273K$. Therefore, negative work is done by ice-water system on the atmosphere or positive work is done on the ice-water system by the atmosphere. Hence option (b) is correct. Secondly heat is absorbed during melting (*i.e.* ΔQ is positive) and as we have seen, work done by ice-water system is negative (ΔW is negative). Therefore, from first law of thermodynamics $\Delta U = \Delta Q - \Delta W$.

Change in internal energy of ice-water system, ΔU will be positive or internal energy will increase.

4. (c) Process is isothermal. There fore, T = constant, $\left(P \propto \frac{1}{V}\right)$ volume is increasing, therefore pressure will decreases.

In chamber A :

$$\Delta P = P_i - P_f = \frac{\mu_A RT}{V} - \frac{\mu_A RT}{2V} = \frac{\mu_A RT}{2V} \quad .....(i)$$

In chamber B :

$$1.5\Delta P = P_i - P_f = \frac{\mu_B RT}{V} - \frac{\mu_B RT}{2V} = \frac{\mu_B RT}{2V} \quad .....(ii)$$

from equations (i) and (ii) $\frac{\mu_A}{\mu_B} = \frac{1}{1.5} = \frac{2}{3}$

$\Rightarrow \frac{m_A / M}{m_B / M} = \frac{2}{3} \Rightarrow 3m_A = 2m_B$.

5. (d) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \Rightarrow \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{L_2 A}{L_1 A}\right)^{\frac{5}{3}-1} = \left(\frac{L_2}{L_1}\right)^{\frac{2}{3}}$

6. (d) Using Boyle's law, we have $\frac{V}{T}$ = constant

$\Rightarrow \frac{\frac{l}{2}+5}{373} = \frac{\frac{l}{2}-5}{273}$

As the piston moves 5 cm, the length of one side will be $\left(\frac{l}{2}+5\right)$ and other side $\left(\frac{l}{2}-5\right)$. On solving this equation, we get l = 64.6 cm.

7. (c) $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = (\Delta Q)_P - \Delta U = (\Delta Q)_P\left[1 - \frac{(\Delta Q)_V}{(\Delta Q)_P}\right]$

$$= (\Delta Q)_P\left[1 - \frac{C_V}{C_P}\right] = Q = \left[1 - \frac{3}{5}\right] = \frac{2}{5}Q$$

$\because (\Delta Q)_P = Q$ and $\gamma = \frac{5}{3}$ for monatomic gas

8. (d) Oxygen is diatomic gas, hence its energy of two moles $= 2 \times \frac{5}{2}RT = 5RT$

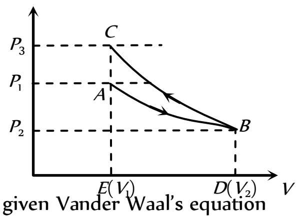
Argon is a monoatomic gas, hence its internal energy of 4 moles $= 4 \times \frac{3}{2}RT = 6RT$

Total Internal energy $= (6+5)RT = 11RT$

9. (c) From graph it is clear that $P_3 > P_1$.

Since area under adiabatic process (*BCED*) is greater than that of isothermal process (*ABDE*). Therefore net work done

$W = W_i + (-W_A)$ $\because W_A > W_i$ $\Rightarrow$ $W < 0$



10. (a) According to given Vander Waal's equation

$$P = \frac{nRT}{V - n\beta} - \frac{\alpha n^2}{V^2}$$

Work done, $W = \int_{V_1}^{V_2} P dV = nRT\int_{V_1}^{V_2}\frac{dV}{V - n\beta} - \alpha n^2\int_{V_1}^{V_2}\frac{dV}{V^2}$

$$= nRT\left[\log_e(V - n\beta)\right]_{V_1}^{V_2} + \alpha n^2\left[\frac{1}{V}\right]_{V_1}^{V_2}$$

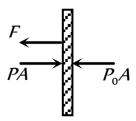
$$= nRT\log_e\frac{V_2 - n\beta}{V_1 - n\beta} + \alpha n^2\left(\frac{V_1 - V_2}{V_1 V_2}\right)$$

11. (b) Volume of the gas is constant V = constant $\therefore$ $P \propto T$

i.e., pressure will be doubled if temperature is doubled

$\therefore$ $P = 2P_0$

Now let F be the tension in the wire. Then equilibrium of any one piston gives



$F = (P - P_0)A = (2P_0 - P_0)A = P_0 A$

12. (c) $dU = C_V dT = \left(\frac{5}{2}R\right)dT$ or $dT = \frac{2(dU)}{5R}$

From first law of thermodynamics

$dU = dQ - dW = Q - \frac{Q}{4} = \frac{3Q}{4}$. Now molar heat capacity

$$C = \frac{dQ}{dT} = \frac{Q}{\frac{2(dU)}{5R}} = \frac{5RQ}{2\left(\frac{3Q}{4}\right)} = \frac{10}{3}R.$$

13. (b) $Q = \Delta U = U_f - U_i$ = [internal energy of 4 moles of a monoatomic gas + internal energy of 2 moles of a diatomic gas] – [internal energy of 4 moles of a diatomic gas]

$$= \left(4 \times \frac{3}{2}RT + 2 \times \frac{5}{2}RT\right) - \left(4 \times \frac{5}{2}RT\right) = RT$$

Note : (a) 2 moles of diatomic gas becomes 4 moles of a monoatomic gas when gas dissociated into atoms.

(b) Internal energy of μ moles of an ideal gas of degrees of freedom F is given by $U = \frac{f}{2}\mu RT$

F = 3 for a monoatomic gas and 5 for diatomic gas.

14. (c) $PV^\gamma = K$ or $P\gamma V^{\gamma-1}dV + dP.\, V^\gamma = 0$

or $\frac{dP}{P} = -\gamma\frac{dV}{V}$ or $\frac{dP}{P} \times 100 = -\gamma\left(\frac{dV}{V} \times 100\right)$

$$= -1.4 \times 5 = 7\%$$

15. (a) $TV^{\gamma-1}$ = constant

$\therefore$ $\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$ or $\left(\frac{1}{2}\right)^{\gamma-1} = \sqrt{\frac{1}{2}}$

$\therefore$ $\gamma - 1 = \frac{1}{2}$ or $\gamma = \frac{3}{2}$ $\therefore$ $PV^{3/2}$ = constant

16. (c) $\eta_A = \frac{T_1 - T_2}{T_1} = \frac{W_A}{Q_1} \Rightarrow \eta_B = \frac{T_2 - T_3}{T_2} = \frac{W_B}{Q_2}$

$\therefore$ $\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \times \frac{T_2 - T_3}{T_1 - T_2} = \frac{T_1}{T_2}$ $\therefore$ $W_A = W_B$

$\therefore$ $T_2 = \frac{T_1 + T_3}{2} = \frac{800 + 300}{2} = 550K$

17. (b) For monoatomic gas

$\gamma = \frac{C_P}{C_V} = \frac{5}{3}$ we know $\Delta Q = nC_P\Delta T$

and $\Delta U = nC_V\Delta T \Rightarrow \frac{\Delta U}{\Delta Q} = \frac{C_V}{C_P} = \frac{3}{5}$

i.e. fraction of heat energy to increase the internal energy be 3/5.

18. (a) $\Delta Q = \Delta U + \Delta W \Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{\Delta U}{\Delta Q} = 1 - \frac{nC_V dT}{nC_P dT}$

$$\Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{C_V}{C_P} = 1 - \frac{3}{5} = \frac{2}{5} = 0.4$$

19. (b) $\Delta U = \mu C_V\Delta T = \frac{m}{M}C_V\Delta T = \frac{N}{N_A}C_V\Delta T$

$$\Rightarrow (\Delta U)_N = \frac{56 \times 10^3}{14} \times \frac{5}{2}R \times 300$$

and $(\Delta U)_A = \frac{6 \times 10^{26}}{6 \times 10^{23}} \times \frac{3}{2}R \times 900 \Rightarrow (\Delta U)_N > (\Delta U)_A$

20. (c) A is compressed isothermally, hence

$P_1 V = P_2\frac{V}{2} \Rightarrow P_2 = 2P_1$

and B is compressed adiabatically, hence

$P_1 V^\gamma = P_2\left(\frac{V}{2}\right)^\gamma \Rightarrow P_2 = (2)^\gamma P_1$

Since $\gamma > 1$, hence $P_2' > P_2$ or $P_2 < P_2'$

21. (b) In isothermal process $P_1 V_1 = P_2 V_2$

or $PV = P_2 \times 4V$ $\therefore$ $P_2 = \frac{P}{4}$

In adiabatic process

$$P_2V_2^{\gamma} = P_3V_3^{\gamma} \Rightarrow \frac{P}{4} \times (4V)^{1.5} = P_2V^{1.5} \Rightarrow P_3 = 2P$$

22. (d) Volume of the ideal gas is constant so $W = P\Delta V = 0$ using FLOT $\Delta Q = \Delta U \Rightarrow \Delta U = i^2Rt = 1^2 \times 100 \times 5 \times 60$

$= 30 \times 10^3 = 30KJ$

23. (d) Initially $\eta = \left(1 - \frac{T_2}{T_1}\right) = \frac{W}{Q} = \frac{1}{6}$ ...(i)

Finally $\eta' = \left(1 - \frac{T_2'}{T_1}\right) = \left(1 - \frac{(T_2 - 62)}{T_1}\right) = 1 - \frac{T_2}{T_1} + \frac{62}{T_1}$

$= \eta + \frac{62}{T_1}$ ....(ii)

It is given that $\eta' = 2\eta$. Hence solving equation (i) and (ii)

$\Rightarrow T_1 = 372\,K = 99°C$ and $T_2 = 310K = 37°C$

24. (b) Input energy $= \frac{1g}{\sec} \times \frac{2kcal}{g} = 2kcal/\sec$.

Output energy $= 10\ KW = 10\ K\ J/S = \frac{10}{4.2} kcal/\sec$.

$\Rightarrow \eta = \frac{\text{output energy}}{\text{input energy}} = \frac{10}{4.2 \times 2} > 1$, it is impossible.

25. (b) Gain of entropy of ice

$$S_1 = \frac{\Delta Q}{T} = \frac{mL}{T} = \frac{80 \times 100}{(0 + 273)} = \frac{8 \times 10^3}{273} cal/K$$

Loss of entropy of water $= S_2 = -\frac{\Delta Q}{T} = -\frac{mL}{T}$

$$= \frac{80 \times 100}{(273 + 50)} = \frac{8 \times 10^3}{323} cal/K$$

Total change of entropy

$$S_1 + S_2 = \frac{8 \times 10^3}{273} - \frac{8 \times 10^3}{323} = +4.5\ cal/K$$

26. (b) $PV^2 =$ constant represents adiabatic equation. So during the expansion of ideal gas internal energy of gas decreases and temperature falls.

27. (d) Initially $\eta = \frac{T_1 - T_2}{T_1} \Rightarrow 0.5 = \frac{T_1 - (273 + 7)}{T_1}$

$\Rightarrow \quad \frac{1}{2} = \frac{T_1 - 280}{T_1} \Rightarrow T_1 = 560K$

Finally $\eta_1' = \frac{T_1' - T_2}{T_1'} \Rightarrow 0.7 = \frac{T_1' - (273 + 7)}{T_1'} \Rightarrow T_1' = 933K$

$\therefore$ increase in temperature $= 933 - 560 = 373K \approx 380K$

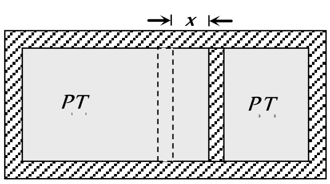
28. (c) P-V diagram of the gas is a straight line passing through origin. Hence $P \propto V$ or $PV^{-1} =$ constant

Molar heat capacity in the process $PV^x =$ constant is

$C = \frac{R}{\gamma - 1} + \frac{R}{1 - x}$; Here $\gamma = 1.4$ (For diatomic gas)

$\Rightarrow C = \frac{R}{1.4 - 1} + \frac{R}{1 + 1} \Rightarrow C = 3R$

29. (c) As finally the piston is in equilibrium, both the gases must be at same pressure P_f. It is given that displacement of piston be in final state x and if A is the area of cross-section of the piston. Hence the final volumes of the left and right part finally can be given by figure as



$V_L = \frac{V_0}{2} + Ax$ and $V_R = \frac{V_0}{2} - Ax$

As it is given that the container walls and the piston are adiabatic in left side and the gas undergoes adiabatic expansion and on the right side the gas undergoes adiabatic compressive. Thus we have for initial and final state of gas on left side

$$P_1\left(\frac{V_0}{2}\right)^{\gamma} = P_f\left(\frac{V_0}{2} + Ax\right)^{\gamma} \quad .....(i)$$

Similarly for gas in right side, we have

$$P_2\left(\frac{V_0}{2}\right)^{\gamma} = P_f\left(\frac{V_0}{2} - Ax\right)^{\gamma} \quad .....(ii)$$

From eq. (i) and (ii)

$$\frac{P_1}{P_2} = \frac{\left(\frac{V_0}{2} + Ax\right)^{\gamma}}{\left(\frac{V_0}{2} - Ax\right)^{\gamma}} \Rightarrow Ax = \frac{V_0}{2}\frac{\left[P_1^{1/\gamma} - P_2^{1/\gamma}\right]}{\left[P_1^{1/\gamma} + P_2^{1/\gamma}\right]}$$

Now from equation (i) $P_f = \frac{P_1\left(\frac{V_0}{2}\right)^{\gamma}}{\left[\frac{V_0}{2} + Ax\right]^{\gamma}}$

30. (d) In both cylinders A and B the gases are diatomic (γ = 1.4). Piston A is free to move *i.e.* it is isobaric process. Piston B is fixed *i.e.* it is isochoric process. If same amount of heat ΔQ is given to both then

$(\Delta Q)_{\text{isobaric}} = (\Delta Q)_{\text{isochoric}} \Rightarrow \mu C_p(\Delta T)_A = \mu C_v(\Delta T)_B$

$\Rightarrow (\Delta T)_B = \frac{C_p}{C_v}(\Delta T)_A = \gamma(\Delta T)_A = 1.4 \times 30 = 42\ K.$

Graphical Questions

1. (c) As internal energy is a point function therefore change in internal energy does not depends upon the path followed i.e. $\Delta U_{\text{I}} = \Delta U_{\text{II}}$

2. (b) Work done by the system = Area of shaded portion on P-V diagram

$= (300 - 100)10^{-6} \times (200 - 10) \times 10^3 = 20\ J$

3. (a) Work done = Area enclosed by triangle $ABC = \frac{1}{2} AC \times BC = \frac{1}{2} \times (3V - V) \times (3P - P) = 2\ PV$

4. (c) Area enclosed between a and f is maximum. So work done in closed cycles follows a and f is maximum.

5. (a) Initial and final states are same in all the process.

Hence $\Delta\ U = 0$; in each case.

By FLOT; $\Delta Q = \Delta W =$ Area enclosed by curve with volume axis.

$\because$ (Area)$_1$ < (Area)$_2$ < (Area)$_1$ $\Rightarrow Q_1 < Q_2 < Q_3$.

6. (a) For an isothermal process $PV =$ constant

$$\Rightarrow PdV + VdP = 0 \Rightarrow -\frac{1}{V}\left(\frac{dV}{dP}\right) = \frac{1}{P}$$

So, $\beta = \frac{1}{P}$ $\therefore$ graph will be rectangular hyperbola.

7. (a) By adjoining graph $W_{AB} = 0$ and

$W_{BC} = 8 \times 10^4 [5-2] \times 10^{-3} = 240\, J$

$\therefore\ W_{AC} = W_{AB} + W_{BC} = 0 + 240 = 240\, J$

Now, $\Delta Q_{AC} = \Delta Q_{AB} + \Delta Q_{BC} = 600 + 200 = 800\, J$

From FLOT $\Delta Q_{AC} = \Delta U_{AC} + \Delta W_{AC}$

$\Rightarrow 800 = \Delta U_{AC} + 240 \Rightarrow \Delta U_{AC} = 560\, J.$

8. (b) In adiabatic process, slope of *PV*-graph.

$$\frac{dP}{dV} = -\gamma \frac{P}{V} \Rightarrow |\text{Slope}| \propto \gamma$$

From the given graph $(\text{Slope})_2 > (\text{Slope})_1 \Rightarrow \gamma_2 > \gamma_1$

therefore 1 should correspond to O_2 (γ = 1.4) and 2 should correspond to *He* (γ = 1.66)

9. (c) As we know that slope of isothermal and adiabatic curves are always negative and slope of adiabatic curve is always greater than that of isothermal curve

Hence in the given graph curve *A* and *B* represents adiabatic and isothermal changes respectively.

10. (d) Process *CD* is isochoric as volume is constant, Process *DA* is isothermal as temperature constant and Process *AB* is isobaric as pressure is constant.

11. (d) Heat given $\Delta Q = 20\, cal = 20 \times 4.2 = 84\, J$.

Work done ΔW = – 50 *J* [As process is anticlockwise]

By first law of thermodynamics

$\Rightarrow \Delta U = \Delta Q - \Delta W = 84 - (-50) = 134\, J$

12. (a) For cyclic process. Total work done $= W_{AB} + W_{BC} + W_{CA}$

$\Delta W_{AB} = P\Delta V = 10(2-1) = 10J$ and $\Delta W_{BC} = 0$

(as V = constant)

From FLOT, $\Delta Q = \Delta U + \Delta W$

$\Delta U = 0$ (Process *ABCA* is cyclic)

$\Rightarrow \Delta Q = \Delta W_{AB} + \Delta W_{BC} + \Delta W_{CA}$

$\Rightarrow\ 5 = 10 + 0 + \Delta W_{CA} \Rightarrow \Delta W_{CA} = -5\, J$

13. (b) The cyclic process 1 is clockwise where as process 2 is anticlockwise. Clockwise area represents positive work and anticlockwise area represents negative work. Since negative area (2) > positive area (1), hence net work done is negative.

14. (c) Process *AB* is isochoric, $\therefore\ W_{AB} = P\,\Delta V = 0$

Process *BC* is isothermal $\therefore\ W_{BC} = RT_2 . \ln\left(\frac{V_2}{V_1}\right)$

Process *CA* is isobaric

$\therefore\ W_{CA} = -P\Delta V = -R\Delta T = -R(T_1 - T_2) = R(T_2 - T_1)$

(Negative sign is taken because of compression)

15. (a) *AB* is isobaric process, *BC* is isothermal process, *CD* is isometric process and *DA* is isothermal process

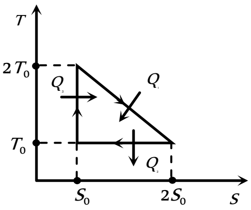
These process are correctly represented by graph (a).

16. (c) Work done by the gas (as cyclic process is clockwise) $\therefore\ \Delta W$ = Area *ABCD*

So from the first law of thermodynamics ΔQ (net heat absorbed) = ΔW = Area *ABCD*

As change in internal energy in cycle $\Delta U = 0$.

17. (a) $Q_1 = T_0 S_0 + \frac{1}{2} T_0 S_0 = \frac{3}{2} T_0 S_0$



$Q_2 = T_0 S_0$ and $Q_3 = 0$

$\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$

$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{2}{3} = \frac{1}{3}$

18. (a) Work done = Area of closed *PV* diagram

$= (2V - V) \times (2P - P) = PV$

19. (c) From the given *VT* diagram,

In process *AB*, $V \propto T \Rightarrow$ Pressure is constant (As quantity of the gas remains same)

In process *BC*, V = Constant and in process *CA*, T = constant

$\therefore$ These processes are correctly represented on *PV* diagram by graph (c).

20. (d) $\Delta Q = \Delta U + \Delta W$; ΔU does not depend upon path.

$\because\ \Delta W_A > \Delta W_B \Rightarrow \Delta Q_A > \Delta Q_B$

21. (d) Work done = Area under curve $= \frac{6P_1 \times 3V_1}{2} = 9\, P_1 V_1$

22. (d) Work done $= \frac{1}{2} \times 2P_1 \times 2V_1 = 2P_1 V_1$

23. (c) In a cyclic, $\Delta U = 0$

From FLOT, $\Delta Q = \Delta U + \Delta W = 0 + \Delta W$ = Area of closed curve

$\Rightarrow \Delta Q = \pi r\ \pi\left(\frac{20}{2}\right)^2 kP_a \times litre$

$= 100\,\pi \times 10^3 \times 10^{-3}\, J = 100\,\pi J$

24. (c) The work done in cyclic process is equal to the area enclosed by the *PV* diagram

25. (d) In all given cases, process is cyclic and in cyclic process $\Delta U = 0$.

26. (b) In cyclic process ΔQ = Work done = Area inside the closed curve.

Treat the circle as an ellipse of area $= \frac{\pi}{4}(P_2 - P_1)(V_2 - V_1)$

$\Rightarrow\ \Delta Q = \frac{\pi}{4}\{(150 - 50) \times 10^3\} = \frac{\pi}{2}\, J$

27. (d) W_{BCOB} = – Area of triangle $BCO = -\frac{P_0 V_0}{2}$

W_{AODA} = + Area of triangle $AOD = +\frac{P_0 V_0}{2}$

28. (c) *AD* and *BC* represent adiabatic process (more slope)

AB and *DC* represent isothermal process (less slope)

29. (c) Work done = Area of curve enclosed

$= 2V \times 2P = 4PV$

30. (c) Work done = Area of *PV* graph (here trapezium)

$= \frac{1}{2}(1 \times 10^5 + 5 \times 10^5) \times (5 - 1) = 12 \times 10^5\, J$

31. (d) For path *ab* : $(\Delta U)_{ab} = 7000\, J$

By using $\Delta U = \mu C_V \Delta T$

$7000 = \mu \times \frac{5}{2} R \times 700 \Rightarrow \mu = 0.48$

For path *ca* :

$(\Delta Q)_{ca} = (\Delta U)_{ca} + (\Delta W)_{ca}$ ....(i)

$\because (\Delta U)_{ab} + (\Delta U)_{bc} + (\Delta U)_{ca} = 0$

$\therefore 7000 + 0 + (\Delta U)_{ca} = 0 \Rightarrow (\Delta U)_{ca} = -7000\ J$ ....(ii)

Also $(\Delta W)_{ca} = P_1(V_1 - V_2) = \mu R(T_1 - T_2)$

$= 0.48 \times 8.31 \times (300 - 1000) = -2792.16\ J$ ....(iii)

on solving equations (i), (ii) and (iii)

$(\Delta Q)_{ca} = -7000 - 2792.16 = -9792.16\ J = -9800\ J$

32. (b) Work done = Area enclosed by indicator diagram

$$= \frac{1}{2} \times (3V - V)(4P - P) = 3PV$$

33. (d) ΔU, remains same for both path

For path iaf: $\Delta U = \Delta Q - \Delta W = 50 - 20 = 30J$.

For path fi : $\Delta U = -30\ J$ and $\Delta W = -13J$

$\Rightarrow \Delta Q = -30 - 13 = -43\ J$.

34. (a) $\Delta E_{\text{int}} = 0$, for a complete cycle and for given cycle work done is negative, so from first law of thermodynamics Q will be negative *i.e.* $Q < 0$.

35. (d) Work done = Area enclosed by the curve

$$= \frac{1}{2}(3V - V)(2P - P) = PV$$

36. (d) W = Area bonded by the indicator diagram with V-axis)

$$= \frac{1}{2}(P_A + P_B)(V_B - V_A)$$

37. (a) Heat given ΔQ = 40 J and Work done ΔW = 30 J

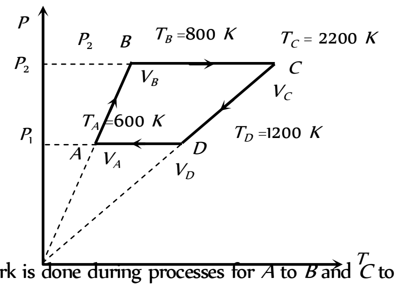
$\Rightarrow \Delta U = \Delta Q - \Delta W = 40 - 30 = 10\ J$.

38. (a) As the volume is continuously increasing and the work of expansion is always positive, so the work done by the system continuously increases.

39. (c) Processes A to B and C to D are parts of straight line graphs of the form $y = mx$

Also $P = \frac{\mu R}{V} T$ (μ = 6)

$\Rightarrow P \propto T$. So volume remains constant for the graphs AB and CD



So no work is done during processes for A to B and C to D *i.e.*, W_{AB} = W_{CD} = 0 and $W_{BC} = P_2(V_C - V_B) = \mu R(T_C - T_B)$

$= 6R\,(2200 - 800) = 6R \times 1400\ J$

Also $W_{DA} = P_1(V_A - V_D) = \mu R(T_A - T_B)$

$= 6R\,(600 - 1200) = -6R \times 600\ J$

Hence work done in complete cycle

$W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= 0 + 6R \times 1400 + 0 - 6R \times 600$

$= 6R \times 900 = 6 \times 8.3 \times 800 \approx 40\ kJ$

40. (b) In isothermal process $P \propto \frac{1}{V}$.

Hence graph between P and V is a hyperbola.

41. (d) Adiabatic curves are more stepper than isothermal curves.

42. (d) During process A to B, pressure and volume both are decreasing. Therefore, temperature and hence, internal energy of the gas will decrease ($T \propto PV$) or $\Delta U_{A\to B}$ = negative. Further $\Delta W_{A\to B}$ is also negative as the volume of the gas is decreasing. Thus $\Delta Q_{A\to B}$ is negative.

In process B to C pressure of the gas is constant while volume is increasing. Hence temperature should increase or $\Delta U_{B\to C}$ = positive. During C to A volume is constant while pressure is increasing. Therefore, temperature and hence, internal energy of the gas should increase or $\Delta U_{C\to A}$ = positive. During process CAB volume of the gas is decreasing. Hence, work done by the gas is negative.

43. (a) $\Delta W_{AB} = 0$ as V = constant

$\therefore \Delta Q_{AB} = \Delta U_{AB} = 50J$ (Given)

$U_A = 1500J \ \therefore \ U_B = (1500 + 50)J = 1550J$

$\Delta W_{BC} = -\Delta U_{BC} = -40J$ (Given)

$\therefore \Delta U_{BC} = 40J \ \therefore \ U_C = (1550 + 40)J = 1590J$

44. (a) For adiabatic process $T_1 V_b^{\gamma-1}$ = Constant

For bc curve $T_1 V_b^{\gamma-1} = T_2 V_c^{\gamma-1}$ or $\frac{T_2}{T_1} = \left(\frac{V_b}{V_c}\right)^{\gamma-1}$ .....(i)

For ad curve $T_1 V_a^{\gamma-1} = T_2 V_d^{\gamma-1}$ or $\frac{T_2}{T_1} = \left(\frac{V_a}{V_d}\right)^{\gamma-1}$ .....(ii)

From equation (i) and (ii) $\frac{V_b}{V_c} = \frac{V_a}{V_d}$

Assertion and Reason

1. (a) In a perfectly reversible system, there is no loss of energy. Losses can be minimised, friction can be reduced, the resistance in L-C oscillating system can also be negligible. But one cannot completely eliminate energy losses. This makes a perfectly reversible system, an ideal.

2. (a) Adiabatic expansion produces cooling.

3. (a) In reversible process, there always occurs some loss of energy. This is because energy spent in working against the dissipative force is not recovered back. Some irreversible process occur in nature such as friction where extra work to cancel the effect of friction. Salt dissolves in water but a salt does not separate by itself into pure salt and pure water.

4. (a) When a bottle of cold carbonated drink is opened. A slight fog forms around the opening. This is because of adiabatic expansion of gas causes lowering of temperature and condensation of water vapours.

5. (e) As isothermal processes are very slow and so the different isothermal curves have different slopes so they cannot intersect each other.

6. (d) Adiabatic compression is a rapid action and both the internal energy and the temperature increases.

7. (e) As there is no change in internal energy of the system during an isothermal change. Hence, the energy taken by the gas is utilised by doing work against external pressure. According to FLOT $\Delta Q = \Delta U + P\Delta V$

Hence $\Delta Q = \Delta U = P\Delta V$

Therefore, reason is true and assertion is false.

8. (d) We can change the temperature of a body without giving (or taking) heat to (or from) it. For example in an adiabatic compression temperature rises and in an adiabatic expansion temperature false, although no heat is given or taken from the system in the respective changes.

9. (a) $c = \dfrac{Q}{m.\Delta\theta}$; a gas may be heated by putting pressure, so it can have values for 0 to ∞.

C_P and C_V are it's two principle specific heats, out of infinite possible values.

In adiabatic process $C = 0$ and in isothermal process $C = \infty$.

10. (a) Heat is similar to work in that both represent ways of transferring energy. Neither heat nor work is an intrinsic property of a system, that is, we cannot say that a system contains a certain amount of heat or work.

11. (d) According to first law of thermodynamics, $\Delta Q = \Delta U + \Delta W = \Delta U + P\Delta V$. If heat is supplies in such a manner that volume does not change $\Delta V = 0$ *i.e.*, isochoric process, then whole of the heat energy supplied to the system will increase internal energy only. But, in any other process it is not possible.

Also heat may absorbed or evolved when state of thermal equilibrium changes.

12. (d) When the door of refrigerator is kept open, heat rejected by the refrigerator to the room will be more than the heat taken by the refrigerator from the room (by an amount equal to work done by the compressor). Therefore, temperature of room will increase and so it will be warmed gradually. As according to 2nd law of thermodynamics, heat cannot be transferred on its own, from a body at lower temperature to another at higher temperature.

13. (a) Second law of thermodynamics can be explained with the help of example of refrigerator, as we know that refrigerator, the working substance extracts heat from colder body and rejects a large amount of heat to a hotter body with the help of an external agency i.e., the electric supply of the refrigerator. No refrigerator can ever work without external supply of electric energy to it.

14. (d) If an electric fan is switched on in a closed room, the air will be heated because due to motion of the fan, the speed of air molecules will increase. In fact, we feel cold due to evaporation of our sweat.

15. (c) The internal energy of system depends only on its temperature. In isothermal process temperature does not change, therefore, internal energy of the system remains the same.

16. (c) In an adiabatic process, no exchange of heat is permissible i.e., $\Delta Q = 0$.

As, $\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta U = -\Delta W$.

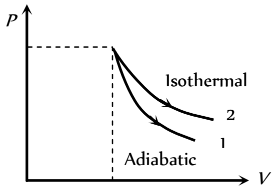
Also in adiabatic process, temperature of gas changes.

17. (a) Change in entropy, $\Delta S = \dfrac{\Delta Q}{T}$. In an adiabatic change, heat transfer $\Delta Q = 0$. $\therefore$ $\Delta S = 0$, or $S =$ constant i.e., entropy remains constant in an adiabatic process, or an adiabatic process is an isoentropic process.

18. (b) As we know, in thermodynamic processes work done = Area covered by *P-V* diagram with volume axis.

Hence, according to following graph.

$(\text{Area})_1 < (\text{Area})_2 \Rightarrow W_{adi} < W_{iso}$



Also in isothermal changes temperature remains same but in adiabatic changes temperature also changes.

19. (c) First law of thermodynamics is restatement of the principal of conservation of energy as applied to heat energy.

20. (e) Zeroth law of thermodynamics explain the concept of temperature. According to which there exist a scalar quantity called temperature which is property of all thermodynamic system.

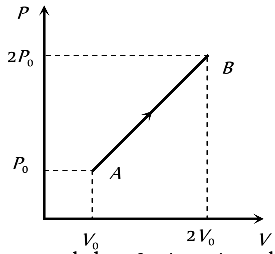
21. (b) Efficiency of cannot cycle $\eta = \dfrac{W}{Q_1} = 1 - \dfrac{T_2}{T_1}$, for Carnot engine when T_2 decrease η increases.

22. (a) Entropy is a measure of the disorder or randomness of the system. Greater the randomness, greater the entropy.

Thermodynamics

SET Self Evaluation Test -14

1. The P-V diagram of 2 gm of helium gas for a certain process $A \rightarrow B$ is shown in the figure. what is the heat given to the gas during the process $A \rightarrow B$



(a) $4P_oV_o$

(b) $6P_oV_o$

(c) $4.5P_oV_o$

(d) $2P_oV_o$

2. A certain mass of gas at 273 K is expanded to 81 times its volume under adiabatic condition. If $\gamma = 1.25$ for the gas, then its final temperature is [Pb. PET 1997]

(a) $-235°C$ (b) $-182°C$

(c) $-91°C$ (d) $0°C$

3. In an adiabatic process $90J$ of work is done on the gas. The change in internal energy of the gas is [CPMT 1996]

(a) $-90\ J$

(b) $+90\ J$

(c) $0\ J$

(d) Depends on initial temperature

4. If a Carnot's engine functions at source temperature 127°C and at sink temperature 87°C, what is its efficiency [DCE 1997]

(a) 10% (b) 25%

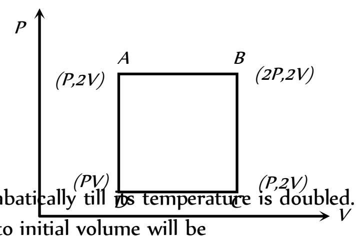
(c) 40% (d) 50%

5. In the case of diatomic gas, the heat given at constant pressure is that part of energy which is used for the expansion of gas, is

(a) $\frac{2}{5}$ (b) $\frac{3}{7}$

(c) $\frac{2}{7}$ (d) $\frac{5}{7}$

6. An ideal monoatomic gas is taken round the cycle $ABCDA$ shown in the PV diagram in the given fig. The work done during the cycle is



(a) $\frac{1}{2}PV$

(b) $2\ PV$

(c) PV

(d) Zero

7. A gas is compressed adiabatically till its temperature is doubled. The ratio of its final volume to initial volume will be [BHU 1997]

(a) 1 / 2 (b) More than 1 / 2

(c) Less than 1 / 2 (d) Between 1 and 2

8. A tyre filled with air (27^oC, and 2 atm) bursts, then what is temperature of air ($\gamma = 1.5$) [RPMT 2002]

(a) -33^oC (b) 0^oC

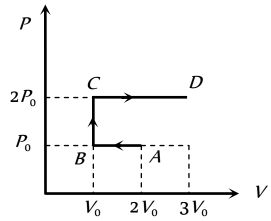
(c) 27^oC (d) 240^oC

9. A gas expands adiabatically at constant pressure such that its temperature $T \propto \frac{1}{\sqrt{V}}$, the value of C_P / C_V of gas is [RPMT 2002; MHCET 2004]

(a) 1.30 (b) 1.50

(c) 1.67 (d) 2.00

10. P-V diagram of an ideal gas is as shown in figure. Work done by the gas in process $ABCD$ is



(a) $4\ P_0V_0$

(b) $2\ P_0V_0$

(c) $3\ P_0V_0$

(d) P_0V_0

11. An engineer claims to have made an engine delivering 10 kW power with fuel consumption of $1\,g\,s^{-1}$. The calorific value of fuel is 2k cal/g. His claim [J & K CET 2000]

(a) Is non-valid (b) Is valid

(c) Depends on engine (d) Depends on load

12. An ideal gas heat engine operates in a Carnot cycle between 27°C and 127°C. It absorbs 6 $kcal$ at the higher temperature. The amount of heat (in $kcal$) converted into work is equal to

(a) 3.5 (b) 1.6

(c) 1.2 (d) 4.8

13. A gas expands with temperature according to the relation $V = kT^{2/3}$. What is the work done when the temperature changes by 30^oC [UPSEAT 1998]

(a) 10 R (b) 20 R

(c) 30 R (d) 40 R

14. An ideal gas ($\gamma = 1.5$) is expanded adiabatically. How many times has the gas to be expanded to reduce the root mean square velocity of molecules 2.0 times

(a) 4 times (b) 16 times

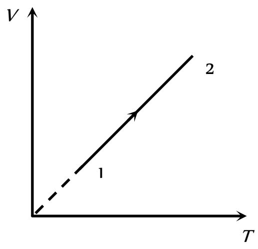
(c) 8 times (d) 2 times

15. Three samples of the same gas A, B and $C(\gamma = 3/2)$ have initially equal volume. Now the volume of each sample is doubled. The process is adiabatic for A isobaric for B and isothermal for C. If the final pressures are equal for all three samples, the ratio of their initial pressures are

(a) $2\sqrt{2}:2:1$ (b) $2\sqrt{2}:1:2$

(c) $\sqrt{2}:1:2$ (d) $2:1:\sqrt{2}$

16. Volume versus temperature graph of two moles of helium gas is as shown in figure. The ratio of heat absorbed and the work done by the gas in process 1-2 is



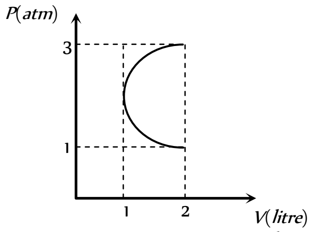
(a) 3

(b) $\frac{5}{2}$

(c) $\frac{5}{3}$

(d) $\frac{7}{2}$

17. In the *P-V* diagram shown in figure *ABC* is a semicircle. The work done in the process *ABC* is



(a) Zero

(b) $\frac{\pi}{2}atm-lt$

(c) $-\frac{\pi}{2}atm-lt$

(d) 4 *atm-lt*

18. Heat is supplied to a diatomic gas at constant pressure. The ratio of $\Delta Q:\Delta U:\Delta W$ is

(a) 5 : 3 : 2 (b) 5 : 2 : 3

(c) 7 : 5 : 2 (d) 7 : 2 : 5

19. A gas undergoes a change of state during which 100 *J* of heat is supplied to it and it does 20 *J* of work. The system is brought back to its original state through a process during which 20 *J* of heat is released by the gas. The work done by the gas in the second process is

(a) 60 *J* (b) 40 *J*

(c) 80 *J* (d) 20 *J*

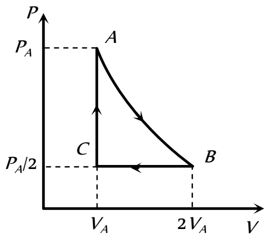
20. *N* moles of an ideal diatomic gas are in a cylinder at temperature *T*. suppose on supplying heat to the gas, its temperature remain constant but *n* moles get dissociated into atoms. Heat supplied to the gas is

(a) Zero (b) $\frac{1}{2}nRT$

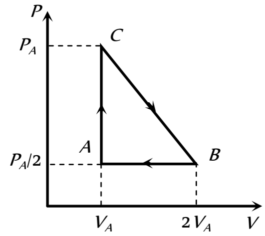
(c) $\frac{3}{2}nRT$ (d) $\frac{3}{2}(N-n)RT$

21. Three moles of an ideal gas $\left(C_P=\frac{7}{2}R\right)$ at pressure P_A and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally the gas is compressed at constant volume to its original pressure P_A. The correct *P-V* and *P-T* diagrams indicating the process are

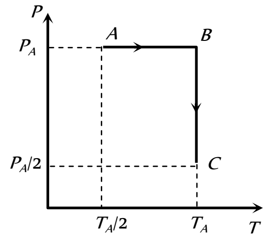
(a)



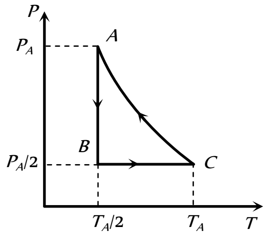
(b)



(c)



(d)



22. A cylinder of mass 1*kg* is given heat of 20000 *J* at atmospheric pressure. If initially temperature of cylinder is 20°*C*, then work done by the cylinder will be (Given that Specific heat of cylinder = 400 *J kg*, Coefficient of volume expansion = 9 × 10 °*C*, Atmospheric pressure = 10 *N/m* and density of cylinder 9000 *kg/m*)

(a) 0.02 *J* (b) 0.05 *J*

(c) 0.08 *J* (d) 0.1 *J*

23. In a thermodynamic process pressure of a fixed mass of a gas is changed in such a manner that the gas releases 30 *joules* of heat and 10 joules of work was done on the gas. If the initial internal energy of the gas was 30 *joules*, then the final internal energy will be [**CPMT 1986**]

(a) 2 *J* (b) – 18 *J*

(c) 10 *J* (d) 58 *J*

24. In an adiabatic change, the pressure *P* and temperature *T* of a monoatomic gas are related by the relation $P\propto T^C$, where *c* equals [**CBSE PMT 1994; BHU 1997; AIIMS 2001; MH CET 2000**]

(a) 5 / 3 (b) 2 / 5

(c) 3 / 5 (d) 5 / 2

25. The internal energy of an ideal gas increases during an isothermal process when the gas is [**SCRA 1998**]

(a) Expanded by adding more molecules to it

(b) Expanded by adding more heat to it

(c) Expanded against zero pressure

(d) Compressed by doing work on it

Answers and Solutions

(SET -14)

1. (b) Change in internal energy from $A\rightarrow B$ is

$$\Delta U=\frac{f}{2}\mu R\Delta T=\frac{f}{2}(P_fV_f-P_iV_i)$$

$= \frac{3}{2}(2P_0 \times 2V_0 - P_0 \times V_0) = \frac{9}{2}P_0V_0$

Work done in process $A \to B$ is equal to the Area covered by the graph with volume axis i.e.,

$W_{A\to B} = \frac{1}{2}(P_0 + 2P_0) \times (2V_0 - V_0) = \frac{3}{2}P_0V_0$

Hence, $\Delta Q = \Delta U + \Delta W = \frac{9}{2}P_0V_0 + \frac{3}{2}P_0V_0 = 6P_0V_0$

2. (b) For adiabatic process $TV^{\gamma-1}$ = constant

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \Rightarrow T_2 = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \times T_1$

$\Rightarrow T_2 = \left(\frac{1}{81}\right)^{1.25-1} \times 273 = \left(\frac{1}{81}\right)^{0.25} \times 273$

$= \frac{273}{3} = 91K \to -182°C$

3. (b) For adiabatic process $\Delta Q = 0$

From $\Delta Q = \Delta U + \Delta W \Rightarrow 0 = \Delta U - 90 \Rightarrow \Delta U = +90J$

4. (d) $\eta = \frac{T_1 - T_2}{T_1} = \frac{(127+273)-(87+273)}{(127+273)}$

$= \frac{400-360}{400} = 0.1 \to 10\%$

5. (c) $\Delta W =$ energy used for expansion $= PdV = RdT$

$\Delta Q =$ heat supplied to diatomic gas at constant P

$= C_p dT = \frac{7}{2}RdT \ (\because C_p = \frac{7}{2}R) \ \therefore \frac{\Delta W}{\Delta Q} = \frac{RdT}{\frac{7}{2}RdT} = \frac{2}{7}$

6. (c)

7. (c) $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 2 \Rightarrow \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{1}{2} \Rightarrow \frac{V_2}{V_1} = \left(\frac{1}{2}\right)^{\frac{1}{\gamma-1}} < \frac{1}{2}$

$\Rightarrow V_2 < \frac{V_1}{2}$

8. (a) $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{(273+27)} = \left(\frac{1}{2}\right)^{\frac{1.5-1}{1.5}} = \left(\frac{1}{2}\right)^{\frac{1}{3}} = \frac{1}{2.5}$

$\Rightarrow T_2 = \frac{T_1}{1.25} = \frac{(273+27)}{1.25} = 238\,K = -34.8°C$

9. (b) $TV^{\gamma-1} =$ constant $\Rightarrow T \propto V^{1-\gamma}$

According to question $T \propto V^{-\frac{1}{2}}$

Hence $1-\gamma = -\frac{1}{2} \Rightarrow \gamma \frac{3}{2} = 1.5$

10. (c) $W_{AB} = -P_0V_0$, $W_{BC} = 0$ and $W_{CD} = 4P_0V_0$

$\Rightarrow W_{ABCD} = -P_0V_0 + 0 + 4P_0V_0 = 3P_0V_0$

11. (a) Power $= 10\,KW = 10000\,J/s = \frac{10000}{4.2} = 2.38\,k\,cal/gm$

But the calorific value of fuel is only 2 *k cal/gm*. Hence claim is invalid.

12. (c) Efficiency of a carnot engine is given by $\eta = 1 - \frac{T_2}{T_1}$

or $\frac{W}{Q} = 1 - \frac{T_2}{T_1} \Rightarrow \frac{W}{6} = 1 - \frac{(273+127)}{(273+227)} \Rightarrow W = 1.2\,k\,cal$

13. (b) $W = \int PdV = \int \frac{RT}{V}dV$

Since $V = kT^{2/3} \Rightarrow dV = \frac{2}{3}KT^{-1/3}dT$

Eliminating K, we find $\frac{dV}{V} = \frac{2}{3}\frac{dT}{T}$

Hence $W = \int_{T_1}^{T_2} \frac{2}{3}\frac{RT}{T}dT = \frac{2}{3}R(T_2 - T_1) = \frac{2}{3}R(30) = 20\,R$

14. (b) $v_{rms} = \sqrt{\frac{3RT}{M}} \Rightarrow v_{rms} \propto \sqrt{T}$

v_{rms} is to reduce two times *i.e.* temperature of the gas will have to reduce four times or $\frac{T'}{T} = \frac{1}{4}$

During adiabatic process $TV^{\gamma-1} = T'V'^{\gamma-1}$

$\Rightarrow \frac{V'}{V} = \left(\frac{T}{T'}\right)^{\frac{1}{\gamma-1}} = (4)^{\frac{1}{1.5-1}} = (4)^2 = 16 \Rightarrow V' = 16V$

15. (b) Let the initial pressure of the three samples be P_A, P_B and P_C, then $P_A(V)^{3/2} = (2V)^{3/2}P$, $P_B = P$ and $P_C(V) = P(2V)$

$\Rightarrow P_A : P_B : P_C = (2)^{3/2} : 1 : 2 = 2\sqrt{2} : 1 : 2$

16. (b) *V-T* graph is a straight line passing through origin. Hence, $V \propto T$ or $P =$ constant

$\therefore \quad \Delta Q = nC_P\Delta T$ and $\Delta U = nC_V\Delta T$

Also $\Delta W = \Delta Q - \Delta U = \mu(C_P - C_V)\Delta T$

$\therefore \quad \frac{\Delta Q}{\Delta W} = \frac{nC_P\Delta T}{n(C_P - C_V)\Delta T} = \frac{C_P}{C_P - C_V} = \frac{1}{1 - \frac{C_V}{C_P}}$

$\frac{C_V}{C_P} = \frac{3}{5}$ for helium gas. Hence $\frac{\Delta Q}{\Delta W} = \frac{1}{1 - 3/5} = \frac{5}{2}$

17. (b) W_{AB} is negative (volume is decreasing) and

W_{BC} is positive (volume is increasing) and

since, $|W_{BC}| > |W_{AB}|$

$\therefore$ net work done is positive and area between semicircle which is equal to $\frac{\pi}{2} atm - lt.$

18. (c) $\Delta Q = \mu C_P\Delta T = \frac{7}{2}\mu R\Delta T \quad \left(C_P = \frac{7}{2}R\right)$

$\Delta U = \mu C_V\Delta T = \frac{5}{2}\mu R\Delta T \quad \left(C_V = \frac{5}{2}R\right)$

and $\Delta W = \Delta Q - \Delta U = \mu R\Delta T$

$\Rightarrow \Delta Q : \Delta U : \Delta W = 7 : 5 : 2$

19. (a) In a cyclic process $\Delta U = 0 \Rightarrow \Delta Q = \Delta W$

$\Rightarrow (100 - 20) = 20 + W_2 \Rightarrow W_2 = 60\ J$

20. (b) Since the gas is enclosed in a vessel, therefore, during heating process, volume of the gas remains constant. Hence, no work is done by the gas. It means heat supplied to the gas is used to increase its internal energy only.

Initial internal energy of the gas is $U_1 = N\left(\frac{5}{2}R\right)T$

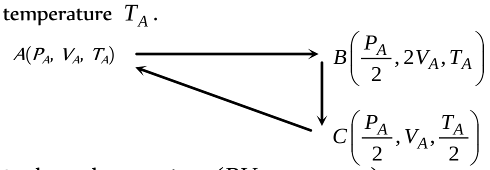
Since n moles get dissociated into atoms, therefore, after heating, vessel contains $(N - n)$ moles of diatomic gas and $2n$ moles of a mono-atomic gas. Hence the internal energy for the gas, after heating, will be equal to

$$U_2 = (N - n)\left(\frac{5}{2}R\right)T + 2n\left(\frac{3}{2}R\right)T = \frac{5}{2}NRT + \frac{1}{2}nRT$$

Hence, the heat supplied = increase in internal energy

$$=(U_2 - U_1) = \frac{1}{2}nRT$$

21. (a) Let the process start from initial pressure P_A, volume V_A and temperature T_A.



(i) Isothermal expansion $(PV = \text{constant})$ at temperature T_A to twice the initial volume V_A

(ii) Compression at constant pressure $\frac{P_A}{2}$ to original volume V_A $(i.e. V \propto T)$

(iii) Isochoric process (at volume V_A) to initial condition $(i.e. P \propto T)$

22. (b) $\Delta Q = mc\Delta T \Rightarrow \Delta T = \frac{20000J}{1kg \times (400J/kg°C)} = 50°C$

$\Rightarrow T_{Final} = 70°C$

Hence $W = P_{atm}\Delta V = P_{atm}V_0\gamma\,\Delta T$

$$= (10^5\,N/m^2)\left(\frac{1}{9\times 10^3}m^3\right)(9\times 10^{-5}/°C)(50°C) = 0.05J$$

23. (c) $\Delta Q = \Delta U + \Delta W = (U_f - U_i) + \Delta W$

$\Rightarrow -30 = (U_f - 30) - 10 \Rightarrow U_f = 10\ J$

24. (d) $T^{\gamma}P^{1-\gamma}$ = constant $\Rightarrow P \propto T^{\frac{\gamma}{\gamma - 1}}$

Comparing above equation with given equation

$$P \propto T^C \Rightarrow C = \frac{\gamma}{\gamma - 1} = \frac{5/3}{5/3 - 1} = \frac{5}{2}$$

25. (a) Internal energy of an ideal gas is given by

$$U = \frac{f}{2}\mu RT = \frac{f}{2}\left(\frac{N}{N_A}\right)RT \Rightarrow U \propto NT.$$

In isothermal process T = constant $\Rightarrow U \propto N$.

i.e. internal energy increases by increasing number of molecules (N).

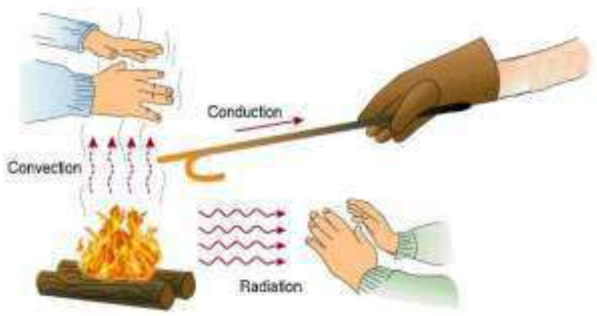
***

Chapter 15

Transmission of Heat

Heat energy transfers from a body at higher temperature to a body at lower temperature. The transfer of heat from one body to another may take place by one of the following modes.

Conduction, Convection and **Radiation**



Conduction

The process of transmission of heat energy in which the heat is transferred from one particle to other particle without dislocation of the particle from their equilibrium position is called conduction.

(1) Heat flows from hot end to cold end. Particles of the medium simply oscillate but do not leave their place.

(2) Medium is necessary for conduction

Fig. 15.1

(3) It is a slow process

(4) The temperature of the medium increases through which heat flows

(5) Conduction is a process which is possible in all states of matter.

(6) When liquid and gases are heated from the top, they conduct heat from top to bottom.

(7) In solids only conduction takes place

(8) In non-metallic solids and fluids the conduction takes place only due to vibrations of molecules, therefore they are poor conductors.

(9) In metallic solids free electrons carry the heat energy, therefore they are good conductor of heat.

Conduction in Metallic Rod

When one end of a metallic rod is heated, heat flows by conduction from the hot end to the cold end.

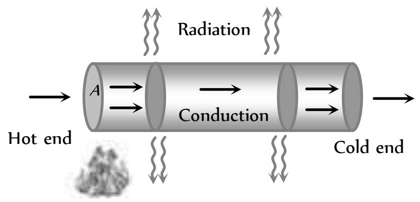


Fig. 15.2

(1) **Variable state :** In this state temperature of every part of the rod increases

Heat received by each cross-section of the rod from hotter end used in three ways.

(i) A part increases temperature of itself.

(ii) Another part transferred to neighbouring cross-section.

(iii) Remaining part radiates.

- $\theta_1 > \theta_2 > \theta_3 > \theta_4 > \theta_5$
- $\theta \rightarrow$ Changing

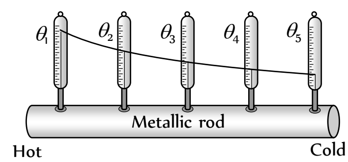
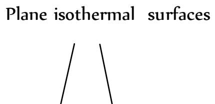
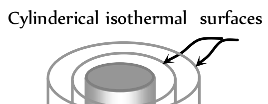


Fig. 15.3

(2) **Steady state :** After sometime, a state is reached when the temperature of every cross-section of the rod becomes constant. In this state, no heat is absorbed by the rod. The heat that reaches any cross-section is transmitted to the next except that a small part of heat is lost to surrounding from the sides by convection & radiation. This state of the rod is called steady state.

(3) **Isothermal surface :** Any surface (within a conductor) having its all points at the same temperature, is called isothermal surface. The direction





of flow of heat through a conductor at any point is perpendicular to the isothermal surface passing through that point.

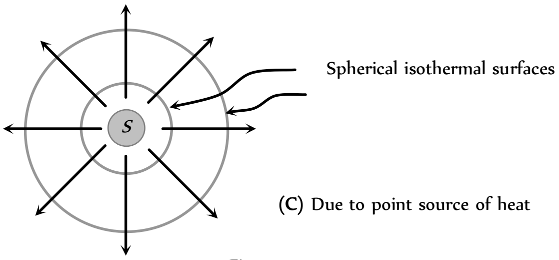


Fig. 15.4

(4) **Temperature gradient (T.G.) :** The rate of change of temperature with distance between two isothermal surfaces is called temperature gradient. Hence

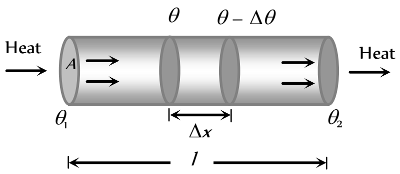


Fig. 15.5

(i) Temperature gradient = $\frac{-\Delta\theta}{\Delta x}$

(ii) The negative sign show that temperature θ decreases as the distance *x* increases in the direction of heat flow.

(iii) For uniform temperature fall $\frac{\theta_1 - \theta_2}{l} = \frac{\Delta\theta}{\Delta x}$

(iv) Unit : *K/m* or *°C/m* (S.I.) and Dimensions $[L^{-1}\theta]$

(5) **Law of thermal conductivity :** Consider a rod of length *l* and area of cross-section *A* whose faces are maintained at temperature θ and θ respectively. The curved surface of rod is kept insulated from surrounding to avoid leakage of heat

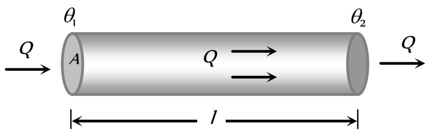


Fig. 15.6

(i) In steady state the amount of heat flowing from one face to the other face in time *t* is given by $Q = \frac{KA(\theta_1 - \theta_2)t}{l}$

where *K* is coefficient of thermal conductivity of material of rod.

(ii) Rate of flow of heat *i.e.* heat current $\frac{Q}{t} = H = \frac{KA(\theta_1 - \theta_2)}{l}$

(iii) In case of non-steady state or variable cross-section, a more general equation can be used to solve problems.

$$\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$$

(6) **More about *K* :** It is the measure of the ability of a substance to conduct heat through it.

(i) Units : *Cal/cm-sec °C* (in C.G.S.), *kcal/m-sec-K* (in M.K.S.) and *W/m- K* (in S.I.). Dimension : $[MLT^{-3}\theta^{-1}]$

(ii) The magnitude of *K* depends only on nature of the material.

(iii) Substances in which heat flows quickly and easily are known as good conductor of heat. They possesses large thermal conductivity due to large number of free electrons *e.g.* Silver, brass *etc.* For perfect conductors, $K = \infty$.

(iv) Substances which do not permit easy flow of heat are called bad conductors. They possess low thermal conductivity due to very few free electrons *e.g.* Glass, wood *etc.* and for perfect insulators, $K = 0$.

(v) The thermal conductivity of pure metals decreases with rise in temperature but for alloys thermal conductivity increases with increase of temperature.

(vi) Human body is a bad conductor of heat (but it is a good conductor of electricity).

(vii) **Decreasing order of conductivity :** For some special cases it is as follows

(a) $K_{Ag} > K_{Cu} > K_{Al}$

(b) $K_{Solid} > K_{Liquid} > K_{Gas}$

(c) $K_{Metals} > K_{Non-metals}$

Table 15.1 : Thermal conductivity of some material

Substance	Thermal conductivity (*W/m-K*)	Substance	Thermal conductivity (*W/m-K*)
Aluminium	240	Concrete	0.9
Copper	400	Water	0.6
Gold	300	Glass wool	0.04
Iron	80	Air	0.024
Lead	35	Helium	0.14
Glass	0.9	Hydrogen	0.17
Wood	0.1-0.2	Oxygen	0.024

(7) **Relation between temperature gradient and thermal conductivity :** In steady state, rate of flow of heat $\frac{dQ}{dt} = -KA\frac{d\theta}{dx} = -KA \times$ (T.G.) $\Rightarrow$

(T.G.) $\propto \frac{1}{K}$ ($\frac{dQ}{dt}$ = constant)

Temperature difference between the hot end and the cold end in steady state is inversely proportional to *K*, *i.e.* in case of good conductors temperature of the cold end will be very near to hot end.

In ideal conductor where $K = \infty$, temperature difference in steady state will be zero.

(8) **Thermal resistance (*R*) :** The thermal resistance of a body is a measure of its opposition to the flow of heat through it.

It is defined as the ratio of temperature difference to the heat current (= Rate of flow of heat)

(i) Hence $R = \frac{\theta_1 - \theta_2}{H} = \frac{\theta_1 - \theta_2}{KA(\theta_1 - \theta_2)/l} = \frac{l}{KA}$

(ii) **Unit :** $^oC \times sec/cal$ or $K \times sec/kcal$ and Dimension : $[M^{-1}L^{-2}T^3\theta]$

(9) **Wiedmann-Franz law :** At a given temperature *T*, the ratio of thermal conductivity to electrical conductivity is constant *i.e.*, $(K/\sigma T)$ = constant, *i.e.,* a substance which is a good conductor of heat (*e.g.,* silver) is also a good conductor of electricity. Mica is an exception to above law.

(10) **Thermometric conductivity or diffusivity :** It is a measure of rate of change of temperature (with time) when the body is not in steady state (*i.e.,* in variable state)

It is defined as the ratio of the coefficient of thermal conductivity to the thermal capacity per unit volume of the material. Thermal capacity per unit volume = $\frac{mc}{V}$ = ρc

(ρ = density of substance) $\Rightarrow$ Diffusivity (*D*) = $\frac{K}{\rho c}$

Unit : *m/sec* and Dimension : $[L^2T^{-1}]$

Table 15.2 : Electrical Analogy for Thermal Conduction

Electrical conduction	Thermal conduction
Electric charge flows from higher potential to lower potential	Heat flows from higher temperature to lower temperature
The rate of flow of charge is called the electric current, *i.e.* $I = \frac{dq}{dt}$	The rate of flow of heat may be called as heat current *i.e.* $H = \frac{dQ}{dt}$
The relation between the electric current and the potential difference is given by Ohm's law, that is $I = \frac{V_1 - V_2}{R}$ where *R* is the electrical resistance of the conductor	Similarly, the heat current may be related with the temperature difference as $H = \frac{\theta_1 - \theta_2}{R}$ where *R* is the thermal resistance of the conductor
The electrical resistance is defined as $R = \frac{\rho l}{A} = \frac{l}{\sigma A}$ where ρ = Resistivity and σ = Electrical conductivity	The thermal resistance may be defined as $R = \frac{l}{KA}$ where *K* = Thermal conductivity of conductor
$\frac{dq}{dt} = I = \frac{V_1 - V_2}{R} = \frac{\sigma A}{l}(V_1 - V_2)$	$\frac{dQ}{dt} = H = \frac{\theta_1 - \theta_2}{R} = \frac{KA}{l}(\theta_1 - \theta_2)$

Applications of Conductivity in Daily Life

(1) Cooking utensils are provided with wooden handles, because wood is a poor conductor of heat. The hot utensils can be easily handled from the wooden handles and our hands are saved from burning.

Fig. 15.7

(2) We feel warmer in a fur coat. The air enclosed in the fur coat being bad conductor heat does not allow the body heat to flow outside. Hence we feel warmer in a fur coat.

(3) Eskimos make double walled houses of the blocks of ice. Air enclosed in between the double walls prevents transmission of heat from the house to the cold surroundings.

Fig. 15.8

For exactly the same reason, two thin blankets are warmer than one blanket of their combined thickness. The layer of air enclosed in between the two blankets makes the difference.

(4) Wire gauze is placed over the flame of Bunsen burner while heating the flask or a beaker so that the flame does not go beyond the gauze and hence there is no direct contact between the flame and the flask. The wire gauze being a good conductor of heat, absorb the heat of the flame and transmit it to the flask.

Fig. 15.9

Davy's safety lamp has been designed on this principle. The gases in the mines burn inside the gauze placed around the flame of the lamp. The temperature outside the gauze is not high, so the gases outside the gauze do not catch fire.

(5) Birds often swell their feathers in winter. By doing so, they enclose more air between their bodies and the feathers. The air, being bad conductor of heat prevents the out flow of their body heat. Thus, birds feel warmer in winter by swelling their feathers.

Combination of Metallic Rods

(1) **Series combination :** Let *n* slabs each of cross-sectional area *A*, lengths $l_1, l_2, l_3, ...\ l_n$ and conductivities $K_1, K_2, K_3 ......\ K_n$ respectively be connected in the series

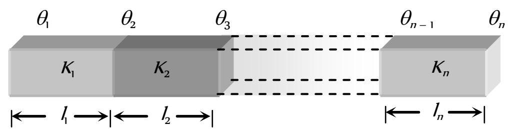


Fig. 15.10

(i) **Heat current :** Heat current is the same in all the conductors.*i.e.,*

$$\frac{Q}{t} = H_1 = H_2 = H_3 .... = H_n$$

$$\frac{K_1 A(\theta_1 - \theta_2)}{l_1} = \frac{K_2 A(\theta_2 - \theta_3)}{l_2} = \frac{K_n A(\theta_{n-1} - \theta_n)}{l_n}$$

(ii) **Equivalent thermal resistance :** $R = R_1 + R_2 + ...\ R_n$

(iii) **Equivalent thermal conductivity :** It can be calculated as follows

From $R_S = R_1 + R_2 + R_3 + ...$

$$\frac{l_1 + l_2 + ...l_n}{K_s} = \frac{l_1}{K_1 A} + \frac{l_2}{K_2 A} + ... + \frac{l_n}{K_n A}$$

$$\Rightarrow K_s = \frac{l_1 + l_2 + ...\ l_n}{\frac{l_1}{K_1} + \frac{l_2}{K_2} + ... \frac{l_n}{K_n}}$$

(a) For *n* slabs of equal length $K_s = \frac{n}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + ... \frac{1}{K_n}}$

(b) For two slabs of equal length, $K_s = \frac{2K_1 K_2}{K_1 + K_2}$

(iv) **Temperature of interface of composite bar** : Let the two bars are arranged in series as shown in the figure.

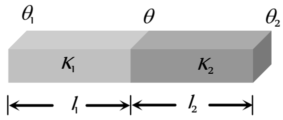


Fig. 15.11

Then heat current is same in the two conductors.

i.e., $\dfrac{Q}{t} = \dfrac{K_1 A(\theta_1 - \theta)}{l_1} = \dfrac{K_2 A(\theta - \theta_2)}{l_2}$

By solving we get $\theta = \dfrac{\dfrac{K_1}{l_1}\theta_1 + \dfrac{K_2}{l_2}\theta_2}{\dfrac{K_1}{l_1} + \dfrac{K_2}{l_2}}$

(a) If $l_1 = l_2$ then $\theta = \dfrac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

(b) If $K_1 = K_2$ and $l_1 = l_2$ then $\theta = \dfrac{\theta_1 + \theta_2}{2}$

(2) **Parallel Combination :** Let *n* slabs each of length *l*, areas $A_1, A_2, A_3, \ldots\ldots A_n$ and thermal conductivities $K_1, K_2, K_3, \ldots\ldots K_n$ are connected in parallel then

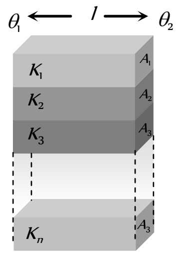


Fig. 15.12

(i) **Equivalent resistance :** $\dfrac{1}{R_s} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \ldots\ldots \dfrac{1}{R_n}$

For two slabs $R_s = \dfrac{R_1 R_2}{R_1 + R_2}$

(ii) **Temperature gradient :** Same across each slab.

(iii) **Heat current :** in each slab will be different. Net heat current will be the sum of heat currents through individual slabs. *i.e.,* $H = H_1 + H_2 + H_3 + \ldots. H_n$

$$\frac{K(A_1 + A_2 + \ldots\ldots + A_n)(\theta_1 - \theta_2)}{l}$$

$$= \frac{K_1 A_1(\theta_1 - \theta_2)}{l} + \frac{K_2 A_2(\theta_1 - \theta_2)}{l} + \ldots + \frac{K_n A_n(\theta_1 - \theta_2)}{l}$$

$$\Rightarrow K = \frac{K_1 A_1 + K_2 A_2 + K_3 A_3 + \ldots\ldots K_n A_n}{A_1 + A_2 + A_3 + \ldots\ldots A_n}$$

(a) For *n* slabs of equal area $K = \dfrac{K_1 + K_2 + K_3 + \ldots\ldots K_n}{n}$

(b) For two slabs of equal area $K = \dfrac{K_1 + K_2}{2}$.

Ingen-Hauz Experiment

It is used to compare thermal conductivities of different materials. If l_1, l_2 and l_3 are the lengths of wax melted on rods as shown in the figure, then the ratio of thermal conductivities is $K_1 : K_2 : K_3 = l_1^2 : l_2^2 : l_3^2$

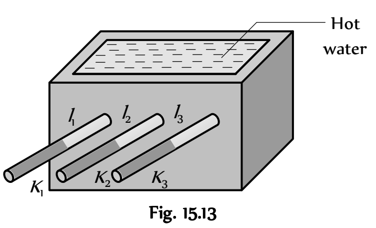


Fig. 15.13

$\Rightarrow$ Thermal conductivity (*K*) $\propto$ (Melted length l)^2

Searle's Experiment

It is a method of determination of *K* of a metallic rod.

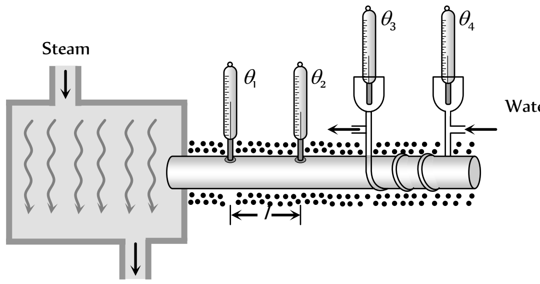


Fig. 15.14

(1) In this experiment a temperature difference $(\theta_1 - \theta_2)$ is maintained across a rod of length *l* and area of cross section A. If the thermal conductivity of the material of the rod is *K*, then the amount of heat transmitted by the rod from the hot end to the cold end in time *t* is given by, $Q = \dfrac{KA(\theta_1 - \theta_2)t}{l}$ ......(i)

(2) In Searle's experiment, this heat reaching the other end is utilized to raise the temperature of certain amount of water flowing through pipes circulating around the other end of the rod. If temperature of the water at the inlet is θ_3 and at the outlet is θ_4, then the amount of heat absorbed by water is given by, $Q = mc(\theta_4 - \theta_3)$ ......(ii)

(3) Where, *m* is the mass of the water which has absorbed this heat and temperature is raised and *c* is the specific heat of the water

Equating (i) and (ii), *K* can be determined *i.e.,* $K = \dfrac{mc(\theta_4 - \theta_3)l}{A(\theta_1 - \theta_2)t}$

(4) In numericals we may have the situation where the amount of heat travelling to the other end may be required to do some other work *e.g.,* it may be required to melt the given amount of ice. In that case equation (i) will have to be equated to *mL*.

i.e. $mL = \dfrac{KA(\theta_1 - \theta_2)t}{l}$

Growth of Ice on Lake

(1) Water in a lake starts freezing if the atmospheric temperature drops below $0^o C$. Let *y* be the thickness of ice layer in the lake at any instant *t* and atmospheric temperature is $-\theta^o C$.

(2) The temperature of water in contact with lower surface of ice will be zero.

(3) If *A* is the area of lake, heat escaping through ice in time *dt* is $dQ_1 = \dfrac{KA[0 - (-\theta)]dt}{y}$

(4) Suppose the thickness of ice layer increases by *dy* in time *dt*, due to escaping of above heat. Then $dQ_2 = mL = \rho(dy\, A)L$

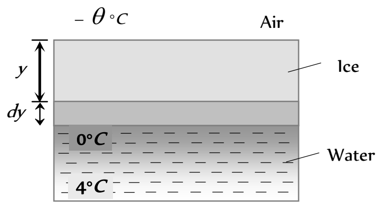


Fig. 15.15

(5) As $dQ_1 = dQ_2$, hence, rate of growth of ice will be $(dy/dt) = (K\theta / \rho L y)$

So, the time taken by ice to grow to a thickness y is

$$t = \frac{\rho L}{K\theta}\int_0^y y\,dy = \frac{\rho L}{2K\theta}y^2$$

(6) If the thickness is increased from y_1 to y_2 then time taken $t = \frac{\rho L}{K\theta}\int_{y_1}^{y_2} y dy = \frac{\rho L}{2K\theta}(y_2^2 - y_1^2)$

(7) Take care and do not apply a negative sign for putting values of temperature in formula and also do not convert it to absolute scale.

(8) Ice is a poor conductor of heat, therefore the rate of increase of thickness of ice on ponds decreases with time.

(9) It follows from the above equation that time taken to double and triple the thickness, will be in the ratio of

$$t_1 : t_2 : t_3 :: 1^2 : 2^2 : 3^2, \text{ i.e., } t_1 : t_2 : t_3 :: 1 : 4 : 9$$

(10) The time intervals to change the thickness from 0 to y, from y to $2y$ and so on will be in the ratio

$$\Delta t_1 : \Delta t_2 : \Delta t_3 :: (1^2 - 0^2) : (2^2 - 1^2) : (3^2 : 2^2)$$

$$\Rightarrow \Delta t_1 : \Delta t_2 : \Delta t_3 :: 1 : 3 : 5$$

Convection

Mode of transfer of heat by means of migration of material particles of medium is called convection. It is of two types.

(1) **Natural convection :** This arise due to difference of densities at two places and is a consequence of gravity because on account of gravity the hot light particles rise up and cold heavy particles try setting down. It mostly occurs on heating a liquid/fluid.

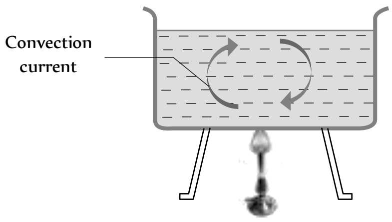


Fig. 15.16

(2) **Forced convection :** If a fluid is forced to move to take up heat from a hot body then the convection process is called forced convection. In this case Newton's law of cooling holds good. According to which rate of loss of heat from a hot body due to moving fluid is directly proportional to the surface area of body and excess temperature of body over its surroundings *i.e.*

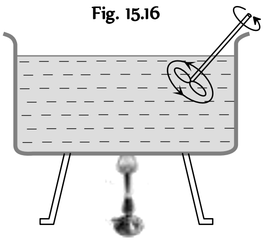


Fig. 15.17

$$\frac{Q}{t} \propto A(T - T_0) \Rightarrow \frac{Q}{t} = h\,A(T - T_0)$$

where h = Constant of proportionality called convection coefficient, T = Temperature of body and T_0 = Temperature of surrounding

Convection coefficient (h) depends on properties of fluid such as density, viscosity, specific heat and thermal conductivity.

(3) Natural convection takes place from bottom to top while forced convection in any direction.

(4) In case of natural convection, convection currents move warm air upwards and cool air downwards. That is why heating is done from base, while cooling from the top.

(5) Natural convection plays an important role in ventilation, in changing climate and weather and in forming land and sea breezes and trade winds.

(6) Natural convection is not possible in a gravity free region such as a free falling lift or an orbiting satellite.

(7) The force of blood in our body by heart helps in keeping the temperature of body constant.

(8) If liquids and gases are heated from the top (so that convection is not possible) they transfer heat (from top to bottom) by conduction.

(9) Mercury though a liquid is heated by conduction and not by convection.

Radiation

(1) The process of the transfer of heat from one place to another place without heating the intervening medium is called radiation.

Fig. 15.18

(2) Precisely it is electromagnetic energy transfer in the form of electromagnetic wave through any medium. It is possible even in vacuum *e.g.* the heat from the sun reaches the earth through radiation.

(3) The wavelength of thermal radiations ranges from $7.8 \times 10^{-7}\,m$ to $4 \times 10^{-4}\,m$. They belong to *infra-red* region of the electromagnetic spectrum. That is why thermal radiations are also called *infra-red* radiations.

(4) Medium is not required for the propagation of these radiations.

(5) They produce sensation of warmth in us but we can't see them.

(6) Every body whose temperature is above zero Kelvin emits thermal radiation.

(7) Their speed is equal to that of light *i.e.* $(= 3 \times 10^8\,m/s)$.

(8) Their intensity is inversely proportional to the square of distance of point of observation from the source (*i.e.* $I \propto 1/d^2$).

(9) Just as light waves, they follow laws of reflection, refraction, interference, diffraction and polarisation.

(10) When these radiations fall on a surface then exert pressure on that surface which is known as radiation pressure.

(11) While travelling these radiations travel just like photons of other electromagnetic waves. They manifest themselves as heat only when they are absorbed by a substance.

(12) Spectrum of these radiations can not be obtained with the help of glass prism because it absorbs heat radiations. It is obtained by quartz or rock salt prism because these materials do not have free electrons and interatomic vibrational frequency is greater than the radiation frequency, hence they do not absorb heat radiations.

(13) **Diathermanous Medium :** A medium which allows heat radiations to pass through it without absorbing them is called diathermanous medium. Thus the temperature of a diathermanous medium does not increase irrespective of the amount of the thermal radiations passing through it *e.g.*, dry air, SO_2, rock salt (*NaCl*).

(i) Dry air does not get heated in summers by absorbing heat radiations from sun. It gets heated through convection by receiving heat from the surface of earth.

(ii) In winters heat from sun is directly absorbed by human flesh while the surrounding air being diathermanous is still cool. This is the reason that sun's warmth in winter season appears very satisfying to us.

(14) **Athermanous medium :** A medium which partly absorbs heat rays is called a thermous medium As a result temperature of an athermanous medium increases when heat radiations pass through it *e.g.*, wood, metal, moist air, simple glass, human flesh *etc*.

Colour of Heated Object

When a body is heated, all radiations having wavelengths from zero to infinity are emitted.

(1) Radiations of longer wavelengths are predominant at lower temperature.

(2) The wavelength corresponding to maximum emission of radiations shifts from longer wavelength to shorter wavelength as the temperature increases. Due to this the colour of a body appears to be changing.

(3) A blue flame is at a higher temperature than a yellow flame

Table 15.3 : Variation of colour of a body on heating

Temperature	Colour
525°*C*	Dull red
900°*C*	Cherry red
1100°*C*	Orange red
1200°*C*	Yellow
1600°*C*	White

Interaction of Radiation with Matter

When thermal radiations (*Q*) fall on a body, they are partly reflected, partly absorbed and partly transmitted.

(1) $Q = Q_a + Q_r + Q_t$

(2) $\frac{Q_a}{Q} + \frac{Q_r}{Q} + \frac{Q_t}{Q} = a + r + t = 1$

(3) $a = \frac{Q_a}{Q}$ = Absorptance or absorbing power

$r = \frac{Q_r}{Q}$ = Reflectance or reflecting power

$t = \frac{Q_t}{Q}$ = Transmittance or transmitting power

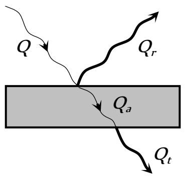


Fig. 15.19

(4) *r*, *a* and *t* all are the pure ratios so they have no unit and dimension.

(5) **Different bodies**

(i) If $a = t = 0$ and $r = 1 \rightarrow$ body is perfect reflector

(ii) If $r = t = 0$ and $a = 1 \rightarrow$ body is perfectly black body

(iii) If, $a = r = 0$ and $t = 1 \rightarrow$ body is perfect transmitter

(iv) If $t = 0 \Rightarrow r + a = 1$ or $a = 1 - r$ *i.e.* good reflectors are bad absorbers.

Emissive Power, Absorptive Power and Emissivity

If temperature of a body is more than it's surrounding then body emits thermal radiation

(1) **Monochromatic Emittance or Spectral emissive power (e_λ) :** For a given surface it is defined as the radiant energy emitted per sec per unit area of the surface with in a unit wavelength around λ *i.e.* lying between $\left(\lambda - \frac{1}{2}\right)$ to $\left(\lambda + \frac{1}{2}\right)$.

Spectral emissive power $(e_\lambda) = \frac{\text{Energy}}{\text{Area} \times \text{time} \times \text{wavelength}}$

Unit : $\frac{Joule}{m^2 \times sec \times Å}$ and Dimension : $[ML^{-1}T^{-3}]$

(2) **Total emittance or total emissive power (*e*) :** It is defined as the total amount of thermal energy emitted per unit time, per unit area of the body for all possible wavelengths.

$$e = \int_0^\infty e_\lambda d\lambda$$

Unit : $\frac{Joule}{m^2 \times \sec}$ or $\frac{Watt}{m^2}$ and Dimension : $[MT^{-3}]$

(3) **Monochromatic absorptance or spectral absorptive power (a_λ) :** It is defined as the ratio of the amount of the energy absorbed in a certain time to the total heat energy incident upon it in the same time, both in the unit wavelength interval. It is dimensionless and unit less quantity. It is represented by a_λ.

(4) **Total absorptance or total absorpting power (*a*):** It is defined as the total amount of thermal energy absorbed per unit time, per unit area of the body for all possible wavelengths.

$$a = \int_0^\infty a_\lambda d\lambda$$

(5) **Emissivity (ε) :** Emissivity of a body at a given temperature is defined as the ratio of the total emissive power of the body (*e*) to the total emissive power of a perfect black body (*E*) at that temperature *i.e.* $\varepsilon = \frac{e}{E}$

($\varepsilon \rightarrow$ read as epsilon)

(i) For perfectly black body $\varepsilon = 1$

(ii) For highly polished body $\varepsilon = 0$

(iii) But for practical bodies emissivity (ε) lies between zero and one ($0 < \varepsilon < 1$).

Perfectly Black Body

(1) A perfectly black body is that which absorbs completely the radiations of all wavelengths incident on it.

(2) As a perfectly black body neither reflects nor transmits any radiation, therefore the absorptance of a perfectly black body is unity *i.e.* $t = 0$ and $r = 0 \Rightarrow a = 1$.

(3) We know that the colour of an opaque body is the colour (wavelength) of radiation reflected by it. As a black body reflects no wavelength so, it appears black, whatever be the colour of radiations incident on it.

(4) When perfectly black body is heated to a suitable high temperature, it emits radiation of all possible wavelengths. For example, temperature of the sun is very high (6000 K approx.) it emits all possible radiation so it is an example of black body.

(5) **Ferry's black body :** A perfectly black body can't be realised in practice. The nearest example of an ideal black body is the Ferry's black body. It is a doubled walled evacuated spherical cavity whose inner wall is blackened. The space between the wall is evacuated to prevent the loss of heat by conduction and radiation. There is a fine hole in it. All the radiations incident upon this hole are absorbed by this black body. If this black body is heated to high temperature then it emits radiations of all wavelengths. It is the hole which is to be regarded as a black body and not the total enclosure

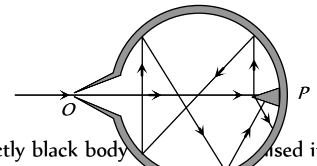
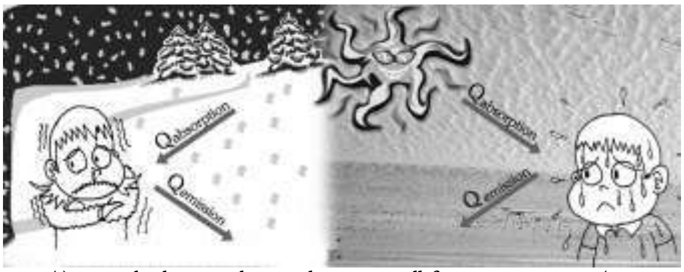


Fig. 15.20

(6) A perfectly black body [illegible]sed in practice but materials like Platinum black or Lamp black come close to being ideal black bodies. Such materials absorbs 96% to 85% of the incident radiations.

Prevost Theory of Heat Exchange



(1) Every body emits heat radiations at all finite temperature (Except 0 K) as well as it absorbs radiations from the surroundings.

(2) Exchange of energy along various bodies takes place via radiation.

(3) The process of heat exchange among various bodies is a continuous phenomenon.

(4) At absolute zero temperature (0 K or – 273°C) this law is not applicable because at this temperature the heat exchange among various bodies ceases.

(5) If $Q_{emission} > Q_{absorbed} \rightarrow$ temperature of body decreases and consequently the body appears colder.

If $Q_{emission} < Q_{absorbed} \rightarrow$ temperature of body increases and it appears hotter.

If $Q_{emission} = Q_{absorbed} \rightarrow$ temperature of body remains constant (thermal equilibrium)

Kirchoff's Law

According to this law the ratio of emissive power to absorptive power is same for all surfaces at the same temperature and is equal to the emissive power of a perfectly black body at that temperature. Hence $\frac{e_1}{a_1} = \frac{e_2}{a_2} = ... \left(\frac{E}{A}\right)_{\text{Perfectly black body}}$

But for perfectly black body $A = 1$ *i.e.* $\frac{e}{a} = E$

If emissive and absorptive powers are considered for a particular wavelength λ, $\left(\frac{e_\lambda}{a_\lambda}\right) = (E_\lambda)_{\text{black}}$

Now since $(E_\lambda)_{black}$ is constant at a given temperature, according to this law if a surface is a good absorber of a particular wavelength it is also a good emitter of that wavelength.

This in turn implies that a good absorber is a good emitter (or radiator)

Applications of Kirchoff's Law

(1) Sand is rough black, so it is a good absorber and hence in deserts, days (when radiation from the sun is incident on sand) will be very hot. Now in accordance with Kirchoff's law, good absorber is a good emitter so nights (when sand emits radiation) will be cold. This is why days are hot and nights are cold in desert.

(2) Sodium vapours, on heating, emit two bright yellow lines. These are called D_1, D_2 lines of sodium. When continuos white light from an arc lamp is made to pass through sodium vapours at low temperature, the continuous spectrum is intercepted by two dark lines exactly in the same places as D_1 and D_2 lines. Hence sodium vapours when cold, absorbs the same wavelength, as they emit while hot. This is in accordance with Kirchoff's law.

(3) When a shining metal ball having some black spots on its surface is heated to a high temperature and is seen in dark, the black spots shine brightly and the shining ball becomes dull or invisible. The reason is that the black spots on heating absorb radiation and so emit these in dark while the polished shining part reflects radiations and absorb nothing and so does not emit radiations and becomes invisible in the dark.

(4) When a green glass is heated in furnace and taken out, it is found to glow with red light. This is because red and green are complimentary colours. At ordinary temperatures, a green glass appears green, because it transmits green colour and absorb red colour strongly. According to Kirchoff's law, this green glass, on heating must emit the red colour, which is absorbed strongly. Similarly when a red glass is heated to a high temperature it will glow with green light.

(5) A person with black skin experiences more heat and more cold as compared to a person of white skin because when the outside temperature is greater, the person with black skin absorbs more heat and when the outside temperature is less the person with black skin radiates more energy.

(6) **Kirchoff' law also explains the Fraunhoffer lines :**

(i) Sun's inner most part (photosphere) emits radiation of all wavelength at high temperature.

(ii) When these radiation enters in outer part (chromosphere) of sun, few wavelength are absorbed by some terrestrial elements (present in vapour form at lower temperature)

(iii) These absorbed wavelengths, which are missing appear as dark lines in the spectrum of the sun called **Fraunhoffer lines.**

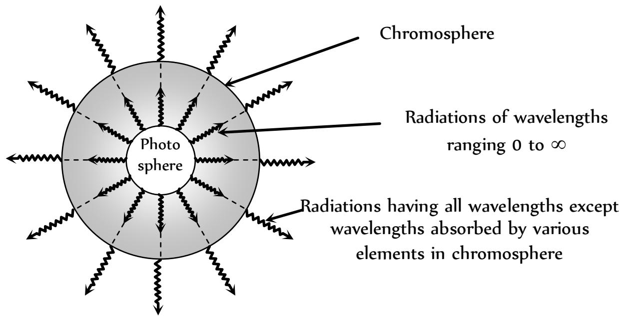


Fig. 15.21

(iv) During total solar eclipse these lines appear bright because the gases and vapour present in the chromosphere start emitting those radiation which they had absorbed.

Stefan's Law

According to it the radiant energy emitted by a perfectly black body per unit area per sec (*i.e.* emissive power of black body) is directly proportional to the fourth power of its absolute temperature, *i.e.* $E \propto T^4$ $\Rightarrow$ $E = \sigma T^4$

where σ is a constant called Stefan's constant having dimension $[MT^{-3}\theta^{-4}]$ and value $5.67 \times 10^{-8} W/m^2K^4$.

(i) For ordinary body : $e = \varepsilon E = \varepsilon\sigma T^4$

(ii) Radiant energy : If Q is the total energy radiated by the ordinary body then $e = \dfrac{Q}{A \times t} = \varepsilon\sigma T^4 \Rightarrow Q = A\varepsilon\sigma T^4 t$

(iii) Radiant power (P) : It is defined as energy radiated per unit area *i.e.* $P = \dfrac{Q}{t} = A\varepsilon\sigma T^4$.

(iv) If an ordinary body at temperature T is surrounded by a body at temperature T_0, then Stefan's law may be put as

$$e = \varepsilon\,\sigma(T^4 - T_0^4)$$

Rate of Loss of Heat (R_H) and Rate of Cooling (R_C)

(1) **Rate of loss of heat (or initial rate of loss of heat) :** If an ordinary body at temperature T is placed in an environment of temperature T_0 (T_0 < T) then heat loss by radiation is given by

$$\Delta Q = Q_{\text{emission}} - Q_{\text{absorption}} = A\varepsilon\,\sigma(T^4 - T_0^4)$$

(2) Rate of loss of heat $(R_H) = \dfrac{dQ}{dt} = A\varepsilon\,\sigma(T^4 - T_0^4)$

(i) If two bodies are made of same material, have same surface finish and are at the same initial temperature then $\dfrac{dQ}{dt} \propto A \Rightarrow \dfrac{\left(\dfrac{dQ}{dt}\right)_1}{\left(\dfrac{dQ}{dt}\right)_2} = \dfrac{A_1}{A_2}$

(3) **Initial rate of fall in temperature (Rate of cooling):** If m is the body and c is the specific heat then

$$\frac{dQ}{dt} = mc.\frac{dT}{dt} = mc\,\frac{d\theta}{dt} \qquad (\because Q = mc\,\Delta T \text{ and } dT = d\theta)$$

(i) Rate of cooling $(R_c) = \dfrac{d\theta}{dt} = \dfrac{(dQ/dt)}{mc} = \dfrac{A\varepsilon\,\sigma}{mc}(T^4 - T_0^4)$

$= \dfrac{A\varepsilon\,\sigma}{V\rho\,c}(T^4 - T_0^4)$; where m = density (ρ) × volume (V)

(ii) for two bodies of the same material under identical environments, the ratio of their rate of cooling is $\dfrac{(R_c)_1}{(R_c)_2} = \dfrac{A_1}{A_2}.\dfrac{V_2}{V_1}$

(4) **Dependence of rate of cooling :** When a body cools by radiation the rate of cooling depends on

(i) Nature of radiating surface *i.e.* greater the emissivity, faster will be the cooling.

(ii) Area of radiating surface, *i.e.* greater the area of radiating surface, faster will be the cooling.

(iii) Mass of radiating body *i.e.* greater the mass of radiating body slower will be the cooling.

(iv) Specific heat of radiating body *i.e.* greater the specific heat of radiating body slower will be cooling.

(v) Temperature of radiating body *i.e.* greater the temperature of body faster will be cooling.

(vi) Temperature of surrounding *i.e.* greater the temperature of surrounding slower will be cooling.

Table 15.4 : Comparison of rate of heat loss (R_H) and rate of cooling (R_c) for different bodies

Body	Condition	Rate of heat loss $R_H = \dfrac{dQ}{dt}$	Rate of cooling $R_c = \dfrac{dT}{dt}$ or $\dfrac{d\theta}{dt}$
Two solid sphere	T, T_0 , c, ρ are same	$R_H \propto A \propto r^2$ $\Rightarrow \dfrac{(R_H)_1}{(R_H)_2} = \dfrac{r_1^2}{r_2^2}$	$R_c \propto \dfrac{A}{V} \propto$ $\propto \dfrac{r^2}{r^3} \propto \dfrac{1}{r}$
Two solid sphere of diff. material	T, T_0 – same	$R_H \propto A \propto r^2$	$R_c \propto \dfrac{A}{V\rho c}$ $\propto \dfrac{1}{r\rho c}$
Different shape bodies like cube, sphere plate	T, T_0, c, ρ - same	$R_H \propto A$ $A_{\max} \rightarrow$ Plate $A_{\min} \rightarrow$ sphere	$R_c \propto \dfrac{A}{V}$
Bodies of different materials	T, T_0, m, A are same but c diff.	$R_H \rightarrow$ same for all. bodies	$R_c \propto \dfrac{1}{c}$

Newton's Law of Cooling

When the temperature difference between the body and its surrounding is not very large *i.e.* $T - T_0 = \Delta T$ then $T^4 - T_0^4$ may be approximated as $4T_0^3\Delta T$

By Stefan's law, $\frac{dT}{dt} = \frac{A\varepsilon\sigma}{mc}[T^4 - T_0^4]$

Hence $\frac{dT}{dt} = \frac{A\varepsilon\sigma}{mc} 4T_0^3\Delta T \Rightarrow \frac{dT}{dt} \propto \Delta T$ or $\frac{d\theta}{dt} \propto \theta - \theta_0$

i.e., if the temperature of body is not very different from surrounding, **rate of cooling is proportional to temperature difference** between the body and its surrounding. This law is called Newton's law of cooling.

(1) Greater the temperature difference between body and its surrounding greater will be the rate of cooling.

(2) If $\theta = \theta_0$, $\frac{d\theta}{dt} = 0$ *i.e.* a body can never be cooled to a temperature lesser than its surrounding by radiation.

(3) If a body cools by radiation from $\theta_1^o C$ to $\theta_2^o C$ in time *t*, then $\frac{d\theta}{dt} = \frac{\theta_1 - \theta_2}{t}$ and $\theta = \theta_{av} = \frac{\theta_1 + \theta_2}{2}$. The Newton's law of cooling becomes $\left[\frac{\theta_1 - \theta_2}{t}\right] = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$.

This form of law helps in solving numericals.

(4) Practical examples

(i) Hot water loses heat in smaller duration as compared to moderate warm water.

(ii) Adding milk in hot tea reduces the rate of cooling.

Cooling Curves

(1) **Curve between log(θ – θ_0) and time**

As $\frac{d\theta}{dt} \propto -(\theta - \theta_0) \Rightarrow \frac{d\theta}{(\theta - \theta_0)} = -Kdt$

Integrating $\log_e(\theta - \theta_0) = -Kt + C$

$\log_e(\theta - \theta_0) = -Kt + \log_e A$

This is a straight line with negative slope

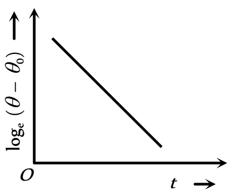


Fig. 15.22

(2) **Curve between temperature of body and time**

As $\log_e(\theta - \theta_0) = -Kt + \log_e A \Rightarrow \log_e \frac{\theta - \theta_0}{A} = -Kt$

$\Rightarrow \theta - \theta_0 = Ae^{-kt}$

which indicates temperature decreases exponentially with increasing time.

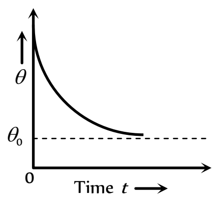


Fig. 15.23

(3) **Curve between the rate of cooling** (*R*) and body temperature (θ).

$R = K(\theta - \theta_0) = K\theta - K\theta_0$

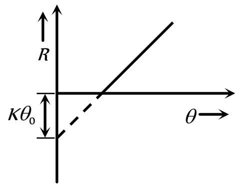


Fig. 15.24

This is a straight line intercept *R*-axis at $-K\theta_0$

(4) **Curve between rate of cooling (*R*)** and temperature difference between body (θ) and surrounding (θ_0)

$R \propto (\theta - \theta_0)$. This is a straight line passing through origin.

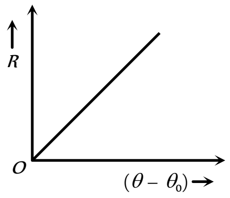


Fig. 15.25

Determination of Specific Heat of Liquid

If volume, radiating surface area, nature of surface, initial temperature and surrounding of water and given liquid are equal and they are allowed to cool down (by radiation) then rate of loss of heat and fall in temperature of both will be same.

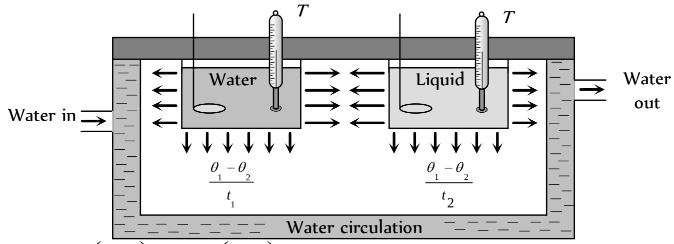


Fig. 15.26

i.e. $\left(\frac{dQ}{dt}\right)_{water} = \left(\frac{dQ}{dt}\right)_{liquid}$

$$(m_W c_W + W)\frac{(\theta_1 - \theta_2)}{t_1} = (m_l c_l + W)\frac{(\theta_1 - \theta_2)}{t_2}$$

or $\left[\frac{m_W c_W + W}{t_1}\right] = \left[\frac{m_l c_l + W}{t_2}\right]$

$W = m_c c_c$ = Water equivalent of calorimeter, where m_c and c_c are mass and specific heat of calorimeter.

If density of water and liquid is ρ and ρ' respectively then $m_W = V\rho_W$ and $m_l = V\rho_l$

Specific heat of liquid $c_l = \frac{1}{m_l}\left[\frac{t_l}{t_W}(m_W c_W + W) - W\right]$

Distribution of Energy in the Spectrum of Black Body

A perfectly black body emits radiation of all possible wavelength.

Langley and later on Lummer and Pringsheim investigated the distribution of energy amongst the different wavelengths in the thermal spectrum of a black body radiation. The results obtained are shown in figure. From these curves it is clear that

(1) At a given temperature energy is not uniformly distributed among different wavelengths.

(2) At a given temperature intensity of heat radiation increases with wavelength, reaches a maximum at a particular wavelength and with further increase in wavelength it decreases.

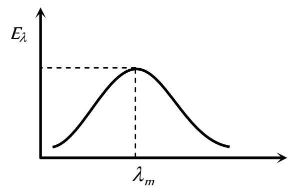


Fig. 15.27

(3) For all wavelengths an increase in temperature causes an increase in intensity.

(4) The area under the curve will represent the total intensity of radiation at a particular temperature *i.e.* Area = $E = \int E_\lambda d\lambda$

From Stefan's law $E = \sigma T \Rightarrow$ Area under E_λ - λ curve $(A) \propto T$

(5) The energy (E_m) emitted corresponding to the wavelength of maximum emission (λ_m) increases with fifth power of the absolute temperature of the black body *i.e.*, $E_{max} \propto T^5$

Wien's Displacement Law

According to Wien's law the product of wavelength corresponding to maximum intensity of radiation and temperature of body (in Kelvin) is constant, *i.e.* $\lambda_m T = b = \text{constant}$

where b is Wien's constant and has value $2.89 \times 10^{-3} m\text{-}K$.

As the temperature of the body increases, the wavelength at which the spectral intensity (E_λ) is maximum shifts towards left. Therefore it is also called Wien's displacement law.

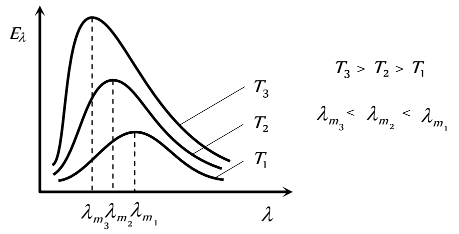


Fig. 15.28

This law is of great importance in 'Astrophysics' as through the analysis of radiations coming from a distant star, by finding λ_m the temperature of the star $T(= b/\lambda_m)$ is determined.

Law of Distribution of Energy (Plank's Hypothesis)

(1) The theoretical explanation of black body radiation was done by Planck.

(2) According to Plank's atoms of the walls of a uniform temperature enclosure behave as oscillators, each with a characteristic frequency of oscillation.

(3) These oscillations emits electromagnetic radiations in the form of photons (The radiation coming out from a small hole in the enclosure are called black body radiation). The energy of each photon is $h\nu$. Where ν is the frequency of oscillator and h is the Plank's constant. Thus emitted energies may be $h\nu$, $2h\nu$, $3h\nu$ ... $nh\nu$ but not in between.

According to Planck's law $E_\lambda d\lambda = \dfrac{8\pi hc}{\lambda^5} \dfrac{1}{[e^{hc/\lambda KT} - 1]} d\lambda$

where c = speed of light and k = Boltzmann's constant. This equation is known as Plank's radiation law. It is correct and complete law of radiation

(4) This law is valid for radiations of all wavelengths ranging from zero to infinite.

(5) For radiations of short wavelength $\left(\lambda << \dfrac{hc}{KT}\right)$ Planck's law reduces to *Wien's energy distribution law* $E_\lambda d\lambda = \dfrac{A}{\lambda^5} e^{-B/\lambda T} d\lambda$

(6) For radiations of long wavelength $\left(\lambda >> \dfrac{hc}{KT}\right)$ Planck's law reduces to *Rayleigh-Jeans energy distribution law* $E_\lambda d\lambda = \dfrac{8\pi KT}{\lambda^4} d\lambda$

Temperature of the Sun and Solar Constant

If R is the radius of the sun and T its temperature, then the energy emitted by the sun per sec through radiation in accordance with Stefan's law will be given by

$$P = A\sigma T^4 = 4\pi R^2 \sigma T^4$$

In reaching earth this energy will spread over a sphere of radius r (= average distance between sun and earth); so the intensity of solar radiation at the surface of earth (called solar constant S) will be given by

$$S = \frac{P}{4\pi r^2} = \frac{4\pi R^2 \sigma T^4}{4\pi r^2}$$

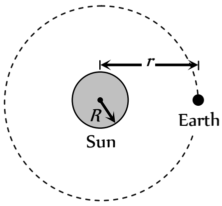


Fig. 15.29

$$i.e.\ T = \left[\left(\frac{r}{R}\right)^2 \frac{S}{\sigma}\right]^{1/4}$$

$$= \left[\left(\frac{1.5 \times 10^8}{7 \times 10^5}\right)^2 \times \frac{1.4 \times 10^3}{5.67 \times 10^{-8}}\right]^{1/4} \simeq 5800\,K$$

As $r = 1.5 \times 10^8$ *km*, $R = 7 \times 10^5$ *km*,

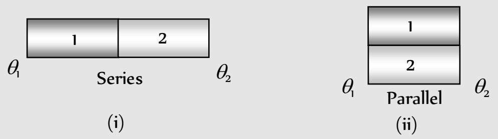
$$S = 2\frac{cal}{cm^2 min} = 1.4\frac{kW}{m^2} \text{ and } \sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$$

This result is in good agreement with the experimental value of temperature of sun, *i.e.*, 6000 *K*.

Tips & Tricks

✍ Glass and water vapours transmit shorter wavelengths through them but reflects longer wavelengths. This concept is utilised in Green house effect. Glass transmits those waves which are emitted by a source at a temperature greater than 100°*C*. So, heat rays emitted from sun are able to enter through glass enclosure but heat emitted by small plants growing in the nursery gets trapped inside the enclosure.

✍ Suppose two metallic rods are first connected in series then in parallel.



If Q_s heat flows in time t_s in series combination and Q_p heat flows in time t_p in parallel combine, then $\dfrac{Q_p}{Q_s} = \dfrac{t_p}{t_s} \times \dfrac{R_s}{R_p}$

If Rods are identical then $R_S = \frac{R}{2}$ and $R_p = 2R \Rightarrow \frac{Q_p}{Q_s} = 4\left(\frac{t_p}{t_s}\right)$

✍ If temperature of a body becomes θ_1 to θ_2 in t time and it becomes θ_2 to θ_3 in next time then use

$$\frac{\theta_2 - \theta_0}{\theta_1 - \theta_0} = \frac{\theta_3 - \theta_0}{\theta_2 - \theta_0}$$ (θ_0 = temperature of enviroment)

✍ Newton's law of cooling can be used to compare the specific heat of the two liquids.

If equal masses of two liquids having same surface are and finish cools from same initial temperature to same final temperature with same surrounding then $\frac{t_1}{t_2} = \frac{K_2}{K_1} = \frac{C_1}{C_2}$

✍ Radiations from sun take 8 *min* and 20 *sec* to reach earth.

✍ Suppose temperature of a body decreases $\theta_1°C$ to $\theta_2°C$ in time t_1 and $\theta_2°C$ to $\theta_3°C$ in time t_2 in the same invirment

If $(\theta_1 - \theta_2) \geq (\theta_2 - \theta_3)$ then $t_2 > t_1$

✍ Green glass is a good absorber of red light and a good reflector of green light. Consequently at lower temperature it is a good emitter of red light.

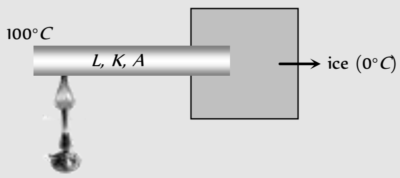
Hence Green $\rightleftharpoons$ Red

Also Yellow $\rightleftharpoons$ Blue

✍ While solving the problems of heat flow, remember the following equation

e.g. If we are interested in finding the mass of ice which transfoms into water in unit time. For this we will take

$$\frac{T.D.}{R} = L_f.\frac{dm}{dt}$$



$$\Rightarrow \frac{dm}{dt} = \frac{T.D.}{(L_f)(R)}$$

✍ **Confusion**

The rate of cooling has been used in many books, with double meanings. At some places. Rate of cooling $= \frac{dQ}{dt}$ and at other places, rate of cooling $= \frac{d\theta}{dt}$. Our suggestion is that look for the units, if the rate of cooling is in *cal/m* in or *J/sec etc.*, then it is $\frac{dQ}{dt}$. But if rate of cooling is in °*C/min* it means $\frac{d\theta}{dt}$.

Ordinary Thinking

Objective Questions

Conduction

1. In which case the thermal conductivity increases from left to right[NCERT 1974

(a) *Al, Cu, Ag* (b) *Ag, Cu, Al*

(c) *Cu, Ag, Al* (d) *Al, Ag, Cu*

2. Which of the following cylindrical rods will conduct most heat, when their ends are maintained at the same steady temperature [CPMT 1981; NCERT 19

MP PMT 1987; CBSE PMT 1995]

(a) Length 1 *m*; radius 1 *cm*

(b) Length 2 *m*; radius 1 *cm*

(c) Length 2 *m*; radius 2 *cm*

(d) Length 1 *m*; radius 2 *cm*

3. The heat is flowing through two cylindrical rods of same material. The diameters of the rods are in the ratio 1 : 2 and their lengths are in the ratio 2 : 1. If the temperature difference between their ends is the same, the ratio of rate of flow of heat through them will be

[NCERT 1982; CBSE PMT 1995; EAMCET 1997]

(a) 1 : 1 (b) 2 : 1

(c) 1 : 4 (d) 1 : 8

4. Two identical square rods of metal are welded end to end as shown in figure (i), 20 calories of heat flows through it in 4 minutes. If the rods are welded as shown in figure (ii), the same amount of heat will flow through the rods in

[NCERT 1982]

(i) (ii)

(a) 1 minute (b) 2 minutes

(c) 4 minutes (d) 16 minutes

5. For cooking the food, which of the following type of utensil is most suitable

[MNR 1986; MP PET 1990; CPMT 1991;

SCRA 1998; MP PMT/PET 1998, 2000; RPET 2001]

(a) High specific heat and low conductivity

(b) High specific heat and high conductivity

(c) Low specific heat and low conductivity

(d) Low specific heat and high conductivity

6. Under steady state, the temperature of a body [CPMT 1978]
(a) Increases with time
(b) Decreases with time
(c) Does not change with time and is same at all the points of the body
(d) Does not change with time but is different at different points of the body

7. The coefficient of thermal conductivity depends upon
[MP PET/PMT 1984; AFMC 1996; Orissa JEE 2005]
(a) Temperature difference of two surfaces
(b) Area of the plate
(c) Thickness of the plate
(d) Material of the plate

8. When two ends of a rod wrapped with cotton are maintained at different temperatures and after some time every point of the rod attains a constant temperature, then
[MP PET/PMT 1988]
(a) Conduction of heat at different points of the rod stops because the temperature is not increasing
(b) Rod is bad conductor of heat
(c) Heat is being radiated from each point of the rod
(d) Each point of the rod is giving heat to its neighbour at the same rate at which it is receiving heat

9. The length of the two rods made up of the same metal and having the same area of cross-section are 0.6 *m* and 0.8 *m* respectively. The temperature between the ends of first rod is 90^oC and 60^oC and that for the other rod is 150 and 110^oC. For which rod the rate of conduction will be greater
(a) First (b) Second
(c) Same for both (d) None of the above

10. The ratio of thermal conductivity of two rods of different material is 5 : 4. The two rods of same area of cross-section and same thermal resistance will have the lengths in the ratio
(a) 4 : 5 (b) 9 : 1
(c) 1 : 9 (d) 5 : 4

11. The thermal conductivity of a material in CGS system is 0.4. In steady state, the rate of flow of heat 10 *cal/sec-cm*, then the thermal gradient will be [MP PMT 1989]
(a) $10°C/cm$ (b) $12°C/cm$
(c) $25°C/cm$ (d) $20°C/cm$

12. Two rectangular blocks *A* and *B* of different metals have same length and same area of cross-section. They are kept in such a way that their cross-sectional area touch each other. The temperature at one end of *A* is 100°*C* and that of *B* at the other end is 0°*C*. If the ratio of their thermal conductivity is 1 : 3, then under steady state, the temperature of the junction in contact will be
(a) 25°*C* (b) 50°*C*
(c) 75°*C* (d) 100°*C*

13. Two vessels of different materials are similar in size in every respect. The same quantity of ice filled in them gets melted in 20 minutes and 30 minutes. The ratio of their thermal conductivities will be [MP PMT 1989; CMEET Bihar 1995]
(a) 1.5 (b) 1
(c) 2/3 (d) 4

14. Two rods *A* and *B* are of equal lengths. Their ends are kept between the same temperature and their area of cross-sections are A_1 and A_2 and thermal conductivities K_1 and K_2. The rate of heat transmission in the two rods will be equal, if [MP PMT 1991; CBSE PMT 2002]
(a) $K_1A_2 = K_2A_1$ (b) $K_1A_1 = K_2A_2$
(c) $K_1 = K_2$ (d) $K_1A_1^2 = K_2A_2^2$

15. In variable state, the rate of flow of heat is controlled by
(a) Density of material (b) Specific heat
(c) Thermal conductivity (d) All the above factors

16. If the ratio of coefficient of thermal conductivity of silver and copper is 10 : 9, then the ratio of the lengths upto which wax will melt in Ingen Hausz experiment will be
[DPMT 2001]
(a) 6 : 10 (b) $\sqrt{10}:3$
(c) 100 : 81 (d) 81 : 100

17. The thickness of a metallic plate is 0.4 cm. The temperature between its two surfaces is 20^oC. The quantity of heat flowing per second is 50 calories from $5cm^2$ area. In CGS system, the coefficient of thermal conductivity will be
(a) 0.4 (b) 0.6
(c) 0.2 (d) 0.5

18. In Searle's method for finding conductivity of metals, the temperature gradient along the bar [MP PMT 1984]
(a) Is greater nearer the hot end
(b) Is greater nearer to the cold end
(c) Is the same at all points along the bar
(d) Increases as we go from hot end to cold end

19. The dimensions of thermal resistance are
[MP PET 1984; BVP 2003]
(a) $M^{-1}L^{-2}T^3K$ (b) $ML^2T^{-2}K^{-1}$
(c) $ML^2T^{-3}K$ (d) $ML^2T^{-2}K^{-2}$

20. A piece of glass is heated to a high temperature and then allowed to cool. If it cracks, a probable reason for this is the following property of glass [CPMT 1985]
(a) Low thermal conductivity
(b) High thermal conductivity
(c) High specific heat
(d) High melting point

21. Two walls of thicknesses d_1 and d_2 and thermal conductivities k_1 and k_2 are in contact. In the steady state, if the temperatures at the outer surfaces are T_1 and T_2, the temperature at the common wall is [MP PMT 1985]
[MP PMT 1990; CBSE PMT 1999]
(a) $\frac{k_1T_1d_2+k_2T_2d_1}{k_1d_2+k_2d_1}$ (b) $\frac{k_1T_1+k_2d_2}{d_1+d_2}$
(c) $\left(\frac{k_1d_1+k_2d_2}{T_1+T_2}\right)T_1T_2$ (d) $\frac{k_1d_1T_1+k_2d_2T_2}{k_1d_1+k_2d_2}$

22. A slab consists of two parallel layers of copper and brass of the same thickness and having thermal conductivities in the ratio 1 : 4. If

the free face of brass is at $100^o C$ and that of copper at $0^o C$, the temperature of interface is

[IIT 1981; MP PMT 1987, 2001]

(a) $80°C$ (b) $20°C$

(c) $60°C$ (d) $40°C$

23. The temperature gradient in a rod of 0.5 m long is $80^o C/m$. If the temperature of hotter end of the rod is $30^o C$, then the temperature of the cooler end is

(a) $40^o C$ (b) $-10^o C$

(c) $10^o C$ (d) $0^o C$

24. On heating one end of a rod, the temperature of whole rod will be uniform when

(a) $K = 1$ (b) $K = 0$

(c) $K = 100$ (d) $K = \infty$

25. Snow is more heat insulating than ice, because

(a) Air is filled in porous of snow

(b) Ice is more bad conductor than snow

(c) Air is filled in porous of ice

(d) Density of ice is more

26. Two thin blankets keep more hotness than one blanket of thickness equal to these two. The reason is

(a) Their surface area increases

(b) A layer of air is formed between these two blankets, which is bad conductor

(c) These have more wool

(d) They absorb more heat from outside

27. Ice formed over lakes has

(a) Very high thermal conductivity and helps in further ice formation

(b) Very low conductivity and retards further formation of ice

(c) It permits quick convection and retards further formation of ice

(d) It is very good radiator

28. Two rods of same length and material transfer a given amount of heat in 12 seconds, when they are joined end to end. But when they are joined lengthwise, then they will transfer same heat in same conditions in

[BHU 1998; UPSEAT 2002]

(a) 24 *s* (b) 3 *s*

(c) 1.5 *s* (d) 48 *s*

29. Wires *A* and *B* have identical lengths and have circular cross-sections. The radius of *A* is twice the radius of *B* *i.e.* $r_A = 2r_B$. For a given temperature difference between the two ends, both wires conduct heat at the same rate. The relation between the thermal conductivities is given by

(a) $K_A = 4K_B$ (b) $K_A = 2K_B$

(c) $K_A = K_B/2$ (d) $K_A = K_B/4$

30. Two identical plates of different metals are joined to form a single plate whose thickness is double the thickness of each plate. If the coefficients of conductivity of each plate are 2 and 3 respectively, then the conductivity of composite plate will be

(a) 5 (b) 2.4

(c) 1.5 (d) 1.2

31. If the radius and length of a copper rod are both doubled, the rate of flow of heat along the rod increases

(a) 4 times (b) 2 times

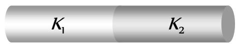
(c) 8 times (d) 16 times

32. The coefficients of thermal conductivity of copper, mercury and glass are respectively *K*, *K* and *K* such that *K* > *K* > *K*. If the same quantity of heat is to flow per second per unit area of each and corresponding temperature gradients are *X*, *X* and *X*, then

(a) $X_c = X_m = X_g$ (b) $X_c > X_m > X_g$

(c) $X_c < X_m < X_g$ (d) $X_m < X_c < X_g$

33. If two metallic plates of equal thicknesses and thermal conductivities K_1 and K_2 are put together face to face and a common plate is constructed, then the equivalent thermal conductivity of this plate will be [MP PMT 1991]



(a) $\dfrac{K_1K_2}{K_1+K_2}$ (b) $\dfrac{2K_1K_2}{K_1+K_2}$

(c) $\dfrac{(K_1^2+K_2^2)^{3/2}}{K_1K_2}$ (d) $\dfrac{(K_1^2+K_2^2)^{3/2}}{2K_1K_2}$

34. The quantity of heat which crosses unit area of a metal plate during conduction depends upon

[MP PMT 1992; JIPMER 1997]

(a) The density of the metal

(b) The temperature gradient perpendicular to the area

(c) The temperature to which the metal is heated

(d) The area of the metal plate

35. The ends of two rods of different materials with their thermal conductivities, radii of cross-sections and lengths all are in the ratio 1 : 2 are maintained at the same temperature difference. If the rate of flow of heat in the larger rod is 4 $4\ cal/\sec$, that in the shorter rod in $cal/\sec$ will be

[EAMCET 1986]

(a) 1 (b) 2

(c) 8 (d) 16

36. Two spheres of different materials one with double the radius and one-fourth wall thickness of the other, are filled with ice. If the time taken for complete melting ice in the large radius one is 25 *minutes* and that for smaller one is 16 *minutes*, the ratio of thermal conductivities of the materials of larger sphere to the smaller sphere is [EAMCET 1991]

(a) 4 : 5 (b) 5 : 4

(c) 25 : 1 (d) 1 : 25

37. The ratio of the diameters of two metallic rods of the same material is 2 : 1 and their lengths are in the ratio 1 : 4. If the temperature difference between their ends are equal, the rate of flow of heat in them will be in the ratio [MP PET 1994]

(a) 2 : 1 (b) 4 : 1

(c) $8:1$ (d) 16 : 1

38. Two cylinders P and Q have the same length and diameter and are made of different materials having thermal conductivities in the ratio 2 : 3. These two cylinders are combined to make a cylinder. One end of P is kept at $100°C$ and another end of Q at $0°C$. The temperature at the interface of P and Q is [MP PMT 1994; EAMCET 2000]

(a) 30^oC (b) 40^oC

(c) 50^oC (d) 60^oC

39. Two identical rods of copper and iron are coated with wax uniformly. When one end of each is kept at temperature of boiling water, the length upto which wax melts are $8.4 cm$ and $4.2 cm$ respectively. If thermal conductivity of copper is 0.92, then thermal conductivity of iron is [MP PET 1995]

(a) 0.23 (b) 0.46

(c) 0.115 (d) 0.69

40. Mud houses are cooler in summer and warmer in winter because [BVP 2003]

(a) Mud is superconductor of heat

(b) Mud is good conductor of heat

(c) Mud is bad conductor of heat

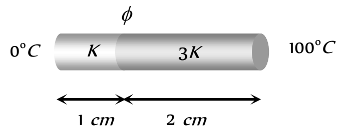
(d) None of these

41. The temperature of hot and cold end of a $20 cm$ long rod in thermal steady state are at 100^oC and 20^oC respectively. Temperature at the centre of the rod is [MP PMT 1996]

(a) 50^oC (b) 60^oC

(c) 40^oC (d) 30^oC

42. Two bars of thermal conductivities K and $3K$ and lengths $1 cm$ and $2 cm$ respectively have equal cross-sectional area, they are joined lengths wise as shown in the figure. If the temperature at the ends of this composite bar is 0^oC and 100^oC respectively (see figure), then the temperature ϕ of the interface is



(a) 50^oC (b) $\frac{100}{3}\,^oC$

(c) 60^oC (d) $\frac{200}{3}\,^oC$

43. A heat flux of $4000\ J/s$ is to be passed through a copper rod of length $10\ cm$ and area of cross-section $100\ cm^2$. The thermal conductivity of copper is $400\ W/m\ ^oC$. The two ends of this rod must be kept at a temperature difference of

(a) 1^oC (b) 10^oC

(c) 100^oC (d) 1000^oC

44. On a cold morning, a metal surface will feel colder to touch than a wooden surface because [AIIMS 1998]

(a) Metal has high specific heat

(b) Metal has high thermal conductivity

(c) Metal has low specific heat

(d) Metal has low thermal conductivity

45. In order that the heat flows from one part of a solid to another part, what is required [Pb. PMT 1999; EAMCET 1998]

(a) Uniform density (b) Density gradient

(c) Temperature gradient (d) Uniform temperature

46. At a common temperature, a block of wood and a block of metal feel equally cold or hot. The temperatures of block of wood and block of metal are [AIIMS 1999]

(a) Equal to temperature of the body

(b) Less than the temperature of the body

(c) Greater than temperature of the body

(d) Either (b) or (c)

47. According to the experiment of Ingen Hausz the relation between the thermal conductivity of a metal rod is K and the length of the rod whenever the wax melts is [UPSEAT 1999]

(a) K/l = constant (b) K^2/l = constant

(c) K/l^2 = constant (d) Kl = constant

48. Temperature of water at the surface of lake is -20^oC. Then temperature of water just below the lower surface of ice layer is

(a) -4^oC (b) 0^oC

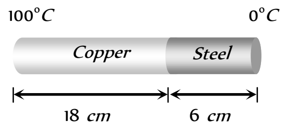
(c) 4^oC (d) -20^oC

49. One end of a metal rod of length 1.0 m and area of cross section $100 cm^2$ is maintained at 100^oC. If the other end of the rod is maintained at 0^oC, the quantity of heat transmitted through the rod per minute is (Coefficient of thermal conductivity of material of rod = 100 W/m-K) [EAMCET (Engg.) 2000]

(a) $3\times10^3 J$ (b) $6\times10^3 J$

(c) $9\times10^3 J$ (d) $12\times10^3 J$

50. The coefficient of thermal conductivity of copper is nine times that of steel. In the composite cylindrical bar shown in the figure. What will be the temperature at the junction of copper and steel



(a) 75^oC

(b) 67^oC

(c) 33^oC

(d) 25^oC

51. The lengths and radii of two rods made of same material are in the ratios 1 : 2 and 2 : 3 [MP PMT 1999] respectively. If the temperature difference between the ends for the two rods be the same, then in the steady state, the amount of heat flowing per second through them will be in the ratio [MP PET 2000]

(a) 1 : 3 (b) 4 : 3

(c) 8 : 9 (d) 3 : 2

52. A slab consists of two parallel layers of two different materials of same thickness having thermal conductivities K_1 and K_2. The equivalent conductivity of the combination is [BHU 2001]

(a) $K_1 + K_2$ (b) $\frac{K_1 + K_2}{2}$

(c) $\frac{2K_1K_2}{K_1 + K_2}$ (d) $\frac{K_1 + K_2}{2K_1K_2}$

53. There are two identical vessels filled with equal amounts of ice. The vessels are of different metals., If the ice melts in the two vessels in 20 and 35 minutes respectively, the ratio of the coefficients of thermal conductivity of the two metals is [AFMC 1998; MP PET 2001]

(a) 4 : 7 (b) 7 : 4

(c) 16 :49 (d) 49 : 16

54. Surface of the lake is at $2°C$. Find the temperature of the bottom of the lake [Orissa JEE 2002]

(a) $2^o C$ (b) $3^o C$

(c) $4^o C$ (d) $1^o C$

55. The heat is flowing through a rod of length 50 *cm* and area of cross-section $5cm^2$. Its ends are respectively at $25^o C$ and $125^o C$. The coefficient of thermal conductivity of the material of the rod is 0.092 *kcal/m×s×C*. The temperature gradient in the rod is [MP PET 2002]

(a) $2^o C / cm$ (b) $2^o C / m$

(c) $20^o C / cm$ (d) $20^o C / m$

56. In the Ingen Hauz's experiment the wax melts up to lengths 10 and 25 *cm* on two identical rods of different materials. The ratio of thermal conductivities of the two materials is [MP PET 2002]

(a) $1 : 6.25$ (b) 6.25 : 1

(c) $1 : \sqrt{2.5}$ (d) 1 : 2.5

57. Heat current is maximum in which of the following (rods are of identical dimension) [Orissa JEE 2003]

(a) 

(b) 

(c) 

(d) 

58. Two rods of same length and cross section are joined along the length. Thermal conductivities of first and second rod are K_1 and K_2. The temperature of the free ends of the first and second rods are maintained at θ_1 and θ_2 respectively. The temperature of the common junction is [MP PET 2003]

(a) $\frac{\theta_1 + \theta_2}{2}$ (b) $\frac{K_2K_2}{K_1 + K_2}(\theta_1 + \theta_2)$

(c) $\frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$ (d) $\frac{K_2\theta_1 + K_1\theta_2}{K_1 + K_2}$

59. Consider a compound slab consisting of two different materials having equal thickness and thermal conductivities K and $2K$ respectively. The equivalent thermal conductivity of the slab is [CBSE PMT 2003]

(a) $\sqrt{2K}$ (b) $3K$

(c) $\frac{4}{3}K$ (d) $\frac{2}{3}K$

60. Two rods having thermal conductivity in the ratio of 5 : 3 having equal lengths and equal cross-sectional area are joined by face to face. If the temperature of the free end of the first rod is $100° C$ and free end of the second rod is $20° C$. Then temperature of the junction is [CPMT 1996; DPMT 1997, 03; BVP 2004]

(a) $70° C$ (b) $50° C$

(c) $50° C$ (d) $90° C$

61. Woollen clothes are used in winter season because woolen clothes[EAMCET 1978

(a) Are good sources for producing heat

(b) Absorb heat from surroundings

(c) Are bad conductors of heat

(d) Provide heat to body continuously

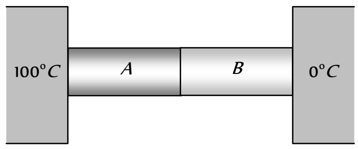
62. Two metal cubes A and B of same size are arranged as shown in the figure. The extreme ends of the combination are maintained at the indicated temperatures. The arrangement is thermally insulated. The coefficients of thermal conductivity of A and B are $300\, W/m\, ^oC$ and $200\, W/m\, ^oC$, respectively. After steady state is reached, the temperature of the interface will be [IIT 1996]

(a) $45^o C$

(b) $90^o C$

(c) $30^o C$

(d) $60^o C$



63. A cylindrical rod having temperature T_1 and T_2 at its ends. The rate of flow of heat is Q_1 *cal/sec*. If all the linear dimensions are doubled keeping temperature constant then rate of flow of heat Q_2 will be [CBSE PMT 2001]

(a) $4Q_1$ (b) $2Q_1$

(c) $\frac{Q_1}{4}$ (d) $\frac{Q_1}{2}$

64. A body of length 1*m* having cross sectional area 0.75*m* has heat flow through it at the rate of 6000 *Joule/sec*. Then find the temperature difference if $K = 200 Jm^{-1}K^{-1}$ [CPMT 2001]

(a) $20°C$ (b) $40°C$

(c) $80°C$ (d) $100°C$

65. A wall has two layers *A* and *B* made of different materials. The thickness of both the layers is the same. The thermal conductivity of *A* and *B* are *K* and *K* such that *K* = 3*K*. The temperature across the wall is $20°C$. In thermal equilibrium

(a) The temperature difference across $A = 15°C$

(b) The temperature difference across $A = 5°C$

(c) The temperature difference across *A* is $10°C$

(d) The rate of transfer of heat through *A* is more than that through *B*.

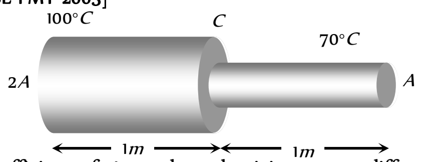
66. A metal rod of length 2*m* has cross sectional areas 2*A* and *A* as shown in figure. The ends are maintained at temperatures $100°C$ and $70°C$. The temperature at middle point *C* is [CPMT 2000]

(a) $80°C$

(b) $85°C$

(c) $90°C$

(d) $95°C$



67. The ratio of the coefficient of thermal conductivity of two different materials is 5 : 3. If the thermal resistance of the rod of same thickness resistance of the rods of same thickness of these materials is same, then the ratio of the length of these rods will be

(a) 3 : 5 (b) 5 : 3

(c) 3 : 4 (d) 3 : 2

68. Which of the following circular rods. (given radius r and length l) each made of the same material as whose ends are maintained at the same temperature will conduct most heat [CBSE PMT 2005]

(a) $r = 2r_0; l = 2l_0$ (b) $r = 2r_0; l = l_0$

(c) $r = r_0; l = l_0$ (d) $r = r_0; l = 2l_0$

Convection

1. It is hotter for the same distance over the top of a fire than it is in the side of it, mainly because [NCERT 1976, 79, 80; AIIMS 2000]

(a) Air conducts heat upwards

(b) Heat is radiated upwards

(c) Convection takes more heat upwards

(d) Convection, conduction and radiation all contribute significantly transferring heat upwards

2. One likes to sit under sunshine in winter season, because

(a) The air surrounding the body is hot by which body gets heat

(b) We get energy by sun

(c) We get heat by conduction by sun

(d) None of the above

3. Air is bad conductor of heat or partly conducts heat, still vacuum is to be placed between the walls of the thermos flask because

(a) It is difficult to fill the air between the walls of thermos flask

(b) Due to more pressure of air, the thermos can get crack

(c) By convection, heat can flow through air

(d) On filling the air, there is no advantage

4. While measuring the thermal conductivity of a liquid, we keep the upper part hot and lower part cool, so that [CPMT 1985; MP PMT/PET 1988]

(a) Convection may be stopped

(b) Radiation may be stopped

(c) Heat conduction is easier downwards

(d) It is easier and more convenient to do so

5. For proper ventilation of building, windows must be open near the bottom and top of the walls so as to let pass

(a) In more air

(b) In cool air near the bottom and hot air out near the roof

(c) In hot air near the roof and cool air out near the bottom

(d) Out hot air near the roof

6. The layers of atmosphere are heated through [MP PET 1986]

(a) Convection (b) Conduction

(c) Radiation (d) (b) and (c) both

7. Mode of transmission of heat, in which heat is carried by the moving particles, is [KCET 1999]

(a) Radiation (b) Conduction

(c) Convection (d) Wave motion

[BHU 2000]

8. In a closed room, heat transfer takes place by [BHU 2001]

(a) Conduction (b) Convection

(c) Radiation (d) All of these

9. In heat transfer, which method is based on gravitation [CBSE PMT 2000]

(a) Natural convection (b) Conduction

(c) Radiation (d) Stirring of liquids

10. When fluids are heated from the bottom, convection currents are produced because [UPSEAT 2000]

(a) Molecular motion of fluid becomes aligned

(b) Molecular collisions take place within the fluid

(c) Heated fluid becomes more dense than the cold fluid above it

(d) Heated fluid becomes less dense than the cold fluid above it

11. If a liquid is heated in weightlessness, the heat is transmitted through [RPMT1996]

(a) Conduction

(b) Convection

(c) Radiation

(d) Neither, because the liquid cannot be heated in weightlessness

12. The rate of loss of heat from a body cooling under conditions of forced convection is proportional to its (A) heat capacity (B) surface area (C) absolute temperature (D) excess of temperature over that of surrounding : state if [NCERT 1982]

(a) A, B, C are correct (b) Only A and C are correct

(c) Only B and D are correct (d) Only D is correct

13. In which of the following process, convection does not take place primarily [IIT-JEE (Screening) 2005]

(a) Sea and land breeze

(b) Boiling of water

(c) Warming of glass of bulb due to filament

(d) Heating air around a furnace

Radiation (General, Kirchoff's law, Black body)

1. On a clear sunny day, an object at temperature T is placed on the top of a high mountain. An identical object at the same temperature is placed at the foot of mountain. If both the objects are exposed to sun-rays for two hours in an identical manner, the object at the top of the mountain will register a temperature

(a) Higher than the object at the foot

(b) Lower than the object at the foot

(c) Equal to the object at the foot

(d) None of the above

2. The velocity of heat radiation in vacuum is [EAMCET 1982; KCET 1998]

(a) Equal to that of light (b) Less than that of light

(c) Greater than that of light (d) Equal to that of sound

3. In which process, the rate of transfer of heat is maximum [EAMCET 1977; MP PMT 1994; MH CET 2001]

(a) Conduction

(b) Convection

(c) Radiation

(d) In all these, heat is transferred with the same velocity

4. Which of the following is the correct device for the detection of thermal radiation [Manipal MEE 1995, UPSEAT 2000]
(a) Constant volume thermometer
(b) Liquid-in-glass thermometer
(c) Six's maximum and minimum thermometer
(d) Thermopile

5. A thermos flask is polished well [AFMC 1996]
(a) To make attractive
(b) For shining
(c) To absorb all radiations from outside
(d) To reflect all radiations from outside

6. Heat travels through vacuum by [AIIMS 1998; CPMT 2003]
(a) Conduction (b) Convection
(c) Radiation (d) Both (a) and (b)

7. The energy supply being cut-off, an electric heater element cools down to the temperature of its surroundings, but it will not cool further because [CPMT 2001]
(a) Supply is cut off
(b) It is made of metal
(c) Surroundings are radiating
(d) Element & surroundings have same temp.

8. We consider the radiation emitted by the human body. Which of the following statements is true [CBSE PMT 2003]
(a) The radiation is emitted only during the day
(b) The radiation is emitted during the summers and absorbed during the winters
(c) The radiation emitted lies in the ultraviolet region and hence is not visible
(d) The radiation emitted is in the infra-red region

9. The earth radiates in the infra-red region of the spectrum. The spectrum is correctly given by [RPET 2002; AIEEE 2003]
(a) Wien's law (b) Rayleigh jeans law
(c) Planck's law of radiation (d) Stefan's law of radiation

10. Infrared radiation is detected by [AIEEE 2002]
(a) Spectrometer (b) Pyrometer
(c) Nanometer (d) Photometer

11. Pick out the statement which is not true [KCET 2002]
(a) *IR* radiations are used for long distance photography
(b) *IR* radiations arise due to inner electron transitions in atoms
(c) *IR* radiations are detected by using a bolometer
(d) Sun is the natural source of *IR* radiation

12. A hot and a cold body are kept in vacuum separated from each other. Which of the following cause decrease in temperature of the hot body [AFMC 2005]
(a) Radiation
(b) Convection
(c) Conduction
(d) Temperature remains unchanged

13. Good absorbers of heat are [J & K CET 2002]
(a) Poor emitters (b) Non-emitters
(c) Good emitters (d) Highly polished

14. For a perfectly black body, its absorptive power is [MP PMT 1989, 92; RPMT 2001; RPET 2001, 03; AFMC 2003]
(a) 1 (b) 0.5
(c) 0 (d) Infinity

15. Certain substance emits only the wavelengths $\lambda_1, \lambda_2, \lambda_3$ and λ_4 when it is at a high temperature. When this substance is at a colder temperature, it will absorb only the following wavelengths
(a) λ_1 (b) λ_2
(c) λ_1 and λ_2 (d) $\lambda_1, \lambda_2, \lambda_3$ and λ_4

16. As compared to the person with white skin, the person with black skin will experience [CPMT 1988]
(a) Less heat and more cold (b) More heat and more cold
(c) More heat and less cold (d) Less heat and less cold

17. Relation between emissivity e and absorptive power a is (for black body)
(a) $e = a$ (b) $e = \frac{1}{a}$
(c) $e = a^2$ (d) $a = e^2$

18. Which of the following statements is wrong [BCECE 2001]
(a) Rough surfaces are better radiators than smooth surface
(b) Highly polished mirror like surfaces are very good radiators
(c) Black surfaces are better absorbers than white ones
(d) Black surfaces are better radiators than white

19. Half part of ice block is covered with black cloth and rest half is covered with white cloth and then it is kept in sunlight. After some time clothes are removed to see the melted ice. Which of the following statements is correct
(a) Ice covered with white cloth will melt more
(b) Ice covered with black cloth will melt more
(c) Equal ice will melt under both clothes
(d) It will depend on the temperature of surroundings of ice

20. If between wavelength λ and $\lambda + d\lambda$, e_λ and a_λ be the emissive and absorptive powers of a body and E_λ be the emissive power of a perfectly black body, then according to Kirchoff's law, which is true [RPMT 1998; MP PET 1991]
(a) $e_\lambda = a_\lambda = E_\lambda$ (b) $e_\lambda E_\lambda = a_\lambda$
(c) $e_\lambda = a_\lambda E_\lambda$ (d) $e_\lambda a_\lambda E_\lambda$ = constant

21. When p calories of heat is given to a body, it absorbs q calories; then the absorbtion power of body will be
(a) p/q (b) q/p
(c) p^2/q^2 (d) q^2/p^2

22. Distribution of energy in the spectrum of a black body can be correctly represented by [MP PMT 1989]
(a) Wien's law (b) Stefan's law
(c) Planck's law (d) Kirchhoff's law

23. In rainy season, on a clear night the black seat of a bicycle becomes wet because

(a) It absorbs water vapour
(b) Black seat is good absorber of heat
(c) Black seat is good radiator of heat energy
(d) None of the above

24. There is a rough black spot on a polished metallic plate. It is heated upto 1400 K approximately and then at once taken in a dark room. Which of the following statements is true [NCERT 1984; CPMT 1998]

(a) In comparison with the plate, the spot will shine more
(b) In camparison with the plate, the spot will appear more black
(c) The spot and the plate will be equally bright
(d) The plate and the black spot can not be seen in the dark room

25. At a certain temperature for given wave length, the ratio of emissive power of a body to emissive power of black body in same circumstances is known as [RPMT 1997]

(a) Relative emissivity (b) Emissivity
(c) Absorption coefficient (d) Coefficient of reflection

26. The cause of Fraunhoffer lines is [RPMT 1996; EAMCET 2001]

(a) Reflection of radiations by chromosphere
(b) Absorption of radiations by chromosphere
(c) Emission of radiations by chromosphere
(d) Transmission of radiations by chromosphere

27. Two thermometers A and B are exposed in sun light. The valve of A is painted black, But that of B is not painted. The correct statement regarding this case is [BHU (Med.) 1999; MH CET 1999]

(a) Temperature of A will rise faster than B but the final temperature will be the same in both
(b) Both A and B show equal rise in beginning
(c) Temperature of A will remain more than B
(d) Temperature of B will rise faster

28. There is a black spot on a body. If the body is heated and carried in dark room then it glows more. This can be explained on the basis of [RPET 2000]

(a) Newton's law of cooling (b) Wien's law
(c) Kirchoff's law (d) Stefan's

29. When red glass is heated in dark room it will seem [RPET 2000]

(a) Green (b) Purple
(c) Black (d) Yellow

30. A hot body will radiate heat most rapidly if its surface is [UPSEAT 1999, 2000]

(a) White & polished (b) White & rough
(c) Black & polished (d) Black & rough

31. A body, which emits radiations of all possible wavelengths, is known as [CPMT 2001; Pb. PET 2002]

(a) Good conductor (b) Partial radiator
(c) Absorber of photons (d) Perfectly black-body

32. Which of the following is the example of ideal black body [AIEEE 2002; CBSE PMT 2002]

(a) Kajal (b) Black board
(c) A pin hole in a box (d) None of these

33. An ideal black body at room temperature is thrown into a furnace. It is observed that [IIT-JEE (Screening) 2002]

(a) Initially it is the darkest body and at later times the brightest
(b) It is the darkest body at all times
(c) It cannot be distinguished at all times
(d) Initially it is the darkest body and at later times it cannot be distinguished

34. Absorption co-efficient of an open window is... [KCET 2004]

(a) Zero (b) 0.5
(c) 1 (d) 0.25

35. Which of the prism is used to see infra-red spectrum of light [RPMT 2000]

(a) Rock-salt (b) Nicol
(c) Flint (d) Crown

36. Which of the following statement is correct [RPMT 2001]

(a) A good absorber is a bad emitter
(b) Every body absorbs and emits radiations at every temperature
(c) The energy of radiations emitted from a black body is same for all wavelengths
(d) The law showing the relation of temperatures with the wavelength of maximum emission from an ideal black body is Plank's law

37. A piece of blue glass heated to a high temperature and a piece of red glass at room temperature, are taken inside a dimly lit room then [KCET 2005]

(a) The blue piece will look blue and red will look as usual
(b) Red look brighter red and blue look ordinary blue
(c) Blue shines like brighter red compared to the red piece
(d) Both the pieces will look equally red.

38. Which of the following law states that "good absorbers of heat are good emitters" [Orissa JEE 2005]

(a) Stefan's law (b) Kirchoff's law
(c) Planck's law (d) Wein's law

Radiation (Wein's law)

1. According to Wein's law [DCE 1995, 96; MP PET/PMT 1988 DPMT 1999; AIIMS 2002; CBSE PMT 2004]

(a) $\lambda_m T$ = constant (b) $\frac{\lambda_m}{T}$ = constant
(c) $\frac{T}{\lambda_m}$ = constant (d) $T + \lambda_m$ = constant

2. On investigation of light from three different stars A, B and C, it was found that in the spectrum of A the intensity of red colour is maximum, in B the intensity of blue colour is maximum and in C the intensity of yellow colour is maximum. From these observations it can be concluded that [CPMT 1989]

(a) The temperature of A is maximum, B is minimum and C is intermediate

(b) The temperature of A is maximum, C is minimum and B is intermediate

(c) The temperature of B is maximum, A is minimum and C is intermediate

(d) The temperature of C is maximum, B is minimum and A is intermediate

3. If wavelengths of maximum intensity of radiations emitted by the sun and the moon are $0.5\times10^{-6}m$ and $10^{-4}m$ respectively, the ratio of their temperatures is [MP PMT 1990]

(a) 1/100 (b) 1/200

(c) 100 (d) 200

4. The wavelength of radiation emitted by a body depends upon

(a) The nature of its surface

(b) The area of its surface

(c) The temperature of its surface

(d) All the above factors

5. If black wire of platinum is heated, then its colour first appear red, then yellow and finally white. It can be understood on the basis of

(a) Wien's displacement law

(b) Prevost theroy of heat exchange

(c) Newton's law of cooling

(d) None of the above

6. Colour of shining bright star is an indication of its [AIIMS 2001; RPMT 1999; BCECE 2005]

(a) Distance from the earth (b) Size

(c) Temperature (d) Mass

7. The wavelength of maximum emitted energy of a body at 700 K is 4.08 μm. If the temperature of the body is raised to 1400 K, the wavelength of maximum emitted energy will be

(a) $1.02\ \mu m$ (b) 16.32 μm

(c) 8.16 μm (d) 2.04 μm

8. A black body at 200 K is found to exit maximum energy at a wavelength of $14\mu m$. When its temperature is raised to 1000K, the wavelength at which maximum energy is emitted is[RPMT 1998; MP PET 1991; BVP 2003]

(a) $14\mu m$ (b) $70\mu F$

(c) $2.8\mu m$ (d) $2.8mm$

9. Two stars emit maximum radiation at wavelength 3600 $\mathring{A}$ and 4800 $\mathring{A}$ respectively. The ratio of their temperatures is [MP PMT 1991]

(a) 1 : 2 (b) 3 : 4

(c) 4 : 3 (d) 2 : 1

10. A black body emits radiations of maximum intensity at a wavelength of $5000\mathring{A}$, when the temperature of the body is 1227^oC. If the temperature of the body is increased by 1000^oC, the maximum intensity of emitted radiation would be observed at

(a) $2754.8\mathring{A}$ (b) $3000\mathring{A}$

(c) $3500\mathring{A}$ (d) $4000\mathring{A}$

11. Four pieces of iron heated in a furnace to different temperatures show different colours listed below. Which one has the highest temperature [MP PET 1992]

(a) White (b) Yellow

(c) Orange (d) Red

12. If a black body is heated at a high temperature, it seems to be

(a) Blue (b) White

(c) Red (d) Black

13. If the temperature of the sun becomes twice its present temperature, then [MP PET 1989; RPMT 1996]

(a) Radiated energy would be predominantly in infrared

(b) Radiated energy would be predominantly in ultraviolet [MP PMT 1992]

(c) Radiated energy would be predominantly in X-ray region

(d) Radiated energy would become twice the present radiated energy

14. The maximum energy in the thermal radiation from a hot source occurs at a wavelength of $11\times10^{-5}cm$. According to Wein's law, the temperature of the source (on Kelvin scale) will be n times the temperature of another source (on Kelvin scale) for which the [MP PMT 1984] wavelength at maximum energy is $5.5\times10^{-5}cm$. The value n is [CPMT 1991]

(a) 2 (b) 4

(c) $\frac{1}{2}$ (d) 1

15. The wavelength of maximum energy released during an atomic explosion was $2.93\times10^{-10}m$. Given that Wein's constant is $2.93\times10^{-3}m-K$, the maximum temperature attained must be of the order of [Haryana CEE 1996; MH CET 2002; Pb. PET 2000]

(a) $10^{-7}K$ [MP PET 1990] (b) $10^{7}K$

(c) $10^{-13}K$ (d) $5.86\times10^{7}K$

16. The maximum wavelength of radiation emitted at $2000\ K$ is $4\mu m$. What will be the maximum wavelength of radiation emitted at [MP PMT/PET 1998; DPMT 2000]

(a) 3.33 μm (b) 0.66 μm

(c) 1 μm (d) 1 m

17. How is the temperature of stars determined by [BHU 1999, 02; DCE 2000, 03]

(a) Stefan's law (b) Wein's displacement law

(c) Kirchhoff's law (d) Ohm's law

18. On increasing the temperature of a substance gradually, which of the following colours will be noticed by you [Pb. PMT 1995; Pb. PET 1996; CPMT 1995, 98; KCET 2000]

(a) White (b) Yellow

(c) Green (d) Red

19. A black body has maximum wavelength λ_m at temperature 2000 K. Its corresponding wavelength at temperature 3000 K will be [CBSE PMT 2001; K [MP PET 1992]

(a) $\frac{3}{2}\lambda_m$ (b) $\frac{2}{3}\lambda_m$

(c) $\frac{4}{9}\lambda_m$ (d) $\frac{9}{4}\lambda_m$

20. Relation between the colour and the temperature of a star is given by **[Kerala PET 2001]**

(a) Wein's displacement law

(b) Planck's law

(c) Hubble's law

(d) Fraunhofer diffraction law

21. A black body at a temperature of 1640 K has the wavelength corresponding to maximum emission equal to 1.75 μ. Assuming the moon to be a perfectly black body, the temperature of the moon, if the wavelength corresponding to maximum emission is 14.35 μ is **[Kerala (Med.) 2002]**

(a) 100 K (b) 150 K

(c) 200 K (d) 250 K

22. The maximum wavelength of radiations emitted at 900 K is $4\mu m$. What will be the maximum wavelength of radiations emitted at 1200 K **[BHU 2002]**

(a) $3\mu m$ (b) $0.3\mu m$

(c) $1\mu m$ (d) $1\ m$

23. Solar radiation emitted by sun resembles that emitted by a black body at a temperature of 6000 K. Maximum intensity is emitted at a wavelength of about 4800Å. If the sun were to cool down from 6000 K to 3000 K then the peak intensity would occur at a wavelength **[UPSEAT 2002]**

(a) 4800Å (b) 9600Å

(c) 7200Å (d) 6400Å

24. What will be the ratio of temperatures of sun and moon if the wavelengths of their maximum emission radiations rates are 140 Å and 4200 Å respectively **[J & K CET 2004]**

(a) 1 : 30 (b) 30 : 1

(c) 42 : 14 (d) 14 : 42

25. The radiation energy density per unit wavelength at a temperature T has a maximum at a wavelength λ. At temperature $2T$, it will have a maximum at a wavelength **[UPSEAT 2004]**

(a) 4λ (b) 2λ

(c) $\lambda/2$ (d) $\lambda/4$

26. The absolute temperatures of two black bodies are 2000 K and 3000 K respectively. The ratio of wavelengths corresponding to maximum emission of radiation by them will be

(a) 2 : 3 (b) 3 : 2

(c) 9 : 4 (d) 4 : 9

27. The temperature of sun is 5500 K and it emits maximum intensity radiation in the yellow region $(5.5\times10^{-7}m)$. The maximum radiation from a furnace occurs at wavelength $11\times10^{-7}m$. The temperature of furnace is **[J & K CET 2000]**

(a) 1125 K (b) 2750 K

(c) 5500 K (d) 11000 K

28. A particular star (assuming it as a black body) has a surface temperature of about $5\times10^4 K$. The wavelength in nanometers at which its radiation becomes maximum is (b = 0.0029 mK) **[EAMCET (Med.) 2003]**

(a) 48 (b) 58

(c) 60 (d) 70

29. The maximum energy in thermal radiation from a source occurs at the wavelength 4000Å. The effective temperature of the source is

(a) $7000\,K$ (b) 80000 K

(c) $10^4\ K$ (d) $10^6\ K$

30. The intensity of radiation emitted by the sun has its maximum value at a wavelength of $510\ nm$ and that emitted by the north star has the maximum value at $350\ nm$. If these stars behave like black bodies, then the ratio of the surface temperature of the sun and north star is **[IIT 1997 Cancelled; JIPMER 2000; AIIMS 2000]**

(a) 1.46 (b) 0.69

(c) 1.21 (d) 0.83

Radiation (Stefan's law)

1. The amount of radiation emitted by a perfectly black body is proportional to **[AFMC 1995; Pb. PMT 1997; CPMT 1974, 98, 02; AIIMS 2000; DPMT 1995, 98, 02]**

(a) Temperature on ideal gas scale

(b) Fourth root of temperature on ideal gas scale

(c) Fourth power of temperature on ideal gas scale

(d) Source of temperature on ideal gas scale

2. A metal ball of surface area $200\ cm^2$ and temperature 527^oC is surrounded by a vessel at 27^oC. If the emissivity of the metal is 0.4, then the rate of loss of heat from the ball is $(\sigma = 5.67\times10^{-8}\ J/m^2 - s - k^4)$ **[MP PMT/PET 1988]**

(a) 108 joules approx. (b) 168 joules approx.

(c) 182 joules approx. (d) 192 joules approx.

3. The rate of radiation of a black body at 0°C is E J/sec. The rate of radiation of this black body at 273^oC will be **[MP PMT 1989; Kerala PET 2002; UPSEAT 2001]**

(a) $16\ E$ (b) $8\ E$

(c) $4\ E$ (d) E

4. A black body radiates energy at the rate of E W/m at a high temperature TK. When the temperature is reduced to $\frac{T}{2}K$, the radiant energy will be **[RPMT 2003]** **[CPMT 1988; UPSEAT 1998; MNR 1993; SCRA 1996; MP PMT 1992; DPMT 2001; MH CET 2001]**

(a) $\frac{E}{16}$ (b) $\frac{E}{4}$

(c) $4E$ (d) $16E$

5. An object is at a temperature of 400^oC. At what temperature would it radiate energy twice as fast? The temperature of the surroundings may be assumed to be negligible **[MP PMT 1990; DPMT 2002]**

(a) 200^oC (b) $200\ K$

(c) 800^oC (d) 800 K

6. A black body at a temperature of 227^oC radiates heat energy at the rate of 5 cal/cm-sec. At a temperature of 727^oC, the rate of heat radiated per unit area in cal/cm will be

(a) 80 (b) 160

(c) 250 (d) 500

7. Energy is being emitted from the surface of a black body at 127^oC temperature at the rate of $1.0\times10^6 J/\sec-m^2$. Temperature of the black body at which the rate of energy emission is $16.0\times10^6 J/\sec-m^2$ will be

[MP PMT 1991; AFMC 1998]

(a) 254^oC (b) 508^oC

(c) 527^oC (d) 727^oC

8. In MKS system, Stefan's constant is denoted by σ. In CGS system multiplying factor of σ will be

(a) 1 (b) 10^3

(c) 10^5 (d) 10^2

9. If temperature of a black body increases from 7^oC to 287^oC, then the rate of energy radiation increases by

[AIIMS 1997; Haryana PMT 2000; RPMT 2003]

(a) $\left(\frac{287}{7}\right)^4$ (b) 16

(c) 4 (d) 2

10. The temperature of a piece of iron is 27^oC and it is radiating energy at the rate of $Q\,kWm^{-2}$. If its temperature is raised to 151^oC, the rate of radiation of energy will become approximately

(a) $2Q\,kWm^{-2}$ (b) $4Q\,kWm^{-2}$

(c) $6Q\,kWm^{-2}$ (d) $8Q\,kWm^{-2}$

11. The temperatures of two bodies *A* and *B* are 727^oC and 127^oC. The ratio of rate of emission of radiations will be

[MP PET 1986]

(a) 727/127 (b) 625/16

(c) 1000/400 (d) 100/16

12. The temperature at which a black body of unit area loses its energy at the rate of 1 *joule/second* is

(a) -65^oC (b) 65^oC

(c) 65 *K* (d) None of these

13. The area of a hole of heat furnace is $10^{-4} m^2$. It radiates 1.58×10^5 calories of heat per hour. If the emissivity of the furnace is 0.80, then its temperature is

(a) 1500 *K* (b) 2000 *K*

(c) 2500 *K* (d) 3000 *K*

14. Two spheres P and Q, of same colour having radii $8\,cm$ and $2\,cm$ are maintained at temperatures 127^oC and 527^oC respectively. The ratio of energy radiated by P and Q is

(a) 0.054 (b) 0.0034

(c) 1 (d) 2

15. A body radiates energy $5W$ at a temperature of 127^oC. If the temperature is increased to 927^oC, then it radiates energy at the rate of

[MP PET 1994;BHU 1995; CPMT 1998; AFMC 2000]

(a) $410W$ (b) $81\,W$

(c) $405\,W$ (d) $200\,W$

16. A thin square steel plate with each side equal to 10 *cm* is heated by a blacksmith. The rate of radiated energy by the heated plate is 1134 *W*. The temperature of the hot steel plate is (Stefan's constant $\sigma = 5.67\times10^{-8} watt\,m^{-2}K^{-4}$, emissivity of the plate = 1)

(a) $1000\,K$ (b) $1189\,K$

(c) $2000\,K$ (d) $2378\,K$

17. The temperatures of two bodies A and B are respectively 727^oC and 327^oC. The ratio $H_A : H_B$ of the rates of heat radiated by them is [UPSEAT 1999;

MP PET 1999; MH CET 2000; AIIMS 2000]

(a) $727:327$ (b) 5 : 3

(c) 25 : 9 (d) 625 : 81

18. The energy emitted per second by a black body at 27^oC is $10\,J$. If the temperature of the black body is increased to 327^oC, the energy emitted per second will be

[CPMT 1999; DCE 1999]

(a) $20\,J$ (b) $40\,J$

(c) $80\,J$ [MP PET 1992] (d) $160\,J$

19. The radiant energy from the sun incident normally at the surface of earth is $20\,kcal/m^2 min$. What would have been the radiant energy incident normally on the earth, if the sun had a temperature twice of the present one

[CBSE PMT 1998; Pb. PET 2001]

(a) $160\,kcal/m^2\,min$ (b) $40\,kcal/m^2\,min$

(c) $320\,kcal/m^2\,min$ (d) $80\,kcal/m^2\,min$

20. A spherical black body with a radius of $12\,cm$ radiates $440\,W$ power at $500\,K$. If the radius were halved and the temperature doubled, the power radiated in watt would be

[IIT 1997 Re-Exam]

(a) 225 (b) 450

(c) 900 (d) 1800

21. If the temperature of the sun (black body) is doubled, the rate of energy received on earth will be increased by a factor of [CBSE PMT 1993; BHU 2

(a) 2 (b) 4

(c) 8 (d) 16

22. The ratio of energy of emitted radiation of a black body at 27^oC and 927^oC is [MP PMT 1994] [Pb. PMT 1995;

CPMT 1997, 2000; CBSE PMT 2000; DPMT 1998, 02, 03]

(a) 1 : 4 (b) 1 : 16

(c) 1 : 64 (d) 1 : 256

23. If the temperature of a black body be increased from 27^oC to 327^oC the radiation emitted increases by a fraction of

[Pb. PET 1997; JIPMER 1999]

(a) 16 (b) 8
(c) 4 (d) 2

24. The rectangular surface of area 8 $cm \times 4 cm$ of a black body at a temperature of $127^o C$ emits energy at the rate of E per second. If the length and breadth of the surface are each reduced to half of the initial value and the temperature is raised to $327^o C$, the rate of emission of energy will become [MP PET 2000]

(a) $\frac{3}{8}E$ (b) $\frac{81}{16}E$
(c) $\frac{9}{16}E$ (d) $\frac{81}{64}E$

25. At temperature T, the power radiated by a body is Q *watts*. At the temperature $3T$ the power radiated by it will be [MP PET 2000]

(a) 3 Q (b) 9 Q
(c) 27 Q (d) 81 Q

26. Two spherical black bodies of radii r_1 and r_2 and with surface temperature T_1 and T_2 respectively radiate the same power. Then the ratio of r_1 and r_2 will be [KCET 2001; UPSEAT 2001]

(a) $\left(\frac{T_2}{T_1}\right)^2$ (b) $\left(\frac{T_2}{T_1}\right)^4$
(c) $\left(\frac{T_1}{T_2}\right)^2$ (d) $\left(\frac{T_1}{T_2}\right)^4$

27. Temperature of a black body increases from $327^o C$ to $927^o C$, the initial energy possessed is 2 *KJ*, what is its final energy

(a) 32 *KJ* (b) 320 *KJ*
(c) 1200 *KJ* (d) None of these

28. The original temperature of a black body is $727^o C$. The temperature at which this black body must be raised so as to double the total radiant energy, is [Pb. PMT 2001]

(a) 971 K (b) 1190 K
(c) 2001 K (d) 1458 K

29. Two black metallic spheres of radius 4m, at 2000 K and 1m at 4000 K will have ratio of energy radiation as [RPET 2000; AIEEE 2002]

(a) 1 : 1 (b) 4 : 1
(c) 1 : 4 (d) 2 : 1

30. The energy spectrum of a black body exhibits a maximum around a wavelength λ_o. The temperature of the black body is now changed such that the energy is maximum around a wavelength $\frac{3\lambda_o}{4}$. The power radiated by the black body will now increase by a factor of [KCET 2002]

(a) 256/81 (b) 64/27
(c) 16/9 (d) 4/3

31. A black body is at a temperature 300 K. It emits energy at a rate, which is proportional to [Pb. PMT 1998; AIIMS 2002; MH CET 2003]

(a) 300 (b) $(300)^2$
(c) $(300)^3$ (d) $(300)^4$

32. If the temperature of a hot body is increased by 50% then the increase in the quantity of emitted heat radiation will be [RPET 1998; EAMCET 2001; MP PMT 2003]

(a) 125% (b) 200%
(c) 300% (d) 400%

33. Two identical metal balls at temperature $200^o C$ and $400^o C$ kept in air at $27^o C$. The ratio of net heat loss by these bodies is

(a) 1/4 (b) 1/2
(c) 1/16 (d) $\frac{473^4 - 300^4}{673^4 - 300^4}$

34. Two spheres made of same material have radii in the ratio 1: 2 Both are at same temperature. Ratio of heat radiation energy emitted per second by them is [MP PMT 2002; MH CET 2004]

(a) 1 : 2 (b) 1 : 8
(c) 1 : 4 (d) 1 : 16

35. A black body at a temperature of 127°C radiates heat at the rate of 1 *cal/cm* × *sec*. At a temperature of 527°C the rate of heat radiation from the body in (*cal/cm* × *sec*) will be [MP PET 2002]

(a) 16.0 (b) 10.45
(c) 4.0 (d) 2.0

36. A black body radiates 20 W at temperature $227^o C$. If temperature of the black body is changed to $727^o C$ then its radiating power will be [DCE 2001] [CBSE PMT 2002; DCE 1999, 03; AIIMS 2003]

(a) 120 W (b) 240 W
(c) 320 W (d) 360 W

37. Two spheres of same material have radius 1 m and 4 m and temperature 4000 K and 2000 K respectively. The energy radiated per second by the first sphere is [Pb. PMT 2002]

(a) Greater than that by the second
(b) Less than that by the second
(c) Equal in both cases
(d) The information is incomplete

38. The radiation emitted by a star A is 10,000 times that of the sun. If the surface temperatures of the sun and the star A are 6000 K and 2000 K respectively, the ratio of the radii of the star A and the sun is

(a) 300 : 1 (b) 600 : 1
(c) 900 : 1 (d) 1200 : 1

39. A black body radiates at the rate of W watts at a temperature T. If the temperature of the body is reduced to $T/3$, it will radiate at the rate of (in *Watts*) [BHU 1998; MP PET 2003]

(a) $\frac{W}{81}$ (b) $\frac{W}{27}$
(c) $\frac{W}{9}$ (d) $\frac{W}{3}$

40. Star A has radius r surface temperature T while star B has radius $4r$ and surface temperature $T/2$. The ratio of the power of two starts, $P_A : P_B$ is [MP PMT 2004]

(a) 16 : 1 (b) 1 : 16

(c) 1 : 1 (d) 1 : 4

41. Suppose the sun expands so that its radius becomes 100 times its present radius and its surface temperature becomes half of its present value. The total energy emitted by it then will increase by a factor of [AIIMS 2004]

(a) 10^4 (b) 625

(c) 256 (d) 16

42. If the temperature of the sun were to be increased from T to $2T$ and its radius from R to $2R$, then the ratio of the radiant energy received on the earth to what it was previously will be

(a) 4 (b) 16

(c) 32 (d) 64

43. At 127° C radiates energy is 2.7×10^3 J/s. At what temperature radiated energy is 4.32×10^6 J/s [BCECE 2004]

(a) 400 K (b) 4000 K

(c) 80000 K (d) 40000 K

44. If the initial temperatures of metallic sphere and disc, of the same mass, radius and nature are equal, then the ratio of their rate of cooling in same environment will be

[J & K CET 2004]

(a) 1 : 4 (b) 4 : 1

(c) 1 : 2 (d) 2 : 1

45. A black body radiates energy at the rate of 1×10^5 $J/s \times m^2$ at temperature of 227° C. The temperature to which it must be heated so that it radiates energy at rate of 1×10^9 J/sm², is

(a) 5000 K (b) 5000°C

(c) 500 K (d) 500°C

46. The temperature of the body is increased from –73° C to 327° C, the ratio of energy emitted per second is :

[CPMT 2001; Pb. PET 2001]

(a) 1 : 3 (b) 1 : 81

(c) 1 : 27 (d) 1 : 9

47. If the temperature of the body is increased by 10%, the percentage increase in the emitted radiation will be

[RPMT 2001, 02]

(a) 46% (b) 40%

(c) 30% (d) 80%

48. If the sun's surface radiates heat at $6.3 \times 10^7 Wm^{-2}$. Calculate the temperature of the sun assuming it to be a black body $(\sigma = 5.7 \times 10^{-8} Wm^{-2}K^{-4})$ [BHU (Med.) 2000]

(a) $5.8 \times 10^3 K$ (b) $8.5 \times 10^3 K$

(c) $3.5 \times 10^8 K$ (d) $5.3 \times 10^8 K$

49. A sphere at temperature 600K is placed in an environment of temperature is 200K. Its cooling rate is H. If its temperature reduced to 400K then cooling rate in same environment will become [CBSE PMT 1999; BHU 2001]

(a) (3/16)H (b) (16/3)H

(c) (9/27)H (d) (1/16)H

50. The value of Stefan's constant is [RPMT 2002]

(a) $5.67 \times 10^{-8} W/m^2\text{-}K^4$ (b) $5.67 \times 10^{-5} W/m^2\text{-}K^4$

(c) $5.67 \times 10^{-11} W/m^2\text{-}K^4$ (d) None of these

51. Rate of cooling at 600K, if surrounding temperature is 300K is R. The rate of cooling at 900K is [DPMT 2002]

(a) $\frac{16}{3}R$ (b) $2R$

(c) $3R$ (d) $\frac{2}{3}R$

52. A black body of surface area 10cm^2 is heated to 127°C and is suspended in a room at temperature 27°C. The initial rate of loss of heat from the body at the room temperature will be [AIEEE 2004]

(a) 2.99 W (b) 1.89 W

(c) 1.18 W (d) 0.99 W

53. Two identical objects A and B are at temperatures T_A and T_B respectively. Both objects are placed in a room with perfectly absorbing walls maintained at temperatures T $(T_A > T > T_B)$. The objects A and B attain temperature T eventually which one of the following is correct statement

[CPMT 1997]

(a) 'A' only emits radiations while B only absorbs them until both attain temperature

(b) A loses more radiations than it absorbs while B absorbs more radiations that it emits until temperature T is attained

(c) Both A and B only absorb radiations until they attain temperature T

(d) Both A and B only emit radiations until they attain temperature T

[DPMT 2004]

54. When the body has the same temperature as that of surroundings [UPSEAT 199

(a) It does not radiate heat

(b) It radiates the same quantity of heat as it absorbs

(c) It radiates less quantity of heat as it receives from surroundings

(d) It radiates more quantity of heat as it receives heat from surroundings

55. The ratio of radiant energies radiated per unit surface area by two bodies is 16 : 1, the temperature of hotter body is 1000K, then the temperature of colder body will be

[UPSEAT 2001]

(a) 250 K (b) 500 K

(c) 1000 K (d) 62.5 K

56. The spectral energy distribution of star is maximum at twice temperature as that of sun. The total energy radiated by star is

(a) Twice as that of the sun

(b) Same as that of the sun

(c) Sixteen times as that of the sun

(d) One sixteenth of sun

Radiation (Newton's Law of Cooling)

1. Hot water cools from $60^o C$ to $50^o C$ in the first 10 minutes and to $42^o C$ in the next 10 minutes. The temperature of the surrounding is [MP PET 1993]

(a) $5^o C$ (b) $10^o C$

(c) $15^o C$ (d) $20^o C$

2. A bucket full of hot water cools from $75^o C$ to $70^0 C$ in time T_1, from $70^o C$ to $65^o C$ in time T_2 and from $65^o C$ to $60^o C$ in time T_3, then [NCERT 1980; MP PET 1989; CBSE PMT 1995; KCET 2003; MH CET 1999]

(a) $T_1 = T_2 = T_3$ (b) $T_1 > T_2 > T_3$

(c) $T_1 < T_2 < T_3$ (d) $T_1 > T_2 < T_3$

3. Consider two hot bodies B_1 and B_2 which have temperatures $100^o C$ and $80^o C$ respectively at $t = 0$. The temperature of the surroundings is $40^o C$. The ratio of the respective rates of cooling R_1 and R_2 of these two bodies at $t = 0$ will be

(a) $R_1 : R_2 = 3 : 2$ (b) $R_1 : R_2 = 5 : 4$

(c) $R_1 : R_2 = 2 : 3$ (d) $R_1 : R_2 = 4 : 5$

4. Newton's law of cooling is a special case of

(a) Stefan's law (b) Kirchhoff's law

(c) Wien's law (d) Planck's law

5. Equal masses of two liquids are filled in two similar calorimeters. The rate of cooling will [MP PMT 1987]

(a) Depend on the nature of the liquids

(b) Depend on the specific heats of liquids

(c) Be same for both the liquids

(d) Depend on the mass of the liquids

6. In Newton's experiment of cooling, the water equivalent of two similar calorimeters is 10 *gm* each. They are filled with 350 *gm* of water and 300 *gm* of a liquid (equal volumes) separately. The time taken by water and liquid to cool from $70^o C$ to $60^o C$ is 3 *min* and 95 *sec* respectively. The specific heat of the liquid will be

(a) 0.3 $Cal/gm \times ^\circ C$ (b) 0.5 $Cal/gm \times ^\circ C$

(c) 0.6 $Cal/gm \times ^\circ C$ (d) 0.8 $Cal/gm \times ^\circ C$

7. Newton's law of cooling is used in laboratory for the determination of the [CPMT 1973; CPMT 2002]

(a) Specific heat of the gases (b) The latent heat of gases

(c) Specific heat of liquids (d) Latent heat of liquids

8. A body cools from $60^o C$ to $50^o C$ in 10 *minutes* when kept in air at $30^o C$. In the next 10 *minutes* its temperature will be

(a) Below $40^o C$ (b) $40^o C$

(c) Above $40^o C$ (d) Cannot be predicted

9. Liquid is filled in a vessel which is kept in a room with temperature $20^o C$. When the temperature of the liquid is $80^o C$, then it loses heat at the rate of $60\ cal/\sec$. What will be the rate of loss of heat when the temperature of the liquid is $40^o C$

(a) $180\ cal/\sec$ (b) $40\ cal/\sec$

(c) $30\ cal/\sec$ (d) $20\ cal/\sec$

10. Which of the following statements is true/correct [Manipal MEE 1995]

(a) During clear nights, the temperature rises steadily upward near the ground level

(b) Newton's law of cooling, an approximate form of Stefan's law, is valid only for natural convection

(c) The total energy emitted by a black body per unit time per unit area is proportional to the square of its temperature in the Kelvin scale

(d) Two spheres of the same material have radii $1m$ and $4m$ and temperatures 4000 *K* and 2000 *K* respectively. The energy radiated per second by the first sphere is greater than that radiated per second by the second sphere

11. A body takes 4 *minutes* to cool from $100^o C$ to $70^o C$. To cool from $70^o C$ to $40^o C$ it will take (room temperature is $15^o C$)

(a) 7 *minutes* (b) 6 *minutes*

(c) 5 *minutes* (d) 4 *minutes*

12. A cup of tea cools from $80^0 C$ to $60^o C$ in one minute. The ambient temperature is $30^o C$. In cooling from $60^o C$ to $50^o C$ it will take [MP PET 1990] [MP PMT 1995; UPSEAT 2000; MH CET 2002]

(a) 30 seconds (b) 60 seconds

(c) 90 seconds (d) 50 seconds

13. A liquid cools down from $70^o C$ to $60^o C$ in 5 *minutes*. The time taken to cool it from $60^o C$ to $50^o C$ will be [MP PET 1992, 2000; MP PMT 1996]

(a) 5 *minutes*

(b) Lesser than 5 *minutes*

(c) Greater than 5 *minutes*

(d) Lesser or greater than 5 *minutes* depending upon the density of the liquid

14. If a metallic sphere gets cooled from $62^o C$ to $50^o C$ in 10 minutes and in the next 10 minutes gets cooled to $42^o C$, then the temperature of the surroundings is [MP PET 1997]

(a) $30^o C$ (b) $36^o C$

(c) $26^o C$ (d) $20^o C$

15. The rates of cooling of two different liquids put in exactly similar calorimeters and kept in identical surroundings are the same if

(a) The masses of the liquids are equal

(b) Equal masses of the liquids at the same temperature are taken

(c) Different volumes of the liquids at the same temperature are taken [MP PET 1994]

(d) Equal volumes of the liquids at the same temperature are taken

16. A body cools from $60^o C$ to $50^o C$ in 10 *minutes*. If the room temperature is $25^o C$ and assuming Newton's law of cooling to hold good, the temperature of the body at the end of the next 10 *minutes* will be [MP PMT 1994] [MP PMT/PET 1998; BHU 2000; Pb. PMT 2001]

(a) $38.5^o C$ (b) $40^o C$

(c) $42.85^o C$ (d) $45^o C$

17. The temperature of a liquid drops from $365 K$ to 361 *K* in 2 *minutes*. Find the time during which temperature of the liquid drops from $344\ K$ to $342 K$. Temperature of room is $293\ K$

(a) 84 *sec* (b) 72 *sec*

(c) 66 *sec* (d) 60 *sec*

18. A body cools from 50.0^oC to 49.9^oC in $5\ s$. How long will it take to cool from 40.0^oC to 39.9^oC? Assume the temperature of surroundings to be 30.0^oC and Newton's law of cooling to be valid [CBSE PMT 1994]

(a) 2.5 *s* (b) 10 *s*

(c) 20 *s* (d) 5 *s*

19. A container contains hot water at 100^oC. If in time T_1 temperature falls to 80^oC and in time T_2 temperature falls to 60^oC from 80^oC, then [CPMT 1997]

(a) $T_1 = T_2$ (b) $T_1 > T_2$

(c) $T_1 < T_2$ (d) None

20. Hot water kept in a beaker placed in a room cools from 70^oC to $60^\circ C$ in 4 *minutes*. The time taken by it to cool from 69^oC to 59^oC will be [JIPMER 1999]

(a) The same 4 minutes (b) More than 4 minutes

(c) Less than 4 minutes (d) We cannot say definitely

21. Newton's law of cooling, holds good only if the temperature difference between the body and the surroundings is [BHU 2000]

(a) Less than 10^oC (b) More than 10^oC

(c) Less than 100^oC (d) More than 100^oC

22. In a room where the temperature is 30^oC, a body cools from 61^oC to 59^oC in 4 minutes. The time (in min.) taken by the body to cool from 51^0C to 49^0C will be [UPSEAT 2000]

(a) 4 *min* (b) 6 *min*

(c) 5 *min* (d) 8 *min*

23. According to 'Newton's Law of cooling', the rate of cooling of a body is proportional to the [MP PET 2001]

(a) Temperature of the body

(b) Temperature of the surrounding

(c) Fourth power of the temperature of the body

(d) Difference of the temperature of the body and the surroundings

24. A body cools in 7 minutes from 60^oC to 40^oC What time (in minutes) does it take to cool from 40^oC to 28^oC if the surrounding temperature is 10^oC? Assume Newton's Law of cooling holds [Kerala (Engg.) 2001]

(a) 3.5 (b) 11

(c) 7 (d) 10

25. A body takes 5 minutes for cooling from 50^oC to 40^oC. Its temperature comes down to 33.33^oC in next 5 minutes. Temperature of surroundings is [MP PMT 2002]

(a) 15^oC (b) 20^oC

(c) 25^oC (d) 10^oC

26. The temperature of a body falls from 50^oC to 40^oC in 10 minutes. If the temperature of the surroundings is 20^oC Then temperature of the body after another 10 minutes will be

(a) 36.6^oC (b) 33.3^oC

(c) 35^oC (d) 30^oC

27. It takes 10 minutes to cool a liquid from $61^\circ C$ to $59^\circ C$. If room temperature is $30^\circ C$ then time taken in cooling from $51^\circ C$ to $49^\circ C$ is

(a) 10 *min* (b) 11 *min*

(c) 13 *min* (d) 15 *min*

28. A calorimeter of mass 0.2 *kg* and specific heat 900 *J/kg-K*. Containing 0.5 *kg* of a liquid of specific heat 2400*J* /*kg-K*. Its temperature falls from $60^\circ C$ to $55^\circ C$ in one minute. The rate of cooling is [MP PET 2003]

(a) 5 *J/s* (b) 15 *J/s*

(c) 100 *J/s* (d) 115 *J/s*

29. According to Newton's law of cooling, the rate of cooling of a body is proportional to $(\Delta\theta)^n$, where $\Delta\theta$ is the difference of the temperature of the body and the surroundings, and *n* is equal to

(a) One (b) Two

(c) Three (d) Four

30. The initial temperature of a body is $80^\circ C$. If its temperature falls to $64^\circ C$ in 5 *minutes* and in 10 *minutes* to $52^\circ C$ then the temperature of surrounding will be [MP PMT 2003]

(a) $26^\circ C$ (b) $49^\circ C$

(c) $35^\circ C$ (d) $42^\circ C$

31. A liquid cools from $50^\circ C$ to $45^\circ C$ in 5 minutes and from $45^\circ C$ to $41.5^\circ C$ in the next 5 minutes. The temperature of the surrounding is

(a) $27^\circ C$ (b) $40.3^\circ C$

(c) $23.3^\circ C$ (d) $33.3^\circ C$

32. A cup of tea cools from $65.5^\circ C$ to $62.5^\circ C$ in one minute in a room of $22.5^\circ C$. How long will the same cup of tea take, in............. minutes, to cool from $46.50^\circ C$ to $40.5^\circ C$ in the same room ? (choose nearest value) [Kerala PMT 2004]

(a) 1 (b) 2

(c) 3 (d) 4

33. The temperature of a body falls from $62^\circ C$ to $50^\circ C$ in 10 *minutes*. If the temperature of the surroundings is $26^\circ C$, the temperature in next 10 *minutes* will become [RPMT 2002]

(a) $42^\circ C$ (b) $40^\circ C$

(c) $56^\circ C$ (d) $55^\circ C$

34. A body takes 5 *minutes* to cool from $90^\circ C$ to $60^\circ C$. If the temperature of the surroundings is $20^\circ C$, the time taken by it to cool from $60^\circ C$ to $30^\circ C$ will be. [RPMT 2003]

(a) 5 *min* (b) 8 *min*

(c) 11 *min* (d) 12 *min*

35. An object is cooled from $75^\circ C$ to $65^\circ C$ in 2 minutes in a room at $30^\circ C$. The time taken to cool another object from $55^\circ C$ to $45^\circ C$ in the same room in minutes is [EAMCET (Med.) 1996]

(a) 4 (b) 5

(c) 6 (d) 7

36. A body takes 5 minute to cool from 80°*C* to 50°*C*. How much time it will take to cool from 60°*C* to 30°*C*, if room temperature is 20°*C*.

(a) 40 minute (b) 9 minute

(c) 30 minute (d) 20 minute

37. A cane is taken out from a refrigerator at 0°*C*. The atmospheric temperature is 25°*C*. If t is the time taken to heat from 0°*C* to 5°*C* and t is the time taken from 10°*C* to 15°*C*, then

(a) $t_1 > t_2$ (b) $t_1 < t_2$

(c) $t_1 = t_2$ (d) There is no relation

Critical Thinking

Objective Questions

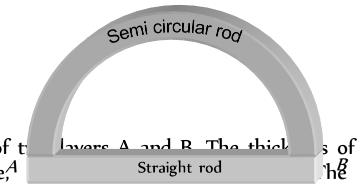
1. Two rods (one semi-circular and other straight) of same material and of same cross-sectional area are joined as shown in the figure. The points A and B are maintained at different temperature. The ratio of the heat transferred through a cross-section of a semi-circular rod to the heat transferred through a cross section of the straight rod in a given time is [UPSEAT 2002]

(a) 2 : π

(b) 1 : 2

(c) π : 2

(d) 3 : 2



2. A wall is made up of two layers A and B. The thickness of the two layers is the same, but materials are different. The thermal conductivity of A is double than that of B. In thermal equilibrium the temperature difference between the two ends is 36^oC. Then the difference of temperature at the two surfaces of A will be

BHU 1997; MP PET 1996, 99; DPMT 2000]

(a) 6^oC (b) 12^oC

(c) 18^oC (d) 24^oC

3. Ice starts forming in lake with water at 0^oC and when the atmospheric temperature is -10^oC. If the time taken for 1 *cm* of ice be 7 *hours*, then the time taken for the thickness of ice to change from 1 *cm* to 2 *cm* is

[NCERT 1971; MP PMT/PET 1988; UPSEAT 1996]

(a) 7 *hours* (b) 14 *hours*

(c) Less than 7 *hours* (d) More than 7 *hours*

4. A cylinder of radius R made of a material of thermal conductivity K_1 is surrounded by a cylindrical shell of inner radius R and outer radius 2R made of material of thermal conductivity K_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in steady state. The effective thermal conductivity of the system is

[IIT 1988; MP PMT 1994, 97; SCRA 1998]

(a) $K_1 + K_2$ (b) $\frac{K_1K_2}{K_1+K_2}$

(c) $\frac{K_1+3K_2}{4}$ (d) $\frac{3K_1+K_2}{4}$

5. Three rods made of the same material and having the same cross section have been joined as shown in the figure. Each rod is of the same length. The left and right ends are kept at 0^oC and 90^oC respectively. The temperature of the junction of the three rods will be [IIT-JEE (Screening) 2001]

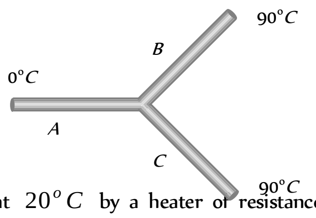
[RPET 1998]

(a) 45^oC

(b) 60^oC

(c) 30^oC

(d) 20^oC



[Orissa JEE 2005]

6. A room is maintained at 20^oC by a heater of resistance 20 *ohm* connected to 200 *volt* mains. The temperature is uniform through out the room and heat is transmitted through a glass window of area $1m^2$ and thickness 0.2 *cm*. What will be the temperature outside? Given that thermal conductivity *K* for glass is $0.2\ cal/m/^oC/sec$ and *J* = 4.2 *J/cal*

[IIT 1978]

(a) 15.24^oC (b) 15.00°*C*

(c) 24.15^oC (d) None of the above

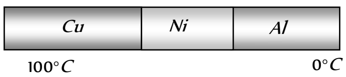
7. There is formation of layer of snow $x\,cm$ thick on water, when the temperature of air is $-\theta^oC$ (less than freezing point). The thickness of layer increases from x to y in the time t, then the value of t is given by

(a) $\frac{(x+y)(x-y)\rho L}{2k\theta}$ (b) $\frac{(x-y)\rho L}{2k\theta}$

(c) $\frac{(x+y)(x-y)\rho L}{k\theta}$ (d) $\frac{(x-y)\rho Lk}{2\theta}$

[IIT 1980; CPMT 1991;

8. A composite metal bar of uniform section is made up of length 25 *cm* of copper, 10 *cm* of nickel and 15 *cm* of aluminium. Each part being in perfect thermal contact with the adjoining part. The copper end of the composite rod is maintained at 100^oC and the aluminium end at 0^oC. The whole rod is covered with belt so that there is no heat loss occurs at the sides. If $K_{Cu} = 2K_{Al}$ and $K_{Al} = 3K_{Ni}$, then what will be the temperatures of $Cu-Ni$ and $Ni-Al$ junctions respectively



(a) 23.33^oC and 78.8^oC (b) 83.33^oC and 20^oC

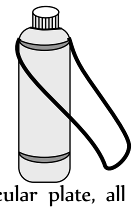
(c) 50^oC and 30^oC (d) 30^oC and 50^oC

9. Three rods of identical area of cross-section and made from the same metal form the sides of an isosceles triangle ABC, right angled at B. The points A and B are maintained at temperatures T and $\sqrt{2}T$ respectively. In the steady state the temperature of the point C is T_C. Assuming that only heat conduction takes place, $\frac{T_C}{T}$ is equal to [IIT 1995]

(a) $\frac{1}{(\sqrt{2}+1)}$ (b) $\frac{3}{(\sqrt{2}+1)}$

(c) $\frac{1}{2(\sqrt{2}-1)}$ (d) $\frac{1}{\sqrt{3}(\sqrt{2}-1)}$

10. The only possibility of heat flow in a thermos flask is through its cork which is 75 *cm* in area and 5 *cm* thick. Its thermal conductivity is 0.0075 *cal/cmsec°C*. The outside temperature is 40°C and latent heat of ice is 80 *cal/g*. Time taken by 500 *g* of ice at 0°C in the flask to melt into water at 0°C is [CPMT 1974, 78; MNR 1983]



(a) 2.47 *hr*
(b) 4.27 *hr*
(c) 7.42 *hr*
(d) 4.72 *hr*

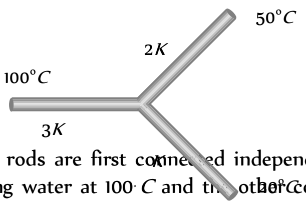
11. A sphere, a cube and a thin circular plate, all made of the same material and having the same mass are initially heated to a temperature of 1000°*C*. Which one of these will cool first

J & K CET 2000 MH CET 2000; UPSEAT 2001]

(a) Plate (b) Sphere
(c) Cube (d) None of these

12. Three rods of the same dimension have thermal conductivities 3*K*, 2*K* and *K*. They are arranged as shown in fig. Given below, with their ends at 100°*C*, 50°*C* and 20°*C*. The temperature of their junction is

(a) $60^o\ C$
(b) $70^o\ C$
(c) 50° *C*
(d) 35° *C*



13. Two identical conducting rods are first connected independently to two vessels, one containing water at 100°*C* and the other containing ice at 0°*C*. In the second case, the rods are joined end to end and connected to the same vessels. Let q_1 and q_2 g / s be the rate of melting of ice in two cases respectively. The ratio of q_1/q_2 is

[IIT-JEE (Screening) 2004]

(a) $\frac{1}{2}$ (b) $\frac{2}{1}$

(c) $\frac{4}{1}$ (d) $\frac{1}{4}$

14. A solid cube and a solid sphere of the same material have equal surface area. Both are at the same temperature $120^o C$, then [MP PET 1992, 96; MP PMT 2000]

(a) Both the cube and the sphere cool down at the same rate
(b) The cube cools down faster than the sphere
(c) The sphere cools down faster than the cube
(d) Whichever is having more mass will cool down faster

15. Two bodies A and B have thermal emissivities of 0.01 and 0.81 respectively. The outer surface areas of the two bodies are the same. The two bodies emit total radiant power at the same rate. The wavelength λ_B corresponding to maximum spectral radiancy in the radiation from B is shifted from the wavelength corresponding to maximum spectral radiancy in the radiation from A, by $1.00\mu m$. If the temperature of A is $5802\ K$

(a) The temperature of B is $1934\ K$
(b) $\lambda_B = 1.5\mu m$
(c) The temperature of B is $11604\ K$
(d) The temperature of B is $2901\ K$

16. A black body is at a temperature of $2880\ K$. The energy of radiation emitted by this object with wavelength between $499\ nm$ and $500\ nm$ is U_1, between $999\ nm$ and $1000\ nm$ is U_2 and between $1499\ nm$ and $1500\ nm$ is U_3. The Wein's constant $b = 2.88\times10^6\ nm\,K$. Then

[IIT 1998]

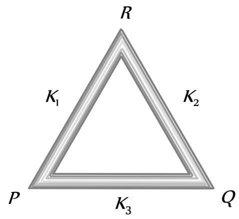
(a) $U_1 = 0$ (b) $U_3 = 0$
(c) $U_1 > U_2$ [IIT 1972; MP PMT 1993; (d) $U_2 > U_1$

17. A black metal foil is warmed by radiation from a small sphere at temperature T and at a distance d. It is found that the power received by the foil is *P*. If both the temperature and the distance are doubled, the power received by the foil will be

(a) 16*P* (b) 4*P*
[UPSEAT 2002]
(c) 2*P* (d) *P*

18. Three rods of same dimensions are arranged as shown in figure they have thermal conductivities K_1, K_2 and K_3 The points *P* and *Q* are maintained at different temperatures for the heat to flow at the same rate along *PRQ* and *PQ* then which of the following option is correct [KCET 2001]

(a) $K_3 = \frac{1}{2}(K_1 + K_2)$
(b) $K_3 = K_1 + K_2$
(c) $K_3 = \frac{K_1K_2}{K_1 + K_2}$
(d) $K_3 = 2(K_1 + K_2)$



19. Two metallic spheres S_1 and S_2 are made of the same material and have identical surface finish. The mass of S_1 is three times that of S_2. Both the spheres are heated to the same high temperature and placed in the same room having lower temperature but are thermally insulated from each other. The ratio of the initial rate of cooling of S_1 to that of S_2 is [IIT 1995]

(a) $1/3$ (b) $(1/3)^{1/3}$

(c) $1/\sqrt{3}$ (d) $\sqrt{3}/1$

20. Three discs *A*, *B* and *C* having radii 2*m*, 4*m*, and 6*m* respectively are coated with carbon black on their other surfaces. The wavelengths corresponding to maximum intensity are 300 *nm*, 400 *nm* and 500 *nm*, respectively. The power radiated by them are Q_1, Q_2 and Q_3 respectively

[IIT-JEE (Screening) 2004]

(a) Q is maximum (b) Q is maximum

(c) Q is maximum (d) $Q = Q = Q$

21. The total energy radiated from a black body source is collected for one minute and is used to heat a quantity of water. The temperature of water is found to increase form $20^o C$ to $20.5^o C$. If the absolute temperature of the black body is doubled and the experiment is repeated with the same quantity of water at $20^o C$, the temperature of water will be [UPSEAT 2004]

(a) $21^o C$ (b) $22^o C$

(c) $24^o C$ (d) $28^o C$

22. A solid sphere and a hollow sphere of the same material and size are heated to the same temperature and allowed to cool in the same surroundings. If the temperature difference between each sphere and its surroundings is T, then

[Manipal MEE 1995]

(a) The hollow sphere will cool at a faster rate for all values of T

(b) The solid sphere will cool at a faster rate for all values of T

(c) Both spheres will cool at the same rate for all values of T

(d) Both spheres will cool at the same rate only for small values of T

23. A solid copper cube of edges $1\,cm$ is suspended in an evacuated enclosure. Its temperature is found to fall from $100^o C$ to $99^o C$ in $100\,s$. Another solid copper cube of edges $2\,cm$, with similar surface nature, is suspended in a similar manner. The time required for this cube to cool from $100^o C$ to $99^o C$ will be approximately [MP PMT 1997]

(a) $25\,s$ (b) $50\,s$

(c) $200\,s$ (d) $400\,s$

24. A body initially at $80^\circ C$ cools to $64^\circ C$ in 5 *minutes* and to $52^\circ C$ in 10 *minutes*. The temperature of the body after 15 *minutes* will be [UPSEAT 2000; Pb. PET 2004]

(a) $42.7^\circ C$ (b) $35^\circ C$

(c) $47^\circ C$ (d) $40^\circ C$

25. A 5*cm* thick ice block is there on the surface of water in a lake. The temperature of air is –10°*C*; how much time it will take to double the thickness of the block

(L = 80 *cal/g*, K = 0.004 *Erg/s-k*, d = 0.92 *g cm*$^{-3}$)

[RPET 1998]

(a) 1 *hour* (b) 191 *hours*

(c) 19.1 *hours* (d) 1.91 *hours*

26. Four identical rods of same material are joined end to end to form a square. If the temperature difference between the ends of a diagonal is $100^o C$, then the temperature difference between the ends of other diagonal will be

[MP PET 1989; RPMT 2002]

(a) $0^o C$

(b) $\frac{100}{l}\,^o C$; where l is the length of each rod

(c) $\frac{100}{2l}\,^o C$

(d) $100^o C$

27. A cylindrical rod with one end in a steam chamber and the other end in ice results in melting of 0.1*gm* of ice per second. If the rod is replaced by another with half the length and double the radius of the first and if the thermal conductivity of material of second rod is $\frac{1}{4}$ that of first, the rate at which ice melts in $gm/\sec$ will be [EAMCET 1987]

(a) 3.2 (b) 1.6

(c) 0.2 (d) 0.1

28. One end of a copper rod of length $1.0\,m$ and area of cross-section 10^{-3} is immersed in boiling water and the other end in ice. If the coefficient of thermal conductivity of copper is $92\,cal/m\text{-}s\text{-}^oC$ and the latent heat of ice is $8 \times 10^4\,cal/kg$, then the amount of ice which will melt in one minute is

[MNR 1994]

(a) $9.2 \times 10^{-3}\,kg$ (b) $8 \times 10^{-3}\,kg$

(c) $6.9 \times 10^{-3}\,kg$ (d) $5.4 \times 10^{-3}\,kg$

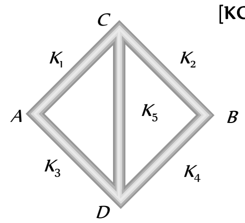
29. An ice box used for keeping eatable cold has a total wall area of $1\,metre^2$ and a wall thickness of $5.0\,cm$. The thermal conductivity of the ice box is $K = 0.01\,joule/metre-^oC$. It is filled with ice at $0^o C$ along with eatables on a day when the temperature is 30°*C*. The latent heat of fusion of ice is $334 \times 10^3\,joules/kg$. The amount of ice melted in one day is ($1\,day = 86{,}400\,seconds$) [MP PMT 1995]

(a) $776\,gms$ (b) $7760\,gms$

(c) $11520\,gms$ (d) $1552\,gms$

30. Five rods of same dimensions are arranged as shown in the figure. They have thermal conductivities K, K, K, K and K. When points A and B are maintained at different temperatures, no heat flows through the central rod if

[KCET 2002]



(a) $K_1 = K_4$ and $K_2 = K_3$

(b) $K_1 K_4 = K_2 K_3$

(c) $K_1 K_2 = K_3 K_4$

(d) $\frac{K_1}{K_4} = \frac{K_2}{K_3}$

31. A hot metallic sphere of radius r radiates heat. It's rate of cooling is

(a) Independent of r (b) Proportional to r

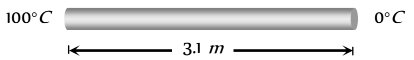
(c) Proportional to r^2 (d) Proportional to $1/r$

32. A solid copper sphere (density ρ and specific heat capacity c) of radius r at an initial temperature 200*K* is suspended inside a chamber whose walls are at almost 0*K*. The time required (in μ s) for the temperature of the sphere to drop to 100 *K* is

(a) $\frac{72}{7}\frac{r\rho c}{\sigma}$ (b) $\frac{7}{72}\frac{r\rho c}{\sigma}$

(c) $\frac{27}{7}\frac{r\rho c}{\sigma}$ (d) $\frac{7}{27}\frac{r\rho c}{\sigma}$

33. One end of a copper rod of uniform cross-section and of length 3.1 *m* is kept in contact with ice and the other end with water at 100°*C*. At what point along it's length should a temperature of 200°*C* be maintained so that in steady state, the mass of ice melting be equal to that of the steam produced in the same interval of time. Assume that the whole system is insulated from the surroundings. Latent heat of fusion of ice and vaporisation of water are 80 *cal/gm* and 540 *cal/gm* respectively



(a) 40 cm from 100°C end (b) 40 cm from 0°C end

(c) 125 cm from 100°C end (d) 125 cm from 0°C end

34. A sphere and a cube of same material and same volume are heated upto same temperature and allowed to cool in the same surroundings. The ratio of the amounts of radiations emitted will be

(a) 1 : 1 (b) $\frac{4\pi}{3} : 1$

(c) $\left(\frac{\pi}{6}\right)^{1/3} : 1$ (d) $\frac{1}{2}\left(\frac{4\pi}{3}\right)^{2/3} : 1$

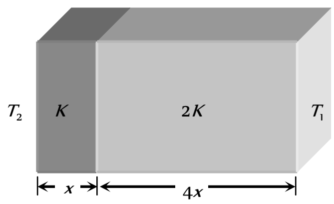
35. The temperature of the two outer surfaces of a composite slab, consisting of two materials having coefficients of thermal conductivity K and $2K$ and thickness x and $4x$, respectively are T_2 and T_1 ($T_2 > T_1$). The rate of heat transfer through the slab, in a steady state is $\left(\frac{A(T_2 - T_1)K}{x}\right)f$, with f which equal to**[AIEEE 2004]**

(a) 1

(b) $\frac{1}{2}$

(c) $\frac{2}{3}$

(d) $\frac{1}{3}$



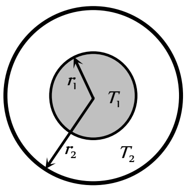
36. The figure shows a system of two concentric spheres of radii r_1 and r_2 and kept at temperatures T_1 and T_2 respectively. The radial rate of flow of heat in a substance between the two concentric spheres is proportional to **[AIEEE 2005]**

(a) $\frac{r_1 r_2}{(r_1 - r_2)}$

(b) $(r_2 - r_1)$

(c) $(r_2 - r_1)(r_1 r_2)$

(d) $\ln\left(\frac{r_2}{r_1}\right)$



37. Four rods of identical cross-sectional area and made from the same metal form the sides of square. The temperature of two diagonally opposite points and T and $\sqrt{2}\ T$ respective in the steady state. Assuming that only heat conduction takes place, what will be the temperature difference between other two points

(a) $\frac{\sqrt{2}+1}{2}T$ (b) $\frac{2}{\sqrt{2}+1}T$

(c) 0 (d) None of these

Graphical Questions

1. The graph. Shown in the adjacent diagram, represents the variation of temperature (T) of two bodies, x and y having same surface area, with time (t) due to the emission of radiation. Find the correct relation between the emissivity (e) and absorptivity (a) of the two bodies

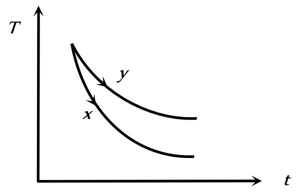
[IIT-JEE (Screening) 2003]

(a) $e_x > e_y$ & $a_x < a_y$

(b) $e_x < e_y$ & $a_x > a_y$

(c) $e_x > e_y$ & $a_x > a_y$

(d) $e_x < e_y$ & $a_x < a_y$



2. The plots of intensity versus wavelength for three black bodies at temperatures T_1, T_2 and T_3 respectively are as shown. Their temperature are such that

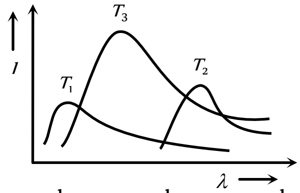
[IIT-JEE (Screening) 2000]

(a) $T_1 > T_2 > T_3$

(b) $T_1 > T_3 > T_2$

(c) $T_2 > T_3 > T_1$

(d) $T_3 > T_2 > T_1$



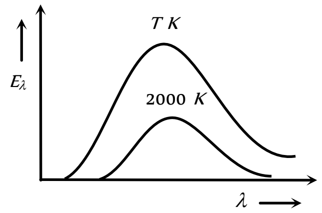
3. The adjoining diagram shows the spectral energy density distribution E_λ of a black body at two different temperatures. If the areas under the curves are in the ratio 16 : 1, the value of temperature T is **[DCE 1999]**

(a) 32,000 K

(b) 16,000 K

(c) 8,000 K

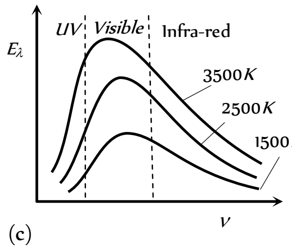
(d) 4,000 K



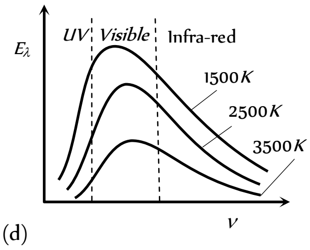
[BCECE 2005]

4. Following graph shows the correct variation in intensity of heat radiations by black body and frequency at a fixed temperature

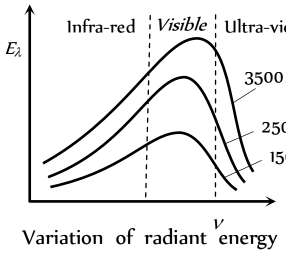
(a)



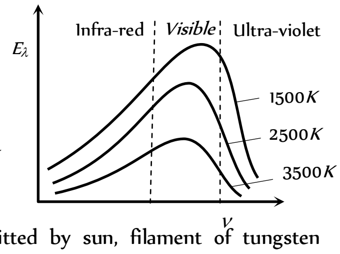
(b)



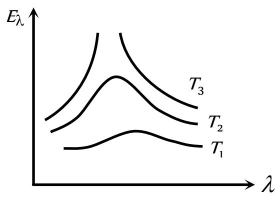
(c)



(d)



5. Variation of radiant energy emitted by sun, filament of tungsten lamp and welding arc as a function of its wavelength is shown in figure. Which of the following option is the correct match



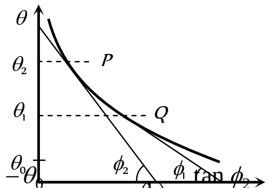
(a) Sun- T_1, tungsten filament $-T_2$, welding arc $-T_3$

(b) Sun $-T_2$, tungsten filament $-T_1$, welding arc $-T_3$

(c) Sun $-T_3$, tungsten filament $-T_2$, welding arc $-T_1$

(d) Sun $-T_1$, tungsten filament $-T_3$, welding arc $-T_2$

6. A body cools in a surrounding which is at a constant temperature of θ_0. Assume that it obeys Newton's law of cooling. Its temperature θ is plotted against time *t*. Tangents are drawn to the curve at the points $P(\theta=\theta_1)$ and $Q(\theta=\theta_2)$. These tangents meet the time axis at angles of ϕ_2 and ϕ_1, as shown

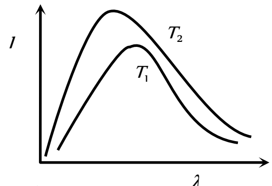


(a) $\frac{\tan\phi_2}{\tan\phi_1}=\frac{\theta_1-\theta_0}{\theta_2-\theta_0}$ (b) $\frac{\tan\phi_2}{\tan\phi_1}=\frac{\theta_2-\theta_0}{\theta_1-\theta_0}$

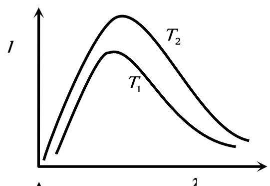
(c) $\frac{\tan\phi_1}{\tan\phi_2}=\frac{\theta_1}{\theta_2}$ (d) $\frac{\tan\phi_1}{\tan\phi_2}=\frac{\theta_2}{\theta_1}$

7. Shown below are the black body radiation curves at temperatures T_1 and T_2 ($T_2>T_1$). Which of the following plots is correct

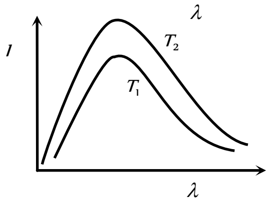
(a)



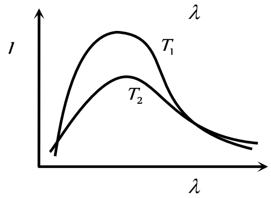
(b)



(c)



(d)



[IIT-JEE (Screening) 2005]

8. The spectrum of a black body at two temperatures 27°C and 327°C is shown in the figure. Let A_1 and A_2 be the areas under the two curves respectively. The value of $\frac{A_2}{A_1}$ is

(a) 1 : 16

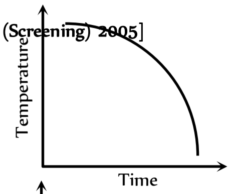
(b) 4 : 1

(c) 2 : 1

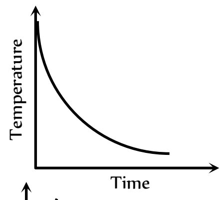
(d) 16 : 1

9. A block of metal is heated to a temperature much higher than the room temperature and allowed to cool in a room free from air currents. Which of the following curves correctly represents the rate of cooling [Manipal MEE 1995]

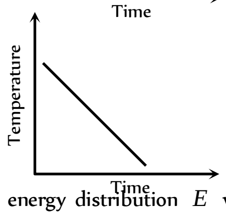
(a)



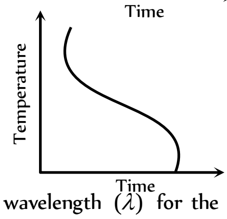
(b)



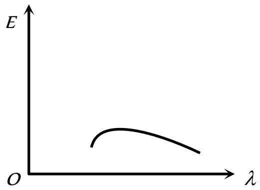
(c)



(d)



10. The energy distribution E with the wavelength (λ) for the black body radiation at temperature T *Kelvin* is shown in the figure. As the temperature is increased the maxima will



(a) Shift towards left and become higher

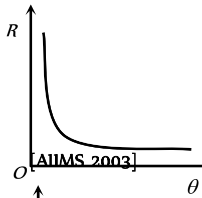
(b) Rise high but will not shift

(c) Shift towards right and become higher

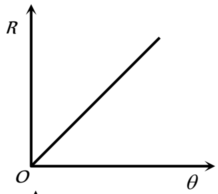
(d) Shift towards left and the curve will become broader

11. For a small temperature difference between the body and the surroundings the relation between the rate of loss heat R and the temperature of the body is depicted by [AIIMS 2003]

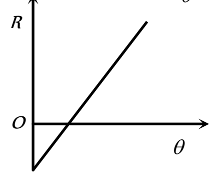
(a)



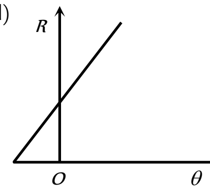
(b)



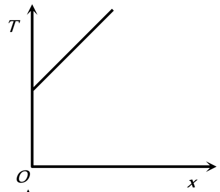
(c)

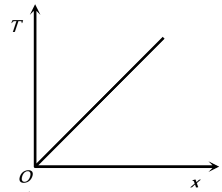


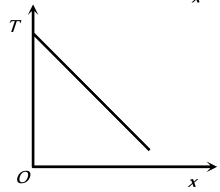
(d)

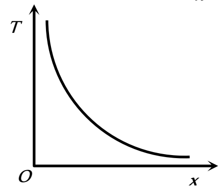


12. Heat is flowing through a conductor of length l from $x = 0$ to $x = l$. If its thermal resistance per unit length is uniform, which of the following graphs is correct

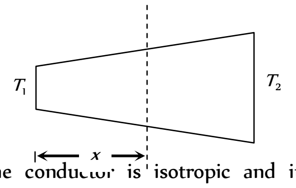
(a) 

(b) 

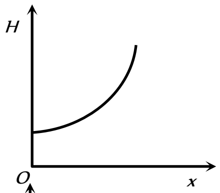
(c) 

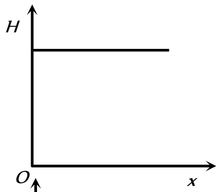
(d) 

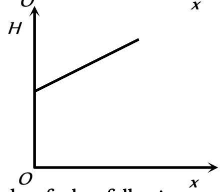
13. Radius of a conductor increases uniformly from left end to right end as shown in fig.

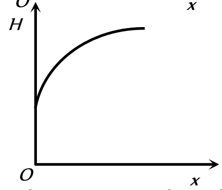


Material of the conductor is isotropic and its curved surface is thermally isolated from surrounding. Its ends are maintained at temperatures T_1 and T_2 ($T_1 > T_2$): If, in steady state, heat flow rate is equal to H, then which of the following graphs is correct

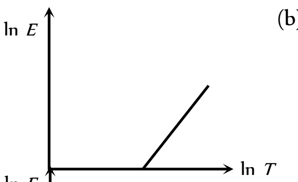
(a) 

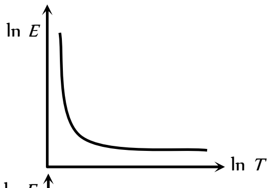
(b) 

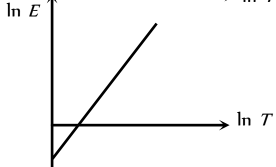
(c) 

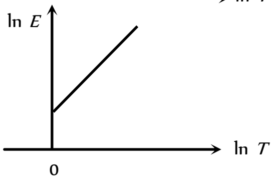
(d) 

14. Which of the following graphs correctly represents the relation between ln E and ln T where E is the amount of radiation emitted per unit time from unit area of a body and T is the absolute temperature **[DCE 2002]**

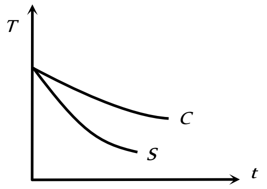
(a) 

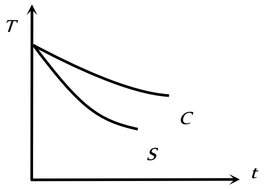
(b) 

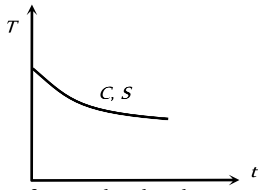
(c) 

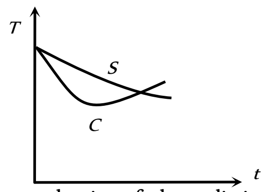
(d) 

15. A hollow copper sphere S and a hollow copper cube C, both of negligible thin walls of same area, are filled with water at 90°C and allowed to cool in the same environment. The graph that correctly represents their cooling is

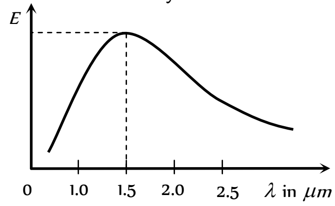
(a) 

(b) 

(c) 

(d) 

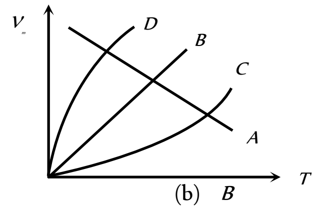
16. In the figure, the distribution of energy density of the radiation emitted by a black body at a given temperature is shown. The possible temperature of the black body is



(a) 1500 K (b) 2000 K

(c) 2500 K (d) 3000 K

17. Which of the following is the $\nu_m = T$ graph for a perfectly black body (ν_m =maximum frequency of radiation) **[RPMT 1996]**



(a) A (b) B

(c) C (d) D

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : A body that is a good radiator is also a good absorber of radiation at a given wavelength.
Reason : According to Kirchoff's law the absorptivity of a body is equal to its emissivity at a given wavelength. [AIIMS 2005]

2. Assertion : For higher temperature, the peak emission wavelength of a black body shifts to lower wavelengths.
Reason : Peak emission wavelength of a blackbody is proportional to the fourth power of temperature. [AIIMS 2005]

3. Assertion : Temperatures near the sea coast are moderate.
Reason : Water has a high thermal conductivity. [AIIMS 2003]

4. Assertion : It is hotter over the top of a fire than at the same distance on the sides.
Reason : Air surrounding the fire conducts more heat upwards. [AIIMS 2003]

5. Assertion : Bodies radiate heat at all temperatures.
Reason : Rate of radiation of heat is proportional to the fourth power of absolute temperature. [AIIMS 1999, 2002]

6. Assertion : Woolen clothes keep the body warm in winter.
Reason : Air is a bad conductor of heat. [AIIMS 2002]

7. Assertion : The equivalent thermal conductivity of two plates of same thickness in contact (series) is less than the smaller value of thermal conductivity.
Reason : For two plates of equal thickness in contact (series) the equivalent thermal conductivity is given by [AIIMS 1997]

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}$$

8. Assertion : A hollow metallic closed container maintained at a uniform temperature can act as a source of black body radiation.
Reason : All metals acts as a black body [AIIMS 1996]

9. Assertion : If the temperature of a star is doubled then the rate of loss of heat from it becomes 16 times.
Reason : Specific heat varies with temperature. [AIIMS 1996]

10. Assertion : The radiation from the sun's surface varies as the fourth power of its absolute temperature.
Reason : The sun is not a black body. [AIIMS 1999]

11. Assertion : Blue star is at high temperature than red star.
Reason : Wein's displacement law states that $T\propto(1/\lambda_m)$. [AIIMS 2002]

12. Assertion : The S.I. unit of thermal conductivity is watt $m^{-1}\ K^{-1}$.
Reason : Thermal conductivity is a measure of ability of the material to allow the passage of heat through it.

13. Assertion : A brass tumbler feels much colder than a wooden tray on a chilly day.
Reason : The thermal conductivity of brass is less than that of wood.

14. Assertion : Like light radiations, thermal radiations are also electromagnetic radiation.
Reason : The thermal radiations require no medium for propagation.

15. Assertion : Snow is better insulator than ice.
Reason : Snow contain air packet and air is good insulator of heat.

16. Assertion : Water can be boiled inside satellite by convection.
Reason : Convection is the process in which heat is transmitted from a place of higher temperature to a place of lower temperature by means of particles with their migrations from one place to another.

17. Assertion : The absorbance of a perfect black body is unity.
Reason : A perfect black body when heated emits radiations of all possible wavelengths at that temperature.

18. Assertion : A man would feel iron or wooden balls equally hot at $98.4°F$.
Reason : At $98.4°F$ both iron and wood have same thermal conductivity.

19. Assertion : As temperature of a black body is raised, wavelength corresponding to maximum energy reduces.
Reason : Higher temperature would mean higher energy and hence higher wavelength.

20. Assertion : All black coloured objects are considered black bodies.
Reason : Black colour is a good absorber of heat.

21. Assertion : Greater is the coefficient of thermal conductivity of a material, smaller is the thermal resistance of a rod of that material.
Reason : Thermal resistance is the ratio of temperature difference between the ends of the conductor and rate of flow of heat.

22. Assertion : Radiation is the speediest mode of heat transfer.
Reason : Radiation can be transmitted in zig-zag motion.

23. Assertion : Two thin blankets put together are warmer than a single blanket of double the thickness.

Reason : Thickness increases because of air layer enclosed between the two blankets.

24. Assertion : Animals curl into a ball, when they feel very cold.

Reason : Animals by curling their body reduces the surface area.

Answers

Conduction

1	a	2	d	3	d	4	a	5	d
6	d	7	d	8	d	9	c	10	d
11	c	12	a	13	a	14	b	15	d
16	b	17	c	18	c	19	a	20	a
21	a	22	a	23	b	24	d	25	a
26	b	27	b	28	d	29	d	30	b
31	b	32	c	33	b	34	b	35	a
36	d	37	d	38	b	39	a	40	c
41	b	42	c	43	c	44	b	45	c
46	a	47	c	48	b	49	b	50	a
51	c	52	b	53	b	54	c	55	a
56	a	57	a	58	c	59	c	60	a
61	c	62	d	63	b	64	b	65	b
66	c	67	b	68	b				

Convection

1	c	2	a	3	c	4	a	5	b
6	a	7	c	8	b	9	a	10	d
11	a	12	c	13	c				

Radiation (General, Kirchoff's law, Black body)

1	b	2	a	3	c	4	d	5	d
6	c	7	d	8	d	9	c	10	b
11	b	12	a	13	c	14	a	15	d
16	b	17	a	18	b	19	b	20	c
21	b	22	c	23	c	24	a	25	b
26	b	27	a	28	c	29	a	30	d
31	d	32	c	33	a	34	c	35	a
36	d	37	c	38	b				

Radiation (Wein's law)

1	a	2	c	3	d	4	c	5	a
6	c	7	d	8	c	9	c	10	b
11	a	12	b	13	b	14	c	15	b
16	a	17	b	18	a	19	b	20	a
21	c	22	a	23	b	24	b	25	c
26	b	27	b	28	b	29	a	30	b

Radiation (Stefan's law)

1	c	2	c	3	a	4	a	5	d
6	a	7	c	8	b	9	b	10	b
11	b	12	c	13	c	14	c	15	c
16	b	17	d	18	d	19	c	20	d
21	d	22	d	23	a	24	d	25	d
26	a	27	a	28	b	29	a	30	a
31	d	32	d	33	d	34	c	35	a
36	c	37	c	38	c	39	a	40	c
41	b	42	d	43	c	44	d	45	a
46	b	47	a	48	a	49	a	50	a
51	a	52	d	53	b	54	b	55	b
56	c								

Radiation (Newton's Law of Cooling)

1	b	2	c	3	a	4	a	5	b
6	c	7	c	8	c	9	d	10	b
11	b	12	d	13	c	14	c	15	d
16	c	17	a	18	b	19	c	20	b
21	a	22	b	23	d	24	c	25	b
26	b	27	d	28	d	29	a	30	b
31	d	32	d	33	a	34	c	35	a
36	b	37	b						

Critical Thinking Questions

1	a	2	b	3	d	4	c	5	b
6	a	7	a	8	b	9	b	10	a
11	a	12	b	13	c	14	b	15	ab
16	d	17	b	18	c	19	b	20	b
21	d	22	a	23	c	24	a	25	c
26	a	27	c	28	c	29	d	30	b
31	d	32	b	33	a	34	c	35	d
36	a	37	c						

Graphical Questions

1	c	2	b	3	d	4	c	5	c
6	b	7	a	8	d	9	b	10	a
11	c	12	c	13	b	14	d	15	c
16	b	17	b						

Assertion & Reason

1	a	2	c	3	b	4	c	5	e
6	a	7	d	8	c	9	b	10	c

11	a	12	b	13	c	14	b	15	a
16	e	17	b	18	c	19	c	20	e
21	b	22	c	23	c	24	a		

Answers and Solutions

Conduction

1. (a) Cu is better conductor than Al and Ag is better conductor than Cu. Hence conductivity in increasing order is $Al < Cu < Ag$.

2. (d) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

$\because \frac{r^2}{l}$ is maximum in option (d), hence it will conduct more heat.

3. (d) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{d^2}{l}$ (d = Diameter of rod)

$\Rightarrow \frac{(Q/t)_1}{(Q/t)_2} = \left(\frac{d_1}{d_2}\right)^2 \times \frac{l_2}{l_1} = \left(\frac{1}{2}\right)^2 \times \left(\frac{1}{2}\right) = \frac{1}{8}$

4. (a) $\frac{Q}{t} = \frac{KA\,\Delta\theta}{l} = \frac{\Delta\theta}{(l/KA)} = \frac{\Delta\theta}{R}$ (R = Thermal resistance)

$\Rightarrow t \propto R$ ($\because$ Q and $\Delta\theta$ are same)

$\Rightarrow \frac{t_P}{t_S} = \frac{R_P}{R_S} = \frac{R/2}{2R} = \frac{1}{4} \Rightarrow t_P = \frac{t_S}{4} = \frac{4}{4} = 1\text{ min}$.

(Series resistance $R_S = R_1 + R_2$ and parallel resistance $R_P = \frac{R_1 R_2}{R_1 + R_2}$)

5. (d) For cooking utensils, low specific heat is preferred for it's material as it should need less heat to raise it's temperature and it should have high conductivity, because, it should transfer heat quickly.

6. (d) In steady state there is no absorption of heat in any position. Heat passes on or is radiated from it's surface. Therefore, in steady state the temperature of the body does not change with time but can be different at different points of the body.

7. (d) It is the property of material.

8. (d) Because steady state has been reached.

9. (c) $\frac{Q_1}{t} = \frac{KA(90-60)}{0.6} = 50\,KA$

and $\frac{Q_2}{t} = \frac{KA(150-110)}{0.8} = 50\,KA$

10. (d) Given $A_1 = A_2$ and $\frac{K_1}{K_2} = \frac{5}{4}$

$\because R_1 = R_2 \Rightarrow \frac{l_1}{K_1 A} = \frac{l_2}{K_2 A} \Rightarrow \frac{l_1}{l_2} = \frac{K_1}{K_2} = \frac{5}{4}$.

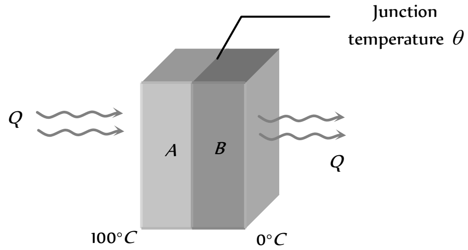
11. (c) $\frac{\Delta Q}{\Delta t} = \frac{KA\,\Delta\theta}{\Delta x} \Rightarrow$ Thermal gradient $\frac{\Delta\theta}{\Delta x}$

$= \frac{(\Delta Q/\Delta t)}{KA} = \frac{10}{0.4} = 25°C/cm$

12. (a) It is given that $\frac{K_1}{K_2} = \frac{1}{3} \Rightarrow K_1 = K$ then $K_2 = 3K$

the temperature of the junction in contact

$\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2} = \frac{1\times 100 + 3\times 0}{1+3} = \frac{100}{4} = 25°C$



13. (a) $Q = \frac{KA(\theta_1 - \theta_2)t}{l}$; in both the cases, A, l and $(\theta_1 - \theta_2)$ are same so Kt = constant $\Rightarrow \frac{K_1}{K_2} = \frac{t_1}{t_2} = \frac{30}{20} = \frac{3}{2} = 1.5$.

14. (b) $\left(\frac{Q}{t}\right)_1 = \frac{K_1A_1(\theta_1-\theta_2)}{l}$ and $\left(\frac{Q}{t}\right)_2 = \frac{K_2A_2(\theta_1-\theta_2)}{l}$

given $\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 \Rightarrow K_1A_1 = K_2A_2$

15. (d) In variable state $\frac{Q}{t} \propto K$ and $\frac{Q}{t} \propto \frac{1}{\rho c} \Rightarrow \frac{Q}{t} \propto \frac{K}{\rho c}$

(K = thermal conductivity, ρ = density, c = specific heat)

16. (b) $K_1 : K_2 = l_1^2 : l_2^2 \Rightarrow \frac{l_1}{l_2} = \sqrt{\frac{K_1}{K_2}} = \sqrt{\frac{10}{9}} = \frac{\sqrt{10}}{3}$

17. (c) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow 50 = \frac{5\times 20\ K}{0.4} \Rightarrow K = \frac{1}{5} = 0.2$

18. (c)

19. (a) Thermal resistance

$= \frac{l}{KA} = \left[\frac{L}{MLT^{-3}K^{-1}\times L^2}\right] = [M^{-1}L^{-2}T^3K]$

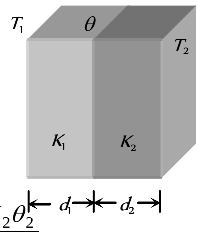
20. (a) When a piece of glass is heated, due to low thermal conductivity it does not conduct heat fast. Hence unequal expansion of it's layers crack the glass.

21. (a) In series both walls have same rate of heat flow. Therefore

$\frac{dQ}{dt} = \frac{K_1A(T_1-\theta)}{d_1} = \frac{K_2A(\theta-T_2)}{d_2}$

$\Rightarrow K_1d_2(T_1-\theta) = K_2d_1(\theta-T_2)$

$\Rightarrow \theta = \frac{K_1d_2T_1+K_2d_1T_2}{K_1d_2+K_2d_1}$



22. (a) Temperature of interface $\theta = \frac{K_1\theta_1+K_2\theta_2}{K_1+K_2}$

$(\because \frac{K_1}{K_2} = \frac{1}{4} \Rightarrow$ If $K_1 = K$ then $K_2 = 4K)$

$\Rightarrow \theta = \frac{K\times 0+4K\times 100}{5K} = 80°C$

23. (b) $\frac{\theta_1-\theta_2}{l} = 80 \Rightarrow \frac{30-\theta_2}{0.5} = 80 \Rightarrow \theta_2 = -10^oC$

24. (d) $\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$; when $K = \infty$, $\frac{d\theta}{dx} = 0$

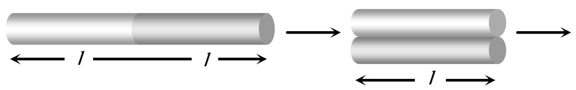
i.e. θ is independent of x *i.e.* constant or uniform.

25. (a) Air is poor conductor of heat.

26. (b)

27. (b)

28. (d) Let the heat transferred be Q.



When rods are joined end to end. Heat transferred by each rod $= Q = \frac{KA\Delta\theta}{l}\times 12$ .....(i)

When rods are joined lengthwise, $Q = \frac{KA\Delta\theta}{2l}t$ .....(ii)

From equation (i) and (ii) we get $t = 48\ s$

29. (d) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_B}\right)^2 = \frac{1}{4} \Rightarrow K_A = \frac{K_B}{4}$

30. (b) Thermal conductivity of composite plate

$K_{eq} = \frac{2K_1K_2}{K_1+K_2} = \frac{2\times 2\times 3}{2+3} = \frac{12}{5} = 2.4$

31. (b) $Q \propto \frac{A}{l} \propto \frac{r^2}{l} \Rightarrow \frac{Q_2}{Q_1} = \frac{r_2^2}{r_1^2}\times\frac{l_1}{l_2}$

$\Rightarrow \frac{Q_2}{Q_1} = \frac{4}{1}\times\frac{1}{2} \Rightarrow Q_2 = 2Q_1$

32. (c) $\frac{Q}{At} = K\frac{\Delta\theta}{l} \Rightarrow K\frac{\Delta\theta}{l}$ = constant $\Rightarrow \frac{\Delta\theta}{l} \propto \frac{1}{K}$

Hence If $K_c > K_m > K_g$, then

$\left(\frac{\Delta\theta}{l}\right)_c < \left(\frac{\Delta\theta}{l}\right)_m < \left(\frac{\Delta\theta}{l}\right)_g \Rightarrow X_c < X_m < X_g$

because higher K implies lower value of the temperature gradient.

33. (b) In series $R_{eq} = R_1 + R_2 \Rightarrow \frac{2l}{K_{eq}A} = \frac{l}{K_1A} + \frac{l}{K_2A}$

$\Rightarrow \frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} \Rightarrow K_{eq} = \frac{2K_1K_2}{K_1+K_2}$

34. (b) $\frac{dQ}{dt} = KA\frac{d\theta}{dl} \Rightarrow \frac{dQ}{dt} \propto \frac{d\theta}{dl}$ (Temperature gradient)

35. (a) $\frac{dQ}{dt} = \frac{K(\pi r^2)d\theta}{dl} \Rightarrow \frac{\left(\frac{dQ}{dt}\right)_s}{\left(\frac{dQ}{dt}\right)_l} = \frac{K_s\times r_s^2\times l_l}{K_l\times r_l^2\times l_s} = \frac{1}{2}\times\frac{1}{4}\times\frac{2}{1}$

$\Rightarrow \left(\frac{dQ}{dt}\right)_s = \frac{\left(\frac{dQ}{dt}\right)_l}{4} = \frac{4}{4} = 1$

36. (d) $Q = \frac{KA(\Delta\theta)t}{l}$

$\because$ Q and $\Delta\theta$ are same for both spheres hence

$K \propto \frac{l}{At} \propto \frac{l}{r^2t} \Rightarrow \frac{K_{\text{larger}}}{K_{\text{smaller}}} = \frac{l_l}{l_s}\times\left(\frac{r_s}{r_l}\right)^2\times\frac{t_s}{t_l}$. It is given that $r_l = 2r_s$, $l_l = \frac{1}{4}l_s$ and $t_1 = 25$ *min*, $t_s = 16$ *min.*

$\Rightarrow \frac{K_{\text{larger}}}{K_{\text{smaller}}} = \left(\frac{1}{4}\right)\left(\frac{1}{2}\right)^2\times\frac{16}{25} = \frac{1}{25}$

37. (d) $\frac{Q}{t} = \frac{KA(\Delta\theta)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

$\Rightarrow \frac{(Q/t)_1}{(Q/t)_2} = \left(\frac{r_1}{r_2}\right)^2\times\frac{l_2}{l_1} = \left(\frac{2}{1}\right)^2\times\left(\frac{4}{1}\right) = \frac{16}{1}$

38. (b) Temperature of interface $\theta = \frac{K_1\theta_1+K_2\theta_2}{K_1+K_2}$

where $K_1 = 2K$ and $K_2 = 3K$ $\left(\because \frac{K_1}{K_2} = \frac{2}{3}\right)$

$\Rightarrow \theta = \frac{2K\times 100+3K\times 0}{2K+3K} = \frac{200K}{5K} = 40°C$

39. (a) $\frac{K_1}{K_2} = \frac{l_1^2}{l_2^2}$ $\therefore K_2 = \frac{K_1 l_2^2}{l_1^2} = \frac{0.92 \times (4.2)^2}{(8.4)^2} = 0.23$

40. (c) Mud is bad conductor of heat. So it prevents the flow of heat between surroundings and inside.

41. (b) Temperature gradient $= \frac{100-20}{20} = 4°C/cm$

temperature at centre $= 100 - 4 \times 10 = 60°C$

42. (c) Temperature of interface

$$\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1} = \frac{K \times 0 \times 2 + 3K \times 100 \times 1}{K \times 2 + 3K \times 1}$$

$$= \frac{300K}{5K} = 60°C$$

43. (c) $\Delta\theta = \frac{Q \times l}{KAt} = \frac{4000 \times 0.1}{400 \times 10^{-2}} = 100^o C$

44. (b) Heat passes quickly from the body into the metal which leads to a cold feeling.

45. (c) Heat energy always flow from higher temperature to lower temperature. Hence, temperature difference *w.r.t.* length (temperature gradient) is required to flow heat from one part of a solid to other part.

46. (a) When the temperature of an object is equal to that of human body, no heat is transferred from the object to body and vice versa, Therefore block of wood and block of metal feel equally cold and hot if they have same temperature as human body.

47. (c)

48. (b) Temperature of water just below the lower surface of ice layer is $0°C$.

49. (b) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} = \frac{100 \times 100 \times 10^{-4}(100-0)}{1}$

$$\Rightarrow \frac{Q}{t} = 100\ Joule/sec = 6 \times 10^3\ Joule/min$$

50. (a) Temperature of interface $\theta = \frac{K_1\theta_1 l_2 + K_2\theta_2 l_1}{K_1 l_2 + K_2 l_1}$

It is given that $K_{Cu} = 9K_S$. So if $K_S = K_1 = K$ then

$K_{Cu} = K_2 = 9K$

$$\Rightarrow \theta = \frac{9K \times 100 \times 6 + K \times 0 \times 18}{9K \times 6 + K \times 18} = \frac{5400K}{72K} = 75°C$$

51. (c) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$

[As $(\theta_1 - \theta_2)$ and K are constants]

$$\Rightarrow \frac{\left(\frac{Q}{t}\right)_1}{\left(\frac{Q}{t}\right)_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1} = \frac{4}{9} \times \frac{2}{1} = \frac{8}{9}$$

52. (b) In parallel combination equivalent conductivity

$$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2} \text{ (As } A_1 = A_2\text{)}$$

53. (b) $Q = \frac{KA(\theta_1 - \theta_2)}{l} t \Rightarrow K_1 t_1 = K_2 t_2 \Rightarrow \frac{K_1}{K_2} = \frac{t_2}{t_1} = \frac{35}{20} = \frac{7}{4}$

(As Q, l, A and $(\theta_1 - \theta_2)$ are same)

54. (c) A lake cools from the surface down. Above $4°C$, the cooled water at the surface flows to the bottom because of it's greater density. But when the surface temperature drops below $4°C$ (here it is $2°C$), the water near the surface is less dense than the warmer water below. Hence the downward flow ceases, the water at the bottom remains at $4°C$ until nearly the entire lake, is frozen.

55. (a) Temperature gradient $\frac{d\theta}{dx} = \frac{(125-25)^o C}{50\ cm} = 2°C/cm$

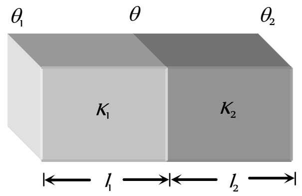
56. (a) $K \propto l^2 \Rightarrow \frac{K_1}{K_2} = \frac{l_1^2}{l_2^2} = \left(\frac{10}{25}\right)^2 = \frac{1}{6.25}$

57. (a) Thermal resistance of Cu is lesser than the thermal resistance of steel. Hence only in option (*a*) thermal resistance is minimum so heat current is maximum.

58. (c) At steady state, rate of heat flow for both blocks will be same

i.e., $\frac{K_1A(\theta_1 - \theta)}{l_1} = \frac{K_2A(\theta - \theta_2)}{l_2}$ (given $l_1 = l_2$)

$$\Rightarrow K_1A(\theta_1 - \theta) = K_2A(\theta - \theta_2) \Rightarrow \theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$$



59. (c) $K = \frac{2K_1K_2}{K_1 + K_2} = \frac{2.K.2K}{K + 2K} = \frac{4}{3}K$

60. (a) Temperature of interface $\theta = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

It is given that $\frac{K_1}{K_2} = \frac{5}{3} \Rightarrow K_1 = 5K$ and $K_2 = 3K$

$$\theta = \frac{5K \times 100 + 3K \times 20}{5K + 3K} = \frac{560K}{8K} = 70°C$$

61. (c) In winter, the temperature of surrounding is low compared to the body temperature $(37.4^o C)$. Since woolen clothes are bad conductors of heat, so they keep the body warm.

62. (d) Temperature of interface $T = \frac{K_1\theta_1 + K_2\theta_2}{K_1 + K_2}$

$$= \frac{300 \times 100 + 200 \times 0}{300 + 200} = 60°C$$

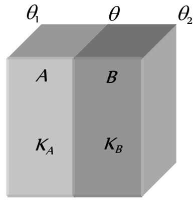
63. (b) Rate of heat flow $\left(\frac{Q}{t}\right) = \frac{k\pi r^2(\theta_1 - \theta_2)}{L} \propto \frac{r^2}{L}$

$$\therefore \frac{Q_1}{Q_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{l_2}{l_1}\right) = \left(\frac{1}{2}\right)^2 \times \left(\frac{2}{1}\right) = \frac{1}{2} \Rightarrow Q_2 = 2Q_1$$

64. (b) $\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow 6000 = \frac{200 \times 0.75 \times \Delta\theta}{1}$

$$\therefore \Delta\theta = \frac{6000 \times 1}{200 \times 0.75} = 40°C$$

65. (b) In series rate of flow of heat is same



$\Rightarrow \dfrac{K_A A(\theta_1 - \theta)}{l} = \dfrac{K_B A(\theta - \theta_2)}{l}$

$\Rightarrow 3K_B(\theta_1 - \theta) = K_B(\theta - \theta_2)$

$\Rightarrow 3(\theta_1 - \theta) = (\theta - \theta_2)$

$\Rightarrow 3\theta_1 - 3\theta = \theta - \theta_2 \Rightarrow 4\theta_1 - 4\theta = \theta_1 - \theta_2$

$\Rightarrow 4(\theta_1 - \theta) = (\theta_1 - \theta_2)$

$\Rightarrow 4(\theta_1 - \theta) = 20 \Rightarrow (\theta_1 - \theta) = 5°C$

66. (c) Let θ be temperature middle point C and in series rate of heat flow is same $\Rightarrow K(2A)(100 - \theta) = KA(\theta - 70)$

$\Rightarrow 200 - 2\theta = \theta - 70 \Rightarrow 3\theta = 270 \Rightarrow \theta = 90°C$

67. (b) Thermal resistances are same

$\Rightarrow \dfrac{l_1}{K_1 A_1} = \dfrac{l_2}{K_2 A_2} \Rightarrow \dfrac{l_1}{K_1} = \dfrac{l_2}{K_2}$ $(\because A_1 = A_2)$

$\Rightarrow \dfrac{l_1}{l_2} = \dfrac{K_1}{K_2} = \dfrac{5}{3}$

68. (b) $\dfrac{Q}{t} \propto \dfrac{r^2}{l}$; from the given options, option (b) has higher value of $\dfrac{r^2}{l}$.

Convection

1. (c) Convection significantly transferring heat upwards (Gravity effect).

2. (a) Heat flows from hot air to cold body so person feels comfort.

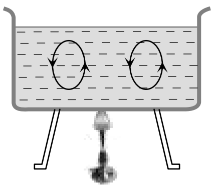
3. (c) No flow of heat by convection in vacuum.

4. (a)

5. (b) Density of hot air is lesser than the density of cold air so hot air rises up.

6. (a)

7. (c) In convection hot particles moves up ward (due to low density) and light particle moves downward (due to high density).



8. (b)

9. (a) Natural convection arises due to difference of density at two places and is a consequence of gravity.

10. (d)

11. (a) Convection is not possible in weightlessness. So the liquid will be heated through conduction.

12. (c) In forced convection rate of loss of heat $\dfrac{Q}{t} \propto A(T - T_0)$

13. (c)

Radiation (General, Kirchoff's law, Black body)

1. (b) Because of uneven surfaces of mountains, most of it's parts remain under shadow. So, most of the mountains. Land is not heated up by sun rays. Besides this, sun rays fall slanting on the mountains and are spread over a larger area. So, the heat received by the mountains top per unit area is less and they are less heated compared to planes (Foot).

2. (a) The velocity of heat radiation in vacuum is equal to that of light.

3. (c) Radiation is the fastest mode of heat transfer.

4. (d) A thermopile is a sensitive instrument, used for detection of heat radiation and measurement of their intensity.

5. (d) The polished surface reflects all the radiation.

6. (c) Heat radiations are electromagnetic waves of high wavelength.

7. (d) When element and surrounding have same temperature. There will be no temperature difference, hence heat will not flow from the filament and it's temperature remains constant.

8. (d) Every body at all time, at all temperatures emits radiation (except at $T = 0$). The radiation emitted by the human body is in the infra-red region.

9. (c)

10. (b) Infrared radiations are detected by pyrometer.

11. (b)

12. (a) In vacuum heat flows by the radiation mode only.

13. (c) Good absorbers are always good emitters of heat.

14. (a) A perfectly black body is a good absorber of radiations falls on it. So it's absorptive power is 1.

15. (d) According to Kirchoff's law in spectroscopy. If a substance emit certain wavelengths at high temperature, it absorbs the same wavelength at comparatively lower temperature.

16. (b) A person with dark skin absorbs more heat radiation and feels more heat. It also radiates more heat and feels more cold.

17. (a) For a black body emissivity = absorptive power.

18. (b) Highly polished mirror like surfaces are good reflectors, but not good radiators.

19. (b) Black cloth is a good absorber of heat, therefore ice covered by black cloth melts more as compared to that covered by white cloth.

20. (c) According to Kirchoff's law, the ratio of emissive power to absorptive power is same for all bodies is equal to the emissive power of a perfectly black body *i.e.,*

$\left(\dfrac{e}{a}\right)_{body} = E_{\text{Blackbody}}$ for a particular wave length

$\left(\dfrac{e_\lambda}{a_\lambda}\right)_{\text{body}} = (E_\lambda)_{\text{Blackbody}} \Rightarrow e_\lambda = a_\lambda E_\lambda$

21. (b) Absorption power $= \dfrac{\text{Heat absorbed}}{\text{Total heat given}}$

22. (c) Because Planck's law explains the distribution of energy correctly at low temperature as well as at high temperature.

23. (c)

24. (a) The black spot on heating absorbs radiations and so emits them in the dark room while the polished shining part reflects radiation and absorbs nothing and so does not emit radiations and becomes invisible in the dark.

25. (b)

26. (b) When the light emitted from the sun's photosphere passes through it's outer part Chromosphere, certain wave lengths are absorbed. In the spectrum of sunlight, a large number of dark lines are seen called Fraunhoffer lines.

27. (a) As for a black body rate of absorption of heat is more. Hence thermometer A shows faster rise in temperature but finally both will acquire the atmospheric temperature.

28. (c) According to Kirchoff's law, a good emitter is also a good absorber.

29. (a) Red and green colours are complementary to each other. When red glass is heated it absorbs green light strongly, hence according to Kirchoff's law, the emissive power of red glass should be maximum for green light. That's why when this heated red glass is taken in dark room it strongly emits green light and looks greenish.

30. (d) Black and rough surfaces are good absorber that's why they emit well. (Kirchoff's law).

31. (d)

32. (c) When light incident on pin hole, enters into the box and suffers successive reflection at the inner wall. At each reflection some energy is absorbed. Hence the ray once it enters the box can never come out and pin hole acts like a perfect black body.

33. (a) Initially black body absorbs all the radiant energy incident on it, So it is the darkest one. Black body radiates maximum energy if all other condition are same. So when the temperature of the black body becomes equal to the temperature of furnace it will be brightest of all.

34. (c) Open window behaves like a perfectly black body.

35. (a) Ordinary glass prism (crown, flint) absorbs the infrared radiation but rock salt prism transmit them. Hence it is used to obtain the spectrum of infrared radiation.

36. (d) A good absorber is a good emitter hence option (a) is wrong. Every body stops absorbing and emitting radiation at 0 K hence option (b) is wrong.

The energy of radiation emitted from a black body is not same for all wavelength hence option (c) is wrong.

Plank's law relates the wavelength (λ) and temperature (T) according to the relation $E_\lambda d_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{[e^{hc/kT}-1]}d_\lambda$. Hence option (d) is correct.

37. (c) When blue glass is heated at high temperature, it absorbs all the radiation of, higher wavelength except blue. If it is taken inside a dark room, it emits all the radiation of higher wavelength, hence it looks brighter red as compared to the red piece.

38. (b)

Radiation (Wein's law)

1. (a)

2. (c) According to Wein's law, $\lambda_m T$ = constant

$\lambda_r > \lambda_y > \lambda_b \Rightarrow T_r < T_y < T_b$ or $T_A < T_C < T_B$

3. (d) $\lambda_m T$ =constant $\Rightarrow \frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} \Rightarrow \frac{10^{-4}}{0.5\times10^{-5}}$ =200.

4. (c) $\lambda_m T$ = constant

5. (a) According to Wein's law $\lambda_m T$ = constant, on heating up to ordinary temperatures, only long wavelength (red) radiation is emitted. As the temperature rises, shorter wavelengths are also emitted in more and more quantity. Hence the colour of radiation emitted by the hot wire shifts from red to yellow, then to blue and finally to white.

6. (c) According to Wein's displacement law.

7. (d) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \frac{\lambda_{m_1}T_1}{T_2} = 4.08\times\frac{700}{1400} = 2.04\,m$

8. (c) $\lambda_{m_1}T_1 = \lambda_{m_2}T_2 \Rightarrow \lambda_{m_2} = \frac{\lambda_{m_1}T_1}{T_2} = \frac{14\times200}{1000} = 2.8\ \mu m$

9. (c) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4800}{3600} \Rightarrow \frac{48}{36} = \frac{4}{3}$

10. (b) $\lambda_{m_2} = \frac{T_1}{T_2}\times\lambda_{m_1} = \frac{1500}{2500}\times5000 = 3000\text{Å}$

11. (a) At low temperature short wavelength radiation is emitted. As the temperature rise colour of emitted radiation are in the following order

Red→Yellow→Blue→White (at highest temperature)

12. (b) Similar to Q. 11

13. (b) The wavelength corresponding to maximum emission of radiation from the sun is $\lambda_{\max} = 4753\text{Å}$ (close to the wavelength of violet colour of visible region). Hence if temperature is doubled λ is decreased $\left(\lambda_m \propto \frac{1}{T}\right)$ *i.e.* mostly ultraviolet radiations emits.

14. (c) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{5.5\times10^5}{11\times10^5} = \frac{1}{2} \Rightarrow n = \frac{1}{2}$.

15. (b) $\therefore T = \frac{b}{\lambda_m} = \frac{2.93\times10^{-3}}{2.93\times10^{-10}} = 10^7\ K$

16. (a) $\therefore \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{T_1}{T_2} \Rightarrow \lambda_{m_2} = \frac{2000}{2400}\times4 = 3.33\ \mu m$

17. (b)

18. (a)

19. (b) $\lambda_{m_2} = \frac{T_1}{T_2}\times\lambda_{m_1} = \frac{2000}{3000}\times\lambda_{m_1} = \frac{2}{3}\lambda_{m_1} = \frac{2}{3}\lambda_m$

20. (a)

21. (c) $\frac{T_2}{T_1} = \frac{\lambda_{m_1}}{\lambda_{m_2}} = \frac{1.75}{14.35} \Rightarrow T_2 = \frac{1.75}{14.35}\times1640 = 200\ K$

22. (a) $\frac{\lambda_2}{\lambda_1} = \frac{T_1}{T_2} \Rightarrow \lambda_2 = \frac{T_1}{T_2}\times\lambda_1 = \frac{900}{1200}\times4 = 3\mu m$

23. (b) $\lambda_{m_2} = \frac{\lambda_{m_1}T_1}{T_2} = \frac{4800\times6000}{3000} = 9600\text{Å}$

24. (b) $\frac{T_1}{T_2} = \frac{\lambda_{m_2}}{\lambda_{m_1}} = \frac{4200}{140} = \frac{30}{1}$

25. (c) $\because \lambda_m T = \lambda'_m T' \Rightarrow \lambda_0 T = \lambda'\times2T \Rightarrow \lambda' = \frac{\lambda_0}{2}$

26. (b) $\lambda_m T = \lambda'_m T' \Rightarrow \frac{\lambda_m}{\lambda'_m} = \frac{T'}{T} = \frac{3000}{2000} = \frac{3}{2}$

27. (b) $\lambda_{m_1}T = \lambda_{m_2}T_2 \Rightarrow 5.5\times10^{-7}\times5500 = 11\times10^{-7}T$

$T = 550\times5K = 2750K$

28. (b) According to Wein's displacement law

$\lambda_m T = b$ or $\lambda_m = \frac{b}{T} = \frac{0.0029}{5\times10^4} = 58\times10^{-9}m = 58nm$

29. (a) $\lambda_m = \frac{b}{T} \Rightarrow T = \frac{b}{\lambda_m} = \frac{2.93\times10^{-3}}{4000\times10^{-10}} = 7325\ K$

30. (b) $\frac{T_S}{T_N} = \frac{(\lambda_N)_{\max}}{(\lambda_S)_{\max}} = \frac{350}{510} = 0.69$

Radiation (Stefan's law)

1. (c) $E \propto T^4$ (Stefan's law)

2. (c) Rate of heat loss $E = \sigma e A(T^4 - T_0^4)$

$= 5.67\times10^{-8}\times0.4\times200\times10^{-4}\times[(273+527)^4-(273+27)^4]$

$= 5.67\times10^{-8}\times0.4\times200\times10^{-4}\times(800)^4-(300)^4 = 182 J/sec$

3. (a) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{E}{E_2} = \left(\frac{273+0}{273+273}\right)^4 \Rightarrow E_2 = 16\ E.$

4. (a) $E \propto T^4 \Rightarrow \frac{E_1}{E_2} = \frac{T^4}{T^4}\times2^4 \Rightarrow E_2 = \frac{E}{16}$

5. (d) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{420+273}{T}\right)^4 = \left(\frac{673}{T}\right)^4$

$\Rightarrow T = 2^{1/4}\times673 = 800K.$

6. (a) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+727}{237+227}\right) = \frac{(1000)^4}{(500)^4} = 16 \Rightarrow E_2 = 80$

7. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow T_2 = \left(\frac{E_2}{E_1}\right)^{1/4}\times T_1 = (16)^{1/4}\times(273+127)$

$\Rightarrow T = 800\ K = 527^oC$

8. (b) In M.K.S. system unit of σ is $\frac{J}{m^2\times sec\times K^4}$

$\Rightarrow 1\frac{J}{m^2\times sec\times K^4} = \frac{10^7 erg}{10^4 cm^2\times sec\times K^4}$

$= 10^3\frac{erg}{cm^2\times sec\times K^4}$

9. (b) For a block body rate of energy $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left\{\frac{(273+7)}{(273+287)}\right\}^4 = \frac{1}{16}$

10. (b) $E_2 = E_1\frac{T_2^4}{T_1^4} = Q\times\frac{(273+151)^4}{(273+27)^4} = \left(\frac{424}{300}\right)^4 = 3.99Q \approx 4Q$

11. (b) $\frac{E_1}{E_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{727+273}{127+273}\right)^4 = \frac{(1000)^4}{(400)^4} = \frac{10^4}{4^4} = \frac{625}{16}$

12. (c) $E = \sigma T^4 \Rightarrow 5.6\times10^{-8}\times T^4 = 1$

$\Rightarrow T = \left[\frac{1}{5.6\times10^{-8}}\right]^{1/4} = 65\ K$

13. (c) According to Stefen's law $E = \sigma\varepsilon AT^4$

$\Rightarrow \frac{1.58\times10^5\times4.2}{60\times60} = 5.6\times10^{-8}\times10^{-4}\times0.8\times T^4$

$T \approx 2500\,K$

14. (c) Total energy radiated from a body $Q = A\varepsilon\sigma T^4 t$

$\Rightarrow Q \propto AT^4 \propto r^2T^4$ $(\because\ A = 4\pi r^2)$

$\Rightarrow \frac{Q_P}{Q_Q} = \left(\frac{r_P}{r_Q}\right)^2\left(\frac{T_P}{T_Q}\right)^4 = \left(\frac{8}{2}\right)^2\left\{\frac{(273+127)}{(273+527)}\right\}^4 = 1$

15. (c) Rate of energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4 \Rightarrow P \propto T^4$

$\Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{927+273}{127+273}\right)^4 \Rightarrow P_1 = 405\ W$

16. (b) The rate of radiated energy $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$\Rightarrow 1134 = 5.67\times10^{-8}\times(0.1)^2T^4 \Rightarrow T = 1189\ K$

17. (d) $Q \propto T^4 \Rightarrow \frac{H_A}{H_B} = \left(\frac{273+727}{273+327}\right)^4 = \left(\frac{10}{6}\right)^4 = \left(\frac{5}{3}\right)^4 = \frac{625}{81}$

18. (d) $(Q)_{Blackbody} = A\sigma T^4 t \Rightarrow Q \propto T^4$

$\Rightarrow Q_2 = Q_1\left(\frac{T_2}{T_1}\right)^4 = 10\left(\frac{273+327}{273+27}\right)^4 = 10\left(\frac{600}{300}\right)^4 = 160J$

19. (c) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{E_2}{20} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow E_2 = 320\ kcal/m^2\ min.$

20. (d) Radiated power by blackbody $P = \frac{Q}{t} = A\sigma T^4$

$\Rightarrow P \propto AT^4 \propto r^2T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_1}{r_2}\right)^2\left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{440}{P_2} = \left(\frac{12}{6}\right)^2\left(\frac{500}{1000}\right)^4 \Rightarrow P_2 = 1760\,W \approx 1800\,W$

21. (d) Amount of energy radiated $\propto$ (Temperature)^4.

22. (d) $\frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{273+27}{273+927}\right)^4 = \left(\frac{1}{4}\right)^4 = \frac{1}{256}$

23. (a) $\frac{E_2}{E_1} = \frac{T_2^4}{T_1^4} = \left(\frac{237+227}{273+27}\right)^4 = \left(\frac{600}{300}\right)^4 = 16$

24. (d) $(Q)_{Blackbody} = A\sigma T^4 t \Rightarrow \frac{Q}{t} \propto P = A\sigma T^4$

Breadth are halved so area becomes one fourth.

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2}\times\left(\frac{T_1}{T_2}\right)^4 \Rightarrow \frac{A_1}{(A_1/4)}\times\left(\frac{273+327}{273+127}\right)$

$\Rightarrow P_2 = \frac{81}{64}E$

25. (d) Power radiated $P \propto T^4 \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q}{P_2} = \left(\frac{T}{3T}\right)^4 \Rightarrow P_2 = 81Q$

26. (a) For black body, $P = A\varepsilon\sigma T^4$. For same power $A \propto \frac{1}{T^4}$

$\Rightarrow \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{r_1}{r_2} = \left(\frac{T_2}{T_1}\right)^2$

27. (a) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{273+927}{273+327}\right)^4 = \left(\frac{1200}{600}\right)^4 = 16$

$\Rightarrow Q = 32\ KJ$

28. (b) $\frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{2}{1} = \left(\frac{T_2}{T_1}\right)^4$

$\Rightarrow T_2^4 = 2 \times T_1^4 = 2 \times (273 + 727)^4 \Rightarrow T_2 = 1190K$.

29. (a) $\frac{Q_1}{Q_2} = \frac{r_1^2 T_1^4}{r_2^2 T_2^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

30. (a) According to Wein's law λT = constant

$\Rightarrow \lambda_{m_1} T_1 = \lambda_{m_2} T_2 \Rightarrow T_2 = \frac{\lambda_{m_1}}{\lambda_{m_2}} T_1 = \frac{\lambda_0}{3\lambda_0 / 4} \times T_1 = \frac{4}{3} T_1$

Now $P \propto T^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{P_1} = \left(\frac{4/3\ T_1}{T_1}\right)^4 = \frac{256}{81}$

31. (d) $E \propto T^4$

32. (d) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4$

$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T}{T + T/2}\right)^4 = \frac{16}{81} \Rightarrow Q_2 = \frac{81}{16} Q_1$

% increase in energy $= \frac{Q_2 - Q_1}{Q_1} \times 100 = 400\%$

33. (d) If temperature of surrounding is considered then net loss of energy of a body by radiation

$Q = A\varepsilon\sigma(T^4 - T_0^4)t \Rightarrow Q \propto (T^4 - T_0^4) \Rightarrow \frac{Q_1}{Q_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4}$

$= \frac{(273+200)^4 - (273+27)^4}{(273+400)^4 - (273+27)^4} = \frac{(473)^4 - (300)^4}{(673)^4 - (300)^4}$

34. (c) $Q = A\varepsilon\sigma T^4 \Rightarrow Q \propto A \propto r^2$ ($\because T$ = constant)

$\Rightarrow \frac{Q_1}{Q_2} = \frac{r_1^2}{r_2^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

35. (a) $\frac{Q_2}{Q_1} = \frac{T_2^4}{T_1^4} = \left(\frac{273+527}{273+127}\right)^4 = \left(\frac{800}{400}\right)^4 \Rightarrow Q_2 = 16 \frac{cal}{cm^2 \times s}$

36. (c) For a black body $\frac{Q}{t} = P = A\sigma T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{P_2}{20} = \left(\frac{273+727}{273+227}\right)^4$

$\Rightarrow \frac{P_2}{20} = (2)^4 \Rightarrow P_2 = 320W$

37. (c) Energy radiated per sec $\frac{Q}{t} = P = A\varepsilon\sigma T^4$

$P \propto r^2 T^4 \Rightarrow \frac{P_2}{P_1} = \frac{r_2^2}{r_1^2} . \frac{T_2^4}{T_1^4} = \frac{4^2}{1^2} \times \left(\frac{2000}{4000}\right)^4 = 1$

38. (c) $Q \propto AT^4 \propto r^2 T^4 \Rightarrow \frac{Q_{star}}{Q_{sun}} = \frac{r^2_{star} . T^4_{star}}{r^2_{sun} \times T^4_{sun}}$

$\Rightarrow \frac{10000}{1} = \frac{r_{star}^2}{r_{sun}^2} \times \left(\frac{6000}{2000}\right)^4 \Rightarrow \frac{r_{star}}{r_{sun}} = \frac{100 \times 9}{1} = \frac{900}{1}$

39. (a) $P = \left(\frac{Q}{t}\right) \propto T^4 \Rightarrow \frac{W}{P_2} = \left(\frac{T}{T/3}\right)^4 \Rightarrow P_2 = \frac{W}{81}$.

40. (c) Power $P \propto AT^4 \propto r^2 T^4$

$\Rightarrow \frac{P_2}{P_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{4r}{r}\right)^2 \times \left(\frac{T/2}{T}\right)^4 = 1.$

41. (b) $\frac{Q_2}{Q_1} = \left(\frac{r_2^2}{r_1^2}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = \left(\frac{100}{1}\right)^2 \times \left(\frac{1}{2}\right)^4 = 625$

42. (d) $Q \propto r^2 T^4 \Rightarrow \frac{Q_2}{Q_1} = \left(\frac{r_2}{r_1}\right)^2 \times \left(\frac{T_2}{T_1}\right)^4 = (2)^2 \times (2)^4 = 64$

43. (c) Energy radiated from a body $Q = A\varepsilon\sigma T^4 t$

$\Rightarrow \frac{Q_2}{Q_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1} = \left(\frac{Q_2}{Q_1}\right)^{1/4} = \left(\frac{4.32 \times 10^6}{2.7 \times 10^{-3}}\right)^{1/4}$

$= \left(\frac{16 \times 27}{27} \times 10^8\right)^{1/4} = 2 \times 10^2$

$\Rightarrow T_2 = 200 \times T_1 = 80000\,K$

44. (d) $E \propto AT^4 \Rightarrow \frac{E_{sphere}}{E_{Disc}} = \frac{4\pi r^2}{2\pi r^2} \times \left(\frac{T}{T}\right)^4 = \frac{2}{1}$

45. (a) $\frac{E_2}{E_1} = \left(\frac{T_2}{T_1}\right)^4 \Rightarrow \frac{T_2}{T_1} = \left(\frac{E_2}{E_1}\right)^{1/4} = \left(\frac{10^9}{10^5}\right)^{1/4} = 10$

$\Rightarrow T_2 = 10T_1 = 10 \times (273 + 227) = 5000\,K$

46. (b) Energy per second $P\left(= \frac{Q}{t}\right) \propto T^4$

$\frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 = \left(\frac{273-73}{273+327}\right)^4 = \left(\frac{200}{600}\right)^4 = \frac{1}{81}$

47. (a) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T_1}{T_2}\right)^4$

If $T_1 = T$ then $T_2 = T + \frac{10}{100} T = 1.1T$

$\Rightarrow \frac{Q_1}{Q_2} = \left(\frac{T}{1.1T}\right)^4 \Rightarrow Q_2 = 1.46\,Q_1$

$\Rightarrow$ % increase in energy $= \frac{Q_2 - Q_1}{Q_1} \times 100 = 46\%$

48. (a) From Stefan's law $E = \sigma T^4$

$T^4 = \frac{E}{\sigma} = \frac{6.3 \times 10^7}{5.7 \times 10^8} = 1.105 \times 10^{15} = 0.1105 \times 10^{16}$

$T = 0.58 \times 10^4\,K = 5.8 \times 10^3\,K$

49. (a) Rate of cooling $\propto (T^4 - T_0^4)$

$\Rightarrow \frac{H}{H'} = \frac{(T_1^4 - T_0^4)}{(T_2^4 - T_0^4)} = \frac{400^4 - 200^4}{600^4 - 200^4}$

or $H' = \frac{(16+4)(16-4)H}{(36+4)(36-4)} = \frac{3}{16}H$

50. (a)

51. (a) Rate of cooling $\propto (T^4 - T_0^4) \Rightarrow \frac{R_1}{R_2} = \frac{(T_1^4 - T_0^4)}{(T_2^4 - T_0^4)}$

$\Rightarrow \frac{R}{R_2} = \frac{(600)^4 - (300)^4}{(900)^4 - (300)^4}$ or $R_2 = \frac{16}{3}R$

52. (d) Loss of heat $\Delta Q = A\varepsilon\sigma(T^4 - T_0^4)t$

$\Rightarrow$ Rate of loss of heat $\frac{\Delta Q}{t} = A\varepsilon\sigma(T^4 - T_0^4)$

$= 10\times10^{-4}\times1\times5.67\times10^{-8}\{273+127)^4 - (273+27)^4\}$

= 0.99 *W*.

53. (b) According to Prevost theory every body radiate heat at all temperature (except 0*K*) and also absorbs heat from surroundings.

$\because$ $T_A > T$ $\Rightarrow$ Object *A* emits radiations more than the radiations it absorbs.

and $T_B < T$ $\Rightarrow$ Object *B* absorbs more radiations than it emits.

After a certain time all bodies attains a common temperature.

54. (b) According to Prevost theory

55. (b) $Q \propto T^4 \Rightarrow \frac{Q_1}{Q_2} = \frac{T_1^4}{T_2^4} \Rightarrow T_2^4 = \left(\frac{E_2}{E_1}\right)T_1^4$

$\Rightarrow T_2^4 = \frac{1}{16}\times(1000)^4 = \left(\frac{1000}{2}\right)^4 \Rightarrow T_2 = 500K$

56. (c) $Q \propto T^4$

Radiation (Newton's Law of Cooling)

1. (b) According to Newton's law of cooling

$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1+\theta_2}{2} - \theta_0\right]$

In the first case, $\frac{(60-50)}{10} = K\left[\frac{60+50}{2} - \theta_0\right]$

$1 = K(55-\theta)$ ....(i)

In the second case, $\frac{(50-42)}{10} = K\left[\frac{50+42}{2} - \theta_0\right]$

$0.8 = K(46-\theta_0)$ ....(ii)

Dividing (i) by (ii), we get $\frac{1}{0.8} = \frac{55-\theta_0}{46-\theta_0}$

or $46 - \theta_0 = 44 - 0.8\theta_0 \Rightarrow \theta_0 = 10^oC$

2. (c) According to Newton's law of cooling

Rate of cooling $\propto$ Mean temperature difference

$\Rightarrow \frac{\text{Fall in temperature}}{\text{Time}} \propto \left(\frac{\theta_1+\theta_2}{2} - \theta_0\right)$

$\because \left(\frac{\theta_1+\theta_2}{2}\right)_1 > \left(\frac{\theta_1+\theta_2}{2}\right)_2 > \left(\frac{\theta_1+\theta_2}{2}\right)_3$

$\Rightarrow T_1 < T_2 < T_3$

3. (a) Initially at $t = 0$

Rate of cooling (*R*) $\propto$ Fall in temperature of body ($\theta - \theta$)

$\Rightarrow \frac{R_1}{R_2} = \frac{\theta_1 - \theta_0}{\theta_2 - \theta_0} = \frac{100-40}{80-40} = \frac{3}{2}$

4. (a) For small difference of temperature, it is the special case of Stefan's law.

5. (b) Liquid having more specific heat has slow rate of cooling because for equal masses rate of cooling $\frac{d\theta}{dt} \propto \frac{1}{c}$.

6. (c) $S_l = \frac{1}{m_l}\left[\frac{t_l}{t_W}(m_W C_W + W) - W\right]$

$= \frac{1}{300}\left[\frac{95}{3\times60}(350\times1+10) - 10\right]$ =0.6 $Cal/gm\times^\circ C$

7. (c) Newton's law of cooling is used for the determination of specific heat of liquids.

8. (c) By Newton's law of cooling.

9. (d) Rate of loss of heat $\left(\frac{\Delta Q}{t}\right) \propto$ temperature difference $\Delta\theta$

$\frac{\left(\frac{\Delta Q}{t}\right)_1}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{\Delta\theta_2}{\Delta\theta_1} \Rightarrow \frac{60}{\left(\frac{\Delta Q}{t}\right)_2} = \frac{80-60}{40-20} \Rightarrow \left(\frac{\Delta Q}{t}\right)_2 = \frac{20\,cal}{sec}$

10. (b) During clear nights object on surface of earth radiate out heat and temperature falls. Hence option (a) is wrong.

The total energy radiated by a body per unit time per unit area $E \propto T$. Hence option (*c*) is wrong.

Energy radiated per second is given by $\frac{Q}{t} = PA\varepsilon\sigma T^4$

$\Rightarrow \frac{P_1}{P_2} = \frac{A_1}{A_2}\cdot\left(\frac{T_1}{T_2}\right)^4 = \left(\frac{r_1}{r_2}\right)^2\cdot\left(\frac{T_1}{T_2}\right)^4 = \left(\frac{1}{4}\right)^2\left(\frac{4000}{200}\right) = \frac{1}{1}$

$\because P = P$, hence option (d) is wrong.

Newton's law is an approximate form of Stefan's law of radiation and works well for natural convection. Hence option (b) is correct.

11. (b) $\frac{\theta_1 - \theta_2}{t} = K\left(\frac{\theta_1+\theta_2}{2} - \theta_0\right)$

$\therefore \frac{100-70}{4} = K\left(\frac{100+70}{2} - 15\right)$ = 60$K \Rightarrow K = \frac{1}{8}$

Again $\frac{70-40}{t} = \frac{1}{8}\left(\frac{70+40}{2} - 15\right)$ = 5 $\Rightarrow$ t = 6 *min*.

12. (d) $\frac{80-60}{1} = K\left(\frac{80+60}{2} - 30\right) \Rightarrow K = \frac{1}{2}$

Again $\frac{60-50}{t} = \frac{1}{2}\left(\frac{60+50}{2} - 30\right) \Rightarrow t = 0.8\times60 = 48$ *sec.*

13. (c) According to Newton's law of cooling

Rate of cooling $\propto$ mean temperature difference.

Initially, mean temperature difference

$=\left(\frac{70+60}{2}-\theta_0\right)=(65-\theta_0)$

Finally, mean temperature difference

$=\left(\frac{60+50}{2}-\theta_0\right)=(55-\theta_0)$

In second case mean temperature difference decreases, so rate of fall of temperature decreases, so it takes more time to cool through the same range.

14. (c) $\frac{\theta_1-\theta_2}{t}=K\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

In the first 10 minute

$\frac{62-50}{10}=K\left[\frac{62+50}{2}-\theta_0\right]\Rightarrow 1.2=K[56-\theta_0]$ .... (i)

$\frac{50-42}{10}=K\left[\frac{50+42}{2}-\theta_0\right]\Rightarrow 0.8=K[46-\theta_0]$ .... (ii)

from equations (i) and (ii) $\frac{1.2}{0.8}=\frac{(56-\theta_0)}{(46-\theta_0)}\Rightarrow \theta_0=26°C$

15. (d) $\frac{d\theta}{dt}=\frac{\sigma A}{mc}(T^4-T_0^4)$. If the liquids put in exactly similar calorimeters and identical surrounding then we can consider T and A constant then $\frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{mc}$ ......(i)

If we consider that equal masses of liquid (m) are taken at the same temperature then $\frac{d\theta}{dt}\propto\frac{1}{c}$

So for same rate of cooling c should be equal which is not possible because liquids are of different nature. Again from equation (i)

$\frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{mc}\Rightarrow\frac{d\theta}{dt}\propto\frac{(T^4-T_0^4)}{V\rho c}$

Now if we consider that equal volume of liquid (V) are taken at the same temperature then $\frac{d\theta}{dt}\propto\frac{1}{\rho c}$.

So for same rate of cooling multiplication of $\rho\times c$ for two liquid of different nature can be possible. So option (d) may be correct.

16. (c) $\frac{60-50}{10}=K\left(\frac{60+50}{2}-25\right)$ .....(i)

$\frac{50-\theta}{10}=K\left[\frac{50+\theta}{2}-25\right]$ .....(ii)

On dividing, we get $\frac{10}{50-\theta}=\frac{60}{\theta}\Rightarrow\theta=42.85^o C$

17. (a) $\frac{365-361}{2}=K\left[\frac{365+361}{2}-293\right]$ = 70 $K\Leftrightarrow K=\frac{1}{35}$

Again $\frac{344-342}{t}=\frac{1}{35}\left[\frac{344-342}{2}-293\right]=\frac{10}{7}$

$\Rightarrow t=\frac{14}{10}\text{min}=\frac{14}{10}\times 60=84$ *sec.*

18. (b) $\frac{50-49.9}{5}=K\left(\frac{50+49.9}{2}-30\right)$ .....(i)

$\frac{40-39.9}{t}=K\left[\frac{40+39.9}{2}-30\right]$ .....(ii)

from equations (i) and (ii) we get $t\approx 10$ *sec.*

19. (c) Rate of loss of heat is directly proportional to the temperature difference between water and the surroundings.

20. (b) Rate of cooling $=\frac{-d\theta}{dt}\propto\left(\frac{\theta_1+\theta_2}{2}-\theta_0\right)$

In second case average temperature will be less hence rate of cooling will be less. Therefore time taken will be more than 4 minutes.

21. (a)

22. (b) First case, $\frac{61-59}{4}=K\left[\frac{61+59}{2}-30\right]$ .....(i)

Second case, $\frac{51-49}{t}=K\left[\frac{51+49}{2}-30\right]$ .....(ii)

By solving equation (i) and (ii) we get $t=6$ *min.*

23. (d)

24. (c) In first case $\frac{60-40}{7}=K\left[\frac{60+40}{2}-10\right]$ ....(i)

In second case $\frac{40-28}{t}=K\left[\frac{40+28}{2}-10\right]$ ....(ii)

By solving $t=7$ *minutes*

25. (b) In first case $\frac{50-40}{5}=K\left[\frac{50+40}{2}-\theta_0\right]$ ....(i)

In second case $\frac{40-33.33}{5}=K\left[\frac{40+33.33}{2}-\theta_0\right]$ ....(ii)

By solving $\theta_0=20^o C$.

26. (b) In first case $\frac{50-40}{10}=K\left[\frac{50+40}{2}-20\right]$ ....(i)

In second case $\frac{40-\theta_2}{10}=K\left[\frac{40+\theta_2}{2}-20\right]$ ....(ii)

By solving $\theta_2=33.3^o C$.

27. (d) In first case $\frac{61-59}{10}=K\left[\frac{61+59}{2}-30\right]$ ....(i)

In second case $\frac{51-49}{10}=K\left[\frac{51+49}{2}-30\right]$ ....(ii)

By solving $t=15$ *min.*

28. (d) Rate of cooling (here it is rate of loss of heat)

$\frac{dQ}{dt}=(mc+W)\frac{d\theta}{dt}=(m_lc_l+m_cc_c)\frac{d\theta}{dt}$

$\Rightarrow\frac{dQ}{dt}=(0.5\times 2400+0.2\times 900)\left(\frac{60-55}{60}\right)=115\frac{J}{\text{sec}}$.

29. (a) According to Newton's law

Rate of cooling $\propto$ temperature difference $\Delta\theta$

30. (b) According to Newton's law $\frac{\theta_1-\theta_2}{t}=k\left[\frac{\theta_1+\theta_2}{2}-\theta_0\right]$

Initially,

$$\frac{(80-64)}{5}=K\left(\frac{80+64}{2}-\theta_0\right) \Rightarrow 3.2=K[72-\theta_0] \;\ldots\text{(i)}$$

Finally

$$\frac{(64-52)}{10}=K\left[\frac{64+52}{2}-\theta_0\right] \Rightarrow 1.2=K[58-\theta_0]\ldots\text{(ii)}$$

On solving equation (i) and (ii) $\theta_0=49°C$.

31. (d) $\frac{50-45}{5}=K\left(\frac{50+45}{2}-\theta_0\right)$ .....(i)

$\frac{45-41.5}{5}=K\left(\frac{45+41.5}{2}-\theta_0\right)$ .....(ii)

Solving equation (i) and (ii) we set $\theta_0=33.3\ °C$.

32. (d) $\frac{65.5-62.5}{1}=K\left(\frac{65.5+62.5}{2}-22.5\right) \Rightarrow K=\frac{3}{41.5}$

And again $\frac{46.5-40.5}{t}=\frac{3}{41.5}\left(\frac{46.5+40.5}{2}-22.5\right)$

$\Rightarrow \frac{6}{t}=\frac{3}{41.5}\times 21 \Rightarrow t=\frac{82}{21}\simeq 4$ minute.

33. (a) $\frac{62-50}{10}=K\left(\frac{62+50}{2}-26\right) \Rightarrow \frac{6}{5}=K\times 30 \Rightarrow K=\frac{1}{25}$

And, $\frac{50-\theta}{10}=\frac{1}{25}\left(\frac{50+\theta}{2}-26\right) \Rightarrow \theta=42°\ C.$

34. (c) $\frac{90-60}{5}=K\left(\frac{90+60}{2}-20\right) \Rightarrow 6=K\times 55 \Rightarrow K=\frac{6}{55}$

And, $\frac{60-30}{t}=\frac{6}{55}\left(\frac{60+30}{2}-20\right) \Rightarrow t$ = 11 minute.

35. (a) According to Newton's law of cooling

in first case, $\frac{75-65}{t}=K\left[\frac{75+65}{2}-30\right]$ .....(i)

in second case, $\frac{55-45}{t}=K\left[\frac{55+45}{2}-30\right]$ .....(ii)

Dividing eq. (i) by (ii) we get $\frac{5t}{10}=\frac{40}{20} \Rightarrow t=4$ minutes

36. (b) According to Newton's law of cooling

in first case, $\frac{80-50}{5}=K\left[\frac{80+50}{2}-20\right]$ .....(i)

in second case, $\frac{60-30}{t}=K\left[\frac{60+30}{2}-20\right]$ (ii)

Dividing equation (i) by (ii) we get, $\frac{t}{2}=\frac{45}{25} \Rightarrow t=9$ min.

37. (b) According to Newton's law of cooling.

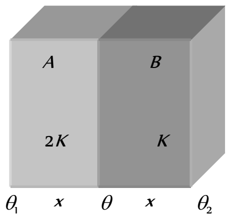
Critical Thinking Questions

1. (a) $\frac{dQ}{dt}=\frac{KA\Delta\theta}{l}$, For both rods K, A and $\Delta\theta$ are same $\Rightarrow$ $\frac{dQ}{dt}\propto\frac{1}{l}$ So $\frac{(dQ/dt)_{semi\ circular}}{(dQ/dt)_{straight}}=\frac{l_{straight}}{l_{semicircular}}=\frac{2r}{\pi r}=\frac{2}{\pi}$.

2. (b) Suppose thickness of each wall is x then $\left(\frac{Q}{t}\right)_{combination}=\left(\frac{Q}{t}\right)_A \Rightarrow \frac{K_S A(\theta_1-\theta_2)}{2x}=\frac{2KA(\theta_1-\theta)}{x}$

$\because K_S=\frac{2\times 2K\times K}{(2K+K)}=\frac{4}{3}K$ and $(\theta_1-\theta_2)=36°$

$\Rightarrow \frac{\frac{4}{3}KA\times 36}{2x}=\frac{2KA(\theta_1-\theta)}{x}$



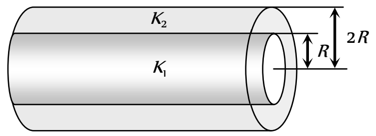
Hence temperature difference across wall A is

$(\theta_1-\theta)=12^oC$

3. (d) $t=\frac{\rho L}{2K\theta}(x_2^2-x_1^2) \Rightarrow t\propto(x_2^2-x_1^2)$

$\Rightarrow \frac{t}{t'}=\frac{(x_2^2-x_1^2)}{(x'_2{}^2-x'_1{}^2)} \Rightarrow \frac{9}{t'}=\frac{(1^2-0^2)}{(2^2-1^2)} \Rightarrow t'=21\,hours$

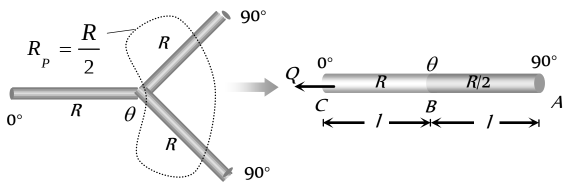
4. (c) Both the cylinders are in parallel, for the heat flow from one end as shown.



Hence $K_{eq}=\frac{K_1A_1+K_2A_2}{A_1+A_2}$; where A = Area of cross-section of inner cylinder = πR and A_2 = Area of cross-section of cylindrical shell $=\pi\{(2R)^2-(R)^2\}=3\pi R^2$

$\Rightarrow K_{eq}=\frac{K_1(\pi R^2)+K_2(3\pi R^2)}{\pi R^2+3\pi R^2}=\frac{K_1+3K_2}{4}$

5. (b) Let the temperature of junction be θ. Since roads B and C are parallel to each other (because both having the same temperature difference). Hence given figure can be redrawn as follows



$\because \frac{Q}{t}=\frac{(\theta_1-\theta_2)}{R}$ and $\left(\frac{Q}{t}\right)_{AB}=\left(\frac{Q}{t}\right)_{BC}$

$\Rightarrow \frac{(90-\theta)}{R/2}=\frac{(\theta-0)}{R} \Rightarrow 180-2\theta=\theta \Rightarrow \theta=60°C$

6. (a) Heat developed by the heater $H=\frac{V^2}{R}.\frac{t}{J}=\frac{(200)^2\times t}{20\times 4.2}$

Heat conducted by the glass $H=\frac{0.2\times 1\times(20-\theta)t}{0.002}$

Hence $\frac{(200)^2\times t}{20\times 4.2}=\frac{0.2\times(20-\theta)t}{0.002} \Rightarrow \theta=15.24^oC$

7. (a) Since $t = \frac{\rho L}{2k\theta}(x_2^2 - x_1^2)$

$\therefore t = \frac{\rho L}{2k\theta}(x^2 - y^2) = \frac{\rho L(x+y)(x-y)}{2K\theta}$

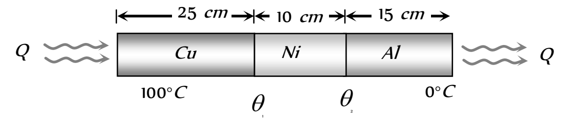
8. (b) If suppose $K_{Ni} = K \Rightarrow K_{Al} = 3K$ and $K_{Cu} = 6K$.

Since all metal bars are connected in series

So $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu} = \left(\frac{Q}{t}\right)_{Al} = \left(\frac{Q}{t}\right)_{Ni}$

and $\frac{3}{K_{eq}} = \frac{1}{K_{Cu}} + \frac{1}{K_{Al}} + \frac{1}{K_{Ni}} = \frac{1}{6K} + \frac{1}{3K} + \frac{1}{K} = \frac{9}{6K}$

$\Rightarrow K_{eq} = 2K$



Hence, if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Cu}$

$\Rightarrow \frac{K_{eq}A(100-0)}{l_{Combination}} = \frac{K_{Cu}A(100-\theta_1)}{l_{Cu}}$

$\Rightarrow \frac{2K\,A(100-0)}{(25+10+15)} = \frac{6K\,A(100-\theta_1)}{25} \Rightarrow \theta_1 = 83.33°C$

Similar if $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_{Al}$

$\Rightarrow \frac{2K\,A(100-0)}{50} = \frac{3K\,A(\theta_2 - 0)}{15} \Rightarrow \theta_2 = 20^o C$

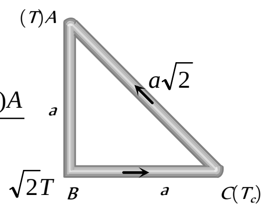
9. (b) $\because T_B > T_A \Rightarrow$ Heat will flow *B* to *A* via two paths (i) *B* to *A* (ii) and along *BCA* as shown.

Rate of flow of heat in path *BCA* will be same

i.e. $\left(\frac{Q}{t}\right)_{BC} = \left(\frac{Q}{t}\right)_{CA}$

$\Rightarrow \frac{k(\sqrt{2}T - T_C)A}{a} = \frac{k(T_C - T)A}{\sqrt{2}a}$

$\Rightarrow \frac{T_C}{T} = \frac{3}{1+\sqrt{2}}$

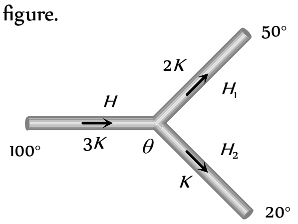


10. (a) $mL = \frac{KA\Delta\theta\ t}{\Delta x} \Rightarrow 500 \times 80 = \frac{0.0075 \times 75 \times (40-0)t}{5}$

$\Rightarrow t = 8.9 \times 10^3$ *sec* = 2.47 *hr.*

11. (a) Rate of cooling $\frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc} \Rightarrow \frac{\Delta\theta}{t} \propto A$. Since area of plate is largest so it will cool fastest.

12. (b) Let the temperature of junction be θ then according to following figure.

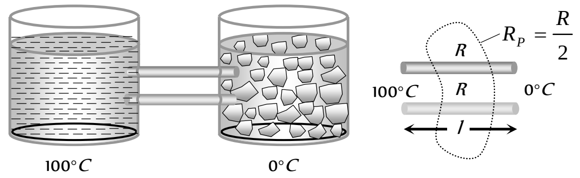


$H = H_1 + H_2$

$\Rightarrow \frac{3K \times A \times (100-\theta)}{l} = \frac{2KA(\theta - 50)}{l} + \frac{KA(\theta - 20)}{l}$

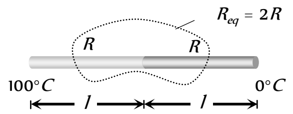
$\Rightarrow 300 - 3\theta = 3\theta - 120 \Rightarrow \theta = 70°C$

13. (c) Initially the rods are placed in vessels as shown below



$\frac{Q}{t} = \frac{(\theta_1 - \theta_2)}{R} \Rightarrow \left(\frac{Q}{t}\right)_1 = \frac{mL}{t} = q_1 L = \frac{(100-0)}{\frac{R}{2}}$ ... (i)

Finally when rods are joined end to end as shown



$\Rightarrow \left(\frac{Q}{t}\right)_2 = \frac{mL}{t} = q_2 L = \frac{(100-0)}{2R}$ ... (ii)

From equation (i) and (ii), $\frac{q_1}{q_2} = \frac{4}{1}$

14. (b) Rate of cooling of a body $R = \frac{\Delta\theta}{t} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{Volume}}$

$\Rightarrow$ For the same surface area. $R \propto \frac{1}{\text{Volume}}$

$\because$ Volume of cube < Volume of sphere

$\Rightarrow R_{Cube} > R_{Sphere}$ *i.e.* cube, cools down with faster rate.

15. (a,b) According to Stefan's law

$E = eA\sigma T^4 \Rightarrow E_1 = e_1 A\sigma T_1^4$ and $E_2 = e_2 A\sigma T_2^4$

$\because E_1 = E_2 \therefore e_1 T_1^4 = e_2 T_2^4$

$\Rightarrow T_2 = \left(\frac{e_1}{e_2}T_1^4\right)^{\frac{1}{4}} = \left(\frac{1}{81} \times (5802)^4\right)^{\frac{1}{4}} \Rightarrow T_B = 1934\ K$

And, from Wein's law $\lambda_A \times T_A = \lambda_B \times T_B$

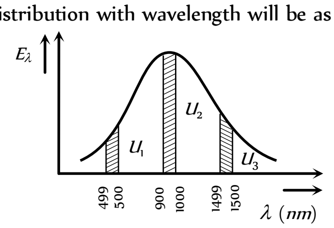
$\Rightarrow \frac{\lambda_A}{\lambda_B} = \frac{T_B}{T_A} \Rightarrow \frac{\lambda_B - \lambda_A}{\lambda_B} = \frac{T_A - T_B}{T_A}$

$\Rightarrow \frac{1}{\lambda_B} = \frac{5802 - 1934}{5802} = \frac{3968}{5802} \Rightarrow \lambda_B = 1.5\ \mu m$

16. (d) Wein's displacement law is $\lambda_m T = b$

$\Rightarrow \lambda_m = \frac{b}{T} = \frac{2.88 \times 10^6}{2880} = 1000\,nm.$

Energy distribution with wavelength will be as follows



From the graph it is clear that $U_2 > U_1$.

17. (b) Energy received per second *i.e.*, power $P \propto (T^4 - T_0^4)$

$\Rightarrow P \propto T^4 \qquad (\because T_0 << T)$

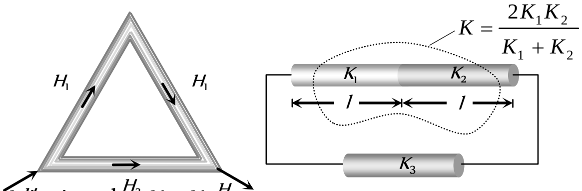
Also energy received per sec $(p) \propto \dfrac{1}{d^2}$

(inverse square law)

$$\Rightarrow P \propto \frac{T^4}{d^2} \Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4 \times \left(\frac{d_2}{d_1}\right)^2$$

$$\Rightarrow \frac{P}{P_2} = \left(\frac{T}{2T}\right)^2 \times \left(\frac{2d}{d}\right)^2 = \frac{1}{4} \Rightarrow P_2 = 4P.$$

18. (c) The given arrangement of rods can be redrawn as follows



It is given that $H_1 = H_2$

$$\Rightarrow \frac{KA(\theta_1 - \theta_2)}{2l} = \frac{K_3A(\theta_1 - \theta_2)}{l} \Rightarrow K_3 = \frac{K}{2} = \frac{K_1K_2}{K_1 + K_2}$$

19. (b) Rate of cooling $(R) = \dfrac{\Delta\theta}{t} = \dfrac{A \in \sigma(T^4 - T_0^4)}{mc}$

$$\Rightarrow R \propto \frac{A}{m} \propto \frac{\text{Area}}{\text{volume}} \propto \frac{r^2}{r^3} \propto \frac{1}{r}$$

$$\Rightarrow \text{Rate } (R) \propto \frac{1}{r} \propto \frac{1}{m^{1/3}} \left[\because m = \rho \times \frac{4}{3}\pi r^3 \Rightarrow r \propto m^{1/3}\right]$$

$$\Rightarrow \frac{R_1}{R_2} = \left(\frac{m_2}{m_1}\right)^{1/3} = \left(\frac{1}{3}\right)^{1/3}$$

20. (b) Radiated power $P = A\varepsilon\sigma T^4 \Rightarrow P \propto AT^4$

From Wein's law, $\lambda_m T = \text{constant} \Rightarrow T \propto \dfrac{1}{\lambda_m}$

$$\therefore P \propto \frac{A}{(\lambda_m)^4} \propto \frac{r^2}{(\lambda_m)^4}$$

$$\Rightarrow Q_A : Q_B : Q_C = \frac{2^2}{(300)^4} : \frac{4^2}{(400)^4} : \frac{6^2}{(500)^4}$$

$\therefore Q_B$ will be maximum.

21. (d) The total energy radiated from a black body per minute.

$$Q \propto T^4 \Rightarrow \frac{Q_2}{Q_1} = \left(\frac{2T}{T}\right)^4 = 16 \Rightarrow Q_2 = 16Q_1$$

If m be mass of water taken and S be its specific heat capacity, then $Q_1 = ms(20.5 - 20)$ and $Q_2 = ms(\theta - 20)$

$\theta°C$ = Final temperature of water

$$\Rightarrow \frac{Q_2}{Q_1} = \frac{\theta - 20}{0.5} \Rightarrow \frac{16}{1} = \frac{\theta - 20}{0.5} \Rightarrow \theta = 28°C$$

22. (a) Rate of cooling $\dfrac{\Delta\theta}{t} = \dfrac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

As surface area, material and temperature difference are same, so rate of loss of heat is same in both the spheres. Now in this case rate of cooling depends on mass.

$\Rightarrow$ Rate of cooling $\dfrac{\Delta\theta}{t} \propto \dfrac{1}{m}$

$\because m_{solid} > m_{hollow}$. Hence hollow sphere will cool fast.

23. (c) Rate of cooling $\dfrac{\Delta\theta}{t} = \dfrac{A\varepsilon\sigma(T^4 - T_0^4)}{mc}$

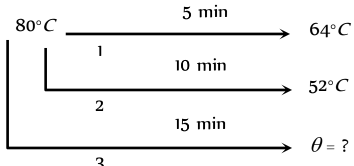
$$\Rightarrow t \propto \frac{m}{A} \qquad [\because \Delta\theta, t, \sigma, (T^4 - T_0^4) \text{ are constant}]$$

$$\Rightarrow t \propto \frac{m}{A} \propto \frac{\text{Volume}}{\text{Area}} \propto \frac{a^3}{a^2} \Rightarrow t \propto a \Rightarrow \frac{t_1}{t_2} = \frac{a_1}{a_2}$$

$$\Rightarrow \frac{100}{t_2} = \frac{1}{2} \Rightarrow t_2 = 200 sec.$$

24. (a) According to Newton law of cooling

$$\frac{\theta_1 - \theta_2}{t} = K\left[\frac{\theta_1 + \theta_2}{2} - \theta_0\right]$$



For first process : $\dfrac{(80 - 64)}{5} = K\left[\dfrac{80 + 64}{2} - \theta_0\right]$ ...(i)

For second process : $\dfrac{(80 - 52)}{10} = K\left[\dfrac{80 + 52}{2} - \theta_0\right]$ ...(ii)

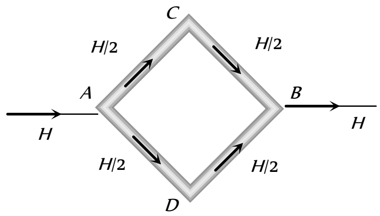
For third process : $\dfrac{(80 - \theta)}{15} = K\left[\dfrac{80 + \theta}{2} - \theta_0\right]$ ...(iii)

On solving equation (i) and (ii) we get $K = \dfrac{1}{15}$ and $\theta_0 = 24°C$. Putting these values in equation (iii) we get $\theta = 42.7°C$

25. (c) $t = \dfrac{Ql}{KA(\theta_1 - \theta_2)} = \dfrac{mLl}{KA(\theta_1 - \theta_2)} = \dfrac{V\rho Ll}{KA(\theta_1 - \theta_2)}$

$$= \frac{5 \times A \times 0.92 \times 80 \times \dfrac{5 + 10}{2}}{0.004 \times A \times 10 \times 3600} = 19.1\, hours.$$

26. (a) Suppose temperature difference between A and B is 100°C and $\theta_A > \theta_B$



Heat current will flow from A to B via path ACB and ADB. Since all the rod are identical so $(\Delta\theta)_{AC} = (\Delta\theta)_{AD}$

(Because heat current $H = \dfrac{\Delta\theta}{R}$; here R = same for all.)

$\Rightarrow \theta_A - \theta_C = \theta_A - \theta_D \Rightarrow \theta_C = \theta_D$

i.e. temperature difference between C and D will be zero.

27. (c) $\frac{Q}{t}=\frac{KA\Delta\theta}{l}\Rightarrow\frac{mL}{t}=\frac{K(\pi r^2)\Delta\theta}{l}$

$\Rightarrow$ Rate of melting of ice $\left(\frac{m}{t}\right)\propto\frac{Kr^2}{l}$

Since for second rod K becomes $\frac{1}{4}th$ r becomes double and length becomes half, so rate of melting will be twice *i.e.* $\left(\frac{m}{t}\right)_2=2\left(\frac{m}{t}\right)_1=2\times0.1=0.2\ gm/sec.$

28. (c) Heat transferred in one minute is utilised in melting the ice so,

$\frac{KA(\theta_1-\theta_2)t}{l}=m\times L$

$\Rightarrow m=\frac{10^{-3}\times92\times(100-0)\times60}{1\times8\times10^4}=6.9\times10^{-3}kg$

29. (d) $\frac{dQ}{dt}=\frac{KA}{l}d\theta=\frac{0.01\times1}{0.05}\times30=6J/sec$

Heat transferred in on day (86400 *sec*)

$\theta=6\times86400=518400\ J$

Now $Q=mL\Rightarrow m=\frac{Q}{L}=\frac{518400}{334\times10^3}$

$=1.552\ kg=1552g.$

30. (b) For no current flow between C and D

$\left(\frac{Q}{t}\right)_{AC}=\left(\frac{Q}{t}\right)_{CB}\Rightarrow\frac{K_1A(\theta_A-\theta_C)}{l}=\frac{K_2A(\theta_C-\theta_B)}{l}$

$\Rightarrow\frac{\theta_A-\theta_C}{\theta_C-\theta_B}=\frac{K_2}{K_1}$ ...(i)

Also $\left(\frac{Q}{t}\right)_{AD}=\left(\frac{Q}{t}\right)_{DB}\Rightarrow\frac{K_3A(\theta_A-\theta_D)}{l}=\frac{K_4A(\theta_D-\theta_B)}{l}$

$\Rightarrow\frac{\theta_A-\theta_D}{\theta_D-\theta_B}=\frac{K_4}{K_3}$ ...(ii)

It is given that $\theta_C=\theta_D$, hence from equation (i) and (ii) we get $\frac{K_2}{K_1}=\frac{K_4}{K_3}\Rightarrow K_1K_4=K_2K_3$

31. (d) Rate of cooling $R_C=\frac{d\theta}{dt}=\frac{A\varepsilon\sigma(T^4-T_0^4)}{mc}$

$\Rightarrow\frac{d\theta}{dt}\propto\frac{A}{V}\propto\frac{r^2}{r^3}\Rightarrow\frac{d\theta}{dt}\propto\frac{1}{r}$

32. (b) $\frac{dT}{dt}=\frac{\sigma A}{mcJ}(T^4-T_0^4)$ [In the given problem fall in temperature of body $dT=(200-100)=100K$, temp. of surrounding $T_0=0K$, Initial temperature of body $T=200K$].

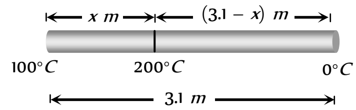
$\frac{100}{dt}=\frac{\sigma4\pi r^2}{\frac{4}{3}\pi r^3\rho c\ J}(200^4-0^4)$

$\Rightarrow dt=\frac{r\rho c\ J}{48\sigma}\times10^{-6}s=\frac{r\rho c}{\sigma}.\frac{4.2}{48}\times10^{-6}$

$=\frac{7}{80}\frac{r\rho c}{\sigma}\mu s\simeq\frac{7}{72}\frac{r\rho c}{\sigma}\mu s$ [As $J=4.2$]

33. (a) Rate of flow of heat is given by $\frac{dQ}{dt}=\frac{\Delta\theta}{l/KA}$ also $\frac{dQ}{dt}=L\frac{dm}{dt}$ (where L = Latent heat)

$\Rightarrow\frac{dm}{dt}=\frac{KA}{l}\left(\frac{\Delta\theta}{L}\right)$. Let the desire point is at a distance x from water at 100°*C*.



$\because$ Rate of ice melting = Rate at which steam is being produced

$\Rightarrow\left(\frac{dm}{dt}\right)_{Steam}=\left(\frac{dm}{dt}\right)_{Ice}\Rightarrow\left(\frac{\Delta\theta}{Ll}\right)_{Steam}=\left(\frac{\Delta\theta}{Ll}\right)_{Ice}$

$\Rightarrow\frac{(200-100)}{540\times x}=\frac{(200-0)}{80(3.1-x)}\Rightarrow x=0.4\ m=40\ cm$

34. (c) $Q=\sigma A\ t\ (T^4-T_0^4)$

If T, T_0, σ and t are same for both bodies then

$\frac{Q_{sphere}}{Q_{cube}}=\frac{A_{sphere}}{A_{cube}}=\frac{4\pi r^2}{6a^2}$ .....(i)

But according to problem, volume of sphere = Volume of cube

$\Rightarrow\frac{4}{3}\pi r^3=a^3\Rightarrow a=\left(\frac{4}{3}\pi\right)^{1/3}r$

Substituting the value of a in equation (i) we get

$\frac{Q_{sphere}}{Q_{cube}}=\frac{4\pi r^2}{6a^2}=\frac{4\pi r^2}{6\left\{\left(\frac{4}{3}\pi\right)^{1/3}r\right\}^2}$

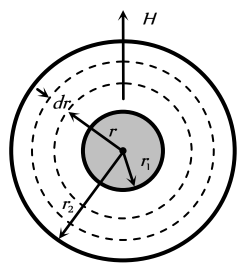
$=\frac{4\pi r^2}{6\left(\frac{4}{3}\pi\right)^{2/3}r^2}=\left(\frac{\pi}{6}\right)^{1/3}:1$

35. (d) Equation of thermal conductivity of the given combination $K_{eq}=\frac{l_1+l_2}{\frac{l_1}{K_1}+\frac{l_2}{K_2}}=\frac{x+4x}{\frac{x}{K}+\frac{4x}{2K}}=\frac{5}{3}K$. Hence rate of flow of heat through the given combination is

$\frac{Q}{t}=\frac{K_{eq}.A(T_2-T_1)}{(x+4x)}=\frac{\frac{5}{3}K\ A(T_2-T_1)}{5x}=\frac{\frac{1}{3}K\ A(T_2-T_1)}{x}$

On comparing it with given equation we get $f=\frac{1}{3}$

36. (a) Consider a concentric spherical shell of radius r and thickness dr as shown in fig.



The radial rate of flow of heat through this shell in steady state will be $H = \frac{dQ}{dt} = -KA\frac{dT}{dr} = -K(4\pi r^2)\frac{dT}{dr}$

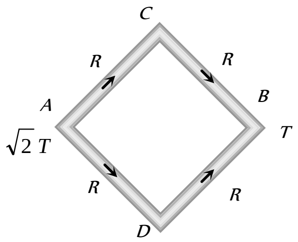
$$\Rightarrow \int_{r_1}^{r_2} \frac{dr}{r^2} = -\frac{4\pi K}{H}\int_{T_1}^{T_1} dT$$

Which on integration and simplification gives

$$H = \frac{dQ}{dt} = \frac{4\pi K r_1 r_2 (T_1 - T_2)}{r_2 - r_1} \Rightarrow \frac{dQ}{dt} \propto \frac{r_1 r_2}{(r_2 - r_1)}$$

37. (c) Similar to Q.No.26

Temperature difference between C and D is zero.



Graphical Questions

1. (c) Rate of cooling $\left(-\frac{dT}{dt}\right) \propto$ emissivity (e)

From graph, $\left(-\frac{dT}{dt}\right)_x > \left(-\frac{dT}{dt}\right)_y \Rightarrow e_x > e_y$

Further emissivity $(e) \propto$ Absorptive power $(a) \Rightarrow a_x > a_y$

($\because$ good absorbers are good emitters).

2. (b) According to Wien's law $\lambda_m \propto \frac{1}{T}$ and from the figure $(\lambda_m)_1 < (\lambda_m)_3 < (\lambda_m)_2$ therefore $T_1 > T_3 > T_2$.

3. (d) $\frac{A_T}{A_{2000}} = \frac{16}{1}$ (given)

Area under $e_\lambda - \lambda$ curve represents the emissive power of body and emissive power $\propto T^4$

(Hence area under $e_\lambda - \lambda$ curve) $\propto T^4$

$$\Rightarrow \frac{AT}{A_{2000}} = \left(\frac{T}{2000}\right)^4 \Rightarrow \frac{16}{1} = \left(\frac{T}{2000}\right)^4 \Rightarrow T = 4000K.$$

4. (c) According to Wein's law $\lambda_m \propto \frac{1}{T} \Rightarrow \nu_m \propto T$. As the temperature of body increases, frequency corresponding to maximum energy in radiation (ν) increases this is shown in graph (c).

5. (c) According to Wein's displacement law.

6. (b) For θ-t plot, rate of cooling $= \frac{d\theta}{dt} =$ slope of the curve.

At P, $\frac{d\theta}{dt} = \tan\phi_2 = k(\theta_2 - \theta_0)$, where k = constant.

At Q $\frac{d\theta}{dt} = \tan\phi_1 = k(\theta_1 - \theta_0) \Rightarrow \frac{\tan\phi_2}{\tan\phi_1} = \frac{\theta_2 - \theta_0}{\theta_1 - \theta_0}$

7. (a) According to Wein's displacement law

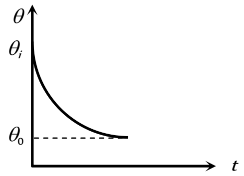
$$\lambda_m \propto \frac{1}{T} \Rightarrow \lambda_{m_2} < \lambda_{m_1} \quad (\because\ T_1 < T_2)$$

There fore I–λ graph for T_2 have lesser wavelength (λ_m) and so curve for T_2 will shift towards left side.

8. (d) Area under given curve represents emissive power and emissive power $\propto T \Rightarrow A \propto T^4$

$$\Rightarrow \frac{A_2}{A_1} = \frac{T_2^4}{T_1^4} = \frac{(273+327)^4}{(273+27)^4} = \left(\frac{600}{300}\right)^4 = \frac{16}{1}$$

9. (b) According to Newton's law of cooling



Rate of cooling ∝ Temperature difference

$\Rightarrow -\frac{d\theta}{dt} \propto (\theta - \theta_0) \Rightarrow -\frac{d\theta}{dt} = \alpha\,(\theta - \theta_0)$ (α= constant)

$\Rightarrow \int_{\theta_i}^{\theta} \frac{d\theta}{(\theta - \theta_0)} = -\alpha \int_0^t dt \Rightarrow \theta = \theta_0 + (\theta_i - \theta_0)e^{-\alpha t}$

This relation tells us that, temperature of the body varies exponentially with time from θ_i to θ_0

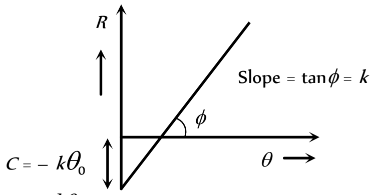
Hence graph (*b*) is correct.

10. (a) According to Wein's displacement law $\lambda_m \propto \frac{1}{T}$. Hence, if temperature increases λ_m decreases *i.e.,* peak of the $E - \lambda$ curve shift towards left.

11. (c) Rate of loss of heat (*R*) ∝ temperature difference

$\Rightarrow R \propto (\theta - \theta_0) \Rightarrow R = k(\theta - \theta_0) = k\theta - k\theta_0$ (*k*= constant)

on comparing it with $y = mx + c$ it is observed that, the graph between *R* and θ will be straight line with slope =*k* and intercept $= -k\theta_0$



12. (c) $\frac{dQ}{dt} = -KA\frac{d\theta}{dx}$

$\because \frac{dQ}{dt}$, *K* and *A* are constants for all points

$\Rightarrow d\theta \propto -dx$; *i.e.* temperature will decrease linearly with *x*.

13. (b) Since the curved surface of the conductor is thermally insulated, therefore, in steady state, the rate of flow of heat at every section will be the same. Hence the curve between *H* and *x* will be straight line parallel to *x*-axis.

14. (d) According to Stefan's law $E = \sigma T^4$

$\Rightarrow \log E = \log\sigma + 4\log T \Rightarrow \log E = 4\log T + \log\sigma$

on comparing this equations with $y = mx + C$

we find that graph between log *E* and log *T* will be a straight line, having positive slope (*m* = 4) and intercept on log *E* axis equal to $\log\sigma$

15. (c) $\frac{d\theta}{dt} = \frac{\varepsilon A\sigma}{mc} 4\theta_0^3 \Delta\theta$

For given sphere and cube $\frac{\varepsilon A\sigma}{mc} 4\theta_0^3 \Delta\theta$ is constant so for both rate of fall of temperature $\frac{d\theta}{dt}$ = constant

16. (b) $\lambda_m T = b$ where $b = 2.89 \times 10^{-3} mK$

$\Rightarrow T = \frac{b}{\lambda_m} = \frac{2.89 \times 10^{-3}}{1.5 \times 10^{-6}} \approx 2000K$

17. (b) Wein's law $\lambda_m \propto \frac{1}{T}$ or $\nu_m \propto T$

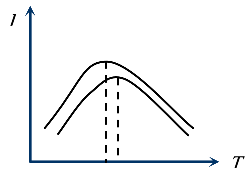
ν increases with temperature. So the graph will be straight line.

Assertion and Reason

1. (a) According to Kirchoff's law $\frac{e_\lambda}{a_\lambda} = E_\lambda$

If for a particular wave length $E_\lambda = 1 \Rightarrow e_\lambda = a_\lambda$ *i.e.,* aborptivity of a body is equal to it's emissivity. This statement also reveals that a good radiator is also a good absorber and vice versa.

2. (c) According to Weins law $\lambda_m T$ = constant *i.e.,* peak emission wavelength $\lambda_m \propto \frac{1}{T}$. Also as T increases λ_m decreases.



Hence assertion is true but reason is false.

3. (b) During the day when water is cooler than the land, the wind blows off the water onto the land (as warm air rises and cooler air fills the place). Also at night, the effect is reversed (since the water is usually warmer than the surrounding air on land). Due to this wind flow the temperature near the sea coast remains moderate.

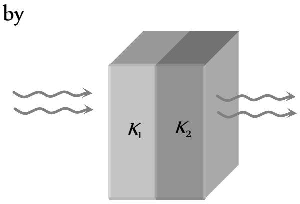
4. (c) Heat is carried away from a fire sideways mainly by radiations. Above the fire, heat is carried by both radiation and by convection of air. The latter process carries much more heat.

5. (e) Assertion is false because at absolute zero (0 *K*), heat is neither radiates nor absorbed. Reason is the statement of Stefan's law, as $E \propto T^4$.

6. (a) Woolen fibres encloses a large amount of air in them. Both wool and air are the bad conductors of heat and the coefficient of thermal conductivity is small. So, they prevent any loss of heat from our body.

7. (d) Equivalent thermal conductivity of two equally thick plates in series combination is given by

$\frac{2}{K} = \frac{1}{K_1} + \frac{1}{K_2}$



If $K_1 < K_2$

then $K_1 < K < K_2$

Hence assertion and reason both are false.

8. (c) Hollow metallic closed container maintained at a uniform temperature can act as source of black body. It is also well-known that all metals cannot act as black body because if we take a highly metallic polished surface. It will not behave as a perfect black body.

9. (b) This is in accordance with the Stefan's law $E \propto T^4$.

10. (c) At a high temperature (6000 *K*), the sun acts like a perfect blackbody emitting complete radiation. That's why the radiation coming from the sun's surface follows Stefan's law $E = \sigma T^4$.

11. (a) From Wein's displacement law, temperature $(T) \propto 1/\lambda_m$ (where λ_m is the maximum wavelength). Thus temperature of a body is inversely proportional to the wavelength. Since blue star has smaller wavelength and red star has maximum wavelength, therefore blue star is at higher temperature then red star.

12. (b) From the definition heat flow, $Q = \dfrac{KA.\Delta\theta t}{l}$

Thermal conductivity $K = \dfrac{\theta \times l}{A \times \Delta\theta \times t}$

$\Rightarrow K = \dfrac{J \times m}{m^2 \times K \times \sec} = \dfrac{watt}{m \times K}$

If thermal conductivity of a substance is high, it will pass more heat.

13. (c) The thermal conductivity of brass is high *i.e.,* brass is a good conductor of heat. So, when a brass tumbler is touched, heat quickly flows from human body to tumbler. Consequently, the tumbler appears colder, on the other hand wood is a bad conductor. So, heat does not flow from the human body to the wooden tray in this case. Thus it appears comparatively hotter.

14. (b) Light radiations and thermal radiations both belongs to electromagnetic spectrum. Light radiations belongs to visible region while thermal radiation belongs to infrared region of *EM* spectrum. Also *EM* radiations requires no medium for propagation.

15. (a) When the temperature of the atmosphere reaches below 0°*C*, then the water vapours present in air, instead of condensing, freeze directly in the form of minute particles of ice. Many particles coalesce and take cotton-like shape which is called snow. Thus snow contains air packets in which convection currents cannot be formed. Hence snow is a good heat insulator. In ice there is no air, so it is a bad insulator.

16. (e) In the process of convection, the liquid at the bottom, becoming lighter, rises up. Thus the basis of convection is the difference in weight and upthrust. In weightlessness, this difference does not exist. So convection is not possible.

17. (b) Both assertion and reason are true but reason is not correctly explaining the assertion.

18. (c) The 98.4°*F* is the standard body temperature of a man. If a man touch a iron or wooden ball at 98.4° *F*, no heat transfer takes place between ball and man, so both the balls would feel equally hot for the man.

19. (c) According to Wien's displacement law the $\lambda_m \propto \dfrac{1}{T}$.

Hence assertion is true but reason is false.

20. (e) It is not necessary that all black coloured object are black bodies. For example, if we take a black surface which is highly polished, it will not behave as a perfect black body.

A perfectly black body absorbs all the radiations incident on it.

21. (b) By definition, $R = \dfrac{(\theta_1 - \theta_2)}{Q/t} = \dfrac{l}{KA} \Rightarrow R \propto \dfrac{1}{K}$.

22. (c) Actually, the process of radiation does not require any material for transmission of heat.

Thermal radiation travels with the velocity of light and hence the fastest mode of the transfer. Thermal radiation is always transmitted in a straight line.

23. (c) Two thin blankets put together are more warm because an insulating layer of air (as air is good insulator of heat) is enclosed between two blankets due to which it gives more warmness.

24. (a) When the animals feel cold, they curl their bodies into a ball so as to decrease the surface area of their bodies. As total energy radiated by body varies directly as the surface area of the body, the loss of heat due to radiation would be reduced.

Transmission of Heat

SET Self Evaluation Test -15

1. A rod of 40 cm in length and temperature difference of 80^oC at its two ends. Another rod B of length 60 cm and of temperature difference 90^oC, having the same area of cross-section. If the rate of flow of heat is the same, then the ratio of their thermal conductivities will be
   (a) 3 : 4 (b) 4 : 3
   (c) 1 : 2 (d) 2 : 1

2. Two vessels of different materials are similar in size in every respect. The same quantity of ice filled in them gets melted in 20 *minutes* and 40 *minutes* respectively. The ratio of thermal conductivities of the materials is [AFMC 1998]
   (a) 5 : 6 (b) 6 : 5
   (c) 3 : 1 (d) 2 : 1

3. In a steady state of thermal conduction, temperature of the ends *A* and *B* of a 20 *cm* long rod are 100^oC and 0^oC respectively. What will be the temperature of the rod at a point at a distance of 6 *cm* from the end *A* of the rod
   (a) -30^oC (b) 70^oC
   (c) 5^oC (d) None of the above

4. Four rods of silver, copper, brass and wood are of same shape. They are heated together after wrapping a paper on it, the paper will burn first on
   (a) Silver (b) Copper
   (c) Brass (d) Wood

5. The two opposite faces of a cubical piece of iron (thermal conductivity = 0.2 CGS units) are at 100^oC and 0^oC in ice. If the area of a surface is $4cm^2$, then the mass of ice melted in 10 minutes will be
   (a) 30 *gm* (b) 300 *gm*
   (c) 5 *gm* (d) 50 *gm*

6. Wein's constant is 2892×10^{-6} MKS unit and the value of λ_m from moon is 14.46 microns. What is the surface temperature of moon
   (a) 100 *K* (b) 300 *K*
   (c) 400 *K* (d) 200 *K*

7. If at temperature $T_1 = 1000K$, the wavelength is $1.4\times10^{-6}m$, then at what temperature the wavelength will be $2.8\times10^{-6}m$
   (a) 2000*K* (b) 500*K*
   (c) 250*K* (d) None of these

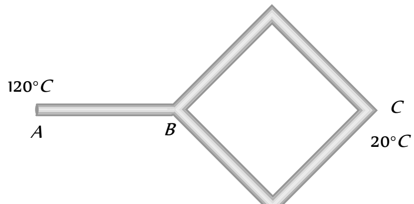
8. The wavelength of maximum intensity of radiation emitted by a star is 289.8 *nm*. The radiation intensity for the star is : (Stefan's constant $5.67\times10^{-8}Wm^{-2}K^{-4}$, constant $b = 2898\mu mK$) -
   (a) $5.67\times10^8\ W/m^2$ (b) $5.67\times10^{12} W/m^2$
   (c) $10.67\times10^7 W/m^2$ (d) $10.67\times10^{14} W/m^2$

9. Two friends *A* and *B* are waiting for another friend for tea. *A* took the tea in a cup and mixed the cold milk and then waits. *B* took the tea in the cup and then mixed the cold milk when the friend comes. Then the tea will be hotter in the cup of

   (a) *A*
   (b) *B*
   (c) Tea will be equally hot in both cups
   (d) Friend's cup

10. There are two spherical balls *A* and *B* of the same material with same surface, but the diameter of *A* is half that of *B*. If *A* and *B* are heated to the same temperature and then allowed to cool, then
   (a) Rate of cooling is same in both
   (b) Rate of cooling of *A* is four times that of *B*
   (c) Rate of cooling of *A* is twice that of *B*
   (d) Rate of cooling of *A* is $\frac{1}{4}$ times that of *B*

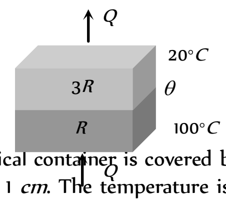
11. Five identical rods are joined as shown in figure. Point *A* and *C* are maintained at temperature 120°*C* and 20°*C* respectively. The temperature of junction *B* will be



   (a) 100°*C*
   (b) 80°*C*
   (c) 70°*C*
   (d) 0°*C*

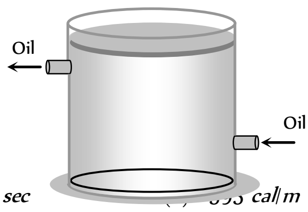
12. Can we boil water inside the earth satellite by convection
   (a) Yes
   (b) No
   (c) Nothing can be said
   (d) In complete information is given

13. In the following figure, two insulating sheets with thermal resistances *R* and 3*R* as shown in figure. The temperature θ is



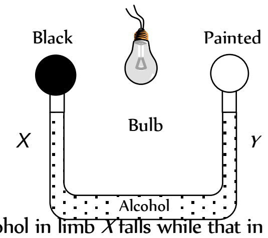
   (a) 20°*C*
   (b) 60°*C*
   (c) 75°*C*
   (d) 80°*C* [RPMT 2004]

14. The top of insulated cylindrical container is covered by a disc having emissivity 0.6 and thickness 1 *cm*. The temperature is maintained by circulating oil as shown in figure. If temperature of upper surface of disc is 127°*C* and temperature of surrounding is 27°*C*, then the radiation loss to the surroundings will be (Take $\sigma = \frac{17}{3}\times10^{-8} W/m^2K^4$) [EAMCET 2001]



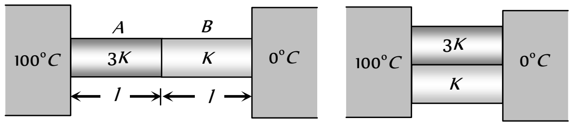
   (a) 595 *J/m × sec* (b) 595 *cal/m × sec*
   (c) 991.0 *J/m × sec* (d) 440 *J/m × sec*

15. The following figure shows two air-filled bulbs connected by a U-tube partly filled with alcohol. What happens to the levels of alcohol in the limbs X and Y when an electric bulb placed midway between the bulbs is lighted



(a) The level of alcohol in limb X falls while that in limb Y rises
(b) The level of alcohol in limb X rises while that in limb Y falls
(c) The level of alcohol falls in both limbs
(d) There is no change in the levels of alcohol in the two limbs

16. Two conducting rods A and B of same length and cross-sectional area are connected (i) In series (ii) In parallel as shown. In both combination a temperature difference of 100°C is maintained. If thermal conductivity of A is $3K$ and that of B is K then the ratio of heat current flowing in parallel combination to that flowing in series combination is



(i) (ii)

(a) $\frac{16}{3}$ (b) $\frac{3}{16}$
(c) $\frac{1}{1}$ (d) $\frac{1}{3}$

17. The area of the glass of a window of a room is $10\ m^2$ and thickness 2mm. The outer and inner temperature are 40^oC and 20^oC respectively. Thermal conductivity of glass in MKS system is 0.2. The heat flowing in the room per second will be

(a) 3×10^4 *joules* (b) 2×10^4 *joules*
(c) 30 *joules* (d) 45 *joules*

18. The spectrum from a black body radiation is a

[MP PMT 1989; RPET 2000]

(a) Line spectrum
(b) Band spectrum
(c) Continuous spectrum
(d) Line and band spectrum both

19. The Wien's displacement law express relation between

[CBSE PMT 2002]

(a) Frequency and temperature
(b) Temperature and amplitude
(c) Wavelength and radiating power of black body
(d) Wavelength corresponding to maximum energy and temperature

20. A black body is heated from 27^oC to 127^oC. The ratio of their energies of radiations emitted will be

[AIIMS 2001]

(a) 3: 4 (b) 9 : 16
(c) 27 : 64 (d) 81: 256

21. A body takes T *minutes* to cool from 62^oC to 61^oC when the surrounding temperature is 30^oC. The time taken by the body to cool from 46^oC to 45.5^oC is

[MP PET 1999]

(a) Greater than T *minutes*
(b) Equal to T *minutes*
(c) Less than T *minutes*
(d) Equal to $T/2$ *minutes*

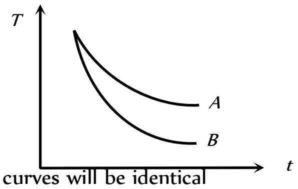
22. A partition wall has two layers A and B in contact, each made of a different material. They have the same thickness but the thermal conductivity of layer A is twice that of layer B. If the steady state temperature difference across the wall is $60K$, then the corresponding difference across the layer A is

[SCRA 1994; JIPMER 2001]

(a) $10\ K$ (b) $20\ K$
(c) $30K$ (d) $40\ K$

23. Water and turpentine oil (specific heat less than that of water) are both heated to same temperature. Equal amounts of these placed in identical calorimeters are then left in air

[MP PMT 1989]



(a) Their cooling curves will be identical
(b) A and B will represent cooling curves of water and oil respectively
(c) B and A will represent cooling curves of water and oil respectively
(d) None of the above

Answers and Solutions

(SET -15)

1. (a) $\frac{dQ}{dt}=\frac{KA(\theta_1-\theta_2)}{d}$

$\Rightarrow \frac{K_1\Delta\theta_1}{l_1}=\frac{K_2\Delta\theta_2}{l_2}$ $\left(\because \frac{dQ}{dt}\text{ and } A \text{ are same}\right)$

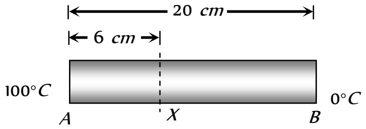
$\Rightarrow \frac{K_1\times80}{40}=\frac{K_2\times90}{60}\Rightarrow\frac{K_1}{K_2}=\frac{3}{4}$

2. (d) $\frac{Q}{t}=\frac{KA(\theta_1-\theta_2)}{l}\Rightarrow\frac{mL}{t}=\frac{KA(\theta_1-\theta_2)}{l}$

$\Rightarrow K\propto\frac{1}{t}$ ($\because$ remaining quantities are same)

$\Rightarrow \frac{K_1}{K_2}=\frac{t_2}{t_1}=\frac{40}{20}=\frac{2}{1}$.

3. (b) In steady state, temperature gradient = constant



$$\Rightarrow \frac{(\theta_A - \theta_x)}{6} = \frac{(\theta_A - \theta_B)}{20} \Rightarrow (100 - \theta) = \frac{6}{20} \times (100 - 0)$$

$$\Rightarrow \theta_x = 70°C$$

4. (d) In conducting rod given heat transmits so burning temperature does not reach soon. In wooden rod heat doesn't conducts.

5. (b) $Q = mL = KA\frac{(\theta_1 - \theta_2)}{l}t \Rightarrow m = \frac{1}{L} \times KA\frac{(\theta_1 - \theta_2)}{l} \times t$

$$= \frac{1}{80} \times 0.2 \times 4 \times \frac{(100-0)}{\sqrt{4}} \times 10 \times 60 \quad (\because l^2 = 4 \Rightarrow l = \sqrt{4})$$

$$= \frac{0.2 \times 4 \times 100 \times 600}{80 \times 2} = 300\ gm$$

6. (d) $\lambda_m T = 2892 \times 10^{-6} \Rightarrow T = \frac{2892 \times 10^{-6}}{14.46 \times 10^{-6}} = 200\ K$

7. (a) $\lambda_m \propto \frac{1}{T} \Rightarrow \lambda m_1 T_1 = \lambda m_2 T_2$

$$\Rightarrow T_2 = \frac{\lambda m_1 T_1}{\lambda m_2} = \frac{1.4 \times 10^{-6} \times 1000}{2.8 \times 10^{-6}} = 2000K$$

8. (a) We know $\lambda_{max} T = b$

$$\Rightarrow T = \frac{b}{\lambda_{max}} = \frac{2898 \times 10^{-6}}{289.8 \times 10^{-9}} = 10^4 K$$

According to Stefan's Law

$$E = \sigma T^4 = (5.67 \times 10^{-8})(10^4)^4 = 5.67 \times 10^8 W/m^2$$

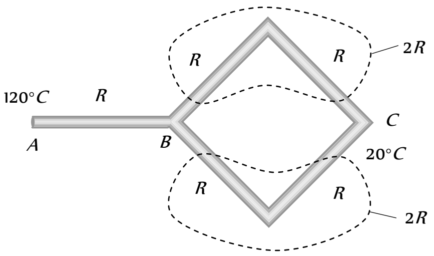
9. (a) The rate of heat loss is proportional to the difference in temperature. The difference of temperature between the tea in cup A and the surrounding is reduced, so it loses less heat. the tea in cup B loses more heat because of large temperature difference. Hence the tea in cup A will be hotter.

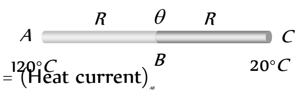
10. (c) Rate of cooling $R_C = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{mc} = \frac{A\varepsilon\sigma(T^4 - T_0^4)}{V\rho C}$

$$\Rightarrow R_C \propto \frac{A}{V} \propto \frac{1}{r} \propto \frac{1}{(\text{Diameter})} \qquad (\because m = \rho V)$$

Since diameter of A is half that of B so it's rate of cooling will be doubled that of B

11. (c) If thermal resistance of each rod is considered R then, the given combination can be redrawn as follows





$(\text{Heat current})_{AC} = (\text{Heat current})_{AB}$

$$\frac{(120-20)}{R} = \frac{(120-\theta)}{R} \Rightarrow \theta = 70°C$$

12. (b) No, In convection the hot liquid at the bottom becomes lighter and hence it rises up. In this way the base of the convection is the difference in weight and upthrust. In the state of weightlessness this difference does not occur, so convection is not possible.

13. (b)

14. (d) For the two sheets $H_1 = H_2$ (H = Rate of heat flow)

$$\Rightarrow \frac{(100-\theta)}{R} = \frac{(\theta - 20)}{3R} \Rightarrow \theta = 80°C$$

15. (a) Rate of heat loss per unit area due to radiation *i.e.* emissive power $e = \varepsilon\sigma(T^4 - T_0^4)$

$$= 0.6 \times \frac{17}{3} \times 10^{-8} \times [(400)^4 - (300)^4]$$

$$= 3.4 \times 10^{-8} \times (175 \times 10^8) = 3.4 \times 175 = 595\ J/m^2 \times \sec$$

16. (a) Black bulb absorbs more heat in comparison with painted bulb. So air in black bulb expands more. Hence the level of alcohol in limb X falls while that in limb Y rises.

17. (a) Heat current $H = \frac{\Delta\theta}{R} \Rightarrow \frac{H_P}{H_S} = \frac{R_S}{R_P}$

In first case : $R_S = R_1 + R_2 = \frac{l}{(3K)A} + \frac{l}{KA} = \frac{4}{3}\frac{l}{KA}$

In second case : $R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{\frac{l}{(3K)A} \times \frac{l}{KA}}{\left(\frac{l}{(3K)A} + \frac{l}{KA}\right)} = \frac{l}{4KA}$

$$\therefore \frac{H_P}{H_S} = \frac{\frac{4l}{3KA}}{\frac{l}{4KA}} = \frac{16}{3}$$

17. (b) $\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} = \frac{0.2 \times 10 \times 20}{2 \times 10^{-3}} = 2 \times 10^4\ J/\sec$

18. (c) All wavelengths are emitted.

19. (d)

20. (d) $\frac{Q_1}{Q_2} = \frac{T_1^4}{T_2^4} = \left(\frac{273+27}{273+127}\right)^4 = \left(\frac{300}{400}\right)^4 = \frac{81}{256}$

21. (b) In first step

$$\frac{62-61}{T} = K\left[\frac{62-61}{2} - 30°\right] \Rightarrow \frac{1}{T} = K[81.5] \qquad \text{...(i)}$$

In second step, suppose process takes T' min then

$$\frac{46-45.5}{T'} = K\left[\frac{46-45.5}{2} - 30\right] \frac{0.5}{T'} = K[15.75] \qquad \text{...(ii)}$$

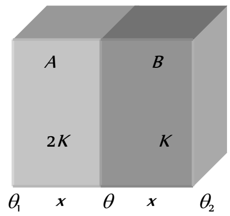
On diving equation (i) and (ii) $\frac{2T'}{T} = 2 \Rightarrow T' = T$

***

22. (b) Suppose conductivity of layer B is K, then it is $2K$ for layer A. Also conductivity of

combination layers A and B is K

$$= \frac{2\times 2K\times K}{(2K+K)} = \frac{4}{3}K$$



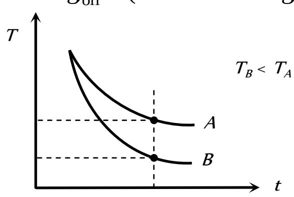
Hence $\left(\frac{Q}{t}\right)_{Combination} = \left(\frac{Q}{t}\right)_A$

$$\Rightarrow \frac{4}{3}\frac{KA\times 60}{2x} = \frac{2K.A\times(\Delta\theta)_A}{x} \Rightarrow (\Delta\theta)_A = 20K$$

23. (b) As we know, Rate of cooling $\propto \frac{1}{\text{specific heat(c)}}$

$\because c_{oil} < c_{Water}$

$\Rightarrow$ (Rate of cooling)$_{oil}$ > (Rate of cooling)$_{Water}$



It is clear that, at a particular time after start cooling, temperature of oil will be less than that of water.

So graph B represents the cooling curve of oil and A represents the cooling curve of water

16
Simple Harmonic Motion

Periodic and Oscillatory (Vibratory) Motion

(1) A motion, which repeat itself over and over again after a regular interval of time is called a periodic motion

Revolution of earth around the sun (period one year), Rotation of earth about its polar axis (period one day), Motion of hour's hand of a clock (period 12-hour) *etc* are common example of periodic motion.

(2) Oscillatory or vibratory motion is that motion in which a body moves to and fro or back and forth repeatedly about a fixed point in a definite interval of time. In such a motion, the body is confined with in well-defined limits on either side of mean position. Oscillatory motion is also called as harmonic motion.

(i) Common examples are

(a) The motion of the pendulum of a wall clock

(b) The motion of a load attached to a spring, when it is pulled and then released.

(c) The motion of liquid contained in U-tube when it is compressed once in one limb and left to itself.

(d) A loaded piece of wood floating over the surface of a liquid when pressed down and then released executes oscillatory motion.

(ii) Harmonic oscillation is that oscillation which can be expressed in terms of single harmonic function (*i.e.* sine or cosine function). *Example* : $y = a\sin\omega t$ or $y = a\cos\omega t$

(iii) Non-harmonic oscillation is that oscillation which can not be expressed in terms of single harmonic function. It is a combination of two or more than two harmonic oscillations. *Example* : $y = a\sin\omega t + b\sin 2\omega t$.

Simple Harmonic Motion

(1) Simple harmonic motion is a special type of periodic motion, in which a particle moves to and fro repeatedly about a mean position.

(2) In linear S.H.M. a restoring force which is always directed towards the mean position and whose magnitude at any instant is directly proportional to the displacement of the particle from the mean position at that instant *i.e.* Restoring force $\propto$ Displacement of the particle from mean position.

$$F \propto -x \Rightarrow F = -kx$$

Where k is known as force constant. Its S.I. unit is Newton/meter and dimension is $[MT^{-2}]$.

(3) In stead of straight line motion, if particle or centre of mass of body is oscillating on a small arc of circular path, then for angular S.H.M.

Restoring torque $(\tau) \propto -$ Angular displacement (θ)

Some Important Definitions

(1) **Time period** (T) **:** It is the least interval of time after which the periodic motion of a body repeats itself.

S.I. unit of time period is second.

(2) **Frequency** (n) **:** It is defined as the number of oscillations executed by body per second. S.I unit of frequency is hertz (Hz).

(3) **Angular Frequency** (ω) **:** Angular frequency of a body executing periodic motion is equal to product of frequency of the body with factor 2π. Angular frequency $\omega = 2\pi n$

Its unit is *rad/sec.*

(4) **Phase** (ϕ) **:** Phase of a vibrating particle at any instant is a physical quantity, which completely express the position and direction of motion, of the particle at that instant with respect to its mean position.

In oscillatory motion the phase of a vibrating particle is the argument of *sine* or *cosine* function involved to represent the generalised equation of motion of the vibrating particle.

$$y = a\sin\theta = a\sin(\omega t + \phi_0)$$

here, $\theta = \omega t + \phi_0$ = phase of vibrating particle.

ϕ = Initial phase or epoch. It is the phase of a vibrating particle at t = 0.

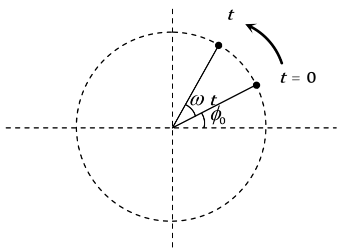


Fig. 16.2

(1) **Same phase :** Two vibrating particle are said to be in same phase, if the phase difference between them is an even multiple of π or path difference is an even multiple of $(\lambda / 2)$ or time interval is an even multiple of $(T/2)$ because 1 time period is equivalent to 2π *rad* or 1 wave length (λ).

(2) **Opposite phase :** When the two vibrating particles cross their respective mean positions at the same time moving in opposite directions, then the phase difference between the two vibrating particles is 180°.

Opposite phase means the phase difference between the particle is an odd multiple of π (say π, 3π, 5π, 7π.....) or the path difference is an odd multiple of λ (say $\frac{\lambda}{2}, \frac{3\lambda}{2}$,.......) or the time interval is an odd multiple of $(T/2)$.

(3) **Phase difference :** If two particles performs S.H.M and their equation are

$$y_1 = a\sin(\omega t + \phi_1) \text{ and } y_2 = a\sin(\omega t + \phi_2)$$

then phase difference $\Delta\phi = (\omega t + \phi_2) - (\omega t + \phi_1) = \phi_2 - \phi_1$

Displacement in S.H.M.

(1) The displacement of a particle executing S.H.M. at an instant is defined as the distance of particle from the mean position at that instant.

(2) Simple harmonic motion is also defined as the projection of uniform circular motion on any diameter of circle of reference.

(3) If the projection is taken on *y*-axis. then from the figure

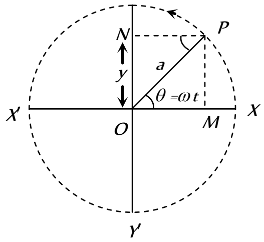


Fig. 16.3

$$y = a\sin\omega t = a\sin\frac{2\pi}{T}t = a\sin 2\pi n t = a\sin(\omega t \pm \phi)$$

(i) $y = a\sin\omega t$ when the time is noted from the instant when the vibrating particle is at mean position.

(ii) $y = a\cos\omega t$ when the time is noted from the instant when the vibrating particle is at extreme position.

(iii) $y = a\sin(\omega t \pm \phi)$ when the vibrating particle is ϕ phase leading or lagging from the mean position.

(4) If the projection of P is taken on *X*-axis then equations of S.H.M. can be given as

$$x = a\cos(\omega t \pm \phi) = a\cos\left(\frac{2\pi}{T}t \pm \phi\right) = a\cos(2\pi n t \pm \phi)$$

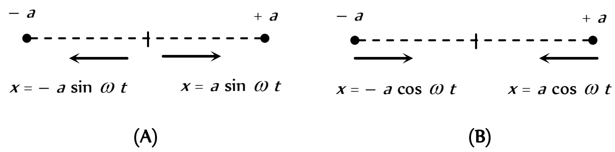


Fig. 16.4

(5) Direction of displacement is always away from the equilibrium position, particle either is moving away from or is coming towards the equilibrium position.

Velocity in S.H.M.

(1) Velocity of the particle executing S.H.M. at any instant, is defined as the time rate of change of its displacement at that instant.

(2) In case of S.H.M. when motion is considered from the equilibrium position, displacement $y = a\sin\omega t$

So $v = \frac{dy}{dt} = a\omega\cos\omega t = a\omega\sqrt{1 - \sin^2\omega t} = \omega\sqrt{a^2 - y^2}$

[As $\sin\omega t = y/a$]

(3) At mean position or equilibrium position (y = 0 and $\theta = \omega t$ = 0), velocity of particle is maximum and it is $v_{max} = a\omega$.

(4) At extreme position ($y = \pm a$ and $\theta = \omega t = \pi/2$), velocity of oscillating particle is zero *i.e.* v = 0.

(5) From $v = \omega\sqrt{a^2 - y^2} \Rightarrow v^2 = \omega^2(a^2 - y^2) \Rightarrow \frac{v^2}{\omega^2} = a^2 - y^2$

$$\Rightarrow \frac{v^2}{a^2\omega^2} + \frac{y^2}{a^2} = 1$$

This is the equation of ellipse. Hence the graph between v and y is an ellipse.

For ω = 1, graph between v and y is a circle.

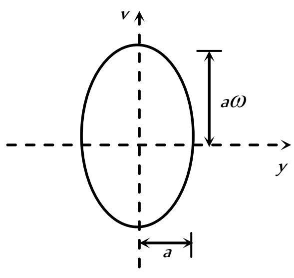


Fig. 16.5

(6) Direction of velocity is either towards or away from mean position depending on the position of particle.

Acceleration in S.H.M.

(1) The acceleration of the particle executing S.H.M. at any instant, is defined as the rate of change of its velocity at that instant. So acceleration

$$A = \frac{dv}{dt} = \frac{d}{dt}(a\omega\cos\omega t) = -\omega^2 a\sin\omega t = -\omega^2 y$$

[As $y = a\sin\omega t$]

(2) In S.H.M. as $|\text{Acceleration}| = \omega^2 y$ is not constant. So equations of translatory motion can not be applied.

(3) In S.H.M. acceleration is maximum at extreme position (at $y = \pm a$).

Hence $|A_{max}| = \omega^2 a$ when $|\sin\omega t| = \text{maximum} = 1$ *i.e.* at $t = \frac{T}{4}$ or $\omega t = \frac{\pi}{2}$. From equation (ii) $|A_{max}| = \omega^2 a$ when $y = a$.

(i) In S.H.M. acceleration is minimum at mean position

From equation (i) $A_{min} = 0$ when $\sin\omega t = 0$ *i.e.* at $t = 0$ or $t = \frac{T}{2}$ or $\omega t = \pi$. From equation (ii) $A_{min} = 0$ when $y = 0$

(ii) Acceleration is always directed towards the mean position and so is always opposite to displacement

i.e., $A \propto -y$

Graph between acceleration (A) and displacement (y) is a straight line as shown

Slope of the line = $-\omega$

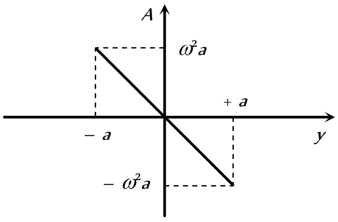


Fig. 16.6

Comparative Study of Displacement Velocity and Acceleration

(1) All the three quantities displacement, velocity and acceleration show harmonic variation with time having same period.

(2) The velocity amplitude is ω times the displacement amplitude

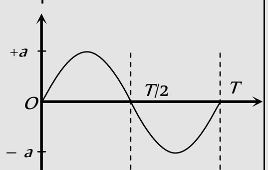
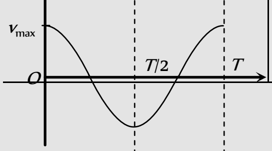
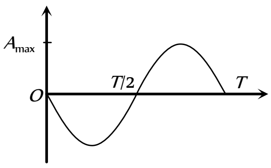
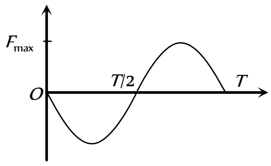
(3) The acceleration amplitude is ω^2 times the displacement amplitude

(4) In S.H.M. the velocity is ahead of displacement by a phase angle $\pi / 2$

(5) In S.H.M. the acceleration is ahead of velocity by a phase angle $\pi / 2$

(6) The acceleration is ahead of displacement by a phase angle of π

Table 16.1 : Various physical quantities in S.H.M. at different position :

Graph	Formula	At mean position	At extreme position
Displacement 	$y = a\sin\omega t$	$y = 0$	$y = \pm a$
Velocity 	$v = a\omega\cos\omega t$ $= a\omega\sin(\omega t + \frac{\pi}{2})$ or $v = \omega\sqrt{a^2 - y^2}$	$v_{max} = a\omega$	$v_{min} = 0$
Acceleration 	$A = -a\omega^2\sin\omega t$ $= a\omega^2\sin(\omega t + \pi)$ or $\lvert A\rvert = \omega^2 y$	$A_{min} = 0$	$\lvert A_{max}\rvert = \omega^2 a$
Force 	$F = -m\omega^2 a\sin\omega t$ or $F = m\omega^2 y$	$F_{min} = 0$	$F_{max} = m\omega^2 a$

Energy in S.H.M.

(1) **Potential energy :** This is an account of the displacement of the particle from its mean position.

(i) The restoring force $F = -ky$ against which work has to be done. Hence potential energy U is given by

$$U = \int dU = -\int dW = -\int_0^x F dx = \int_0^y ky\, dy = \frac{1}{2}ky^2 + U_0$$

where U_0 = Potential energy at equilibrium position.

If $U_0 = 0$ then $U = \frac{1}{2}m\omega^2 y^2$ [As $\omega^2 = k/m$]

(ii) Also $U = \frac{1}{2}m\omega^2 a^2\sin^2\omega t = \frac{1}{4}m\omega^2 a^2(1 - \cos 2\omega t)$

[As $y = a\sin\omega t$]

Hence potential energy varies periodically with double the frequency of S.H.M.

(iii) Potential energy maximum and equal to total energy at extreme positions

$$U_{max} = \frac{1}{2}ka^2 = \frac{1}{2}m\omega^2 a^2 \text{ when } y = \pm a;\ \omega t = \pi/2;\ t = \frac{T}{4}$$

(iv) Potential energy is minimum at mean position

$U_{min} = 0$ when $y = 0$; $\omega t = 0$; $t = 0$

(2) **Kinetic energy :** This is because of the velocity of the particle

Kinetic Energy $K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2(a^2 - y^2)$

[As $v = \omega\sqrt{a^2 - y^2}$]

(i) Also $K = \frac{1}{2}m\omega^2 a^2\cos^2\omega t = \frac{1}{4}m\omega^2 a^2(1 + \cos 2\omega t)$

[As $v = a\omega\cos\omega t$]

Hence kinetic energy varies periodically with double the frequency of S.H.M.

(ii) Kinetic energy is maximum at mean position and equal to total energy at mean position.

$$K_{max} = \frac{1}{2} m\omega^2 a^2 \text{ when } y = 0 \; ; \; t = 0 \; ; \; \omega t = 0$$

(iii) Kinetic energy is minimum at extreme position.

$$K_{min} = 0 \qquad \text{when } y = a \; ; \; t = T/4 \; , \; \omega t = \pi/2$$

(3) **Total mechanical energy :** Total mechanical energy always remains constant and it is equal to sum of potential energy and kinetic energy *i.e.* $E = U + K$

$$E = \frac{1}{2} m\omega^2 (a^2 - y^2) + \frac{1}{2} m\omega^2 y^2 = \frac{1}{2} m\omega^2 a^2$$

Total energy is not a position function.

(4) **Energy position graph**

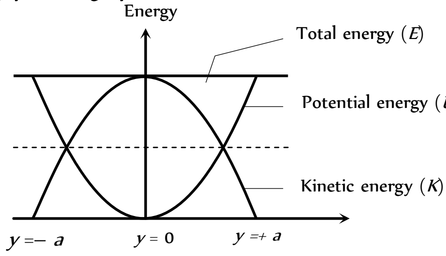


Fig. 16.7

(i) At $y = 0$; $U = 0$ and $K = E$

(ii) At $y = \pm a$; $U = E$ and $K = 0$

(iii) At $y = \pm \frac{a}{2}$; $U = \frac{E}{4}$ and $K = \frac{3E}{4}$

(iv) At $y = \pm \frac{a}{\sqrt{2}}$; $U = K = \frac{E}{2}$

Average Value of P.E. and K.E.

The average value of potential energy for complete cycle is given by

$$U_{average} = \frac{1}{T}\int_0^T U\,dt = \frac{1}{T}\int_0^T \frac{1}{2} m\,\omega^2 a^2 \sin^2(\omega t + \phi) = \frac{1}{4} m\omega^2 a^2$$

The average value of kinetic energy for complete cycle

$$K_{average} = \frac{1}{T}\int_0^T K\,dt = \frac{1}{T}\int_0^T \frac{1}{2} m\,\omega^2 a^2 \cos^2 \omega t\,dt = \frac{1}{4} m\omega^2 a^2$$

Thus average values of kinetic energy and potential energy of harmonic oscillator are equal and each equal to half of the total energy $K_{average} = U_{average} = \frac{1}{2} E = \frac{1}{4} m\omega^2 a^2$.

Differential Equation of S.H.M.

For S.H.M. (linear) Acceleration $\propto$ – (Displacement)

$$A \propto -y \quad \text{or} \quad A = -\omega^2 y \quad \text{or} \quad \frac{d^2 y}{dt^2} = -\omega^2 y$$

or $m\frac{d^2 y}{dt^2} + ky = 0$ [As $\omega = \sqrt{\frac{k}{m}}$]

For angular S.H.M. $\tau = -c\theta$ and $\frac{d^2\theta}{dt^2} + \omega^2\theta = 0$

where $\omega^2 = \frac{c}{I}$ [As c = Restoring torque constant and I = Moment of inertia]

How to Find Frequency and Time Period of S.H.M.

Step 1 : When particle is in its equilibrium position, balance all forces acting on it and locate the equilibrium position mathematically.

Step 2 : From the equilibrium position, displace the particle slightly by a displacement y and find the expression of net restoring force on it.

Step 3 : Try to express the net restoring force acting on particle as a proportional function of its displacement from mean position. The final expression should be obtained in the form.

$$F = -ky$$

Here we put – *ve* sign as direction of F is opposite to the displacement y. If a be the acceleration of particle at this displacement, we have $a = -\left(\frac{k}{m}\right)y$

Step 4 : Comparing this equation with the basic differential equation of S.H.M. we get $\omega^2 = \frac{k}{m} \Rightarrow \omega = \sqrt{\frac{k}{m}}$ or $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

As ω is the angular frequency of the particle in S.H.M., its time period of oscillation can be given as $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

(i) In different types of S.H.M. the quantities m and k will go on taking different forms and names. In general m is called inertia factor and k is called spring factor.

Thus $T = 2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$ or $n = \frac{1}{2\pi}\sqrt{\frac{\text{Spring factor}}{\text{Inertia factor}}}$

(ii) In linear S.H.M. the spring factor stands for force per unit displacement and inertia factor for mass of the body executing S.H.M. and in Angular S.H.M. k stands for restoring torque per unit angular displacement and inertial factor for moment of inertia of the body executing S.H.M.

For linear S.H.M.

$$T = 2\pi\sqrt{\frac{m}{k}} = \sqrt{\frac{m}{\text{Force/Displacement}}} = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}}$$

Simple Pendulum

(1) An ideal simple pendulum consists of a heavy point mass body (bob) suspended by a weightless, inextensible and perfectly flexible string from a rigid support about which it is free to oscillate.

(2) But in reality neither point mass nor weightless string exist, so we can never construct a simple pendulum strictly according to the definition.

(3) Suppose simple pendulum of length l is displaced through a small angle θ from it's mean (vertical) position. Consider mass of the bob is m and linear displacement from mean position is x

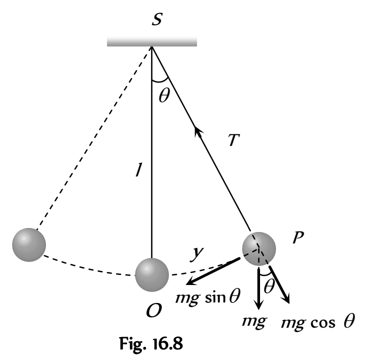


Fig. 16.8

Restoring force acting on the bob

$$F = -mg\sin\theta \quad \text{or} \quad F = -mg\theta = -mg\frac{x}{l}$$

(When θ is small $\sin\theta \simeq \theta = \frac{\text{Arc}}{\text{Length}} = \frac{OP}{l} = \frac{x}{l}$)

$$\therefore \quad \frac{F}{x} = \frac{-mg}{l} = k \quad \text{(Spring factor)}$$

So $T = 2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}} = 2\pi\sqrt{\frac{m}{mg/l}} = 2\pi\sqrt{\frac{l}{g}}$

Factor Affecting Time Period of Simple Pendulum

(1) **Amplitude :** The period of simple pendulum is independent of amplitude as long as its motion is simple harmonic. But if θ is not small, $\sin\theta \neq \theta$ then motion will not remain simple harmonic but will become oscillatory. In this situation if θ is the amplitude of motion. Time period

$$T = 2\pi\sqrt{\frac{l}{g}}\left[1 + \frac{1}{2^2}\sin^2\left(\frac{\theta_0}{2}\right) + ...\right] \approx T_0\left[1 + \frac{{\theta_0}^2}{16}\right]$$

(2) **Mass of the bob :** Time period of simple pendulum is also independent of mass of the bob. This is why

(i) If the solid bob is replaced by a hollow sphere of same radius but different mass, time period remains unchanged.

(ii) If a girl is swinging in a swing and another sits with her, the time period remains unchanged.

(3) **Length of the pendulum :** Time period $T \propto \sqrt{l}$ where l is the distance between point of suspension and center of mass of bob and is called effective length.

(i) When a sitting girl on a swinging swing stands up, her center of mass will go up and so l and hence T will decrease.

(ii) If a hole is made at the bottom of a hollow sphere full of water and water comes out slowly through the hole and time period is recorded till the sphere is empty, initially and finally the center of mass will be at the center of the sphere. However, as water drains off the sphere, the center of mass of the system will first move down and then will come up. Due to this l and hence T first increase, reaches a maximum and then decreases till it becomes equal to its initial value.

(iii) Different graphs

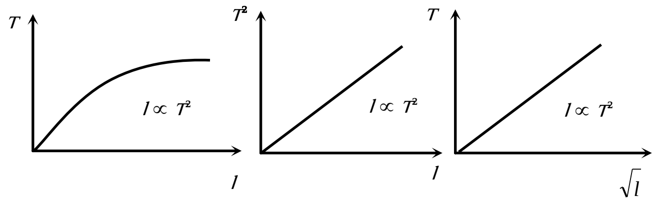


Fig. 16.9

(4) **Effect of g :** $T \propto \frac{1}{\sqrt{g}}$ *i.e.* as g increase T decreases.

(i) As we go high above the earth surface or we go deep inside the mines the value of g decrease, hence time period of pendulum (T) increases.

(ii) If a clock, based on simple pendulum is taken to hill (or on any other planet), g will decrease so T will increases and clock will become slower.

(iii) Different graphs

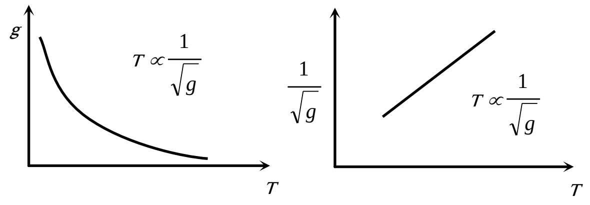


Fig. 16.10

(5) **Effect of temperature on time period :** If the bob of simple pendulum is suspended by a wire then effective length of pendulum will increase with the rise of temperature due to which the time period will increase.

$l = l_0(1 + \alpha\Delta\theta)$ (If $\Delta\theta$ is the rise in temperature, l_0 = initial length of wire, l = final length of wire)

$$\frac{T}{T_0} = \sqrt{\frac{l}{l_0}} = (1 + \alpha\Delta\theta)^{1/2} \approx 1 + \frac{1}{2}\alpha\Delta\theta$$

So $\frac{T}{T_0} - 1 = \frac{1}{2}\alpha\Delta\theta$ *i.e.* $\frac{\Delta T}{T} \approx \frac{1}{2}\alpha\Delta\theta$

Oscillation of Pendulum in Different Situations

(1) **Oscillation in liquid :** If bob a simple pendulum of density ρ is made to oscillate in some fluid of density σ (where $\sigma < \rho$) then time period of simple pendulum gets increased.

As thrust will oppose its weight hence $mg_{eff.} = mg -$ Thrust

or $g_{eff.} = g - \frac{V\sigma g}{V\rho}$ *i.e.* $g_{eff.} = g\left[1 - \frac{\sigma}{\rho}\right]$

$$\Rightarrow \frac{g_{eff.}}{g} = \frac{\rho - \sigma}{\rho}$$

$$\Rightarrow \frac{T'}{T} = \sqrt{\frac{g}{g_{eff.}}} = \sqrt{\frac{\rho}{\rho - \sigma}} > 1$$

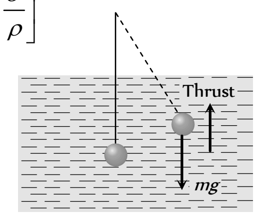


Fig. 16.11

(2) **Oscillation under the influence of electric field :** If a bob of mass m carries a positive charge q and pendulum is placed in a uniform electric field of strength E

(i) If electric field directed vertically upwards.

Effective acceleration

$$g_{eff.} = g - \frac{qE}{m}$$

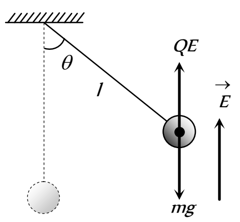


Fig. 16.12

So $T = 2\pi\sqrt{\dfrac{l}{g - \dfrac{qE}{m}}}$

(ii) If electric field is vertically downward then

$$g_{eff.} = g + \frac{qE}{m}$$

$$T = 2\pi\sqrt{\frac{l}{g + \dfrac{qE}{m}}}$$

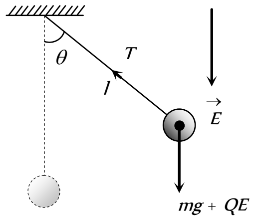


Fig. 16.13

(3) **Pendulum in a lift :** If the pendulum is suspended from the ceiling of the lift.

(i) If the lift is at rest or moving down ward /up ward with constant velocity.

$$T = 2\pi\sqrt{\frac{l}{g}}$$

and $n = \dfrac{1}{2\pi}\sqrt{\dfrac{g}{l}}$

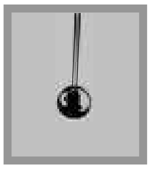


Fig. 16.14

(ii) If the lift is moving up ward with constant acceleration *a*

$$T = 2\pi\sqrt{\frac{l}{g+a}}$$

and $n = \dfrac{1}{2\pi}\sqrt{\dfrac{g+a}{l}}$

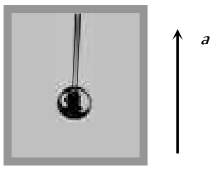


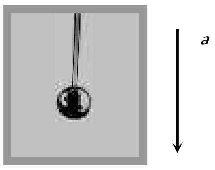
Fig. 16.15

Time period decreases and frequency increases

(iii) If the lift is moving down ward with constant acceleration *a*

$$T = 2\pi\sqrt{\frac{l}{g-a}}$$

and $n = \dfrac{1}{2\pi}\sqrt{\dfrac{g-a}{l}}$



Time period increase and frequency decreases

Fig. 16.16

(iv) If the lift is moving down ward with acceleration $a = g$

$$T = 2\pi\sqrt{\frac{l}{g-g}} = \infty$$

and $n = \dfrac{1}{2\pi}\sqrt{\dfrac{g-g}{l}} = 0$

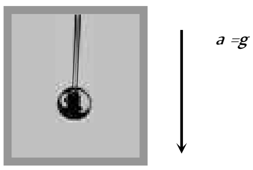


Fig. 16.17

It means there will be no oscillation in a pendulum.

Similar is the case in a satellite and at the centre of earth where effective acceleration becomes zero and pendulum will stop.

(4) **Pendulum in an accelerated vehicle :** The time period of simple pendulum whose point of suspension moving horizontally with acceleration *a*

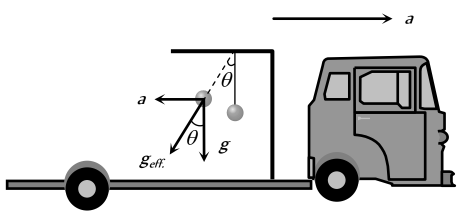


Fig. 16.18

In this case effective acceleration $g_{eff.} = \sqrt{g^2 + a^2}$

$$T = 2\pi\sqrt{\frac{l}{(g^2 + a^2)^{1/2}}} \quad \text{and} \quad \theta = \tan^{-1}(a/g)$$

If simple pendulum suspended in a car that is moving with constant speed *v* around a circle of radius *r*.

$$T = 2\pi\frac{\sqrt{l}}{\sqrt{g^2 + \left(\dfrac{v^2}{r}\right)^2}}$$

Some Other Types of Pendulum

(1) **Infinite length pendulum :** If the length of the pendulum is comparable to the radius of earth then

$$T = 2\pi\sqrt{\frac{1}{g\left[\dfrac{1}{l} + \dfrac{1}{R}\right]}}$$

(i) If $l << R$, then $\dfrac{1}{l} >> \dfrac{1}{R}$ so $T = 2\pi\sqrt{\dfrac{l}{g}}$

(ii) If $l >> R (\to \infty)$ then $\dfrac{1}{l} < \dfrac{1}{R}$

so $T = 2\pi\sqrt{\dfrac{R}{g}} = 2\pi\sqrt{\dfrac{6.4 \times 10^6}{10}} \cong 84.6$ *minutes*

and it is the maximum time period which an oscillating simple pendulum can have

(iii) If $l = R$ so $T = 2\pi\sqrt{\dfrac{R}{2g}} \cong 1 hour$

(2) **Second's Pendulum :** It is that simple pendulum whose time period of vibrations is two seconds.

Putting $T = 2$ *sec* and $g = 9.8 m/\sec^2$ in $T = 2\pi\sqrt{\dfrac{l}{g}}$ we get

$$l = \frac{4 \times 9.8}{4\pi^2} = 0.993\ m = 99.3\ cm$$

Hence length of second's pendulum is 99.3 *cm* or nearly 1 meter on earth surface.

For the moon the length of the second's pendulum will be 1/6 meter

[As $g_{moon} = \dfrac{g_{\text{Earth}}}{6}$]

(3) **Compound pendulum :** Any rigid body suspended from a fixed support constitutes a physical pendulum. Consider the situation when the body is displaced through a small angle θ. Torque on the body about *O* is given by

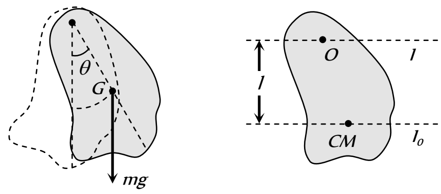


Fig. 16.19

$\tau = mgl\sin\theta$ ...(i)

where l = distance between point of suspension and centre of mass of the body.

If I be the M.I. of the body about O. Then $\tau = I\alpha$ ...(ii)

From (i) and (ii), we get $I\dfrac{d^2\theta}{dt^2} = -mgl\sin\theta$ as θ and $\dfrac{d^2\theta}{dt^2}$ are oppositely directed $\Rightarrow \dfrac{d^2\theta}{dt^2} = -\dfrac{mgl}{I}\theta$ since θ is very small

Comparing with the equation $\dfrac{d^2\theta}{dt^2} = -\omega^2\theta$, we get

$$\omega = \sqrt{\frac{mgl}{I}} \Rightarrow T = 2\pi\sqrt{\frac{I}{mgl}}$$

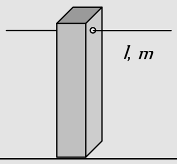
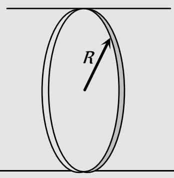
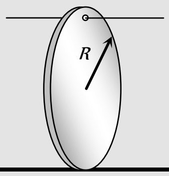
Also $I = I_{cm} + ml^2$ (Parallel axis theorem)

$= mk^2 + ml^2$ (where k = radius of gyration)

$$\therefore\ T = 2\pi\sqrt{\frac{mK^2 + ml^2}{mgl}} = 2\pi\sqrt{\frac{\frac{K^2}{l} + l}{g}} = 2\pi\sqrt{\frac{l_{eff}}{g}}$$

l_{eff} = Effective length of pendulum = Distance between point of suspension and centre of mass.

Table 16. 2: Some common physical pendulum

Body	Time period
Bar 	$T = 2\pi\sqrt{\dfrac{2l}{3g}}$
Ring 	$T = 2\pi\sqrt{\dfrac{2R}{g}}$
Disc 	$T = 2\pi\sqrt{\dfrac{3R}{2g}}$

Spring System

When a spring is stretched or compressed from its normal position (x = 0) by a small distance x, then a restoring force is produced in the spring because it obeys Hook's law

i.e. $F \propto -x \Rightarrow F = -k\,x$

where k is called spring constant.

(i) It's S.I. unit *Newton/metre*, C.G.S unit *Dyne/cm* and dimension is $[MT^{-2}]$

(ii) Actually k is a measure of the stiffness/softness of the spring.

(iii) For massless spring constant restoring elastic force is same every where

(iv) When a spring compressed or stretched then work done is stored in the form of elastic potential energy in it.

(v) Spring constant depend upon radius and length of the wire used in spring.

(vi) The spring constant k is inversely proportional to the spring length.

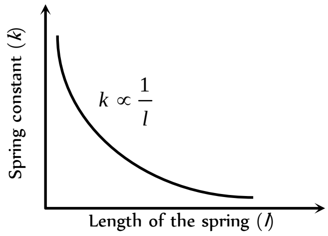


Fig. 16.20

$$k \propto \frac{1}{\text{Extension}} \propto \frac{1}{\text{Length of spring}}$$

That means if the length of spring is halved then its force constant becomes double.

(vii) When a spring of length l is cut in two pieces of length l_1 and l_2 such that $l_1 = nl_2$.

If the constant of a spring is k then spring constant of first part

$$k_1 = \frac{k(n+1)}{n}$$

Spring constant of second part $k_2 = (n+1)k$

and ratio of spring constant $\dfrac{k_1}{k_2} = \dfrac{1}{n}$

Spring Pendulum

A point mass suspended from a mass less spring or placed on a frictionless horizontal plane attached with spring (fig.) constitutes a linear harmonic spring pendulum

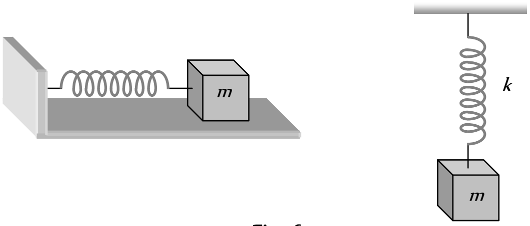


Fig. 16.21

Time period $T = 2\pi\sqrt{\dfrac{\text{Inertia factor}}{\text{Spring factor}}} = 2\pi\sqrt{\dfrac{m}{k}}$

and Frequency $n = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}}$

(1) Time period of a spring pendulum depends on the mass suspended

$\Rightarrow T \propto \sqrt{m}$ or $n \propto \dfrac{1}{\sqrt{m}}$ *i.e.* greater the mass greater will be the inertia and so lesser will be the frequency of oscillation and greater will be the time period.

(2) The time period depends on the force constant k of the spring *i.e.* $T \propto \dfrac{1}{\sqrt{k}}$ or $n \propto \sqrt{k}$

(3) Time of a spring pendulum is independent of acceleration due to gravity. That is why a clock based on spring pendulum will keep proper time every where on a hill or moon or in a satellite and time period of a spring pendulum will not change inside a liquid if damping effects are neglected.

(4) **Massive spring :** If the spring has a mass M and mass m is suspended from it, effective mass is given by $m_{eff} = m + \frac{M}{3}$. Hence

$$T = 2\pi\sqrt{\frac{m_{eff}}{k}}$$

(5) **Reduced mass :** If two masses of mass m_1 and m_2 are connected by a spring and made to oscillate on horizontal surface, the reduced mass m_r is given by $\frac{1}{m_r} = \frac{1}{m_1} + \frac{1}{m_2}$ so that

$$T = 2\pi\sqrt{\frac{m_r}{k}}$$

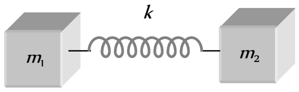


Fig. 16.22

(6) If a spring pendulum, oscillating in a vertical plane is made to oscillate on a horizontal surface, (or on inclined plane) time period will remain unchanged.

(7) Equilibrium position for a spring in a horizontal plain is the position of natural length of spring as weight is balanced by reaction. While in case of vertical motion equilibrium position will be $l + y_0$ with $ky_0 = mg$

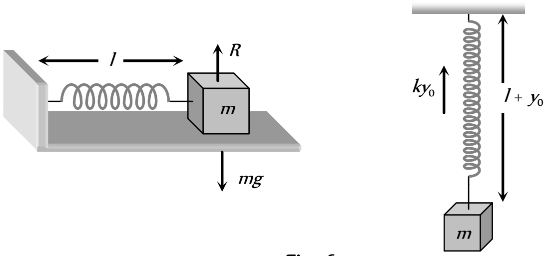


Fig. 16.23

If the stretch in a vertically loaded spring is y_0 then for equilibrium of mass m, $ky_0 = mg$ *i.e.* $\frac{m}{k} = \frac{y_0}{g}$

So that $$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{y_0}{g}}$$

Time period does not depends on 'g' because along with g, y_0 will also change in such a way that $\frac{y_0}{g} = \frac{m}{k}$ remains constant

Oscillation of Spring Combination

(1) **Series combination :** If two springs of spring constants K_1 and K_2 are joined in series as shown then

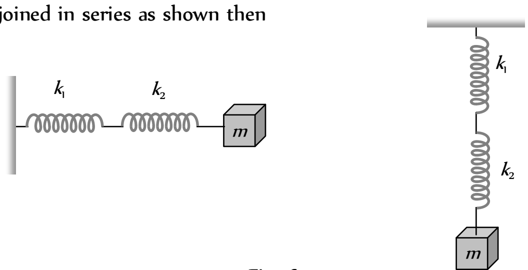


Fig. 16.24

(i) In series combination equal forces acts on spring but extension in springs are different.

(ii) Spring constants of combination

$$\frac{1}{k_s} = \frac{1}{k_1} + \frac{1}{k_2} \Rightarrow k_s = \frac{k_1 k_2}{k_1 + k_2}$$

(iii) If n springs of different force constant are connected in series having force constant k_1, k_2, k_3....... respectively then

$$\frac{1}{k_S} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + ...$$

If all spring have same spring constant then $k_S = \frac{k}{n}$

(iv) Time period of combination $T = 2\pi\sqrt{\frac{m}{k_S}} = 2\pi\sqrt{\frac{m(k_1 + k_2)}{k_1 k_2}}$

(2) **Parallel combination :** If the springs are connected in parallel as shown

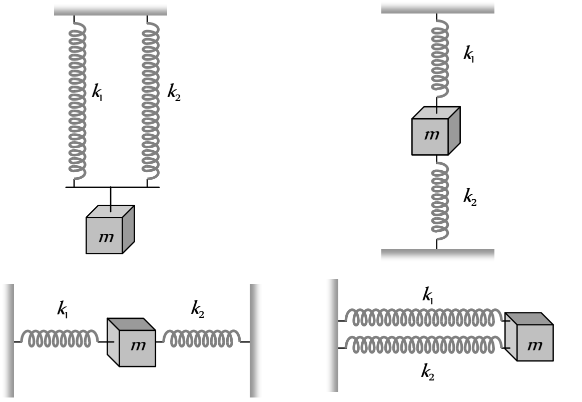


Fig. 16.25

(i) In parallel combination different forces acts on different springs but extension in springs are same

(ii) Spring constants of combination $k_P = k_1 + k_2$

(iii) If n springs of different force constant are connected in parallel having force constant k_1, k_2, k_3....... respectively then $k_P = k_1 + k_2 + k_3 + ...$

If all spring have same spring constant then $k_P = nk$

(iv) Time period of combination $T_P = 2\pi\sqrt{\frac{m}{k_P}} = 2\pi\sqrt{\frac{m}{(k_1 + k_2)}}$

Various Formulae of S.H.M.

(1) **S.H.M. of a liquid in U tube :** If a liquid of density ρ contained in a vertical U tube performs S.H.M. in its two limbs. Then time period

$$T = 2\pi\sqrt{\frac{L}{2g}} = 2\pi\sqrt{\frac{h}{g}}$$

where L = Total length of liquid column,

h = Height of undisturbed liquid in each limb (L=2h)

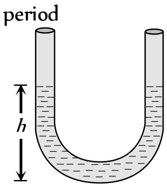


Fig. 16.26

(2) **S.H.M. of a floating cylinder :** If l is the length of cylinder dipping in liquid then

Time period $T = 2\pi\sqrt{\frac{l}{g}}$

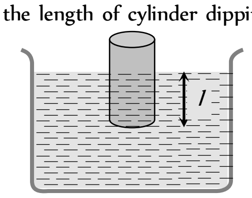


Fig. 16.27

(3) **S.H.M. of a small ball rolling down in hemi-spherical bowl**

$$T = 2\pi\sqrt{\frac{R - r}{g}}$$

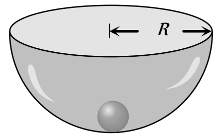


Fig. 16.28

R = Radius of the bowl

r =Radius of the ball

(4) **S.H.M. of a piston in a cylinder**

$$T = 2\pi\sqrt{\frac{Mh}{PA}}$$

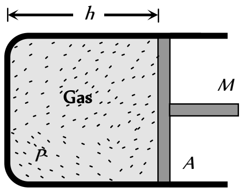


Fig. 16.29

M = mass of the piston

A = area of cross section

h = height of cylinder

P = pressure in a cylinder

(5) **S.H.M. of a body in a tunnel dug along any chord of earth**

$$T = 2\pi\sqrt{\frac{R}{g}} = 84.6 \text{ minutes}$$

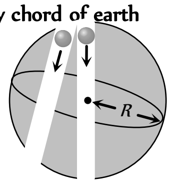


Fig. 16.30

(6) **Torsional pendulum :** In a torsional pendulum an object is suspended from a wire. If such a wire is twisted, due to elasticity it exert a restoring toque $\tau = C\theta$.

In this case time period is given by

$$T = 2\pi\sqrt{\frac{I}{C}}$$

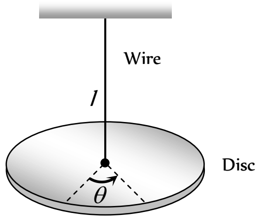


Fig. 16.31

where I = Moment of inertia a disc

C = Torsional constant of wire = $\frac{\pi\eta r^4}{2l}$

η = Modulus of elasticity of wire and r = Radius of wire

(7) **Longitudinal oscillations of an elastic wire :** Wire/string pulled a distance Δl and left. It executes longitudinal oscillations. Restoring force

$$F = -AY\left(\frac{\Delta l}{l}\right)$$

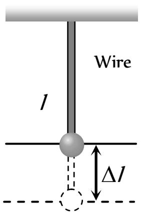


Fig. 16.32

Y = Young's modulus

A = Area of cross-section

Hence $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{ml}{AY}}$

Free, Damped, Forced and Maintained Oscillations

(1) **Free oscillation**

(i) The oscillation of a particle with fundamental frequency under the influence of restoring force are defined as free oscillations

(ii) The amplitude, frequency and energy of oscillation remains constant

(iii) Frequency of free oscillation is called natural frequency because it depends upon the nature and structure of the body.

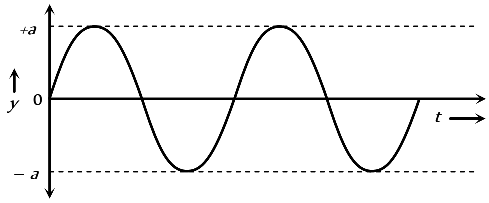


Fig. 16.33

(2) **Damped oscillation**

(i) The oscillation of a body whose amplitude goes on decreasing with time are defined as damped oscillation

(ii) In these oscillation the amplitude of oscillation decreases exponentially due to damping forces like frictional force, viscous force, hystersis *etc*.

(iii) Due to decrease in amplitude the energy of the oscillator also goes on decreasing exponentially

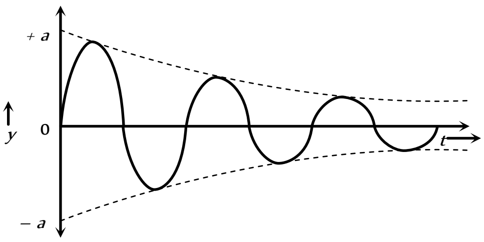


Fig. 16.34

(iv) The force produces a resistance to the oscillation is called damping force.

If the velocity of oscillator is v then

Dumping force $F_d = -bv$, b = damping constant

(v) Resultant force on a damped oscillator is given by

$$F = F_R + F_d = -Kx - Kv \Rightarrow \frac{md^2x}{dt^2} + b\frac{dx}{dt} + Kx = 0$$

(vi) Displacement of damped oscillator is given by

$x = x_m e^{-bt/2m}\sin(\omega' t + \phi)$ where ω' = angular frequency of the damped oscillator = $\sqrt{\omega_0^2 - (b/2m)^2}$

The amplitude decreases continuously with time according to

$$x = x_m e^{-(b/2m)t}$$

(vii) For a damped oscillator if the damping is small then the mechanical energy decreases exponentially with time as

$$E = \frac{1}{2}Kx_m^2 e^{-bt/m}$$

(3) **Forced oscillation**

(i) The oscillation in which a body oscillates under the influence of an external periodic force are known as forced oscillation

(ii) The amplitude of oscillator decrease due to damping forces but on account of the energy gained from the external source it remains constant.

(iii) Resonance : When the frequency of external force is equal to the natural frequency of the oscillator. Then this state is known as the state of resonance. And this frequency is known as resonant frequency.

(iv) While swinging in a swing if you apply a push periodically by pressing your feet against the ground, you find that not only the oscillations can now be maintained but the amplitude can also be increased. Under this condition the swing has forced or driven oscillation.

(v) In forced oscillation, frequency of damped oscillator is equal to the frequency of external force.

(vi) Suppose an external driving force is represented by

$F(t) = F_0 \cos \omega_d t$

The motion of a particle under combined action of

(a) Restoring force $(-Kx)$

(b) Damping force $(-bv)$ and

(c) Driving force $F(t)$ is given by $ma = -Kx - bv + F_0 \cos \omega_d t$

$$\Rightarrow m^2 \frac{d^2x}{d^2} + Kx + b\frac{dx}{dt} = F_0 \cos \omega_d t$$

The solution of this equation gives $x = x_0 \sin(\omega_d t + \phi)$ with amplitude $x_0 = \dfrac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2) + (b\omega/m)^2}}$ and $\tan\theta = \dfrac{(\omega^2 - \omega_0^2)}{b\omega/m}$

where $\omega_0 = \sqrt{\dfrac{K}{m}}$ = Natural frequency of oscillator.

(vii) **Amplitude resonance :** The amplitude of forced oscillator depends upon the frequency ω_d of external force.

When $\omega = \omega_d$, the amplitude is maximum but not infinite because of presence of damping force. The corresponds frequency is called resonant frequency (ω_0).

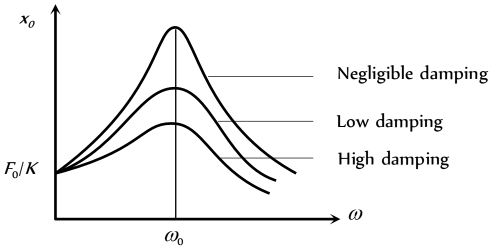


Fig. 16.35

(viii) **Energy resonance :** At $\omega = \omega_0$, oscillator absorbs maximum kinetic energy from the driving force system this state is called energy resonance.

At resonance the velocity of a driven oscillator is in phase with the driving term.

The sharpness of the resonance of a driven oscillator depends on the damping.

In the driven oscillator, the power input of the driving term in maximum at resonance.

(4) **Maintained oscillation :** The oscillation in which the loss of oscillator is compensated by the supplying energy from an external source are known as maintained oscillation.

Super Position of S.H.M's (Lissajous Figures)

If two S.H.M's act in perpendicular directions, then their resultant motion is in the form of a straight line or a circle or a parabola etc. depending on the frequency ratio of the two S.H.M. and initial phase difference. These figures are called Lissajous figures.

Let the equations of two mutually perpendicular S.H.M's of same frequency be

$x = a_1 \sin\omega t$ and $y = a_2 \sin(\omega t + \phi)$

then the general equation of Lissajou's figure can be obtained as

$$\frac{x^2}{a_1^2} + \frac{y^2}{a_2^2} - \frac{2xy}{a_1 a_2}\cos\phi = \sin^2\phi$$

For $\phi = 0°$: $\dfrac{x^2}{a_1^2} + \dfrac{y^2}{a_2^2} - \dfrac{2xy}{a_1 a_2} = 0 \Rightarrow \left(\dfrac{x}{a_1} - \dfrac{y}{a_2}\right)^2 = 0$

$$\Rightarrow \frac{x}{a_1} = \frac{y}{a_2} \Rightarrow y = \frac{a_2}{a_1}x$$

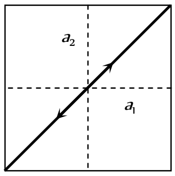
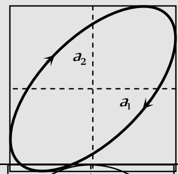
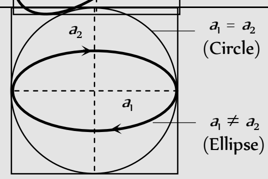
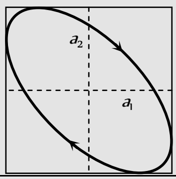
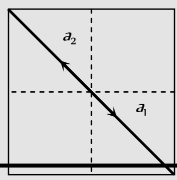


Fig. 16.36

This is a straight line passes through origin and it's slope is $\dfrac{a_2}{a_1}$.

Table 16.3 : Lissajou's figures in other conditions

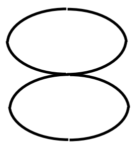
(with $\dfrac{\omega_1}{\omega_2} = 1$)

Phase diff.(ϕ)	Equation	Figure
$\frac{\pi}{4}$	$\frac{x^2}{a_1^2} + \frac{y^2}{a_2^2} - \frac{\sqrt{2}xy}{a_1 a_2} = \frac{1}{2}$	Oblique ellipse 
$\frac{\pi}{2}$	$\frac{x^2}{a_1^2} + \frac{y^2}{a_2^2} = 1$	
$\frac{3\pi}{4}$	$\frac{x^2}{a_1^2} + \frac{y^2}{a_2^2} - \frac{\sqrt{2}xy}{a_1 a_2} = \frac{1}{2}$	Oblique ellipse 
π	$\frac{x}{a_1} + \frac{y}{a_2} = 0$ $\Rightarrow y = -\frac{a_2}{a_1}x$	Straight line 

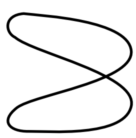
For the frequency ratio $\omega_1 : \omega_2 = 2 : 1$ the two perpendicular S.H.M's are

$x = a_1 \sin(\omega t + \phi)$ and $y = a_2 \sin\omega t$

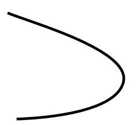
Different Lissajou's figures as follows



ϕ = 0, π, 2π
Figure of eight



$\phi = \pi/4, 3\pi/4$
Double parabola



$\phi = \pi/2$
Parabola

$\phi = 5\pi/4,\ 7\pi/4$
Double parabola

$\phi = 3\pi/2$
Parabola

Fig. 16.37

Tips & Tricks

✍ Suppose a body of mass m vibrate separately with two different springs (of spring constants k and k) with time period T and T respectively. $T_1 = 2\pi\sqrt{\dfrac{m}{k_1}}$ and $T_2 = 2\pi\sqrt{\dfrac{m}{k_2}}$

If the same body vibrates with series combination of these two springs then for the system time period $T = \sqrt{T_1^2 + T_2^2}$

If the same body vibrates with parallel combination of these two springs then time period of the system $T = \dfrac{T_1T_2}{\sqrt{T_1^2 + T_2^2}}$

✍ The pendulum clock runs slow due to increase in its time period whereas it becomes fast due to decrease in time period.

✍ If infinite spring with force constant $k, 2k, 4k, 8k$ .... respectively are connected in series. The effective force constant of the spring will be $k/2$.

✍ Percentage change in time period with l and g.

If g is constant and length varies by $n\%$. Then % change in time period $\dfrac{\Delta T}{T}\times 100 = \dfrac{n}{2}\times 100$

If l is constant and g varies by $n\%$. Then % change in time period $\dfrac{\Delta T}{T}\times 100 = -\dfrac{n}{2}\times 100$

(Valid only for small percentage change say 5%).

✍ Suppose a spring of force constant k oscillates with time period T. If it is divided in to n equal parts then spring constant of each part will become nk and time period of oscillation of each part will become $\dfrac{T}{\sqrt{n}}$.

If these n parts connected in parallel then $k_{eff} = n^2k$. So time period of the system becomes $T' = \dfrac{T}{n}$

✍ If a particle performs S.H.M. whose velocity is v_1 at a x_1 distance from mean position and velocity v_2 at distance x_2

$$\omega = \sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}\ ;\ T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$$

$$a = \sqrt{\frac{v_1^2x_2^2 - v_2^2x_1^2}{v_1^2 - v_2^2}}\ ;\ v_{\max} = \sqrt{\frac{v_1^2x_2^2 - v_2^2x_1^2}{x_2^2 - x_1^2}}$$

✍ If $y_1 = a\sin\omega t$ and $y_2 = b\cos\omega t$ are two S.H.M. then by the superimposition of these two S.H.M. we get $\vec{y} = \vec{y_1} + \vec{y_2}$

$\Rightarrow\ y = a\sin\omega t + b\cos\omega t\ \Rightarrow y = A\sin(\omega t + \phi)$ this is also the equation of S.H.M.; where $A = \sqrt{a^2 + b^2}$ and $\phi = \tan^{-1}(b/a)$

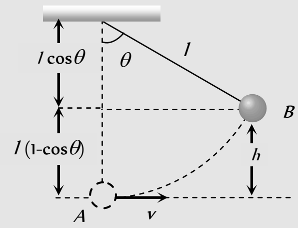
✍ In the absence of resistive force the work done by a simple pendulum in one complete oscillation is zero

✍ If θ is the angular amplitude of pendulum then

Height rises by the bob $h = l(1 - \cos\theta)$

Velocity at mean position

$$v = \sqrt{2gl(1 - \cos\theta)}$$



Work done in displacement

$$W = U = mgl(1 - \cos\theta)$$

K.E. at mean position

$$KE_{mean} = mgl(1 - \cos\theta)$$

Tension in the string of pendulum

At mean position : $T_A(\max) = mg + \dfrac{mv^2}{l} = (3mg - 2mg\cos\theta)$

At extream position : $T = mg\cos\theta$

Ordinary Thinking

Objective Questions

Displacement of S.H.M. and Phase

1. The phase of a particle executing simple harmonic motion is $\dfrac{\pi}{2}$ when it has **[MP PET 1985]**

(a) Maximum velocity (b) Maximum acceleration

(c) Maximum energy (d) Maximum displacement

2. A particle starts S.H.M. from the mean position. Its amplitude is A and time period is T. At the time when its speed is half of the maximum speed, its displacement y is

[Haryana CEE 1996; CBSE PMT 1996; MH CET 2002]

(a) $\dfrac{A}{2}$ (b) $\dfrac{A}{\sqrt{2}}$

(c) $\dfrac{A\sqrt{3}}{2}$ (d) $\dfrac{2A}{\sqrt{3}}$

3. The amplitude and the periodic time of a S.H.M. are $5\,cm$ and $6\,sec$ respectively. At a distance of $2.5\,cm$ away from the mean position, the phase will be

(a) $5\pi/12$ (b) $\pi/4$

(c) $\pi/3$ (d) $\pi/6$

4. Two equations of two S.H.M. are $y = a\sin(\omega t - \alpha)$ and $y = b\cos(\omega t - \alpha)$. The phase difference between the two is

[MP PMT 1985]

(a) 0° (b) $\alpha°$

(c) 90° (d) 180°

5. The amplitude and the time period in a S.H.M. is 0.5 *cm* and 0.4 *sec* respectively. If the initial phase is $\pi/2$ radian, then the equation of S.H.M. will be

(a) $y = 0.5\sin 5\pi t$ (b) $y = 0.5\sin 4\pi t$

(c) $y = 0.5\sin 2.5\pi t$ (d) $y = 0.5\cos 5\pi t$

6. The equation of S.H.M. is $y = a\sin(2\pi nt + \alpha)$, then its phase at time *t* is [DPMT 2001]

(a) $2\pi nt$ (b) α

(c) $2\pi nt + \alpha$ (d) $2\pi t$

7. A particle is oscillating according to the equation $X = 7\cos 0.5\pi t$, where *t* is in second. The point moves from the position of equilibrium to maximum displacement in time [CPMT 1989]

(a) 4.0 *sec* (b) 2.0 *sec*

(c) 1.0 *sec* (d) 0.5 *sec*

8. A simple harmonic oscillator has an amplitude *a* and time period *T*. The time required by it to travel from *x* = *a* to *x* = *a* / 2 is [CBSE PMT 1992; SCRA 1996; BHU 1997]

(a) $T/6$ (b) $T/4$

(c) $T/3$ (d) $T/2$

9. Which of the following expressions represent simple harmonic motion [Roorkee 1999]

(a) $x = A\sin(\omega t + \delta)$ (b) $x = B\cos(\omega t + \phi)$

(c) $x = A\tan(\omega t + \phi)$ (d) $x = A\sin\omega t\cos\omega t$

10. A $1.00 \times 10^{-20} kg$ particle is vibrating with simple harmonic motion with a period of $1.00 \times 10^{-5} sec$ and a maximum speed of $1.00 \times 10^{3} m/s$. The maximum displacement of the particle is [AMU (Med.) 1999]

(a) 1.59 *mm* (b) 1.00 *m*

(c) 10 *m* (d) None of these

11. The phase (at a time *t*) of a particle in simple harmonic motion tells [AMU (Engg.) 1999]

(a) Only the position of the particle at time *t*

(b) Only the direction of motion of the particle at time *t*

(c) Both the position and direction of motion of the particle at time *t*

(d) Neither the position of the particle nor its direction of motion at time *t*

12. A particle is moving with constant angular velocity along the circumference of a circle. Which of the following statements is true [AMU (Engg.) 1999]

(a) The particle so moving executes S.H.M.

(b) The projection of the particle on any one of the diameters executes S.H.M.

(c) The projection of the particle on any of the diameters executes S.H.M.

(d) None of the above

13. A particle is executing simple harmonic motion with a period of *T* *seconds* and amplitude *a* *metre*. The shortest time it takes to reach a point $\frac{a}{\sqrt{2}} m$ from its mean position in *seconds* is [EAMCET (Med.) 2000]

(a) *T* (b) *T*/4

(c) *T*/8 (d) *T*/16

14. A simple harmonic motion is represented by $F(t) = 10\sin(20t + 0.5)$. The amplitude of the S.H.M. is

[DPMT 1998; CBSE PMT 2000; MH CET 2001]

(a) *a* = 30 (b) *a* = 20

(c) *a* = 10 (d) *a* = 5

15. Which of the following equation does not represent a simple harmonic motion [Kerala (Med.) 2002]

(a) $y = a\sin\omega t$ (b) $y = a\cos\omega t$

(c) $y = a\sin\omega t + b\cos\omega t$ (d) $y = a\tan\omega t$

16. A particle in S.H.M. is described by the displacement function $x(t) = a\cos(\omega t + \theta)$. If the initial $(t = 0)$ position of the particle is 1 *cm* and its initial velocity is $\pi\, cm/s$. The angular frequency of the particle is $\pi\, rad/s$, then it's amplitude is

(a) 1 *cm* (b) $\sqrt{2}$ *cm*

(c) 2 *cm* (d) 2.5 *cm*

17. A particle executes a simple harmonic motion of time period *T*. Find the time taken by the particle to go directly from its mean position to half the amplitude [UPSEAT 2002]

(a) $T/2$ (b) $T/4$

(c) $T/8$ (d) $T/12$

18. A particle executing simple harmonic motion along *y*-axis has its motion described by the equation $y = A\sin(\omega t) + B$. The amplitude of the simple harmonic motion is

[Orissa JEE 2003]

(a) *A* (b) *B*

(c) *A* + *B* (d) $\sqrt{A + B}$

19. A particle executing S.H.M. of amplitude 4 *cm* and *T* = 4 *sec*. The time taken by it to move from positive extreme position to half the amplitude is [BHU 1995]

(a) 1 *sec* (b) 1/3 *sec*

(c) 2/3 *sec* (d) $\sqrt{3/2}$ *sec*

20. Which one of the following is a simple harmonic motion

[CBSE PMT 1994]

(a) Wave moving through a string fixed at both ends

(b) Earth spinning about its own axis

(c) Ball bouncing between two rigid vertical walls

(d) Particle moving in a circle with uniform speed

21. A particle is moving in a circle with uniform speed. Its motion is [CPMT 1978; CI

(a) Periodic and simple harmonic

(b) Periodic but not simple harmonic

(c) A periodic

(d) None of the above

22. Two simple harmonic motions are represented by the equations $y_1 = 0.1\sin\left(100\pi t + \frac{\pi}{3}\right)$ and $y_2 = 0.1\cos\pi t$. The phase difference of the velocity of particle 1 with respect to the velocity of particle 2 is [AIEEE 2005]

(a) $\frac{-\pi}{3}$ (b) $\frac{\pi}{6}$

(c) $\frac{-\pi}{6}$ (d) $\frac{\pi}{3}$

23. Two particles are executing S.H.M. The equation of their motion are $y_1 = 10\sin\left(\omega t + \frac{\pi T}{4}\right)$, $y_2 = 25\sin\left(\omega t + \frac{\sqrt{3}\pi T}{4}\right)$. What is the ratio of their amplitude [DCE 1996]

(a) 1 : 1 (b) 2 : 5

(c) 1 : 2 (d) None of these

24. The periodic time of a body executing simple harmonic motion is 3 *sec*. After how much interval from time *t* = 0, its displacement will be half of its amplitude [BHU 1998]

(a) $\frac{1}{8}$ *sec* (b) $\frac{1}{6}$ *sec*

(c) $\frac{1}{4}$ *sec* (d) $\frac{1}{3}$ *sec*

25. A system exhibiting S.H.M. must possess [KCET 1994]

(a) Inertia only

(b) Elasticity as well as inertia

(c) Elasticity, inertia and an external force

(d) Elasticity only

26. If $x = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and $x' = a\cos\omega t$, then what is the phase difference between the two waves [RPET 1996]

(a) $\pi/3$ (b) $\pi/6$

(c) $\pi/2$ (d) π

Velocity of Simple Harmonic Motion

1. A simple pendulum performs simple harmonic motion about *X* = 0 with an amplitude *A* and time period *T*. The speed of the pendulum at $X = \frac{A}{2}$ will be [MP PMT 1987]

(a) $\frac{\pi A\sqrt{3}}{T}$ (b) $\frac{\pi A}{T}$

(c) $\frac{\pi A\sqrt{3}}{2T}$ (d) $\frac{3\pi^2 A}{T}$

2. A body is executing simple harmonic motion with an angular frequency $2 rad/s$. The velocity of the body at 20 *mm* displacement, when the amplitude of motion is 60 *mm*, is

CPMT 1999]

(a) 40 *mm /s* (b) $60 mm/s$

(c) $113 mm/s$ (d) $120 mm/s$

3. A body of mass 5 *gm* is executing S.H.M. about a point with amplitude 10 *cm*. Its maximum velocity is 100 *cm/sec*. Its velocity will be 50 *cm/sec* at a distance [CPMT 1976]

(a) 5 (b) $5\sqrt{2}$

(c) $5\sqrt{3}$ (d) $10\sqrt{2}$

4. A simple harmonic oscillator has a period of 0.01 *sec* and an amplitude of 0.2 *m*. The magnitude of the velocity in $m\,\sec^{-1}$ at the centre of oscillation is [JIPMER 1997]

(a) 20π (b) 100

(c) 40π (d) 100π

5. A particle executes S.H.M. with a period of 6 second and amplitude of 3 *cm*. Its maximum speed in *cm/sec* is

[AIIMS 1982]

(a) $\pi/2$ (b) π

(c) 2π (d) 3π

6. A particle is executing S.H.M. If its amplitude is 2 *m* and periodic time 2 *seconds*, then the maximum velocity of the particle will be

(a) $\pi\, m/s$ (b) $\sqrt{2\pi}\, m/s$

(c) $2\pi\, m/s$ (d) $4\pi\, m/s$

7. A S.H.M. has amplitude '*a*' and time period *T*. The maximum velocity will be

[MP PMT 1985; CPMT 1997; UPSEAT 1999]

(a) $\frac{4a}{T}$ (b) $\frac{2a}{T}$

(c) $2\pi\sqrt{\frac{a}{T}}$ (d) $\frac{2\pi a}{T}$

8. A body is executing S.H.M. When its displacement from the mean position is 4 *cm* and 5 *cm*, the corresponding velocity of the body is 10 *cm/sec* and 8 *cm/sec*. Then the time period of the body is [CPMT 1991; MP PE

(a) $2\pi\, sec$ (b) $\pi/2\, sec$

(c) $\pi\, sec$ (d) $3\pi/2\, sec$

9. A particle has simple harmonic motion. The equation of its motion is $x = 5\sin\left(4t - \frac{\pi}{6}\right)$, where *x* is its displacement. If the displacement of the particle is 3 units, then it velocity is

[MP PMT 1994]

(a) $\frac{2\pi}{3}$ (b) $\frac{5\pi}{6}$

(c) 20 (d) 16

10. [Pb. CET 1998; Pb. PMT 1997; AFMC 1998] If a simple pendulum oscillates with an amplitude of 50 *mm* and time period of 2 *sec*, then its maximum velocity is

[AIIMS 1998; MH CET 2000; DPMT 2000]

(a) 0.10 *m / s* (b) 0.15 *m / s*

(c) 0.8 *m / s* (d) 0.26 *m / s*

11. If the displacement of a particle executing SHM is given by $y = 0.30\sin(220t + 0.64)$ in *metre*, then the frequency and maximum velocity of the particle is [AFMC 1998]

(a) 35 *Hz*, 66 *m / s* (b) 45 *Hz*, 66 *m / s*

(c) 58 *Hz*, 113 *m / s* (d) 35 *Hz*, 132 *m / s*

12. The maximum velocity and the maximum acceleration of a body moving in a simple harmonic oscillator are $2\,m/s$ and $4\,m/s^2$. Then angular velocity will be

[Pb. PMT 1998; MH CET 1999, 2003]

(a) 3 *rad/sec* (b) 0.5 *rad/sec*

(c) 1 *rad/sec* (d) 2 *rad/sec*

13. If a particle under S.H.M. has time period 0.1 *sec* and amplitude $2\times10^{-3}\,m$. It has maximum velocity

[RPET 2000]

(a) $\frac{\pi}{25}\,m/s$ (b) $\frac{\pi}{26}\,m/s$

(c) $\frac{\pi}{30}\,m/s$ (d) None of these

14. A particle executing simple harmonic motion has an amplitude of 6 *cm*. Its acceleration at a distance of 2 *cm* from the mean position is $8\,cm/s^2$. The maximum speed of the particle is [EAMCET (Engg.) 2000]

(a) 8 *cm/s* (b) 12 *cm/s*

(c) 16 *cm/s* (d) 24 *cm/s*

15. A particle executes simple harmonic motion with an amplitude of 4 *cm*. At the mean position the velocity of the particle is 10 *cm/s*. The distance of the particle from the mean position when its speed becomes 5 *cm/s* is

[EAMCET (Med.) 2000]

(a) $\sqrt{3}\,cm$ (b) $\sqrt{5}\,cm$

(c) $2(\sqrt{3})\,cm$ (d) $2(\sqrt{5})\,cm$

16. Two particles *P* and *Q* start from origin and execute Simple Harmonic Motion along *X*-axis with same amplitude but with periods 3 *seconds* and 6 *seconds* respectively. The ratio of the velocities of *P* and *Q* when they meet is

[EAMCET 2001]

(a) 1 : 2 (b) 2 : 1

(c) 2 : 3 (d) 3 : 2

17. A particle is performing simple harmonic motion with amplitude *A* and angular velocity ω. The ratio of maximum velocity to maximum acceleration is [Kerala (Med.) 2002]

(a) ω (b) $1/\omega$

(c) ω (d) $A\omega$

18. The angular velocities of three bodies in simple harmonic motion are $\omega_1, \omega_2, \omega_3$ with their respective amplitudes as A_1, A_2, A_3. If all the three bodies have same mass and velocity, then

(a) $A_1\omega_1 = A_2\omega_2 = A_3\omega_3$ (b) $A_1\omega_1^2 = A_2\omega_2^2 = A_3\omega_3^2$

(c) $A_1^2\omega_1 = A_2^2\omega_2 = A_3^2\omega_3$ (d) $A_1^2\omega_1^2 = A_2^2\omega_2^2 = A^2$

19. The velocity of a particle performing simple harmonic motion, when it passes through its mean position is

[MH CET (Med.) 2002; BCECE 2004]

(a) Infinity (b) Zero

(c) Minimum (d) Maximum

20. The velocity of a particle in simple harmonic motion at displacement *y* from mean position is

[BCECE 2003; RPMT 2003]

(a) $\omega\sqrt{a^2+y^2}$ (b) $\omega\sqrt{a^2-y^2}$

(c) ωy (d) $\omega^2\sqrt{a^2-y^2}$

21. A particle is executing the motion $x = A\cos(\omega t-\theta)$. The maximum velocity of the particle is

[BHU 2003; CPMT 2004]

(a) $A\omega\cos\theta$ (b) $A\omega$

(c) $A\omega\sin\theta$ (d) None of these

22. A particle executing simple harmonic motion with amplitude of 0.1 *m*. At a certain instant when its displacement is 0.02 *m*, its acceleration is 0.5 *m/s*. The maximum velocity of the particle is (in *m/s*)

(a) 0.01 (b) 0.05

(c) 0.5 (d) 0.25

23. The amplitude of a particle executing SHM is 4 *cm*. At the mean position the speed of the particle is 16 *cm/sec*. The distance of the particle from the mean position at which the speed of the particle becomes $8\sqrt{3}\,cm/s$, will be

[Pb. PET 2003]

(a) $2\sqrt{3}\,cm$ (b) $\sqrt{3}\,cm$

(c) 1 *cm* (d) 2 *cm*

24. The maximum velocity of a simple harmonic motion represented by $y = 3\sin\left(100\,t+\frac{\pi}{6}\right)$ is given by

[BCECE 2005]

(a) 300 (b) $\frac{3\pi}{6}$

(c) 100 (d) $\frac{\pi}{6}$

25. The displacement equation of a particle is $x = 3\sin 2t + 4\cos 2t$. The amplitude and maximum velocity will be respectively

(a) 5, 10 (b) 3, 2

(c) 4, 2 (d) 3, 4

26. Velocity at mean position of a particle executing S.H.M. is *v*, they velocity of the particle at a distance equal to half of the amplitude

(a) 4*v* (b) 2*v*

(c) $\frac{\sqrt{3}}{2}v$ (d) $\frac{\sqrt{3}}{4}v$

27. The instantaneous displacement of a simple pendulum oscillator is given by $x = A\cos\left(\omega t+\frac{\pi}{4}\right)$. Its speed will be maximum at time [BHU 2002]

(a) $\frac{\pi}{4\omega}$ (b) $\frac{\pi}{2\omega}$

(c) $\frac{\pi}{\omega}$ (d) $\frac{2\pi}{\omega}$

Acceleration of Simple Harmonic Motion

1. Which of the following is a necessary and sufficient condition for S.H.M. [NCERT 1974]

(a) Constant period

(b) Constant acceleration

(c) Proportionality between acceleration and displacement from equilibrium position

(d) Proportionality between restoring force and displacement from equilibrium position

2. If a hole is bored along the diameter of the earth and a stone is dropped into hole [CPMT 1984]

(a) The stone reaches the centre of the earth and stops there

(b) The stone reaches the other side of the earth and stops there

(c) The stone executes simple harmonic motion about the centre of the earth

(d) The stone reaches the other side of the earth and escapes into space

3. The acceleration of a particle in S.H.M. is [MP PMT 1993]

(a) Always zero

(b) Always constant

(c) Maximum at the extreme position

(d) Maximum at the equilibrium position

4. The displacement of a particle moving in S.H.M. at any instant is given by $y = a\sin\omega t$. The acceleration after time $t = \frac{T}{4}$ is (where *T* is the time period) [MP PET 1984]

(a) $a\omega$ (b) $-a\omega$

(c) $a\omega^2$ (d) $-a\omega^2$

5. The amplitude of a particle executing S.H.M. with frequency of 60 *Hz* is 0.01 *m*. The maximum value of the acceleration of the particle is

[DPMT 1998; CBSE PMT 1999; AFMC 2001; Pb. PMT 2001; Pb. PET 2001, 02; CPMT 1993, 95, 04; RPMT 2005; MP PMT 2005]

(a) $144\pi^2 m/sec^2$ (b) $144 m/sec^2$

(c) $\frac{144}{\pi^2} m/sec^2$ (d) $288\pi^2 m/sec^2$

6. A small body of mass 0.10 *kg* is executing S.H.M. of amplitude 1.0 *m* and period 0.20 *sec*. The maximum force acting on it is

(a) 98.596 *N* (b) 985.96 *N*

(c) 100.2 *N* (d) 76.23 *N*

7. A body executing simple harmonic motion has a maximum acceleration equal to $24 metres/sec^2$ and maximum velocity equal to $16 \; metres/sec$. The amplitude of the simple harmonic motion is

[MP PMT 1995; DPMT 2002; RPET 2003; Pb. PET 2004]

(a) $\frac{32}{3} metres$ (b) $\frac{3}{32} metres$

(c) $\frac{1024}{9} metres$ (d) $\frac{64}{9} metres$

8. For a particle executing simple harmonic motion, which of the following statements is not correct

[MP PMT 1997; AIIMS 1999; Kerala PMT 2005]

(a) The total energy of the particle always remains the same

(b) The restoring force of always directed towards a fixed point

(c) The restoring force is maximum at the extreme positions

(d) The acceleration of the particle is maximum at the equilibrium position

9. A particle of mass 10 *grams* is executing simple harmonic motion with an amplitude of 0.5 *m* and periodic time of $(\pi/5)$ *seconds*. The maximum value of the force acting on the particle is[MP PET 1999; MP PMT

(a) 25 *N* (b) 5 *N*

(c) 2.5 *N* (d) 0.5 *N*

10. The displacement of an oscillating particle varies with time (in *seconds*) according to the equation *y (cm)* = sin $\frac{\pi}{2}\left(\frac{t}{2}+\frac{1}{3}\right)$. The maximum acceleration of the particle is approximately

(a) $5.21 cm/s^2$ (b) $3.62 cm/s^2$

(c) $1.81 cm/s^2$ (d) $0.62 cm/s^2$

11. A particle moving along the *x*-axis executes simple harmonic motion, then the force acting on it is given by

[CBSE PMT 1994]

(a) – *A Kx* (b) *A* cos (*Kx*)

(c) *A exp* (– *Kx*) (d) *A Kx*

Where *A* and *K* are positive constants

12. A body is vibrating in simple harmonic motion with an amplitude of 0.06 *m* and frequency of 15 *Hz*. The velocity and acceleration of body is [AFMC 1999]

(a) $5.65 \, m/s$ and $5.32 \times 10^2 m/s^2$

(b) $6.82 \, m/s$ and $7.62 \times 10^2 m/s^2$

(c) $8.91 \, m/s$ and $8.21 \times 10^2 m/s^2$

(d) $9.82 \, m/s$ and $9.03 \times 10^2 m/s^2$

13. A particle executes harmonic motion with an angular velocity and maximum acceleration of 3.5 *rad/sec* and 7.5 *m/s* respectively. The amplitude of oscillation is

[AIIMS 1999; Pb. PET 1999]

(a) 0.28 *m* (b) 0.36 *m*

(c) 0.53 *m* (d) 0.61 *m*

14. A 0.10 *kg* block oscillates back and forth along a horizontal surface. Its displacement from the origin is given by: $x = (10\,cm)\cos[(10\,rad/s)t + \pi/2\,rad]$. What is the maximum acceleration experienced by the block [AMU (Engg.) 2000]

(a) $10 \; m/s^2$ (b) $10\,\pi \, m/s^2$

(c) $\frac{10\pi}{2} m/s^2$ (d) $\frac{10\pi}{3} m/s^2$

15. In S.H.M. maximum acceleration is at

[RPET 2001; BVP 2003]

(a) Amplitude (b) Equilibrium

(c) Acceleration is constant (d) None of these

16. A particle is executing simple harmonic motion with an amplitude of 0.02 *metre* and frequency 50 *Hz*. The maximum acceleration of the particle is [MP PET 2001]

(a) $100\ m/s^2$ (b) $100\pi^2\ m/s^2$

(c) $100\ m/s^2$ (d) $200\pi^2\ m/s^2$

17. Acceleration of a particle, executing SHM, at it's mean position is[MH CET (Med.) 2002]

(a) Infinity (b) Varies

(c) Maximum (d) Zero

18. Which one of the following statements is true for the speed v and the acceleration a of a particle executing simple harmonic motion

(a) When v is maximum, a is maximum

(b) Value of a is zero, whatever may be the value of v

(c) When v is zero, a is zero

(d) When v is maximum, a is zero

19. What is the maximum acceleration of the particle doing the SHM $y = 2\sin\left[\frac{\pi t}{2} + \phi\right]$ where 2 is in *cm* [DCE 2003]

(a) $\frac{\pi}{2} cm/s^2$ (b) $\frac{\pi^2}{2} cm/s^2$

(c) $\frac{\pi}{4} cm/s^2$ (d) $\frac{\pi}{4} cm/s^2$

20. A particle executes linear simple harmonic motion with an amplitude of 2 *cm*. When the particle is at 1 *cm* from the mean position the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is

[Kerala PET 2005]

(a) $\frac{1}{2\pi\sqrt{3}}$ (b) $2\pi\sqrt{3}$

(c) $\frac{2\pi}{\sqrt{3}}$ (d) $\frac{\sqrt{3}}{2\pi}$

21. In simple harmonic motion, the ratio of acceleration of the particle to its displacement at any time is a measure of

[UPSEAT 2001]

(a) Spring constant (b) Angular frequency

(c) (Angular frequency)^2 (d) Restoring force

Energy of Simple Harmonic Motion

1. The total energy of a particle executing S.H.M. is proportional to

[CPMT 1974, 78; EAMCET 1994; RPET 1999; MP PMT 2001; Pb. PMT 2002; MH CET 2002]

(a) Displacement from equilibrium position

(b) Frequency of oscillation

(c) Velocity in equilibrium position

(d) Square of amplitude of motion

2. A particle executes simple harmonic motion along a straight line with an amplitude A. The potential energy is maximum when the displacement is [CPMT 1982]

(a) $\pm A$ (b) Zero

(c) $\pm\frac{A}{2}$ (d) $\pm\frac{A}{\sqrt{2}}$

3. A particle is vibrating in a simple harmonic motion with an amplitude of 4 *cm*. At what displacement from the equilibrium position, is its energy half potential and half kinetic[NCERT 1984; MNR 1995; RPMT 1995; DCE 2000; UPSEAT 2000]

(a) 1 *cm* (b) $\sqrt{2}$ *cm*

(c) 3 *cm* (d) $2\sqrt{2}$ *cm*

4. For a particle executing simple harmonic motion, the kinetic energy K is given by $K = K_o\cos^2\omega t$. The maximum value of potential energy is [CPMT 1981]

[CBSE PMT 2004]

(a) K_0 (b) Zero

(c) $\frac{K_0}{2}$ (d) Not obtainable

5. The potential energy of a particle with displacement X is $U(X)$. The motion is simple harmonic, when (K is a positive constant)

(a) $U = -\frac{KX^2}{2}$ (b) $U = KX^2$

(c) $U = K$ (d) $U = KX$

6. The kinetic energy and potential energy of a particle executing simple harmonic motion will be equal, when displacement (amplitude = a) is

[MP PMT 1987; CPMT 1990; DPMT 1996; MH CET 1997, 99; AFMC 1999; CPMT 2000]

(a) $\frac{a}{2}$ (b) $a\sqrt{2}$

(c) $\frac{a}{\sqrt{2}}$ (d) $\frac{a\sqrt{2}}{3}$

7. The total energy of the body executing S.H.M. is E. Then the kinetic energy when the displacement is half of the amplitude, is

[RPMT 1994, 96; CBSE PMT 1995; JIPMER 2002]

(a) $\frac{E}{2}$ (b) $\frac{E}{4}$

(c) $\frac{3E}{4}$ (d) $\frac{\sqrt{3}}{4}E$

8. The potential energy of a particle executing S.H.M. is 2.5 *J*, when its displacement is half of amplitude. The total energy of the particle be

(a) 18 *J* (b) 10 *J*

(c) 12 *J* (d) 2.5 *J*

9. The angular velocity and the amplitude of a simple pendulum is ω and a respectively. At a displacement X from the mean position if its kinetic energy is T and potential energy is V, then the ratio of T to V is [CBSE PMT 1991]

(a) $X^2\omega^2/(a^2 - X^2\omega^2)$ (b) $X^2/(a^2 - X^2)$

(c) $(a^2 - X^2\omega^2)/X^2\omega^2$ (d) $(a^2 - X^2)/X^2$

10. When the potential energy of a particle executing simple harmonic motion is one-fourth of its maximum value during the oscillation, the displacement of the particle from the equilibrium position in terms of its amplitude a is

[CBSE PMT 1993; EAMCET (Engg.) 1995;

MP PMT 1994, 2000; MP PET 1995, 96, 2002]

(a) $a/4$ (b) $a/3$

(c) $a/2$ (d) $2a/3$

11. A particle of mass 10 *gm* is describing S.H.M. along a straight line with period of 2 *sec* and amplitude of 10 *cm*. Its kinetic energy when it is at 5 *cm* from its equilibrium position is

(a) $37.5\pi^2 ergs$ (b) $3.75\pi^2 ergs$

(c) $375\pi^2 ergs$ (d) $0.375\pi^2 ergs$

12. When the displacement is half the amplitude, the ratio of potential energy to the total energy is

[CPMT 1999; JIPMER 2000; Kerala PET 2002]

(a) $\frac{1}{2}$ (b) $\frac{1}{4}$

(c) 1 (d) $\frac{1}{8}$

13. The P.E. of a particle executing SHM at a distance *x* from its equilibrium position is

[Roorkee 1992; CPMT 1997; RPMT 1999]

(a) $\frac{1}{2}m\omega^2 x^2$ (b) $\frac{1}{2}m\omega^2 a^2$

(c) $\frac{1}{2}m\omega^2(a^2 - x^2)$ (d) Zero

14. A vertical mass-spring system executes simple harmonic oscillations with a period of 2 *s*. A quantity of this system which exhibits simple harmonic variation with a period of 1 *s* is

(a) Velocity

(b) Potential energy

(c) Phase difference between acceleration and displacement

(d) Difference between kinetic energy and potential energy

15. For any S.H.M., amplitude is 6 *cm*. If instantaneous potential energy is half the total energy then distance of particle from its mean position is [RPET 2000]

(a) 3 *cm* (b) 4.2 *cm*

(c) 5.8 *cm* (d) 6 *cm*

16. A body of mass $1 kg$ is executing simple harmonic motion. Its displacement $y(cm)$ at t seconds is given by $y = 6\sin(100t + \pi/4)$. Its maximum kinetic energy is

[EAMCET (Engg.) 2000]

(a) 6 *J* (b) 18 *J*

(c) 24 *J* (d) 36 *J*

17. A particle is executing simple harmonic motion with frequency *f*. The frequency at which its kinetic energy change into potential energy is [MP PET 2000]

(a) *f*/2 (b) *f*

(c) 2 *f* (d) 4 *f*

18. There is a body having mass *m* and performing S.H.M. with amplitude *a*. There is a restoring force $F = -Kx$, where *x* is the displacement. The total energy of body depends upon

[CBSE PMT 2001]

(a) *K, x* (b) *K, a*

(c) *K, a, x* (d) *K, a, v*

[MP PMT 1996]

19. The total energy of a particle executing S.H.M. is 80 *J*. What is the potential energy when the particle is at a distance of 3/4 of amplitude from the mean position

[Kerala (Engg.) 2001]

(a) 60 *J* (b) 10 *J*

(c) 40 *J* (d) 45 *J*

20. In a simple harmonic oscillator, at the mean position

[AIEEE 2002]

(a) Kinetic energy is minimum, potential energy is maximum

(b) Both kinetic and potential energies are maximum

(c) Kinetic energy is maximum, potential energy is minimum

(d) Both kinetic and potential energies are minimum

21. Displacement between maximum potential energy position and maximum kinetic energy position for a particle executing S.H.M. is

(a) $-a$ (b) $+a$

(c) $\pm a$ (d) $\pm\frac{a}{4}$

22. When a mass *M* is attached to the spring of force constant *k*, then the spring stretches by *l*. If the mass oscillates with amplitude *l*, what will be maximum potential energy stored in the spring

(a) $\frac{kl}{2}$ (b) $2kl$

(c) $\frac{1}{2}Mgl$ [SCRA 1998] (d) *Mgl*

23. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is (where *E* is the total energy)

(a) $\frac{1}{8}E$ (b) $\frac{1}{4}E$

(c) $\frac{1}{2}E$ (d) $\frac{2}{3}E$

24. A body executes simple harmonic motion. The potential energy (P.E.), the kinetic energy (K.E.) and total energy (T.E.) are measured as a function of displacement *x*. Which of the following statements is true [AIEEE 2003]

(a) P.E. is maximum when $x = 0$

(b) K.E. is maximum when $x = 0$

(c) T.E. is zero when $x = 0$

(d) K.E. is maximum when *x* is maximum

25. If <*E*> and <*U*> denote the average kinetic and the average potential energies respectively of mass describing a simple harmonic motion, over one period, then the correct relation is

(a) <*E*> = <*U*> (b) <*E*> = 2<*U*>

(c) <*E*> = – 2<*U*> (d) <*E*>= – <*U*>

26. The total energy of a particle, executing simple harmonic motion is

(a) $\propto x$ (b) $\propto x^2$

(c) Independent of x (d) $\propto x^{1/2}$

27. The kinetic energy of a particle executing S.H.M. is 16 *J* when it is at its mean position. If the mass of the particle is 0.32 *kg*, then what is the maximum velocity of the particle

[MH CET 2004]

(a) $5m/s$ (b) $15m/s$

(c) $10m/s$ (d) $20m/s$

28. Consider the following statements. The total energy of a particle executing simple harmonic motion depends on its

(1) Amplitude (2) Period (3) Displacement

Of these statements [RPMT 2001; BCECE 2005]

(a) (1) and (2) are correct

(b) (2) and (3) are correct

(c) (1) and (3) are correct

(d) (1), (2) and (3) are correct

29. A particle starts simple harmonic motion from the mean position. Its amplitude is *a* and total energy *E*. At one instant its kinetic energy is $3E/4$. Its displacement at that instant is

[Kerala PET 2005]

(a) $a/\sqrt{2}$ (b) $a/2$

(c) $\frac{a}{\sqrt{3/2}}$ (d) $a/\sqrt{3}$

30. A particle executes simple harmonic motion with a frequency f. The frequency with which its kinetic energy oscillates is [IIT JEE 1973, 87; Manipal MEE 1995; MP PET 1997; DCE 1997; DCE 1999; UPSEAT 2000; RPET 2002; RPMT 2004; BHU 2005]

(a) $f/2$ (b) f

(c) $2f$ (d) $4f$

31. The amplitude of a particle executing SHM is made three-fourth keeping its time period constant. Its total energy will be

(a) $\frac{E}{2}$ (b) $\frac{3}{4}E$

(c) $\frac{9}{16}E$ (d) None of these

32. A particle of mass *m* is hanging vertically by an ideal spring of force constant *K*. If the mass is made to oscillate vertically, its total energy is [CPMT 1978; RPET 1999]

(a) Maximum at extreme position

(b) Maximum at mean position

(c) Minimum at mean position

(d) Same at all position

33. A body is moving in a room with a velocity of 20 *m* / s perpendicular to the two walls separated by 5 *meters*. There is no friction and the collisions with the walls are elastic. The motion of the body is [MP PMT 1999]

(a) Not periodic

(b) Periodic but not simple harmonic

(c) Periodic and simple harmonic

(d) Periodic with variable time period

34. A body is executing Simple Harmonic Motion. At a displacement x its potential energy is E_1 and at a displacement y its potential energy is E_2. The potential energy E at displacement $(x+y)$ is [EAMCET 20

(a) $\sqrt{E}=\sqrt{E_1}-\sqrt{E_2}$ (b) $\sqrt{E}=\sqrt{E_1}+\sqrt{E_2}$

(c) $E=E_1+E_2$ (d) $E=E_1+E_2$

Time Period and Frequency

1. A particle moves such that its acceleration a is given by $a=-bx$, where x is the displacement from equilibrium position and b is a constant. The period of oscillation is

[NCERT 1984; CPMT 1991; MP PMT 1994; MNR 1995; UPSEAT 2000]

(a) $2\pi\sqrt{b}$ (b) $\frac{2\pi}{\sqrt{b}}$

(c) $\frac{2\pi}{b}$ (d) $2\sqrt{\frac{\pi}{b}}$

2. The equation of motion of a particle is $\frac{d^2y}{dt^2}+Ky=0$, where K is positive constant. The time period of the motion is given by

(a) $\frac{2\pi}{K}$ (b) $2\pi K$

(c) $\frac{2\pi}{\sqrt{K}}$ (d) $2\pi\sqrt{K}$

3. A tunnel has been dug through the centre of the earth and a ball is released in it. It will reach the other end of the tunnel after

(a) 84.6 *minutes*

(b) 42.3 *minutes*

(c) 1 day

(d) Will not reach the other end

[RPMT 2004]

4. The maximum speed of a particle executing S.H.M. is $1m/s$ and its maximum acceleration is $1.57m/sec^2$. The time period of the particle will be [DPMT 2002]

(a) $\frac{1}{1.57}sec$ (b) 1.57 *sec*

(c) 2 *sec* (d) 4 *sec*

5. The motion of a particle executing S.H.M. is given by $x=0.01\sin 100\pi(t+.05)$, where x is in *metres* and time is in seconds. The time period is [CPMT 1990]

(a) 0.01 *sec* (b) 0.02 *sec*

(c) 0.1 *sec* (b) 0.2 *sec*

6. The kinetic energy of a particle executing S.H.M. is 16 *J* when it is in its mean position. If the amplitude of oscillations is 25 *cm* and the mass of the particle is 5.12 *kg*, the time period of its oscillation is

[Haryana CEE 1996; AFMC 1998]

(a) $\frac{\pi}{5}$ *sec* (b) 2π *sec*

(c) 20π *sec* (d) 5π *sec*

7. The acceleration of a particle performing S.H.M. is $12 cm/sec^2$ at a distance of 3 *cm* from the mean position. Its time period is [MP PET 1996; MP PMT 1997]

(a) 0.5 *sec* (b) 1.0 *sec*

(c) 2.0 *sec* (d) 3.14 *sec*

8. To make the frequency double of an oscillator, we have to [CPMT 1999]

(a) Double the mass

(b) Half the mass

(c) Quadruple the mass

(d) Reduce the mass to one-fourth

9. What is constant in S.H.M. [UPSEAT 1999]

(a) Restoring force (b) Kinetic energy

(c) Potential energy (d) Periodic time

10. If a simple harmonic oscillator has got a displacement of 0.02 *m* and acceleration equal to $2.0 ms^{-2}$ at any time, the angular frequency of the oscillator is equal to [CBSE PMT 1992; RPMT 1996]

(a) $10\, rad s^{-1}$ (b) $0.1\, rad s^{-1}$

(c) $100\, rad s^{-1}$ (d) $1\, rad s^{-1}$

11. The equation of a simple harmonic motion is $X = 0.34\cos(3000t + 0.74)$ where *X* and *t* are in *mm* and *sec*. The frequency of motion is [Kerala (Engg.) 2002]

(a) 3000 (b) $3000/2\pi$

(c) $0.74/2\pi$ (d) $3000/\pi$

12. Mark the wrong statement [MP PMT 2003]

(a) All S.H.M.'s have fixed time period

(b) All motion having same time period are S.H.M.

(c) In S.H.M. total energy is proportional to square of amplitude

(d) Phase constant of S.H.M. depends upon initial conditions

13. A particle in SHM is described by the displacement equation $x(t) = A\cos(\omega t + \theta)$. If the initial ($t = 0$) position of the particle is 1 *cm* and its initial velocity is π *cm/s*, what is its amplitude? The angular frequency of the particle is πs^{-1} [DPMT 2004]

(a) 1 *cm* (b) $\sqrt{2}$ *cm*

(c) 2 *cm* (d) 2.5 *cm*

14. A particle executes SHM in a line 4 *cm* long. Its velocity when passing through the centre of line is 12 *cm/s*. The period will be

(a) 2.047 *s* (b) 1.047 *s*

(c) 3.047 *s* (d) 0.047 *s*

15. The displacement *x* (in *metre*) of a particle in, simple harmonic motion is related to time *t* (in seconds) as

$$x = 0.01\cos\left(\pi t + \frac{\pi}{4}\right)$$

The frequency of the motion will be [UPSEAT 2004]

(a) 0.5 *Hz* (b) 1.0 *Hz*

(c) $\frac{\pi}{2} Hz$ (d) $\pi\, Hz$

16. A simple harmonic wave having an amplitude *a* and time period *T* is represented by the equation $y = 5\sin\pi(t+4)m$. Then the value of amplitude (*a*) in (*m*) and time period (*T*) in second are [Pb. PET 2004]

(a) $a = 10, T = 2$ (b) $a = 5, T = 1$

(c) $a = 10, T = 1$ (d) $a = 5, T = 2$

17. A particle executing simple harmonic motion of amplitude 5 *cm* has maximum speed of 31.4 *cm/s*. The frequency of its oscillation is

(a) 3 *Hz* (b) 2 *Hz*

(c) 4 *Hz* (d) 1 *Hz*

18. The displacement *x* (in *metres*) of a particle performing simple harmonic motion is related to time *t* (in *seconds*) as $x = 0.05\cos\left(4\pi t + \frac{\pi}{4}\right)$. The frequency of the motion will be

(a) 0.5 *Hz* (b) 1.0 *Hz*

(c) 1.5 *Hz* (d) 2.0 *Hz*

Simple Pendulum

1. The period of a simple pendulum is doubled, when [CPMT 1974; MNR 1980; AFMC 1995; Pb. PET/PMT 2002]

(a) Its length is doubled

(b) The mass of the bob is doubled

(c) Its length is made four times

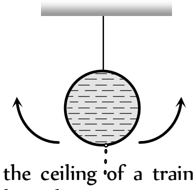
(d) The mass of the bob and the length of the pendulum are doubled

2. The period of oscillation of a simple pendulum of constant length at earth surface is *T*. Its period inside a mine is [CPMT 1973; DPMT 2001]

(a) Greater than *T* (b) Less than *T*

(c) Equal to *T* (d) Cannot be compared

3. A simple pendulum is made of a body which is a hollow sphere containing mercury suspended by means of a wire. If a little mercury is drained off, the period of pendulum will [NCERT 1972; BHU 1979]



(a) Remains unchanged

(b) Increase

(c) Decrease

(d) Become erratic

4. A pendulum suspended from the ceiling of a train has a period *T*, when the train is at rest. When the train is accelerating with a uniform acceleration *a*, the period of oscillation will [NCERT 1980; CPMT 1997] [Pb. PET 2000]

(a) Increase (b) Decrease

(c) Remain unaffected (d) Become infinite

5. The mass and diameter of a planet are twice those of earth. The period of oscillation of pendulum on this planet will be (If it is a second's pendulum on earth) [IIT 1973; DCE 2002]

(a) $\frac{1}{\sqrt{2}}$ *sec* (b) $2\sqrt{2}$ *sec*

(c) 2 *sec* (d) $\frac{1}{2}$ *sec*

6. A simple pendulum is set up in a trolley which moves to the right with an acceleration a on a horizontal plane. Then the thread of the pendulum in the mean position makes an angle θ with the vertical

(a) $\tan^{-1}\frac{a}{g}$ in the forward direction

(b) $\tan^{-1}\frac{a}{g}$ in the backward direction

(c) $\tan^{-1}\frac{g}{a}$ in the backward direction

(d) $\tan^{-1}\frac{g}{a}$ in the forward direction

7. Which of the following statements is not true ? In the case of a simple pendulum for small amplitudes the period of oscillation is

(a) Directly proportional to square root of the length of the pendulum

(b) Inversely proportional to the square root of the acceleration due to gravity

(c) Dependent on the mass, size and material of the bob

(d) Independent of the amplitude

8. The time period of a second's pendulum is 2 *sec*. The spherical bob which is empty from inside has a mass of 50 *gm*. This is now replaced by another solid bob of same radius but having different mass of 100 *gm*. The new time period will be

(a) 4 *sec* (b) 1 *sec*

(c) 2 *sec* (d) 8 *sec*

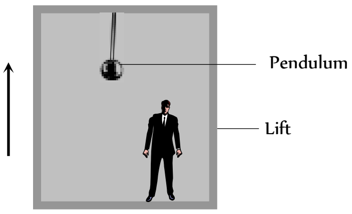
9. A man measures the period of a simple pendulum inside a stationary lift and finds it to be T sec. If the lift accelerates upwards with an acceleration $g/4$, then the period of the pendulum will be

(a) T

(b) $\frac{T}{4}$

(c) $\frac{2T}{\sqrt{5}}$

(d) $2T\sqrt{5}$



10. A simple pendulum is suspended from the roof of a trolley which moves in a horizontal direction with an acceleration a, then the time period is given by $T = 2\pi\sqrt{\frac{l}{g'}}$, where g' is equal to

(a) g (b) $g-a$

(c) $g+a$ (d) $\sqrt{g^2+a^2}$

11. A second's pendulum is placed in a space laboratory orbiting around the earth at a height $3R$, where R is the radius of the earth. The time period of the pendulum is

[CPMT 1989; RPMT 1995]

(a) Zero (b) $2\sqrt{3}$ *sec*

(c) 4 *sec* (d) Infinite

12. The bob of a simple pendulum of mass m and total energy E will have maximum linear momentum equal to

[CPMT 1983] [MP PMT 1986]

(a) $\sqrt{\frac{2E}{m}}$ (b) $\sqrt{2mE}$

(c) $2mE$ (d) mE^2

13. The length of the second pendulum on the surface of earth is 1 *m*. The length of seconds pendulum on the surface of moon, where g is 1/6th value of g on the surface of earth, is

[CPMT 1971]

(a) 1 / 6 *m* (b) 6 *m*

(c) 1 / 36 *m* (d) 36 *m*

[NCERT 1982]

14. If the length of second's pendulum is decreased by 2%, how many seconds it will lose per day [CPMT 1992]

(a) 3927 *sec* (b) 3727 *sec*

(c) 3427 *sec* (d) 864 sec

15. The period of simple pendulum is measured as T in a stationary lift. If the lift moves upwards with an acceleration of 5 g, the period will be [MNR 1979]

(a) The same (b) Increased by 3/5

(c) Decreased by 2/3 times (d) None of the above

[NCERT 1972]

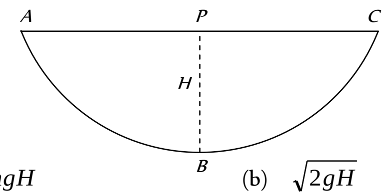
16. The length of a simple pendulum is increased by 1%. Its time period will [MP PET 1994; RPET 2001]

(a) Increase by 1% (b) Increase by 0.5%

(c) Decrease by 0.5% (d) Increase by 2%

17. A simple pendulum with a bob of mass 'm' oscillates from A to C and back to A such that PB is H. If the acceleration due to gravity is 'g', then the velocity of the bob as it passes through B is [NCERT 1990; BHU 2001]

[CBSE PMT 1995; DPMT 1995; Pb. PMT 1996]



(a) mgH (b) $\sqrt{2gH}$

(c) $2gH$ (d) Zero

18. Identify correct statement among the following [BHU 1997]

[Manipal MEE 1995]

(a) The greater the mass of a pendulum bob, the shorter is its frequency of oscillation

(b) A simple pendulum with a bob of mass M swings with an angular amplitude of 40^o. When its angular amplitude is 20^o, the tension in the string is less than $Mg\cos 20^o$.

(c) As the length of a simple pendulum is increased, the maximum velocity of its bob during its oscillation will also decreases

(d) The fractional change in the time period of a pendulum on changing the temperature is independent of the length of the pendulum

19. The bob of a pendulum of length l is pulled aside from its equilibrium position through an angle θ and then released. The bob will then pass through its equilibrium position with a speed v, where v equals [Haryana CEE 1996]

(a) $\sqrt{2gl(1-\sin\theta)}$ (b) $\sqrt{2gl(1+\cos\theta)}$

(c) $\sqrt{2gl(1-\cos\theta)}$ (d) $\sqrt{2gl(1+\sin\theta)}$

20. A simple pendulum executing S.H.M. is falling freely along with the support. Then

(a) Its periodic time decreases

(b) Its periodic time increases

(c) It does not oscillate at all

(d) None of these

21. A pendulum bob has a speed of 3 *m/s* at its lowest position. The pendulum is 0.5 *m* long. The speed of the bob, when the length makes an angle of 60^o to the vertical, will be (If $g = 10 m/s^2$)

(a) $3 m/s$ (b) $\frac{1}{3} m/s$

(c) $\frac{1}{2} m/s$ (d) $2 m/s$

22. The time period of a simple pendulum is 2 *sec*. If its length is increased 4 times, then its period becomes

[CBSE PMT 1999; DPMT 1999]

(a) 16 *sec* (b) 12 *sec*

(c) 8 *sec* (d) 4 *sec*

23. If the metal bob of a simple pendulum is replaced by a wooden bob, then its time period will [AIIMS 1998, 99]

(a) Increase

(b) Decrease

(c) Remain the same

(d) First increase then decrease

24. In a simple pendulum, the period of oscillation T is related to length of the pendulum l as [EAMCET (Med.) 1995]

(a) $\frac{l}{T} =$ constant (b) $\frac{l^2}{T} =$ constant

(c) $\frac{l}{T^2} =$ constant (d) $\frac{l^2}{T^2} =$ constant

25. A pendulum has time period T. If it is taken on to another planet having acceleration due to gravity half and mass 9 times that of the earth then its time period on the other planet will be

(a) $\sqrt{T}$ (b) T

(c) $T^{1/3}$ (d) $\sqrt{2}$ T

26. A simple pendulum is executing simple harmonic motion with a time period T. If the length of the pendulum is increased by 21%, the percentage increase in the time period of the pendulum of increased length is

[BHU 1994, 96; Pb. PMT 1995; AFMC 2001;

AIIMS 2001; AIEEE 2003]

(a) 10% (b) 21%

(c) 30% (d) 50%

27. If the length of simple pendulum is increased by 300%, then the time period will be increased by [RPMT 1999]

(a) 100% (b) 200%

(c) 300% (d) 400%

28. The length of a seconds pendulum is [RPET 2000]

(a) 99.8 *cm* (b) 99 *cm*

(c) 100 *cm* (d) None of these

29. The time period of a simple pendulum in a lift descending with constant acceleration g is [DCE 1998; MP PMT 2001]

(a) $T = 2\pi\sqrt{\frac{l}{g}}$ (b) $T = 2\pi\sqrt{\frac{l}{2g}}$

(c) Zero (d) Infinite

[MP PET 1996]

30. A chimpanzee swinging on a swing in a sitting position, stands up suddenly, the time period will

[KCET (Engg./Med.) 2000; AIEEE 2002; DPMT 2004]

(a) Become infinite (b) Remain same

(c) Increase (d) Decrease

31. The acceleration due to gravity at a place is $\pi^2 m/sec^2$. Then the time period of a simple pendulum of length one *metre* is

(a) $\frac{2}{\pi} sec$ (b) $2\pi\, sec$

(c) $2\, sec$ (d) $\pi\, sec$

32. A plate oscillated with time period '*T*'. Suddenly, another plate put on the first plate, then time period [AIEEE 2002]

(a) Will decrease (b) Will increase

(c) Will be same (d) None of these

33. A simple pendulum of length l has a brass bob attached at its lower end. Its period is T. If a steel bob of same size, having density x times that of brass, replaces the brass bob and its length is changed so that period becomes $2T$, then new length is

(a) 2 l (b) 4 l

(c) $4\, l\, x$ (d) $\frac{4l}{x}$

34. In a seconds pendulum, mass of bob is 30 *gm*. If it is replaced by 90 *gm* mass. Then its time period will

[CMEET Bihar 1995]

[Orissa PMT 2001]

(a) 1 *sec* (b) 2 *sec*

(c) 4 *sec* (d) 3 *sec*

35. The time period of a simple pendulum when it is made to oscillate on the surface of moon [J & K CET 2004]

(a) Increases (b) Decreases

(c) Remains unchanged (d) Becomes infinite

36. A simple pendulum is attached to the roof of a lift. If time period of oscillation, when the lift is stationary is T. Then frequency of oscillation, when the lift falls freely, will be [DCE 2002]

(a) Zero (b) T

(c) $1/T$ (d) None of these

37. A simple pendulum, suspended from the ceiling of a stationary van, has time period T. If the van starts moving with a uniform velocity the period of the pendulum will be [RPMT 2003]

(a) Less than T (b) Equal to $2T$

(c) Greater than T (d) Unchanged

38. If the length of the simple pendulum is increased by 44%, then what is the change in time period of pendulum [MH CET 2004; UPSEAT 2005]

(a) 22% (b) 20%

(c) 33% (d) 44%

39. To show that a simple pendulum executes simple harmonic motion, it is necessary to assume that [CPMT 2001]

(a) Length of the pendulum is small

(b) Mass of the pendulum is small

(c) Amplitude of oscillation is small

(d) Acceleration due to gravity is small

40. The height of a swing changes during its motion from 0.1 m to 2.5 m. The minimum velocity of a boy who swings in this swing is

(a) 5.4 m/s (b) 4.95 m/s

(c) 3.14 m/s (d) Zero

41. The amplitude of an oscillating simple pendulum is 10cm and its period is 4 sec. Its speed after 1 sec after it passes its equilibrium position, is

(a) Zero (b) $0.57 m/s$

(c) $0.212 m/s$ (d) $0.32 m/s$

42. A simple pendulum consisting of a ball of mass m tied to a thread of length l is made to swing on a circular arc of angle θ in a vertical plane. At the end of this arc, another ball of mass m is placed at rest. The momentum transferred to this ball at rest by the swinging ball is [NCERT 1977]

(a) Zero (b) $m\theta\sqrt{\frac{g}{l}}$

(c) $\frac{m\theta}{l}\sqrt{\frac{l}{g}}$ (d) $\frac{m}{l}2\pi\sqrt{\frac{l}{g}}$

43. A simple pendulum hangs from the ceiling of a car. If the car accelerates with a uniform acceleration, the frequency of the simple pendulum will [Pb. PMT 2000]

(a) Increase (b) Decrease

(c) Become infinite (d) Remain constant

44. The periodic time of a simple pendulum of length 1 m and amplitude 2 cm is 5 seconds. If the amplitude is made 4 cm, its periodic time in seconds will be [MP PMT 1985]

(a) 2.5 (b) 5

(c) 10 (d) $5\sqrt{2}$

45. The ratio of frequencies of two pendulums are 2 : 3, then their length are in ratio [DCE 2005]

(a) $\sqrt{2/3}$ (b) $\sqrt{3/2}$

(c) $4/9$ (d) $9/4$

46. Two pendulums begin to swing simultaneously. If the ratio of the frequency of oscillations of the two is 7 : 8, then the ratio of lengths of the two pendulums will be [J & K CET 2005]

(a) 7 : 8 (b) 8 : 7

(c) 49 : 64 (d) 64 : 49

47. A simple pendulum hanging from the ceiling of a stationary lift has a time period T_1. When the lift moves downward with constant velocity, the time period is T_2, then [Orissa JEE 2005]

(a) T_2 is infinity (b) $T_2 > T_1$

(c) $T_2 < T_1$ (d) $T_2 = T_1$

48. If the length of a pendulum is made 9 times and mass of the bob is made 4 times then the value of time period becomes [BHU 2005]

(a) $3T$ (b) $3/2T$

(c) $4T$ (d) $2T$

49. A simple pendulum is taken from the equator to the pole. Its period [CPMT 1997]

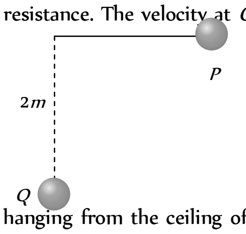
(a) Decreases

(b) Increases

(c) Remains the same

(d) Decreases and then increases

50. A pendulum of length $2m$ lift at P. When it reaches Q, it losses 10% of its total energy due to air resistance. The velocity at Q is



(a) 6 m/sec

(b) 1 m/sec

(c) 2 m/sec

(d) 8 m/sec

51. There is a simple pendulum hanging from the ceiling of a lift. When the lift is stand still, the time period of the pendulum is T. If the resultant acceleration becomes $g/4$, then the new time period of the pendulum is [DCE 2004]

(a) 0.8 T (b) 0.25 T

(c) 2 T (d) 4 T

52. The period of a simple pendulum measured inside a stationary lift is found to be T. If the lift starts accelerating upwards with acceleration of $g/3$, then the time period of the pendulum is [RPMT 2000; DPM

(a) $\frac{T}{\sqrt{3}}$ (b) $\frac{T}{3}$

(c) $\frac{\sqrt{3}}{2}T$ (d) $\sqrt{3}\,T$

53. Time period of a simple pendulum will be double, if we [MH CET 2003]

(a) Decrease the length 2 times
(b) Decrease the length 4 times
(c) Increase the length 2 times
(d) Increase the length 4 times

54. Length of a simple pendulum is l and its maximum angular displacement is θ, then its maximum K.E. is [RPMT 1995; BHU 2003]

(a) $mgl\sin\theta$ (b) $mgl(1+\sin\theta)$
(c) $mgl(1+\cos\theta)$ (d) $mgl(1-\cos\theta)$

55. The velocity of simple pendulum is maximum at [RPMT 2004]

(a) Extremes (b) Half displacement
(c) Mean position (d) Every where

56. A simple pendulum is vibrating in an evacuated chamber, it will oscillate with [Pb. PMT 2004]

(a) Increasing amplitude (b) Constant amplitude
(c) Decreasing amplitude (d) First (c) then (a)

57. The time period of a simple pendulum of length L as measured in an elevator descending with acceleration $\frac{g}{3}$ is [CPMT 2000]

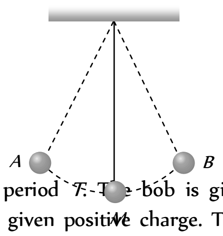
(a) $2\pi\sqrt{\frac{3L}{g}}$ (b) $\pi\sqrt{\left(\frac{3L}{g}\right)}$
(c) $2\pi\sqrt{\left(\frac{3L}{2g}\right)}$ (d) $2\pi\sqrt{\frac{2L}{3g}}$

58. If a body is released into a tunnel dug across the diameter of earth, it executes simple harmonic motion with time period

(a) $T=2\pi\sqrt{\frac{R_e}{g}}$ (b) $T=2\pi\sqrt{\frac{2R_e}{g}}$
(c) $T=2\pi\sqrt{\frac{R_e}{2g}}$ (d) $T=2$ seconds

59. What is the velocity of the bob of a simple pendulum at its mean position, if it is able to rise to vertical height of 10*cm* (g = 9.8 *m/s*)

(a) 2.2 *m/s*
(b) 1.8 *m/s*
(c) 1.4 *m/s*
(d) 0.6 *m/s*



60. A simple pendulum has time period T. The bob is given negative charge and surface below it is given positive charge. The new time period will be [AFMC 2004]

(a) Less than T (b) Greater than T
(c) Equal to T (d) Infinite

61. What effect occurs on the frequency of a pendulum if it is taken from the earth surface to deep into a mine [AFMC 2005]

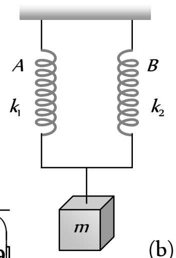
(a) Increases
(b) Decreases
(c) First increases then decrease
(d) None of these

Spring Pendulum

1. Two bodies M and N of equal masses are suspended from two separate massless springs of force constants k_1 and k_2 respectively. If the two bodies oscillate vertically such that their maximum velocities are equal, the ratio of the amplitude M to that of N is [IIT-JEE 1988; MP PET 1997, 2001; MP PMT 1997; BHU 1998; Pb. PMT 1998; MH CET 2000, 03; AIEEE 2003]

(a) $\frac{k_1}{k_2}$ (b) $\sqrt{\frac{k_1}{k_2}}$
(c) $\frac{k_2}{k_1}$ (d) $\sqrt{\frac{k_2}{k_1}}$

2. A mass m is suspended by means of two coiled spring which have the same length in unstretched condition as in figure. Their force constant are k_1 and k_2 respectively. When set into vertical vibrations, the period will be [MP PMT 2001]



(a) $2\pi\sqrt{\left(\frac{m}{k_1k_2}\right)}$ [CPMT 1999] (b) $2\pi\sqrt{m\left(\frac{k_1}{k_2}\right)}$
(c) $2\pi\sqrt{\left(\frac{m}{k_1-k_2}\right)}$ (d) $2\pi\sqrt{\left(\frac{m}{k_1+k_2}\right)}$

3. A spring has a certain mass suspended from it and its period for vertical oscillation is T. The spring is now cut into two equal halves and the same mass is suspended from one of the halves. The period of vertical oscillation is now [BHU 2000] [MP PET 1995]

(a) $\frac{T}{2}$ (b) $\frac{T}{\sqrt{2}}$
(c) $\sqrt{2}T$ (d) $2T$

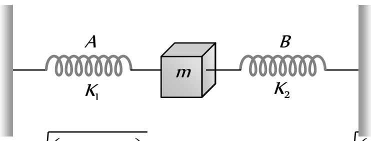
4. Two masses m_1 and m_2 are suspended together by a massless spring of constant k. When the masses are in equilibrium, m_1 is removed without disturbing the system. Then the angular frequency of oscillation of m_2 is

(a) $\sqrt{\frac{k}{m_1}}$ (b) $\sqrt{\frac{k}{m_2}}$

(c) $\sqrt{\frac{k}{m_1+m_2}}$ (d) $\sqrt{\frac{k}{m_1m_2}}$

5. In arrangement given in figure, if the block of mass m is displaced, the frequency is given by

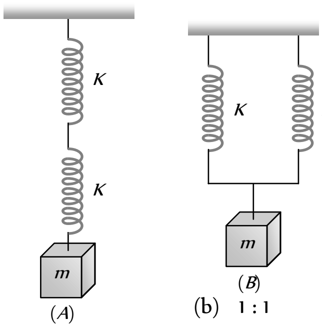
[BHU 1994; Pb. PET 2001]



(a) $n=\frac{1}{2\pi}\sqrt{\left(\frac{k_1-k_2}{m}\right)}$ (b) $n=\frac{1}{2\pi}\sqrt{\left(\frac{k_1+k_2}{m}\right)}$

(c) $n=\frac{1}{2\pi}\sqrt{\left(\frac{m}{k_1+k_2}\right)}$ (d) $n=\frac{1}{2\pi}\sqrt{\left(\frac{m}{k_1-k_2}\right)}$

6. Two identical spring of constant K are connected in series and parallel as shown in figure. A mass m is suspended from them. The ratio of their frequencies of vertical oscillations will be [MP PET 1993; BHU 1997]



(a) 2 : 1 (b) 1 : 1

(c) 1 : 2 (d) 4 : 1

7. A mass m is suspended from the two coupled springs connected in series. The force constant for springs are K_1 and K_2. The time period of the suspended mass will be

[CBSE PMT 1990; Pb. PET 2002]

(a) $T=2\pi\sqrt{\left(\frac{m}{K_1+K_2}\right)}$ (b) $T=2\pi\sqrt{\left(\frac{m}{K_1+K_2}\right)}$

(c) $T=2\pi\sqrt{\left(\frac{m(K_1+K_2)}{K_1K_2}\right)}$ (d) $T=2\pi\sqrt{\left(\frac{mK_1K_2}{K_1+K_2}\right)}$

8. A spring is stretched by 0.20 *m*, when a mass of 0.50 *kg* is suspended. When a mass of 0.25 *kg* is suspended, then its period of oscillation will be $(g=10m/s^2)$

(a) 0.328 *sec* (b) 0.628 *sec*

(c) 0.137 *sec* (d) 1.00 *sec*

9. A mass M is suspended from a spring of negligible mass. The spring is pulled a little and then released so that the mass executes simple harmonic oscillations with a time period T. If the mass is increased by m then the time period becomes $\left(\frac{5}{4}T\right)$. The ratio of $\frac{m}{M}$ is[CPMT 1991]

(a) 9/16 (b) 25/16

(c) 4/5 (d) 5/4

10. A spring having a spring constant 'K' is loaded with a mass 'm'. The spring is cut into two equal parts and one of these is loaded again with the same mass. The new spring constant is [NCERT 1990; KCET 1999; Kerala PMT 2004; BCECE 2004]

(a) $K/2$ (b) K

(c) $2K$ (d) K^2

11. A weightless spring which has a force constant oscillates with frequency n when a mass m is suspended from it. The spring is cut into two equal halves and a mass $2m$ is suspended from it. The frequency of oscillation will now become

[CPMT 1988]

(a) n (b) $2n$

(c) $n/\sqrt{2}$ (d) $n(2)^{1/2}$

12. A mass M is suspended from a light spring. An additional mass m added displaces the spring further by a distance x. Now the combined mass will oscillate on the spring with period[CPMT 1989, 1998 ; UPSEA

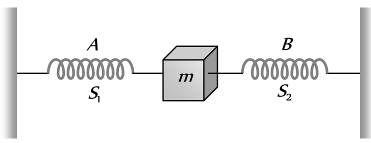
(a) $T=2\pi\sqrt{(mg/x(M+m))}$

(b) $T=2\pi\sqrt{((M+m)x/mg)}$

(c) $T=(\pi/2)\sqrt{(mg/x(M+m))}$

(d) $T=2\pi\sqrt{((M+m)/mgx)}$

13. In the figure, S_1 and S_2 are identical springs. The oscillation frequency of the mass m is f. If one spring is removed, the frequency will become [CPMT 1971]



(a) f (b) $f\times 2$

(c) $f\times\sqrt{2}$ (d) $f/\sqrt{2}$

14. The vertical extension in a light spring by a weight of 1 *kg* suspended from the wire is 9.8 *cm*. The period of oscillation

[CPMT 1981; MP PMT 2003]

(a) 20π sec (b) 2π sec

(c) $2\pi/10$ sec (d) 200π sec

15. A particle of mass 200 *gm* executes S.H.M. The restoring force is provided by a spring of force constant 80 *N / m*. The time period of oscillations is [MP PET 1994]

(a) 0.31 *sec* (b) 0.15 *sec*

(c) 0.05 *sec* (d) 0.02 *sec*

16. The length of a spring is l and its force constant is k. When a weight W is suspended from it, its length increases by x. If the spring is cut into two equal parts and put in parallel and the same weight W is suspended from them, then the extension will be

(a) $2x$ (b) x

(c) $\frac{x}{2}$ (d) $\frac{x}{4}$

17. A block is placed on a frictionless horizontal table. The mass of the block is m and springs are attached on either side with force constants K_1 and K_2. If the block is displaced a little and left to oscillate, then the angular frequency of oscillation will be

(a) $\left(\frac{K_1+K_2}{m}\right)^{1/2}$ (b) $\left[\frac{K_1K_2}{m(K_1+K_2)}\right]^{1/2}$

(c) $\left[\frac{K_1K_2}{(K_1-K_2)m}\right]^{1/2}$ (d) $\left[\frac{K_1^2+K_2^2}{(K_1+K_2)m}\right]^{1/2}$

18. A uniform spring of force constant k is cut into two pieces, the lengths of which are in the ratio 1 : 2. The ratio of the force constants of the shorter and the longer pieces is

[Manipal MEE 1995]

(a) 1 : 3 (b) 1 : 2

(c) 2 : 3 (d) 2 : 1

19. A mass m =100 *gms* is attached at the end of a light spring which oscillates on a frictionless horizontal table with an amplitude equal to 0.16 *metre* and time period equal to 2 *sec*. Initially the mass is released from rest at t = 0 and displacement $x = -0.16$ *metre*. The expression for the displacement of the mass at any time t is [MP PMT 1995]

(a) $x = 0.16\cos(\pi t)$ (b) $x = -0.16\cos(\pi t)$

(c) $x = 0.16\sin(\pi t+\pi)$ (d) $x = -0.16\sin(\pi t+\pi)$

20. A block of mass m, attached to a spring of spring constant k, oscillates on a smooth horizontal table. The other end of the spring is fixed to a wall. The block has a speed v when the spring is at its natural length. Before coming to an instantaneous rest, if the block moves a distance x from the mean position, then

(a) $x = \sqrt{m/k}$ (b) $x = \frac{1}{v}\sqrt{m/k}$

(c) $x = v\sqrt{m/k}$ (d) $x = \sqrt{mv/k}$

21. The force constants of two springs are K_1 and K_2. Both are stretched till their elastic energies are equal. If the stretching forces are F_1 and F_2, then $F_1 : F_2$ is

[MP PET 2002]

(a) $K_1 : K_2$ (b) $K_2 : K_1$

(c) $\sqrt{K_1} : \sqrt{K_2}$ (d) $K_1^2 : K_2^2$

22. A mass m is vertically suspended from a spring of negligible mass; the system oscillates with a frequency n. What will be the frequency of the system if a mass 4 m is suspended from the same spring

(a) $n/4$ (b) $4n$

(c) $n/2$ (d) $2n$

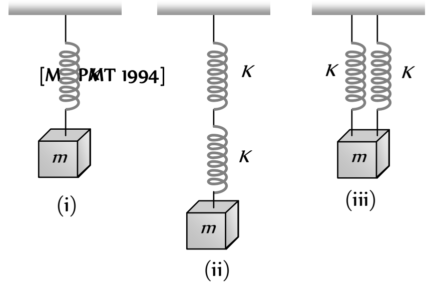
23. If the period of oscillation of mass m suspended from a spring is 2 *sec*, then the period of mass $4m$ will be

[AIIMS 1998]

(a) 1 *sec* (b) 2 *sec*

(c) 3 *sec* (d) 4 *sec*

24. Five identical springs are used in the following three configurations. The time periods of vertical oscillations in configurations (i), (ii) and (iii) are in the ratio [AMU 1995]



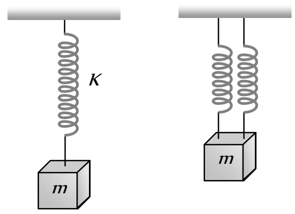
[M P PMT 1994]

(a) $1 : \sqrt{2} : \frac{1}{\sqrt{2}}$ (b) $2 : \sqrt{2} : \frac{1}{\sqrt{2}}$

(c) $\frac{1}{\sqrt{2}} : 2 : 1$ (d) $2 : \frac{1}{\sqrt{2}} : 1$

25. A mass m performs oscillations of period T when hanged by spring of force constant K. If spring is cut in two parts and arranged in parallel and same mass is oscillated by them, then the new time period will be

[CPMT 1995; RPET 1997; RPMT 2003]



(a) $2T$

(b) T

(c) $\frac{T}{\sqrt{2}}$

(d) $\frac{T}{2}$ [MP PET 1996]

26. If a watch with a wound spring is taken on to the moon, it

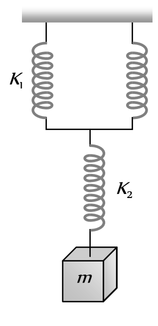
[AFMC 1993]

(a) Runs faster (b) Runs slower

(c) Does not work (d) Shows no change

27. What will be the force constant of the spring system shown in the figure

[RPET 1996; Kerala (Med./ Engg.) 2005]



(a) $\frac{K_1}{2} + K_2$

(b) $\left[\frac{1}{2K_1}+\frac{1}{K_2}\right]^{-1}$ [CBSE PMT 1998]

(c) $\frac{1}{2K_1}+\frac{1}{K_2}$

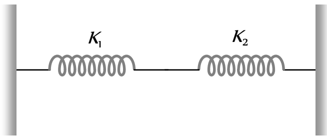
(d) $\left[\frac{2}{K_1}+\frac{1}{K_1}\right]^{-1}$

28. Two springs have spring constants K_A and K_B and $K_A > K_B$. The work required to stretch them by same extension will be

(a) More in spring A (b) More in spring B

(c) Equal in both (d) Noting can be said

29. The effective spring constant of two spring system as shown in figure will be [RPMT 1999]



(a) $K_1 + K_2$ (b) $K_1K_2 / K_1 + K_2$

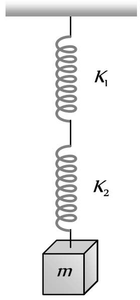
(c) $K_1 - K_2$ (d) $K_1K_2 / K_1 - K_2$

30. A mass m attached to a spring oscillates every 2 *sec*. If the mass is increased by 2 *kg*, then time-period increases by 1 *sec*. The initial mass is [CBSE PMT 2000; AIIMS 2000; MP PET 2000; DPMT 2001; Pb. PMT 2003]

(a) 1.6 *kg* (b) 3.9 *kg*

(c) 9.6 *kg* (d) 12.6 *kg*

31. A mass M is suspended by two springs of force constants K_1 and K_2 respectively as shown in the diagram. The total elongation (stretch) of the two springs is [MP PMT 2000; RPET 2001]



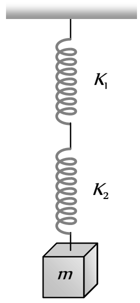
(a) $\dfrac{Mg}{K_1 + K_2}$

(b) $\dfrac{Mg(K_1 + K_2)}{K_1K_2}$

(c) $\dfrac{Mg\,K_1K_2}{K_1 + K_2}$

(d) $\dfrac{K_1 + K_2}{K_1K_2Mg}$

32. The frequency of oscillation of the springs shown in the figure will be [AIIMS 2001; Pb. PET 2002]



(a) $\dfrac{1}{2\pi}\sqrt{\dfrac{K}{m}}$

(b) $\dfrac{1}{2\pi}\sqrt{\dfrac{(K_1 + K_2)m}{K_1K_2}}$

(c) $2\pi\sqrt{\dfrac{K}{m}}$

(d) $\dfrac{1}{2\pi}\sqrt{\dfrac{K_1K_2}{m(K_1 + K_2)}}$

33. The scale of a spring balance reading from 0 to 10 *kg* is 0.25 m long. A body suspended from the balance oscillates vertically with a period of $\pi/10$ second. The mass suspended is (neglect the mass of the spring) [Kerala (Engg.) 2001]

(a) 10 *kg* (b) 0.98 *kg*

(c) 5 *kg* (d) 20 *kg*

34. If a spring has time period T, and is cut into n equal parts, then the time period of each part will be [AIEEE 2002]

(a) $T\sqrt{n}$ (b) $T/\sqrt{n}$

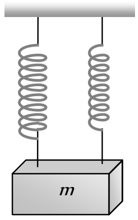
(c) nT (d) T

35. One-forth length of a spring of force constant K is cut away. The force constant of the remaining spring will be [MP PET 2002]

(a) $\dfrac{3}{4}K$ (b) $\dfrac{4}{3}K$

(c) K (d) 4 K

36. A mass m is suspended separately by two different springs of spring constant K_1 and K_2 gives the time-period t_1 and t_2 respectively. If same mass m is connected by both springs as shown in figure then time-period t is given by the relation [CBSE PMT 2002]



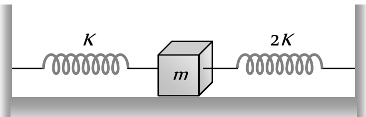
(a) $t = t_1 + t_2$

(b) $t = \dfrac{t_1.t_2}{t_1 + t_2}$

(c) $t^2 = t_1{}^2 + t_2{}^2$

(d) $t^{-2} = t_1{}^{-2} + t_2{}^{-2}$

37. Two springs of force constants K and $2K$ are connected to a mass as shown below. The frequency of oscillation of the mass is [RPMT 1996; DCE 200



(a) (1 / 2 ... /m)

(c) $(1/2\pi)\sqrt{(3K/m)}$ (d) $(1/2\pi)\sqrt{(m/K)}$

38. Two springs of constant k_1 and k_2 are joined in series. The effective spring constant of the combination is given by [CBSE PMT 2004]

(a) $\sqrt{k_1k_2}$ (b) $(k_1 + k_2)/2$

(c) $k_1 + k_2$ (d) $k_1k_2/(k_1 + k_2)$

39. A particle at the end of a spring executes simple harmonic motion with a period t_1, while the corresponding period for another spring is t_2. If the period of oscillation with the two springs in series is T, then [AIEEE 2004]

(a) $T = t_1 + t_2$ (b) $T^2 = t_1^2 + t_2^2$

(c) $T^{-1} = t_1^{-1} + t_2^{-1}$ (d) $T^{-2} = t_1^{-2} + t_2^{-2}$

40. Infinite springs with force constant k, $2k$, $4k$ and $8k$.... respectively are connected in series. The effective force constant of the spring will be [J & K CET 2004]

(a) 2K (b) k

(c) $k/2$ (d) 2048

41. To make the frequency double of a spring oscillator, we have to

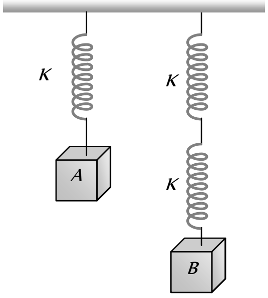
(a) Reduce the mass to one fourth

(b) Quardruple the mass

(c) Double of mass

(d) Half of the mass

42. The springs shown are identical. When $A = 4kg$, the elongation of spring is 1 *cm*. If $B = 6kg$, the elongation produced by it is



(a) 4 *cm* (b) 3 *cm*
(c) 2 *cm* (d) 1 *cm*

43. When a body of mass 1.0 *kg* is suspended from a certain light spring hanging vertically, its length increases by 5 *cm*. By suspending 2.0 *kg* block to the spring and if the block is pulled through 10 *cm* and released the maximum velocity in it in *m/s* is : (Acceleration due to gravity $= 10 m/s^2$) [EAMCET 2003]

(a) 0.5 (b) 1
(c) 2 (d) 4

44. Two springs with spring constants $K_1 = 1500\, N/m$ and $K_2 = 3000\, N/m$ are stretched by the same force. The ratio of potential energy stored in spring will be [RPET 2001]

(a) 2 : 1 (b) 1 : 2
(c) 4 : 1 (d) 1 : 4

45. If a spring extends by *x* on loading, then energy stored by the spring is (if *T* is the tension in the spring and *K* is the spring constant)

(a) $\frac{T^2}{2x}$ (b) $\frac{T^2}{2K}$
(c) $\frac{2K}{T^2}$ (d) $\frac{2T^2}{K}$

46. A weightless spring of length 60 *cm* and force constant 200 *N/m* is kept straight and unstretched on a smooth horizontal table and its ends are rigidly fixed. A mass of 0.25 *kg* is attached at the middle of the spring and is slightly displaced along the length. The time period of the oscillation of the mass is [MP PET 2003]

(a) $\frac{\pi}{20} s$ (b) $\frac{\pi}{10} s$
(c) $\frac{\pi}{5} s$ (d) $\frac{\pi}{\sqrt{200}} s$

47. The time period of a mass suspended from a spring is *T*. If the spring is cut into four equal parts and the same mass is suspended from one of the parts, then the new time period will be [MP PMT 2002; CBSE PMT 2003]

(a) *T* (b) $\frac{T}{2}$
(c) 2 *T* (d) $\frac{T}{4}$

48. A mass *M* is suspended from a spring of negligible mass. The spring is pulled a little and then released so that the mass executes S.H.M. of time period *T*. If the mass is increased by m, the time period becomes 5*T*/3. Then the ratio of *m*/*M* is [Pb. PET 2002]

(a) $\frac{5}{3}$ (b) $\frac{3}{5}$
(c) $\frac{25}{9}$ (d) $\frac{16}{9}$

49. An object is attached to the bottom of a light vertical spring and set vibrating. The maximum speed of the object is 15 *cm/sec* and the period is 628 *milli-seconds*. The amplitude of the motion in centimeters is [EAMCET 2003]

(a) 3.0 (b) 2.0
(c) 1.5 (d) 1.0

50. When a mass *m* is attached to a spring, it normally extends by 0.2 *m*. The mass *m* is given a slight addition extension and released, then its time period will be [MH CET 2001]

(a) $\frac{1}{7}$ *sec* (b) 1 *sec*
(c) $\frac{2\pi}{7}$ *sec* (d) $\frac{2}{3\pi}$ *sec*

51. If a body of mass 0.98 *kg* is made to oscillate on a spring of force constant 4.84 *N/m*, the angular frequency of the body is

(a) 1.22 *rad/s* (b) 2.22 *rad/s*
(c) 3.22 *rad/s* (d) 4.22 *rad/s*

52. A mass *m* is suspended from a spring of length *l* and force constant *K*. The frequency of vibration of the mass is f_1. The spring is cut into two equal parts and the same mass is suspended from one of the parts. The new frequency of vibration of mass is f_2. Which of the following relations between the frequencies is correct [AFMC 2000]

[NCERT 1983; CPMT 1986; MP PMT 1991; DCE 2002]

(a) $f_1 = \sqrt{2} f_2$ (b) $f_1 = f_2$
(c) $f_1 = 2f_2$ (d) $f_2 = \sqrt{2} f_1$

53. A mass *m* oscillates with simple harmonic motion with frequency $f = \frac{\omega}{2\pi}$ and amplitude *A* on a spring with constant K, therefore

(a) The total energy of the system is $\frac{1}{2}KA^2$

(b) The frequency is $\frac{1}{2\pi}\sqrt{\frac{K}{M}}$

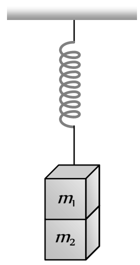
(c) The maximum velocity occurs, when $x = 0$

(d) All the above are correct

54. Two masses m_1 and m_2 are suspended together by a massless spring of constant *K*. When the masses are in equilibrium, m_2 is removed without disturbing the system. The amplitude of oscillations is

(a) $\frac{m_1 g}{K}$

(b) $\frac{m_2 g}{K}$



(c) $\frac{(m_1+m_2)g}{K}$

(d) $\frac{(m_1-m_2)g}{K}$

55. A spring executes SHM with mass of 10*kg* attached to it. The force constant of spring is 10*N/m*.If at any instant its velocity is 40*cm/sec*, the displacement will be (where amplitude is 0.5*m*)

(a) 0.09 *m* (b) 0.3 *m*

(c) 0.03 *m* (d) 0.9 *m*

Superposition of S.H.M's and Resonance

1. The S.H.M. of a particle is given by the equation $y = 3\sin\omega t + 4\cos\omega t$. The amplitude is [MP PET 1993]

(a) 7 (b) 1

(c) 5 (d) 12

2. If the displacement equation of a particle be represented by $y = A\sin PT + B\cos PT$, the particle executes [MP PET 1986]

(a) A uniform circular motion

(b) A uniform elliptical motion

(c) A S.H.M.

(d) A rectilinear motion

3. The motion of a particle varies with time according to the relation $y = a(\sin\omega t + \cos\omega t)$, then

(a) The motion is oscillatory but not S.H.M.

(b) The motion is S.H.M. with amplitude a

(c) The motion is S.H.M. with amplitude $a\sqrt{2}$

(d) The motion is S.H.M. with amplitude $2a$

4. The resultant of two rectangular simple harmonic motions of the same frequency and unequal amplitudes but differing in phase by $\frac{\pi}{2}$ is [BHU 2003; CPMT 2004; MP PMT 1989, 2005; BCECE 2005]

(a) Simple harmonic (b) Circular

(c) Elliptical (d) Parabolic

5. The composition of two simple harmonic motions of equal periods at right angle to each other and with a phase difference of π results in the displacement of the particle along

(a) Straight line (b) Circle

(c) Ellipse (d) Figure of eight

6. Two mutually perpendicular simple harmonic vibrations have same amplitude, frequency and phase. When they superimpose, the resultant form of vibration will be [MP PMT 1992]

(a) A circle (b) An ellipse

(c) A straight line (d) A parabola

7. The displacement of a particle varies according to the relation $x = 4(\cos\pi t + \sin\pi t)$. The amplitude of the particle is [AIEEE 2003]

(a) 8 (b) – 4

(c) 4 (d) $4\sqrt{2}$

8. A S.H.M. is represented by $x = 5\sqrt{2}(\sin 2\pi t + \cos 2\pi t)$. The amplitude of the S.H.M. is [MH CET 2004] [RPMT 2004]

(a) 10 *cm* (b) 20 *cm*

(c) $5\sqrt{2}$ *cm* (d) 50 *cm*

9. Resonance is an example of [CBSE PMT 1999; BHU 1999; 2005]

(a) Tuning fork (b) Forced vibration

(c) Free vibration (d) Damped vibration

10. In case of a forced vibration, the resonance wave becomes very sharp when the [CBSE PMT 2003]

(a) Restoring force is small

(b) Applied periodic force is small

(c) Quality factor is small

(d) Damping force is small

11. Amplitude of a wave is represented by

$$A = \frac{c}{a+b-c}$$

Then resonance will occur when [CPMT 1984]

(a) $b = -c/2$ (b) $b = 0$ and $a = -c$

(c) $b = -a/2$ (d) None of these

12. A particle with restoring force proportional to displacement and resisting force proportional to velocity is subjected to a force $F\sin\omega t$. If the amplitude of the particle is maximum for $\omega = \omega_1$ and the energy of the particle is maximum for $\omega = \omega_2$, then (where ω_0 natural frequency of oscillation of particle) [CBSE PMT 1990]

(a) $\omega_1 = \omega_0$ and $\omega_2 \neq \omega_o$ (b) $\omega_1 = \omega_0$ and $\omega_2 = \omega_o$

(c) $\omega_1 \neq \omega_0$ and $\omega_2 = \omega_o$ (d) $\omega_1 \neq \omega_0$ and $\omega_2 \neq \omega_o$

13. A simple pendulum is set into vibrations. The bob of the pendulum comes to rest after some time due to [AFMC 2003; JIPMER 1999]

(a) Air friction

(b) Moment of inertia

(c) Weight of the bob

(d) Combination of all the above

14. A simple pendulum oscillates in air with time period T and amplitude A. As the time passes [CPMT 2005]

(a) T and A both decrease

(b) T increases and A is constant

(c) T increases and A decreases

(d) T decreases and A is constant

Critical Thinking

Objective Questions

1. Two particles executes S.H.M. of same amplitude and frequency along the same straight line. They pass one another when going in opposite directions, and each time their displacement is half of their amplitude. The phase difference between them is

(a) 30° (b) 60°

(c) 90° (d) 120°

2. The displacement of a particle varies with time as $x = 12\sin\omega t - 16\sin^3 \omega t$ (in *cm*). If its motion is S.H.M., then its maximum acceleration is

(a) $12\,\omega^2$ (b) $36\,\omega^2$

(c) $144\,\omega^2$ (d) $\sqrt{192}\,\omega^2$

3. A linear harmonic oscillator of force constant $2\times10^6 N/m$ times and amplitude 0.01 *m* has a total mechanical energy of 160 *joules*. Its [IIT JEE 1989; CPMT 1995; CBSE PMT 1996; KECT (Med.) 1999; AMU (Engg.) 2000; UPSEAT 2001]

(a) Maximum potential energy is 100 *J*

(b) Maximum K.E. is 100 *J*

(c) Maximum P.E. is 160 *J*

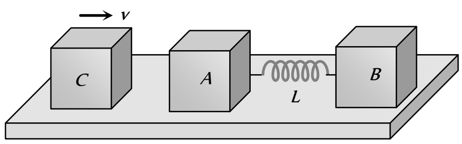
(d) Minimum P.E. is zero

4. A particle of mass *m* is executing oscillations about the origin on the *x*-axis. Its potential energy is $U(x) = k[x]^3$, where k is a positive constant. If the amplitude of oscillation is *a*, then its time period *T* is

(a) Proportional to $\frac{1}{\sqrt{a}}$ (b) Independent of *a*

(c) Proportional to $\sqrt{a}$ (d) Proportional to $a^{3/2}$

5. Two blocks *A* and *B* each of mass *m* are connected by a massless spring of natural length *L* and spring constant *K*. The blocks are initially resting on a smooth horizontal floor with the spring at its natural length as shown in figure. A third identical block *C* also of mass *m* moves on the floor with a speed *v* along the line joining *A* and *B* and collides with *A*. Then [IIT-JEE 1993]



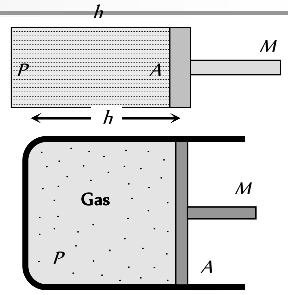
(a) The kinetic energy of the *A*-*B* system at maximum compression of the spring is zero

(b) The kinetic energy of the *A*-*B* system at maximum compression of the spring is $mv^2/4$

(c) The maximum compression of the spring is $v\sqrt{m/K}$

(d) The maximum compression of the spring is $v\sqrt{m/2K}$

6. A cylindrical piston of mass *M* slides smoothly inside a long cylinder closed at one end, enclosing a certain mass of gas. The cylinder is kept with its axis horizontal. If the piston is disturbed from its equilibrium position, it oscillates simple harmonically. The period of oscillation will be [IIT-JEE 1981]



(a) $T = 2\pi\sqrt{\left(\frac{Mh}{PA}\right)}$

(b) $T = 2\pi\sqrt{\left(\frac{MA}{Ph}\right)}$

(c) $T = 2\pi\sqrt{\left(\frac{M}{PAh}\right)}$ [MP PMT 1999]

(d) $T = 2\pi\sqrt{MPhA}$

7. A sphere of radius *r* is kept on a concave mirror of radius of curvature *R*. The arrangement is kept on a horizontal table (the surface of concave mirror is frictionless and sliding not rolling). If the sphere is displaced from its equilibrium position and left, then it executes S.H.M. The period of oscillation will be

(a) $2\pi\sqrt{\left(\frac{(R-r)1.4}{g}\right)}$ (b) $2\pi\sqrt{\left(\frac{R-r}{g}\right)}$

(c) $2\pi\sqrt{\left(\frac{rR}{a}\right)}$ (d) $2\pi\sqrt{\left(\frac{R}{gr}\right)}$

8. The amplitude of vibration of a particle is given by $a_m = (a_0)/(a\omega^2 - b\omega + c)$; where a_0, a, b and *c* are positive. The condition for a single resonant frequency is [CPMT 1982]

(a) $b^2 = 4ac$ [IIT-JEE 1998] (b) $b^2 > 4ac$

(c) $b^2 = 5ac$ (d) $b^2 = 7ac$

9. A *U* tube of uniform bore of cross-sectional area *A* has been set up vertically with open ends facing up. Now *m* gm of a liquid of density *d* is poured into it. The column of liquid in this tube will oscillate with a period *T* such that

(a) $T = 2\pi\sqrt{\frac{M}{g}}$ (b) $T = 2\pi\sqrt{\frac{MA}{gd}}$

(c) $T = 2\pi\sqrt{\frac{M}{gdA}}$ (d) $T = 2\pi\sqrt{\frac{M}{2Adg}}$

10. A particle is performing simple harmonic motion along *x*-axis with amplitude 4 *cm* and time period 1.2 *sec*. The minimum time taken by the particle to move from *x* =2 *cm* to *x* = + 4 *cm* and back again is given by [AIIMS 1995]

(a) 0.6 *sec* (b) 0.4 *sec*

(c) 0.3 *sec* (d) 0.2 *sec*

11. A large horizontal surface moves up and down in SHM with an amplitude of 1 *cm*. If a mass of 10 *kg* (which is placed on the surface) is to remain continually in contact with it, the maximum frequency of S.H.M. will be [SCRA 1994; AIIMS 1995]

(a) 0.5 *Hz* (b) 1.5 *Hz*

(c) 5 *Hz* (d) 10 *Hz*

12. Due to some force F_1 a body oscillates with period 4/5 *sec* and due to other force F_2 oscillates with period 3/5 *sec*. If both forces act simultaneously, the new period will be

[RPET 1997]

(a) 0.72 *sec* (b) 0.64 *sec*

(c) 0.48 *sec* (d) 0.36 *sec*

13. A horizontal platform with an object placed on it is executing S.H.M. in the vertical direction. The amplitude of oscillation is $3.92\times10^{-3}m$. What must be the least period of these oscillations, so that the object is not detached from the platform

(a) 0.1256 *sec* (b) 0.1356 *sec*

(c) 0.1456 *sec* (d) 0.1556 *sec*

14. A particle executes simple harmonic motion (amplitude = *A*) between $x=-A$ and $x=+A$. The time taken for it to go from 0 to *A*/2 is T_1 and to go from *A*/2 to *A* is T_2. Then

[IIT-JEE (Screening) 2001]

(a) $T_1 < T_2$ (b) $T_1 > T_2$

(c) $T_1 = T_2$ (d) $T_1 = 2T_2$

15. A simple pendulum of length *L* and mass (bob) *M* is oscillating in a plane about a vertical line between angular limits $-\phi$ and $+\phi$. For an angular displacement $\theta(|\theta|<\phi)$, the tension in the string and the velocity of the bob are T and v respectively. The following relations hold good under the above conditions

(a) $T\cos\theta = Mg$

(b) $T - Mg\cos\theta = \frac{Mv^2}{L}$

(c) The magnitude of the tangential acceleration of the bob $|a_T| = g\sin\theta$

(d) $T = Mg\cos\theta$

16. Two simple pendulums of length 5 *m* and 20 *m* respectively are given small linear displacement in one direction at the same time. They will again be in the phase when the pendulum of shorter length has completed .... oscillations.

[CBSE PMT 1998; JIPMER 2001, 02]

(a) 5 (b) 1

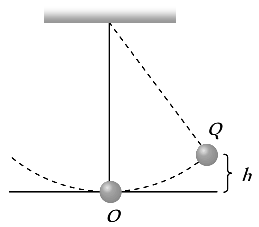
(c) 2 (d) 3

17. The bob of a simple pendulum is displaced from its equilibrium position *O* to a position *Q* which is at height *h* above *O* and the bob is then released. Assuming the mass of the bob to be *m* and time period of oscillations to be 2.0 *sec*, the tension in the string when the bob passes through *O* is

(a) $m(g+\pi\sqrt{2gh})$

(b) $m(g+\sqrt{\pi^2 gh})$

(c) $m\left(g+\sqrt{\frac{\pi^2}{2}gh}\right)$



(d) $m\left(g+\sqrt{\frac{\pi^2}{3}gh}\right)$

18. The metallic bob of a simple pendulum has the relative density ρ. The time period of this pendulum is *T*. If the metallic bob is immersed in water, then the new time period is given by

(a) $T\frac{\rho-1}{\rho}$ (b) $T\frac{\rho}{\rho-1}$

(c) $T\sqrt{\frac{\rho-1}{\rho}}$ [AIIMS 1999] (d) $T\sqrt{\frac{\rho}{\rho-1}}$

19. A clock which keeps correct time at 20^oC, is subjected to 40^oC. If coefficient of linear expansion of the pendulum is $12\times10^{-6}/°C$. How much will it gain or loose in time

[BHU 1998]

(a) 10.3 *seconds / day* (b) 20.6 *seconds / day*

(c) 5 *seconds / day* (d) 20 *minutes / day*

20. The period of oscillation of a simple pendulum of length *L* suspended from the roof of a vehicle which moves without friction down an inclined plane of inclination α, is given by

[IIT-JEE (Screening) 2000]

(a) $2\pi\sqrt{\frac{L}{g\cos\alpha}}$ (b) $2\pi\sqrt{\frac{L}{g\sin\alpha}}$

(c) $2\pi\sqrt{\frac{L}{g}}$ (d) $2\pi\sqrt{\frac{L}{g\tan\alpha}}$

[IIT 1986; UPSEAT 1998]

21. The bob of a simple pendulum executes simple harmonic motion in water with a period *t*, while the period of oscillation of the bob is t_0 in air. Neglecting frictional force of water and given that the density of the bob is (4/3) ×1000 *kg/m*. What relationship between t and t_0 is true [AIEEE 2004]

(a) $t = t_0$ (b) $t = t_0/2$

(c) $t = 2t_0$ (d) $t = 4t_0$

22. A spring of force constant *k* is cut into two pieces such that one piece is double the length of the other. Then the long piece will have a force constant of

[IIT-JEE (Screening) 1999]

(a) $(2/3)k$ (b) $(3/2)k$

(c) $3k$ (d) $6k$

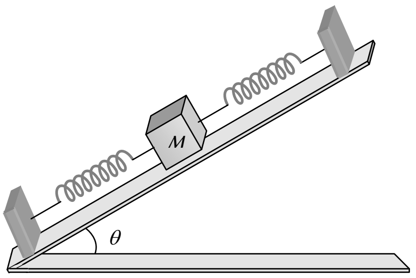
23. One end of a long metallic wire of length *L* is tied to the ceiling. The other end is tied to massless spring of spring constant *K*. *A* mass *m* hangs freely from the free end of the spring. The area of cross-section and Young's modulus of the wire are *A* and *Y* respectively. If the mass is slightly pulled down and released, it will oscillate with a time period *T* equal to [IIT 1993]

[AMU 1995]

(a) $2\pi\left(\frac{m}{K}\right)$ (b) $2\pi\left\{\frac{(YA+KL)m}{YAK}\right\}^{1/2}$

(c) $2\pi\frac{mYA}{KL}$ (d) $2\pi\frac{mL}{YA}$

24. On a smooth inclined plane, a body of mass *M* is attached between two springs. The other ends of the springs are fixed to firm supports. If each spring has force constant *K*, the period of oscillation of the body (assuming the springs as massless) is



(a) $2\pi\left(\frac{m}{2K}\right)^{1/2}$

(b) $2\pi\left(\frac{2M}{K}\right)^{1/2}$

(c) $2\pi\frac{Mg\sin\theta}{2K}$

(d) $2\pi\left(\frac{2Mg}{K}\right)^{1/2}$

25. A particle of mass m is attached to a spring (of spring constant k) and has a natural angular frequency ω_0 -An external force $F(t)$ proportional to $\cos\omega t((\omega \neq \omega_0)$ is applied to the oscillator. The time displacement of the oscillator will be proportional to

(a) $\frac{m}{\omega_0^2-\omega^2}$ (b) $\frac{1}{m(\omega_0^2-\omega^2)}$

(c) $\frac{1}{m(\omega_1^2+\omega^2)}$ (d) $\frac{m}{\omega_1^2+\omega^2}$

26. A 15 g ball is shot from a spring gun whose spring has a force constant of 600 N/m. The spring is compressed by 5 cm. The greatest possible horizontal range of the ball for this compression is (g = 10 m/s) [DPMT 2004]

(a) 6.0 m (b) 10.0 m

(c) 12.0 m (d) 8.0 m

27. An ideal spring with spring-constant K is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is

[IIT-JEE (Screening) 2002]

(a) 4 Mg/K (b) 2 Mg/K

(c) Mg/K (d) $Mg/2K$

28. The displacement y of a particle executing periodic motion is given by $y = 4\cos^2(t/2)\sin(1000t)$. This expression may be considered to be a result of the superposition of .... independent harmonic motions [IIT 1992]

(a) Two (b) Three

(c) Four (d) Five

29. Three simple harmonic motions in the same direction having the same amplitude a and same period are superposed. If each differs in phase from the next by 45^o, then

(a) The resultant amplitude is $(1+\sqrt{2})a$

(b) The phase of the resultant motion relative to the first is 90°

(c) The energy associated with the resulting motion is $(3+2\sqrt{2})$ times the energy associated with any single motion

(d) The resulting motion is not simple harmonic

30. The function $\sin^2(\omega t)$ represents [AIEEE 2005]

(a) A simple harmonic motion with a period $2\pi/\omega$

(b) A simple harmonic motion with a period π/ω

(c) A periodic but not simple harmonic motion with a period $2\pi/\omega$

(d) A periodic but not simple harmonic, motion with a period π/ω

31. A simple pendulum has time period T_1. The point of suspension is now moved upward according to equation $y = kt^2$ where $k = 1\,m/sec^2$. If new time period is T_2 then ratio $\frac{T_1^2}{T_2^2}$ will be

(a) 2/3 (b) 5/6

(c) 6/5 (d) 3/2

32. A simple pendulum is hanging from a peg inserted in a vertical wall. Its bob is stretched in horizontal position from the wall and is left free to move. The bob hits on the wall the coefficient of restitution $\frac{2}{\sqrt{5}}$ [AIEEE 2004] After how many collisions the amplitude of vibration will become less than 60°

[UPSEAT 1999]

(a) 6 (b) 3

(c) 5 (d) 4

33. A brass cube of side a and density σ is floating in mercury of density ρ. If the cube is displaced a bit vertically, it executes S.H.M. Its time period will be

(a) $2\pi\sqrt{\frac{\sigma a}{\rho g}}$ (b) $2\pi\sqrt{\frac{\rho a}{\sigma g}}$

(c) $2\pi\sqrt{\frac{\rho g}{\sigma a}}$ (d) $2\pi\sqrt{\frac{\sigma g}{\rho a}}$

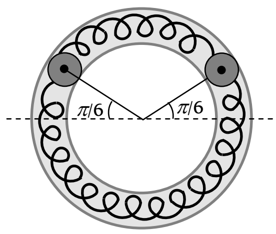
34. Two identical balls A and B each of mass 0.1 kg are attached to two identical massless springs. The spring mass system is constrained to move inside a rigid smooth pipe bent in the form of a circle as shown in the figure. The pipe is fixed in a horizontal plane. The centres of the balls can move in a circle of radius 0.06 m. Each spring has a natural length of 0.06π m and force constant 0.1N/m. Initially both the balls are displaced by an angle $\theta = \pi/6$ radian with respect to the diameter PQ of the circle and released from rest. The frequency of oscillation of the ball B is

(a) $\pi\,Hz$

(b) $\frac{1}{\pi}Hz$

(c) $2\pi\,Hz$ [IIT JEE 1999]

(d) $\frac{1}{2\pi}Hz$



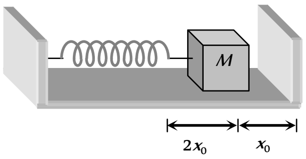
35. A disc of radius R and mass M is pivoted at the rim and is set for small oscillations. If simple pendulum has to have the same period as that of the disc, the length of the simple pendulum should be

(a) $\frac{5}{4}R$ (b) $\frac{2}{3}R$

(c) $\frac{3}{4}R$ (d) $\frac{3}{2}R$

36. One end of a spring of force constant k is fixed to a vertical wall and the other to a block of mass m resting on a smooth horizontal surface. There is another wall at a distance x_0 from the black. The

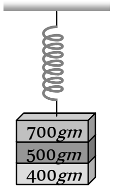
spring is then compressed by $2x_0$ and released. The time taken to strike the wall is



(a) $\frac{1}{6}\pi\sqrt{\frac{k}{m}}$ (b) $\sqrt{\frac{k}{m}}$

(c) $\frac{2\pi}{3}\sqrt{\frac{m}{k}}$ (d) $\frac{\pi}{4}\sqrt{\frac{k}{m}}$

37. Three masses $700g$, $500g$, and $400g$ are suspended at the end of a spring a shown and are in equilibrium. When the $700g$ mass is removed, the system oscillates with a period of 3 seconds, when the 500 *gm* mass is also removed, it will oscillate with a period of



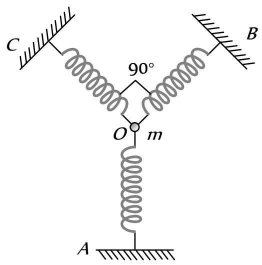
(a) 1 *s*

(b) 2 *s*

(c) 3 *s*

(d) $\sqrt{\frac{12}{5}}\,s$

38. A particle of mass *m* is attached to three identical springs *A, B* and *C* each of force constant *k* a shown in figure. If the particle of mass *m* is pushed slightly against the spring *A* and released then the time period of oscillations is



(a) $2\pi\sqrt{\frac{2m}{k}}$

(b) $2\pi\sqrt{\frac{m}{2k}}$

(c) $2\pi\sqrt{\frac{m}{k}}$

(d) $2\pi\sqrt{\frac{m}{3k}}$

39. A hollow sphere is filled with water through a small hole in it. It is then hung by a long thread and made to oscillate. As the water slowly flows out of the hole at the bottom, the period of oscillation will

[MP PMT 1994; KCET 1994; RPET 1996; AFMC 2000; CBSE PMT 2000; CPMT 2001; AIEEE 2005]

(a) Continuously decrease

(b) Continuously increase

(c) First decrease and then increase to original value

(d) First increase and then decrease to original value

40. Two simple pendulums whose lengths are 100 *cm* and 121 *cm* are suspended side by side. Their bobs are pulled together and then released. After how many minimum oscillations of the longer pendulum, will the two be in phase again

(a) 11 (b) 10

(c) 21 (d) 20

41. The amplitude of a damped oscillator becomes half in one minute. The amplitude after 3 *minute* will be $\frac{1}{X}$ times the original, where *X* is [CPMT 1989; DPMT 2002]

(a) 2×3 (b) 2^3

(c) 3^2 (d) 3×2^2

42. Which of the following function represents a simple harmonic oscillation [AIIMS 2005]

(a) $\sin\omega t - \cos\omega t$ (b) $\sin^2\omega t$

(c) $\sin\omega t + \sin 2\omega t$ (d) $\sin\omega t - \sin 2\omega t$

43. A uniform rod of length 2.0 *m* is suspended through an end and is set into oscillation with small amplitude under gravity. The time period of oscillation is approximately

[AMU (Med.) 2000]

(a) 1.60 *sec* (b) 1.80 *sec*

(c) 2.0 *sec* (d) 2.40 *sec*

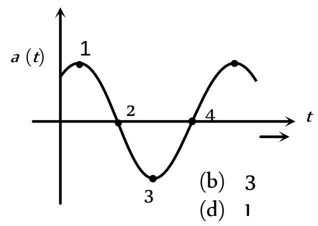
Graphical Questions

1. A particle is executing S.H.M. Then the graph of acceleration as a function of displacement is

(a) A straight line (b) A circle

(c) An ellipse (d) A hyperbola

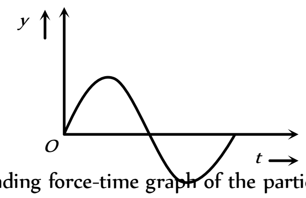
2. The acceleration *a* of a particle undergoing S.H.M. is shown in the figure. Which of the labelled points corresponds to the particle being at $-x_0$ [AMU (Med.) 2000]



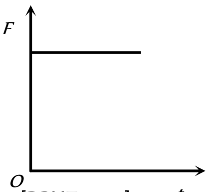
(a) 4 (b) 3

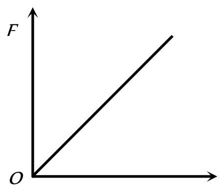
(c) 2 (d) 1

3. The displacement time graph of a particle executing S.H.M. is as shown in the figure [KCET 2003]

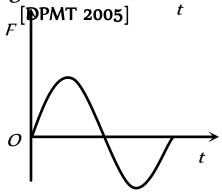


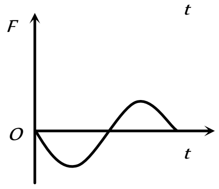
The corresponding force-time graph of the particle is

(a) 

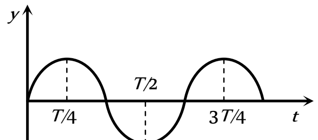
(b) 

[DPMT 2005]

(c) 

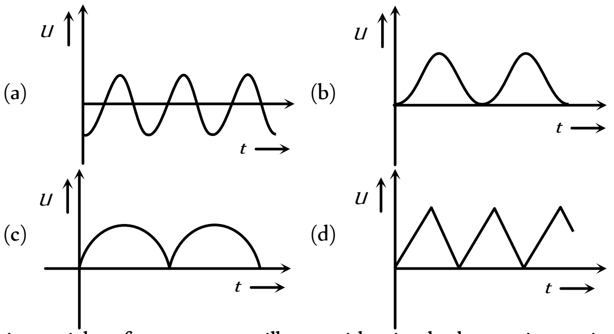
(d) 

4. The graph shows the variation of displacement of a particle executing S.H.M. with time. We infer from this graph that

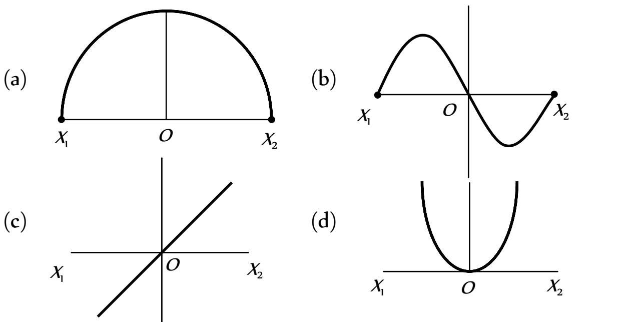


(a) The force is zero at time $3T/4$
(b) The velocity is maximum at time $T/2$
(c) The acceleration is maximum at time T
(d) The P.E. is equal to total energy at time $T/2$

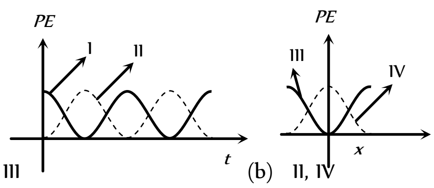
5. As a body performs S.H.M., its potential energy U. varies with time as indicated in [AMU (Med.) 2001]



6. A particle of mass m oscillates with simple harmonic motion between points x_1 and x_2, the equilibrium position being O. Its potential energy is plotted. It will be as given below in the graph



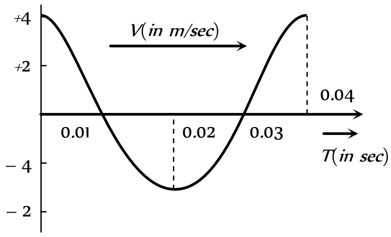
7. For a particle executing S.H.M. the displacement x is given by $x = A\cos\omega t$. Identify the graph which represents the variation of potential energy (P.E.) as a function of time t and displacement x



(a) I, III
(b) II, IV
(c) II, III
(d) I, IV

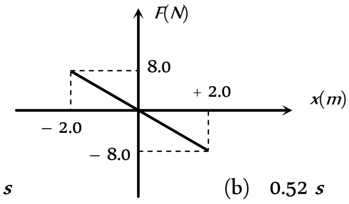
8. The velocity-time diagram of a harmonic oscillator is shown in the adjoining figure. The frequency of oscillation is

[CPMT 1989]



(a) 25 Hz
(b) 50 Hz
(c) 12.25 Hz
(d) 33.3 Hz

9. A body of mass 0.01 kg executes simple harmonic motion (S.H.M.) about $x = 0$ under the influence of a force shown below : The period of the S.H.M. is [AMU (Med.) 2002]



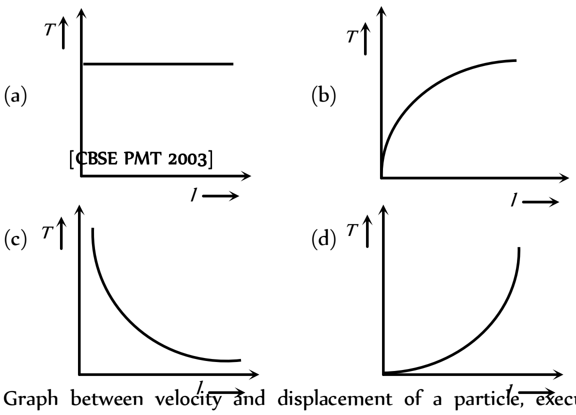
(a) 1.05 s
(b) 0.52 s
(c) 0.25 s
(d) 0.30 s

10. For a simple pendulum the graph between L and T will be.

[CPMT 1992]

(a) Hyperbola
(b) Parabola
(c) A curved line
(d) A straight line

11. In case of a simple pendulum, time period versus length is depicted by [DCE 1999, 2001]

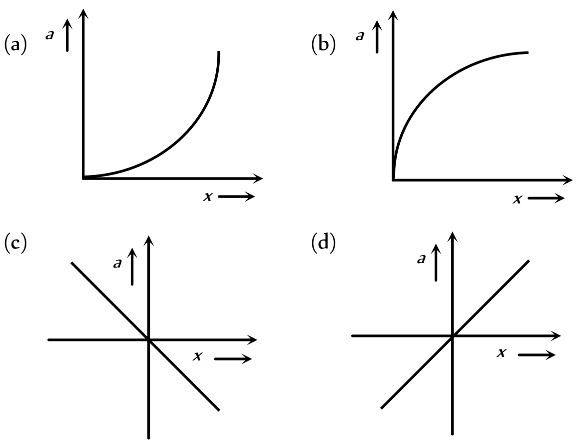


[CBSE PMT 2003]

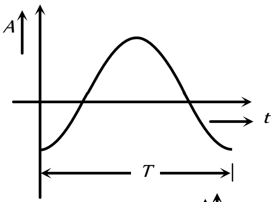
12. Graph between velocity and displacement of a particle, executing S.H.M. is [DPMT 2005]

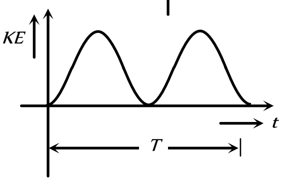
(a) A straight line
(b) A parabola
(c) A hyperbola
(d) An ellipse

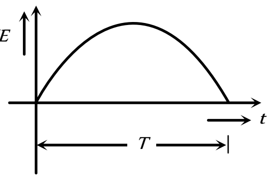
13. The variation of the acceleration a of the particle executing S.H.M. with displacement x is as shown in the figure [IIT JEE (Screening) 2003]

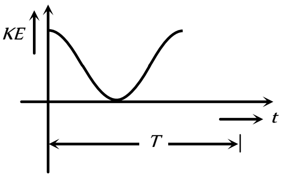


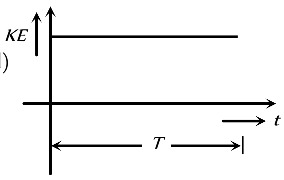
14. Acceleration A and time period T of a body in S.H.M. is given by a curve shown below. Then corresponding graph, between kinetic energy (K.E.) and time t is correctly represented by



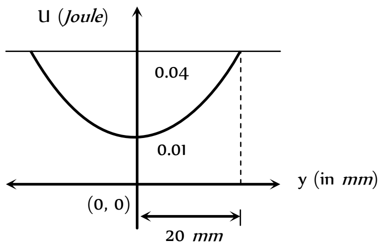
(a)


(b)


(c)


(d)


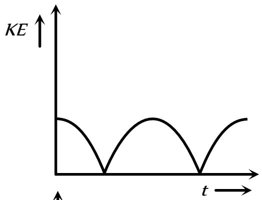
15. The variation of potential energy of harmonic oscillator is as shown in figure. The spring constant is

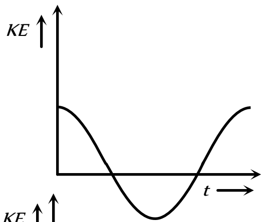


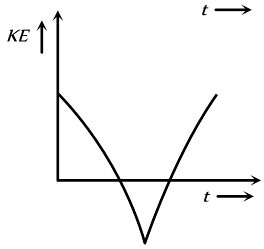
(a) 1×10^2 N/m (b) 150 N/m

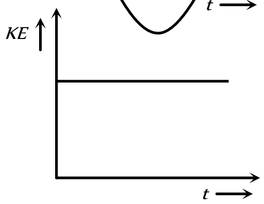
(c) 0.667×10^2 N/m (d) 3×10^2 N/m

16. A body performs S.H.M. Its kinetic energy K varies with time t as indicated by graph

(a)


(b)


(c)


(d)


AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : All oscillatory motions are necessarily periodic motion but all periodic motion are not oscillatory.

Reason : Simple pendulum is an example of oscillatory motion.

2. Assertion : Simple harmonic motion is a uniform motion.

Reason : Simple harmonic motion is the projection of uniform circular motion.

3. Assertion : Acceleration is proportional to the displacement. This condition is not sufficient for motion in simple harmonic.

Reason : In simple harmonic motion direction of displacement is also considered.

4. Assertion : Sine and cosine functions are periodic functions.

Reason : Sinusoidal functions repeats it values after a definite interval of time.

5. Assertion : The graph between velocity and displacement for a harmonic oscillator is a parabola.

Reason : Velocity does not change uniformly with displacement in harmonic motion.

6. Assertion : When a simple pendulum is made to oscillate on the surface of moon, its time period increases.

Reason : Moon is much smaller as compared to earth.

7. Assertion : Resonance is special case of forced vibration in which the natural frequency of vibration of the body is the same as the impressed frequency of external periodic force and the amplitude of forced vibration is maximum.

Reason : The amplitude of forced vibrations of a body increases with an increase in the frequency of the externally impressed periodic force.

[AIIMS 1994]

8. Assertion : The graph of total energy of a particle in SHM *w.r.t.,* position is a straight line with zero slope.

Reason : Total energy of particle in SHM remains constant throughout its motion.

9. Assertion : The percentage change in time period is 1.5%, if the length of simple pendulum increases by 3%.

Reason : Time period is directly proportional to length of pendulum.

10. Assertion : The frequency of a second pendulum in an elevator moving up with an acceleration half the acceleration due to gravity is 0.612 s^{-}.

Reason : The frequency of a second pendulum does not depend upon acceleration due to gravity.

11. Assertion : Damped oscillation indicates loss of energy.

Reason : The energy loss in damped oscillation may be due to friction, air resistance etc.

12. Assertion : In a S.H.M., kinetic and potential energies become equal when the displacement is $1/\sqrt{2}$ times the amplitude.

Reason : In SHM, kinetic energy is zero when potential energy is maximum.

13. Assertion : If the amplitude of a simple harmonic oscillator is doubled, its total energy becomes four times.

Reason : The total energy is directly proportional to the square of amplitude of vibration of the harmonic oscillator.

14. Assertion : For an oscillating simple pendulum, the tension in the string is maximum at the mean position and minimum at the extreme position.

Reason : The velocity of oscillating bob in simple harmonic motion is maximum at the mean position.

15. Assertion : The spring constant of a spring is k. When it is divided into n equal parts, then spring constant of one piece is k/n.

Reason : The spring constant is independent of material used for the spring.

16. Assertion : The periodic time of a hard spring is less as compared to that of a soft spring.

Reason : The periodic time depends upon the spring constant, and spring constant is large for hard spring.

17. Assertion : In extreme position of a particle executing S.H.M., both velocity and acceleration are zero.

Reason : In S.H.M., acceleration always acts towards mean position.

18. Assertion : Soldiers are asked to break steps while crossing the bridge.

Reason : The frequency of marching may be equal to the natural frequency of bridge and may lead to resonance which can break the bridge.

[AIIMS 2001]

19. Assertion : The amplitude of oscillation can never be infinite.

Reason : The energy of oscillator is continuously dissipated.

20. Assertion : In S.H.M., the motion is 'to and fro' and periodic.

Reason : Velocity of the particle $(v) = \omega\sqrt{k^2 - x^2}$ (where x is the displacement and k is amplitude)

[AIIMS 2002]

21. Assertion : The amplitude of an oscillating pendulum decreases gradually with time

Reason : The frequency of the pendulum decreases with time [AIIMS 2003]

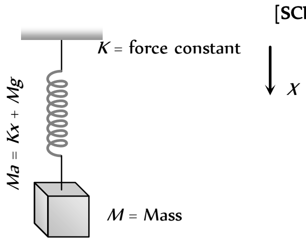
22. Assertion : In simple harmonic motion, the velocity is maximum when acceleration is minimum

Reason : Displacement and velocity of S.H.M. differ is phase by $\pi/2$ [AIIMS 1999]

23. Assertion : Consider motion for a mass spring system under gravity, motion of M is not a simple harmonic motion unless Mg is negligibly small.

Reason : For simple harmonic motion acceleration must be proportional to displacement and is directed towards the mean position

[SCRA 1994]



Answers

Displacement of S.H.M. and Phase

1	b,d	2	c	3	d	4	c	5	d
6	c	7	c	8	a	9	a,b,d	10	a
11	c	12	c	13	c	14	c	15	d
16	b	17	d	18	a	19	c	20	a
21	b	22	c	23	b	24	c	25	b
26	a								

Velocity of Simple Harmonic Motion

1	a	2	c	3	c	4	c	5	b
6	c	7	d	8	c	9	d	10	b
11	a	12	d	13	a	14	b	15	c
16	b	17	b	18	a	19	d	20	b
21	b	22	c	23	d	24	a	25	a
26	c	27	a						

Acceleration of Simple Harmonic Motion

1	d	2	c	3	c	4	d	5	a
6	a	7	a	8	d	9	d	10	d
11	a	12	a	13	d	14	a	15	a
16	d	17	d	18	d	19	b	20	c
21	c								

Energy of Simple Harmonic Motion

1	d	2	a	3	d	4	a	5	a
6	c	7	c	8	b	9	d	10	c
11	c	12	b	13	a	14	a	15	b
16	b	17	c	18	b	19	d	20	c
21	c	22	c	23	b	24	b	25	a
26	c	27	c	28	a	29	b	30	c
31	c	32	d	33	b	34	b		

Time Period and Frequency

1	b	2	c	3	b	4	d	5	b
6	a	7	d	8	d	9	d	10	a
11	b	12	b	13	b	14	b	15	a
16	d	17	d	18	d				

Simple Pendulum

1	c	2	a	3	b	4	b	5	b
6	b	7	c	8	c	9	c	10	d
11	d	12	b	13	a	14	d	15	d

16	b	17	b	18	c	19	c	20	c
21	d	22	d	23	c	24	c	25	d
26	a	27	a	28	b	29	d	30	d
31	c	32	c	33	b	34	b	35	a
36	a	37	d	38	b	39	c	40	d
41	a	42	a	43	a	44	b	45	d
46	d	47	b	48	a	49	a	50	a
51	c	52	c	53	c	54	d	55	c
56	b	57	c	58	a	59	c	60	a
61	b								

Spring Pendulum

1	d	2	d	3	b	4	b	5	b
6	c	7	c	8	b	9	a	10	c
11	a	12	b	13	d	14	c	15	a
16	d	17	a	18	d	19	b	20	c
21	c	22	c	23	d	24	a	25	d
26	d	27	b	28	a	29	a	30	a
31	b	32	d	33	b	34	b	35	b
36	d	37	c	38	d	39	b	40	c
41	a	42	b	43	b	44	a	45	b
46	a	47	b	48	d	49	c	50	c
51	b	52	d	53	d	54	a	55	b

Superposition of S.H.M's and Resonance

1	c	2	c	3	c	4	c	5	a
6	c	7	d	8	a	9	b	10	d
11	b	12	c	13	a	14	c		

Critical Thinking Questions

1	d	2	b	3	b,c	4	a	5	b,d
6	a	7	b	8	a	9	d	10	b
11	c	12	c	13	a	14	a	15	b,c
16	c	17	a	18	d	19	a	20	a
21	c	22	b	23	b	24	a	25	b
26	b	27	b	28	b	29	a,c	30	d
31	c	32	b	33	a	34	b	35	d
36	c	37	b	38	b	39	d	40	b
41	b	42	a	43	d				

Graphical Questions

1	a	2	d	3	d	4	d	5	b
6	d	7	a	8	a	9	d	10	b
11	b	12	d	13	c	14	a	15	b
16	a								

Assertion and Reason

1	b	2	e	3	a	4	a	5	e
6	b	7	c	8	a	9	c	10	c
11	b	12	b	13	a	14	b	15	e
16	a	17	e	18	a	19	a	20	b
21	c	22	b	23	e				

Answers and Solutions

Displacement of S.H.M. and Phase

1. (b,d) For S.H.M. displacement $y = a\sin\omega t$ and acceleration

$A = -\omega^2 y\sin\omega t$ these are maximum at $\omega t = \frac{\pi}{2}$.

2. (c) $v_{max} = \omega A \Rightarrow v = \frac{\omega A}{2} = \omega\sqrt{A^2 - y^2}$

$\Rightarrow A^2 - y^2 = \frac{A^2}{4} \Rightarrow y^2 = \frac{3A^2}{4} \Rightarrow y = \frac{\sqrt{3}A}{2}$

3. (d) Equation of motion is $y = 5\sin\frac{2\pi t}{6}$. For $y = 2.5\,cm$

$2.5 = 5\sin\frac{2\pi t}{6} \Rightarrow \frac{2\pi t}{6} = \frac{\pi}{6} \Rightarrow t = \frac{1}{2}sec$

and phase $= \frac{2\pi t}{6} = \frac{\pi}{6}$.

4. (c) $y = a\sin(\omega t - \alpha) = a\cos\left(\omega t - \alpha - \frac{\pi}{2}\right)$

Another equation is given $y = \cos(\omega t - \alpha)$

So, there exists a phase difference of $\frac{\pi}{2} = 90°$

5. (d) $y = a\sin(\omega t + \phi)$

$= a\sin\left(\frac{2\pi}{T}t + \phi\right) \Rightarrow y = 0.5\sin\left(\frac{2\pi}{0.4}t + \frac{\pi}{2}\right)$

$y = 0.5\sin\left(5\pi t + \frac{\pi}{2}\right) = 0.5\cos 5\pi t$

6. (c) $y = a\sin(2\pi nt + \alpha)$. Its phase at time $t = 2\pi nt + \alpha$

7. (c) From given equation $\omega = \frac{2\pi}{T} = 0.5\pi \Rightarrow T = 4\ sec$

Time taken from mean position to the maximum displacement $= \frac{1}{4}T = 1\ sec.$

8. (a) It is required to calculate the time from extreme position. Hence, in this case equation for displacement of particle can be written as $x = a\sin(\omega t + \frac{\pi}{2}) = a\cos\omega t$

$\Rightarrow \frac{a}{2} = a\cos\omega t \Rightarrow \omega t = \frac{\pi}{3} \Rightarrow \frac{2\pi}{T}.t = \frac{\pi}{3} \Rightarrow t = \frac{T}{6}$

9. (a,b,d) $x = a\sin\omega t\cos\omega t = \frac{a}{2}\sin 2\omega t$

10. (a) $v_{\max} = a\omega = a \times \frac{2\pi}{T} \Rightarrow a = \frac{v_{\max} \times T}{2\pi}$

$a = \frac{1.00\times 10^3 \times (1\times 10^{-5})}{2\pi} = 1.59\ mm$

11. (c)

12. (c)

13. (c) $y = a\sin\frac{2\pi}{T}t \Rightarrow \frac{a}{\sqrt{2}} = a\sin\frac{2\pi}{T}\cdot t$

$\Rightarrow \sin\frac{2\pi}{T}t = \frac{1}{\sqrt{2}} = \sin\frac{\pi}{4} \Rightarrow \frac{2\pi}{T}t = \frac{\pi}{4} \Rightarrow t = \frac{T}{8}$

14. (c)

15. (d) Standard equation of S.H.M. $\frac{d^2y}{dt^2} = -\omega^2 y$, is not satisfied by $y = a\tan\omega t$.

16. (b) $x = a\cos(\omega t + \theta)$ ....(i)

and $v = \frac{dx}{dt} = -a\omega\sin(\omega t + \theta)$ ....(ii)

Given at $t = 0$, $x = 1\,cm$ and $v = \pi$ and $\omega = \pi$

Putting these values in equation (i) and (ii) we will get $\sin\theta = \frac{-1}{a}$ and $\cos\theta = \frac{1}{a}$

$\Rightarrow \sin^2\theta + \cos^2\theta = \left(-\frac{1}{a}\right)^2 + \left(\frac{1}{a}\right)^2 \Rightarrow a = \sqrt{2}\,cm$

17. (d) $y = A\sin\omega t = \frac{A\sin 2\pi}{T}t \Rightarrow \frac{A}{2} = A\sin\frac{2\pi t}{T} \Rightarrow t = \frac{T}{12}$.

18. (a) The amplitude is a maximum displacement from the mean position.

19. (c) Equation of motion $y = a\cos\omega t$

$\Rightarrow \frac{a}{2} = a\cos\omega t \Rightarrow \cos\omega t = \frac{1}{2} \Rightarrow \omega t = \frac{\pi}{3}$

$\Rightarrow \frac{2\pi t}{T} = \frac{\pi}{3} \Rightarrow t = \frac{\frac{\pi}{3}\times T}{2\pi} = \frac{4}{3\times 2} = \frac{2}{3}\sec$

20. (a) Simple harmonic waves are set up in a string fixed at the, two ends.

21. (b)

22. (c) $v_1 = \frac{dy_1}{dt} = 0.1\times 100\pi\cos\left(100\pi t + \frac{\pi}{3}\right)$

$v_2 = \frac{dy_2}{dt} = -0.1\pi\sin\pi t = 0.1\pi\cos\left(\pi t + \frac{\pi}{2}\right)$

Phase difference of velocity of first particle with respect to the velocity of 2nd particle at $t = 0$ is

$\Delta\phi = \phi_1 - \phi_2 = \frac{\pi}{3} - \frac{\pi}{2} = -\frac{\pi}{6}$.

23. (b) $\frac{a_1}{a_2} = \frac{10}{25} = \frac{2}{5}$

24. (c) $y = a\sin\frac{2\pi}{T}t \Rightarrow \frac{a}{2} = a\sin\frac{2\pi t}{3} \Rightarrow \frac{1}{2} = \sin\frac{2\pi t}{3}$

$\Rightarrow \sin\frac{2\pi t}{3} = \sin\frac{\pi}{6} \Rightarrow \frac{2\pi t}{3} = \frac{\pi}{6} \Rightarrow t = \frac{1}{4}\sec$

25. (b)

26. (a) $x = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and $x' = a\cos\omega t = a\sin\left(\omega t + \frac{\pi}{2}\right)$

$\therefore \Delta\phi = \left(\omega t + \frac{\pi}{2}\right) - \left(\omega t + \frac{\pi}{6}\right) = \frac{\pi}{3}$

Velocity of Simple Harmonic Motion

1. (a) Velocity of a particle executing S.H.M. is given by

$v = \omega\sqrt{a^2 - x^2} = \frac{2\pi}{T}\sqrt{A^2 - \frac{A^2}{4}} = \frac{2\pi}{T}\sqrt{\frac{3A^2}{4}} = \frac{\pi A\sqrt{3}}{T}$.

2. (c) $v = \omega\sqrt{(a^2 - y^2)} = 2\sqrt{60^2 - 20^2} = 113\,mm/s$.

3. (c) It is given $v_{max} = 100\,cm/sec$, $a = 10\,cm$.

$\Rightarrow v_{max} = a\omega \Rightarrow \omega = \frac{100}{10} = 10\,rad/sec$

Hence $v = \omega\sqrt{a^2 - y^2} \Rightarrow 50 = 10\sqrt{(10)^2 - y^2}$

$\Rightarrow y = 5\sqrt{3}\,cm$

4. (c) At centre $v_{max} = a\omega = a.\frac{2\pi}{T} = \frac{0.2\times 2\pi}{0.01} = 40\pi$

5. (b) $v_{max} = a\omega = a\frac{2\pi}{T} = 3\times\frac{2\pi}{6} = \pi\,cm/s$

6. (c) $v_{max} = \omega a = \frac{2\pi}{T}\times a \Rightarrow v_{max} = \frac{2\times\pi\times 2}{2} = 2\pi\,m/s$

7. (d) $v_{max} = a\omega = \frac{a.2\pi}{T} = \frac{2\pi a}{T}$

8. (c) $v = \omega\sqrt{a^2 - y^2} \Rightarrow 10 = \omega\sqrt{a^2 - (4)^2}$ and $8 = \omega\sqrt{a^2 - (5)^2}$

On solving $\omega = 2 \Rightarrow \omega = \frac{2\pi}{T} = 2 \Rightarrow T = \pi\,sec$

9. (d) From the given equation, $a = 5$ and $\omega = 4$

$\therefore v = \omega\sqrt{a^2 - y^2} = 4\sqrt{(5)^2 - (3)^2} = 16$

10. (b) $v_{max} = a\omega = a\times\frac{2\pi}{T} = (50\times 10^{-3})\times\frac{2\pi}{2} = 0.15\,m/s$

11. (a) $n = \frac{\omega}{2\pi} = \frac{220}{2\pi} = 35\,Hz$

$v_{max} = \omega a = 220\times 0.30\,m/s = 66\,m/s$

12. (d) $v_{max} = a\omega$ and $A_{max} = a\omega^2 \Rightarrow \omega = \frac{A_{max}}{v_{max}} = \frac{4}{2} = 2\,rad/sec$

13. (a) $v_{max} = a\omega = \frac{a\times 2\pi}{T} = \frac{2\times 10^{-3}\times 2\pi}{0.1} = \frac{\pi}{25}\,m/s$

14. (b) $A = \omega^2 y \Rightarrow \omega = \sqrt{A/y} = \sqrt{\frac{8}{2}} = 2\,rad/sec$

Now $v_{max} = a\omega = 6\times 2 = 12\,cm/sec$

15. (c) $v_{max} = a\omega \Rightarrow \omega = \frac{v_{max}}{a} = \frac{10}{4}$

Now, $v = \omega\sqrt{a^2 - y^2} \Rightarrow v^2 = \omega^2(a^2 - y^2) \Rightarrow y^2 = a^2 - \frac{v^2}{\omega^2}$

$\Rightarrow y = \sqrt{a^2 - \frac{v^2}{\omega^2}} = \sqrt{4^2 - \frac{5^2}{(10/4)^2}} = 2\sqrt{3}\,cm$

16. (b) The particles will meet at the mean position when P completes one oscillation and Q completes half an oscillation

So $\frac{v_P}{v_Q} = \frac{a\omega_P}{a\omega_Q} = \frac{T_Q}{T_P} = \frac{6}{3} = \frac{2}{1}$

17. (b) $\frac{v_{max}}{A_{max}} = \frac{a\omega}{a\omega^2} = \frac{1}{\omega}$

18. (a) Velocity is same. So by using $v = a\omega$

$\Rightarrow A_1\omega_1 = A_2\omega_2 = A_3\omega_3$

19. (d) In S.H.M. at mean position velocity is maximum

So $v = a\omega$ (maximum)

20. (b)

21. (b)

22. (c) Acceleration $A = \omega^2 y \Rightarrow \omega = \sqrt{\frac{A}{y}} = \sqrt{\frac{0.5}{0.02}} = 5$

Maximum velocity $v_{max} = a\omega = 0.1 \times 5 = 0.5$

23. (d) At mean position velocity is maximum

i.e., $v_{max} = \omega a \Rightarrow \omega = \frac{v_{max}}{a} = \frac{16}{4} = 4$

$\therefore v = \omega\sqrt{a^2 - y^2} \Rightarrow 8\sqrt{3} = 4\sqrt{4^2 - y^2}$

$\Rightarrow 192 = 16(16 - y^2) \Rightarrow 12 = 16 - y^2 \Rightarrow y = 2\,cm.$.

24. (a) $v_{max} = a\omega = 3 \times 100 = 300$

25. (a) $x = 3\sin 2t + 4\cos 2t$. From given equation

$a_1 = 3, a_2 = 4$, and $\phi = \frac{\pi}{2}$

$\therefore a = \sqrt{a_1^2 + a_2^2} = \sqrt{3^2 + 4^2} = 5 \Rightarrow v_{max} = a\omega = 5 \times 2 = 10$

26. (c) Velocity in mean position $v = a\omega$, velocity at a distance of half amplitude.

$v' = \omega\sqrt{a^2 - y^2} = \omega\sqrt{a^2 - \frac{a^2}{4}} = \sqrt{\frac{3}{2}}\,a\omega = \sqrt{\frac{3}{2}}\,v$

27. (a) $x = A\cos\left(\omega t + \frac{\pi}{4}\right)$ and $v = \frac{dx}{dt} = -A\omega\sin\left(\omega t + \frac{\pi}{4}\right)$

For maximum speed,

$\sin\left(\omega t + \frac{\pi}{4}\right) = 1 \Rightarrow \omega t + \frac{\pi}{4} = \frac{\pi}{2}$ or $\omega t = \frac{\pi}{2} - \frac{\pi}{4} \Rightarrow t = \frac{\pi}{4\omega}$

Acceleration of Simple Harmonic Motion

1. (d) $F = -kx$

2. (c) The stone execute S.H.M. about centre of earth with time period $T = 2\pi\sqrt{\frac{R}{g}}$; where R = Radius of earth.

3. (c) Acceleration $= \omega^2 a$ at extreme position is maximum.

4. (d) $-a\omega^2$ when it is at one extreme point.

5. (a) Maximum acceleration $= a\omega^2 = a \times 4\pi^2 n^2$

$= 0.01 \times 4 \times (\pi)^2 \times (60)^2 = 144\pi^2 m/\sec$

6. (a) Maximum acceleration

$A_{max} = a\omega^2 = \frac{a \times 4\pi^2}{T^2} = \frac{1 \times 4 \times (3.14)^2}{0.2 \times 0.2}$

$F_{max} = m \times A_{max} = \frac{0.1 \times 4 \times (3.14)^2}{0.2 \times 0.2} = 98.596\ N$

7. (a) Maximum velocity $= a\omega = 16$

Maximum acceleration $= \omega^2 a = 24$

$\Rightarrow a = \frac{(a\omega)^2}{\omega^2 a} = \frac{16 \times 16}{24} = \frac{32}{3} m$

8. (d) Acceleration $\propto$ – displacement, and direction of acceleration is always directed towards the equilibrium position.

9. (d) Maximum force $= m(a\omega^2) = ma\left(\frac{4\pi^2}{T^2}\right)$

$= 0.5\left(\frac{4\pi^2}{\pi^2/25}\right) \times 0.01 = 0.5N$

10. (d) $a_{max} = \omega^2 a = \left(\frac{\pi}{4}\right)^2 a = 0.62\ cm/sec^2$ $[\because a = 1]$

11. (a) For S.H.M. $F = -kx$.

$\therefore$ Force = Mass × Acceleration $\propto -x$

$\Rightarrow F = -Akx$; where A and k are positive constants.

12. (a) Velocity $v = a\omega = a \times 2\pi n$

$= 0.06 \times 2\pi \times 15 = 5.65\ m/s$

Acceleration $A = \omega^2 a = 4\pi^2 n^2 a = 5.32 \times 10^2 m/s^2$

13. (d) $A_{max} = a\omega^2 \Rightarrow a = \frac{A_{max}}{\omega^2} = \frac{7.5}{(3.5)^2} = 0.61\ m$

14. (a) $a = 10 \times 10^{-2} m$ and $\omega = 10\ rad/sec$

$A_{max} = \omega^2 a = 10 \times 10^{-2} \times 10^2 = 10\ m/\sec^2$

15. (a) $A_{max} = \omega^2 a$

16. (d) $A_{max} = 4\pi^2 n^2 a = 4\pi^2 \times (50)^2 \times 0.02 = 200\pi^2 m/s$

17. (d) $A = -\omega^2 y$ at mean position $y = 0$

So acceleration is minimum (zero).

18. (d) In S.H.M. $v = \sqrt{a^2 - y^2}$ and $a = -\omega^2 y$ when $y = a$

$\Rightarrow v_{min} = 0$ and $a_{max} = -\omega^2 a$

19. (b) Comparing given equation with standard equation,

$y = a\sin(\omega t + \phi)$, we get, $a = 2\,cm$, $\omega = \frac{\pi}{2}$

$\therefore A_{max} = \omega^2 A = \left(\frac{\pi}{2}\right)^2 \times 2 = \frac{\pi^2}{2} cm/s^2$.

20. (c) Velocity $v = \omega\sqrt{A^2 - x^2}$ and acceleration $= \omega^2 x$

Now given, $\omega^2 x = \omega\sqrt{A^2 - x^2} \Rightarrow \omega^2.1 = \omega\sqrt{2^2 - 1^2}$

$\Rightarrow \omega = \sqrt{3}\ \therefore\ T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{3}}$

21. (c) $a = -\omega^2 x \Rightarrow \left|\frac{a}{x}\right| = \omega^2$

Energy of Simple Harmonic Motion

1. (d) $E = \frac{1}{2}m\omega^2 a^2 \Rightarrow E \propto a^2$

2. (a) P.E. $=\frac{1}{2}m\omega^2x^2$

It is clear P.E. will be maximum when x will be maximum *i.e.*, at $x=\pm A$

3. (d) Let x be the point where K.E. = P.E.

Hence $\frac{1}{2}m\omega^2(a^2-x^2)=\frac{1}{2}m\omega^2x^2$

$\Rightarrow 2x^2=a^2 \Rightarrow x=\frac{a}{\sqrt{2}}=\frac{4}{\sqrt{2}}=2\sqrt{2}\ cm$

4. (a) Since maximum value of $\cos^2\omega t$ is 1.

$\therefore K_{\max}=K_o\cos^2\omega t=K_o$

Also $K_{\max}=PE_{\max}=K_o$

5. (a) $F=-kx \Rightarrow dW=Fdx=-kxdx$

So $\int_0^W dW=\int_0^x -kx\,dx \Rightarrow W=U=-\frac{1}{2}kx^2$

6. (c) Suppose at displacement y from mean position potential energy = kinetic energy

$\Rightarrow \frac{1}{2}m(a^2-y^2)\omega^2=\frac{1}{2}m\omega^2y^2$

$\Rightarrow a^2=2y^2 \Rightarrow y=\frac{a}{\sqrt{2}}$

7. (c) Total energy in SHM $E=\frac{1}{2}m\omega^2a^2$; (where a = amplitude)

Potential energy $U=\frac{1}{2}m\omega^2(a^2-y^2)=E-\frac{1}{2}m\omega^2y^2$

When $y=\frac{a}{2}\Rightarrow U=E-\frac{1}{2}m\omega^2\left(\frac{a^2}{4}\right)=E-\frac{E}{4}=\frac{3E}{4}$

8. (b) $\frac{\text{Potential energy }(U)}{\text{Total energy }(E)}=\frac{\frac{1}{2}m\omega^2y^2}{\frac{1}{2}m\omega^2a^2}=\frac{y^2}{a^2}$

So $\frac{2.5}{E}=\frac{\left(\frac{a}{2}\right)^2}{a^2} \Rightarrow E=10J$

9. (d) Kinetic energy $T=\frac{1}{2}m\omega^2(a^2-x^2)$

and potential energy, $V=\frac{1}{2}m\omega^2x^2 \quad \therefore \frac{T}{V}=\frac{a^2-x^2}{x^2}$

10. (c) $\frac{U}{U_{\max}}=\frac{\frac{1}{2}m\omega^2y^2}{\frac{1}{2}m\omega^2a^2}\Rightarrow \frac{1}{4}=\frac{y^2}{a^2}\Rightarrow y=\frac{a}{2}$

11. (c) Kinetic energy $K=\frac{1}{2}m\omega^2(a^2-y^2)$

$=\frac{1}{2}\times 10\times\left(\frac{2\pi}{2}\right)^2[10^2-5^2]=375\,\pi^2 ergs$

12. (b) $\frac{U}{E}=\frac{\frac{1}{2}m\omega^2y^2}{\frac{1}{2}m\omega^2a^2}=\frac{y^2}{a^2}=\frac{\left(\frac{a}{2}\right)^2}{a}=\frac{1}{4}$

13. (a)

14. (a) The time period of potential energy and kinetic energy is half that of SHM.

15. (b) If at any instant displacement is y then it is given that $U=\frac{1}{2}\times E \Rightarrow \frac{1}{2}m\omega^2y^2=\frac{1}{2}\times\left(\frac{1}{2}m\omega^2a^2\right)$

$\Rightarrow y=\frac{a}{\sqrt{2}}=\frac{6}{\sqrt{2}}=4.2\,cm$

16. (b) So $a=6cm,\ \omega=100 rad/\sec$

$K_{\max}=\frac{1}{2}m\omega^2a^2=\frac{1}{2}\times 1\times(100)^2\times(6\times10^{-2})^2=18\ J$

17. (c) In S.H.M., frequency of K.E. and P.E.

= 2 × (Frequency of oscillating particle)

18. (b) Total energy $U=\frac{1}{2}Ka^2$

19. (d) $\frac{U}{E}=\frac{\frac{1}{2}m\omega^2y^2}{\frac{1}{2}m\omega^2a^2}=\frac{y^2}{a^2}\Rightarrow\frac{U}{80}=\frac{\left(\frac{3}{4}a\right)^2}{a^2}=\frac{9}{16}\Rightarrow U=45\ J$

20. (c)

21. (c) Maximum potential energy position is $y=\pm a$

and maximum kinetic energy position is $y=0$

22. (c) $Mg=Kl \Rightarrow U_{\max}=\frac{1}{2}Kl^2=\frac{1}{2}mgl$

23. (b) $\frac{U}{E}=\frac{\frac{1}{2}m\omega^2y^2}{\frac{1}{2}m\omega^2a^2}=\frac{y^2}{a^2}=\frac{\left(\frac{a}{2}\right)^2}{a^2}=\frac{1}{4}\Rightarrow U=\frac{E}{4}$

24. (b) In S.H.M., at mean position *i.e.* at $x=0$ kinetic energy will be maximum and pE will be minimum. Total energy is always constant.

25. (a) In SHM for a complete cycle average value of kinetic energy and potential energy are equal *i.e.* $\langle E\rangle=\langle U\rangle$ $=\frac{1}{4}m\omega^2a^2$

26. (c) Total energy $=\frac{1}{2}m\omega^2a^2$ = constant

27. (c) Kinetic energy at mean position,

$K_{\max}=\frac{1}{2}mv_{\max}^2.\Rightarrow v_{\max}=\sqrt{\frac{2K_{\max}}{m}}$

$=\sqrt{\frac{2\times16}{0.32}}=\sqrt{100}=10\,m/s.$

28. (a) $E=\frac{1}{2}ma^2\omega^2=\frac{1}{2}ma^2\left(\frac{4\pi^2}{T^2}\right)\Rightarrow E\propto\frac{a^2}{T^2}$

29. (b) $\frac{K}{E}=\frac{\frac{1}{2}m\omega^2(a^2-y^2)}{\frac{1}{2}m\omega^2a^2}=\frac{a^2-y^2}{a^2}=1-\frac{y^2}{a^2}$

So, $\frac{\left(\frac{3E}{4}\right)}{E} = 1 - \frac{y^2}{a^2} \Rightarrow \frac{y^2}{a^2} = 1 - \frac{3}{4} = \frac{1}{4} \Rightarrow y = \frac{a}{2}$.

30. (c) Kinetic energy $K = \frac{1}{2}mv^2 = \frac{1}{2}ma^2\omega^2\cos^2\omega t$

$= \frac{1}{2}m\omega^2 a^2(1+\cos 2\omega t)$ hence kinetic energy varies periodically with double the frequency of S.H.M. *i.e.* 2ω.

31. (c) $E = \frac{1}{2}m\omega^2 a^2 \Rightarrow \frac{E'}{E} = \frac{a'^2}{a^2} \Rightarrow \frac{E'}{E} = \frac{\left(\frac{3}{4}a\right)^2}{a^2}$ $\left(\because a' = \frac{3}{4}a\right)$

$\Rightarrow E' = \frac{9}{16}E$

32. (d) In simple harmonic motion, energy changes from kinetic to potential and potential to kinetic but the sum of two always remains constant.

33. (b) Body collides elastically with walls of room. So, there will be no loss in its energy and it will remain colliding with walls of room, so it's motion will be periodic.

There is no change in energy of the body, hence there is no acceleration, so it's motion is not SHM.

34. (b) $E_1 = \frac{1}{2}Kx^2 \Rightarrow x = \sqrt{\frac{2E_1}{K}}$, $E_2 = \frac{1}{2}Ky^2 \Rightarrow y = \sqrt{\frac{2E_2}{K}}$

and $E = \frac{1}{2}K(x+y)^2 \Rightarrow x + y = \sqrt{\frac{2E}{K}}$

$\Rightarrow \sqrt{\frac{2E_1}{K}} + \sqrt{\frac{2E_2}{K}} = \sqrt{\frac{2E}{K}} \Rightarrow \sqrt{E_1} + \sqrt{E_2} = \sqrt{E}$

Time Period and Frequency

1. (b) In the given case, $\frac{\text{Displacement}}{\text{Acceleration}} = \frac{1}{b}$

$\therefore$ Time period $T = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}} = \frac{2\pi}{\sqrt{b}}$

2. (c) On comparing with standard equation $\frac{d^2y}{dt^2} + \omega^2 y = 0$ we get $\omega^2 = K \Rightarrow \omega = \frac{2\pi}{T} = \sqrt{K} \Rightarrow T = \frac{2\pi}{\sqrt{K}}$.

3. (b) Ball execute S.H.M. inside the tunnel with time period $T = 2\pi\sqrt{\frac{R}{g}} = 84.63$ min

Hence time to reach the ball from one end to the other end of the tunnel $t = \frac{84.63}{2} = 42.3$ min.

4. (d) Given max velocity $\omega a = 1$ and maximum acceleration $\omega^2 a = 1.57$

$\therefore \frac{\omega^2 a}{\omega a} = 1.57 \Rightarrow \omega = 1.57 \Rightarrow \frac{2\pi}{T} = 1.57 \Rightarrow T = 4$

5. (b) $\omega = \frac{2\pi}{T} = 100\pi \Rightarrow T = 0.02$ sec

6. (a) At mean position, the kinetic energy is maximum.

Hence $\frac{1}{2}ma^2\omega^2 = 16$

On putting the values we get $\omega = 10 \Rightarrow T = \frac{2\pi}{\omega} = \frac{\pi}{5}$ sec

7. (d) $T = 2\pi\sqrt{\frac{\text{Displacement}}{\text{Acceleration}}} = 2\pi\sqrt{\frac{3}{12}} = \pi = 3.14$ sec

8. (d) $\omega = \sqrt{\frac{k}{m}} \Rightarrow \frac{\omega_2}{\omega_1} = \sqrt{\frac{m_1}{m_2}} \Rightarrow 2 = \sqrt{\frac{m_1}{m_2}} \Rightarrow m_2 = \frac{m_1}{4}$

9. (d)

10. (a) $\omega = \sqrt{\frac{\text{Acceleration}}{\text{Displacement}}} = \sqrt{\frac{2.0}{0.02}} = 10\, rad\, s^{-1}$

11. (b) From given equation $\omega = 3000$, $\Rightarrow n = \frac{\omega}{2\pi} = \frac{3000}{2\pi}$

12. (b)

13. (b) Given, $v = \pi\, cm/\sec$, $x = 1\, cm$ and $\omega = \pi s^{-1}$

using $v = \omega\sqrt{a^2 - x^2} \Rightarrow \pi = \pi\sqrt{a^2 - 1}$

$\Rightarrow 1 = a^2 - 1 \Rightarrow a = \sqrt{2}\, cm$.

14. (b) Length of the line = Distance between extreme positions of oscillation = 4 cm

So, Amplitude $a = 2\, cm$.

also $v_{\max} = 12\, cm/s$.

$\because v_{\max} = \omega a = \frac{2\pi}{T}a$

$\Rightarrow T = \frac{2\pi a}{v_{\max}} = \frac{2 \times 3.14 \times 2}{12} = 1.047$ sec

15. (a) Comparing given equation with standard equation,

$x = a\cos(\omega t + \phi)$ we get, $a = 0.01$ and $\omega = \pi$

$\Rightarrow 2\pi n = \pi \Rightarrow n = 0.5\, Hz$

16. (d) $y = 5\sin(\pi t + 4\pi)$, comparing it with standard equation

$y = a\sin(\omega t + \phi) = a\sin\left(\frac{2\pi t}{T} + \phi\right)$

$a = 5\, m$ and $\frac{2\pi t}{T} = \pi t \Rightarrow T = 2$ *sec.*

17. (d) $v_{\max} = a\omega = a \times 2\pi n \Rightarrow n = \frac{v_{\max}}{2\pi a} = \frac{31.4}{2 \times 3.14 \times 5} = 1\, Hz$

18. (d) From the given equitation $\omega = 2\pi n = 4\pi \Rightarrow n = 2Hz$

Simple Pendulum

1. (c) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \sqrt{l}$

2. (a) Inside the mine g decreases

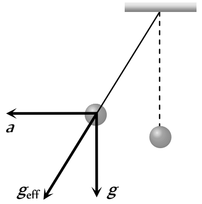
hence from $T = 2\pi\sqrt{\frac{l}{g}}$; T increase

3. (b) When a little mercury is drained off, the position of *c.g.* of ball falls (*w.r.t.* fixed and) so that effective length of pendulum increases hence *T* increase.

4. (b) Initially time period was $T = 2\pi\sqrt{\frac{l}{g}}$.

When train accelerates, the effective value of *g* becomes $\sqrt{(g^2 + a^2)}$ which is greater than *g*

Hence, new time period, becomes less than the initial time period.



5. (b) As we know $g = \frac{GM}{R^2}$

$$\Rightarrow \frac{g_{\text{earth}}}{g_{\text{planet}}} = \frac{M_e}{M_p} \times \frac{R_\rho^2}{R_e^2} \Rightarrow \frac{g_e}{g_p} = \frac{2}{1}$$

Also $T \propto \frac{1}{\sqrt{g}} \Rightarrow \frac{T_e}{T_p} = \sqrt{\frac{g_p}{g_e}} \Rightarrow \frac{2}{T_p} = \sqrt{\frac{1}{2}}$

$$\Rightarrow T_p = 2\sqrt{2}\ \text{sec}.$$

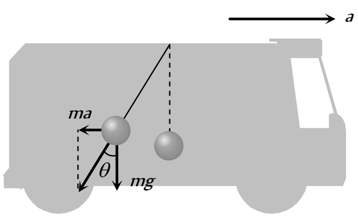
6. (b) In accelerated frame of reference, a fictitious force (pseudo force) *ma* acts on the bob of pendulum as shown in figure.

Hence,

$\tan\theta = \frac{ma}{mg} = \frac{a}{g}$

$\Rightarrow$

$\theta = \tan^{-1}\left(\frac{a}{g}\right)$ in the backward direction.



7. (c)

8. (c) $T = 2\pi\sqrt{\frac{l}{g}}$ (Independent of mass)

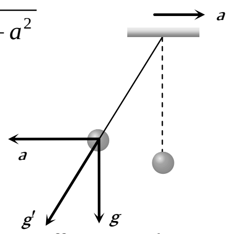
9. (c) In stationary lift $T = 2\pi\sqrt{\frac{l}{g}}$

In upward moving lift $T' = 2\pi\sqrt{\frac{l}{(g+a)}}$

(a = Acceleration of lift)

$$\Rightarrow \frac{T'}{T} = \sqrt{\frac{g}{g+a}} = \sqrt{\frac{g}{\left(g + \frac{g}{4}\right)}} = \sqrt{\frac{4}{5}} \Rightarrow T' = \frac{2T}{\sqrt{5}}$$

10. (d) $g' = \sqrt{g^2 + a^2}$



11. (d) In the given case effective acceleration $g_{eff} = 0 \Rightarrow T = \infty$

12. (b) $p_{\max} = \sqrt{2m\,E_{\max}}$

13. (a) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \sqrt{\frac{l}{g}}$ = constant

$$\Rightarrow l \propto g; \Rightarrow \frac{l_m}{1} = \frac{1}{6}\frac{g}{g} \Rightarrow l_m = \frac{1}{6}m$$

14. (d) $T \propto \sqrt{l} \Rightarrow \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} = \frac{0.02}{2} = 0.01 \Rightarrow \Delta T = 0.01T$

Loss of time per day $= 0.01 \times 24 \times 60 \times 60 = 864\ \text{sec}$

15. (d) $\frac{T'}{T} = \sqrt{\frac{g}{g'+a}} = \sqrt{\frac{g}{g+5g}} = \sqrt{\frac{1}{6}} \Rightarrow T' = \frac{T}{\sqrt{6}}$

16. (b) $T \propto \sqrt{l} \Rightarrow \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} = \frac{1}{2} \times 1\% = 0.5\%$

17. (b) At *B*, the velocity is maximum using conservation of mechanical energy

$$\Delta PE = \Delta KE \Rightarrow mgH = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2gH}$$

18. (c)

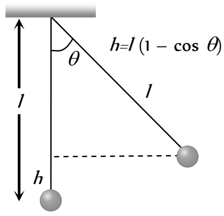
19. (c) If suppose bob rises up to a height *h* as shown then after releasing potential energy at extreme position becomes kinetic energy of mean position

$$\Rightarrow mgh = \frac{1}{2}mv_{\max}^2 \Rightarrow v_{\max} = \sqrt{2gh}$$

Also, from figure $\cos\theta = \frac{l-h}{l}$

$\Rightarrow h = l(1 - \cos\theta)$

So, $v_{\max} = \sqrt{2gl(1-\cos\theta)}$

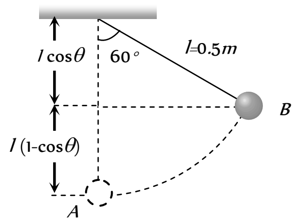


20. (c) $T = 2\pi\sqrt{\frac{l}{g}}$; for freely falling system effective $g = 0$

so $T = \infty$ or $n = 0$

It means that pendulum does not oscillate at all.

21. (d) Let bob velocity be *v* at point *B* where it makes an angle of 60° with the vertical, then using conservation of mechanical energy



$$KE_A + PE_A = KE_B + PE_B$$

$$\Rightarrow \frac{1}{2}m \times 3^2 = \frac{1}{2}mv^2 + mgl(1-\cos\theta)$$

$$\Rightarrow 9 = v^2 + 2 \times 10 \times 0.5 \times \frac{1}{2} \Rightarrow v = 2\ m/s$$

22. (d) $T \propto \sqrt{l} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}} \Rightarrow \frac{2}{T_2} = \sqrt{\frac{l}{4l}} \Rightarrow T_2 = 4sec$

23. (c) Remains the same because time period of simple pendulum *T* is independent of mass of the bob

24. (c) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{l}{T^2} = \frac{g}{4\pi^2}$ = constant

25. (d) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \frac{1}{\sqrt{g}} \Rightarrow \frac{T_P}{T_e} = \sqrt{\frac{g_e}{g_P}} = \sqrt{\frac{2}{1}} \Rightarrow T' = \sqrt{2}T$

26. (a) If initial length $l_1 = 100$ then $l_2 = 121$

By using $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}}$

Hence, $\frac{T_1}{T_2} = \sqrt{\frac{100}{121}} \Rightarrow T_2 = 1.1\,T_1$

% increase = $\frac{T_2 - T_1}{T_1} \times 100 = 10\%$

27. (a) $\frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{100}{400}}$ (If $l_1 = 100$ then $l_2 = 400$)

$\Rightarrow T_2 = 2T_1$

Hence % increase $= \frac{T_2 - T_1}{T_1} \times 100 = 100\%$

28. (b) $T = 2\pi\sqrt{l/g} \Rightarrow l = \frac{gT^2}{4\pi^2} = \frac{9.8 \times 4}{4 \times \pi^2} = 99\ cm$

29. (d) This is the case of freely falling lift and in free fall of lift effective g for pendulum will be zero. So $T = 2\pi\sqrt{\frac{l}{0}} = \infty$

30. (d) After standing centre of mass of the oscillating body will shift upward therefore effective length will decrease and by $T \propto \sqrt{l}$, time period will decrease.

31. (c) $T = 2\pi\sqrt{l/g} = 2\pi\sqrt{\frac{1}{\pi^2}} = 2\ sec$

32. (c) Time period is independent of mass of pendulum.

33. (b) $T \propto \sqrt{l}$ Time period depends only on effective length. Density has no effect on time period. If length made 4 times then time period becomes 2 times.

34. (b) Time period is independent of mass of bob of pendulum.

35. (a) At the surface of moon, g decreases hence time period increases $\left(\text{as } T \propto \frac{1}{\sqrt{g}}\right)$

36. (a) When lift falls freely effective acceleration and frequency of oscillations be zero

$g_{eff} = 0 \Rightarrow T' = \infty$, hence a frequency = 0.

37. (d) Effective value of 'g' remains unchanged.

38. (b) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{l_2}{l_1}} = \sqrt{\frac{144}{100}} = \frac{12}{10}$

$\Rightarrow T_2 = 1.2\ T_1$

Hence % increase $= \frac{T_2 - T_1}{T_1} \times 100 = 20\%$

39. (c) If amplitude is large motion will not remain simple harmonic.

40. (d) Minimum velocity is zero at the extreme positions.

41. (a) At the time $t = \frac{T}{4} = \frac{4}{4} = 1\,\text{sec}$ after passing from mean position, the body reaches at it's extreme position. At extreme, position velocity of body becomes zero.

42. (a) No momentum will be transferred because, at extreme position the velocity of bob is zero.

43. (a) In this case frequency of oscillation is given by $n = \frac{1}{2\pi}\sqrt{\frac{\sqrt{g^2 + a^2}}{l}}$ where a is the acceleration of car. If a increases then n also increases.

44. (b) As periodic time is independent of amplitude.

45. (d) Frequency $n \propto \frac{1}{\sqrt{l}} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{l_2}{l_1}} \Rightarrow \frac{l_1}{l_2} = \frac{n_2^2}{n_1^2} = \frac{3^2}{2^2} = \frac{9}{4}$

46. (d) Suppose at $t = 0$, pendulums begins to swing simultaneously. Hence, they will again swing simultaneously if $n_1T_1 = n_2T_2$

$\Rightarrow \frac{n_1}{n_2} = \frac{T_2}{T_1} = \sqrt{\frac{l_2}{l_1}} \Rightarrow \frac{l_1}{l_2} = \left(\frac{n_2}{n_1}\right)^2 = \left(\frac{8}{7}\right)^2 = \frac{64}{49}$

47. (b) $T \propto \frac{1}{\sqrt{g}}$ and g is same in both cases so time period remain same.

48. (a) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \sqrt{l}$, hence if l made 9 times T becomes 3 times.

Also time period of simple pendulum does not depends on the mass of the bob.

49. (a) As we go from equator to pole the value of g increases. Therefore time period of simple pendulum $\left(T \propto \frac{1}{\sqrt{g}}\right)$ decreases. $\left(\because T \propto \frac{1}{\sqrt{g}}\right)$

50. (a) If v is velocity of pendulum at Q and 10% energy is lost while moving from P to Q

Hence, by applying conservation of between P and Q

$\frac{1}{2}mv^2 = 0.9\,(mgh) \Rightarrow v^2 = 2 \times 0.9 \times 10 \times 2 \Rightarrow v = 6\,m/sec$

51. (c) $T \propto \frac{1}{\sqrt{g}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{g_1}{g_2}} = \sqrt{\left(\frac{g}{g/4}\right)} \Rightarrow T_2 = 2T_1 = 2T$

52. (c) For stationary lift $T_1 = 2\pi\sqrt{\frac{l}{g}}$

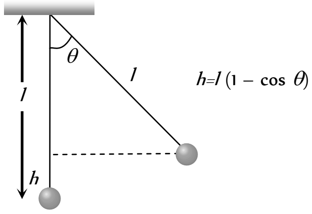
For ascending lift with acceleration a, $T_2 = 2\pi\sqrt{\frac{l}{g + a}}$

$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{g + a}{g}} \Rightarrow \frac{T}{T_2} = \sqrt{\frac{g + \frac{g}{3}}{g}} = \sqrt{\frac{4}{3}} \Rightarrow T_2 = \frac{\sqrt{3}}{2}T$

53. (c) $T \propto \sqrt{l}$

54. (d) Kinetic energy will be maximum at mean position.

From law of conservation of energy maximum kinetic energy at mean position = Potential energy at displaced position



$\Rightarrow K_{\max} = mgh = mgl(1-\cos\theta)$

55. (c)

56. (b) As it is clear that in vacuum, the bob will not experience any frictional force. Hence, there shall be no dissipation therefore, it will oscillate with constant amplitude.

57. (c) The effective acceleration in a lift descending with acceleration $\frac{g}{3}$ is $g_{eff} = g - \frac{g}{3} = \frac{2g}{3}$

$\therefore T = 2\pi\sqrt{\left(\frac{L}{g_{eff}}\right)} = 2\pi\sqrt{\left(\frac{L}{2g/3}\right)} = 2\pi\sqrt{\left(\frac{3L}{2g}\right)}$

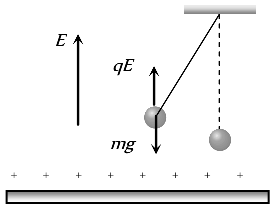
58. (a)

59. (c) According to the principle of conservation of energy, $\frac{1}{2}mv^2 = mgh$ or $v = \sqrt{2gh} = \sqrt{2\times 9.8\times 0.1} = 1.4\, m/s.$

60. (a) In this case time period of pendulum becomes

$T' = 2\pi\sqrt{\frac{l}{\left(g+\frac{qE}{m}\right)}}$

$\Rightarrow T' < T$



61. (b) In deep mine $g' = g\left(1-\frac{d}{R}\right)$; *i.e.*, g decreases so according to $n \propto \sqrt{g}$, frequency also decreases.

Spring Pendulum

1. (d) Maximum velocity $= a\omega = a\sqrt{\frac{k}{m}}$

Given that $a_1\sqrt{\frac{K_1}{m}} = a_2\sqrt{\frac{K_2}{m}} \Rightarrow \frac{a_1}{a_2} = \sqrt{\frac{K_2}{K_1}}$

2. (d) Given spring system has parallel combination, so

$k_{eq} = k_1 + k_2$ and time period $T = 2\pi\sqrt{\frac{m}{(k_1+k_2)}}$

3. (b) $T = 2\pi\sqrt{\frac{m}{k}}$. Also spring constant $(k) \propto \frac{1}{\text{Length}(l)}$, when the spring is half in length, then k becomes twice.

$\therefore T' = 2\pi\sqrt{\frac{m}{2k}} \Rightarrow \frac{T'}{T} = \frac{1}{\sqrt{2}} \Rightarrow T' = \frac{T}{\sqrt{2}}$

4. (b) $\omega = \sqrt{\frac{k}{m}}$

5. (b) With respect to the block the springs are connected in parallel combination.

$\therefore$ Combined stiffness $k = k_1 + k_2$ and $n = \frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m}}$

6. (c) $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \Rightarrow \frac{n_S}{n_P} = \sqrt{\frac{k_S}{k_P}} \Rightarrow \frac{n_s}{n_p} = \sqrt{\frac{\left(\frac{k}{2}\right)}{2k}} = \frac{1}{2}$

7. (c) In series $k_{eq} = \frac{k_1k_2}{k_1+k_2}$ so time period $T = 2\pi\sqrt{\frac{m(k_1+k_2)}{k_1k_2}}$

8. (b) Force constant $k = \frac{F}{x} = \frac{0.5\times 10}{0.2} = 25\ N/m$

Now $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.25}{25}} = 0.628\ sec$

9. (a) $T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow m \propto T^2 \Rightarrow \frac{m_2}{m_1} = \frac{T_2^2}{T_1^2}$

$\Rightarrow \frac{M+m}{M} = \left(\frac{\frac{5}{4}T}{T}\right)^2 \Rightarrow \frac{m}{M} = \frac{9}{16}$

10. (c) Spring constant $(k) \propto \frac{1}{\text{Length of the spirng}(l)}$

as length becomes half, k becomes twice is $2k$.

11. (a) $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \Rightarrow \frac{n}{n'} = \sqrt{\frac{k}{m}\times\frac{m'}{K'}} = \sqrt{\frac{k}{m}\times\frac{2m}{2K}} = 1 \Rightarrow n' = n$

12. (b) As mg produces extension x, hence $k = \frac{mg}{x}$

$\therefore T = 2\pi\sqrt{\frac{(M+m)}{k}} = 2\pi\sqrt{\frac{(M+m)x}{mg}}$

13. (d) For the given figure $f = \frac{1}{2\pi}\sqrt{\frac{k_{eq}}{m}} = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}$ .....(i)

If one spring is removed, then $k_{eq} = k$ and

$f' = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ ....(ii)

From equation (i) and (ii), $\frac{f}{f'} = \sqrt{2} \Rightarrow f' = \frac{f}{\sqrt{2}}$

14. (c) $\because mg = kx \Rightarrow \frac{m}{k} = \frac{x}{g} \Rightarrow T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{x}{g}}$

$= 2\pi\sqrt{\frac{9.8\times 10^{-2}}{9.8}} = \frac{2\pi}{10}\ sec$

15. (a) $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{0.2}{80}} = 0.31\ sec$

16. (d) Spring is cut into two equal halves so spring constant of each part = $2k$

These parts are in parallel so $K_{eq} = 2K + 2K = 4K$

Extension force (*i.e.* *W*) is same hence by using $F = kx \Rightarrow 4k \times x' = kx \Rightarrow x' = \frac{x}{4}$.

17. (a) In this case springs are in parallel, so $k_{eq} = k_1 + k_2$

and $\omega = \sqrt{\frac{k_{eq}}{m}} = \sqrt{\frac{k_1 + k_2}{m}}$

18. (d) Force constant $(k) \propto \frac{1}{\text{Length of the spring}(l)}$

$\Rightarrow \frac{k_1}{k_2} = \frac{l_2}{l_1} = \frac{2}{1}$

19. (b) Standard equation for given condition

$x = a\cos\frac{2\pi}{T}t \Rightarrow x = -0.16\cos(\pi t)$

[As $a = -0.16$ *meter*, $T = 2$ *sec*]

20. (c) By using conservation of mechanical energy

$\frac{1}{2}kx^2 = \frac{1}{2}mv^2 \Rightarrow x = v\sqrt{m/k}$

21. (c) Given elastic energies are equal *i.e.*, $\frac{1}{2}k_1x_1^2 = \frac{1}{2}k_2x_2^2$

$\Rightarrow \frac{k_1}{k_2} = \left(\frac{x_2}{x_1}\right)^2$ and using $F = kx$

$\Rightarrow \frac{F_1}{F_2} = \frac{k_1x_1}{k_2x_2} = \frac{k_1}{k_2} \times \sqrt{\frac{k_2}{k_1}} = \sqrt{\frac{k_1}{k_2}}$

22. (c) $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \Rightarrow n \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{m_2}{m_1}}$

$\Rightarrow \frac{n}{n_2} = \sqrt{\frac{4m}{m}} \Rightarrow n_2 = \frac{n}{2}$

23. (d) $T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{4m}{m}} = 2 \Rightarrow T_2 = 2 \times 2 = 4s$

24. (a) $T \propto \frac{1}{\sqrt{k}} \Rightarrow T_1 : T_2 : T_3 = \frac{1}{\sqrt{k}} : \frac{1}{\sqrt{k/2}} : \frac{1}{\sqrt{2k}} = 1 : \sqrt{2} : \frac{1}{\sqrt{2}}$

25. (d) $T \propto \frac{1}{\sqrt{k}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{k_1}{k_2}} = \sqrt{\frac{k}{4k}} = \frac{1}{2} \Rightarrow T_2 = \frac{T_1}{2}$

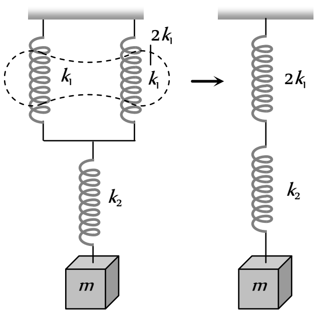
26. (d) The time period of oscillation of a spring does not depend on gravity.

27. (b) In series combination

$\frac{1}{k_S} = \frac{1}{2k_1} + \frac{1}{k_2}$

$\Rightarrow$

$k_S = \left[\frac{1}{2k_1} + \frac{1}{k_2}\right]^{-1}$



28. (a) Work done in stretching $(W) \propto$ Stiffness of spring (*i.e.* *k*)

$\because k_A > k_B \Rightarrow W_A > W_B$

29. (a) When external force is applied, one spring gets extended and another one gets contracted by the same distance hence force due to two springs act in same direction.

i.e. $F = F_1 + F_2 \Rightarrow -kx = -k_1x - k_2x \Rightarrow k = k_1 + k_2$

30. (a) $T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_1}} \Rightarrow \frac{3}{2} = \sqrt{\frac{m+2}{m}} \Rightarrow \frac{9}{4} = \frac{m+2}{m}$

$\Rightarrow m = \frac{8}{5}kg = 1.6\ kg$

31. (b) For series combination $k_{eq} = \frac{k_1k_2}{k_1 + k_2}$

$F = k_{eq}x \Rightarrow mg = \left(\frac{k_1k_2}{k_1 + k_2}\right)x \Rightarrow x = \frac{mg(k_1 + k_2)}{k_1k_2}$

32. (d) $n = \frac{1}{2\pi}\sqrt{\frac{k_{eq}}{m}} = \frac{1}{2\pi}\sqrt{\frac{k_1k_2}{(k_1 + k_2)m}}$

33. (b) Using $F = kx \Rightarrow 10g = k \times 0.25 \Rightarrow k = \frac{10g}{0.25} = 98 \times 4$

Now $T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow m = \frac{T^2}{4\pi^2}k$

$\Rightarrow m = \frac{\pi^2}{100} \times \frac{1}{4\pi^2} \times 98 \times 4 = 0.98\ kg$

34. (b) When spring is cut into *n* equal parts then spring constant of each part will be *nk* and so using $T \propto \frac{1}{\sqrt{k}}$, time period will be $T/\sqrt{n}$.

35. (b) By using $K \propto \frac{1}{l}$

Since one fourth length is cut away so remaining length is $\frac{3}{4}th$, hence *k* becomes $\frac{4}{3}$ times *i.e.*, $k' = \frac{4}{3}x$.

36. (d) $t_1 = 2\pi\sqrt{\frac{m}{K_1}}$ and $t_2 = 2\pi\sqrt{\frac{m}{K_2}}$

Equivalent spring constant for shown combination is $K_1 + K_2$. So time period *t* is given by $t = 2\pi\sqrt{\frac{m}{K_1 + K_2}}$

By solving these equations we get $t^{-2} = t_1^{-2} + t_2^{-2}$

37. (c) $n = \frac{1}{2\pi}\sqrt{\frac{K_{effective}}{m}} = \frac{1}{2\pi}\sqrt{\frac{(K + 2K)}{m}} = \frac{1}{2\pi}\sqrt{\frac{3K}{m}}$

38. (d) In series combination

$\frac{1}{k_S} = \frac{1}{k_1} + \frac{1}{k_2} = \frac{k_2 + k_1}{k_1k_2} \Rightarrow k_S = \frac{k_1k_2}{k_1 + k_2}$.

39. (b) $t_1 = 2\pi\sqrt{\frac{m}{k_1}}$ and $t_2 = 2\pi\sqrt{\frac{m}{k_2}}$

In series, effective spring constant, $k = \dfrac{k_1k_2}{k_1 + k_2}$

$\therefore$ Time period, $T = 2\pi\sqrt{\dfrac{m(k_1+k_2)}{k_1k_2}}$ .....(ii)

Now, $t_1^2 + t_2^2 = 4\pi^2 m\left(\dfrac{1}{k_1} + \dfrac{1}{k_2}\right) = \dfrac{4\pi^2 m(k_1+k_2)}{k_1k_2}$

$t_1^2 + t_2^2 = T^2$. [Using equation (ii)]

40. (c) $\dfrac{1}{k_{eff}} = \dfrac{1}{k} + \dfrac{1}{2k} + \dfrac{1}{4k} + \dfrac{1}{8k} + ...$

$= \dfrac{1}{k}\left[1 + \dfrac{1}{2} + \dfrac{1}{4} + \dfrac{1}{8} + ...\right] = \dfrac{1}{k}\left(\dfrac{1}{1-1/2}\right) = \dfrac{2}{k}$

(By using sum of infinite geometrical progression $a + \dfrac{a}{r} + \dfrac{a}{r^2} + ...\infty$ sum $(S) = \dfrac{a}{1-r}$)

$\therefore k_{eff} = \dfrac{k}{2}$.

41. (a) $n \propto \sqrt{\dfrac{k}{m}}$

42. (b) $F = kx \Rightarrow mg = kx \Rightarrow m \propto kx$

Hence $\dfrac{m_1}{m_2} = \dfrac{k_1}{k_2} \times \dfrac{x_1}{x_2} \Rightarrow \dfrac{4}{6} = \dfrac{k}{k/2} \times \dfrac{1}{x_2}$

$\Rightarrow x_2 = 3\,cm$.

43. (b) Initially when 1 *kg* mass is suspended then by using $F = kx$

$\Rightarrow mg = kx \Rightarrow k = \dfrac{mg}{x} = \dfrac{1\times 10}{5\times 10^{-2}} = 200\,\dfrac{N}{m}$

Further, the angular frequency of oscillation of 2 *kg* mass is

$\omega = \sqrt{\dfrac{k}{M}} = \sqrt{\dfrac{200}{2}} = 10\,rad/sec$

Hence, $v_{max} = a\omega = (10\times 10^{-2})\times 10 = 1\,m/s$

44. (a) $U = \dfrac{F^2}{2K} \Rightarrow U \propto \dfrac{1}{K} \Rightarrow \dfrac{U_1}{U_2} = \dfrac{K_2}{K_1} = 2$

45. (b) $U = \dfrac{1}{2}Kx^2$ but $T = Kx$

So energy stored $= \dfrac{1}{2}\dfrac{(Kx)^2}{K} = \dfrac{1}{2}\dfrac{T^2}{K}$

46. (a) System is equivalent to parallel combination of springs $\therefore K_{eq} = K_1 + K_2 = 400$ and

$T = 2\pi\sqrt{\dfrac{m}{K_{eq}}} = 2\pi\sqrt{\dfrac{0.25}{400}} = \dfrac{\pi}{20}$

47. (b) By cutting spring in four equal parts force constant (*K*) of each parts becomes four times $\left(\because k \propto \dfrac{1}{l}\right)$ so by using

$T = 2\pi\sqrt{\dfrac{m}{K}}$; time period will be half *i.e.* $T' = T/2$

48. (d) $T \propto \sqrt{m} \Rightarrow \dfrac{T_2}{T_1} = \sqrt{\dfrac{m_2}{m_1}} \Rightarrow \dfrac{5}{3} = \sqrt{\dfrac{M+m}{M}}$

$\Rightarrow \dfrac{25}{9} = \dfrac{M+m}{M} \Rightarrow \dfrac{m}{M} = \dfrac{16}{9}$

49. (c) $v_{max} = a\omega = a\dfrac{2\pi}{T}$

$\Rightarrow a = \dfrac{v_{max}T}{2\pi} = \dfrac{15\times 628\times 10^{-3}}{2\times 3.14} = 1.5\,cm$

50. (c) $Kx = mg \Rightarrow \dfrac{m}{K} = \dfrac{x}{g}$

So $T = 2\pi\sqrt{\dfrac{m}{K}} = 2\pi\sqrt{\dfrac{x}{g}} = 2\pi\sqrt{\dfrac{0.2}{9.8}} = \dfrac{2\pi}{7}\sec$

51. (b) $\omega = \sqrt{k/m} = \sqrt{\dfrac{4.84}{0.98}} = 2.22\,rad/\sec$

52. (d) When spring is cut into two equal parts then spring constant of each part will be $2K$ and so using $n \propto \sqrt{K}$, new frequency will be $\sqrt{2}$ times *i.e.* $f_2 = \sqrt{2}\,f_1$.

53. (d)

54. (a) With mass m_2 alone, the extension of the spring l is given as

$m_2 g = kl$ ...(i)

With mass $(m_1 + m_2)$, the extension l' is given by

$(m_1 + m_2)g = k(l + \Delta l)$ ....(ii)

The increase in extension is Δl which is the amplitude of vibration. Subtracting (i) from (ii), we get

$m_1 g = k\Delta l$ or $\Delta l = \dfrac{m_1 g}{k}$

55. (b) Angular velocity $\omega = \sqrt{\left(\dfrac{k}{m}\right)} = \sqrt{\left(\dfrac{10}{10}\right)} = 1$

Now $v = \omega\sqrt{a^2 - y^2} \Rightarrow y^2 = a^2 - \dfrac{v^2}{\omega^2} = (0.5)^2 - \dfrac{(0.4)^2}{1^2}$

$\Rightarrow y^2 = 0.9 = y = 0.3\,m$

Superposition of S.H.M.'s and Resonance

1. (c) Resultant amplitude $= \sqrt{3^2 + 4^2} = 5$

2. (c) $y = A\sin PT + B\cos PT$

Let $A = r\cos\theta$, $B = r\sin\theta$

$\Rightarrow y = r\sin(PT + \theta)$ which is the equation of SHM.

3. (c) $y = a(\cos\omega t + \sin\omega t) = a\sqrt{2}\left[\dfrac{1}{\sqrt{2}}\cos\omega t + \dfrac{1}{\sqrt{2}}\sin\omega t\right]$

$= a\sqrt{2}[\sin 45°\cos\omega t + \cos 45°\sin\omega t]$

$= a\sqrt{2}\sin(\omega t + 45°) \Rightarrow$ Amplitude $= a\sqrt{2}$

4. (c) If first equation is $y_1 = a_1\sin\omega t \Rightarrow \sin\omega t = \dfrac{y_1}{a_1}$ ... (i)

then second equation will be $y_2 = a_2\sin\left(\omega t + \dfrac{\pi}{2}\right)$

$= a_2\left[\sin\omega t\cos\frac{\pi}{2} + \cos\omega t\sin\frac{\pi}{2}\right] = a_2\cos\omega t$

$\Rightarrow \cos\omega t = \frac{y_2}{a_2}$ ... (ii)

By squaring and adding equation (i) and (ii)

$$\sin^2\omega t + \cos^2\omega t = \frac{y_1^2}{a_1^2} + \frac{y_2^2}{a_2^2}$$

$\Rightarrow \frac{y_1^2}{a_1^2} + \frac{y_2^2}{a_2^2} = 1$; This is the equation of ellipse.

5. (a) If $y_1 = a_1\sin\omega t$ and $y_2 = a_2\sin(\omega t + \pi)$

$\Rightarrow \frac{y_1}{a_1} + \frac{y_2}{a_2} = 0 \Rightarrow y_2 = -\frac{a_2}{a_1}y_1$

This is the equation of straight line.

6. (c) If $y_1 = a_1\sin\omega t$ and $y_2 = a_2\sin(\omega t + 0) = a_2\sin\omega t$

$\Rightarrow \frac{y_1^2}{a_1^2} + \frac{y_2^2}{a_2^2} - \frac{2y_1y_2}{a_1a_2} = 0 \Rightarrow y_2 = \frac{a_2}{a_1}y_1$

This is the equation of straight line.

7. (d) For given relation

Resultant amplitude $= \sqrt{4^2 + 4^2} = 4\sqrt{2}$

8. (a) $x = 5\sqrt{2}(\sin 2\pi t + \cos 2\pi t)$

$= 5\sqrt{2}\sin 2\pi t + 5\sqrt{2}\cos 2\pi t$

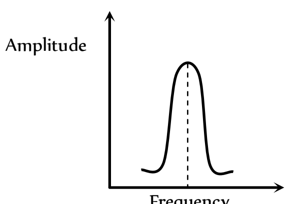
$x = 5\sqrt{2}\sin 2\pi t + 5\sqrt{2}\sin\left(2\pi t + \frac{\pi}{2}\right)$

Phase difference between constituent waves $\phi = \frac{\pi}{2}$

$\therefore$ Resultant amplitude $A = \sqrt{(5\sqrt{2})^2 + (5\sqrt{2})^2}$ =10 *cm*.

9. (b)

10. (d) Less damping force gives a taller and narrower resonance peak



11. (b) $A = \frac{c}{a + b - c}$; when $b = 0$, $a = c$ amplitude

$A \to \infty$. This corresponds to resonance.

12. (c) Energy of particle is maximum at resonant frequency *i.e.,* $\omega_2 = \omega_o$. For amplitude resonance (amplitude maximum) frequency of driver force $\omega = \sqrt{\omega_o^2 - b^2 2m^2} \Rightarrow \omega_1 \neq \omega_o$

13. (a)

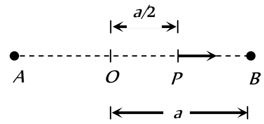
14. (c)

Critical Thinking Questions

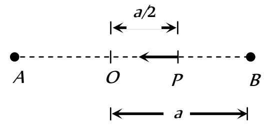
1. (d) $y = a\sin(\omega t + \phi_0)$. According to the question

$y = \frac{a}{2} \Rightarrow \frac{a}{2} = a\sin(\omega t + \phi_0) \Rightarrow (\omega t + \phi_0) = \phi = \frac{\pi}{6}$ or $\frac{5\pi}{6}$

Physical meaning of $\phi = \frac{\pi}{6}$: Particle is at point P and it is going towards B



Physical meaning of $\phi = \frac{5\pi}{6}$: Particle is at point P and it is going towards O



So phase difference $\Delta\phi = \frac{5\pi}{6} - \frac{\pi}{6} = \frac{2\pi}{3} = 120°$

2. (b) $x = 12\sin\omega t - 16\sin^3\omega t = 4[3\sin\omega t - 4\sin^3\omega t]$

$= 4[\sin 3\omega t]$ (By using $\sin 3\theta = 3\sin\theta - 4\sin^3\theta$)

$\therefore$ maximum acceleration $A_{max} = (3\omega)^2 \times 4 = 36\omega^2$

3. (b,c) Harmonic oscillator has some initial elastic potential energy and amplitude of harmonic variation of energy is $\frac{1}{2}Ka^2 = \frac{1}{2}\times 2\times 10^6 \times (0.01)^2 = 100J$

This is the maximum kinetic energy of the oscillator. Thus $K_{max} = 100J$

This energy is added to initial elastic potential energy may give maximum mechanical energy to have value $160J$.

4. (a) $U = k|x|^3 \Rightarrow F == -\frac{dU}{dx} = -3k|x|^2$ ...(i)

Also, for SHM $x = a\sin\omega t$ and $\frac{d^2x}{dt^2} + \omega^2 x = 0$

$\Rightarrow$ acceleration $a = \frac{d^2x}{dt^2} = -\omega^2 x \Rightarrow F = ma$

$= m\frac{d^2x}{dt^2} = -m\omega^2 x$ ...(ii)

From equation (i) & (ii) we get $\omega = \sqrt{\frac{3kx}{m}}$

$\Rightarrow T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{3kx}} = 2\pi\sqrt{\frac{m}{3k(a\sin\omega t)}} \Rightarrow T \propto \frac{1}{\sqrt{a}}$.

5. (b, d) Let the velocity acquired by *A* and *B* be *V*, then

$mv = mV + mV \Rightarrow V = \frac{v}{2}$

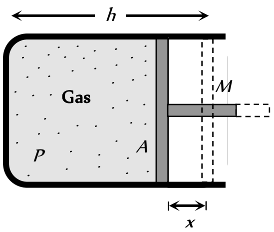
Also $\frac{1}{2}mv^2 = \frac{1}{2}mV^2 + \frac{1}{2}mV^2 + \frac{1}{2}kx^2$

Where x is the maximum compression of the spring. On solving the above equations, we get $x = v\left(\frac{m}{2k}\right)^{1/2}$

At maximum compression, kinetic energy of the

$A - B$ system $= \frac{1}{2}mV^2 + \frac{1}{2}mV^2 = mV^2 = \frac{mv^2}{4}$

6. (a) Let the piston be displaced through distance x towards left, then volume decreases, pressure increases. If ΔP is increase in pressure and ΔV is decrease in volume, then considering the process to take place gradually (i.e. isothermal)



$P_1V_1 = P_2V_2$

$\Rightarrow PV = (P + \Delta P)(V - \Delta V)$

$\Rightarrow PV = PV + \Delta PV - P\Delta V - \Delta P\Delta V$

$\Rightarrow \Delta P.V - P.\Delta V = 0$ (neglecting $\Delta P.\Delta V$)

$\Delta P(Ah) = P(Ax) \Rightarrow \Delta P = \frac{P.x}{h}$

This excess pressure is responsible for providing the restoring force (*F*) to the piston of mass *M*.

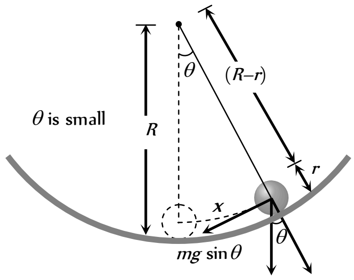
Hence $F = \Delta P.A = \frac{PAx}{h}$

Comparing it with $|F| = kx \Rightarrow k = M\omega^2 = \frac{PA}{h}$

$\Rightarrow \omega = \sqrt{\frac{PA}{Mh}} \Rightarrow T = 2\pi\sqrt{\frac{Mh}{PA}}$

Short trick : by checking the options dimensionally. Option (a) is correct.

7. (b) Tangential acceleration, $a_t = -g\sin\theta = -g\theta$



$a_t = -g\frac{x}{(R-r)}$

Motion is S.H.M., with time period

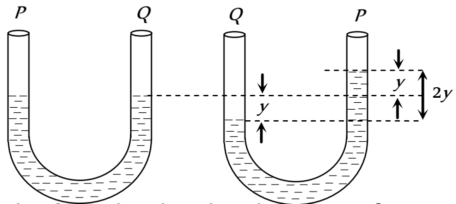
$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}} = 2\pi\sqrt{\frac{x}{\frac{gx}{(R-r)}}} = 2\pi\sqrt{\frac{R-r}{g}}$

8. (a) For resonance amplitude must be maximum which is possible only when the denominator of expression is zero *i.e.*

$a\omega^2 - b\omega + c = 0 \Rightarrow \omega = \frac{+b \pm \sqrt{b^2 - 4ac}}{2a}$

For a single resonant frequency, $b = 4ac$.

9. (d) If the level of liquid is depressed by *y cm* on one side, then the level of liquid in column *P* is *2y cm* higher than *B* as shown.



The weight of extra liquid on the side $P = 2Aydg$.

This becomes the restoring force on mass *M*.

$\therefore$ Restoring acceleration $= \frac{-2Aydg}{M}$

This relation satisfies the condition of SHM i.e. $a \propto -y$.

Hence time period $T = 2\pi\sqrt{\frac{\text{Displacement}}{|\text{Acceleration}|}}$

$= 2\pi\sqrt{\frac{y}{\frac{2Aydg}{M}}} \Rightarrow T = 2\pi\sqrt{\frac{M}{2Adg}}$

10. (b) Time taken by particle to move from *x*=0 (mean position) to *x* = 4 (extreme position) $= \frac{T}{4} = \frac{1.2}{4} = 0.3\ s$

Let *t* be the time taken by the particle to move from *x*=0 to *x*=2 *cm*

$y = a\sin\omega t \Rightarrow 2 = 4\sin\frac{2\pi}{T}t \Rightarrow \frac{1}{2} = \sin\frac{2\pi}{1.2}t$

$\Rightarrow \frac{\pi}{6} = \frac{2\pi}{1.2}t \Rightarrow t = 0.1\ s$. Hence time to move from *x* = 2 to *x* = 4 will be equal to 0.3 – 0.1 = 0.2 s

Hence total time to move from *x* = 2 to *x* = 4 and back again $= 2 \times 0.2 = 0.4\,\text{sec}$

11. (c) For body to remain in contact $a_{\max} = g$

$\therefore \omega^2 A = g \Rightarrow 4\pi^2 n^2 A = g$

$\Rightarrow n^2 = \frac{g}{4\pi^2 A} = \frac{10}{4(3.14)^2 0.01} = 25 \Rightarrow n = 5\ Hz$

12. (c) Under the influence of one force $F_1 = m\omega_1^2 y$ and under the action of another force, $F_2 = m\omega_2^2 y$.

Under the action of both the forces $F = F_1 + F_2$

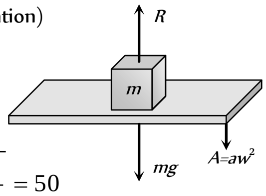
$\Rightarrow m\omega^2 y = m\omega_1^2 y + m\omega^2 y$

$\Rightarrow \omega^2 = \omega_1^2 + \omega_2^2 \Rightarrow \left(\frac{2\pi}{T}\right)^2 = \left(\frac{2\pi}{T_1}\right)^2 + \left(\frac{2\pi}{T_2}\right)^2$

$\Rightarrow T = \sqrt{\frac{T_1^2 T_2^2}{T_1^2 + T_2^2}} = \sqrt{\frac{\left(\frac{4}{5}\right)^2\left(\frac{3}{5}\right)^2}{\left(\frac{4}{5}\right)^2 + \left(\frac{3}{5}\right)^2}} = 0.48 \text{ sec}$

13. (a) By drawing free body diagram of object during the downward motion at extreme position, for equilibrium of mass

$mg - R = mA$ (A = Acceleration)



For critical condition $R = 0$

so $mg = mA \Rightarrow mg = ma\omega^2$

$\Rightarrow \omega = \sqrt{g/a} = \sqrt{\frac{9.8}{3.92 \times 10^{-3}}} = 50$

$\Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi}{50} = 0.1256 sec$

14. (a) Using $x = A\sin\omega t$

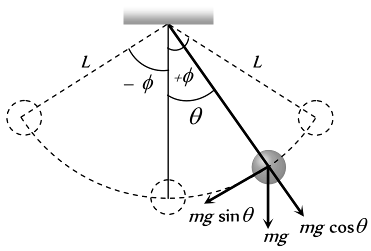
For $x = A/2,\ \sin\omega T_1 = 1/2 \Rightarrow T_1 = \frac{\pi}{6\omega}$

For $x = A, \sin\omega(T_1 + T_2) = 1 \Rightarrow T_1 + T_2 = \frac{\pi}{2\omega}$

$\Rightarrow T_2 = \frac{\pi}{2\omega} - T_1 = \frac{\pi}{2\omega} - \frac{\pi}{6\omega} = \frac{\pi}{3\omega}$ i.e. $T_1 < T_2$

Alternate method : In S.H.M., velocity of particle also oscillates simple harmonically. Speed is more near the mean position and less near the extreme position. Therefore the time taken for the particle to go from 0 to $\frac{A}{2}$ will be less than the time taken to go from $\frac{A}{2}$ to A. Hence $T_1 < T_2$.

15. (b, c) From following figure it is clear that



$T - Mg\cos\theta =$ Centripetal force

$\Rightarrow T - Mg\cos\theta = \frac{Mv^2}{L}$

Also tangential acceleration $|a_T| = g\sin\theta$.

16. (c) If t is the time taken by pendulums to come in same phase again first time after $t = 0$.

and $N_S =$ Number of oscillations made by shorter length pendulum with time period T_S.

$N_L =$ Number of oscillations made by longer length pendulum with time period T_L.

Then $t = N_S T_S = N_L T_L$

$\Rightarrow N_S 2\pi\sqrt{\frac{5}{g}} = N_L \times 2\pi\sqrt{\frac{20}{g}}$ $\left(\because T = 2\pi\sqrt{\frac{l}{g}}\right)$

$\Rightarrow N_S = 2N_L$ i.e. if $N_L = 1 \Rightarrow N_S = 2$

17. (a) Tension in the string when bob passes through lowest point

$T = mg + \frac{mv^2}{r} = mg + mv\omega$ $(\because v = r\omega)$

putting $v = \sqrt{2gh}$ and $\omega = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi$

we get $T = m(g + \pi\sqrt{2gh})$

18. (d) When the bob is immersed in water its effective weight =

$\left(mg - \frac{m}{\rho}g\right) = mg\left(\frac{\rho - 1}{\rho}\right)$ $\therefore g_{eff} = g\left(\frac{\rho-1}{\rho}\right)$

$\frac{T'}{T} = \sqrt{\frac{g}{g_{eff}}} \Rightarrow T' = T\sqrt{\frac{\rho}{(\rho - 1)}}$

19. (a) Time period $T \propto \sqrt{l} \Rightarrow \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} = \frac{1}{2}\alpha\Delta\theta$

Also according to thermal expansion $l' = (1 + \alpha\Delta\theta)$

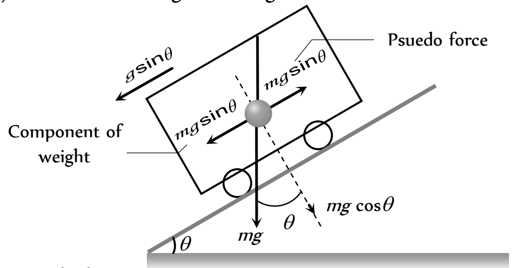
$\frac{\Delta l}{l} = \alpha + \theta$. Hence $\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} = \frac{1}{2}\alpha\Delta\theta$

$= \frac{1}{2} \times 12 \times 10^{-6} \times (40 - 20) = 12 \times 10^{-5}$

$\Rightarrow \Delta T = 12 \times 10^{-5} \times 86400$ *seconds / day*

$\therefore \Delta T \approx 10.3$ *seconds / day*

20. (a) See the following force diagram.



Vehicle is moving down the frictionless inclined surface so, it's acceleration is $g\sin\theta$. Since vehicle is accelerating, a pseudo force $m(g\sin\theta)$ will act on bob of pendulum which cancel the $\sin\theta$ component of weight of the bob.

Hence net force on the bob is $F_{\_} = mg\cos\theta$ or net acceleration of the bob is $g_{eff} = g\cos\theta$

$\therefore$ Time period $T = 2\pi\sqrt{\frac{l}{g_{eff}}} = 2\pi\sqrt{\frac{l}{g\cos\theta}}$

21. (c) $\because t_o = 2\pi\sqrt{\frac{l}{g}}$

Effective weight of bob inside water,

$W' = mg - \text{thrust} = V\rho g - V\rho' g$

$\Rightarrow V\rho g_{eff} = V(\rho - \rho')g$, where, ρ = Density of bob

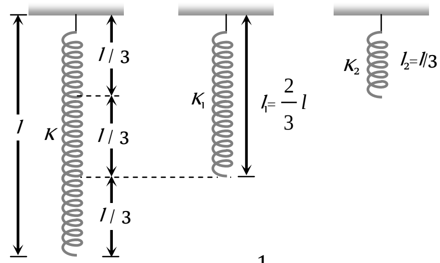
$\Rightarrow g_{eff} = \left(1 - \frac{\rho'}{\rho}\right)g$ and ρ' = Density of water

$$\therefore t = 2\pi\sqrt{\frac{l}{g_{eff}}} = 2\pi\sqrt{\frac{l}{(1-\rho'/\rho)g}}$$

$$\therefore \frac{t}{t_0} = \sqrt{\frac{1}{1-\rho'/\rho}} = \sqrt{\frac{1}{1-\frac{3}{4}}} \quad \left(\because \rho' = 10^3 kg/m^3, \ \rho = \frac{4}{3}\times 10^3 kg/m^3\right)$$

$\Rightarrow t = 2t_0$.

22. (b)



Force constant $(k) \propto \frac{1}{\text{Length of spring}}$

$$\Rightarrow \frac{K}{K_1} = \frac{l_1}{l} = \frac{\frac{2}{3}l}{l} \Rightarrow K_1 = \frac{3}{2}K.$$

23. (b) The wire may be treated as a string for which force constant

$$k_1 = \frac{\text{Force}}{\text{Extension}} = \frac{YA}{L} \quad \left(\because Y = \frac{F}{A}\times\frac{L}{\Delta L}\right)$$

Spring constant of the spring $k_2 = K$

Hence spring constant of the combination (series)

$$k_{eq} = \frac{k_1 k_2}{k_1 + k_2} = \frac{(YA/L)K}{(YA/L)+K} = \frac{YAK}{YA+KL}$$

$\because$ Time period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\left[\frac{(YA+KL)m}{YAK}\right]^{1/2}$

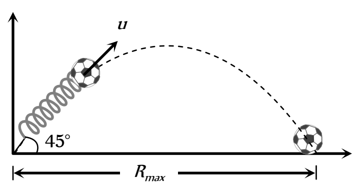
24. (a) Slope is irrelevant hence $T = 2\pi\left(\frac{M}{2K}\right)^{1/2}$

25. (b) For forced oscillation,

$x = x_0 \sin(\omega t + \phi)$ and $F = F_0 \cos\omega t$

where, $x_0 = \frac{F_o}{m(\omega_o^2 - \omega^2)} \propto \frac{1}{m(\omega_o^2 - \omega^2)}$.

26. (b) For getting horizontal range, there must be some inclination of spring with ground to project ball.



$\Rightarrow R_{\max} = \frac{u^2}{g}$ .....(i)

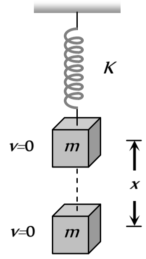
But K.E. acquired by ball = P.E. of spring gun

$\Rightarrow \frac{1}{2}mu^2 = \frac{1}{2}kx^2 \Rightarrow u^2 = \frac{kx^2}{m}$ .....(ii)

From equation (i) and (ii)

$$R_{\max} = \frac{kx^2}{mg} = \frac{600\times(5\times10^{-2})^2}{15\times10^{-3}\times10} = 10\,m.$$

27. (b) Let x be the maximum extension of the spring. From energy conservation



Loss in gravitational potential energy

= Gain in potential energy of spring

$Mgx = \frac{1}{2}Kx^2$

$\Rightarrow x = \frac{2Mg}{K}$

28. (b) $y = 4\cos^2\left(\frac{t}{2}\right)\sin 1000\,t$

$\Rightarrow y = 2(1+\cos t)\sin 1000\,t$

$\Rightarrow y = 2\sin 1000\,t + 2\cos t \sin 1000t$

$\Rightarrow y = 2\sin 1000\,t + \sin 999\,t + \sin 1001\,t$

It is a sum of three S.H.M.

29. (a, c) Let simple harmonic motions be represented by

$y_1 = a\sin\left(\omega t - \frac{\pi}{4}\right)$; $y_2 = a\sin\omega t$ and

$y_3 = a\sin\left(\omega t + \frac{\pi}{4}\right)$. On superimposing, resultant SHM will be $y = a\left[\sin\left(\omega t - \frac{\pi}{4}\right) + \sin\omega t + \sin\left(\omega t + \frac{\pi}{4}\right)\right]$

$= a\left[2\sin\omega t\cos\frac{\pi}{4} + \sin\omega t\right]$

$= a[\sqrt{2}\sin\omega t + \sin\omega t] = a(1+\sqrt{2})\sin\omega t$

Resultant amplitude $= (1+\sqrt{2})a$

Energy is S.H.M. $\propto$ (Amplitude)^2

$$\therefore \frac{E_{\text{Resultant}}}{E_{\text{Single}}} = \left(\frac{A}{a}\right)^2 = (\sqrt{2}+1)^2 = (3+2\sqrt{2})$$

$\Rightarrow E_{\text{Resultant}} = (3+2\sqrt{2})E_{\text{Single}}$

30. (d) $y = \sin^2\omega t = \frac{1-\cos 2\omega t}{2} \Rightarrow$ Period, $T = \frac{2\pi}{2\omega} = \frac{\pi}{\omega}$

The given function is not satisfying the standard differential equation of S.H.M. $\frac{d^2y}{dx^2} = -\omega^2 y$. Hence it represents periodic motion but not S.H.M.

31. (c) $y = Kt^2 \Rightarrow \frac{d^2y}{dt^2} = a_y = 2K = 2\times 1 = 2\,m/s$ ($\because K = 1\,m/s$)

Now, $T_1 = 2\pi\sqrt{\frac{l}{g}}$ and $T_2 = 2\pi\sqrt{\frac{l}{(g+a_y)}}$

Dividing, $\frac{T_1}{T_2} = \sqrt{\frac{g + a_y}{g}} \Rightarrow \sqrt{\frac{6}{5}} \Rightarrow \frac{T_1^2}{T_2^2} = \frac{6}{5}$

32. (b) From the relation of restitution $\frac{h_n}{h_0} = e^{2n}$ and

$$h_n = h_0(1 - \cos 60°) \Rightarrow \frac{h_n}{h_0} = 1 - \cos 60° = \left(\frac{2}{\sqrt{5}}\right)^{2n}$$

$$\Rightarrow 1 - \frac{1}{2} = \left(\frac{4}{5}\right)^n \Rightarrow \frac{1}{2} = \left(\frac{4}{5}\right)^n$$

Taking log of both sides we get

$$\log 1 - \log 2 = n(\log 4 - \log 5)$$

$$0 - 0.3010 = n(0.6020 - 0.6990)$$

$$-0.3010 = -n \times 0.097 \Rightarrow n = \frac{0.3010}{0.097} = 3.1 \approx 3$$

33. (a) As a is the side of cube σ is its density.

Mass of cube is $a^2\sigma$, its weight $= a^3\sigma g$

Let h be the height of cube immersed in liquid of density ρ in equilibrium then, $F = a^2 h \rho g = Mg = a^3 \sigma g$

If it is pushed down by y then the buoyant force $F' = a^2(h + y)\rho g$

Restoring force is $\Delta F = F' - F = a^2(h + y)\sigma g - a^2 h \sigma g$

$$= a^2 y \rho g$$

Restoring acceleration $= \frac{\Delta F}{M} = -\frac{a^2 y \rho g}{M} = -\frac{a^2 \rho g}{a^2 \sigma} y$

Motion is S.H.M.

$$\Rightarrow T = 2\pi\sqrt{\frac{a^3\sigma}{a^2 \rho g}} = 2\pi\sqrt{\frac{a\sigma}{\rho g}}$$

34. (b) As here two masses are connected by two springs, this problem is equivalent to the oscillation of a reduced mass m_r of a spring of effective spring constant.

$$T = 2\pi\sqrt{\frac{m_r}{K_{eff.}}}$$

Here $m_r = \frac{m_1 m_2}{m_1 + m_2} = \frac{m}{2} \Rightarrow K_{eff.} = K_1 + K_2 = 2K$

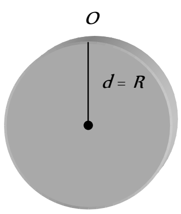
$$\therefore n = \frac{1}{2\pi}\sqrt{\frac{K_{eff.}}{m_r}} = \frac{1}{2\pi}\sqrt{\frac{2K}{m} \times 2} = \frac{1}{\pi}\sqrt{\frac{K}{m}} = \frac{1}{\pi}\sqrt{\frac{0.1}{0.1}} = \frac{1}{\pi} Hz$$

35. (d) Time period of a physical pendulum

$$T = 2\pi\sqrt{\frac{I_0}{mgd}} = 2\pi\sqrt{\frac{\left(\frac{1}{2}mR^2 + mR^2\right)}{mgR}}$$

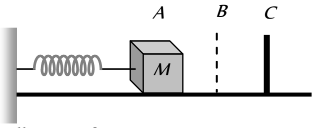
$$= 2\pi\sqrt{\frac{3R}{2g}} \quad .....(i)$$

$$T_{simple\ pendulum} = 2\pi\sqrt{\frac{l}{g}} \quad .....(ii)$$



Equating (i) and (ii), $l = \frac{3}{2}R$.

36. (c) The total time from A to C



$$t_{Ac} = t_{AB} + t_{BC}$$

$$= (T/4) + t_{BC}$$

where T = time period of oscillation of spring mass system

t_{BC} can be obtained from, $BC = AB\sin(2\pi/T)t_{BC}$

Putting $\frac{BC}{AB} = \frac{1}{2}$ we obtain $t_{BC} = \frac{T}{12}$

$$\Rightarrow t_{AC} = \frac{T}{4} + \frac{T}{12} = \frac{2\pi}{3}\sqrt{\frac{m}{k}}.$$

37. (b) When mass 700 gm is removed, the left out mass (500 + 400) gm oscillates with a period of 3 sec

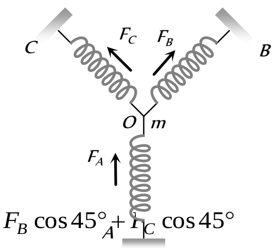
$$\therefore 3 = t = 2\pi\sqrt{\frac{(500 + 400)}{k}} \quad ......(i)$$

When 500 gm mass is also removed, the left out mass is 400 gm.

$$\therefore t' = 2\pi\sqrt{\frac{400}{k}} \quad .....(ii)$$

$$\Rightarrow \frac{3}{t'} = \sqrt{\frac{900}{400}} \Rightarrow t' = 2\,\text{sec}$$

38. (b) When the particle of mass m at O is pushed by y in the direction of A The spring A will be compressed by y while spring B and C will be stretched by $y' = y\cos 45°$. So that the total restoring force on the mass m along OA.



$$F_{net} = F_A + F_B\cos 45° + F_C\cos 45°$$

$$= ky + 2ky'\cos 45° = ky + 2k(y\cos 45°)\cos 45° = 2ky$$

Also $F_{net} = k'y \Rightarrow k'y = 2ky \Rightarrow k' = 2k$

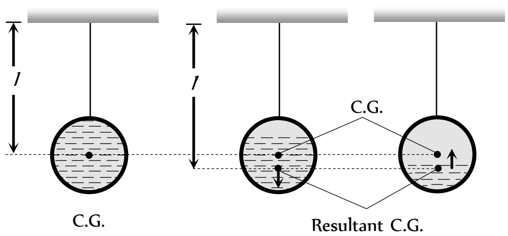
$$T = 2\pi\sqrt{\frac{m}{k'}} = 2\pi\sqrt{\frac{m}{2k}}$$

39. (d) The given system is like a simple pendulum, whose effective length (l) is equal to the distance between point of suspension and C.G. (Centre of Gravity) of the hanging body.

When water slowly flows out the sphere, the C.G. of the system is lowered, and hence l increases, which in turn increases time period (as $T \propto \sqrt{l}$).

After some time weight of water left in sphere become less than the weight of sphere itself, so the resultant C.G. gets clear the C.G. of sphere itself i.e. l decreases and hence T increases.

Finally when the sphere becomes empty, the resulting C.G. is the C.G. of sphere i.e. length becomes equal to the original length and hence the time period becomes equal to the same value as when it was full of water.



40. (b) Let T_1 and T_2 are the time period of the two pendulums

$T_1 = 2\pi\sqrt{\frac{100}{g}}$ and $T_2 = 2\pi\sqrt{\frac{121}{g}}$

$(T_1 < T_2$ because $l_1 < l_2)$.

Let at $t = 0$, they start swinging together. Since their time periods are different, the swinging will not be in unision always. Only when number of completed oscillation differs by an integer, the two pendulum will again begin to swing together.

Let longer length pendulum complete n oscillation and shorter length pendulum complete $(n+1)$ oscillation, for the unision swinging, then $(n+1)T_1 = nT_2$

$$(n+1)\times 2\pi\sqrt{\frac{100}{g}} = n\times 2\pi\sqrt{\frac{121}{g}} \Rightarrow n = 10$$

41. (b) Amplitude of damped oscillator

$A = A_0 e^{-\lambda t}$; $\lambda =$ constant, t = time

For t =1 min. $\frac{A_0}{2} = A_0 e^{-\lambda t} \Rightarrow e^{\lambda} = 2$

For t = 3 min. $A = A_0 e^{-\lambda\times 3} = \frac{A_0}{(e^{\lambda})^3} = \frac{A_0}{2^3}$

$\Rightarrow X = 2^3$

42. (a) The standard differential equation is satisfied by only the function $\sin\omega t - \cos\omega t$. Hence it represents S.H.M.

43. (d) This is the special case of physical pendulum and in this case $T = 2\pi\sqrt{\frac{2l}{3g}}$

$$\Rightarrow\ T = 2\times 3.14\sqrt{\frac{2\times 2}{3\times 9.8}} = 2.31\,\text{sec} \approx 2.4\,\text{sec}$$

Graphical Questions

1. (a) Because acceleration $\propto$ displacement.

2. (d) Using acceleration $A = -\omega^2 x$

$At - x_{\max}$ A will be maximum and positive.

3. (d) Acceleration $= -\omega^2 y$. So $F = -m\omega^2 y$

y is sinusoidal function.

So F will be also sinusoidal function with phase difference π

4. (d) At time $\frac{T}{2}$; $v = 0$ $\therefore$ Total energy = Potential energy.

5. (b) PE varies from zero to maximum. It is always positive sinusoidal function.

6. (d) Potential energy of particle performing SHM is given by: $PE = \frac{1}{2}m\omega^2 y^2$ *i.e.* it varies parabolically such that at mean position it becomes zero and maximum at extreme position.

7. (a) Potential energy is minimum (in this case zero) at mean position $(x = 0)$ and maximum at extreme position $(x = \pm A)$.

At time $t = 0$, $x = A$, hence potential should be maximum. Therefore graph I is correct. Further in graph III. Potential energy is minimum at $x = 0$, hence this is also correct.

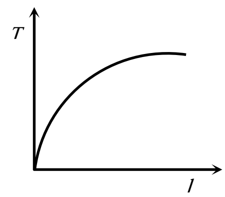
8. (a) $f = \frac{1}{T} = \frac{1}{0.04} = 25\ Hz$

9. (d) From graph, slope $K = \frac{F}{x} = \frac{8}{2} = 4$

$$T = 2\pi\sqrt{\frac{m}{K}} \Rightarrow T = 2\pi\sqrt{\frac{0.01}{4}} = 0.3\,\text{sec}$$

10. (b) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow l \propto T^2$ (Equation of parabola)

11. (b) $T \propto \sqrt{l} \Rightarrow T^2 \propto l$



12. (d) In simple harmonic motion

$y = a\sin\omega t$ and $v = a\omega\cos\omega t$ from this we have

$\frac{y^2}{a^2} + \frac{v^2}{a^2\omega^2} = 1$, which is a equation of ellipse.

13. (c)

14. (a) In S.H.M. when acceleration is negative maximum or positive maximum, the velocity is zero so kinetic energy is also zero. Similarly for zero acceleration, velocity is maximum so kinetic energy is also maximum.

15. (b) Total potential energy = 0.04 J

Resting potential energy =0.01 J

Maximum kinetic energy =(0.04–0.01)

$$= 0.03J = \frac{1}{2}m\,\omega^2 a^2 = \frac{1}{2}ka^2$$

$$0.03 = \frac{1}{2}\times k\times\left(\frac{20}{1000}\right)^2$$

$k = 0.06\times 2500\ N/m = 150\ N/m$.

16. (a) Kinetic energy varies with time but is never negative.

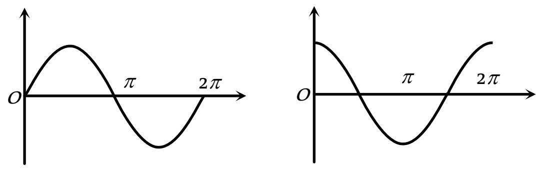
Assertion and Reason

1. (b) Both assertion and reason are correct but reason is not the correct explanation of assertion.

2. (e) In simple harmonic motion, $v = \omega\sqrt{a^2 - y^2}$ as y changes, velocity v will also change. So simple harmonic motion is not uniform motion. But simple harmonic motion may be defined as the projection of uniform circular motion along one of the diameter of the circle.

3. (a) In SHM, the acceleration is always in a direction opposite to that of the displacement *i.e.,* proportional to $(-y)$.

4. (a) A periodic function is one whose value repeats after a definite interval of time. $\sin\theta$ and $\cos\theta$ are periodic functions because they repeat itself after 2π interval of time.



sin curve cos curve

It is also true that moon is smaller than the earth, but this statement is not explaining the assertion.

5. (e) In SHM, $v = \omega\sqrt{a^2 - y^2}$ or $v^2 = \omega^2 a^2 - \omega^2 y^2$.

Dividing both sides by $\omega^2 a^2$, $\frac{v^2}{\omega^2 a^2} + \frac{y^2}{a^2} = 1$. This is the equation of an ellipse. Hence the graph between v and y is an ellipse not a parabola.

6. (b) $T = 2\pi\sqrt{\frac{l}{g}}$. On moon, g is much smaller compared to g on earth. Therefore, T increases.

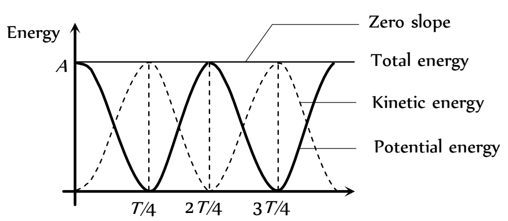
7. (c) Amplitude of oscillation for a forced, damped oscillator is $A = \frac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2) + (b\omega/m)^2}}$, where b is constant related to the strength of the resistive force, $\omega_0 = \sqrt{k/m}$ is natural frequency of undamped oscillator ($b = 0$).

When the frequency of driving force $(\omega) \approx \omega_0$, then amplitude A is very larger.

For $\omega < \omega_0$ or $\omega > \omega_0$, the amplitude decrease.

8. (a) The total energy of S.H.M. = Kinetic energy of particle + potential energy of particle.

The variation of total energy of the particle in SHM with time is shown in a graph.



9. (c) Time period of simple pendulum of length l is,

$$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \sqrt{l} \Rightarrow \sqrt{\frac{\Delta T}{T}} = \frac{1}{2}\frac{\Delta l}{l}$$

$$\therefore \frac{\Delta T}{T} = \frac{1}{2} \times 3 = 1.5\%$$

10. (c) Frequency of second pendulum $n = (1/2)s^{-1}$. When elevator is moving upwards with acceleration *g/2*, the effective acceleration due to gravity is

$$g = g + a = g + g/2 = 3g/2.$$

As $n = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$ so $n^2 \propto g$.

$$\therefore \frac{n_1^2}{n_2^2} = \frac{g_1}{g} = \frac{3g/2}{g} = \frac{3}{2} \text{ or, } \frac{n_1}{n} = \sqrt{\frac{3}{2}} = 1.225$$

or, $n_1 = 1.225n = 1.225 \times (1/2) = 0.612\ s^{-1}$.

11. (b) Energy of damped oscillator at an any instant t is given by

$$E = E_0 e^{-bt/m} \quad [\text{where } E_0 = \frac{1}{2}kx^2 = \text{maximum energy}]$$

Due to damping forces the amplitude of oscillator will go on decreasing with time whose energy is expressed by above equation.

12. (b) In SHM. $K.E. = \frac{1}{2}m\omega^2(a^2 - y^2)$ and $P.E. = \frac{1}{2}m\omega^2 y^2$.

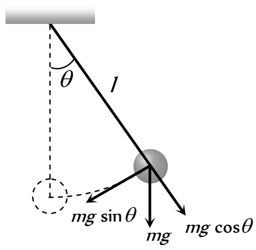
For *K.E.* = *P.E.* $\Rightarrow 2y^2 = a^2 \Rightarrow y = a/\sqrt{2}$. Since total energy remains constant through out the motion, which is $E = K.E. + P.E.$ So, when *P.E.* is maximum then *K.E.* is zero and viceversa.

13. (a) Total energy of the harmonic oscillator,

$$E = \frac{1}{2}m\omega^2 a^2 \quad i.e., \ E \propto a^2.$$

Therefore $\frac{E'}{E} = \left(\frac{2a}{a}\right)^2$ or, $E' = 4E$.

14. (b) In simple pendulum, when bob is in deflection position, the tension in the string is $T = mg\cos\theta + \frac{mv^2}{l}$. Since the value of θ is different at different positions, hence tension in the string is not constant throughout the oscillation. At end points θ is maximum; the value of $\cos\theta$ is least, hence the value of tension in the string is least. At the mean position, the value of $\theta = 0°$ and $\cos 0° = 1$, so the value of tension is largest.



Also velocity is given by $v = \omega\sqrt{a^2 - y^2}$ which is maximum when $y = 0$, at mean position.

15. (e) Spring constant $\propto \frac{1}{\text{Length of spring}}$

$\Rightarrow k' = \frac{k}{n}$

Also, spring constant depends on material properties of the spring.

Hence assertion is false, but reason is true.

16. (a) The time period of a oscillating spring is given by,

$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow T \propto \frac{1}{\sqrt{k}}$. Since the spring constant is large for hard spring, therefore hard spring has a less periodic time as compared to soft spring.

17. (e) In simple harmonic motion the velocity is given by,

$v = \omega\sqrt{a^2 - y^2}$ at extreme position, $y = a$.

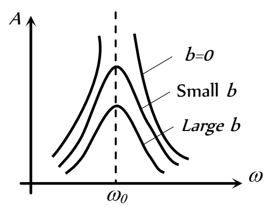
$\therefore v = 0$. But acceleration $A = -\omega^2 a$, which is maximum at extreme position.

18. (a) If the soldiers while crossing a suspended bridge march in steps, the frequency of marching steps of soldiers may match with the natural frequency of oscillations of the suspended bridge. In that situation resonance will take place, then the amplitude of oscillation of the suspended bridge will increase enormously, which may cause the collapsing of the bridge. To avoid situations the soldiers are advised to go out steps on suspended bridge.

19. (a) From equation, amplitude of oscillation

$$A = \frac{F_0 / m}{\sqrt{(\omega^2 - \omega_0^2)^2 + (b\omega / m)^2}}$$

In absence of damping force (b = 0), that the steady state amplitude approaches infinity as $\omega \to \omega_0$. That is, if there is no resistive force in the system and then it is possible to drive an oscillator with sinusoidal force at the resonance frequency, the amplitude of motion will build up without limit. This does not occur in practice because some damping is always present in real oscillation.



20. (b)

21. (c) The amplitude of an oscillating pendulum decreases with time because of friction due to air. Frequency of pendulum is independent $\left(T = \frac{1}{2\pi}\sqrt{\frac{g}{l}}\right)$ of amplitude.

22. (b) $x = a\sin\omega t$ and $v = \frac{dx}{dt} = a\omega\cos\omega t$

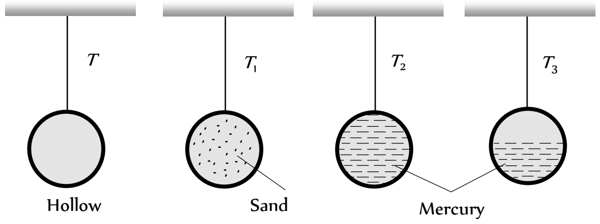
It is clear phase difference between 'x' and 'a' is $\pi / 2$.

23. (e)

Simple Harmonic Motion

SET Self Evaluation Test -16

1. The period of a simple pendulum, whose bob is a hollow metallic sphere, is T. The period is T_1 when the bob is filled with sand, T_2 when it is filled with mercury and T_3 when it is half filled with mercury. Which of the following is true



(a) $T = T_1 = T_2 > T_3$ (b) $T_1 = T_1 = T_3 > T$

(c) $T > T_3 > T_1 = T_2$ (d) $T = T_1 = T_2 < T_3$

2. A pendulum clock that keeps correct time on the earth is taken to the moon it will run (it is given that $g_{Moon} = g_{Earth}/6$)

(a) At correct rate (b) 6 time faster

(c) $\sqrt{6}$ times faster (d) $\sqrt{6}$ times slowly

3. A pendulum has time period T in air. When it is made to oscillate in water, it acquired a time period $T' = \sqrt{2}T$. The density of the pendulum bob is equal to (density of water = 1)

(a) $\sqrt{2}$ (b) 2

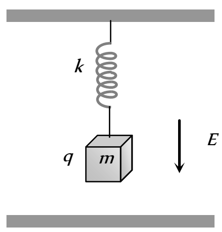
(c) $2\sqrt{2}$ (d) None of these

4. An object of mass 0.2 kg executes simple harmonic along X-axis with frequency of $\frac{25}{\pi} Hz$. At the position $x = 0.04m$, the object has kinetic energy of 0.5 J and potential energy of 0.4 J amplitude of oscillation in meter is equal to

(a) 0.05 (b) 0.06

(c) 0.01 (d) None of these

5. Time period of a block suspended from the upper plate of a parallel plate capacitor by a spring of stiffness k is T. When block is uncharged. If a charge q is given to the block them, the new time period of oscillation will be



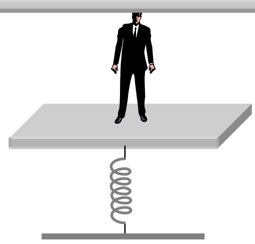
(a) T

(b) $> T$

(c) $< T$

(d) $\geq T$

6. A man weighing 60 kg stands on the horizontal platform of a spring balance. The platform starts executing simple harmonic motion of amplitude 0.1 m and frequency $\frac{2}{\pi} Hz$. Which of the following statement is correct



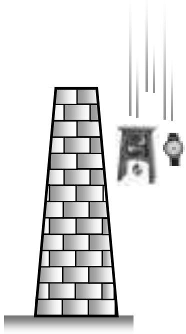
(a) The spring balance reads the weight of man as 60 kg

(b) The spring balance reading fluctuates between 60 kg. and 70 kg

(c) The spring balance reading fluctuates between 50 kg and 60 kg

(d) The spring balance reading fluctuates between 50 kg and 70 kg

7. A man having a wrist watch and a pendulum clock rises on a TV tower. The wrist watch and pendulum clock per chance fall from the top of the tower. Then



(a) Both will keep correct time during the fall.

(b) Both will keep incorrect time during the fall.

(c) Wrist watch will keep correct time and clock will become fast.

(d) Clock will stop but wrist watch will function normally.

8. A force of 6.4 N stretches a vertical spring by 0.1 m. The mass that must be suspended from the spring so that it oscillates with a period of $\left(\frac{\pi}{4}\right)$ sec. is **[Roorkee 1990]**

(a) $\left(\frac{\pi}{4}\right) kg$ (b) $1\, kg$

(c) $\left(\frac{1}{\pi}\right) kg$ (d) $10\, kg$

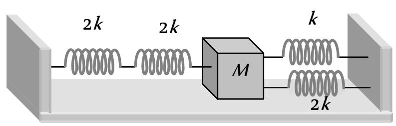
9. A spring with 10 coils has spring constant k. It is exactly cut into two halves, then each of these new springs will have a spring constant **[Kerala PMT 2004]**

(a) $k/2$ (b) $3k/2$

(c) $2k$ (d) $3k$

(e) $4k$

10. Four massless springs whose force constants are $2k$, $2k$, k and $2k$ respectively are attached to a mass M kept on a frictionless plane (as shown in figure). If the mass M is displaced in the horizontal direction, then the frequency of oscillation of the system is



(a) $\frac{1}{2\pi}\sqrt{\frac{k}{4M}}$ (b) $\frac{1}{2\pi}\sqrt{\frac{4k}{M}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{k}{7M}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{7k}{M}}$

11. Values of the acceleration A of a particle moving in simple harmonic motion as a function of its displacement x are given in the table below.

A $(mm\ s^{-2})$	16	8	0	– 8	– 16
x (mm)	– 4	– 2	0	2	4

The period of the motion is

(a) $\frac{1}{\pi}s$ (b) $\frac{2}{\pi}s$

(c) $\frac{\pi}{2}s$ (d) $\pi\, s$

12. Two pendulums have time periods T and $\frac{5T}{4}$. They start S.H.M. at the same time from the mean position. What will be the phase difference between them after the bigger pendulum has complete one oscillation

(a) 45° (b) 90°

(c) 60° (d) 30°

13. The periodic time of a particle doing simple harmonic motion is 4 *second*. The time taken by it to go from its mean position to half the maximum displacement (amplitude) is

(a) 2*s* (b) 1*s*

(c) $\frac{2}{3}s$ (d) $\frac{1}{3}s$

14. The displacement of a particle from its mean position (in metre) is given by $y = 0.2\sin(10\pi t + 1.5\pi)\cos(10\pi t + 1.5\pi)$. The motion of particle is **[CPMT 1998]**

(a) Periodic but not S.H.M.

(b) Non-periodic

(c) Simple harmonic motion with period 0.1 *s*

(d) Simple harmonic motion with period 0.2 *s*

15. The kinetic energy and the potential energy of a particle executing S.H.M. are equal. The ratio of its displacement and amplitude will be **[RPMT 2003; CPMT 2001]**

(a) $\frac{1}{\sqrt{2}}$ (b) $\frac{\sqrt{3}}{2}$

(c) $\frac{1}{2}$ (d) $\sqrt{2}$

16. Two simple pendulums of lengths 1.44 *m* and 1 *m* start swinging together. After how many vibrations will they again start swinging together **[J & K CET 2005]**

(a) 5 oscillations of smaller pendulum

(b) 6 oscillations of smaller pendulum

(c) 4 oscillations of bigger pendulum

(d) 6 oscillations of bigger pendulum

17. Equations $y_1 = A\sin\omega t$ and $y_2 = \frac{A}{2}\sin\omega t + \frac{A}{2}\cos\omega t$ represent S.H.M. The ratio of the amplitudes of the two motions is

(a) 1 (b) 2

(c) 0.5 (d) $\sqrt{2}$

18. A particle doing simple harmonic motion, amplitude = 4 *cm*, time period = 12 *sec*. The ratio between time taken by it in going from its mean position to 2 *cm* and from 2 *cm* to extreme position is

(a) 1 (b) 1/3

(c) 1/4 (d) 1/2

19. On a planet a freely falling body takes 2 *sec* when it is dropped from a height of 8 *m*, the time period of simple pendulum of length 1 *m* on that planet is **[Pb. PMT 2004]**

(a) 3.14 *sec* (b) 16.28 *sec*

(c) 1.57 *sec* (d) None of these

20. If a simple pendulum is taken to place where g decreases by 2%, then the time period **[Pb. PET 2002]**

(a) Decreases by 1% (b) Increases by 2%

(c) Increases by 2% (d) Increases by 1%

21. Two simple pendulum first of bob mass M_A and length L_A second of bob mass M_B and length L_B. $M_A = M_B$ and $L_A = 2L_B$. If these vibrational energy of both is same. Then which is correct

(a) Amplitude of B greater than A

(b) Amplitude of B smaller than A

(c) Amplitudes will be same

(d) None of these

Answers and Solutions

(SET -16)

1. (d) Time period of pendulum doesn't depends upon mass but it depends upon length (distance between point of suspension and centre of mass).

In first three cases length are same so $T = T_1 = T_2$ but in last case centre of mass lowers which in turn increases the length. So in this case time period will be more than the other cases.

2. (d) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow \frac{T_e}{T_m} = \sqrt{\frac{g_m}{g_e}} = \sqrt{\frac{g_e/6}{g_e}} = \frac{1}{\sqrt{6}}$

$\Rightarrow T_m = \sqrt{6}T_e$ *i.e.* clock becomes slower.

3. (b) The effective acceleration of a bob in water

$= g' = g\left(1 - \frac{\sigma}{\rho}\right)$ where σ and ρ are the density of water and the bob respectively. Since the period of oscillation of the bob in air and water are given as $T = 2\pi\sqrt{\frac{l}{g}}$ and

$T' = 2\pi\sqrt{\frac{l}{g'}}$

$\therefore \frac{T}{T'} = \sqrt{\frac{g'}{g}} = \sqrt{\frac{g(1-\sigma/\rho)}{g}} = \sqrt{1 - \frac{\sigma}{\rho}} = \sqrt{1 - \frac{1}{\rho}}$

Putting $\frac{T}{T'} = \frac{1}{\sqrt{2}}$. We obtain, $\frac{1}{2} = 1 - \frac{1}{\rho} \Rightarrow \rho = 2$

4. (b) $E = \frac{1}{2}m\omega^2 A^2 \Rightarrow E = \frac{1}{2}m(2\pi f)^2 A^2 \Rightarrow A = \frac{1}{2\pi f}\sqrt{\frac{2E}{m}}$

Putting $E = K + U$ we obtain,

$A = \frac{1}{2\pi\left(\frac{25}{\pi}\right)}\sqrt{\frac{2\times(0.5+0.4)}{0.2}} \Rightarrow A = 0.06\,m$

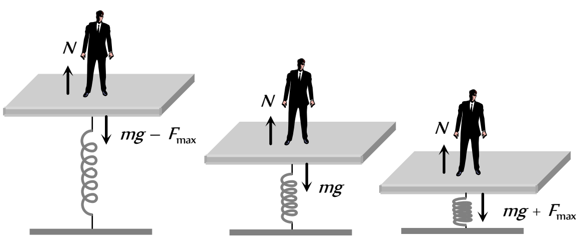
5. (a) The forces that act on the block are qE and mg. Since qE and mg are constant forces, the only variable elastic force changes by kx. Where x is the elongation in the spring $\Rightarrow$ unbalanced (restoring) force $= F = -kx$

$\Rightarrow -m\omega^2 X = -KX \Rightarrow \omega = \sqrt{\frac{k}{M}} = T$.

6. (d) The maximum force acting on the body executing simple harmonic motion is

$m\omega^2 a = m\times(2\pi f)^2 a = 60\times\left(2\pi\times\frac{2}{\pi}\right)^2\times 0.1\ N$

$= 60\times 16\times 0.1 = 96N = \frac{96}{9.8} \approx 10kgf$ and this force is towards mean position.



Upper extreme   Equilibrium position   Lower extreme

The reaction of the force on the platform away from the mean position. It reduces the weight of man on upper extreme *i.e.* net weight = (60 – 10) *kgf.*

This force adds to the weight at lower extreme position *i.e.* net weight becomes = (60 + 10) *kgf.*

Therefore, the reading the weight recorded by spring balance fluctuates between 50 *kgf* and 70 *kgf.*

7. (d) Function of wrist watch depends upon spring action so it is not effected by gravity but pendulum clock has time period, $T = 2\pi\sqrt{\frac{l}{g}}$. During free fall effective acceleration becomes zero, so time period comes out to be infinity i.e. the clock stops.

8. (b) Force constant of a spring is given by $F = kx$

$6.4 = k(0.1)$ or $k = 64\,N/m$

$\because T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow \frac{\pi}{4} = 2\pi\sqrt{\frac{m}{64}}$; $\frac{m}{64} = \left(\frac{1}{8}\right)^2$; $m = 1kg$

9. (b) $K \propto \frac{1}{l} \Rightarrow Kl = K'\times\frac{l}{2} \Rightarrow K' = 2K$

10. (b) The two springs on left side having spring constant of $2k$ each are in series, equivalent constant is $\frac{1}{\left(\frac{1}{2k}+\frac{1}{2k}\right)} = k$. The two springs on right hand side of mass M are in parallel. Their effective spring constant is $(k + 2k) = 3k$.

Equivalent spring constants of value k and $3k$ are in parallel and their net value of spring constant of all the four springs is $k + 3k = 4k$

$\therefore$ Frequency of mass is $n = \frac{1}{2\pi}\sqrt{\frac{4k}{M}}$

11. (d) $|A| = \omega x \Rightarrow \frac{|A|}{x} = \omega^2$

From the given value $\frac{|A|}{x} = \omega^2 = 4 \Rightarrow \omega = 2$.

Also $\omega = \frac{2\pi}{T} \Rightarrow 2 = \frac{2\pi}{T} \Rightarrow T = \pi\ sec$

12. (b) $\frac{5T}{4} = T + \frac{T}{4}$

Bigger pendulum ($5T/4$)   Smaller pendulum (T)

By the time, the bigger pendulum makes one full oscillation, the smaller pendulum will make $\left(1+\frac{1}{4}\right)$ oscillation. The bigger pendulum will be in the mean position and the smaller one will be in the positive extreme position. Thus, phase difference = 90°

13. (d) $y = A\sin\left(\frac{2\pi}{T}\right)\cdot t$

$\Rightarrow \frac{A}{2} = A\sin\left(\frac{2\pi}{4}\right)t \Rightarrow \frac{\pi t}{2} = \frac{\pi}{6} \Rightarrow t = \frac{1}{3}\ sec$

14. (c) $y = 0.2\sin(10\pi t + 1.5\pi)\cos(10\pi t + 1.5\pi)$

$= 0.1\sin 2(10\pi t + 1.5\pi)$ $[\because \sin 2A = 2\sin A\cos A]$

$= 0.1\sin(20\pi t + 3.0\pi)$

$\therefore$ Time period, $T = \frac{2\pi}{\omega} = \frac{2\pi}{20\pi} = \frac{1}{10} = 0.1\ sec$

15. (a) Given $K.E. = P.E. \Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}kx^2$

$\Rightarrow \frac{1}{2}m\omega^2(a^2 - x^2) = \frac{1}{2}m\omega^2 x^2$

$\Rightarrow a^2 - x^2 = x^2 \Rightarrow x^2 = \frac{a^2}{2} \Rightarrow \frac{x}{a} = \frac{1}{\sqrt{2}}.$

16. (b) $n \propto \frac{1}{\sqrt{l}} \Rightarrow \frac{n_2}{n_1} = \sqrt{\frac{1.44}{1}} = \frac{1.2}{1} \Rightarrow n_2 = 1.2 n_1$

For n be integer minimum value of n should be 5 and then n = 6 *i.e.,* after 6 oscillations of smaller pendulum both will be in phase.

***

17. (d) $y_2 = \frac{A}{2}\sin\omega t + \frac{A}{2}\cos\omega t$

$y_2 = \frac{A}{2}(\sin\omega t + \cos\omega t) = \frac{A}{2} \times \sqrt{2}\ [\sin(\omega t + 45^o)]$

$y_2 = \frac{A}{\sqrt{2}}\sin(\omega t + 45^o) \Rightarrow \frac{A_1}{A_2} = \frac{A}{A/\sqrt{2}} = \sqrt{2}$

18. (d) $\omega = \frac{2\pi}{T} = \frac{2\pi}{12} = \frac{\pi}{6}\frac{rad}{sec}$ (For y = 2 *cm*) $2 = 4\left(\sin\frac{\pi}{6}t_1\right)$

By solving $t_1 = 1\ sec$ (For y = 4 *cm*) $t_2 = 3\ sec$

So time taken by particle in going from 2 *cm* to extreme position is

$t_2 - t_1 = 2\ sec$. Hence required ratio will be $\frac{1}{2}$.

19. (a) On a planet, if a body dropped initial velocity (u = 0) from a height h and takes time t to reach the ground then

$h = \frac{1}{2}g_P t^2 \Rightarrow g_P = \frac{2h}{t^2} = \frac{2\times 8}{4} = 4\ m/s^2$

Using $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T = 2\pi\sqrt{\frac{1}{4}} = \pi = 3.14\ sec.$

20. (d) $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \frac{l}{\sqrt{g}}$

$\Rightarrow \frac{\Delta T}{T}\times 100 = -\frac{1}{2}\left(\frac{\Delta g}{g}\right)\times 100 = -\frac{1}{2}(-2\%) = 1\%.$

21. (b) $n = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \Rightarrow n \propto \frac{1}{\sqrt{l}} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{l_2}{l_1}} = \sqrt{\frac{L_2}{2L_2}}$

$\Rightarrow \frac{n_1}{n_2} = \frac{1}{\sqrt{2}} \Rightarrow n_2 = \sqrt{2}\,n_1 \Rightarrow n_2 > n_1$

Energy $E = \frac{1}{2}m\omega^2 a^2 = 2\pi^2 mn^2 a^2$

$\Rightarrow \frac{a_1^2}{a_2^2} = \frac{m_2 n_2^2}{m_1 n_1^2}$ ($\because$ E is same)

Given $n_2 > n_1$ and $m_1 = m_2 \Rightarrow a_1 > a_2$

Chapter 17

Waves and Sound

Waves

Ripple on a pond

Musical sound

Seismic waves

(Earth quake)

Tsunami

on.

stem is disturbed from equilibrium and wh r propagate from one region of the system to another. Wave can carry energy and momentum. The energy in light waves from the sun warms the surface of our planet; the energy in seismic waves can crack our planet's crust.

Characteristics of Wave Motion

(1) When a wave motion passes through a medium, particles of the medium only vibrate simple harmonically about their mean position. They do leave their position and move with the disturbance.

(2) In wave motion, the phase of particles of medium keeps on changing.

(3) The velocity of the particle during their vibration is different at different position.

(4) The velocity of wave motion through a particular medium is constant. It depends only on the nature of medium not on the frequency, wavelength or intensity.

(5) Energy is propagated along with the wave motion without any net transport of the medium.

(6) For the propagation of wave, a medium should have following characteristics.

(i) Elasticity : So that particles can return to their mean position, after having been.

(ii) Inertia : So that particles can store energy and overshoot their mean position.

(iii) Minimum friction amongst the particles of the medium.

(iv) Uniform density of the medium.

Types of Waves

Waves can be classified in a number of ways based on the following characteristics

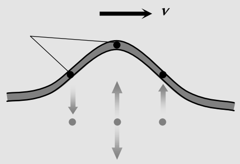
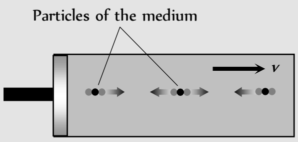
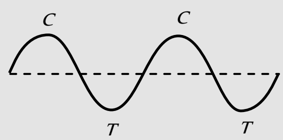
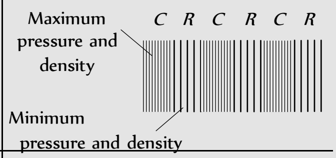
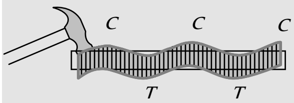
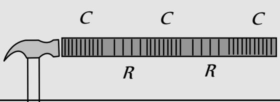
(1) **On the basis necessity of medium**

(i) **Mechanical waves :** Require medium for their propagation *e.g.* Waves on string and spring, waves on water surface, sound waves, seismic waves.

(ii) **Non-mechanical waves :** Do not require medium for their propagation are called *e.g,* Light, heat (Infrared), radio waves, γ- rays, X-rays *etc.*

(2) **On the basis of vibration of particle :** On the basis of vibration of particle of medium waves can be classified as transverse waves and longitudinal waves.

Table 17.1 : Transverse and longitudinal waves

Transverse waves	Longitudinal waves
Particles of the medium vibrates in a direction perpendicular to the direction of propagation of wave.  Transverse wave on a string	Particles of a medium vibrate in the direction of wave motion.  Longitudinal wave in a fluid
It travels in the form of crests (C) and troughs (T). 	It travels in the form of compression (C) and rarefaction (R). 
Transverse waves can be transmitted through solids, they can be setup on the surface of liquids. But they can not be transmitted into liquids and gases.  Transverse wave in a rod	These waves can be transmitted through solids, liquids and gases because for these waves propagation, volume elasticity is necessary.  Longitudinal wave in a rod
Medium should posses the property of rigidity	Medium should posses the property of elasticity
Transverse waves can be polarised.	Longitudinal waves can not be polarised.
Movement of string of a sitar or violin, movement of the membrane of a Tabla or Dholak, movement of kink on a rope, waves set-up on the surface of water.	Sound waves travel through air, Vibration of air column in organ pipes Vibration of air column above the surface of water in the tube of resonance apparatus

(3) **On the basis of energy propagation**

(i) **Progressive wave :** These waves advances in a medium with definite velocity. These waves propagate energy in the medium *e.g.* Sound wave and light waves.

(ii) **Stationary wave :** These waves remains stationary between two boundaries in medium. Energy is not propagated by these waves but it is confined in segments (or loops) *e.g.*. Wave in a string, waves in organ pipes.

(4) **On the basis of dimension**

(i) **One dimensional wave :** Energy is transferred in a single direction only *e.g.* Wave propagating in a stretched string.

(ii) **Two dimensional wave :** Energy is transferred in a plane in two mutually perpendicular directions *e.g.* Wave propagating on the surface of water.

(iii) **Three dimensional wave :** Energy in transferred in space in all direction *e.g.* Light and sound waves propagating in space.

(5) **Some other waves**

(i) **Matter waves :** The waves associated with the moving particles are called matter waves.

(ii) **Audible or sound waves :** Range 20 *Hz* to 20 *KHz.* These are generated by vibrating bodies such as vocal cords, stretched strings or membrane.

(iii) **Infrasonic waves :** Frequency lie below 20 *Hz* and wavelengths are greater than 16.6 *cm. Example* : waves produced during earth quake, ocean waves *etc.*

(iv) **Ultrasonic waves :** Frequency greater than 20 *KHz.* Human ear cannot detect these waves, certain creatures such as mosquito, dog and bat show response to these. As velocity of sound in air is 332 *m/sec* so the wavelength λ < 1.66 *cm.*

These waves are used for navigation under water (SONAR).

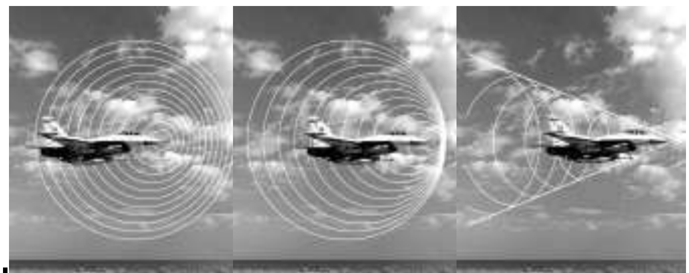
They are used in ultrasonography (in photography or scanning soft tissue of body).

Their used to repel mosquitoes or attract fishes

(v) **Shock waves :** When an object moves with a velocity greater than that of sound, it is termed as **Supersonic**. When such a supersonic body or plane travels in air, it produces energetic disturbance which moves in backward direction and diverges in the form of a cone. Such disturbance are called the shock waves.

The speed of supersonic is measured in Mach number. One mach number is the speed of sound.

Mach Number $= \dfrac{\text{Velocity of source}}{\text{Velocity of sound}}$.



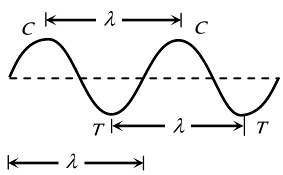
Important Terms Regarding Wave Motion

(1) **Amplitude** (a) **:** Maximum displacement of a vibrating particle of medium from it's mean position is called amplitude.

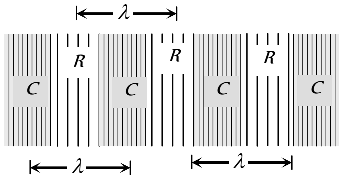
(2) **Wavelength** (λ) **:** It is equal to the distance travelled by the wave during the time in which any one particle of the medium completes one vibration about its mean position.

(i) Or distance travelled by the wave in one time period is known as wavelength.

(ii) Or is the distance between the two successive points with the same phase.



(A) Transverse wave



(B) Longitudinal wave

Fig. 17.1

(3) **Frequency** (n) **:** Frequency of vibration of a particle is defined as the number of vibrations completed by particle in one second.

It is the number of complete wavelengths traversed by the wave in one second.

Units of frequency are hertz (Hz) and per second.

(4) **Time period** (T) **:** Time period of vibration of particle is defined as the time taken by the particle to complete one vibration about its mean position.

It is the time taken by the wave to travel a distance equal to one wavelength

Time period = 1/Frequency $\Rightarrow T = 1/n$

(5) **Wave pulse :** It is a short wave produced in a medium when the disturbance created for a short time.

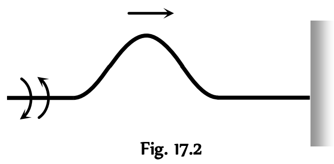


Fig. 17.2

(6) **Wave train :** A series of wave pulse is called wave train.

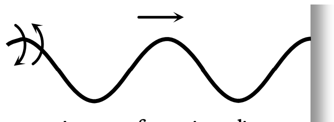
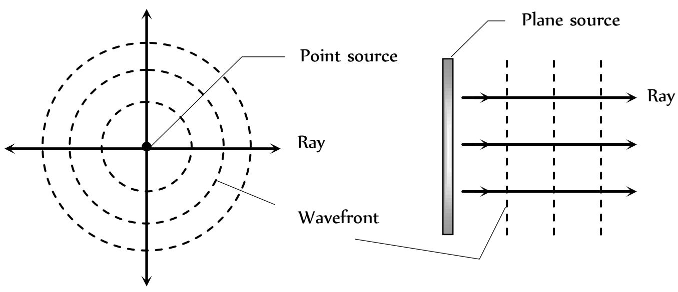


Fig. 17.3

(7) **Wave front :** A wave front is a line or surface on which the disturbance has **the** same phase at all points. If the source is periodic, it produces a succession of wave front, all of the same shape. Ripples on a pond are the example of wave fronts.



(A) Spherical wavefront (B) Plane wavefront

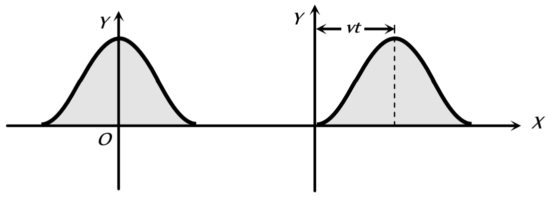
Fig. 17.4

(8) **Wave function ;** It is a mathematical description of the disturbance created by a wave. For a string, the wave function is a displacement for sound waves. It is a pressure or density fluctuation where as for light waves it is electric or magnetic field.

Now let us consider a one dimensional wave travelling along x-axis. During wave motion, a particle with equilibrium position x is displaced some distance y in the direction perpendicular to the x-axis. In this case y is a function of position (x) and time (t).

i.e. $y = f(x, t)$. This is called wave function .

Let the wave pulse is travelling with a speed v, after a time t, the pulse reaches a distance vt along the $+x$-axis as shown. The wave function now can be represented as $y = f(x - vt)$



(A) Pulse at time $t = 0$ (B) Pulse after time t

Fig. 17.5

If the wave pulse is travelling along $-x$-axis then $y = f(x + vt)$

If order of a wave function to represent a wave, the three quantities x, v, t must appear in combinations $(x + vt)$ or $(x - vt)$

Thus $y = (x - vt)$, $\sqrt{(x - vt)}$, $Ae^{-B(x-vt)^2}$ *etc.* represents travelling waves while $y = (x^2 - v^2t^2), (\sqrt{x} - \sqrt{vt})$, $A \sin(4x - 9t)$ *etc.* doesn't represents a wave.

(9) **Harmonic wave :** If a travelling wave is a sin or cos function of $(x \pm vt)$ the wave is said to be harmonic or plane progressive wave.

(10) **The wave equation :** All the travelling waves satisfy a differential equation which is called the wave equation. It is given by $\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}$; where $v = \frac{\omega}{k}$

It is satisfied by any equation of the form $y = f(x \pm vt)$

(11) **Angular wave number or propagation constant (k) :** Number of wavelengths in the distance 2π is called the wave number or propagation constant *i.e.* $k = \frac{2\pi}{\lambda}$.

It is unit is *rad/m.*

(12) **Wave velocity** (v) **:** It is the distance travelled by the disturbance in one time period. It only depends on the properties of the medium and it independent of time and position.

$$v = n\lambda = \frac{\lambda}{T} = \frac{\omega}{2\pi} = \frac{\omega}{k}$$

(13) **Group velocity** (v) **:** The velocity with which the group of waves travels is known as group velocity

or the velocity with which a wave packet travels is known as group velocity $v_g = \frac{d\omega}{dk}$.

(14) **Phase** (ϕ) **:** The quantity which express at any instant, the displacement of the particle and it's direction of motion is called the phase of the particle.

If two particles of the medium, at any instant are at the same distance in the same direction from their equilibrium positions and are moving in the same direction then they are said to be in same phase *e.g.* In the following figure particles 1, 3 and 5 are in same phase and point 6, 7 are also in same phase.

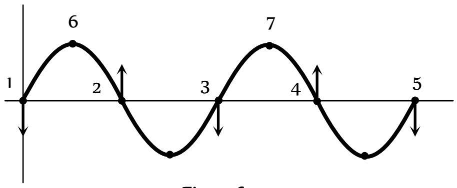


Fig. 17.6

(15) **Intensity of wave :** The wave intensity is defined as the average amount of energy flow in medium per unit time and per unit of it's cross-sectional area. It's unit is W/m^2

Hence intensity (I) $= \dfrac{\text{Energy}}{\text{Area} \times \text{Time}} = \dfrac{\text{Power}}{\text{Area}} = 2\pi n a \rho v$

$\Rightarrow I \propto a^2$ (when v, ρ = constant)

where a = Amplitude, n =Frequency, v = Wave velocity,

ρ = Density of medium.

At a distance r from a point source of power P the intensity is given by $I = \dfrac{P}{4\pi r^2} \Rightarrow I \propto \dfrac{1}{r^2}$

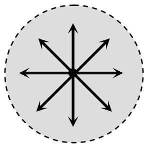


Fig. 17.7

The human ear can hear sound of intensity up to 10^{-12} W/m^2. This is called **threshold of intensity**. The upper limit of intensity of sound which can be tolerated by human ear is 1 W/m^2. This is called **threshold of pain**.

(16) **Energy density :** The energy associated with unit volume of the medium is defined as energy density

Energy density $= \dfrac{\text{Energy}}{\text{Volume}} = \dfrac{\text{Intensity}}{\text{Velocity}} = \dfrac{2\pi^2 n^2 a^2 \rho v}{v} = 2\pi^2 n^2 a^2 \rho$

Velocity of Transverse Wave

The velocity of a transverse wave in a stretched string is given by $v = \sqrt{\dfrac{T}{m}}$; where T = Tension in the string; m = Linear density of string (mass per unit length).

(1) If A is the area of cross-section of the wire then $m = \rho A$

$\Rightarrow v = \sqrt{\dfrac{T}{\rho A}} = \sqrt{\dfrac{S}{\rho}}$; where S = Stress $= \dfrac{T}{A}$

(2) If string is stretched by some weight then

$T = Mg$

$\Rightarrow v = \sqrt{\dfrac{Mg}{m}}$

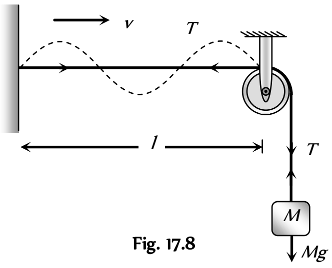


Fig. 17.8

(3) If suspended weight is immersed in a liquid of density σ and ρ = density of material of the suspended load then

$T = Mg\left(1 - \dfrac{\sigma}{\rho}\right)$

$\Rightarrow v = \sqrt{\dfrac{Mg(1 - \sigma/\rho)}{m}}$

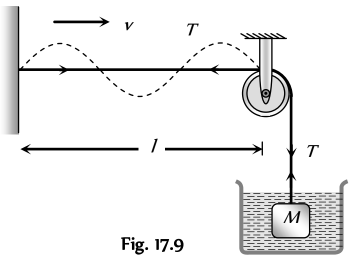


Fig. 17.9

(4) If two rigid supports of stretched string are maintained at temperature difference of $\Delta\theta$ then due to elasticity of string.

$T = YA\,\alpha\,\Delta\theta$

$\Rightarrow v = \sqrt{\dfrac{YA\,\alpha\Delta\theta}{m}}$

$= \sqrt{\dfrac{Y\alpha\Delta\theta}{d}}$

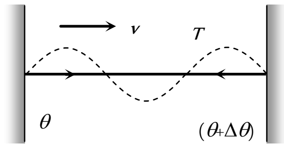


Fig. 17.10

where Y = Young's modulus of elasticity of string, A = Area of cross section of string, α = Temperature coefficient of thermal expansion, d = Density of wire $= \dfrac{m}{A}$

(5) In a solid body : $v = \sqrt{\dfrac{\eta}{\rho}}$

where η = Modulus of rigidity; ρ = Density of the material.

Velocity of Longitudinal Wave (Sound Wave)

(1) **Velocity of sound in any elastic medium :** It is given by $v = \sqrt{\dfrac{E}{\rho}} = \sqrt{\dfrac{\text{Elasticity of the medium}}{\text{Density of the medium}}}$

(i) In solids $v = \sqrt{\dfrac{Y}{\rho}}$; where Y = Young's modulus of elasticity

(ii) In a liquid and gaseous medium $v = \sqrt{\dfrac{B}{\rho}}$; where B = Bulk modulus of elasticity of liquid or gaseous medium.

(iii) As solids are most elastic while gases least *i.e.* $E_S > E_L > E_G$. So the velocity of sound is maximum in solids and minimum in gases, hence $v_{steel} > v_{water} > v_{air}$

5000 m/s > 1500 m/s > 330 m/s

(iv) The velocity of sound in case of extended solid (crust of the earth) $v = \sqrt{\dfrac{B + \frac{4}{3}\eta}{\rho}}$; B = Bulk modulus; η = Modulus of rigidity; ρ = Density

(2) **Newton's formula :** He assumed that when sound propagates through air temperature remains constant. *i.e.* the process is isothermal. For isothermal process

B = Isothermal elasticity (E_θ) = Pressure (P) $\Rightarrow v = \sqrt{\dfrac{B}{\rho}} = \sqrt{\dfrac{P}{\rho}}$

For air at NTP : $P = 1.01 \times 10^5$ N/m^2 and $\rho = 1.29$ kg/m^3.

$\Rightarrow v_{air} = \sqrt{\dfrac{1.01 \times 10^5}{1.29}} \approx 280\, m/s$

However the experimental value of sound in air is 332 m/sec which is greater than that given by Newton's formula.

(3) **Laplace correction :** He modified Newton's formula assuming that propagation of sound in gaseous medium is adiabatic process. For adiabatic process

B = Adiabatic elasticity (E_ϕ) $= \gamma P$

$\Rightarrow v = \sqrt{\frac{B}{\rho}} = \sqrt{\frac{E_\phi}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$

For air : $\gamma = 1.41 \Rightarrow v_{air} = \sqrt{1.41} \times 280 \approx 332$ *m/sec*

(4) **Relation between velocity of sound and root mean square velocity :**

If sound travel in a gaseous medium then $v_{sound} = \sqrt{\frac{\gamma RT}{M}}$ and *r.m.s.* velocity of gas $v_{rms} = \sqrt{\frac{3RT}{M}}$

So $\frac{v_{rms}}{v_{sound}} = \sqrt{\frac{3}{\gamma}}$ or $v_{sound} = [\gamma/3]^{1/2} v_{rms}$.

Factors Affecting Velocity of Sound in Gaseous Medium

(1) **Effect of pressure at constant temperature :** Velocity of sound is independent of the pressure of gas, because as pressure increases, density also increases hence $\frac{P}{\rho}$ ratio remains constant. So from $v = \sqrt{\frac{\gamma P}{\rho}}$,

(2) **Effect of temperature :** With rise in temperature velocity of sound increases.

$$v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{T} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{(273 + t_1°C)}{(273 + t_2°C)}}$$

When the temperature change is small then $v_t = v_0 + 0.61\,t$

where v_t = Velocity of sound at $t°C$

v_0 = Velocity of sound at $0°C$ = 332 *m/sec*

t = Small temperature change

If $t = 1°C$ then $v_t = (v_0 + 0.61)$ *m/sec*. Hence for $1°C$ rise, speed of sound in air increases by 0.61 *m/sec*.

(3) **Effect of density :** $v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow v \propto \frac{1}{\sqrt{\rho}}$

(4) **Effect of humidity :** With increase in humidity, density of air decreases. So with rise in humidity velocity of sound increases.

Sound travels faster in humid air (rainy season) than in dry air (summer) at the same temperature because

$$\rho_{moist\ air} < \rho_{dry\ air} \Rightarrow v_{moist\ air} > v_{dry\ air}$$

(5) **Effect of wind velocity :** Because wind drifts the medium (air) along its direction of motion therefore the velocity of sound in a particular direction is the algebraic sum of the velocity of sound and the component of wind velocity in that direction. Resultant velocity of sound towards observer $v' = v + w\cos\theta$.

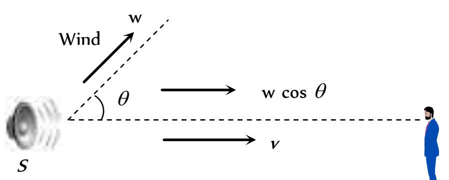


Fig. 17.11

(6) Sound of any frequency or wavelength travels through a given medium with the same velocity.

For a given medium velocity remains constant. All other factors like phase, loudness pitch, quality *etc.* have practically no effect on sound velocity.

Equation of a Plane Progressive Waves

(1) If during the propagation of a progressive wave, the particles of the medium perform SHM about their mean position, then the waves is known as a harmonic progressive wave.

(2) Suppose a plane simple harmonic wave travels from the origin along the positive direction of *x-axis* from left to right as shown in the figure.

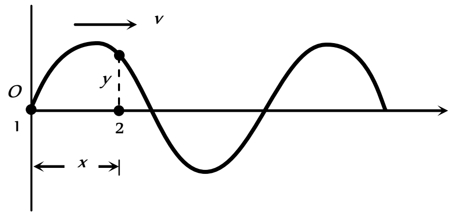


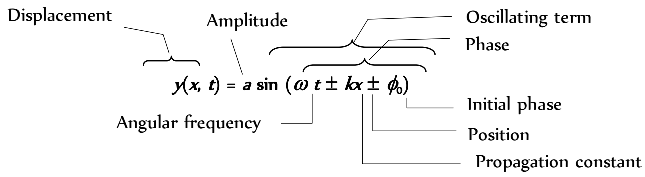
Fig. 17.12

The displacement y of a particle 1 at O from its mean position at any time t is given by $y = a\sin\omega t$.

The wave reaches the particle 2 after time $t = \frac{x}{v}$. Hence displacement y of a particle 2 is given by

$$y = a\sin\omega\left(t - \frac{x}{v}\right) = a\sin(\omega t - kx) \qquad \left(\because k = \frac{\omega}{v}\right)$$

The general equation of a plane progressive wave with initial phase is



(3) Various forms of progressive wave function.

(i) $y = a\sin(\omega t - kx)$

(ii) $y = a\sin\left(\omega t - \frac{2\pi}{\lambda}x\right)$

(iii) $y = a\sin 2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right]$

(iv) $y = a\sin\frac{2\pi}{T}\left(t - x\frac{T}{\lambda}\right)$

(v) $y = a\sin\frac{2\pi}{\lambda}(vt - x)$

(vi) $y = a\sin\omega\left(t - \frac{x}{v}\right)$

(4) **Particle velocity :** The rate of change of displacement y *w.r.t.* time t is known as particle velocity

Hence from $y = a\sin(\omega t - kx)$

Particle velocity $v_p = \frac{\partial y}{\partial t} = a\omega \cos(\omega t - kx)$

Maximum particle velocity $(v_p)_{max} = a\omega$

Also $\frac{\partial y}{\partial t} = -\frac{\omega}{k} \times \frac{\partial y}{\partial x}$ $\Rightarrow v_p = -v \times$ Slope of wave at that point

(5) **Important relations for numerical solving**

(i) Angular frequency ω = co-efficient of t

(ii) Propagation constant k = co-efficient of x

Wave speed $v = \frac{\text{co-efficient of } t}{\text{co-efficient of } x} = \frac{\omega}{k}$

(iii) Wave length $\lambda = \frac{\text{co-efficient of } x}{2\pi}$

(iv) Time period $T = \frac{2\pi}{\text{co-efficient of } t}$

(v) Frequency $n = \frac{\text{co-efficient of } t}{2\pi}$

(vi) $(v_p)_{max} = a\omega = a(2\pi n) = \frac{a2\pi}{T}$

(vii) If the sign between t and x terms is negative the wave is propagating along positive X-axis and if the sign is positive then the wave moves in negative X-axis direction.

(viii) Co-efficient of sin or cos functions *i.e.* Argument of sin or cos function is represented by phase *i.e.* $(\omega t - kx)$ = Phase.

(ix) **Phase difference and path difference :** At any instant t, if ϕ_1 and ϕ_2 are the phases of two particles whose distances from the origin are x_1 and x_2 respectively then $\phi_1 = (\omega t - kx_1)$ and $\phi_2 = (\omega t - kx_2)$ $\Rightarrow$ $\phi_1 - \phi_2 = k(x_2 - x_1)$

$\Rightarrow$ Phase difference $(\Delta\phi) = \frac{2\pi}{\lambda}$. Path difference (Δx)

(x) **Phase difference and time difference :** If the phases of a particle distance x from the origin is ϕ_1 at time t_1 and ϕ_2 at time t_2, then $\phi_1 = (\omega t_1 - kx)$ and $\phi_1 = (\omega t_2 - kx)$ $\Rightarrow \phi_1 - \phi_2 = \omega(t_1 - t_2)$

$\Rightarrow$ Phase difference $(\Delta\phi) = \frac{2\pi}{T}$. Time difference (Δt)

Pressure Waves

A longitudinal sound wave can be expressed either in terms of the longitudinal displacement of the particles of the medium or in terms of excess pressure produced due to compression or rarefaction. (at compression, the pressure is more than the normal pressure of the medium and at rarefaction the pressure is lesser than the normal). The first type is called the displacement wave and the second type the pressure wave.

If the displacement wave is represented by $y = a\sin(\omega t - kx)$ then the corresponding pressure wave will be represented by $\Delta P = -B\frac{dy}{dx}$ (B = Bulk modulus of elasticity of medium)

$\Rightarrow \Delta P = \Delta P_0 \cos(\omega t - kx)$

where ΔP_0 = pressure amplitude $= akB$

Pressure wave is $\left(\frac{\pi}{2}\right)$ out of phase with displacement wave. *i.e.* pressure is maximum when displacement is minimum and vice-versa.

Reflection and Refraction of Waves

When waves are incident on a boundary between two media, a part of incident waves returns back into the initial medium (reflection) while the remaining is partly absorbed and partly transmitted into the second medium (refraction)

(1) **Rarer and denser medium :** A medium is said to be denser (relative to the other) if the speed of wave in this medium is less than the speed of the wave in other medium.

In comparison to air speed of sound is maximum in water, hence water is rarer medium for sound waves *w.r.t.* air. But it is not true for light (EM-waves). For light waves water is denser medium *w.r.t.* air.

(2) In reflection or refraction frequency remains same

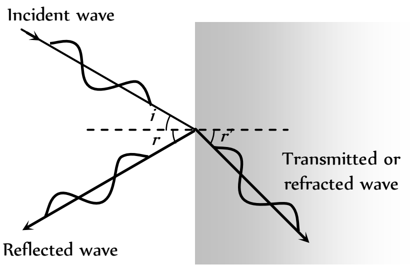


Fig. 17.13

(3) For reflection angle of incidence (i) = Angle of reflection (r)

(4) In case of refraction or transmission $\frac{\sin i}{\sin r'} = \frac{v_i}{v_t}$

(5) **Boundary conditions :** Reflection of a wave pulse from some boundary depends on the nature of the boundary.

(i) **Rigid end :** When the incident wave reaches a fixed end, it exerts an upward pull on the end, according to Newton's law the fixed end exerts an equal and opposite down ward force on the string. It result an inverted pulse or phase change of π.

Crest (C) reflects as trough (T) and vice-versa, Time changes by $\frac{T}{2}$ and Path changes by $\frac{\lambda}{2}$

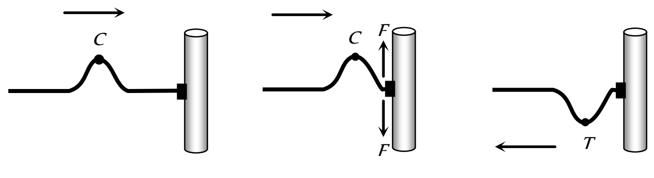


Fig. 17.14

(ii) **Free end :** When a wave or pulse is reflected from a free end, then there is no change of phase (as there is no reaction force).

Crest (C) reflects as crest (C) and trough (T) reflects as trough (T), Time changes by zero and Path changes by zero.

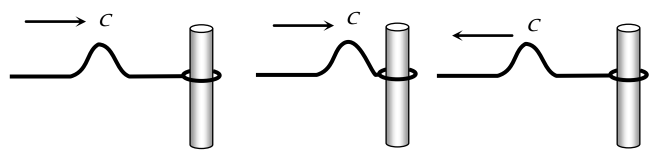


Fig. 17.15

(iii) **Exception :** Longitudinal pressure waves suffer no change in phase from rigid end *i.e.* compression pulse reflects as compression pulse. On the other hand if longitudinal pressure wave reflects from free end, it suffer a phase change of π *i.e.* compression reflects as rarefaction and vice-versa.

(iv) **Effect on different variables :** In case of reflection, because medium is same and hence, speed, frequency (ω) and wavelength λ (or k) do not changes. On the other hand in case of transmitted wave since medium changes and hence speed, wavelength (or k) changes but frequency (ω) remains the same.

(6) **Wave in a combination of string**

(i) **Wave goes from rarer to denser medium**

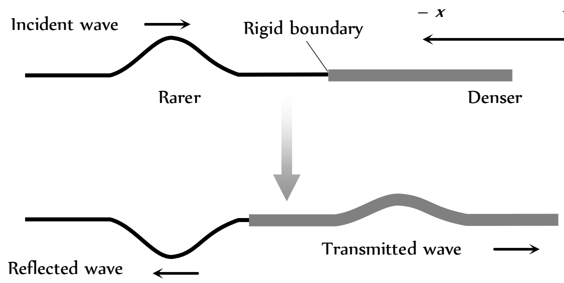


Fig. 17.16

Incident wave $y_i = a_i \sin(\omega t - k_1 x)$

Reflected wave $y_r = a_r \sin[\omega t - k_1(-x) + \pi] = -a \sin(\omega t + k_1 x)$

Transmitted wave $y_t = a_t \sin(\omega t - k_2 x)$

(ii) **Wave goes from denser to rarer medium**

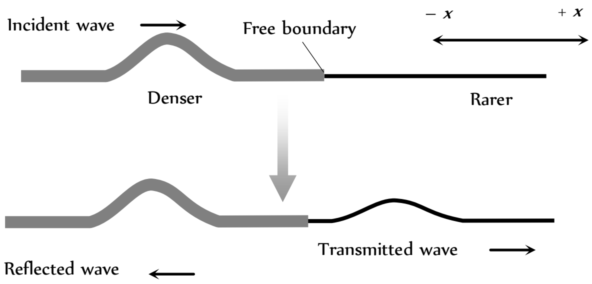


Fig. 17.17

Incident wave $y_i = a_i \sin(\omega t - k_1 x)$

Reflected wave $y_r = a_r \sin[\omega t - k_1(-x) + 0] = a \sin(\omega t + k_1 x)$

Transmitted wave $y_t = a_t \sin(\omega t - k_2 x)$

(iii) **Ratio of amplitudes :** It is given as follows

$$\frac{a_r}{a_i} = \frac{k_1 - k_2}{k_1 + k_2} = \frac{v_2 - v_1}{v_2 + v_1} \text{ and } \frac{a_t}{a_i} = \frac{2k_1}{k_1 + k_2} = \frac{2v_2}{v_1 + v_2}$$

Echo

An echo is simply the repetition of speaker's own voice caused by reflection at a distance surface *e.g.* a cliff. a row of building or any other extended surface.

If there is a sound reflector at a distance d from source, then the time interval between original source and it's echo at the site of source will be

$$t = \frac{d}{v} + \frac{d}{v} = \frac{2d}{v}$$

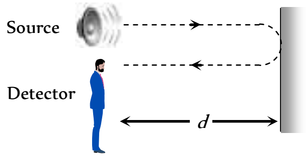


Fig. 17.18

As the persistence of hearing for human ear is 0.1 *sec*, therefore in order that an echo of short sound (*e.g.* clap or gun fire) will be heard if $t > 0.1 \Rightarrow \frac{2d}{v} > 0.1 \Rightarrow d > \frac{v}{20}$

If v = Speed of sound = 340 *m/s* then $d > 17$ *m*.

Principle of Superposition

(1) The displacement at any time due to any number of waves meeting simultaneously at a point in a medium is the vector sum of the individual displacements due each one of the waves at that point at the same time.

(2) If $\vec{y}_1, \vec{y}_2, \vec{y}_3$ .... are the displacements at a particular time at a particular position, due to individual waves, then the resultant displacement.

$$\vec{y} = \vec{y}_1 + \vec{y}_2 + \vec{y}_3 + ...$$

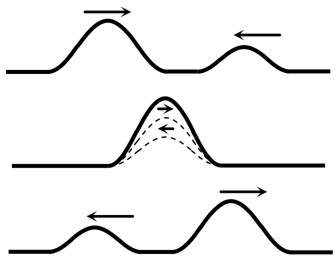


Fig. 17.19

(3) Important applications of superposition principle

(i) **Interference of waves :** Adding waves that differs in phase

(ii) **Formation of stationary waves :** Adding wave that differs in direction.

(iii) **Formation of beats :** Adding waves that differs in frequency.

(iv) **Formation of Lissaju's figure :** Adding two perpendicular simple harmonic motions. (See S.H.M. for more detail)

Interference of Sound Waves

(1) When two waves of same frequency, same wavelength, same velocity (nearly equal amplitude) moves in the same direction, Their superimposition results in the interference.

(2) Due to interference the resultant intensity of sound at that point is different from the sum of intensities due to each wave separately.

(3) Interference is of two type (i) Constructive interference (ii) Destructive interference.

(4) In interference energy is neither created nor destroyed but is redistributed.

(5) For observable interference, the sources (producing interfering waves) must be coherent.

(6) Let at a given point two waves arrives with phase difference ϕ and the equation of these waves is given by

$y_1 = a_1 \sin \omega t$, $y_2 = a_2 \sin(\omega t + \phi)$ then by the principle of superposition $\vec{y} = \vec{y}_1 + \vec{y}_2$

$\Rightarrow y = a_1 \sin \omega t + a_2 \sin(\omega t + \phi) = A \sin(\omega t + \theta)$

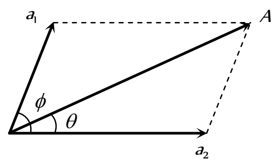


Fig. 17.20

where $A = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi}$

and $\tan\theta = \dfrac{a_2 \sin\phi}{a_1 + a_2 \cos\phi}$

since Intensity (I) $\propto$ (Amplitude A)^2 $\Rightarrow \dfrac{I_1}{I_2} = \left(\dfrac{a_1}{a_2}\right)^2$

Therefore, the resultant intensity is given by

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

Table 17.2 : Constructive and destructive interference

Constructive interference	Destructive interference
When the waves meets a point with same phase, constructive interference is obtained at that point (*i.e.* maximum sound).	When the wave meets a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum sound)
Phase difference between the waves at the point of observation $\phi = 0^o$ or $2n\pi$	Phase difference $\phi = 180^o$ or $(2n-1)\pi$; n = 1, 2, ...
Path difference between the waves at the point of observation $\Delta = n\lambda$ (*i.e.* even multiple of $\lambda/2$)	Path difference $\Delta = (2n-1)\dfrac{\lambda}{2}$ (*i.e.* odd multiple of $\lambda/2$)
Resultant amplitude at the point of observation will be maximum $A_{max} = a_1 + a_2$ If $a_1 = a_2 = a_0 \Rightarrow A_{max} = 2a_0$	Resultant amplitude at the point of observation will be minimum $A_{min} = a_1 - a_2$ If $a_1 = a_2 \Rightarrow A_{min} = 0$
Resultant intensity at the point of observation will be maximum $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ $= \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{max} = 4I_0$	Resultant intensity at the point of observation will be minimum $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$ $= \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$ If $I_1 = I_2 = I_0 \Rightarrow I_{min} = 0$

(7) $\dfrac{I_{max}}{I_{min}} = \left(\dfrac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\dfrac{\sqrt{\dfrac{I_1}{I_2}} + 1}{\sqrt{\dfrac{I_1}{I_2}} - 1}\right)^2 = \left(\dfrac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\dfrac{\dfrac{a_1}{a_2} + 1}{\dfrac{a_1}{a_2} - 1}\right)^2$

Quink's Tube

This is an apparatus used to demonstrate the phenomenon of interference and also used to measure velocity of sound in air. This is made up of two U-tube A and B as shown in figure. Here the tube B can slide in and out from the tube A. There are two openings P and Q in the tube A. At opening P, a tuning fork or a sound source of known frequency n_0 is placed and at the other opening a detector is placed to detect the resultant sound of interference occurred due to superposition of two sound waves coming from the tubes A and B.

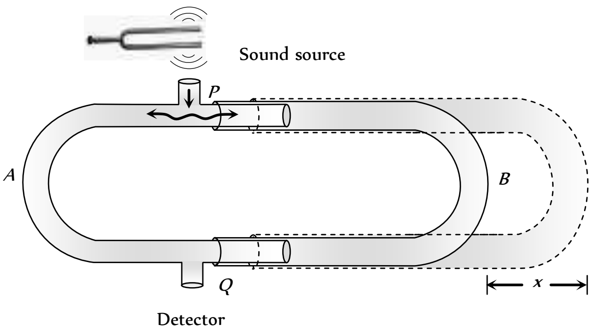


Fig. 17.21

Initially tube B is adjusted so that detector detects a maximum. At this instant if length of paths covered by the two waves from P and Q from the side of A and side of B are l_1 and l_2 respectively then for constructive interference we must have

$$l_2 - l_1 = N\lambda \quad .... \text{(i)}$$

If now tube B is further pulled out by a distance x so that next maximum is obtained and the length of path from the side of B is l'_2 then we have

$$l'_2 = l_2 + 2x \quad .... \text{(ii)}$$

where x is the displacement of the tube. For next constructive interference of sound at point Q, we have

$$l'_2 - l_1 = (N+1)\lambda \quad .... \text{(iii)}$$

From equation (i), (ii) and (iii), we get

$$l'_2 - l_2 = 2 \times x = \lambda \Rightarrow x = \frac{\lambda}{2}$$

Thus by experiment we get the wavelength of sound as for two successive points of constructive interference, the path difference must be λ. As the tube B is pulled out by x, this introduces a path difference $2x$ in the path of sound wave through tube B. If the frequency of the source is known, n_0, the velocity of sound in the air filled in tube can be gives as $v = n_0.\lambda = 2n_0 x$

Standing Waves or Stationary Waves

When two sets of progressive wave trains of same type (both longitudinal or both transverse) having the same amplitude and same time period/frequency/wavelength travelling with same speed along the same straight line in opposite directions superimpose, a new set of waves are formed. These are called stationary waves or standing waves.

In practice, a stationary wave is formed when a wave train is reflected at a boundary. The incident and reflected waves then interfere to produce a stationary wave.

(1) Suppose that the two super imposing waves are incident wave $y_1 = a\sin(\omega t - kx)$ and reflected wave $y_2 = a\sin(\omega t + kx)$

(As y_2 is the displacement due to a reflected wave from a free boundary)

Then by principle of superposition

$$y = y_1 + y_2 = a[\sin(\omega t - kx) + \sin(\omega t + kx)]$$

(By using $\sin C + \sin D = 2\sin\dfrac{C+D}{2}\cos\dfrac{C-D}{2}$)

$$\Rightarrow \quad y = 2a\cos kx \sin\omega t$$

(If reflection takes place from rigid end, then equation of stationary wave will be $y = 2a\sin kx \cos\omega t$)

(2) As this equation satisfies the wave equation

$\frac{\partial^2 y}{\partial t^2} = v^2 \frac{\partial^2 y}{\partial x^2}$. It represents a wave.

(3) As it is not of the form $f(ax \pm bt)$, the wave is not progressive.

(4) Amplitude of the wave $A_{SW} = 2a\cos kx$.

Table 17.3 : Amplitude in two different cases

Reflection at open end	Reflection at closed end
$A_{SW} = 2a\cos kx$	$A_{SW} = 2a\sin kx$
Amplitude is maximum when cos kx = ± 1 $\Rightarrow kx = 0, \pi, 2\pi, ... n\pi.$ $\Rightarrow x = 0, \frac{\lambda}{2}, \lambda .... \frac{n\lambda}{2}$ where $k = \frac{2\pi}{\lambda}$ and $n = 0, 1, 2, 3, ...$	Amplitude is maximum when sin kx = ± 1 $\Rightarrow kx = \frac{\pi}{2}, \frac{3\pi}{2} ..... \frac{(2n-1)\pi}{2}$ $\Rightarrow x = \frac{\lambda}{4}, \frac{3\lambda}{4} ....$ where $k = \frac{2\pi}{\lambda}$ and $n = 1, 2, 3, ...$
Amplitude is minimum when $\cos kx = 0$ $\Rightarrow kx = \frac{\pi}{2}, \frac{3\pi}{2} ..... \frac{(2n-1)\pi}{2}$ $\Rightarrow x = \frac{\lambda}{4}, \frac{3\lambda}{4} ....$	Amplitude is minimum when $\sin kx = 0$ $\Rightarrow kx = \frac{\pi}{2}, \frac{3\pi}{2} ..... \frac{(2n-1)\pi}{2}$ $\Rightarrow x = 0, \frac{\lambda}{2}, \lambda ...... \frac{n\lambda}{2}$

(5) **Nodes** (*N*) **:** The points where amplitude is minimum are called nodes.

(i) Distance between two successive nodes is $\frac{\lambda}{2}$.

(ii) Nodes are at permanents rest.

(iii) At nodes air pressure and density both are high.

(6) **Antinodes** (*A*) **:** The points of maximum amplitudes are called antinodes.

(i) The distance between two successive antinodes is $\frac{\lambda}{2}$

(ii) At nodes air pressure and density both are low.

(iii) The distance between a node (*N*) and adjoining antinode (*A*) is $\frac{\lambda}{4}$.

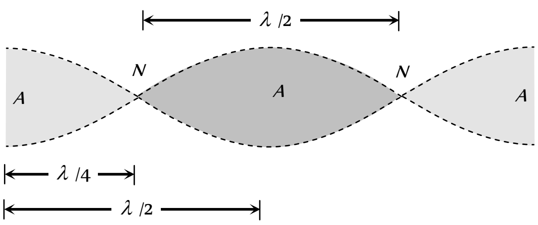


Fig. 17.22

Characteristics of Standing Waves

(1) Standing waves can be transverse or longitudinal.

(2) The disturbance confined to a particular region between the starting point and reflecting point of the wave.

(3) There is no forward motion of the disturbance from one particle to the adjoining particle and so on, beyond this particular region.

(4) The total energy associated with a stationary wave is twice the energy of each of incident and reflected wave. As in stationary waves nodes are permanently at rest. So no energy can be transmitted across then *i.e.* energy of one region (segment) is confined in that region. However this energy oscillates between elastic potential energy and kinetic energy of particles of the medium.

(5) The medium splits up into a number of segments. Each segment is vibrating up and down as a whole.

(6) All the particles in one particular segment vibrate in the same phase. Particles in two consecutive segments differ in phase by 180°.

(7) All the particles except those at nodes, execute simple harmonic motion about their mean position with the same time period.

(8) The amplitude of vibration of particles varies from zero at nodes to maximum at antinodes (2*a*).

(9) All points (except nodes) pass their mean position twice in one time period.

(10) Velocity of particles while crossing mean position varies from maximum $(\omega A_{SW} = \omega .2a)$ at antinodes to zero at nodes.

(11) In standing waves, if amplitude of component waves are not equal. Resultant amplitude at nodes will be minimum (but not zero). Therefore, some energy will pass across nodes and waves will be partially standing.

(12) Application of stationary waves

(i) Vibration in stretched string

(ii) Vibration in organ pipes (closed and open)

(iii) Kundt's tube

Table 17.4 : Progressive v/s stationary wave

Progressive wave	Stationary wave
These waves transfers energy	These wave does not transfers energy
All particles have the same amplitude	Between a node and an antinode all particles have different amplitudes
Over one wavelength span all particles have difference phase	Between a node and an antnodes all particles have same phase.
No point is at rest	Nodes are always at rest
All particles do not cross the mean position simultaneously.	All particles cross the mean position simultaneously.

Terms Related to the Application of Stationary Wave

(1) **Note :** Any musical sound produced by the simple harmonic oscillations of the source is called note.

(2) **Tone :** Every musical sound consists of a number of components of different frequencies every component is known as a Tone.

(3) **Fundamental note and fundamental frequency :** The note of lowest frequency produced by an instrument is called fundamental note. The frequency of this note is called fundamental frequency.

(4) **Harmonics :** The frequency which are the integral multiple of the fundamental frequency are known as harmonics *e.g.* if *n* be the fundamental frequency, then the frequencies *n*, 2*n*, 3*n* .... are termed as first, second, third .... harmonics.

(5) **Overtone :** The harmonics other than the first (fundamental note) which are actually produced by the instrument are called overtones. *e.g.* the tone with frequency immediately higher than the fundamental is defined as first overtone.

(6) **Octave :** The tone whose frequency is doubled the fundamental frequency is defined as Octave.

(i) If $n_2 = 2n_1$ it means n_2 is an octave higher than n_1 or n_1 is an octave lower than n_2.

(ii) If $n_2 = 2^3 n_1$, it means n_2 is 3-octave higher or n_1 is 3-octave lower.

(iii) Similarly if $n_2 = 2^n n_1$ it means n_2 is n-octave higher n_1 is n octave lower.

(7) **Unison :** If the interval is one *i.e.* two frequencies are equal then vibrating bodies are said to be in unison.

(8) **Resonance :** The phenomenon of making a body vibrate with its natural frequency under the influence of another vibrating body with the same frequency is called resonance.

Standing Waves on a String

(1) Consider a string of length l, stretched under tension T between two fixed points.

(2) If the string is plucked and then released, a transverse harmonic wave propagate along it's length and is reflected at the end.

(3) The incident and reflected waves will superimpose to produce transverse stationary waves in a string.

(4) Nodes (N) are formed at rigid end and antinodes (A) are formed in between them.

(5) Number of antinodes = Number of nodes – 1

(6) Velocity of wave (incident or reflected wave) is given by $v = \sqrt{\frac{T}{m}}$; m = Mass per unit length of the wire

(7) Frequency of vibration (n) = Frequency of wave

$$= \frac{v}{\lambda} = \frac{1}{\lambda}\sqrt{\frac{T}{m}}$$

(8) For obtaining p loops (p-segments) in string, it has to be plucked at a distance $\frac{l}{2p}$ from one fixed end.

(9) **Fundamental mode of vibration**

(i) Number of loops $p = 1$

(ii) Plucking at $\frac{l}{2}$

(from one fixed end)

(iii) $l = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2l$

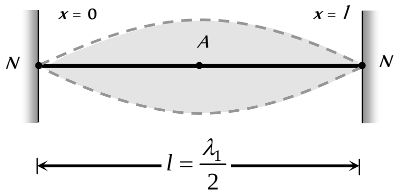


Fig. 17.23

(iv) Fundamental frequency or first harmonic

$$n_1 = \frac{1}{\lambda_1}\sqrt{\frac{T}{m}} = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

(10) **Second mode of vibration** (First over tone or second harmonic)

(i) Number of loops $p = 2$

(ii) Plucking at $\frac{l}{2 \times 2} = \frac{l}{4}$

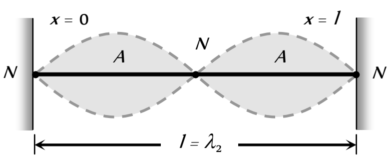


Fig. 17.24

(from one fixed end)

(iii) $l = \lambda_2$

(iv) Second harmonic or first over tone

$$n_2 = \frac{1}{\lambda_2}\sqrt{\frac{T}{m}} = \frac{1}{l}\sqrt{\frac{T}{m}} = 2n_1$$

(11) **Third normal mode of vibration** (Second over tone or third harmonic)

(i) Number of loops $p = 3$

(ii) Plucking at $\frac{l}{2 \times 3} = \frac{l}{6}$

(from one fixed end)

(iii) $l = \frac{3\lambda_3}{2} \Rightarrow \lambda_3 = \frac{2l}{3}$

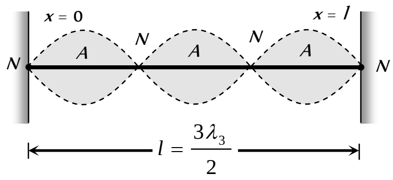


Fig. 17.25

(iv) Third harmonic or second over tone

$$n_3 = \frac{1}{\lambda_3}\sqrt{\frac{T}{m}} = \frac{3}{2l}\sqrt{\frac{T}{m}} = 3n_1$$

(12) **More about string vibration**

(i) In general, if the string is plucked at length $\frac{l}{2p}$, then it vibrates in p segments (loops) and we have the p harmonic is give $f_p = \frac{p}{2l}\sqrt{\frac{T}{m}}$

(ii) All even and odd harmonics are present. Ratio of harmonic = 1 : 2 : 3 .....

(iii) Ratio of over tones = 2 : 3 : 4 ....

(iv) General formula for wavelength $\lambda = \frac{2l}{N}$; where N = 1,2,3, ... correspond to 1st, 2nd, 3rd modes of vibration of the string.

(v) General formula for frequency $n = N \times \frac{v}{2l}$

(vi) **Position of nodes :** $x = 0, \frac{l}{N}, \frac{2l}{N}, \frac{3l}{N} ..... l$

(vii) **Position of antinodes :** $x = \frac{l}{2N}, \frac{3l}{2N}, \frac{5l}{2N} .... \frac{(2N-1)l}{2N}$

Melde's Experiment

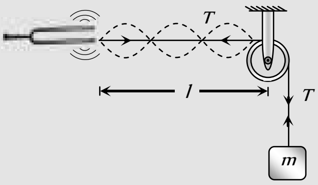
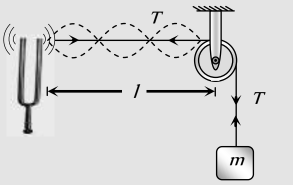
(1) It is an experimental representation of transverse stationary wave.

(2) In Melde's experiment, one end of a flexible piece of string is tied to the end of a tuning fork. The other end passes over a smooth pulley carries a suitable load.

(3) If p is the number of loop's formed in stretched string and T is the tension in the string then Melde's law is $p\sqrt{T}$ = constant

$$\Rightarrow \frac{p_1}{p_2} = \sqrt{\frac{T_2}{T_1}}$$ (For comparing two cases)

Table 17.5 ; Two arrangements of connecting a string to turning fork

Transversely	Example
	
Prongs of tuning fork vibrates at right angles to the thread.	Prongs vibrated along the length of the thread.
Frequency of vibration of turning fork : frequency of vibration of the thread.	Frequency of turning fork =2 × (Frequency of vibration of thread)
If number of loops in string is P then $l = \frac{p\lambda}{2} \Rightarrow \lambda = \frac{2l}{p}$	It number of loop so in string is p then $l = \frac{p\lambda}{2} \Rightarrow \lambda = \frac{2l}{p}$
$\Rightarrow$ Frequency of string $= \frac{v}{\lambda} = \frac{p}{2l}\sqrt{\frac{T}{m}}$ $\left(\because v = \sqrt{\frac{T}{m}}\right)$	$\Rightarrow$ Frequency of string $= \frac{v}{\lambda} = \frac{p}{2l}\sqrt{\frac{T}{m}}$
$\Rightarrow$ Frequency of tuning fork $= \frac{p}{2l}\sqrt{\frac{T}{m}}$	$\Rightarrow$ Frequency of turning fork $I = \frac{P}{l}\sqrt{\frac{T}{m}}$
$\Rightarrow$ If $l, m, n \rightarrow$ constant then $p\sqrt{T}$ = constant	$\Rightarrow$ If $l, m, n \rightarrow$ constant then $p\sqrt{T}$ = constant

Sonometer

(1) It is an apparatus, used to produce resonance (matching frequency) of tuning fork (or any source of sound) with stretched vibrating string.

(2) It consists of a hollow rectangular box of light wood. The experimental fitted on the box as shown.

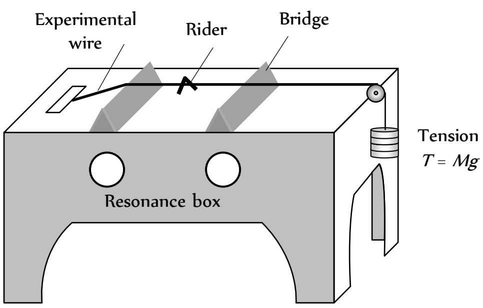


Fig. 17.26

(3) The box serves the purpose of increasing the loudness of the sound produced by the vibrating wire.

(4) If the length of the wire between the two bridges is l, then the frequency of vibration is $n = \frac{1}{2l}\sqrt{\frac{T}{m}} = \sqrt{\frac{T}{\pi r^2 d}}$

(r = Radius of the wire, d = Density of material of wire) m = mass per unit length of the wire)

(5) **Resonance :** When a vibrating tuning fork is placed on the box, and if the length between the bridges is properly adjusted then if $(n)_{Fork} = (n)_{String} \rightarrow$ rider is thrown off the wire.

(6) **Laws of string**

(i) **Law of length :** If T and m are constant then $n \propto \frac{1}{l}$

$\Rightarrow nl$ = constant $\Rightarrow n_1 l_1 = n_2 l_2$

(ii) **Law of mass :** If T and l are constant then $n \propto \frac{1}{\sqrt{m}}$

$\Rightarrow n\sqrt{m}$ = constant $\Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{m_2}{m_1}}$

(iii) **Law of density :** If T, l and r are constant then $n \propto \frac{1}{\sqrt{d}}$

$\Rightarrow n\sqrt{d}$ = constant $\Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{d_2}{d_1}}$

(iv) **Law of tension :** If l and m are constant then $n \propto \sqrt{T}$

$\Rightarrow \frac{n}{\sqrt{T}}$ = constant $\Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_2}{T_1}}$

Vibration of Composite Strings

Suppose two strings of different material and lengths are joined end to end and tied between clamps as shown. Now after plucking, stationary waves are established only at those frequencies which matches with any one harmonic of both the independent string S_1 and S_2

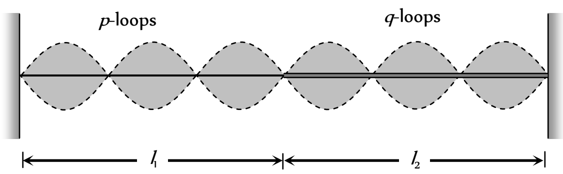


Fig. 17.27

As the frequency of the wave in both strings must be same so

$$\frac{p}{2l_1}\sqrt{\frac{T}{m_1}} = \frac{q}{2l_2}\sqrt{\frac{T}{m_2}} \Rightarrow \frac{p}{q} = \frac{l_1}{l_2}\sqrt{\frac{m_1}{m_2}} = \frac{l_1}{l_2}\sqrt{\frac{\rho_1}{\rho_2}}$$

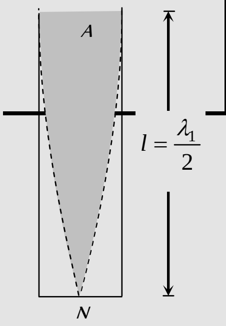
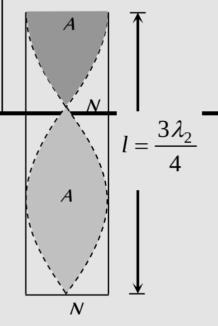
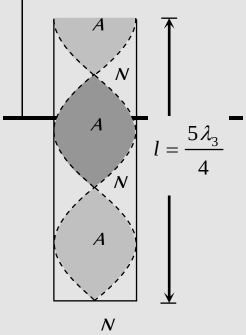
Standing Wave in a Organ Pipe

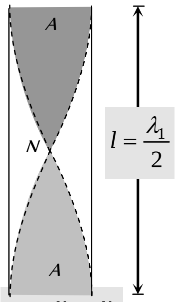
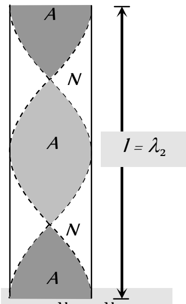
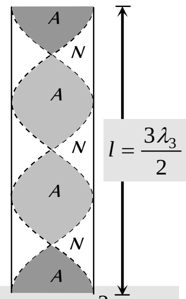
Organ pipes are the musical instrument which are used for producing musical sound by blowing air into the pipe. Longitudinal stationary waves are formed on account of superimposition of incident and reflected longitudinal waves.

Equation of standing wave y = $2a \cos\frac{2\pi vt}{\lambda}\sin\frac{2\pi x}{\lambda}$

Frequency of vibration $n = \frac{v}{\lambda}$

Table 17.6 : Different mode of vibration in organ pipe

Closed organ pipe		
Fundamental mode	Third harmonic First over tone	Fifth harmonic Second over tone
		

$n_1 = \frac{v}{4l}$	$n_2 = \frac{v}{\lambda_2} = \frac{3v}{4l} = 3n_1$	$n_3 = \frac{5v}{4l} = 5n_1$
Open organ pipe		
Fundamental mode	**Second harmonic**	**Third harmonic**
 $l = \frac{\lambda_1}{2}$	 $l = \lambda_2$	 $l = \frac{3\lambda_3}{2}$
$n_1 = \frac{v}{\lambda_1} = \frac{v}{2l}$	$n_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2n_1$	$n_3 = \frac{v}{\lambda_3} = \frac{3v}{2l} = 3n_1$

(1) **Closed organ pipe**

(i) In closed organ pipe only odd harmonic are present. Ratio of harmonic is $n_1 : n_2 : n_3$ ....= 1 : 3 : 5 ....

(ii) p^{th} overtone = $(2p + 1)^{th}$ harmonics

(iii) Ratio of overtones = 3 : 5 : 7 ....

(iv) The maximum possible wavelength is $4l$

(v) General formula for wavelength is $\lambda = \frac{4l}{(2N-1)}$; where N = 1, 2, 3, ... corresponds to order of mode of vibration.

(vi) General formula for frequency $n = \frac{(2N-1)v}{4l}$

(vii) Position of nodes from closed end $x = 0, \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}$.....

(viii) Position of antinodes from closed end $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$...

(2) **Open organ pipe**

(i) In open organ pipe all (even and odd) harmonic are present. Ratio of harmonic is $n_1 : n_2 : n_3$ ....= 1 : 2 : 3 ....

(ii) p^{th} overtone = $(p + 1)^{th}$ harmonics

(iii) Ratio of overtones = 2 : 3 : 5 ....

(iv) The maximum possible wavelength is $2l$

(v) General formula for wavelength is $\lambda = \frac{2l}{N}$; where N = 1, 2, 3, ... corresponds to order of mode of vibration.

(vi) General formula for frequency $n = \frac{Nv}{2l}$

(vii) Position of nodes from one end $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$.....

(viii) Position of antinodes from one end $x = 0, \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}$.....

Tuning Fork

(1) The tuning fork is a metallic device that produces sound of a single frequency.

(2) A tuning fork is really a transversely vibrating rod of rectangular cross-section bent into the shape of U as shown.

(3) The prongs execute transverse vibrations and the stem executes the longitudinal vibration. Both vibrate with the same frequency.

(4) The phase difference between the vibrations produced by both prongs of tuning fork is zero.

Fig. 17.28

(5) Tuning forks are generally taken as the standards of frequency of pure notes.

The frequency of the tuning fork is given by $n \propto \frac{t}{l^2}.\sqrt{\frac{Y}{\rho}}$

where t = Thickness of the prongs, l = Length of the prongs, Y = Young's modulus of elasticity and ρ = Density of the material of tuning fork.

(6) If one prong is broken tuning fork does not vibrate.

Effect on frequency of tuning fork

(i) A fork of shorter prongs gives high frequency tone

(ii) The frequency of a tuning fork decreases when it's prongs are loaded (say with wax) near the end.

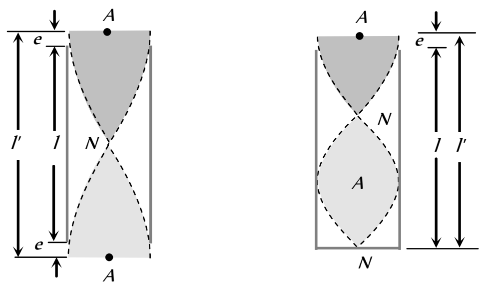
(iii) The frequency of tuning fork increases when prongs are filed near the ends.

(iv) The frequency of a tuning fork decreases if temperature of the fork is increases.

End Correction

Due to finite momentum of air molecules in organ pipe reflection takes place not exactly at open end but some what above it. Hence antinode is not formed exactly at the open end rater it is formed at a little distance away from open end outside it.

The distance of antinode from the open end is known as end correction (e). It is given by e = 0.6 r where r = radius of pipe.



(A) Open pipe (B) Closed pipe

Fig. 17.29

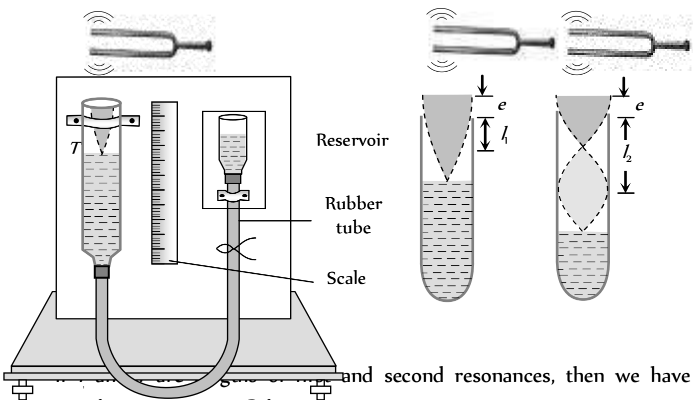
Effect length in open organ pipe $l' = (l + 2e)$

Effect length in closed organ pipe l = (l + e)

Resonance Tube

It is used to determine velocity of sound in air by the help of a tuning fork of known frequency.

It is a closed organ pipe having an air column of variable length. When a tuning fork is brought over it's mouth. It's air column vibrates with the frequency of the fork. If the length of the air column is varied until it's natural frequency equals the frequency of the fork, then the column resonants and emits a loud note.



...and second resonances, then we have

$l_1 + e = \frac{\lambda}{4}$ and $l_2 + e = \frac{3\lambda}{4}$

Fig. 17.30

$$\Rightarrow l_2 - l_1 = \frac{\lambda}{2} \Rightarrow \lambda = 2(l_2 - l_1)$$

Speed of sound in air at room (temperature) $v = n\lambda = 2n(l_2 - l_1)$

Also $\frac{l_2 + e}{l_1 + e} = 3 \Rightarrow l_2 = 3l_1 + 2e$ *i.e.* second resonance is obtained at length more than thrice the length of first resonance.

Kundt's Tube

The apparatus consists of a long glass tube about 5 *cm* in diameter, fixed horizontally. A metal rod *R* clamped firmly at the centre is mounted so that its one end carrying a light disc P_1 (of cork or card board) projects some distance into the glass tube. The other end of the glass tube is closed with a moveable piston P_2. Any desired length of the air or gas can be enclosed in between the two discs P_1 and P_2. A small amount of dry lycopodium powder or cork dust is spread along base of the entire length of the tube.

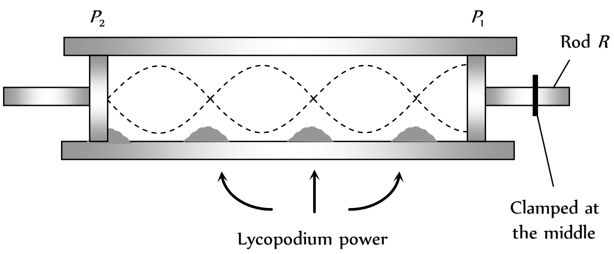


Fig. 17.31

The free end of the metal rod *R* is rubbed (stroked) along the length with resined cloth. The rod begins to vibrate longitudinally and emits a very high pitched shrill note. These vibrations are impressed upon the air column in the tube through disc P_1. Let disc P_2 is so adjusted, that the stationary waves are formed in the air (gas) column in the tube. At antinodes powder is set into oscillations vigorously while it remains uneffected at nodes. Heaps of power are formed at nodes.

Let n is the frequency of vibration of the rod then, this is also the frequency of sound wave in the air column in the tube.

For rod : $\frac{\lambda_{rod}}{2} = l_{rod}$, For air : $\frac{\lambda_{air}}{2} = l_{air}$

where l is the distance between two heaps of power in the tube (*i.e.* distance between two nodes). If v_{air} and v_{rod} are velocity of sound waves in the air and rod respectively, then

$$n = \frac{v_{air}}{\lambda_{air}} = \frac{v_{rod}}{\lambda_{rod}} . \text{ Therefore } \frac{v_{air}}{v_{rod}} = \frac{\lambda_{air}}{\lambda_{rod}} = \frac{\lambda_{air}}{\lambda_{rod}}$$

Thus knowledge of v_{rod}, determiens v_{air}

Kundt's tube may be used for

(i) Comparison of velocities of sound in different gases.

(ii) Comparison of velocities of sound in different solids

(iii) Comparison of velocities of sound in a solid and in a gas.

(iv) Comparison of density of two gases.

(v) Determination of γ of a gas.

(vi) Determination of velocity of sound in a liquid.

Beats

When two sound waves of slightly different frequencies, travelling in a medium along the same direction, superimpose on each other, the intensity of the resultant sound at a particular position rises and falls regularly with time. This phenomenon of regular variation in intensity of sound with time at a particular position is called beats.

(1) **Persistence of hearing :** The impression of sound heard by our ears persist in our mind for $1/10^{th}$ of a second. If another sound is heard before 1/10 second is over, the impression of the two sound mix up and our mind cannot distinguish between the two.

So for the formation of distinct beats, frequencies of two sources of sound should be nearly equal (difference of frequencies less than 10)

(2) **Equation of beats :** If two waves of equal amplitudes '*a*' and slightly different frequencies n_1 and n_2 travelling in a medium in the same direction are.

$y_1 = a \sin \omega_1 t = a \sin 2\pi n_1 t$; $y_2 = a \sin \omega_2 t = a \sin 2\pi n_2 t$

By the principle of super position : $\vec{y} = \vec{y_1} + \vec{y_2}$

$y = A \sin \pi(n_1 + n_2)t$ where $A = 2a \cos \pi (n_1 - n_2)t$ = Amplitude of resultant wave.

(3) **One beat :** If the intensity of sound is maximum at time $t = 0$, one beat is said to be formed when intensity becomes maximum again after becoming minimum once in between.

(4) **Beat period :** The time interval between two successive beats (*i.e.* two successive maxima of sound) is called beat period.

$$n = n_1 \sim n_2$$

(5) **Beat frequency :** The number of beats produced per second is called beat frequency.

$$T = \frac{1}{\text{Beat frequency}} = \frac{1}{n_1 \sim n_2}$$

Determination of Unknown Frequency

Suppose a tuning fork of known frequency (n) is sounded together with another tuning fork of unknown frequency (n) and x beats heard per second.

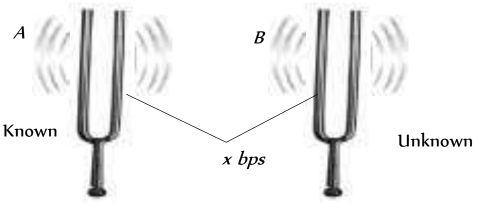


Fig. 17.32

There are two possibilities for known frequency of unknown tuning fork.

$$n_A - n_B = x \quad \text{... (i)}$$

or $$n_B - n_A = x \quad \text{... (ii)}$$

To find the frequency of unknown tuning fork (n) following steps are taken.

(1) Loading or filing of one prong of known or unknown (by wax) tuning fork, so frequency changes (decreases after loading, increases after filing).

(2) Sound them together again, and count the number of heard beats per sec again, let it be x'. These are following four condition arises.

(i) $x' > x$ (ii) $x' < x$ (iii) $x' = 0$ (iv) $x' = x$

(3) With the above information, the exact frequency of the unknown tuning fork can be determined as illustrated below.

Suppose two tuning forks A (frequency n_A is known) and B (frequency n_B is unknown) are sounded together and gives x *beats/sec*. If one prong of unknown tuning fork B is loaded with a little wax (so n_B decreases) and it is sounded again together with known tuning fork A, then in the following four given condition n_B can be determined.

(4) If $x' > x$ than x, then this would happen only when the new frequency of B is more away from n_A. This would happen if originally (before loading), n_B was less than n_A.

Thus initially $n_B = n_A - x$.

(5) If $x' < x$ than x, then this would happen only when the new frequency of B is more nearer to n_A. This would happen if originally (before loading), n_B was more than n_A.

Thus initially $n_B = n_A + x$.

(6) If $x' = x$ then this would means that the new frequency (after loading) differs from n_A by the same amount as was the old frequency (before loading). This means initially $n_B = n_A + x$

(and now it has decreased to $n'_B = n_A - x$)

(7) If $x' = 0$, then this would happen only when the new frequency of B becomes equal to n_A. This would happen if originally n_B was more than n_A.

Thus initially $n_B = n_A + x$.

Table 17.7 ; Frequency of unknown tuning fork for various cases

By loading	
If B is loaded with wax so its frequency decreases	If A is loaded with wax its frequency decreases
If x increases $n_B = n_A - x$	If x increases $n_B = n_A + x$
If x decrease $n_B = n_A + x$	If x decrease $n_B = n_A - x$
If remains same $n_B = n_A + x$	If remains same $n_B = n_A - x$
If x becomes zero $n_B = n_A + x$	If x becomes zero $n_B = n_A - x$
By filing	
If B is filed, its frequency increases	**If A is filed, its frequency increases**
If x increases $n_B = n_A + x$	If x increases $n_B = n_A - x$
If x decrease $n_B = n_A - x$	If x decrease $n_B = n_A + x$
If remains same $n_B = n_A - x$	If remains same $n_B = n_A + x$
If x becomes zero $n_B = n_A - x$	If x becomes zero $n_B = n_A + x$

Doppler's Effect

Whenever there is a relative motion between a source of sound and the observer (listener), the frequency of sound heard by the observer is different from the actual frequency of sound emitted by the source.

The frequency observed by the observer is called the apparent frequency. It may be less than or greater than the actual frequency emitted by the sound source. The difference depends on the relative motion between the source and observer.

(1) **When observer and source are stationary**

(i) Sound waves propagate in the form of spherical wavefronts (shown as circles)

(ii) The distance between two successive circles is equal to wavelength λ.

(iii) Number of waves crossing the observer = Number of waves emitted by the source

(iv) Thus apparent frequency (n') = actual frequency (n).

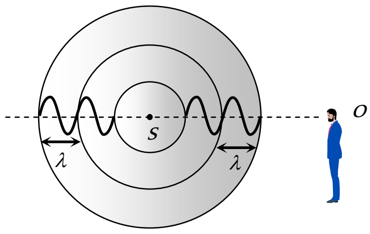


Fig. 17.33

(2) **When source is moving but observer is at rest**

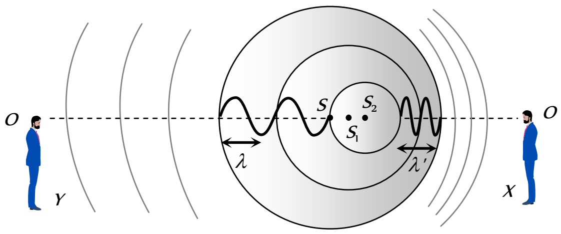


Fig. 17.34

(i) S_1, S_2, S_3 are the positions of the source at three different positions.

(ii) Waves are represented by non-concentric circles, they appear compressed in the forward direction and spread out in backward direction.

(iii) For observer (X)

Apparent wavelength $\lambda' <$ Actual wavelength λ

$\Rightarrow$ Apparent frequency n' > Actual frequency n

For observer (Y) : $\lambda' > \lambda \Rightarrow n' < n$

(3) **When source is stationary but observer is moving**

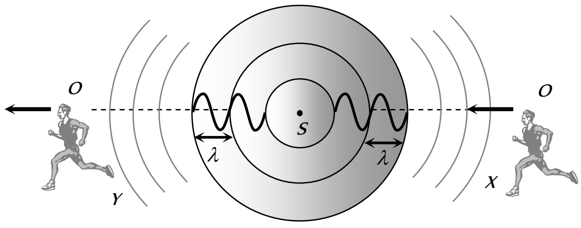


Fig. 17.35

(i) Waves are again represented by concentric circles.

(ii) No change in wavelength received by either observer X or Y.

(iii) Observer X (moving towards) receives wave fronts at shorter interval thus $n' > n$.

(iv) Observer Y receives wavelengths at longer interval thus $n' < n$.

(4) **General expression for apparent frequency** : Suppose observed (O) and source (S) are moving in the same direction along a line with velocities v_o and v_s respectively. Velocity of sound is v and velocity of medium is v_m then apparent frequency observed by observer is given by $n' = \left[\frac{(v + v_m) - v_0}{(v + v_m) - v_S}\right] n$

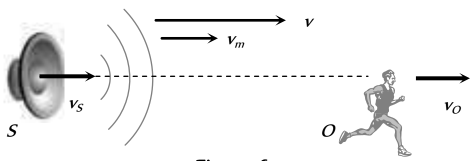


Fig. 17.36

If medium is stationary *i.e.* $v_m = 0$ then $n' = n\left(\frac{v - v_O}{v - v_S}\right)$

Sign convection for different situation

(i) The direction of v is always taken from source to observer.

(ii) All the velocities in the direction of v are taken positive.

(iii) All the velocities in the opposite direction of v are taken negative.

Common Cases in Doppler's Effect

Case 1 : **Source is moving but observer at rest.**

(1) Source is moving towards the observer

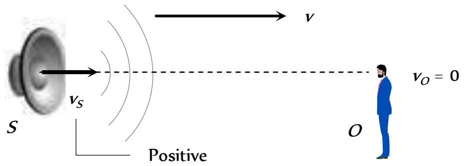


Fig. 17.37

Apparent frequency $n' = n\left[\frac{v - 0}{v - (+v_S)}\right] = n\left(\frac{v}{v - v_S}\right)$

Apparent wavelength $\lambda' = \lambda\left(\frac{v - v_S}{v}\right)$

(2) Source is moving away from the observer.

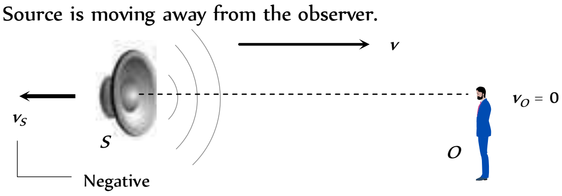


Fig. 17.38

Apparent frequency $n' = n\left[\frac{v - 0}{v - (-v_S)}\right] = n\left(\frac{v}{v + v_S}\right)$

Apparent wavelength $\lambda' = \lambda\left(\frac{v + v_S}{v}\right)$

Case **2: Source is at rest but observer is moving.**

(1) Observer is moving towards the source.

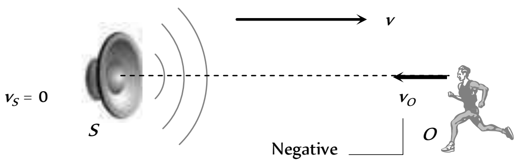


Fig. 17.39

Apparent frequency $n' = n\left[\frac{v - (-v_O)}{v - 0}\right] = n\left[\frac{v + v_O}{v}\right]$

Apparent wavelength $\lambda' = \frac{(v + v_O)}{n'} = \frac{(v + v_O)}{n\frac{(v + v_O)}{v}} = \frac{v}{n} = \lambda$

(2) Observer is moving away from the source

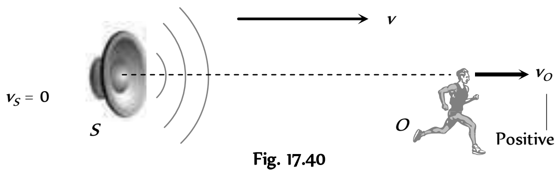


Fig. 17.40

Apparent frequency $n' = n\left[\frac{v - (+v_O)}{v - 0}\right] = n\left[\frac{v - v_O}{v}\right]$

Apparent wavelength $\lambda' = \lambda$

Case **3: When source and observer both are moving**

(1) When both are moving towards each other

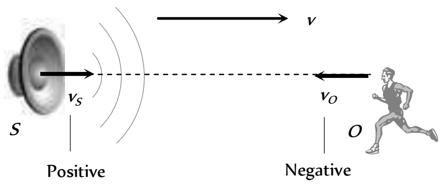


Fig. 17.41

(i) Apparent frequency $n' = n\left[\frac{v - (-v_O)}{v - (+v_S)}\right] = n\left[\frac{v + v_O}{v - v_S}\right]$

(ii) Apparent wavelength $\lambda' = \lambda\left(\frac{v - v_S}{v}\right)$

(iii) Velocity of wave with respect to observer $= (v + v_O)$

(2) When both are moving away from each other.

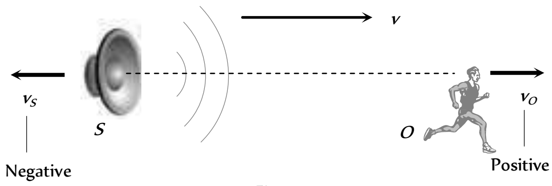


Fig. 17.42

(i) Apparent frequency $n' = n\left[\dfrac{v-(+v_O)}{v-(-v_S)}\right] = n\left[\dfrac{v-v_O}{v+v_S}\right]$

$(n' < n)$

(ii) Apparent wavelength $\lambda' = \lambda\left(\dfrac{v+v_S}{v}\right)$

$(\lambda' > \lambda)$

Velocity of waves with respect to observer = $(v - v)$

(3) When source is moving behind observer

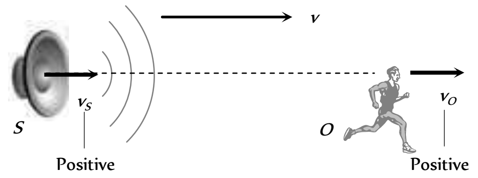


Fig. 17.43

(i) Apparent frequency $n' = n\left(\dfrac{v-v_O}{v-v_S}\right)$

(a) If $v_O < v_S$, then $n' > n$

(b) If $v_O > v_S$ then $n' < n$

(c) If $v_O = v_S$ then $n' = n$

(ii) Apparent wavelength $\lambda' = \lambda\left(\dfrac{v-v_S}{v}\right)$

(iii) Velocity of waves with respect to observer = $(v - v_O)$

(4) When observer is moving behind the source

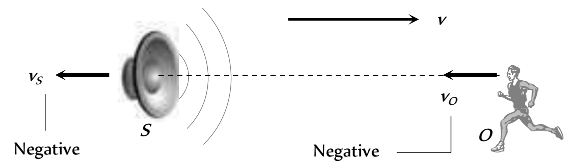


Fig. 17.44

(i) Apparent frequency $n' = n\left(\dfrac{v-(-v_O)}{v-(-v_S)}\right)$

(a) If $v_O > v_S$, then $n' > n$

(b) If $v_O < v_S$ then $n' < n$

(c) If $v_O = v_S$ then $n' = n$

(ii) Apparent wavelength $\lambda' = \lambda\left(\dfrac{v+v_S}{v}\right)$

(iii) The velocity of waves with respect to observer = $(v + v_O)$

***Case* 4: Crossing**

(1) Moving sound source crosses a stationary observer

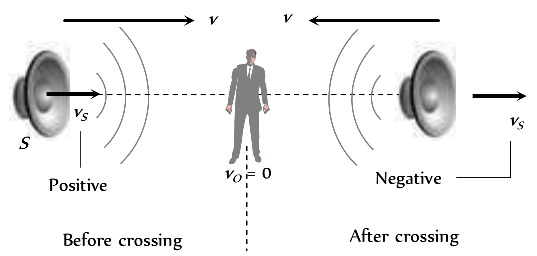


Fig. 17.45

Apparent frequency before crossing

$$n'_{Before} = n\left[\frac{v-0}{v-(+v_S)}\right] = n\left[\frac{v}{v-v_S}\right]$$

Apparent frequency

$$n'_{After} = n\left[\frac{v-0}{v-(-v_S)}\right] = n\left[\frac{v}{v+v_S}\right]$$

Ratio of two frequency $\dfrac{n'_{Before}}{n'_{After}} = \left[\dfrac{v+v_S}{v-v_S}\right] > 1$

Change in apparent frequency $n'_{Before} - n'_{After} = \dfrac{2nv_S v}{(v^2 - v_S^2)}$

If $v_S << v$ then $n'_{Before} - n'_{After} = \dfrac{2nv_S}{v}$

(2) **Moving observer crosses a stationary source**

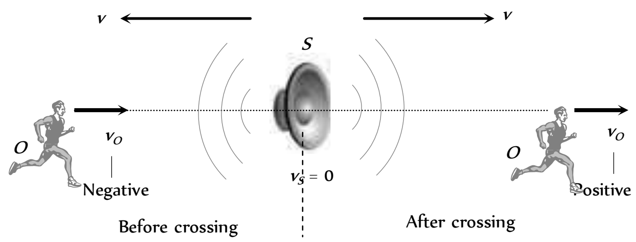


Fig. 17.46

Apparent frequency before crossing

$$n'_{Before} = n\left[\frac{v-(-v_O)}{v-0}\right] = n\left[\frac{v+v_O}{v}\right]$$

Apparent frequency

$$n'_{After} = n\left[\frac{v-(+v_O)}{v-0}\right] = n\left[\frac{v-v_O}{v}\right]$$

Ratio of two frequency $\dfrac{n'_{Before}}{n'_{After}} = \left[\dfrac{v+v_S}{v-v_S}\right]$

Change in apparent frequency $n'_{Before} - n'_{After} = \dfrac{2nv_O}{v}$

***Case* 5:** Both moves in the same direction with same velocity $n' = n$, *i.e.* there will be no Doppler effect because relative motion between source and listener is zero.

***Case* 6:** Source and listener moves at right angle to the direction of wave propagation. $n' = n$

It means there is no change in frequency of sound heard if there is a small displacement of source and listener at right angle to the direction of wave propagation but for a large displacement the frequency decreases because the distance between source of sound and listener increases.

Some Typical Cases of Doppler's Effect

(1) **Moving car towards wall :** When a car is moving towards a stationary wall as shown in figure. If the car sounds a horn, wave travels toward the wall and is reflected from the wall. When the reflected wave is

heard by the driver, it appears to be of relatively high pitch. If we wish to measure the frequency of reflected sound then the problem.

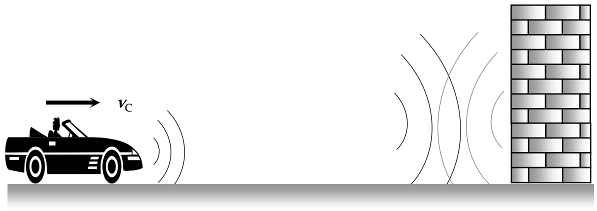


Fig. 17.47

Can be solved in a different manner by using method of sound images. In this procedure we assume the image of the sound source behind the reflector.

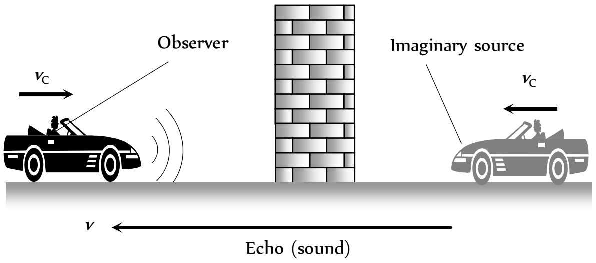


Fig. 17.48

Here we assume that the sound which is reflected by the stationary wall is coming from the image of car which is at the back of it and coming toward it with velocity v_c. Now the frequency of sound heard by car driver can directly be given as

$$n' = n\left[\frac{v-(-v_C)}{v-(+v_C)}\right] = n\left[\frac{v+v_C}{v-v_C}\right]$$

This method of images for solving problems of Doppler effect is very convenient but is used only for velocities of source and observer which are very small compared to the speed of sound and it should not be used frequently when the reflector of sound is moving.

(2) **Moving target :** Let a sound source S and observer O are at rest (stationary). The frequency of sound emitted by the source is n and velocity of waves is v.

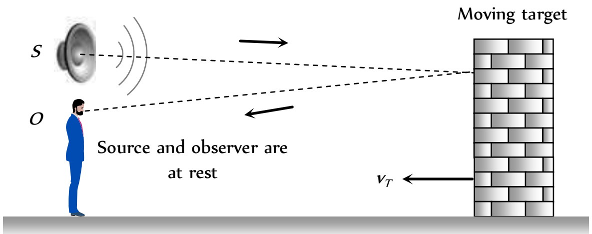


Fig. 17.49

A target is moving towards the source and observer, with a velocity v_t. Our aim is to find out the frequency observed by the observer, for the waves reaching it after reflection from the moving target. The formula is derived by applying Doppler equations twice, first with the target as observer and then with the target as source.

The frequency n' of the waves reaching surface of the moving target (treating it as observer) will be $n' = \left(\frac{v+v_T}{v}\right)n$

Now these waves are reflected by the moving target (which now acts as a source). Therefore the apparent frequency, for the real observer O will be $n'' = \frac{v}{v-v_T}n' \Rightarrow n'' = \frac{v+v_T}{v-v_T}n$

(i) If the target is moving away from the observer, then

$$n' = \frac{v-v_T}{v+v_T}n$$

(ii) If target velocity is much less than the speed of sound, $(v_T << v)$, then $n' = \left(1+\frac{2v_T}{v}\right)n$, for approaching target

and $n' = \left(1-\frac{2v_T}{v}\right)n$, for receding target

(3) **Transverse Doppler's effect**

(i) If a source is moving in a direction making an angle θ *w.r.t.* the observer

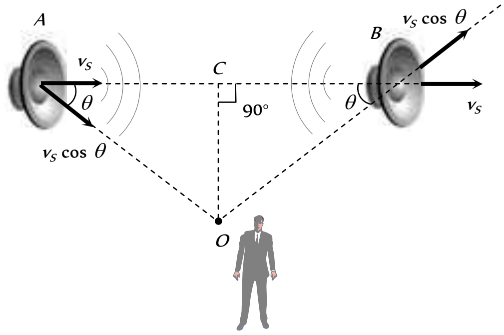


Fig. 17.50

The apparent frequency heard by observer O at rest

At point A : $n' = \dfrac{nv}{v-v_S\cos\theta}$

As source moves along AB, value of θ increases, $\cos\theta$ decreases, n' goes on decreasing.

At point C : $\theta = 90^o$, $\cos\theta = \cos 90^o = 0$, $n' = n$.

At point B : the apparent frequency of sound becomes

$$n'' = \frac{nv}{v+v_s\cos\theta}$$

(ii) When two cars are moving on perpendicular roads : When car-1 sounds a horn of frequency n, the apparent frequency of sound heard by car-2 can be given as $n' = n\left[\frac{v+v_2\cos\theta_2}{v-v_1\cos\theta_1}\right]$

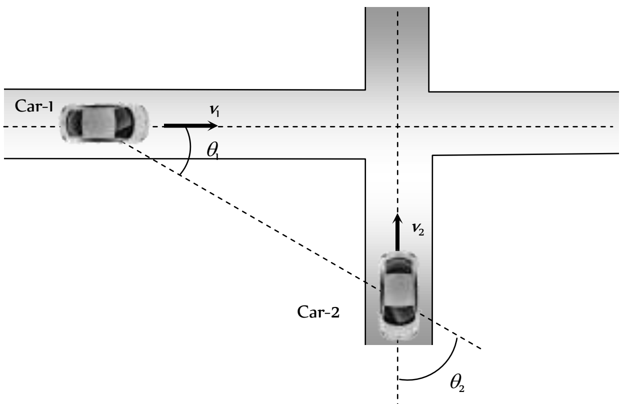


Fig. 17.51

(4) **Rotating source/observer :** Suppose that a source of sound/observer is rotating in a circle of radius r with angular velocity ω (Linear velocity $v_s = r\omega$)

(i) **When source is rotating**

(a) Towards the observer heard frequency will be maximum

i.e. $n_{max} = \frac{nv}{v - v_S}$

(b) Away from the observer heard frequency will be minimum

and $n_{min} = \frac{nv}{v + v_S}$

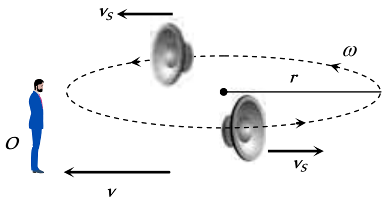


Fig. 17.52

(c) Ratio of maximum and minimum frequency

$$\frac{n_{max}}{n_{min}} = \frac{v + v_S}{v - v_S}$$

(ii) **When observer is rotating**

(a) Towards the source heard frequency will be maximum

i.e. $n_{max} = \frac{nv}{v - v_S}$

(b) Away from the source heard frequency will be minimum

and $n_{min} = \frac{nv}{v + v_S}$

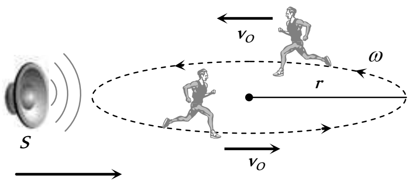


Fig. 17.53

(c) Ratio of maximum and minimum frequency

$$\frac{n_{max}}{n_{min}} = \frac{v + v_S}{v - v_S}$$

(iii) **Observer is situated at the centre of circle :** There will be no change in frequency of sound heard, if the source is situated at the centre of the circle along which listener is moving..

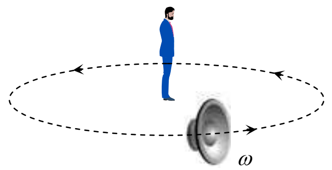


Fig. 17.54

(5) **SONAR :** Sonar means Sound Navigation and Ranging.

(i) Ultrasonic waves are used to detect the presence of big rocks, submarines *etc* in the sea.

(ii) The waves emitted by a source are reflected by the target and received back at the SONAR station.

(iii) If v is velocity of sound waves in water and v_{sub} is velocity of target (submarine), the apparent frequency of reflected waves will be $n' = \left(1 \pm \frac{2v_{sub}}{v}\right)n$

+ sign is for target approaching the receiver and – sign for target moving away.

Conditions for No Doppler's Effect

(1) When source (S) and listener (L) both are at rest.

(2) When medium alone is moving.

(3) When S and L move in such a way that distance between S and L remains constant.

(4) When source S and listener L, are moving in mutually perpendicular directions.

(5) If the velocity of source and listener is equal to or greater than the sound velocity then Doppler effect is not seen.

Musical Sound

other rapidly at regular interval of time without a sudden change in amplitude.

(1) **Noise :** A noise consists of a series of waves following each other at irregular intervals of time with sudden changes in amplitude.

(2) **Pitch :** The pitch of a sound is the characteristic which distinguishes between a shrill (or sharp) sound and a grave (or flat) sound.

(i) A sound of high pitch is said to be shrill and it's frequency is high.

(ii) A sound of low pitch is said to be grave and it's frequency is low.

(iii) The pitch of female voice is higher than the pitch of male voice.

(iv) The pitch of sound produced by roaring of lion is lower where as the pitch of sound produced by mosquito whisper is high.

(3) **Quality (or timbre) :** A musical instrument vibrates with many frequencies at the same time. The quality of any musical sound is determined by the number of overtones and their relative intensities.

(i) The quality of sound enables us to distinguish between two sounds having same intensity and pitch.

(ii) The sounds of different instruments (such as Tabla and Mridang) are said to differ in quality.

(iii) Due to quality of sound one can recognise the voice of his friend without seeing him.

(4) **Loudness :** Characteristic of sound, on account of which the sound appears to be intense or slow.

(i) The loudness that we sense is related to the intensity of sound though it is not directly proportional

(ii) The loudness depends on intensity as well as upon the sensitiveness of ear.

(iii) Our perception of loudness is better co–related with the sound level measured in decible (dB) and defined as follows $\beta = 10\log_{10}\left(\frac{I}{I_0}\right)$;

where I_0 = The minimum intensity that can be heard called threshold of hearing = 10^{-12} W/m^2 at 1 KHz.

(iv) At the threshold of hearing β = 0. At the threshold of pain $\beta = 10\log_{10}\frac{1}{10^{-2}} = 120\, dB.$

(v) When the intensity doubles, the intensity level changes by 3 dB.

(vi) When the intensity increases 10 times the level increases by 10 dB.

Table 17.8 ; Different sound intensity level

Source of sound	*dB*

Rustling leaves	10
Whisper	20
Quiet room	30
Normal level of speech (inside)	30
Street traffic (inside car)	65
Riveting tool	80
Thunder	100
Indoor rock concert	120

Interval : The ratio of the frequencies of the two notes is called the interval between them *e.g.* interval between two notes of frequencies 256 *Hz* and 512 *Hz* is 1 : 2.

Table 17.9 ; Different interval

Name of interval	Frequency ratio
Unison	1 : 1
Octave	2 : 1
Major tone	9 : 8
Minor tone	10 : 9
Semi tone	16 : 15

Musical scale : It consists of a series of notes of successively increasing frequency, having constant intervals. The note of the lowest frequency is called the key note.

These are many kinds of musical scales. The most commonly used scale is called major diatonic scale. It is formed by introducing six more notes between a given note and it's octave, so that these are eight notes in all.

Table 17.10 : Major diatonic scale

Symbol	Indian name	Western name	Frequency in the base of 256 *Hz*	Interval between successive notes
C	*SA*	*DO*	256	9/8
D	*RE*	*RE*	288	10/9
E	*GA*	*MI*	320	16/15
F	MA	*FA*	341	9/8
G	PA	SOL	384	10/9
A	*DHA*	*LA*	427	9/8
B	Ni	*SI*	480	16/15
C_1	*SA*	*DO*	512	

Accoustics of Buildings

Accounstics is the branch of physics that deals with the generation, propagation and reception of sound.

W.C. Sabine was the first to carry out the scientific study of architectural acoustics by laying down following rules.

The sound must be loud enough.

The quality of sound must be unaltered.

The successive sounds of speech or music must remain distinct.

These should not be unnecessary interference or resonance of sound in the auditorium.

These should be no echoes in the auditorium.

(1) **Reverberation :** Phenomenon of persistence or prolongation of sound in the auditorium is called reverberation.

(2) **Reverberation time :** The time gap between the initial direct note and the reflected note upto the minimum audibility level is called reverberation time.

(3) **Sabine law :** Sabine derived an expression of the reverberation time which is $t = K.\frac{V}{\alpha S}$; where *K* is constant, *V* = Volume of the hall, *S* = Surface area exposed to the sound α =Co-efficient of absorption.

(4) **Controlling the reverberation time :** It may be controlled as follows :

By hanging heavy curtains on the doors.

By having few open windows in the hall.

By having large audience.

By using absorbing materials in the walls and roofs of the hall.

Tips & Tricks

✍ In an open pipe all harmonics are present whereas in a closed organ pipe, only alternate harmonics of frequencies $n_1, 3n_1, 5n_1, ...$ *etc.* are present.

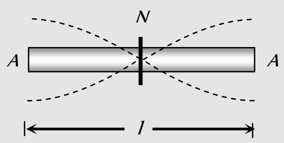
The harmonics of frequencies $2n_1, 4n_1, 6n_1....$ are missing. Hence musical sound produces by an open organ pipe is sweeter than that produced by a closed organ pipe.

✍ If an open pipe is half submerged in water, it will become a closed organ pipe of length half that of a open pipe. It's fundamental frequency will become $n' = \frac{v}{4\left(\frac{l}{2}\right)} = \frac{v}{2l} = n_1$ *i.e.,* equal to that of open pipe.

i.e., frequency remains unchanged.

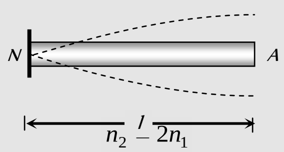
✍ **Vibrating clamped rod :** Frequency of vibration of clamped rod are same as that of organ pipes

Middle clamping : Similar to open organ pipe



$n_1 = \frac{v}{2l}$ $n_2 = 2n_1$ $n_3 = 3n_1$

End clamping : Similar to closed organ pipe



$n_1 = \frac{v}{4l}$ $n_2 = 2n_1$ $n_3 = 3n_1$

✍ Sound produced in air is not heard by the diver deep inside the water because most of the sound is reflected from the surface of water in comparison to the refraction.

✍ If the difference between the apparent frequency of a source of sound as perceived by an observer during it's approach and recession is x% of the natural frequency of source then speed of $v_s = \frac{v_{\text{sound}}}{200}x$ $(v^2 >> v_s^2)$

✍ In a Tabla, the membrane is loaded about the centre why? a note is musical when it is rich in harmonics and not partial overtones. Ordinarily a stretched membrane vibrates with such overtones. But when the stretched membrane is loaded at the centre, its overtones become nearly harmonics, so it's sound becomes fairly musical.

✍ All harmonics are overtones but all overtones are not harmonics.

✍ Stethoscope work on the principle of reflection of sound.

✍ Ultrasonic waves can be produced by utilizing piezoelectric effect.

✍ There is no atmosphere on moon, therefore propagation of sound is not possible there. To do conversation on moon, the astronaut uses an instrument which can transmit and detect electromagnetic waves.

✍ Doppler effect gives information regarding the change in frequency only. It does not says about intensity of sound.

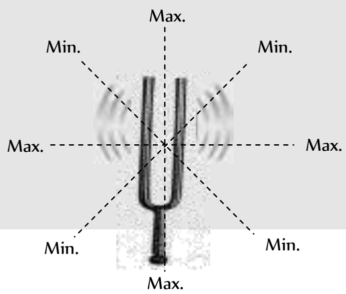
✍ Doppler effect in sound is asymmetric but in light it is symmetric.

✍ If three tuning forks of frequencies n, $n + x$ and $n + 2x$ are sounded together to produce waves of equal amplitude these three wave produces beats with beat frequency = x *beats/sec*

✍ If N tuning forks are so arranged that every fork gives x *beats per sec* with the next then the frequency of last fork will be

$$n_{\text{Last}} = n_{\text{First}} + (N - 1)\,x$$

✍ If a vibrating tuning fork is rotated about it's stem, maximum and minimum number of beats heard by an observer in one revolution of tuning fork are 4.



✍ The tuning of radio receiving set to a particular station is based on forced vibration.

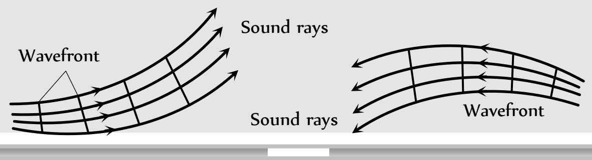
✍ Two avoid resonant vibration of the bridge, soldiers are orderd to break steps while crossing a bridge.

✍ **Confusion :** So many students often confuse whether the equation of a plan progressive wave should be

$$y = a\sin(\omega t - kx) \text{ or } y = a\sin(kx - \omega t)$$

Both the equations represent a travelling wave but these two are not same. These waves are differ by a phae difference of π.

✍ **Audibility of sound in day/night :** During the day temperature of air is maximum and it dimnished upwards. Therefore velocity of sound is also decreases upwards ($v \propto \sqrt{T}$). The plane wavefronts, initially vertical are turned, upwards so sound rays curl up during the day. At night the conditions are reversed hence audibility of sound is better in night as compare to day.



Ordinary Thinking

Objective Questions

Basics of Mechanical Waves

1. Which of the following statements is wrong [NCERT 1976, 79]
   (a) Sound travels in straight line
   (b) Sound is a form of energy
   (c) Sound travels in the form of waves
   (d) Sound travels faster in vacuum than in air

2. The relation between frequency 'n' wavelength 'λ' and velocity of propagation 'v' of wave is [EAMCET 1979; CPMT 1976, 85]
   (a) $n = v\lambda$ (b) $n = \lambda / v$
   (c) $n = v / \lambda$ (d) $n = 1 / v$

3. Ultrasonic, Infrasonic and audible waves travel through a medium with speeds V_u, V_i and V_a respectively, then

[CPMT 1989]

(a) V_u, V_i and V_a are nearly equal

(b) $V_u \geq V_a \geq V_i$

(c) $V_u \leq V_a \leq V_i$

(d) $V_a \leq V_u$ and $V_u \approx V_i$

4. The distance between two consecutive crests in a wave train produced in a string is 5 *cm*. If 2 complete waves pass through any point per second, the velocity of the wave is

[CPMT 1990]

(a) 10 *cm/sec* (b) 2.5 *cm/sec*

(c) 5 *cm/sec* (d) 15 *cm/sec*

5. A tuning fork makes 256 vibrations per second in air. When the velocity of sound is 330 *m/s*, then wavelength of the tone emitted is

MH CET 1999; CBSE PMT 1999]

(a) 0.56 *m* (b) 0.89 *m*

(c) 1.11 *m* (d) 1.29 *m*

6. A man sets his watch by a whistle that is 2 *km* away. How much will his watch be in error. (speed of sound in air 330 *m/sec*)

(a) 3 seconds fast (b) 3 seconds slow

(c) 6 seconds fast (d) 6 seconds slow

7. When a sound wave of frequency 300 *Hz* passes through a medium the maximum displacement of a particle of the medium is 0.1 *cm*. The maximum velocity of the particle is equal to [MNR 1992; UPSEAT 1998, 2000;

RPMT 2002; Pb. PET 2004]

(a) 60 π *cm/sec* (b) 30 π *cm/sec*

(c) 30 *cm/sec* (d) 60 *cm/sec*

8. Sound waves have the following frequencies that are audible to human beings [CPMT 1975]

(a) 5 *c/s* (b) 27000 *c/s*

(c) 5000 *c/s* (d) 50,000 *c/s*

9. Velocity of sound waves in air is 330 *m/sec*. For a particular sound in air, a path difference of 40 *cm* is equivalent to a phase difference of 1.6 π. The frequency of this wave is

[CBSE PMT 1990]

(a) 165 *Hz* (b) 150 *Hz*

(c) 660 *Hz* (d) 330 *Hz*

10. The wavelength of ultrasonic waves in air is of the order of

[EAMCET 1989]

(a) 5×10^{-5} *cm* (b) 5×10^{-8} *cm*

(c) 5×10^{5} *cm* (d) 5×10^{8} *cm*

11. The relation between phase difference ($\Delta\phi$) and path difference (Δx) is [MNR 1995; UPSEAT 1999, 2000]

(a) $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ (b) $\Delta\phi = 2\pi\lambda\Delta x$

(c) $\Delta\phi = \frac{2\pi\lambda}{\Delta x}$ (d) $\Delta\phi = \frac{2\Delta x}{\lambda}$

12. A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 *MHz*. The speed of sound in a tissue is 1.7 *km-s*. The wavelength of sound in the tissue is close to

[CBSE PMT 1995]

(a) $4 \times 10^{-4}\, m$ (b) $8 \times 10^{-3}\, m$

(c) $4 \times 10^{-3}\, m$ (d) $8 \times 10^{-4}\, m$

13. The minimum audible wavelength at room temperature is about

(a) 0.2 $\mathring{A}$ (b) 5 $\mathring{A}$

(c) 5 *cm* to 2 *metre* (d) 20 *mm*

14. The ratio of the speed of sound in nitrogen gas to that in helium gas, at 300 *K* is [IIT 1999]

(a) $\sqrt{2/7}$ (b) $\sqrt{1/7}$

(c) $\sqrt{3}/5$ (d) $\sqrt{6}/5$

15. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 second. The frequency of the wave is [KCET 1994; AFMC 1998;

[CBSE PMT 1998; AIIMS 2001;

AFMC 2002; CPMT 2004]

(a) 1.47 *Hz* (b) 0.36 *Hz*

(c) 0.73 *Hz* (d) 2.94 *Hz*

[MP PET 1991]

16. The number of waves contained in unit length of the medium is called [AIIMS 1998]

(a) Elastic wave (b) Wave number

(c) Wave pulse (d) Electromagnetic wave

17. The frequency of a rod is 200 *Hz*. If the velocity of sound in air is $340\, ms^{-1}$, the wavelength of the sound produced is

[EAMCET (Med.) 1995;

Pb. PMT 1999; CPMT 2000]

(a) 1.7 *cm* (b) 6.8 *cm*

(c) 1.7 *m* (d) 6.8 *m*

18. Frequency range of the audible sounds is

[EAMCET (Med.) 1995; RPMT 1997]

(a) 0 *Hz* – 30 *Hz* (b) 20 *Hz* – 20 *kHz*

(c) 20 *kHz* – 20,000 *kHz* (d) 20 *kHz* – 20 *MHz*

19. In a medium sound travels 2 *km* in 3 *sec* and in air, it travels 3 *km* in 10 *sec*. The ratio of the wavelengths of sound in the two media is

(a) 1 : 8 (b) 1 : 18

(c) 8 : 1 (d) 20 : 9

20. A stone is dropped into a lake from a tower 500 *metre* high. The sound of the splash will be heard by the man approximately after[CPMT 1992; JI

Kerala PMT 2005]

(a) 11.5 seconds (b) 21 seconds

(c) 10 seconds (d) 14 seconds

21. When sound waves travel from air to water, which of the following remains constant

[AFMC 1993; DCE 1999; CPMT 2004]

(a) Velocity (b) Frequency

(c) Wavelength (d) All the above

22. A stone is dropped in a well which is 19.6*m* deep. Echo sound is heard after 2.06 *sec* (after dropping) then the velocity of sound is

(a) 332.6 m/sec (b) 326.7 m/sec

(c) 300.4 m/sec (d) 290.5 m/sec

23. At what temperature velocity of sound is double than that of at $0°C$

(a) 819 K (b) $819°C$

(c) $600°C$ (d) 600 K

24. Velocity of sound is maximum in [AFMC 1998; BCECE 2001; RPMT 1999, 02]

(a) Air (b) Water

(c) Vacuum (d) Steel

25. If velocity of sound in a gas is 360 m/s and the distance between a compression and the nearest rarefaction is 1m, then the frequency of sound is [KCET 1999]

(a) 90 Hz (b) 180 Hz

(c) 360 Hz (d) 720 Hz

26. If the density of oxygen is 16 times that of hydrogen, what will be the ratio of their corresponding velocities of sound waves [KCET 1999]

(a) 1 : 4 (b) 4 : 1

(c) 16 : 1 (d) 1 : 16

27. At which temperature the speed of sound in hydrogen will be same as that of speed of sound in oxygen at $100°C$ [UPSEAT 1999]

(a) $-148°C$ (b) $-212.5°C$

(c) $-317.5°C$ (d) $-249.7°C$

28. A tuning fork produces waves in a medium. If the temperature of the medium changes, then which of the following will change [EAMCET (Med.) 1998; Pb. PMT 1999; MH CET 2001]

(a) Amplitude (b) Frequency

(c) Wavelength (d) Time-period

29. The wave length of light in visible part (λ_V) and for sound (λ_S) are related as [RPMT 1999]

(a) $\lambda_V > \lambda_S$ (b) $\lambda_S > \lambda_V$

(c) $\lambda_S = \lambda_V$ (d) None of these

30. Which of the following is different from others [AFMC 1994; CPMT 1999; Pb. PMT 2004]

(a) Velocity (b) Wavelength

(c) Frequency (d) Amplitude

31. The phase difference between two points separated by 1m in a wave of frequency 120 Hz is $90°$. The wave velocity is [KCET 1999]

(a) 180 m/s (b) 240 m/s

(c) 480 m/s (d) 720 m/s

32. The echo of a gun shot is heard 8 sec. after the gun is fired. How far from him is the surface that reflects the sound (velocity of sound in air = 350 m/s) [JIPMER 1999]

(a) 1400 m (b) 2800 m

(c) 700 m (d) 350 m

33. A man sets his watch by the sound of a siren placed at a distance 1 km away. If the velocity of sound is 330 m/s [JIPMER 1999]

(a) His watch is set 3 sec. faster

(b) His watch is set 3 sec. slower

(c) His watch is set correctly

(d) None of the above [RPMT 1999]

34. Velocity of sound in air is [Pb. PMT 1999; UPSEAT 2000]

(a) Faster in dry air than in moist air

(b) Directly proportional to pressure

(c) Directly proportional to temperature

(d) Independent of pressure of air

35. Two monoatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by [IIT-JEE Screening 2000]

(a) $\sqrt{\frac{m_1}{m_2}}$ (b) $\sqrt{\frac{m_2}{m_1}}$

(c) $\frac{m_1}{m_2}$ (d) $\frac{m_2}{m_1}$

36. A man is standing between two parallel cliffs and fires a gun. If he hears first and second echoes after 1.5 s and 3.5s respectively, the distance between the cliffs is (Velocity of sound in air = 340 ms^{-1}) [EAMCET (Med.) 2000]

(a) 1190 m (b) 850 m

(c) 595 m (d) 510 m

37. When the temperature of an ideal gas is increased by 600 K, the velocity of sound in the gas becomes $\sqrt{3}$ times the initial velocity in it. The initial temperature of the gas is [EAMCET (Med.) 2000]

(a) $-73°C$ (b) $27°C$

(c) $127°C$ (d) $327°C$

38. The frequency of a sound wave is n and its velocity is v. If the frequency is increased to $4n$, the velocity of the wave will be

(a) v (b) $2v$

(c) $4v$ (d) $v/4$

39. The temperature at which the speed of sound in air becomes double of its value at $27°C$ is [CPMT 1997; UPSEAT 2000; DPMT 2003]

(a) $54°C$ (b) $327°C$

(c) $927°C$ (d) $-123°C$

40. The speed of a wave in a certain medium is 960 m/s. If 3600 waves pass over a certain point of the medium in 1 minute, the wavelength is [MP PMT 2000]

(a) 2 *metres* (b) 4 *metres*

(c) 8 *metres* (d) 16 *metres*

41. Speed of sound at constant temperature depends on [RPET 2000; AIIMS 1998]

(a) Pressure (b) Density of gas

(c) Above both (d) None of the above

42. A man standing on a cliff claps his hand hears its echo after 1 *sec*. If sound is reflected from another mountain and velocity of sound in air is 340 *m/sec*. Then the distance between the man and reflection point is **[RPET 2000]**

(a) 680 *m* (b) 340 *m*

(c) 85 *m* (d) 170 *m*

43. What will be the wave velocity, if the radar gives 54 waves per min and wavelength of the given wave is 10 *m* **[RPET 2000]**

(a) 4 *m/sec* (b) 6 *m/sec*

(c) 9 *m/sec* (d) 5 *m/sec*

44. Sound velocity is maximum in **[Pb. CET 2000; RPMT 2000]**

(a) H_2 (b) N_2

(c) He (d) O_2

45. The minimum distance of reflector surface from the source for listening the echo of sound is **[CPMT 1997; RPMT 1999; KCET 2000]**

(a) 28 *m* (b) 18 *m*

(c) 19 *m* (d) 16.5 *m*

46. The type of waves that can be propagated through solid is **[CPMT 2000]**

(a) Transverse (b) Longitudinal

(c) Both (a) and (b) (d) None of these

47. A man stands in front of a hillock and fires a gun. He hears an echo after 1.5 *sec*. The distance of the hillock from the man is (velocity of sound in air is 330 *m/s*) **[EAMCET (Eng.) 1998; CPMT 2000]**

(a) 220 *m* (b) 247.5 *m*

(c) 268.5 *m* (d) 292.5 *m*

48. Velocity of sound in air

I. Increases with temperature

II. Decreases with temperature

III. Increase with pressure

IV. Is independent of pressure

V. Is independent of temperature

Choose the correct answer. **[Kerala (Engg.) 2001]**

(a) Only I and II are true (b) Only I and III are true

(c) Only II and III are true (d) Only I and IV are true

49. The speed of a wave in a medium is 760 m/s. If 3600 waves are passing through a point, in the medium in 2 minutes, then its wavelength is **[AFMC 1998; CPMT 2001]**

(a) 13.8 *m* (b) 25.3 *m*

(c) 41.5 *m* (d) 57.2 *m*

50. If at same temperature and pressure, the densities for two diatomic gases are respectively d_1 and d_2, then the ratio of velocities of sound in these gases will be **[CPMT 2001]**

(a) $\sqrt{\dfrac{d_2}{d_1}}$ (b) $\sqrt{\dfrac{d_1}{d_2}}$

(c) $d_1 d_2$ (d) $\sqrt{d_1 d_2}$

51. The frequency of a tunning fork is 384 per second and velocity of sound in air is 352 *m/s*. How far the sound has traversed while fork completes 36 vibration **[KCET 2001]**

(a) 3 *m* (b) 13 *m*

(c) 23 *m* (d) 33 *m*

52. v_1 and v_2 are the velocities of sound at the same temperature in two monoatomic gases of densities ρ_1 and ρ_2 respectively. If $\rho_1 / \rho_2 = \dfrac{1}{4}$ then the ratio of velocities v_1 and v_2 will be **[KCET 2000; AIIMS**

(a) 1 : 2 (b) 4 : 1

(c) 2 : 1 (d) 1 : 4

53. The temperature at which the speed of sound in air becomes double of its value at $0^o C$ is **[AIEEE 2002]**

(a) $273K$ (b) $546K$

(c) $1092K$ (d) $0K$

54. If wavelength of a wave is $\lambda = 6000Å$. Then wave number will be **[MH CET 2002]**

(a) $166 \times 10^3\ m^{-1}$ (b) $16.6 \times 10^{-1}\ m^{-1}$

(c) $1.66 \times 10^6\ m^{-1}$ (d) $1.66 \times 10^7\ m^{-1}$

55. Velocity of sound measured in hydrogen and oxygen gas at a given temperature will be in the ratio **[RPET 2001; UPSEAT 2001; KCET 2002, 05]**

(a) 1 : 4 (b) 4 : 1

(c) 2 : 1 (d) 1 : 1

56. Find the frequency of minimum distance between compression & rarefaction of a wire. If the length of the wire is 1*m* & velocity of sound in air is 360 *m/s* **[CPMT 2003]**

(a) 90 sec^{-1} (b) 180 s^{-1}

(c) 120 sec^{-1} (d) 360 sec^{-1}

57. The velocity of sound is v_s in air. If the density of air is increased to 4 times, then the new velocity of sound will be **[BHU 2003]**

(a) $\dfrac{v_s}{2}$ (b) $\dfrac{v_s}{12}$

(c) $12v_s$ (d) $\dfrac{3}{2}v_s^2$

58. It takes 2.0 seconds for a sound wave to travel between two fixed points when the day temperature is $10^o C$. If the temperature rise to $30^o C$ the sound wave travels between the same fixed parts in **[Orissa JEE 2**

(a) 1.9 *sec* (b) 2.0 *sec*

(c) 2.1 *sec* (d) 2.2 *sec*

59. If v_m is the velocity of sound in moist air, v_d is the velocity of sound in dry air, under identical conditions of pressure and temperature **[KCET 2002,**

(a) $v_m > v_d$ (b) $v_m < v_d$

(c) $v_m = v_d$ (d) $v_m v_d = 1$

60. A man, standing between two cliffs, claps his hands and starts hearing a series of echoes at intervals of one second. If the speed of sound in air is 340 *ms*, the distance between the cliffs is

(a) 340 *m* (b) 1620 *m*

(c) 680 *m* (d) 1700 *m*

61. A source of sound of frequency 600 *Hz* is placed inside water. The speed of sound in water is 1500 *m/s* and in air is 300 *m/s*. The frequency of sound recorded by an observer who is standing in air is

(a) 200 *Hz* (b) 3000 *Hz*

(c) 120 *Hz* (d) 600 *Hz*

62. If the temperature of the atmosphere is increased the following character of the sound wave is effected

[AFMC 2004]

(a) Amplitude (b) Frequency

(c) Velocity (d) Wavelength

63. An underwater sonar source operating at a frequency of 60 *KHz* directs its beam towards the surface. If the velocity of sound in air is 330 *m/s*, the wavelength and frequency of waves in air are:

(a) 5.5 *mm*, 60 *KHz* (b) 330 *m*, 60 *KHz*

(c) 5.5 *mm*, 20 *KHz* (d) 5.5 *mm*, 80 *KHz*

64. Two sound waves having a phase difference of 60° have path difference of [CBSE PMT 1996; AIIMS 2001]

(a) 2λ (b) $\lambda/2$

(c) $\lambda/6$ (d) $\lambda/3$

65. It is possible to distinguish between the transverse and longitudinal waves by studying the property of

[CPMT 1976; EAMCET 1994]

(a) Interference (b) Diffraction

(c) Reflection (d) Polarisation

66. Water waves are [EAMCET 1979; AIIMS 2004]

(a) Longitudinal

(b) Transverse

(c) Both longitudinal and transverse

(d) Neither longitudinal nor transverse

67. Sound travels in rocks in the form of

[NCERT 1968]

(a) Longitudinal elastic waves only

(b) Transverse elastic waves only

(c) Both longitudinal and transverse elastic waves

(d) Non-elastic waves

68. The waves in which the particles of the medium vibrate in a direction perpendicular to the direction of wave motion is known as

[EAMCT 1981; AIIMS 1998; DPMT 2000]

(a) Transverse wave (b) Longitudinal waves

(c) Propagated waves (d) None of these

69. A medium can carry a longitudinal wave because it has the property of [KCET 1994]

(a) Mass (b) Density

(c) Compressibility (d) Elasticity

70. Which of the following is the longitudinal wave

[AFMC 1997]

(a) Sound waves (b) Waves on plucked string

[KCET 2004]

(c) Water waves (d) Light waves

71. The nature of sound waves in gases is

[RPMT 1999; RPET 2000; J & K CET 2004]

(a) Transverse (b) Longitudinal

(c) Stationary (d) Electromagnetic

[IIT-JEE Screening 2004]

72. Transverse waves can propagate in

[CPMT 1984; KCET 2000; RPET 2001]

(a) Liquids (b) Solids

(c) Gases (d) None of these

73. Sound waves in air are [RPET 2000; AFMC 2001]

(a) Transverse (b) Longitudinal

(c) De-Broglie waves (d) All the above

74. Which of the following is not the transverse wave

[AFMC 1999; BHU 2001]

(a) X-rays (b) γ -rays

[DPMT 2004]

(c) Visible light wave (d) Sound wave in a gas

75. What is the phase difference between two successive crests in the wave [RPMT 2001, 02; MH CET 2004]

(a) π (b) $\pi/2$

(c) 2π (d) 4π

76. A wave of frequency 500 *Hz* has velocity 360 *m/sec*. The distance between two nearest points 60° out of phase, is

[NCERT 1979; MP PET 1989; JIPMER 1997; RPMT 2002, 03; CPMT 1979, 90, 2003; BCECE 2005]

(a) 0.6 *cm* (b) 12 *cm*

(c) 60 *cm* (d) 120 *cm*

77. The following phenomenon cannot be observed for sound waves [NCERT 1982; C

AFMC 2002; RPMT 2003]

(a) Refraction (b) Interference

(c) Diffraction (d) Polarisation

78. When an aeroplane attains a speed higher than the velocity of sound in air, a loud bang is heard. This is because

[NCERT 1972; J & K CET 2002]

(a) It explodes

(b) It produces a shock wave which is received as the bang

(c) Its wings vibrate so violently that the bang is heard

(d) The normal engine noises undergo a Doppler shift to generate the bang

79. Ultrasonic waves are those waves [CPMT 1979]

(a) To which man can hear (b) Man can't hear

(c) Are of high velocity (d) Of high amplitude

80. A big explosion on the moon cannot be heard on the earth because

(a) The explosion produces high frequency sound waves which are inaudible

(b) Sound waves required a material medium for propagation

(c) Sound waves are absorbed in the moon's atmosphere

(d) Sound waves are absorbed in the earth's atmosphere

81. Sound waves of wavelength greater than that of audible sound are called [KCET 1999]

(a) Seismic waves (b) Sonic waves

(c) Ultrasonic waves (d) Infrasonic waves

82. 'SONAR' emits which of the following waves [AIIMS 1999]

(a) Radio waves (b) Ultrasonic waves

(c) Light waves (d) Magnetic waves

83. Which of the following do not require medium for transmission

(a) Cathode ray (b) Electromagnetic wave

(c) Sound wave (d) None of the above

84. Consider the following

I. Waves created on the surfaces of a water pond by a vibrating sources.

II. Wave created by an oscillating electric field in air.

III. Sound waves travelling under water.

Which of these can be polarized [AMU 2001]

(a) I and II (b) II only

(c) II and III (d) I, II and III

85. Mechanical waves on the surface of a liquid are [SCRA 1996]

(a) Transverse

(b) Longitudinal

(c) Torsional

(d) Both transverse and longitudinal

86. The ratio of densities of nitrogen and oxygen is 14:16. The temperature at which the speed of sound in nitrogen will be same at that in oxygen at $55^\circ C$ is [EAMCET (Engg.) 1999]

(a) $35^\circ C$ (b) $48^\circ C$

(c) $65^\circ C$ (d) $14^\circ C$

87. The intensity of sound increases at night due to [CPMT 2000]

(a) Increase in density of air (b) Decreases in density of air

(c) Low temperature (d) None of these

88. A wavelength 0.60 *cm* is produced in air and it travels at a speed of 300 ms^{-1}. It will be an [UPSEAT 2000]

(a) Audible wave (b) Infrasonic wave

(c) Ultrasonic wave (d) None of the above

89. Speed of sound in mercury at a certain temperature is 1450 *m/s*. Given the density of mercury as $13.6 \times 10^3\ kg/m^3$, the bulk modulus for mercury is [JIPMER 2000]

(a) $2.86 \times 10^{10}\ N/m^2$ (b) $3.86 \times 10^{10}\ N/m^2$

(c) $4.86 \times 10^{10}\ N/m^2$ (d) $5.86 \times 10^{10}\ N/m^2$

90. A micro-wave and an ultrasonic sound wave have the same wavelength. Their frequencies are in the ratio (approximately)

(a) $10^6 : 1$ (b) $10^4 : 1$

(c) $10^2 : 1$ (d) $10 : 1$

91. A point source emits sound equally in all directions in a non-absorbing medium, Two points P and Q are at distance of $2m$ and $3m$ respectively from the source. The ratio of the intensities of the waves at P and Q is [CBSE PMT 2005]

(a) 9 : 4 (b) 2 : 3

(c) 3 : 2 (d) 4 : 9

92. A wave has velocity u in medium P and velocity $2u$ in medium Q. If the wave is incident in medium P at an angle of 30° then the angle of refraction will be [J & K CET 2005]

(a) 30° (b) 45°

(c) 60° (d) 90°

[RPMT 2000]

93. An observer standing near the sea shore observes 54 waves per minute. If the wavelength of the water wave is $10m$ then the velocity of water wave is [Kerala (Engg.) 2005]

(a) 540 ms^{-1} (b) 5.4 ms^{-1}

(c) 0.184 ms^{-1} (d) 9 ms^{-1}

94. Ultrasonic signal sent from SONAR returns to it after reflection from a rock after a lapse of 1 *sec*. If the velocity of ultrasound in water is 1600 ms^{-1}, the depth of the rock in water is

(a) 300 *m* (b) 400 *m*

(c) 500 *m* (d) 800 *m*

Progressive Waves

1. The equation of a wave is $y = 2\sin\pi(0.5x - 200t)$, where x and y are expressed in cm and t in sec. The wave velocity is [MP PMT 1986]

(a) 100 *cm/sec* (b) 200 *cm/sec*

(c) 300 *cm/sec* (d) 400 *cm/sec*

2. Equation of a progressive wave is given by

$$y = 0.2\cos\pi\left(0.04t + .02x - \frac{\pi}{6}\right)$$

The distance is expressed in *cm* and time in second. What will be the minimum distance between two particles having the phase difference of $\pi/2$

(a) 4 *cm* (b) 8 *cm*

(c) 25 *cm* (d) 12.5 *cm*

3. A travelling wave passes a point of observation. At this point, the time interval between successive crests is 0.2 seconds and

(a) The wavelength is 5 *m*

(b) The frequency is 5 *Hz*

(c) The velocity of propagation is 5 *m/s*

(d) The wavelength is 0.2 *m*

4. The equation of a transverse wave is given by

$$y = 10\sin\pi(0.01x - 2t)$$

where x and y are in *cm* and t is in second. Its frequency is [MP PET 1990; MNR 1986; RPET 2003]

(a) $10\ sec^{-1}$ (b) $2\ sec^{-1}$

(c) $1\ sec^{-1}$ (d) $0.01\ sec^{-1}$

5. At a moment in a progressive wave, the phase of a particle executing S.H.M. is $\frac{\pi}{3}$. Then the phase of the particle 15 *cm* ahead and at the time $\frac{T}{2}$ will be, if the wavelength is 60 *cm* [Kerala (Engg.) 2002]

(a) $\frac{\pi}{2}$ (b) $\frac{2\pi}{3}$

(c) Zero (d) $\frac{5\pi}{6}$

6. The equation of a wave travelling on a string is $y = 4\sin\frac{\pi}{2}\left(8t - \frac{x}{8}\right)$. If x and y are in *cm*, then velocity of wave is [MP PET 1990]

(a) 64 *cm/sec* in $-x$ direction
(b) 32 *cm/sec* in $-x$ direction
(c) 32 *cm/sec* in $+x$ direction
(d) 64 *cm/sec* in $+x$ direction

7. The equation of a progressive wave is given by

$$y = a\sin(628t - 31.4x)$$

If the distances are expressed in *cms* and time in seconds, then the wave velocity will be [DPMT 1999]

(a) 314 *cm/sec* (b) 628 *cm/sec*
(c) 20 *cm/sec* (d) 400 *cm/sec*

8. Two waves are given by $y_1 = a\sin(\omega t - kx)$ and $y_2 = a\cos(\omega t - kx)$ The phase difference between the two waves is [MP PMT 1993; SCRA 1996; CET 1998; EAMCET 1991; Orissa JEE 2002]

(a) $\frac{\pi}{4}$ (b) π
(c) $\frac{\pi}{8}$ (d) $\frac{\pi}{2}$

9. If amplitude of waves at distance r from a point source is A, the amplitude at a distance $2r$ will be [MP PMT 1985]

(a) $2A$ (b) A
(c) $A/2$ (d) $A/4$

10. The relation between time and displacement for two particles is given by

$$y_1 = 0.06\sin 2\pi(0.04t + \phi_1),\ y_2 = 0.03\sin 2\pi(1.04t + \phi_2)$$

The ratio of the intensity of the waves produced by the vibrations of the two particles will be [MP PMT 1991]

(a) 2 : 1 (b) 1 : 2
(c) 4 : 1 (d) 1 : 4

11. A wave is reflected from a rigid support. The change in phase on reflection will be [MP PMT 1990; RPMT 2002]

(a) $\pi / 4$ (b) $\pi / 2$
(c) π (d) 2π

12. A plane wave is represented by

$$x = 1.2\sin(314\,t + 12.56y)$$

Where x and y are distances measured along in x and y direction in meters and t is time in seconds. This wave has [MP PET 1991]

(a) A wavelength of 0.25 *m* and travels in + *ve x* direction
(b) A wavelength of 0.25 *m* and travels in + *ve y* direction
(c) A wavelength of 0.5 *m* and travels in – *ve y* direction
(d) A wavelength of 0.5 *m* and travels in – *ve x* direction

13. The displacement y (in *cm*) produced by a simple harmonic wave is $y = \frac{10}{\pi}\sin\left(2000\pi t - \frac{\pi x}{17}\right)$. The periodic time and maximum velocity of the particles in the medium will respectively be

(a) 10^{-3} *sec* and 330 *m/sec* (b) 10^{-4} sec and 20 *m/sec*
(c) 10^{-3} *sec* and 200 *m/sec* (d) 10^{-2} *sec* and 2000 *m/sec*

14. The equation of a wave travelling in a string can be written as $y = 3\cos\pi(100\,t - x)$. Its wavelength is [MNR 1985; CPMT 1991; MP PMT 1994, 97; Pb. PET 2004]

(a) 100 *cm* (b) 2 *cm*
(c) 5 *cm* (d) None of the above

15. A transverse wave is described by the equation $Y = Y_0\sin 2\pi\left(ft - \frac{x}{\lambda}\right)$. The maximum particle velocity is four times the wave velocity if [IIT 1984; MP PMT 1997; EAMCET; 1998; CBSE PMT 2000; AFMC 2000; MP PMT/PET 1998; 01; KCET 1999, 04; Pb. PET 2001; DPMT 2005]

(a) $\lambda = \frac{\pi Y_0}{4}$ (b) $\lambda = \frac{\pi Y_0}{2}$
(c) $\lambda = \pi Y_0$ (d) $\lambda = 2\pi Y_0$

16. A wave equation which gives the displacement along the Y direction is given by the equation $y = 10^4\sin(60t + 2x)$, where x and y are in *metres* and t is time in seconds. This represents a wave [MNR 1983; IIT 1982; RPMT 1998; MP PET 2001]

(a) Travelling with a velocity of 30 *m/sec* in the negative X direction
(b) Of wavelength π *metre*
(c) Of frequency $30/\pi$ *Hz*
(d) Of amplitude 10^4 *metre* travelling along the negative X direction

17. A transverse wave of amplitude 0.5 *m* and wavelength 1 *m* and frequency 2 *Hz* is propagating in a string in the negative *x*-direction. The expression for this wave is [AIIMS 1980]

(a) $y(x,t) = 0.5\sin(2\pi x - 4\pi t)$
(b) $y(x,t) = 0.5\cos(2\pi x + 4\pi t)$
(c) $y(x,t) = 0.5\sin(\pi x - 2\pi t)$
(d) $y(x,t) = 0.5\cos(2\pi x + 2\pi t)$

18. The displacement of a particle is given by $y = 5\times 10^{-4}\sin(100t - 50x)$, where x is in meter and t in sec, find out the velocity of the wave [CPMT 1982]

(a) 5000 *m/sec* (b) 2 *m/sec*
(c) 0.5 *m/sec* (d) 300 *m/sec*

19. Which one of the following does not represent a travelling wave

(a) $y = \sin(x - v\,t)$ (b) $y = y_m\sin k(x + v\,t)$
(c) $y = y_m\log(x - v\,t)$ (d) $y = f(x^2 - v\,t^2)$

20. A wave represented by the given equation $Y = A\sin\left(10\,\pi\,x + 15\,\pi\,t + \frac{\pi}{3}\right)$, where x is in meter and t is in second. The expression represents [IIT 1990]

(a) A wave travelling in the positive X direction with a velocity of 1.5 *m/sec*
(b) A [CPMT 1986] wave travelling in the negative X direction with a velocity of 1.5 *m/sec*

(c) A wave travelling in the negative X direction with a wavelength of 0.2 m

(d) A wave travelling in the positive X direction with a wavelength of 0.2 m

21. A plane wave is described by the equation $y = 3\cos\left(\frac{x}{4} - 10t - \frac{\pi}{2}\right)$. The maximum velocity of the particles of the medium due to this wave is [MP PMT 1994]

(a) 30 (b) $\frac{3\pi}{2}$

(c) 3/4 (d) 40

22. The path difference between the two waves $y_1 = a_1 \sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$ and $y_2 = a_2 \cos\left(\omega t - \frac{2\pi x}{\lambda} + \phi\right)$ is [MP PMT 1994]

(a) $\frac{\lambda}{2\pi}\phi$ (b) $\frac{\lambda}{2\pi}\left(\phi + \frac{\pi}{2}\right)$

(c) $\frac{2\pi}{\lambda}\left(\phi - \frac{\pi}{2}\right)$ (d) $\frac{2\pi}{\lambda}\phi$

23. Wave equations of two particles are given by $y_1 = a\sin(\omega t - kx)$, $y_2 = a\sin(kx + \omega t)$, then [BHU 1995]

(a) They are moving in opposite direction

(b) Phase between them is 90°

(c) Phase between them is 180°

(d) Phase between them is 0°

24. A wave is represented by the equation $y = 0.5\sin(10t - x)m$. It is a travelling wave propagating along the + x direction with velocity [Roorkee 1995]

(a) 10 m/s (b) 20 m/s

(c) 5 m/s (d) None of these

25. A wave is represented by the equation

$$y = 7\sin\left(7\pi t - 0.04\, x\pi + \frac{\pi}{3}\right)$$

x is in *metres* and t is in seconds. The speed of the wave is [MP PET 1996; AMU (Engg.) 1999]

(a) 175 m/sec (b) 49 $\pi m/sec$

(c) 49 $/\pi m/sec$ (d) 0.28 $\pi m/sec$

26. The equation of a transverse wave travelling on a rope is given by $y = 10\sin\pi(0.01x - 2.00t)$ where y and x are in cm and t in seconds. The maximum transverse speed of a particle in the rope is about [MP PET 1999; AIIMS 2000]

(a) 63 cm/s (b) 75 cm/s

(c) 100 cm/s (d) 121 cm/s

27. As a wave propagates [IIT-JEE 1999]

(a) The wave intensity remains constant for a plane wave

(b) The wave intensity decreases as the inverse of the distance from the source for a spherical wave

(c) The wave intensity decreases as the inverse square of the distance from the source for a spherical wave

(d) Total intensity of the spherical wave over the spherical surface centered at the source remains constant at all times

28. A transverse wave is represented by the equation

$$y = y_0 \sin\frac{2\pi}{\lambda}(vt - x)$$

For what value of λ, the maximum particle velocity equal to two times the wave velocity [CBSE PMT 1998; JIPMER 2001, 02; AFMC 2002]

(a) $\lambda = 2\pi y_0$ (b) $\lambda = \pi y_0 / 3$

(c) $\lambda = \pi y_0 / 2$ (d) $\lambda = \pi y_0$

29. A travelling wave in a stretched string is described by the equation $y = A\sin(kx - \omega t)$. The maximum particle velocity is [IIT 1997 Re-Exam; UPSEAT 2004]

(a) $A\omega$ (b) ω/k

(c) $d\omega/dk$ (d) x/t

30. A wave travels in a medium according to the equation of displacement given by

$$y(x, t) = 0.03\sin\pi(2t - 0.01x)$$

where y and x are in *metres* and t in seconds. The wavelength of the wave is [EAMCET 1994; CPMT 2004]

(a) 200 m (b) 100 m

(c) 20 m (d) 10 m

31. The particles of a medium vibrate about their mean positions whenever a wave travels through that medium. The phase difference between the vibrations of two such particles

(a) Varies with time

(b) Varies with distance separating them

(c) Varies with time as well as distance

(d) Is always zero

32. A wave is given by $y = 3\sin 2\pi\left(\frac{t}{0.04} - \frac{x}{0.01}\right)$, where y is in cm. Frequency of wave and maximum acceleration of particle will be

(a) $100\,Hz,\ 4.7\times10^3\ cm/s^2$ (b) $50\,Hz,\ 7.5\times10^3\ cm/s^2$

(c) $25\,Hz,\ 4.7\times10^4\ cm/s^2$ (d) $25\,Hz,\ 7.4\times10^4\ cm/s^2$

33. Equation of a progressive wave is given by

$$y = 4\sin\left\{\pi\left(\frac{t}{5} - \frac{x}{9}\right) + \frac{\pi}{6}\right\}$$

Then which of the following is correct [CBSE PMT 1993]

(a) $v = 5\,m/\sec$ (b) $\lambda = 18\,m$

(c) $a = 0.04\,m$ (d) $n = 50\,Hz$

34. With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the propagation direction are [CBSE PMT

(a) Energy, momentum and mass

(b) Energy

(c) Energy and mass

(d) Energy and linear momentum

35. The frequency of the sinusoidal wave $y = 0.40\cos[2000\,t + 0.80\,x]$ would be [CBSE PMT 1992]

(a) 1000 π Hz (b) 2000 Hz

(c) 20 Hz (d) $\frac{1000}{\pi}Hz$

36. Which of the following equations represents a wave [CBSE PMT 1994; JIPMER 2000]

(a) $Y = A(\omega t - kx)$ (b) $Y = A\sin\omega t$

(c) $Y = A\cos kx$ (d) $Y = A\sin(at - bx + c)$

37. The equation of a transverse wave is given by

$y = 100\sin\pi(0.04z - 2t)$

where y and z are in *cm* ant t is in seconds. The frequency of the wave in *Hz* is [SCRA 1998]

(a) 1 (b) 2

(c) 25 (d) 100

38. The equation of a plane progressive wave is given by $y = 0.025\sin(100t + 0.25x)$. The frequency of this wave would be [CPMT 1993; JIPMER 2001, 02]

(a) $\frac{50}{\pi}Hz$ (b) $\frac{100}{\pi}Hz$

(c) 100 *Hz* (d) 50 *Hz*

39. The equation of a sound wave is

$y = 0.0015\sin(62.4x + 316t)$

The wavelength of this wave is [CBSE PMT 1996; AFMC 2002; AIIMS 2002]

(a) 0.2 unit (b) 0.1 unit

(c) 0.3 unit (d) Cannot be calculated

40. In the given progressive wave equation, what is the maximum velocity of particle $Y = 0.5\sin(10\pi t - 5x)$ *cm* [BHU 1997]

(a) 5 *cm/s* (b) 5π *cm/s*

(c) 10 *cm/s* (d) 10.5 *cm/s*

41. A pulse or a wave train travels along a stretched string and reaches the fixed end of the string. It will be reflected back with

(a) The same phase as the incident pulse but with velocity reversed

(b) A phase change of 180° with no reversal of velocity

(c) The same phase as the incident pulse with no reversal of velocity

(d) A phase change of 180° with velocity reversed

42. The equation of a travelling wave is

$y = 60\cos(1800t - 6x)$

where y is in microns, t in seconds and x in metres. The ratio of maximum particle velocity to velocity of wave propagation is [CBSE PMT 1997; JIPMER 2001, 02]

(a) 3.6×10^{-11} (b) 3.6×10^{-6}

(c) 3.6×10^{-4} (d) 3.6

43. The wave equation is $y = 0.30\sin(314t - 1.57x)$ where *t*, *x* and *y* are in second, meter and centimeter respectively. The speed of the wave is [CPMT 1997; AFMC 1999; CPMT 2001]

(a) 100 *m/s* (b) 200 *m/s*

(c) 300 *m/s* (d) 400 *m/s*

44. Equation of the progressive wave is given by : $y = a\sin\pi(40t - x)$ where a and x are in *metre* and t in second. The velocity of the wave is [KCET 1999]

(a) 80 *m/s* (b) 10 *m/s*

(c) 40 *m/s* (d) 20 *m/s*

45. Progressive wave of sound is represented by $y = a\sin[400\pi t - \pi x / 6.85]$ where x is in m and t is in sec. Frequency of the wave will be [RPMT 1999]

(a) 200 *Hz* (b) 400 *Hz*

(c) 500 *Hz* (d) 600 *Hz*

46. Two waves of frequencies 20 *Hz* and 30 *Hz*. Travels out from a common point. The phase difference between them after 0.6 *sec* is

(a) Zero (b) $\frac{\pi}{2}$

(c) π (d) $\frac{3\pi}{4}$

47. The phase difference between two points separated by 0.8 *m* in a wave of frequency 120 *Hz* is 90^o. Then the velocity of wave will be

(a) 192 *m/s* (b) 360 *m/s*

(c) 710 *m/s* (d) 384 *m/s*

48. The equation of progressive wave is $y = 0.2\sin 2\pi\left[\frac{t}{0.01} - \frac{x}{0.3}\right]$, where x and y are in metre and t is in second. The velocity of propagation of the wave is

(a) 30 *m/s* (b) 40 *m/s*

(c) 300 *m/s* (d) 400 *m/s*

49. If the equation of transverse wave is $y = 5\sin 2\pi\left[\frac{t}{0.04} - \frac{x}{40}\right]$, where distance is in *cm* and time in second, then the wavelength of the wave is [MH CET 2000; DPMT 2003]

(a) 60 *cm* (b) 40 *cm*

(c) 35 *cm* (d) 25 *cm*

50. A wave is represented by the equation : $y = a\sin(0.01x - 2t)$ where *a* and *x* are in *cm*. velocity of propagation of wave is [CBSE PMT 1997] [EAMCET 1994; AIIMS 2000; Pb. PMT 2003]

(a) 10 *cm/s* (b) 50 *cm/s*

(c) 100 *cm/s* (d) 200 *cm/s*

51. A simple harmonic progressive wave is represented by the equation : $y = 8\sin 2\pi(0.1x - 2t)$ where x and y are in *cm* and t is in seconds. At any instant the phase difference between two particles separated by 2.0 *cm* in the *x*-direction is [MP PMT 2000]

(a) 18° (b) 36°

(c) 54° (d) 72°

52. The intensity of a progressing plane wave in loss-free medium is

(a) Directly proportional to the square of amplitude of the wave

(b) Directly proportional to the velocity of the wave

(c) Directly proportional to the square of frequency of the wave

(d) Inversely proportional to the density of the medium

53. The equation of progressive wave is $y = a\sin(200t - x)$. where x is in meter and t is in second. The velocity of wave is

(a) 200 *m/sec* (b) 100 *m/sec*

(c) 50 *m/sec* (d) None of these

54. A wave is represented by the equation $y = 7\sin\{\pi(2t - 2x)\}$ where x is in *metres* and t in seconds. The velocity of the wave is [CPMT 2000; CBSE PMT 2000; Pb. PET 2000]

(a) 1 *m/s* (b) 2 *m/s*

(c) 5 *m/s* (d) 10 *m/s*

55. The equation of a longitudinal wave is represented as $y = 20\cos\pi(50t - x)$. Its wavelength is

[UPSEAT 2001; Orissa PMT 2004]

(a) 5 *cm* (b) 2 *cm*

(c) 50 *cm* (d) 20 *cm*

56. A wave equation which gives the displacement along *y*-direction is given by $y = 0.001\sin(100t + x)$ where *x* and *y* are in meterand *t* is time in second. This represented a wave

[UPSEAT 2001]

(a) Of frequency $\frac{100}{\pi}$ *Hz*

(b) Of wavelength one metre

(c) Travelling with a velocity of $\frac{50}{\pi}$ *ms* in the positive *X*-direction

(d) Travelling with a velocity of 100 *ms* in the negative *X*-direction

57. A transverse wave is given by $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$. The maximum particle velocity is equal to 4 times the wave velocity when [MP PMT 2001]

(a) $\lambda = 2\pi A$ (b) $\lambda = \frac{1}{2}\pi A$

(c) $\lambda = \pi A$ (d) $\lambda = \frac{1}{4}\pi A$

58. The equation of a wave is represented by $y = 10^{-4}\sin\left[100\,t - \frac{x}{10}\right]$. The velocity of the wave will be

[CBSE PMT 2001]

(a) 100 *m/s* (b) 250 *m/s*

(c) 750 *m/s* (d) 1000 *m/s*

59. A wave travelling in positive X-direction with $A = 0.2m$ has a velocity of 360 *m/sec*. if $\lambda = 60m$, then correct expression for the wave is [CBSE PMT 2002; KCET 2003]

(a) $y = 0.2\sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$ (b) $y = 0.2\sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$

(c) $y = 0.2\sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$ (d) $y = 0.2\sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$

60. The equation of a wave motion (with t in seconds and x in *metres*) is given by $y = 7\sin\left[7\pi t - 0.4\pi x + \frac{\pi}{3}\right]$. The velocity of the wave will be

[BHU 2002]

(a) 17.5 *m/s* (b) 49π *m/s*

(c) $\frac{49}{2\pi} m/s$ (d) $\frac{2\pi}{49} m/s$

61. Two waves represented by the following equations are travelling in the same medium $y_1 = 5\sin 2\pi(75t - 0.25x)$, $y_2 = 10\sin 2\pi(150t - 0.50x)$

The intensity ratio I_1 / I_2 of the two waves is

[UPSEAT 2002]

(a) 1 : 2 (b) 1 : 4

(c) 1 : 8 (d) 1 : 16

62. The equation of a progressive wave is $y = 8\sin\left[\pi\left(\frac{t}{10} - \frac{x}{4}\right) + \frac{\pi}{3}\right]$. The wavelength of the wave is

[MH CET 2002]

(a) 8 *m* (b) 4 *m*

(c) 2 *m* (d) 10 *m*

63. Which of the following is not true for this progressive wave $y = 4\sin 2\pi\left(\frac{t}{0.02} - \frac{x}{100}\right)$ where y and x are in cm & t in *sec* [CPMT 2003]

(a) Its amplitude is 4 *cm*

(b) Its wavelength is 100 *cm*

(c) Its frequency is 50 *cycles/sec*

(d) Its propagation velocity is 50×10^3 *cm/sec*

64. The equation of a wave is given as $y = 0.07\sin(12\pi x - 3000\pi t)$. Where x is in *metre* and t in sec, then the correct statement is

(a) $\lambda = 1/6m, v = 250m/s$ (b) $a = 0.07m, v = 300m/s$

(c) $n = 1500, v = 200m/s$ (d) None

65. The equation of the propagating wave is $y = 25\sin(20t + 5x)$, where y is displacement. Which of the following statement is not true [MP PET 2003]

(a) The amplitude of the wave is 25 units

(b) The wave is propagating in positive X-direction

(c) The velocity of the wave is 4 units

(d) The maximum velocity of the particles is 500 units

66. In a plane progressive wave given by $y = 25\cos(2\pi t - \pi x)$, the amplitude and frequency are respectively

[BCECE 2003]

(a) 25,100 (b) 25, 1

(c) 25, 2 (d) 50π, 2

67. The displacement y of a wave travelling in the *x*-direction is given by $y = 10^{-4}\sin\left(600t - 2x + \frac{\pi}{3}\right)$ metres, where x is expressed in metres and t in seconds. The speed of the wave-motion, in *ms*, is

(a) 200 (b) 300

(c) 600 (d) 1200

68. The displacement *y* of a particle in a medium can be expressed as: $y = 10^{-6}\sin(100t + 20x + \pi/4)m$, where *t* is in second and *x* in *meter*. The speed of wave is

[AIEEE 2004]

(a) 2000 *m/s* (b) 5 *m/s*

(c) 20 *m/s* (d) $5\pi\, m/s$

69. If the wave equation $y = 0.08\sin\frac{2\pi}{\lambda}(200t - x)$ then the velocity of the wave will be [BCECE 2004]

(a) $400\sqrt{2}$ (b) $200\sqrt{2}$

(c) 400 (d) 200

70. The phase difference between two points separated by 0.8 m in a wave of frequency is 120 Hz is $\frac{\pi}{2}$. The velocity of wave is

(a) 720 m/s (b) 384 m/s

(c) 250 m/s (d) 1 m/s

71. A plane progressive wave is represented by the equation

$y = 0.1\sin\left(200\pi t - \frac{20\pi x}{17}\right)$ where y is displacement in m, t in second and x is distance from a fixed origin in *meter*. The frequency, wavelength and speed of the wave respectively are

(a) 100 Hz, 1.7 m, 170 m/s (b) 150 Hz, 2.4 m, 200 m/s

(c) 80 Hz, 1.1 m, 90 m/s (d) 120 Hz, 1.25 m, 207 m/s

72. The equation of a travelling wave is given by

$y = 0.5\sin(20x - 400t)$ where x and y are in *meter* and t is in *second*. The velocity of the wave is [UPSEAT 2004]

(a) 10 m/s (b) 20 m/s

(c) 200 m/s (d) 400 m/s

73. A transverse progressive wave on a stretched string has a velocity of $10\,ms^{-1}$ and a frequency of 100 Hz. The phase difference between two particles of the string which are 2.5 cm apart will be

(a) $\frac{\pi}{8}$ (b) $\frac{\pi}{4}$

(c) $\frac{3\pi}{8}$ (d) $\frac{\pi}{2}$

74. A transverse sinusoidal wave of amplitude a, wavelength λ and frequency n is travelling on a stretched string. The maximum speed of any point on the string is $v/10$, where v is the speed of propagation of the wave. If $a = 10^{-3}\,m$ and $v = 10\,ms^{-1}$, then λ and n are given by [IIT 1998]

(a) $\lambda = 2\pi \times 10^{-2}\,m$ (b) $\lambda = 10^{-3}\,m$

(c) $n = \frac{10^3}{2\pi} Hz$ (d) $n = 10^4\,Hz$

75. When a longitudinal wave propagates through a medium, the particles of the medium execute simple harmonic oscillations about their mean positions. These oscillations of a particle are characterised by an invariant

[SCRA 1998]

(a) Kinetic energy

(b) Potential energy

(c) Sum of kinetic energy and potential energy

(d) Difference between kinetic energy and potential energy

76. Equation of a progressive wave is given by $y = a\sin\pi\left[\frac{t}{2} - \frac{x}{4}\right]$, where t is in seconds and x is in meters. The distance through which the wave moves in 8 *sec* is (in meter)

(a) 8 (b) 16

(c) 2 (d) 4

77. The phase difference between two waves represented by $y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]m$

$y_2 = 10^{-6}\cos[100\,t + (x/50)]m$

where x is expressed in metres and t is expressed in seconds, is approximately [CBSE PMT 2004]

(a) 1.5 *rad* (b) 1.07 *rad*

(c) 2.07 *rad* [Pb. PET 2000] (d) 0.5 *rad*

78. Equation of motion in the same direction are given by

$y_1 = 2a\sin(\omega t - kx)$ and $y_2 = 2a\sin(\omega t - kx - \theta)$

The amplitude of the medium particle will be [CPMT 2004]

(a) $2a\cos\theta$ (b) $\sqrt{2}a\cos\theta$

(c) $4a\cos\theta/2$ (d) $\sqrt{2}a\cos\theta/2$

79. A particle on the trough of a wave at any instant will come to the mean position after a time (T = time period) [Pb. PET 2001]

[KCET 2005]

(a) $T/2$ (b) $T/4$

(c) T (d) $2T$

80. If the equation of transverse wave is $Y = 2\sin(kx - 2t)$, then the maximum particle velocity is [Orissa JEE 2005]

(a) 4 units (b) 2 units

(c) 0 (d) 6 units

Interference and Superposition of Waves

1. There is a destructive [MP PMT 1994] interference between the two waves of wavelength λ coming from two different paths at a point. To get maximum sound or constructive interference at that point, the path of one wave is to be increased by

[MP PET 1985]

(a) $\frac{\lambda}{4}$ (b) $\frac{\lambda}{2}$

(c) $\frac{3\lambda}{4}$ (d) λ

2. When two sound waves with a phase difference of $\pi/2$, and each having amplitude A and frequency ω, are superimposed on each other, then the maximum amplitude and frequency of resultant wave is [MP PMT 1989]

(a) $\frac{A}{\sqrt{2}} : \frac{\omega}{2}$ (b) $\frac{A}{\sqrt{2}} : \omega$

(c) $\sqrt{2}\,A : \frac{\omega}{2}$ (d) $\sqrt{2}\,A : \omega$

3. If the phase difference between the two wave is 2π during superposition, then the resultant amplitude is

[DPMT 2001]

(a) Maximum (b) Minimum

(c) Maximum or minimum (d) None of the above

4. The superposition takes place between two waves of frequency f and amplitude a. The total intensity is directly proportional to

(a) a (b) $2a$

[KCET 1998] (c) $2a^2$ (d) $4a^2$

5. If two waves of same frequency and same amplitude respectively, on superimposition produced a resultant disturbance of the same amplitude, the waves differ in phase by

(a) π (b) $2\pi/3$

(c) $\pi / 2$ (d) Zero

6. Two sources of sound *A* and *B* produces the wave of 350 *Hz*, they vibrate in the same phase. The particle P is vibrating under the influence of these two waves, if the amplitudes at the point *P* produced by the two waves is 0.3 *mm* and 0.4 *mm*, then the resultant amplitude of the point *P* will be when *AP* – *BP* = 25 *cm* and the velocity of sound is 350 *m/sec*

(a) 0.7 *mm* (b) 0.1 *mm*

(c) 0.2 *mm* (d) 0.5 *mm*

7. Two waves are propagating to the point *P* along a straight line produced by two sources *A* and *B* of simple harmonic and of equal frequency. The amplitude of every wave at *P* is '*a*' and the phase of *A* is ahead by $\frac{\pi}{3}$ than that of *B* and the distance *AP* is greater than *BP* by 50 *cm*. Then the resultant amplitude at the point *P* will be, if the wavelength is 1 *meter* [BVP 2003]

(a) $2a$ (b) $a\sqrt{3}$

(c) $a\sqrt{2}$ (d) a

8. Coherent sources are characterized by the same [KCET 1993]

(a) Phase and phase velocity

(b) Wavelength, amplitude and phase velocity

(c) Wavelength, amplitude and frequency

(d) Wavelength and phase

9. The minimum intensity of sound is zero at a point due to two sources of nearly equal frequencies, when

(a) Two sources are vibrating in opposite phase

(b) The amplitude of two sources are equal

(c) At the point of observation, the amplitudes of two S.H.M. produced by two sources are equal and both the S.H.M. are along the same straight line

(d) Both the sources are in the same phase

10. Two sound waves (expressed in CGS units) given by $y_1 = 0.3\sin\frac{2\pi}{\lambda}(vt - x)$ and $y_2 = 0.4\sin\frac{2\pi}{\lambda}(vt - x + \theta)$ interfere. The resultant amplitude at a place where phase difference is $\pi / 2$ will be [MP PET 1991]

(a) 0.7 *cm* (b) 0.1 *cm*

(c) 0.5 *cm* (d) $\frac{1}{10}\sqrt{7}\ cm$

11. If two waves having amplitudes 2*A* and *A* and same frequency and velocity, propagate in the same direction in the same phase, the resulting amplitude will be [MP PET 1991; DPMT 1999]

(a) $3A$ (b) $\sqrt{5}A$

(c) $\sqrt{2}A$ (d) A

12. The intensity ratio of two waves is 1 : 16. The ratio of their amplitudes is [EAMCET 1983]

(a) 1 : 16 (b) 1 : 4

(c) 4 : 1 (d) 2 : 1

13. Out of the given four waves (1), (2), (3) and (4)

$y = a\sin(kx + \omega t)$ ......(1)

$y = a\sin(\omega t - kx)$ ......(2)

$y = a\cos(kx + \omega t)$ ......(3)

$y = a\cos(\omega t - kx)$ ......(4)

emitted by four different sources S_1, S_2, S_3 and S_4 respectively, interference phenomena would be observed in space under appropriate conditions when [CPMT 1988]

(a) Source S_1 emits wave (1) and S_2 emits wave (2)

(b) Source S_3 emits wave (3) and S_4 emits wave (4)

(c) Source S_2 emits wave (2) and S_4 emits wave (4)

(d) S_4 emits waves (4) and S_3 emits waves (3)

14. Two waves of same frequency and intensity superimpose with each other in opposite phases, then after superposition the

(a) Intensity increases by 4 times

(b) Intensity increases by two times

(c) Frequency increases by 4 times

(d) None of these

15. The superposing waves are represented by the following equations :

$y_1 = 5\sin 2\pi(10\,t - 0.1x)$, $y_2 = 10\sin 2\pi(20\,t - 0.2x)$

Ratio of intensities $\frac{I_{max}}{I_{min}}$ will be [AIIMS 1995; KCET 2001]

(a) 1 (b) 9

(c) 4 (d) 16

16. The displacement of a particle is given by

$x = 3\sin(5\pi\,t) + 4\cos(5\pi\,t)$

The amplitude of the particle is [MP PMT 1999]

(a) 3 (b) 4

(c) 5 (d) 7

17. Two waves

$y_1 = A_1\sin(\omega t - \beta_1)$, $y_2 = A_2\sin(\omega t - \beta_2)$

Superimpose to form a resultant wave whose amplitude is [CPMT 1999]

(a) $\sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\beta_1 - \beta_2)}$

(b) $\sqrt{A_1^2 + A_2^2 + 2A_1A_2\sin(\beta_1 - \beta_2)}$

(c) $A_1 + A_2$

(d) $|\ A_1 + A_2\ |$

18. If the ratio of amplitude of wave is 2 : 1, then the ratio of maximum and minimum intensity is [MH CET 1999]

(a) 9 : 1 (b) 1 : 9

(c) 4 : 1 (d) 1 : 4

19. The two interfering waves have intensities in the ratio 9 : 4. The ratio of intensities of maxima and minima in the interference pattern will be [AMU 2000]

(a) 1 : 25 (b) 25 : 1

(c) 9 : 4 (d) 4 : 9

20. If the ratio of amplitude of two waves is 4 : 3. Then the ratio of maximum and minimum intensity will be [MHCET 2000]

(a) 16 : 18 (b) 18 : 16
(c) 49 : 1 (d) 1 : 49

21. Equation of motion in the same direction is given by $y_1 = A\sin(\omega t - kx)$, $y_2 = A\sin(\omega t - kx - \theta)$. The amplitude of the medium particle will be [BHU 2003]

(a) $2A\cos\frac{\theta}{2}$ (b) $2A\cos\theta$
(c) $\sqrt{2}A\cos\frac{\theta}{2}$ (d) $1.2f, 1.2\lambda$

22. Two waves having the intensities in the ratio of 9 : 1 produce interference. The ratio of maximum to the minimum intensity, is equal to

[CPMT 2001; Pb. PET 2004]

(a) 2 : 1 (b) 4 : 1
(c) 9 : 1 (d) 10 : 8

23. The displacement of the interfering light waves are $y_1 = 4\sin\omega t$ and $y_2 = 3\sin\left(\omega t + \frac{\pi}{2}\right)$. What is the amplitude of the resultant wave

[RPMT 1996; Orissa JEE 2005]

(a) 5 (b) 7
(c) 1 (d) 0

24. Two waves are represented by $y_1 = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and $y_2 = a\cos\omega t$. What will be their resultant amplitude

[RPMT 1996]

(a) a (b) $\sqrt{2}\,a$
(c) $\sqrt{3}\,a$ (d) $2a$

25. The amplitude of a wave represented by displacement equation $y = \frac{1}{\sqrt{a}}\sin\omega t \pm \frac{1}{\sqrt{b}}\cos\omega t$ will be

[BVP 2003]

(a) $\frac{a+b}{ab}$ (b) $\frac{\sqrt{a}+\sqrt{b}}{ab}$
(c) $\frac{\sqrt{a}\pm\sqrt{b}}{ab}$ (d) $\sqrt{\frac{a+b}{ab}}$

26. Two waves having equations

$$x_1 = a\sin(\omega t + \phi_1),\ x_2 = a\sin(\omega t + \phi_2)$$

If in the resultant wave the frequency and amplitude remain equal to those of superimposing waves. Then phase difference between them is [CBSE PMT 2001]

(a) $\frac{\pi}{6}$ (b) $\frac{2\pi}{3}$
(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{3}$

Beats

1. Two tuning forks when sounded together produced 4 *beats/sec*. The frequency of one fork is 256. The number of beats heard increases when the fork of frequency 256 is loaded with wax. The frequency of the other fork is

[CPMT 1976; MP PMT 1993]

(a) 504 (b) 520
(c) 260 (d) 252

2. Beats are the result of

[CPMT 1971; J & K CET 2002]

(a) Diffraction
(b) Destructive interference
(c) Constructive and destructive interference
(d) Superposition of two waves of nearly equal frequency

3. Two adjacent piano keys are struck simultaneously. The notes emitted by them have frequencies n_1 and n_2. The number of beats heard per second is

[CPMT 1974, 78; CBSE PMT 1993]

(a) $\frac{1}{2}(n_1 - n_2)$ (b) $\frac{1}{2}(n_1 + n_2)$
(c) $n_1 \sim n_2$ (d) $2(n_1 - n_2)$

4. A tuning fork of frequency 100 when sounded together with another tuning fork of unknown frequency produces 2 beats per second. On loading the tuning fork whose frequency is not known and sounded together with a tuning fork of frequency 100 produces one beat, then the frequency of the other tuning fork is

(a) 102 (b) 98
(c) 99 (d) 101

5. A tuning fork sounded together with a tuning fork of frequency 256 emits two beats. On loading the tuning fork of frequency 256, the number of beats heard are 1 per second. The frequency of tuning fork is

[NCERT 1975, 81; MP PET 1985]

(a) 257 (b) 258
(c) 256 (d) 254

6. If two tuning forks *A* and *B* are sounded together, they produce 4 beats per second. *A* is then slightly loaded with wax, they produce 2 beats when sounded again. The frequency of *A* is 256. The frequency of *B* will be

[CPMT 1976; RPET 1998]

(a) 250 (b) 252
(c) 260 (d) 262

7. The frequencies of two sound sources are 256 *Hz* and 260 *Hz*. At $t = 0$, the intensity of sound is maximum. Then the phase difference at the time $t = 1/16$ *sec* will be

(a) Zero (b) π
(c) $\pi/2$ (d) $\pi/4$

8. Two tuning forks have frequencies 450 *Hz* and 454 *Hz* respectively. On sounding these forks together, the time interval between successive maximum intensities will be

[MP PET 1989; MP PMT 2003]

(a) 1/4 *sec* (b) 1/2 *sec*
(c) 1 *sec* (d) 2 *sec*

9. When a tuning fork of frequency 341 is sounded with another tuning fork, six beats per second are heard. When the second tuning fork is loaded with wax and sounded with the first tuning fork, the number of beats is two per second. The natural frequency of the second tuning fork is

[MP PET 1989]

(a) 334 (b) 339

(c) 343 (d) 347

10. Two tuning forks of frequencies 256 and 258 vibrations/sec are sounded together, then time interval between consecutive maxima heard by the observer is

[MP PET/PMT 1988]

(a) 2 *sec* (b) 0.5 *sec*

(c) 250 *sec* (d) 252 *sec*

11. A tuning fork gives 5 beats with another tuning fork of frequency 100 *Hz*. When the first tuning fork is loaded with wax, then the number of beats remains unchanged, then what will be the frequency of the first tuning fork

[MP PMT 1985]

(a) 95 *Hz* (b) 100 *Hz*

(c) 105 *Hz* (d) 110 *Hz*

12. Tuning fork F_1 has a frequency of 256 *Hz* and it is observed to produce 6 beats/second with another tuning fork F_2. When F_2 is loaded with wax, it still produces 6 beats/second with F_1. The frequency of F_2 before loading was

[MP PET 1990]

(a) 253 *Hz* (b) 262 *Hz*

(c) 250 *Hz* (d) 259 *Hz*

13. A tuning fork and a sonometer wire were sounded together and produce 4 beats per second. When the length of sonometer wire is 95 *cm* or 100 *cm*, the frequency of the tuning fork is

(a) 156 *Hz* (b) 152 *Hz*

(c) 148 *Hz* (d) 160 *Hz*

14. Two tuning forks *A* and *B* vibrating simultaneously produce 5 beats. Frequency of *B* is 512. It is seen that if one arm of *A* is filed, then the number of beats increases. Frequency of A will be

(a) 502 (b) 507

(c) 517 (d) 522

15. The beats are produced by two sound sources of same amplitude and of nearly equal frequencies. The maximum intensity of beats will be ...... that of one source

[CPMT 1999]

(a) Same (b) Double

(c) Four times (d) Eight times

16. Beats are produced by two waves given by $y_1 = a\sin 2000\,\pi t$ and $y_2 = a\sin 2008\,\pi t$. The number of beats heard per second is

(a) Zero (b) One

(c) Four (d) Eight

17. A tuning fork whose frequency as given by manufacturer is 512 *Hz* is being tested with an accurate oscillator. It is found that the fork produces a beat of 2 *Hz* when oscillator reads 514 *Hz* but produces a beat of 6 *Hz* when oscillator reads 510 *Hz*. The actual frequency of fork is

[MNR 1979; RPMT 1999]

(a) 508 *Hz* (b) 512 *Hz*

(c) 516 *Hz* (d) 518 *Hz*

18. A tuning fork of frequency 480 *Hz* produces 10 beats per second when sounded with a vibrating sonometer string. What must have been the frequency of the string if a slight increase in tension produces lesser beats per second than before

(a) 460 *Hz* (b) 470 *Hz*

(c) 480 *Hz* (d) 490 *Hz*

19. When a tuning fork *A* of unknown frequency is sounded with another tuning fork *B* of frequency 256 *Hz*, then 3 beats per second are observed. After that *A* is loaded with wax and sounded, the again 3 beats per second are observed. The frequency of the tuning fork *A* is

[MP PMT 1994]

(a) 250 *Hz* (b) 253 *Hz*

(c) 259 *Hz* (d) 262 *Hz*

20. A source of sound gives five beats per second when sounded with another source of frequency $100\,s^{-1}$. The second harmonic of the source together with a source of frequency $205\,s^{-1}$ gives five beats per second. What is the frequency of the source

(a) $105\,s^{-1}$ (b) $205\,s^{-1}$

(c) $95\,s^{-1}$ (d) $100\,s^{-1}$

21. When two sound waves are superimposed, beats are produced when they have [MP PET 1995; CBSE PMT 1992, 99; DCE 2000; DPMT 2000, 01]

(a) Different amplitudes and phases

(b) Different velocities

(c) Different phases

(d) Different frequencies

22. Two tuning forks *A* and *B* give 4 beats per second. The frequency of *A* is 256 *Hz*. On loading *B* slightly, we get 5 beats in 2 seconds. The frequency of *B* after loading is [MP PMT 1990]

[Haryana CEE 1996]

(a) 253.5 *Hz* (b) 258.5 *Hz*

(c) 260 *Hz* [MP PMT 1991] (d) 252 *Hz*

23. A tuning fork *A* of frequency 200 *Hz* is sounded with fork *B*, the number of beats per second is 5. By putting some wax on *A*, the number of beats increases to 8. The frequency of fork *B* is

(a) 200 *Hz* (b) 195 *Hz*

(c) 192 *Hz* (d) 205 *Hz*

24. Two tuning forks, *A* and *B*, give 4 *beats per second* when sounded together. The frequency of *A* is 320 *Hz*. When some wax is added to *B* and it is sounded with *A*, 4 *beats per second* are again heard. The frequency of *B* is

[MP PMT 1997]

[CPMT 1990; DCE 1999]

(a) 312 *Hz* (b) 316 *Hz*

(c) 324 *Hz* (d) 328 *Hz*

25. Two tuning forks have frequencies 380 and 384 *Hz* respectively. When they are sounded together, they produce 4 beats. After hearing the maximum sound, how long will it take to hear the minimum sound

[MP PMT/PET 1998]

(a) $\frac{1}{2}$ *sec* (b) $\frac{1}{4}$ *sec*

(c) $\frac{1}{8}$ *sec* (d) $\frac{1}{16}$ *sec*

26. Beats are produced with the help of two sound waves of amplitudes 3 and 5 *units*. The ratio of maximum to minimum intensity in the beats is [MP PMT 1999]

(a) 2 : 1 (b) 5 : 3

(c) 4 : 1 (d) 16 : 1

27. Two waves of lengths 50 *cm* and 51 *cm* produced 12 beats per second. The velocity of sound is

[CBSE PMT 1999; Pb. PET 2001; AFMC 2003]

(a) 306 *m/s* (b) 331 *m/s*

(c) 340 *m/s* (d) 360 *m/s*

28. Two waves $y = 0.25 \sin 316\,t$ and $y = 0.25 \sin 310\,t$ are travelling in same direction. The number of beats produced per second will be

[CPMT 1993; JIPMER 2000]

(a) 6 (b) 3

(c) $3/\pi$ (d) 3π

29. The couple of tuning forks produces 2 beats in the time interval of 0.4 seconds. So the beat frequency is

[CPMT 1996]

(a) 8 *Hz* (b) 5 *Hz*

(c) 2 *Hz* (d) 10 *Hz*

30. An unknown frequency *x* produces 8 beats per seconds with a frequency of 250 *Hz* and 12 beats with 270 *Hz* source, then *x* is

(a) 258 *Hz* (b) 242 *Hz*

(c) 262 *Hz* (d) 282 *Hz*

31. Beats are produced by two waves

$$y_1 = a \sin 1000\pi t,\ \ y_2 = a \sin 998\pi t$$

The number of beats heard/sec is [KCET 1998]

(a) 0 (b) 2

(c) 1 (d) 4

32. The wavelengths of two waves are 50 and 51 *cm* respectively. If the temperature of the room is 20°*C*, then what will be the number of beats produced per second by these waves, when the speed of sound at 0°*C* is 332 *m/sec*

[UPSEAT 1999]

(a) 14 (b) 10

(c) 24 (d) None of these

33. Maximum number of beats frequency heard by a human being is

(a) 10 (b) 4

(c) 20 (d) 6

34. Two sound waves of slightly different frequencies propagating in the same direction produce beats due to

[MP PET 2000]

(a) Interference (b) Diffraction

(c) Polarization (d) Refraction

35. On sounding tuning fork *A* with another tuning fork *B* of frequency 384 *Hz*, 6 *beats* are produced per second. After loading the prongs of *A* with some wax and then sounding it again with *B*, 4 beats are produced per second. What is the frequency of the tuning fork *A*

[MP PMT 2000]

(a) 388 *Hz* (b) 380 *Hz*

(c) 378 *Hz* (d) 390 *Hz*

36. It is possible to hear beats from the two vibrating sources of frequency [UPSEAT 2001]

(a) 100 *Hz* and 150 *Hz* (b) 20 *Hz* and 25 *Hz*

(c) 400 *Hz* and 500 *Hz* (d) 1000 *Hz* and 1500 *Hz*

37. A tuning fork gives 4 beats with 50 cm length of a sonometer wire. If the length of the wire is shortened by 1 cm, the number of beats is still the same. The frequency of the fork is

(a) 396 (b) 400

(c) 404 (d) 384

38. Two sound waves of wavelengths 5*m* and 6*m* formed 30 beats in 3 seconds. The velocity of sound is

[EAMCET 2001]

(a) 300 ms^{-1} (b) 310 ms^{-1}

(c) 320 ms^{-1} (d) 330 ms^{-1}

39. The wavelength of a particle is 99 cm and that of other is 100 cm. Speed of sound is 396 m/s. The number of beats heard is

(a) 4 (b) 5

(c) 1 (d) 8

40. A tuning fork arrangement (pair) produces 4 *beats/sec* with one fork of frequency 288 *cps*. A little wax is placed on the unknown fork and it then produces 2 *beats/sec*. The frequency of the unknown fork is

[CPMT 1997; KCET 2000] [KCET 1998; AIEEE 2002]

(a) 286 *cps* (b) 292 *cps*

(c) 294 *cps* (d) 288 *cps*

41. A tuning fork vibrates with 2 beats in 0.04 second. The frequency of the fork is [AFMC 2003]

(a) 50 *Hz* (b) 100 *Hz*

(c) 80 *Hz* (d) None of these

42. Two sound sources when sounded simultaneously produce four beats in 0.25 second. the difference in their frequencies must be

(a) 4 (b) 8

(c) 16 (d) 1

43. A tuning fork of known frequency 256 *Hz* makes 5 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was

[RPMT 2000] [AIEEE 2003]

(a) 256 + 5 *Hz* (b) 256 + 2*Hz*

(c) 256 – 2 *Hz* (d) 256 – 5*Hz*

44. When temperature increases, the frequency of a tuning fork

[AIEEE 2002]

(a) Increases

(b) Decreases

(c) Remains same

(d) Increases or decreases depending on the material

45. Two strings *X* and *Y* of a sitar produce a beat frequency 4 *Hz*. When the tension of the string *Y* is slightly increased the beat frequency is found to be 2 *Hz*. If the frequency of *X* is 300 *Hz*, then the original frequency of *Y* was

[UPSEAT 2000]

(a) 296 *Hz* (b) 298 *Hz*

(c) 302 *Hz* (d) 304 *Hz*

46. The frequency of tuning forks *A* and *B* are respectively 3% more and 2% less than the frequency of tuning fork *C*. When *A* and *B* are simultaneously excited, 5 beats per second are produced. Then the frequency of the tuning fork '*A*' (in *Hz*) is

(a) 98 (b) 100

(c) 103 (d) 105

47. When a tuning fork vibrates, the waves produced in the fork are

(a) Longitudinal (b) Transverse

(c) Progressive (d) Stationary

48. Two vibrating tuning forks produce progressive waves given by $Y_1 = 4\sin 500\pi t$ and $Y_2 = 2\sin 506\pi t$. Number of beats produced per minute is [CBSE PMT 2005]

(a) 360 (b) 180

(c) 3 (d) 60

49. When a tuning fork produces sound waves in air, which one of the following is same in the material of tuning fork as well as in air

(a) Wavelength (b) Frequency

(c) Velocity (d) Amplitude

50. The disc of a siren containing 60 holes rotates at a constant speed of 360 *rpm*. The emitted sound is in unison with a tuning fork of frequency [KCET 2005]

(a) 10 *Hz* (b) 360 *Hz*

(c) 216 *Hz* (d) 6 *Hz*

51. A sound source of frequency 170 *Hz* is placed near a wall. A man walking from a source towards the wall finds that there is a periodic rise and fall of sound intensity. If the speed of sound in air is 340 *m/s* the distance (in *metres*) separating the two adjacent positions of minimum intensity is

[MNR 1992; UPSEAT 2000; CPMT 2002]

(a) 1/2 (b) 1

(c) 3/2 (d) 2

Stationary Waves

1. The distance between the nearest node and antinode in a stationary wave is

[MP PET 1984; CBSE PMT 1993; AFMC 1996; RPET 2002]

(a) λ (b) $\frac{\lambda}{2}$

(c) $\frac{\lambda}{4}$ (d) 2λ

2. In stationary wave [MP PET 1987; BHU 1995]

(a) Strain is maximum at nodes

(b) Strain is maximum at antinodes

(c) Strain is minimum at nodes

(d) Amplitude is zero at all the points

3. The phase difference between the two particles situated on both the sides of a node is [MP PET 2002]

(a) 0° (b) 90°

(c) 180° (d) 360°

4. Which of the property makes difference between progressive and stationary waves [MP PMT 1987]

(a) Amplitude (b) Frequency

(c) Propagation of energy (d) Phase of the wave

5. Stationary waves are formed when

[NCERT 1983]

(a) Two waves of equal amplitude and equal frequency travel along the same path in opposite directions

(b) Two waves of equal wavelength and equal amplitude travel along the same path with equal speeds in opposite directions [EAMCET 2001]

(c) Two waves of equal wavelength and equal phase travel along the same path with equal speed

(d) Two waves of equal amplitude and equal speed travel along the same path in opposite direction [AFMC 2001]

6. For the stationary wave $y = 4\sin\left(\frac{\pi x}{15}\right)\cos(96\pi t)$, the distance between a node and the next antinode is

[MP PMT 1987]

(a) 7.5 (b) 15

(c) 22.5 (d) 30

7. The equation of stationary wave along a stretched string is given by $y = 5\sin\frac{\pi x}{3}\cos 40\pi t$, where *x* and *y* are in cm and *t* in second. [AFMC 2005]

The separation between two adjacent nodes is [CPMT 1990; MP PET 1999; AMU 19

DPMT 2004; BHU 2005]

(a) 1.5 *cm* (b) 3 *cm*

(c) 6 *cm* (d) 4 *cm*

8. The equation $\vec{\phi}(x,t) = \vec{j}\sin\left(\frac{2\pi}{\lambda}vt\right)\cos\left(\frac{2\pi}{\lambda}x\right)$ represents

[MNR 1994]

(a) Transverse progressive wave

(b) Longitudinal progressive wave

(c) Longitudinal stationary wave

(d) Transverse stationary wave

9. The equation of a stationary wave is $y = 0.8\cos\left(\frac{\pi x}{20}\right)\sin 200\pi t$, where *x* is in *cm* and *t* is in *sec*. The separation between consecutive nodes will be

[MP PET 1994]

(a) 20 *cm* (b) 10 *cm*

(c) 40 *cm* (d) 30 *cm*

10. In a stationary wave, all particles are

[MP PMT 1994]

(a) At rest at the same time twice in every period of oscillation

(b) At rest at the same time only once in every period of oscillation

(c) Never at rest at the same time

(d) Never at rest at all

11. A wave represented by the given equation $y = a\cos(kx - \omega t)$ is superposed with another wave to form a stationary wave such that the point $x = 0$ is a node. The equation for the other wave is

AIIMS 1998; SCRA 1998; MP PET 2001; KCET 2001;

AIEEE 2002; UPSEAT 2004]

(a) $y = a\sin(kx + \omega t)$ (b) $y = -a\cos(kx + \omega t)$

(c) $y = -a\cos(kx - \omega t)$ (d) $y = -a\sin(kx - \omega t)$

12. At a certain instant a stationary transverse wave is found to have maximum kinetic energy. The appearance of string at that instant is

(a) Sinusoidal shape with amplitude $A/3$
(b) Sinusoidal shape with amplitude $A/2$
(c) Sinusoidal shape with amplitude A
(d) Straight line

13. The equation $y = 0.15\sin 5x \cos 300t$, describes a stationary wave. The wavelength of the stationary wave is [MP PMT 1995]

(a) Zero (b) 1.256 *metres*
(c) 2.512 *metres* (d) 0.628 *metre*

14. In stationary waves, antinodes are the points where there is [MP PMT 1996]

(a) Minimum displacement and minimum pressure change
(b) Minimum displacement and maximum pressure change
(c) Maximum displacement and maximum pressure change
(d) Maximum displacement and minimum pressure change

15. In stationary waves all particles between two nodes pass through the mean position [MP PMT 1999; KCET 2001]

(a) At different times with different velocities
(b) At different times with the same velocity
(c) At the same time with equal velocity
(d) At the same time with different velocities

16. Standing waves can be produced [IIT-JEE 1999]

(a) On a string clamped at both the ends
(b) On a string clamped at one end and free at the other
(c) When incident wave gets reflected from a wall
(d) When two identical waves with a phase difference of π are moving in the same direction

17. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is [CBSE PMT 1998; MH CET 2002; AIIMS 2000; BHU 2001]

(a) 1.21 Å (b) 2.42 Å
(c) 6.05 Å (d) 3.63 Å

18. In stationary waves, distance between a node and its nearest antinode is 20 *cm*. The phase difference between two particles having a separation of 60 *cm* will be [CMEET Bihar 1995]

(a) Zero (b) $\pi/2$
(c) π (d) $3\pi/2$

19. Stationary waves of frequency 300 *Hz* are formed in a medium in which the velocity of sound is 1200 *metre/sec*. The distance between a node and the neighbouring antinode is

(a) 1 *m* (b) 2 *m*
(c) 3 *m* (d) 4 *m*

20. Which two of the given transverse waves will give stationary waves when get superimposed [RPET 1997; MP PET 1993]

$z_1 = a\cos(kx - \omega t)$ .....(A)

[AIIMS 1995]

$z_2 = a\cos(kx + \omega t)$ .....(B)

$z_3 = a\cos(ky - \omega t)$ .....(C)

(a) A and B (b) A and C
(c) B and C (d) Any two

21. A standing wave is represented by

$$Y = A\sin(100t)\cos(0.01x)$$

where Y and A are in *millimetre*, t is in seconds and x is in *metre*. The velocity of wave is [CBSE PMT 1994; AFMC 2002]

(a) $10^4\ m/s$
(b) $1\ m/s$
(c) $10^{-4}\ m/s$
(d) Not derivable from above data

22. A wave of frequency 100 *Hz* is sent along a string towards a fixed end. When this wave travels back after reflection, a node is formed at a distance of 10 *cm* from the fixed end of the string. The speed of incident (and reflected) wave are [CBSE PMT 1994]

(a) 40 *m/s* (b) 20 *m/s*
(c) 10 *m/s* (d) 5 *m/s*

23. $y = a\cos(kx + \omega t)$ superimposes on another wave giving a stationary wave having node at $x = 0$. What is the equation of the other wave [BHU 1998; DPMT 2000]

(a) $-a\cos(kx + \omega t)$ (b) $a\cos(kx - \omega t)$
(c) $-a\cos(kx - \omega t)$ (d) $-a\sin(kx + \omega t)$

24. Two waves are approaching each other with a velocity of 20 *m/s* and frequency n. The distance between two consecutive nodes is

(a) $\frac{20}{n}$ (b) $\frac{10}{n}$
(c) $\frac{5}{n}$ (d) $\frac{n}{10}$

25. Energy is not carried by which of the following waves [RPMT 1998; AIIMS 1998, 99]

(a) Stationary (b) Progressive
(c) Transverse (d) Electromagnetic

26. The stationary wave produced on a string is represented by the equation $y = 5\cos(\pi x/3)\sin 40\pi t$. Where x and y are in *cm* and t is in seconds. The distance between consecutive nodes is

(a) 5 *cm* (b) π cm

[SCRA 1994]

(c) 3 *cm* (d) 40 *cm*

27. Two sinusoidal waves with same wavelengths and amplitudes travel in opposite directions along a string with a speed 10 *ms*. If the minimum time interval between two instants when the string is flat is 0.5 *s*, the wavelength of the waves is

(a) 25 *m* (b) 20 *m*
(c) 15 *m* (d) 10 *m*

28. "Stationary waves" are so called because in them [MP PMT 2001]

(a) The particles of the medium are not disturbed at all

(b) The particles of the medium do not execute SHM

(c) There occurs no flow of energy along the wave

(d) The interference effect can't be observed

29. Two waves are approaching each other with a velocity of 16 *m/s* and frequency *n*. The distance between two consecutive nodes is

(a) $\frac{16}{n}$ (b) $\frac{8}{n}$

(c) $\frac{n}{16}$ (d) $\frac{n}{8}$

30. Stationary waves [Kerala (Med.) 2002]

(a) Transport energy

(b) Does not transport energy

(c) Have nodes and antinodes

(d) Both (b) and (c)

31. In a stationary wave all the particles [KCET 2002]

(a) On either side of a node vibrate in same phase

(b) In the region between two nodes vibrate in same phase

(c) In the region between two antinodes vibrate in same phase

(d) Of the medium vibrate in same phase

32. When a stationary wave is formed then its frequency is [Kerala (Engg.) 2002]

(a) Same as that of the individual waves

(b) Twice that of the individual waves

(c) Half that of the individual waves

(d) None of the above

33. In stationary waves [RPMT 1998; JIPMER 2002]

(a) Energy is uniformly distributed

(b) Energy is minimum at nodes and maximum at antinodes

(c) Energy is maximum at nodes and minimum at antinodes

(d) Alternating maximum and minimum energy producing at nodes and antinodes

34. Equation of a stationary wave is $y = 10\sin\frac{\pi x}{4}\cos 20\pi t$. Distance between two consecutive nodes is [MP PMT 2002]

(a) 4 (b) 2

(c) 1 (d) 8

35. At nodes in stationary waves [SCRA 1994; UPSEAT 2000; MP PET 2003; RPET 2003]

(a) Change in pressure and density are maximum

(b) Change in pressure and density are minimum

(c) Strain is zero

(d) Energy is minimum

36. Consider the three waves z_1, z_2 and z_3 as

$z_1 = A\sin(kx - \omega t)$, $z_2 = A\sin(kx + \omega t)$

and $z_3 = A\sin(ky - \omega t)$. Which of the following represents a standing wave [DCE 2004]

(a) $z_1 + z_2$ (b) $z_2 + z_3$

(c) $z_3 + z_1$ (d) $z_1 + z_2 + z_3$

37. The following equations represent progressive transverse waves $Z_1 = A\cos(\omega t - kx)$, $Z_2 = A\cos(\omega t + kx)$, $Z_3 = A\cos(\omega t + ky)$ and $Z_4 = A\cos(2\omega t - 2ky)$. A stationary wave will be formed by superposing [MP PET 1993]

(a) Z_1 and Z_2 (b) Z_1 and Z_4

(c) Z_2 and Z_3 (d) Z_3 and Z_4

38. Two travelling waves $y_1 = A\sin[k(x - ct)]$ and $y_2 = A\sin[k(x + ct)]$ are superimposed on string. The distance between adjacent nodes is [CPMT 2001; Pb. PMT 1999] [IIT 1992]

(a) ct/π (b) $ct/2\pi$

(c) $\pi/2k$ (d) π/k

39. A string vibrates according to the equation $y = 5\sin\left(\frac{2\pi x}{3}\right)\cos 20\pi t$, where *x* and *y* are in *cm* and *t* in *sec*. The distance between two adjacent nodes is [UPSEAT 2005]

(a) 3 *cm* (b) 4.5 *cm*

(c) 6 *cm* (d) 1.5 *cm*

Vibration of String

1. A string fixed at both the ends is vibrating in two segments. The wavelength of the corresponding wave is [SCRA 1994]

(a) $\frac{l}{4}$ (b) $\frac{l}{2}$

(c) l (d) $2l$

2. A 1 *cm* long string vibrates with fundamental frequency of 256 *Hz*. If the length is reduced to $\frac{1}{4}cm$ keeping the tension unaltered, the new fundamental frequency will be [BHU 1997]

(a) 64 (b) 256

(c) 512 (d) 1024

3. Standing waves are produced in a 10 *m* long stretched string. If the string vibrates in 5 segments and the wave velocity is 20 *m/s*, the frequency is [CBSE PMT 1997; AIIMS 1998; JIPMER 2000]

(a) 2 *Hz* (b) 4 *Hz*

(c) 5 *Hz* (d) 10 *Hz*

4. The velocity of waves in a string fixed at both ends is 2 *m/s*. The string forms standing waves with nodes 5.0 *cm* apart. The frequency of vibration of the string in *Hz* is [SCRA 1998]

(a) 40 (b) 30

(c) 20 (d) 10

5. Which of the following is the example of transverse wave [CPMT 1999]

(a) Sound waves

(b) Compressional waves in a spring

(c) Vibration of string

(d) All of these

6. A stretched string of 1*m* length and mass $5 \times 10^{-4} kg$ is having tension of 20*N*. If it is plucked at 25*cm* from one end then it will vibrate with frequency

[RPET 1999; RPMT 2002]

(a) 100 *Hz* (b) 200 *Hz*

(c) 256 *Hz* (d) 400 *Hz*

7. Two similar sonometer wires given fundamental frequencies of 500*Hz*. These have same tensions. By what amount the tension be increased in one wire so that the two wires produce 5 *beats/sec* [RPET 1999]

(a) 1% (b) 2%

(c) 3% (d) 4%

8. A string is producing transverse vibration whose equation is $y = 0.021\sin(x + 30t)$, Where *x* and *y* are in meters and t is in seconds. If the linear density of the string is 1.3×10^{-4} *kg/m*, then the tension in the string in N will be

[RPET 1999; RPMT 2002]

(a) 10 (b) 0.5

(c) 1 (d) 0.117

9. If the tension of sonometer's wire increases four times then the fundamental frequency of the wire will increase by

[RPMT 1999]

(a) 2 times (b) 4 times

(c) 1/2 times (d) None of the above

10. If vibrations of a string are to be increased by a factor of two, then tension in the string must be made

[AIIMS 1999; Pb. PET 2000]

(a) Half (b) Twice

(c) Four times (d) Eight times

11. Four wires of identical length, diameters and of the same material are stretched on a sonometre wire. If the ratio of their tensions is 1 : 4 : 9 : 16 then the ratio of their fundamental frequencies are [KCET 2000]

(a) 16 : 9 : 4 : 1 (b) 4 : 3 : 2 : 1

(c) 1 : 4 : 2 : 16 (d) 1 : 2 : 3 : 4

12. A tuning fork vibrating with a sonometer having 20 *cm* wire produces 5 beats per second. The beat frequency does not change if the length of the wire is changed to 21 *cm*. the frequency of the tuning fork (in Hertz) must be

[UPSEAT 2000; Pb. PET 2004]

(a) 200 (b) 210

(c) 205 (d) 215

13. A stretched string of length l, fixed at both ends can sustain stationary waves of wavelength λ, given by

[UPSEAT 2000; Pb. PET 2004; CPMT 2005]

(a) $\lambda = \frac{n^2}{2l}$ (b) $\lambda = \frac{l^2}{2n}$

(c) $\lambda = \frac{2l}{n}$ (d) $\lambda = 2l\,n$

14. If you set up the seventh harmonic on a string fixed at both ends, how many nodes and antinodes are set up in it

[AMU 2000]

(a) 8, 7 (b) 7, 7

(c) 8, 9 (d) 9, 8

15. If you set up the ninth harmonic on a string fixed at both ends, its frequency compared to the seventh harmonic

[AMU (Engg.) 2000]

(a) Higher (b) Lower

(c) Equal (d) None of the above

16. Frequency of a sonometer wire is *n*. Now its tension is increased 4 times and its length is doubled then new frequency will be

(a) *n*/2 (b) 4*n*

(c) 2*n* (d) *n*

17. A device used for investigating the vibration of a fixed string or wire is [BHU 2000]

(a) Sonometer (b) barometer

(c) Hydrometer (d) None of these

18. A string on a musical instrument is 50 *cm* long and its fundamental frequency is 270 *Hz*. If the desired frequency of 1000 *Hz* is to be produced, the required length of the string is

[EAMCET (Engg.) 1998; CPMT 2000; Pb. PET 2001]

(a) 13.5 *cm* (b) 2.7 *cm*

(c) 5.4 *cm* (d) 10.3 *cm*

19. The tension in a piano wire is 10N. What should be the tension in the wire to produce a note of double the frequency

(a) 5 *N* (b) 20 *N*

(c) 40 *N* (d) 80 *N*

20. To increase the frequency from 100 *Hz* to 400 *Hz* the tension in the string has to be changed by [RPET 2001]

(a) 4 times (b) 16 times

(c) 20 times (d) None of these

21. In order to double the frequency of the fundamental note emitted by a stretched string, the length is reduced to $\frac{3}{4}$ *th* of the original length and the tension is changed. The factor by which the tension is to be changed, is [EAMCET 2001]

(a) $\frac{3}{8}$ (b) $\frac{2}{3}$

(c) $\frac{8}{9}$ (d) $\frac{9}{4}$

22. A string of 7 *m* length has a mass of 0.035 *kg*. If tension in the string is 60.5 *N*, then speed of a wave on the string is

[CBSE PMT 2001]

(a) 77 *m/s* (b) 102 *m/s*

(c) 110 *m/s* (d) 165 *m/s*

23. A second harmonic has to be generated in a string of length l stretched between two rigid supports. The point where the string has to be plucked and touched are

[KCET 2001]

(a) Plucked at $\frac{l}{4}$ and touch at $\frac{l}{2}$

(b) Plucked at $\frac{l}{4}$ and touch at $\frac{3l}{4}$

(c) Plucked at $\frac{l}{2}$ and touched at $\frac{l}{4}$

(d) Plucked at $\frac{l}{2}$ and touched at $\frac{3l}{4}$

24. Transverse waves of same frequency are generated in two steel wires *A* and *B*. The diameter of *A* is twice of *B* and the tension in *A* is half that in *B*. The ratio of velocities of wave in *A* and *B* is

(a) $1 : 3\sqrt{2}$ (b) $1 : 2\sqrt{2}$

(c) $1:2$ (d) $\sqrt{2}:1$

25. A sonometer wire resonates with a given tuning fork forming standing waves with five antinodes between the two bridges when a mass of 9 *kg* is suspended from the wire. When this mass is replaced by a mass *M*, the wire resonates with the same tuning fork forming three antinodes for the same positions of the bridges. The value of *M* is

[IIT-JEE (Screening) 2002]

(a) 25 *kg* (b) 5 *kg*

(c) 12.5 *kg* (d) 1/25 *kg*

26. The tension of a stretched string is increased by 69%. In order to keep its frequency of vibration constant, its length must be increased by [KCET 2002]

(a) 20% (b) 30%

(c) $\sqrt{69}\%$ (d) 69%

27. The length of a sonometer wire tuned to a frequency of 250 *Hz* is 0.60 *metre*. The frequency of tuning fork with which the vibrating wire will be in tune when the length is made 0.40 *metre* is

(a) 250 *Hz* (b) 375 *Hz*

(c) 256 *Hz* (d) 384 *Hz*

28. Length of a string tied to two rigid supports is 40 *cm*. Maximum length (wavelength in *cm*) of a stationary wave produced on it is

(a) 20 (b) 80

(c) 40 (d) 120

29. A string in musical instrument is 50 *cm* long and its fundamental frequency is 800 *Hz*. If a frequency of 1000 *Hz* is to be produced, then required length of string is

[AIIMS 2002]

(a) 62.5 *cm* (b) 50 *cm*

(c) 40 *cm* (d) 37.5 *cm*

30. Two wires are in unison. If the tension in one of the wires is increased by 2%, 5 beats are produced per second. The initial frequency of each wire is [MP PET 2002]

(a) 200 *Hz* (b) 400 *Hz*

(c) 500 *Hz* (d) 1000 *Hz*

31. Two uniform strings *A* and *B* made of steel are made to vibrate under the same tension. if the first overtone of *A* is equal to the second overtone of *B* and if the radius of *A* is twice that of *B*, the ratio of the lengths of the strings is

[EAMCET 2003]

(a) 1: 2 (b) 1 : 3

(c) 1 : 4 (d) 1 : 6

32. If the length of a stretched string is shortened by 40% and the tension is increased by 44%, then the ratio of the final and initial fundamental frequencies is

[EAMCET 2003]

(a) 2 : 1 (b) 3 : 2

(c) 3 : 4 (d) 1 : 3

33. Two wires are fixed in a sonometer. Their tensions are in the ratio 8 : 1. The lengths are in the ratio $36:35$. The diameters are in the ratio 4 : 1. Densities of the materials are in the ratio 1 : 2. If the lower frequency in the setting is 360 *Hz*. the beat frequency when the two wires are sounded together is

(a) 5 (b) 8

(c) 6 (d) 10

34. The first overtone of a stretched wire of given length is 320 *Hz*. The first harmonic is : [DPMT 2004]

(a) 320 *Hz* (b) 160 *Hz*

(c) 480 *Hz* (d) 640 *Hz*

35. Two perfectly identical wires are in unison. When the tension in one wire is increased by 1%, then on sounding them together 3 beats are heard in 2 *sec*. The initial frequency of each wire is :

(a) $220s^{-1}$ (b) $320s^{-1}$

(c) $150s^{-1}$ (d) $300s^{-1}$

36. A tuning fork of frequency 392 *Hz*, resonates with 50 *cm* length of a string under tension (T). If length of the string is decreased by 2%, keeping the tension constant, the number of beats heard when the string and the tuning fork made to vibrate simultaneously is

(a) 4 (b) 6

(c) 8 (d) 12

37. The sound carried by air from a sitar to a listener is a wave of the following type [JIPMER 2002] [MP PMT 1987; RPET 2001]

(a) Longitudinal stationary (b) Transverse progressive

(c) Transverse stationary (d) Longitudinal progressive

38. In Melde's experiment in the transverse mode, the frequency of the tuning fork and the frequency of the waves in the strings are in the ratio [AIEEE 2002] [KCET 2004]

(a) 1 : 1 (b) 1 : 2

(c) 2 : 1 (d) 4 : 1

39. The frequency of transverse vibrations in a stretched string is 200 *Hz*. If the tension is increased four times and the length is reduced to one-fourth the original value, the frequency of vibration will be

(a) 25 *Hz* (b) 200 *Hz*

(c) 400 *Hz* (d) 1600 *Hz*

40. Three similar wires of frequency n, n and n are joined to make one wire. Its frequency will be

[CBSE PMT 2000]

(a) $n = n_1 + n_2 + n_3$ (b) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$

(c) $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}}$ (d) $\frac{1}{n^1} = \frac{1}{n_1^2} + \frac{1}{n_2^2} + \frac{1}{n_3^2}$

41. A steel rod 100 *cm* long is clamped at its mid-point. The fundamental frequency of longitudinal vibrations of the rod is given to be 2.53 *kHz*. What is the speed of sound in steel

[AFMC 2000]

(a) 5.06 *km/s* (b) 6.06 *km/s*

(c) 7.06 *km/s* (d) 8.06 *km/s*

42. Two wires are producing fundamental notes of the same frequency. Change in which of the following factors of one wire will not produce beats between them

[BHU (Med.) 1999]

(a) Amplitude of the vibrations

(b) Material of the wire

[KCET 2003]

(c) Stretching force

(d) Diameter of the wires

43. Calculate the frequency of the second harmonic formed on a string of length 0.5 *m* and mass 2×10^{-4} *kg* when stretched with a tension of 20 *N* **[BHU (Med.) 2000]**

(a) 274.4 *Hz* (b) 744.2 *Hz*

(c) 44.72 *Hz* (d) 447.2 *Hz*

44. The fundamental frequency of a string stretched with a weight of 4 *kg* is 256 *Hz*. The weight required to produce its octave is

(a) 4 *kg wt* (b) 8 *kg wt*

(c) 12 *kg wt* (d) 16 *kg wt*

45. Two vibrating strings of the same material but lengths L and $2L$ have radii $2r$ and r respectively. They are stretched under the same tension. Both the strings vibrate in their fundamental modes, the one of length L with frequency n_1 and the other with frequency n_2. The ratio n_1/n_2 is given by

[IIT-JEE (Screening) 2000]

(a) 2 (b) 4

(c) 8 (d) 1

46. If the tension and diameter of a sonometer wire of fundamental frequency *n* are doubled and density is halved then its fundamental frequency will become

[CBSE PMT 2001]

(a) $\frac{n}{4}$ (b) $\sqrt{2}\, n$

(c) n (d) $\frac{n}{\sqrt{2}}$

47. In a sonometer wire, the tension is maintained by suspending a 50.7 *kg* mass from the free end of the wire. The suspended mass has a volume of 0.0075 m^3. The fundamental frequency of the wire is 260 *Hz*. If the suspended mass is completely submerged in water, the fundamental frequency will become (take g = 10 ms^{-2})

[KCET 2001]

(a) 240 *Hz* (b) 230 *Hz*

(c) 220 *Hz* (d) 200 *Hz*

48. A string is rigidly tied at two ends and its equation of vibration is given by $y = \cos 2\pi t \sin \sin \pi x$. Then minimum length of string is **[RPMT 2001]**

(a) 1 *m* (b) $\frac{1}{2} m$

(c) 5 *m* (d) $2\pi m$

49. Fundamental frequency of sonometer wire is *n*. If the length, tension and diameter of wire are tripled, the new fundamental frequency is

(a) $\frac{n}{\sqrt{3}}$ (b) $\frac{n}{3}$

(c) $n\sqrt{3}$ (d) $\frac{n}{3\sqrt{3}}$

[DPMT 2002]

50. A string of length 2 *m* is fixed at both ends. If this string vibrates in its fourth normal mode with a frequency of 500 *Hz* then the waves would travel on its with a velocity of

[BCECE 2005]

(a) 125 *m/s* (b) 250 *m/s*

(c) 500 *m/s* (d) 1000 *m/s*

51. The fundamental frequency of a sonometre wire is *n*. If its radius is doubled and its tension becomes half, the material of the wire remains same, the new fundamental frequency will be **[BCECE 2005]**

(a) n (b) $\frac{n}{\sqrt{2}}$

(c) $\frac{n}{2}$ (d) $\frac{n}{2\sqrt{2}}$

52. In an experiment with sonometer a tuning fork of frequency 256 *Hz* resonates with a length of 25 *cm* and another tuning fork resonates with a length of 20 *cm*. Tension of the string remaining constant the frequency of the second tuning fork is **[J & K CET 2000]**

(a) 163.84 *Hz* (b) 400 *Hz*

(c) 320 *Hz* (d) 204.8 *Hz*

Organ Pipe (Vibration of Air Column)

1. The length of two open organ pipes are l and $(l + \Delta l)$ respectively. Neglecting end correction, the frequency of beats between them will be approximately

[MP PET 1994; BHU 1995]

(a) $\frac{v}{2l}$ (b) $\frac{v}{4l}$

(c) $\frac{v\Delta l}{2l^2}$ (d) $\frac{v\Delta l}{l}$

(Here v is the speed of sound)

2. A tube closed at one end and containing air is excited. It produces the fundamental note of frequency 512 *Hz*. If the same tube is open at both the ends the fundamental frequency that can be produced is

(a) 1024 *Hz* (b) 512 *Hz*

(c) 256 *Hz* (d) 128 *Hz*

3. A closed pipe and an open pipe have their first overtones identical in frequency. Their lengths are in the ratio

[Roorkee 1999]

(a) 1 : 2 (b) 2 : 3

(c) 3 : 4 (d) 4 : 5

4. The first overtone in a closed pipe has a frequency

[JIPMER 1999]

(a) Same as the fundamental frequency of an open tube of same length

(b) Twice the fundamental frequency of an open tube of same length

(c) Same as that of the first overtone of an open tube of same length

(d) None of the above

5. An empty vessel is partially filled with water, then the frequency of vibration of air column in the vessel

[KCET 2000]

(a) Remains same

(b) Decreases

(c) Increases

(d) First increases then decreases

6. It is desired to increase the fundamental resonance frequency in a tube which is closed at one end. This can be achieved by

(a) Replacing the air in the tube by hydrogen gas

(b) Increasing the length of the tube

(c) Decreasing the length of the tube

(d) Opening the closed end of the tube

7. An air column in a pipe, which is closed at one end, will be in resonance with a vibrating body of frequency 166 *Hz*, if the length of the air column is **[UPSEAT 2001]**

(a) 2.00 *m* (b) 1.50 *m*

(c) 1.00 *m* (d) 0.50 *m*

8. If the velocity of sound in air is 350 *m/s*. Then the fundamental frequency of an open organ pipe of length 50 *cm*, will be [CPMT 1997; MH CET 2001; Pb. PMT 2001]

(a) 350 *Hz* (b) 175 *Hz*

(c) 900 *Hz* (d) 750 *Hz*

9. If the length of a closed organ pipe is 1m and velocity of sound is 330 *m/s*, then the frequency for the second note is [AFMC 2001]

(a) $4 \times \frac{330}{4} Hz$ (b) $3 \times \frac{330}{4} Hz$

(c) $2 \times \frac{330}{4} Hz$ (d) $2 \times \frac{4}{330} Hz$

10. The fundamental note produced by a closed organ pipe is of frequency f. The fundamental note produced by an open organ pipe of same length will be of frequency [BHU 2001]

(a) $\frac{f}{2}$ (b) f

(c) $2f$ (d) $4f$

11. If the velocity of sound in air is 336 m/s. The *maximum* length of a closed pipe that would produce a just audible sound will be [KCET 2001]

(a) 3.2 *cm* (b) 4.2 *m*

(c) 4.2 *cm* (d) 3.2 *m*

12. An organ pipe P_1 closed at one end vibrating in its first overtone and another pipe P_2 open at both ends vibrating in its third overtone are in resonance with a given tuning fork. The ratio of lengths of P_1 and P_2 is [EAMCET 1997; MH CET 1999; AFMC 2001]

(a) 1 : 2 (b) 1 : 3

(c) 3 : 8 (d) 3 : 4

13. A resonance air column of length 20 *cm* resonates with a tuning fork of frequency 250 *Hz*. The speed of sound in air is [AFMC 1999; BHU 2000; CPMT 2001]

(a) 300 *m/s* (b) 200 *m/s*

(c) 150 *m/s* (d) 75 *m/s*

14. A cylindrical tube, open at both ends, has a fundamental frequency f_0 in air. The tube is dipped vertically into water such that half of its length is inside water. The fundamental frequency of the air column now is [RPET 1999; RPMT 1998, 2000; J & K CET 2000; KCET 2002; BHU 2002; BCECE 2003]

(a) $3f_0/4$ (b) f_0

(c) $f_0/2$ (d) $2f_0$

15. If the length of a closed organ pipe is 1.5 *m* and velocity of sound is 330 *m/s*, then the frequency for the second note is [CBSE PMT 2002]

(a) 220 *Hz* (b) 165 *Hz*

(c) 110 *Hz* (d) 55 *Hz*

16. A pipe 30 *cm* long is open at both ends. Which harmonic mode of the pipe is resonantly excited by a 1.1 *kHz* source ? (Take speed of sound in air = 330 *ms*) [AMU 2002]

(a) First (b) Second

(c) Third (d) Fourth

17. Two closed organ pipes, when sounded simultaneously gave 4 beats per sec. If longer pipe has a length of 1*m*. Then length of shorter pipe will be, (v = 300 *m/s*) [Pb. PMT 2002]

(a) 185.5 *cm* (b) 94.9 *cm*

(c) 90 *cm* (d) 80 *cm*

18. A source of sound placed at the open end of a resonance column sends an acoustic wave of pressure amplitude ρ_0 inside the tube. If the atmospheric pressure is ρ_A, then the ratio of maximum and minimum pressure at the closed end of the tube will be

(a) $\frac{(\rho_A + \rho_0)}{(\rho_A - \rho_0)}$ (b) $\frac{(\rho_A + 2\rho_0)}{(\rho_A - 2\rho_0)}$

(c) $\frac{\rho_A}{\rho_A}$ (d) $\frac{\left(\rho_A + \frac{1}{2}\rho_0\right)}{\left(\rho_A - \frac{1}{2}\rho_0\right)}$

19. Two closed pipe produce 10 beats per second when emitting their fundamental nodes. If their length are in ratio of 25 : 26. Then their fundamental frequency in *Hz*, are [MH CET 2002]

(a) 270, 280 (b) 260, 270

(c) 260, 250 (d) 260, 280

20. A closed organ pipe and an open organ pipe are tuned to the same fundamental frequency. What is the ratio of lengths

(a) 1 : 2 (b) 2 : 1

(c) 2 : 3 (d) 4 : 3

21. An open pipe resonates with a tuning fork of frequency 500 *Hz*. it is observed that two successive nodes are formed at distances 16 and 46 *cm* from the open end. The speed of sound in air in the pipe is

(a) 230 *m/s* (b) 300 *m/s*

(c) 320 *m/s* (d) 360 *m/s*

22. Find the fundamental frequency of a closed pipe, if the length of the air column is 42 *m*. (speed of sound in air = 332 *m/sec*)

(a) 2 *Hz* (b) 4 *Hz*

(c) 7 *Hz* (d) 9 *Hz*

23. If v is the speed of sound in air then the shortest length of the closed pipe which resonates to a frequency n [KCET 2003]

(a) $\frac{v}{4n}$ (b) $\frac{v}{2n}$

(c) $\frac{2n}{v}$ (d) $\frac{4n}{v}$

24. The frequency of fundamental tone in an open organ pipe of length 0.48 *m is* 320 *Hz*. Speed of sound is 320 *m/sec*. Frequency of fundamental tone in closed organ pipe will be [MP PMT 2003]

(a) 153.8 *Hz* (b) 160.0 *Hz*

(c) 320.0 *Hz* (d) 143.2 *Hz*

25. If fundamental frequency of closed pipe is 50 *Hz* then frequency of 2nd overtone is [AFMC 2004]

(a) 100 *Hz* (b) 50 *Hz*

(c) 250 *Hz* (d) 150 *Hz*

26. Two open organ pipes of length 25 *cm* and 25.5 *cm* produce 10 *beat/sec*. The velocity of sound will be

[Pb. PMT 2004]

(a) 255 *m/s* (b) 250 *m/s*

(c) 350 *m/s* (d) None of these

27. What is minimum length of a tube, open at both ends, that resonates with tuning fork of frequency 350 *Hz* ? [velocity of sound in air = 350 *m/s*] [DPMT 2004]

(a) 50 *cm* (b) 100 *cm*

(c) 75 *cm* (d) 25 *cm*

28. Two open organ pipes give 4 *beats/sec* when sounded together in their fundamental nodes. If the length of the pipe are 100 *cm* and 102.5 *cm* respectively, then the velocity of sound is : [Pb. PET 2000; CPMT 2001]

(a) 496 *m/s* (b) 328 *m/s*

(c) 240 *m/s* (d) 160 *m/s*

29. The harmonics which are present in a pipe open at one end are [UPSEAT 2000; MHCET 2004]

(a) Odd harmonics

(b) Even harmonics

(c) Even as well as odd harmonics

(c) None of these

30. An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher by 100 *Hz*, then the fundamental frequency of open pipe is: [UPSEAT 2001; Pb. PET 2004]

(a) 480 *Hz* (b) 300 *Hz*

(c) 240 *Hz* (d) 200 *Hz*

31. Tube *A* has both ends open while tube *B* has one end closed, otherwise they are identical. The ratio of fundamental frequency of tube *A* and *B* is

[AIEEE 2002; CPMT 2004]

(a) 1 : 2 (b) 1 : 4

(c) 2 : 1 (d) 4 : 1

32. If the temperature increases, then what happens to the frequency of the sound produced by the organ pipe

[RPET 1996; DPMT 2000; RPMT 2001]

(a) Increases (b) Decreases

(c) Unchanged (d) Not definite

33. Apparatus used to find out the velocity of sound in gas is

[AFMC 2004]

(a) Melde's apparatus (b) Kundt's tube

(c) Quincke's tube (d) None of these

34. Standing stationary waves can be obtained in an air column even if the interfering waves are [CPMT 1972]

(a) Of different pitches

(b) Of different amplitudes

(c) Of different qualities

(d) Moving with different velocities

35. The stationary wave $y = 2a \sin kx \cos \omega t$ in a closed organ pipe is the result of the superposition of $y = a\sin(\omega t - kx)$ and

(a) $y = -a\cos(\omega t + kx)$ (b) $y = -a\sin(\omega t + kx)$

(c) $y = a\sin(\omega t + kx)$ (d) $y = a\cos(\omega t + kx)$

36. Stationary waves are set up in air column. Velocity of sound in air is 330 *m/s* and frequency is 165 *Hz*. Then distance between the nodes is

[EAMCET (Engg.) 1995; CPMT 1999]

(a) 2 *m* (b) 1 *m*

(c) 0.5 *m* (d) 4 *m*

37. An open pipe of length *l* vibrates in fundamental mode. The pressure variation is maximum at

[EAMCET (Med.) 1999]

(a) 1/4 from ends

(b) The middle of pipe

(c) The ends of pipe

(d) At 1/8 from ends of pipe middle of the pipe

38. Fundamental frequency of pipe is 100 *Hz* and other two frequencies are 300 *Hz* and 500 *Hz* then

[RPMT 1998, 2003; CPMT 2001]

(a) Pipe is open at both the ends

(b) Pipe is closed at both the ends

(c) One end open and another end is closed

(d) None of the above

39. Fundamental frequency of an open pipe of length 0.5 *m* is equal to the frequency of the first overtone of a closed pipe of length *l*. The value of *l* is (*m*) [KCET 1999]

(a) 1.5 (b) 0.75

(c) 2 (d) 1

40. In a closed organ pipe the frequency of fundamental note is 50 *Hz*. The note of which of the following frequencies will not be emitted by it [J & K CET 2000]

(a) 50 *Hz* (b) 100 *Hz*

(c) 150 *Hz* (d) None of the above

41. On producing the waves of frequency 1000 *Hz* in a Kundt's tube, the total distance between 6 successive nodes is 85 *cm*. Speed of sound in the gas filled in the tube is

[AFMC 1999]

(a) 330 *m/s* (b) 340 *m/s*

(c) 350 *m/s* (d) 300 *m/s*

42. What is the base frequency if a pipe gives notes of frequencies 425, 255 and 595 and decide whether it is closed at one end or open at both ends [UPSEAT 2001]

(a) 17, closed (b) 85, closed

(c) 17, open (d) 85, open

43. A student determines the velocity of sound with the help of a closed organ pipe. If the observed length for fundamental frequency is 24.7 *m*, the length for third harmonic will be

[RPET 2002]

(a) 74 [Roorkee 1994] (b) 72.7 *cm*

(c) 75.4 *cm* (d) 73.1 *cm*

44. An open pipe of length 33 *cm* resonates with frequency of 100 *Hz*. If the speed of sound is 330 *m/s*, then this frequency is

(a) Fundamental frequency of the pipe

(b) Third harmonic of the pipe

(c) Second harmonic of the pipe

(d) Fourth harmonic of the pipe

45. In a resonance tube the first resonance with a tuning fork occurs at 16 *cm* and second at 49 *cm*. If the velocity of sound is 330 *m/s*, the frequency of tuning fork is

[DPMT 2002]

(a) 500 (b) 300

(c) 330 (d) 165

46. Two closed organ pipes of length 100 *cm* and 101 *cm* 16 beats in 20 *sec*. When each pipe is sounded in its fundamental mode calculate the velocity of sound

[AFMC 2003]

(a) 303 ms^{-1} (b) 332 ms^{-1}

(c) 323.2 ms^{-1} (d) 300 ms^{-1}

47. In open organ pipe, if fundamental frequency is n then the other frequencies are [BCECE 2005]

(a) $n, 2n, 3n, 4n$ (b) $n, 3n, 5n$

(c) $n, 2n, 4n, 8n$ (d) None of these

48. If in an experiment for determination of velocity of sound by resonance tube method using a tuning fork of 512 *Hz*, first resonance was observed at 30.7 *cm* and second was obtained at 63.2 *cm*, then maximum possible error in velocity of sound is (consider actual speed of sound in air is 332 *m/s*)

(a) 204 *cm/sec* (b) 110 *cm/sec*

(c) 58 *cm/sec* (d) 80 *cm/sec*

49. An organ pipe, open from both end produces 5 beats per second when vibrated with a source of frequency 200 *Hz*. The second harmonic of the same pipes produces 10 beats per second with a source of frequency 420 *Hz*. The frequency of source is

(a) 195 *Hz* (b) 205 *Hz*

(c) 190 *Hz* (d) 210 *Hz*

50. In one metre long open pipe what is the harmonic of resonance obtained with a tuning fork of frequency 480 *Hz*

[J & K CET 2005]

(a) First (b) Second

(c) Third (d) Fourth

51. An organ pipe open at one end is vibrating in first overtone and is in resonance with another pipe open at both ends and vibrating in third harmonic. The ratio of length of two pipes is

(a) 1 : 2 (b) 4 : 1

(c) 8 : 3 (d) 3 : 8

52. In a resonance pipe the first and second resonances are obtained at depths 22.7 *cm* and 70.2 *cm* respectively. What will be the end correction [J & K CET 2005]

(a) 1.05 *cm* (b) 115.5 *cm*

(c) 92.5 *cm* (d) 113.5 *cm*

53. An open tube is in resonance with string (frequency of vibration of tube is n). If tube is dipped in water so that 75% of length of tube is inside water, then the ratio of the frequency of tube to string now will be [J & K CET 2005]

(a) 1 (b) 2

(c) $\frac{2}{3}$ (d) $\frac{3}{2}$

Doppler's Effect

1. Doppler shift in frequency does not depend upon

[MP PMT 1993; DPMT 2000]

(a) The frequency of the wave produced

(b) The velocity of the source

(c) The velocity of the observer

(d) Distance from the source to the listener

2. A source of sound of frequency 450 *cycles/sec* is moving towards a stationary observer with 34 *m/sec* speed. If the speed of sound is 340 *m/sec*, then the apparent frequency will be

(a) 410 *cycles/sec* (b) 500 *cycles/sec*

(c) 550 *cycles/sec* (d) 450 *cycles/sec*

3. The wavelength is 120 *cm* when the source is stationary. If the source is moving with relative velocity of 60 *m/sec* towards the observer, then the wavelength of the sound wave reaching to the observer will be (velocity of sound = 330 *m/s*)

(a) 98 *cm* (b) 140 *cm*

(c) 120 *cm* (d) 144 *cm*

4. [IIT-JEE (Screening) 2005 The frequency of a whistle of an engine is 600 *cycles/sec* is moving with the speed of 30 *m/sec* towards an observer. The apparent frequency will be (velocity of sound = 330 *m/s*)

(a) 600 *cps* (b) 660 *cps*

(c) 990 *cps* (d) 330 *cps*

5. A source of sound emits waves with frequency f *Hz* and speed V *m/sec*. Two observers move away from this source in opposite directions [DCE 2005] each with a speed 0.2 V relative to the source. The ratio of frequencies heard by the two observers will be

(a) 3 : 2 (b) 2 : 3

(c) 1 : 1 (d) 4 : 10

6. The source producing sound and an observer both are moving along the direction of propagation of sound waves. If the respective velocities of sound, source and an observer are v, v_s and v_o, then the apparent frequency heard by the observer will be (n = frequency of sound)

[MP PMT 1989]

(a) $\frac{n(v+v_o)}{v-v_o}$ [DCE 2005] (b) $\frac{n(v-v_o)}{v-v_s}$

(c) $\frac{n(v-v_o)}{v+v_s}$ (d) $\frac{n(v+v_o)}{v+v_s}$

7. An observer moves towards a stationary source of sound of frequency n. The apparent frequency heard by him is $2n$. If the velocity of sound in air is 332 m/sec, then the velocity of the observer is [MP PET 1990]

(a) 166 *m/sec* (b) 664 *m/sec*

(c) 332 *m/sec* (d) 1328 *m/sec*

8. An observer is moving towards the stationary source of sound, then

(a) Apparent frequency will be less than the real frequency

(b) Apparent frequency will be greater than the real frequency

(c) Apparent frequency will be equal to real frequency

(d) Only the quality of sound will change

9. A whistle sends out 256 waves in a second. If the whistle approaches the observer with velocity 1/3 of the velocity of sound in air, the number of waves per second the observer will receive [MP PET 1990; DPMT 2002]

(a) 384 (b) 192

(c) 300 (d) 200

10. A person feels 2.5% difference of frequency of a motor-car horn. If the motor-car is moving to the person and the velocity of sound is 320 *m/sec*, then the velocity of car will be

(a) 8 *m/s* (approx.) (b) 800 *m/s*

(c) 7 *m/s* (d) 6 *m/s* (approx.)

11. Two passenger trains moving with a speed of 108 *km/hour* cross each other. One of them blows a whistle whose frequency is 750 *Hz*. If sound speed is 330 *m/s*, then passengers sitting in the other train, after trains cross each other will hear sound whose frequency will be

[MP PMT 1991]

(a) 900 *Hz* (b) 625 *Hz*

(c) 750 *Hz* (d) 800 *Hz*

12. With what velocity an observer should move relative to a stationary source so that he hears a sound of double the frequency of source

(a) Velocity of sound towards the source

(b) Velocity of sound away from the source

(c) Half the velocity of sound towards the source

(d) Double the velocity of sound towards the source

13. A source of sound emitting a note of frequency 200 *Hz* moves towards an observer with a velocity v equal to the velocity of sound. If the observer also moves away from the source with the same velocity v, the apparent frequency heard by the observer is

(a) 50 *Hz* (b) 100 *Hz*

(c) 150 *Hz* (d) 200 *Hz*

14. Doppler's effect will not be applicable when the velocity of sound source is

(a) Equal to that of the sound velocity

(b) Less than the velocity of sound

(c) Greater than the velocity of sound

(d) Zero

15. An observer while going on scooter hears sound of two sirens of same frequencies from two opposite directions. If he travels along the direction of one of the siren, then he

(a) Listens resonance

(b) Listens beats

(c) Will not listen sound due to destructive interference

(d) Will listen intensive sound due to constructive interference

16. A source of sound is travelling towards a stationary observer. The frequency of sound heard by the observer is of three times the original frequency. The velocity of sound is v *m/sec*. The speed of source will be

[MP PET 1991]

(a) $\frac{2}{3}v$ (b) v

(c) $\frac{3}{2}v$ (d) $3v$

17. A sound source is moving towards a stationary observer with 1/10 of the speed of sound. The ratio of apparent to real frequency is

[CPMT 1977; NCERT 1977; KCET 2001, 03]

(a) 10/9 (b) 11/10

(c) $(11/10)^2$ (d) $(9/10)^2$

18. The speed of sound in air at a given temperature is 350 *m/s*. An engine blows whistle at a frequency of 1200 *cps*. It is approaching the observer with velocity 50 *m/s*. The apparent frequency in *cps* heard by the observer will be

[CPMT 1981; MP PET 1989]

[CPMT 1976; RPET 1999; BHU 1997, 2001]

(a) 600 (b) 1050

(c) 1400 (d) 2400

19. Suppose that the speed of sound in air at a given temperature is 400 *m/sec*. An engine blows a whistle at 1200 *Hz* frequency. It is approaching an observer at the speed of 100 *m/sec*. What is the apparent frequency as heard by the observer

(a) 600 *Hz* (b) 1200 *Hz*

(c) 1500 *Hz* (d) 1600 *Hz*

[MP PMT 1991]

20. A source of frequency 150 *Hz* is moving in the direction of a person with a velocity of 110 *m/s*. The frequency heard by the person will be (speed of sound in medium = 330 *m/s*)

(a) 225 *Hz* (b) 200 *Hz*

(c) 150 *Hz* (d) 100 *Hz*

21. The Doppler's effect is applicable for

[AFMC 1998]

(a) Light waves (b) Sound waves

[MP PMT 1990]

(c) Space waves (d) Both (a) and (b)

22. A source of sound is moving with constant velocity of 20 *m/s* emitting a note of frequency 1000 *Hz*. The ratio of frequencies observed by a stationary observer while the source is approaching him and after it crosses him will be

[MP PET 1994]

(a) 9 : 8 (b) 8 : 9

(c) 1 : 1 (d) 9 : 10

(Speed of sound v = 340 *m/s*)

23. A source of sound S is moving with a velocity 50*m/s* towards a stationary observer. The observer measures the frequency of the source as 1000 *Hz*. What will be the apparent frequency of the source when it is moving away from the observer after crossing him ? The velocity of sound in the medium is 350 *m/s*

(a) 750 *Hz* (b) 857 *Hz*

(c) 1143 *Hz* (d) 1333 *Hz*

24. A source and listener are both moving towards each other with speed $v/10$, where v is the speed of sound. If the frequency of the note emitted by the source is f, the frequency heard by the listener would be nearly

[MP PMT 1994; MP PET 2001]

(a) 1.11 f (b) 1.22 f

(c) f (d) 1.27 f

25. A table is revolving on its axis at 5 revolutions per second. A sound source of frequency 1000 *Hz* is fixed on the table at 70 *cm* from the axis. The minimum frequency heard by a listener standing at a distance from the table will be (speed of sound = 352 *m/s*)

(a) 1000 *Hz* (b) 1066 *Hz*

(c) 941 *Hz* (d) 352 *Hz*

26. A source of sound *S* of frequency 500 *Hz* situated between a stationary observer *O* and a wall *W*, moves towards the wall with a speed of 2 *m/s*. If the velocity of sound is 332 *m/s*, then the number of beats per second heard by the observer is (approximately)

(a) 8 (b) 6

(c) 4 (d) 2

27. A motor car blowing a horn of frequency 124 *vib/sec* moves with a velocity 72 *km/hr* towards a tall wall. The frequency of the reflected sound heard by the driver will be (velocity of sound in air is 330 *m/s*) [MP PET 1997]

(a) 109 *vib/sec* (b) 132 *vib/sec*

(c) 140 *vib/sec* (d) 248 *vib/sec*

28. A source of sound of frequency *n* is moving towards a stationary observer with a speed *S*. If the speed of sound in air is *V* and the frequency heard by the observer is n_1, the value of n_1/n is

(a) $(V+S)/V$ (b) $V/(V+S)$

(c) $(V-S)/V$ (d) $V/(V-S)$

29. A vehicle with a horn of frequency *n* is moving with a velocity of 30 *m/s* in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n+n_1$. Then (if the sound velocity in air is 300 *m/s*)

[CBSE PMT 1998; AIIMS 2000]

(a) $n_1 = 10n$ (b) $n_1 = 0$

(c) $n_1 = 0.1n$ (d) $n_1 = -0.1n$

30. A whistle giving out 450 *Hz* approaches a stationary observer at a speed of 33 *m/s*. The frequency heard by the observer in *Hz* is

(a) 409 (b) 429

(c) 517 (d) 500

31. An observer is moving away from source of sound of frequency 100 *Hz*. His speed is 33 *m/s*. If speed of sound is 330 *m/s*, then the observed frequency is

[EAMCET (Engg.) 1995; CPMT 1999]

(a) 90 *Hz* (b) 100 *Hz*

(c) 91 *Hz* (d) 110 *Hz*

32. An observer standing at station observes frequency 219 *Hz* when a train approaches and 184 *Hz* when train goes away from him. If velocity of sound in air is 340 *m*/s, then velocity of train and actual frequency of whistle will be

[RPET 1997]

(a) $15.5\,ms^{-1}$, $200\,Hz$ (b) $19.5\,ms^{-1}$, $205\,Hz$

(c) $29.5\,ms^{-1}$, $200\,Hz$ (d) $32.5\,ms^{-1}$, $205\,Hz$

33. At what speed should a source of sound move so that stationary observer finds the apparent frequency equal to half of the original frequency [RPMT 1996]

(a) $\frac{v}{2}$ (b) $2v$

(c) $\frac{v}{4}$ (d) v

34. A boy is walking away from a wall towards an observer at a speed of 1 *metre/sec* and blows a whistle whose frequency is 680 *Hz*. The number of beats heard by the observer per second is (Velocity of sound in air = 340 *metres/sec*

[MP PMT 1995]

(a) Zero (b) 2

(c) 8 (d) 4

35. The driver of a car travelling with speed 30 *metres per second* towards a hill sounds a horn of frequency 600 *Hz*. If the velocity of sound in air is 330 *metres per second*, the frequency of the reflected sound as heard by the driver is

[MP PMT 1996]

(a) 720 *Hz* (b) 555.5 *Hz*

(c) 550 *Hz* (d) 500 *Hz*

36. Two sirens situated one kilometer apart are producing sound of frequency 330 *Hz*. [MP PMT 1997] An observer starts moving from one siren to the other with a speed of 2 *m/s*. If the speed of sound be 330 *m/s*, what will be the beat frequency heard by the observer [RPMT 1996; CPMT 2002]

(a) 8 (b) 4

(c) 6 (d) 1

37. A source of sound is travelling with a velocity 40 *km/hour* towards observer and emits sound of frequency 2000 *Hz*. If velocity of sound is 1220 *km/hour*, then what is the apparent frequency heard by an observer [AFMC 1997]

(a) 2210 *Hz* (b) 1920 *Hz*

(c) 2068 *Hz* (d) 2086 *Hz*

38. A source of sound and listener are approaching each other with a speed of 40 *m/s*. [IIT 1997 Cancelled] The apparent frequency of note produced by the source is 400 *cps*. Then, its true frequency (in *cps*) is (velocity of sound in air = 360 *m/s*)

[KCET 1999]

(a) 420 (b) 360

(c) 400 (d) 320

39. A siren emitting sound of frequency 500 *Hz* is going away from a static listener with a speed of 50 *m/sec*. The frequency of sound to be heard, directly from the siren, is

[AIIMS 1999; Pb. PMT 2003]

(a) 434.2 *Hz* (b) 589.3 *Hz*

(c) 481.2 *Hz* (d) 286.5 *Hz*

40. A man sitting in a moving train hears the whistle of the engine. The frequency of the whistle is 600 *Hz*

[JIPMER 1999]

(a) The apparent frequency as heard by him is smaller than 600 *Hz*

(b) The apparent frequency is larger than 600 *Hz*

(c) The frequency as heard by him is 600 *Hz*

(d) None of the above

41. A source of sound of frequency 500 *Hz* is moving towards an observer with velocity 30 *m/s*. The speed of sound is 330 *m/s*. the frequency heard by the observer will be

[MP PET 2000; Kerala PMT 2005; UPSEAT 2005]

(a) 550 *Hz* (b) 458.3 *Hz*

(c) 530 *Hz* (d) 545.5 *Hz*

42. A source of sound of frequency 90 vibrations/ *sec* is approaching a stationary observer with a speed equal to 1/10 the speed of sound. What will be the frequency heard by the observer

(a) 80 vibrations/*sec* (b) 90 vibrations/*sec*

(c) 100 vibrations/*sec* (d) 120 vibrations/*sec*

43. A whistle of frequency 500 *Hz* tied to the end of a string of length 1.2 *m* revolves at 400 *rev/min*. A listener standing some distance away in the plane of rotation of whistle hears frequencies in the range (speed of sound = 340 *m/s*)

[KCET 2000; AMU 1999; Pb. PET 2003]

(a) 436 to 586 (b) 426 to 574

(c) 426 to 584 (d) 436 to 674

44. A train moves towards a stationary observer with speed 34 *m/s*. The train sounds a whistle and its frequency registered by the observer is f_1. If the train's speed is reduced to 17 *m/s*, the frequency registered is f_2. If the speed of sound is 340 *m/s* then the ratio f_1 / f_2 is

[IIT-JEE (Screening) 2000]

(a) 18/19 (b) 1/2

(c) 2 (d) 19/18

45. If source and observer both are relatively at rest and if speed of sound is increased then frequency heard by observer will

[RPET 2000; J & K CET 2004]

(a) Increases (b) Decreases

(c) Can not be predicted (d) Will not change

46. A source and an observer move away from each other with a velocity of 10 *m/s* with respect to ground. If the observer finds the frequency of sound coming from the source as 1950 *Hz*, then actual frequency of the source is (velocity of sound in air = 340 *m/s*)

MH CET 2000; AFMC 2000; CBSE PMT 2001]

(a) 1950 *Hz* (b) 2068 *Hz*

(c) 2132 *Hz* (d) 2486 *Hz*

47. A source is moving towards an observer with a speed of 20 *m/s* and having frequency of 240 *Hz*. The observer is now moving towards the source with a speed of 20 *m/s*. Apparent frequency heard by observer, if velocity of sound is 340 *m/s*, is [CPMT 2000; KCET 2001; MH CET 2004]

(a) 240 *Hz* (b) 270 *Hz*

(c) 280 *Hz* (d) 360 *Hz*

48. A siren placed at a railway platform is emitting sound of frequency 5 *kHz*. A passenger sitting in a moving train *A* records a frequency of 5.5 *kHz* while the train approaches the siren. During his return journey in a different train *B* he records a frequency of 6.0 *kHz* while approaching the same siren. The ratio of the velocity of train *B* to that of train *A* is

[IIT-JEE (Screening) 2002]

(a) 242/252 (b) 2

(c) 5/6 (d) 11/6

49. A whistle revolves in a circle with an angular speed of 20 *rad/sec* using a string of length 50 *cm*. If the frequency of sound from the whistle is 385 *Hz*, then what is the minimum frequency heard by an observer, which is far away from the centre in the same plane ? (v = 340 *m/s*) [MP PMT 2000]

[CBSE PMT 2002]

(a) 333 *Hz* (b) 374 *Hz*

(c) 385 *Hz* (d) 394 *Hz*

50. A Siren emitting sound of frequency 800 *Hz* is going away from a static listener with a speed of 30 *m/s*, frequency of the sound to be heard by the listener is (take velocity of sound as 330 *m/s*)

[CPMT 1996; AIIMS 2002; Pb. PMT 2001]

(a) 733.3 *Hz* (b) 644.8 *Hz*

(c) 481.2 *Hz* (d) 286.5 *Hz*

51. A car sounding a horn of frequency 1000 *Hz* passes an observer. The ratio of frequencies of the horn noted by the observer before and after passing of the car is 11 : 9. If the speed of sound is v, the speed of the car is

[MP PET 2002]

(a) $\frac{1}{10}v$ (b) $\frac{1}{2}v$

(c) $\frac{1}{5}v$ (d) v

52. What should be the velocity of a sound source moving towards a stationary observer so that apparent frequency is double the actual frequency (Velocity of sound is v)

[MP PMT 2002]

(a) v (b) $2v$

(c) $\frac{v}{2}$ (d) $\frac{v}{4}$

[EAMCET 1997;

53. Two trains are moving towards each other at speeds of 20 *m/s* and 15 *m/s* relative to the ground. The first train sounds a whistle of frequency 600 *Hz*. the frequency of the whistle heard by a passenger in the second train before the train meets is (the speed of sound in air is 340 *m/s*)

[UPSEAT 2002]

(a) 600 *Hz* (b) 585 *Hz*

(c) 645 *Hz* (d) 666 *Hz*

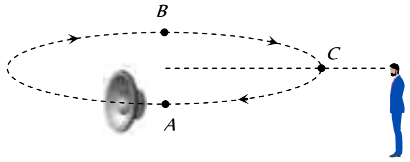
54. A small source of sound moves on a circle as shown in the figure and an observer is standing on O. Let n_1, n_2 and n_3 be the frequencies heard when the source is at A, B and C respectively. Then [UPSEAT 2002]

(a) $n_1 > n_2 > n_3$

(b) $n_2 > n_3 > n_1$

(c) $n_1 = n_2 > n_3$

(d) $n_2 > n_1 > n_3$



55. A source and an observer approach each other with same velocity 50 *m/s*. If the apparent frequency is 435 *sec*, then the real frequency is [CPMT 2003]

(a) 320 *s* (b) 360 *sec*

(c) 390 *sec* (d) 420 *sec*

56. A source emits a sound of frequency of 400 *Hz*, but the listener hears it to be 390 *Hz*. Then [Orissa JEE 2003]

(a) The listener is moving towards the source

(b) The source is moving towards the listener

(c) The listener is moving away from the source

(d) The listener has a defective ear

57. Doppler effect is applicable for [AFMC 2003]

(a) Moving bodies

(b) One is moving and other are stationary

(c) For relative motion

(d) None of these

58. A source and an observer are moving towards each other with a speed equal to $\frac{v}{2}$ where v is the speed of sound. The source is emitting sound of frequency *n*. The frequency heard by the observer will be [MP PET 2003]

(a) Zero (b) n

(c) $\frac{n}{3}$ (d) $3n$

59. When an engine passes near to a stationary observer then its apparent frequencies occurs in the ratio 5/3. If the velocity of engine is [MP PMT 2003]

(a) 540 *m/s* (b) 270 *m/s*

(c) 85 *m/s* (d) 52.5 *m/s*

60. A police car horn emits a sound at a frequency 240 *Hz* when the car is at rest. If the speed of the sound is 330 *m/s*, the frequency heard by an observer who is approaching the car at a speed of 11 *m/s*, is :

(a) 248 *Hz* (b) 244 *Hz*

(c) 240 *Hz* (d) 230 *Hz*

61. A person carrying a whistle emitting continuously a note of 272 *Hz* is running towards a reflecting surface with a speed of 18 *km/hour*. The speed of sound in air is $345ms^{-1}$. The number of beats heard by him is [Kerala (Engg.) 2002]

(a) 4 (b) 6

(c) 8 (d) 3

62. A bus is moving with a velocity of 5 *m/s* towards a huge wall. the driver sounds a horn of frequency 165 *Hz*. If the speed of sound in air is 355 *m/s*, the number of beats heard per second by a passenger on the bus will be [KCET 2001; BHU 2002]

(a) 6 (b) 5

(c) 3 (d) 4

63. A source of sound of frequency 256 *Hz* is moving rapidly towards a wall with a velocity of 5*m/s*. The speed of sound is 330 *m/s*. If the observer is between the wall and the source, then beats per second heard will be [UPSEAT 2002]

(a) 7.8 *Hz* (b) 7.7 *Hz*

(c) 3.9 *Hz* (d) Zero

64. The apparent frequency of a note, when a listener moves towards a stationary source, with velocity of 40 *m/s* is 200 *Hz*. When he moves away from the same source with the same speed, the apparent frequency of the same note is 160 *Hz*. The velocity of sound in air is (in *m/s*) [KCET 1998]

(a) 360 (b) 330

(c) 320 (d) 340

65. An observer moves towards a stationary source of sound, with a velocity one-fifth of the velocity of sound. What is the percentage increase in the apparent frequency [AIEEE 2005]

(a) 5% (b) 20%

(c) Zero (d) 0.5%

Musical Sound

1. The walls of the halls built for music concerts should [NCERT 1979]

(a) Amplify sound (b) Transmit sound

(c) Reflect sound (d) Absorb sound

2. A spherical source of power 4 *W* and frequency 800 *Hz* is emitting sound waves. The intensity of waves at a distance 200 *m* is[CPMT 1999; JIPMER

(a) $8\times10^{-6}\ W/m^2$ (b) $2\times10^{-4}\ W/m^2$

(c) $1\times10^{-4}\ W/m^2$ (d) $4\ W/m^2$

3. If the pressure amplitude in a sound wave is tripled, then the intensity of sound is increased by a factor of [CPMT 1992; JIPMER 2000]

(a) 9 (b) 3

(c) 6 (d) $\sqrt{3}$

4. If the amplitude of sound is doubled and the frequency reduced to one-fourth, the intensity of sound at the same point will be [UPSEAT 2004]

(a) Increased by a factor of 2

(b) Decreased by a factor of 2

(c) Decreased by a factor of 4

(d) Unchanged

5. Intensity level of a sound of intensity *I* is 30 *dB*. The ratio $\frac{I}{I_0}$ is (Where I_0 is the threshold of hearing) [KCET 1999; J & K CET 2005]

(a) 3000 (b) 1000

(c) 300 (d) 30

6. Decibel is unit of [RPMT 2000]

(a) Intensity of light (b) X-rays radiation capacity

(c) Sound loudness (d) Energy of radiation

7. Quality of a musical note depends on [MP PMT 1998; KCET 1999; RPET 2000]

(a) Harmonics present

(b) Amplitude of the wave

(c) Fundamental frequency

(d) Velocity of sound in the medium

8. When we hear a sound, we can identify its source from

[KCET (Med.) 2001]

(a) Amplitude of sound

(b) Intensity of sound

(c) Wavelength of sound

(d) Overtones present in the sound

9. A man X can hear only upto 10 *kHz* and another man y upto 20 *kHz*. A note of frequency 500 *Hz* is produced before them from a stretched string. Then [KCET 2002]

(a) Both will hear sounds of same pitch but different quality

(b) Both will hear sounds of different pitch but same quality

(c) Both will hear sounds of different pitch and different quality

(d) Both will hear sounds of same pitch and same quality

10. The amplitude of two waves are in ratio 5 : 2. If all other conditions for the two waves are same, then what is the ratio of their energy densities [MH CET 2004]

(a) 5 : 2 (b) 10: 4

(c) 2.5 : 1 (d) 25 : 4

11. *A* is singing a note and at the same time *B* is singing a note with exactly one-eighth the frequency of the note of *A*. The energies of two sounds are equal, the amplitude of the note of *B* is [NCERT 1981; AIIMS 2001]

(a) Same that of *A* (b) Twice as that of *A*

(c) Four times as that of *A* (d) Eight times as that of *A*

12. The loudness and pitch of a sound depends on [KCET 2004; Pb. PET 2003]

(a) Intensity and velocity

(b) Frequency and velocity

(c) Intensity and frequency

(d) Frequency and number of harmonics

13. If *T* is the reverberation time of an auditorium of volume *V* then

(a) $T \propto \frac{1}{V}$ (b) $T \propto \frac{1}{V^2}$

(c) $T \propto V^2$ (d) $T \propto V$

14. The intensity of sound from a radio at a distance of 2 *metres* from its speaker is $1 \times 0^{-2}\,\mu\, W/m^2$. The intensity at a distance of 10 meters would be [CPMT 2005]

(a) $0.2 \times 10^{-2}\,\mu\, W/m^2$ (b) $1 \times 10^{-2}\,\mu\, W/m^2$

(c) $4 \times 10^{-4}\,\mu\, W/m^2$ (d) $5 \times 10^{-2}\,\mu\, W/m^2$

15. The intensity of sound wave while passing through an elastic medium falls down by 10% as it covers one metre distance through the medium. If the initial intensity of the sound wave was 100 *decibels*, its value after it has passed through 3 *metre* thickness of the medium will be [CPMT 1988]

(a) 70 *decibel* (b) 72.9 *decibel*

(c) 81 *decibel* (d) 60 *decibel*

16. A musical scale is constructed by providing intermediate frequencies between a note and its octave which [CPMT 1972; NCERT 1980]

(a) Form an arithmetic progression

(b) Form a geometric progression

(c) Bear a simple ratio with their neighbours

(d) Form a harmonic progression

17. In a harmonium the intermediate notes between a note and its octave form [CPMT 1973]

(a) An arithmetic progression

(b) A geometric progression

(c) A harmonic progression

(d) An exponential progression

18. The power of a sound from the speaker of a radio is 20 *mW*. By turning the knob of the volume control, the power of the sound is increased to 400 *mW*. The power increase in decibels as compared to the original power is

(a) 13 *dB* (b) 10 *dB*

(c) 20 *dB* (d) 800 *dB*

19. If separation between screen and source is increased by 2% what would be the effect on the intensity [CPMT 2003]

(a) Increases by 4% (b) Increases by 2%

(c) Decreases by 2% (d) Decreases by 4%

20. The musical interval between two tones of frequencies 320 *Hz* and 240 *Hz* is [MP PMT 1992; AFMC 1992]

(a) 80 (b) $\left(\frac{4}{3}\right)$

(c) 560 (d) 320×240

21. In an orchestra, the musical sounds of different instruments are distinguished from one another by which of the following characteristics [CBSE PMT 1993]

(a) Pitch (b) Loudness

(c) Quality (d) Overtones

22. The intensity level due to two waves of the same frequency in a given medium are 1 *bel* and 5 *bel*. Then the ratio of amplitudes is [KCET 2003]

(a) 1 : 4 (b) 1 : 2

(c) $1 : 10^4$ (d) $1 : 10^2$

23. It is possible to recognise a person by hearing his voice even if he is hidden behind a wall. This is due to the fact that his voice

(a) Has a definite pitch (b) Has a definite quality

(c) Has a definite loudness (d) Can penetrate the wall

24. Of the following the one which emits sound of higher pitch is

(a) Mosquito (b) Lion

(c) Man (d) Woman

25. In the musical octave 'Sa', 'Re', 'Ga'

(a) The frequency of the note 'Sa' is greater than that of 'Re', 'Ga'

(b) The frequency of the note 'Sa' is smaller than that of 'Re', 'Ga'

(c) The frequency of all the notes 'Sa', 'Re', 'Ga' is the same

(d) The frequency decreases in the sequence 'Sa', 'Re', 'Ga'

26. Tone *A* has frequency of 240 *Hz*. Of the following tones, the one which will sound least harmonious with *A* is

(a) 240 (b) 480

(c) 360 (d) 450

27. Learned Indian classical vocalists do not like the accompaniment of a harmonium because [MP PMT 1992]

(a) Intensity of the notes of the harmonium is too large

(b) Notes of the harmonium are too shrill

(c) Diatonic scale is used in the harmonium

(d) Tempered scale is used in the harmonium

28. Each of the properties of sound listed in column A primarily depends on one of the quantities in column B. Choose the matching pairs from two columns

Column A	Column B
Pitch	Waveform
Quality	Frequency
Loudness	Intensity

[IIT 1980]

(a) Pitch-waveform, Quality-frequency; Loudness-intensity

(b) Pitch-frequency, Quality-waveform; Loudness-intensity

(c) Pitch-intensity, Quality-waveform; Loudness- frequency

(d) Pitch-waveform, Quality- intensity; Loudness-frequency

29. Intensity level 200 *cm* from a source of sound is 80 *dB*. If there is no loss of acoustic power in air and intensity of threshold hearing is $10^{-12}\,Wm^{-2}$ then, what is the intensity level at a distance of 400 *cm* from source

(a) Zero (b) 54 *dB*

(c) 64 *dB* (d) 44 *dB*

30. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at distances of $2m$ and $3m$ respectively from the source. The ratio of the intensities of the waves at P and Q is [CBSE PMT 2005]

(a) 9 : 4 (b) 2 : 3

(c) 3 : 2 (d) 4 : 9

31. Quality depends on [AFMC 2003]

(a) Intensity (b) Loudness

(c) Timbre (d) Frequency

32. Two waves having sinusoidal waveforms have different wavelengths and different amplitude. They will be having

[BHU 2005]

(a) Same pitch and different intensity

(b) Same quality and different intensity

(c) Different quality and different intensity

(d) Same quality and different pitch

Critical Thinking

Objective Questions

1. A wave disturbance in a medium is described by $y(x,t) = 0.02\cos\left(50\pi t + \frac{\pi}{2}\right)\cos(10\pi x)$, where x and y are in *metres* and t in seconds [IIT 1995]

(a) A displacement node occurs at $x = 0.15\ m$

(b) An antinode occurs at $x = 0.3\ m$

(c) The wavelength of the wave is 0.2 *m*

(d) The speed of the wave is 5.0 *m/s*

2. The (x, y) coordinates of the corners of a square plate are (0, 0), (*L*, 0), (*L*, *L*) and (0, *L*). The edges of the plate are clamped and transverse standing waves are set up in it. If $u(x, y)$ denotes the displacement of the plate at the point (x, y) at some instant of time, the possible expression(s) for u is(are) (a = positive constant)

[IIT 1998; Orissa PMT 2004]

(a) $a\cos\frac{\pi x}{2L}\cos\frac{\pi y}{2L}$ (b) $a\sin\frac{\pi x}{L}\sin\frac{\pi y}{L}$

(c) $a\sin\frac{\pi x}{L}\sin\frac{2\pi y}{L}$ (d) $a\cos\frac{2\pi x}{L}\cos\frac{\pi y}{L}$

3. The ends of a stretched wire of length L are fixed at $x = 0$ and $x = L$. In one experiment, the displacement of the wire is $y_1 = A\sin(\pi x/L)\sin\omega t$ and energy is E_1, and in another experiment its displacement is $y_2 = A\sin(2\pi x/L)\sin 2\omega t$ and energy is E_2. Then

[IIT-JEE (Screening) 2001]

(a) $E_2 = E_1$ (b) $E_2 = 2E_1$

(c) $E_2 = 4E_1$ (d) $E_2 = 16E_1$

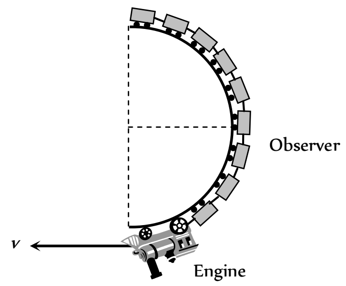
4. In a large room, a person receives direct sound waves from a source 120 *metres* away from him. He also receives waves from the same source which reach him, being reflected from the 25 *metre* high ceiling at a point halfway between them. The two waves interfere constructively for wavelength of

[Roorkee 1982]

(a) 20, 20/3, 20/5 *etc* (b) 10, 5, 2.5 *etc*

(c) 10, 20, 30 *etc* (d) 15, 25, 35 *etc*

5. A train has just complicated a *U*-curve in a track which is a semicircle. The engine is at the forward end of the semi circular part of the track while the last carriage is at the rear end of the semicircular track. The driver blows a whistle of frequency 200 *Hz*. Velocity of sound is 340 *m/sec*. Then the apparent frequency as observed by a passenger in the middle of a train when the speed of the train is 30 *m/sec* is



(a) 209 *Hz* (b) 288 *Hz*

(c) 200 *Hz* (d) 181 *Hz*

6. Two identical flutes produce fundamental notes of frequency 300 *Hz* at 27^o *C*. If the temperature of air in one flute is increased to 31^o *C*, the number of the beats heard per second will be

(a) 1 (b) 2

(c) 3 (d) 4

7. In the experiment for the determination of the speed of sound in air using the resonance column method, the length of the air column that resonates in the fundamental mode, with a tuning fork is 0.1 *m*. when this length is changed to 0.35 *m*, the same tuning fork resonates with the first overtone. Calculate the end correction

[IIT-JEE (Screening) 2003]

(a) 0.012*m* (b) 0.025*m*

(c) 0.05*m* (d) 0.024*m*

8. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open organ pipe is

[IIT-JEE (Screening) 2004]

(a) $\frac{L}{3}$ (b) $\frac{4L}{3}$

(c) $\frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$ (d) $\frac{4L}{3}\sqrt{\frac{\rho_2}{\rho_1}}$

9. A string of length 0.4 m and mass $10^{-2}\ kg$ is tightly clamped at its ends. The tension in the string is 1.6 N. Identical wave pulses are produced at one end at equal intervals of time Δt. The minimum value of Δt which allows constructive interference between successive pulses is [IIT 1998]

(a) 0.05 s (b) 0.10 s
(c) 0.20 s (d) 0.40 s

10. Two identical stringed instruments have frequency 100 Hz. If tension in one of them is increased by 4% and they are sounded together then the number of beats in one second is

[EAMCET (Engg.) 1995]

(a) 1 (b) 8
(c) 4 (d) 2

11. The difference between the apparent frequency of a source of sound as perceived by an observer during its approach and recession is 2% of the natural frequency of the source. If the velocity of sound in air is 300 m/sec, the velocity of the source is (It is given that velocity of source << velocity of sound) [CPMT 1982; RPET 1998]

(a) 6 m/sec (b) 3 m/sec
(c) 1.5 m/sec (d) 12 m/sec

12. A sound wave of frequency ν travels horizontally to the right. It is reflected from a large vertical plane surface moving to the left with a speed v. The speed of sound in the medium is c, then

(a) The frequency of the reflected wave is $\frac{\nu(c+v)}{c-v}$

(b) The wavelength of the reflected wave is $\frac{c(c-v)}{\nu(c+v)}$

(c) The number of waves striking the surface per second is $\frac{\nu(c+v)}{c}$

(d) The number of beats heard by a stationary listener to the left of the reflecting surface is $\frac{v\nu}{c-v}$

13. Two cars are moving on two perpendicular roads towards a crossing with uniform speeds of 72 km/hr and 36 km/hr. If first car blows horn of frequency 280 Hz, then the frequency of horn heard by the driver of second car when line joining the cars make 45° angle with the roads; will be

[RPET 1997]

(a) 321 Hz (b) 298 Hz
(c) 289 Hz (d) 280 Hz

14. Two whistles A and B produces notes of frequencies 660 Hz and 596 Hz respectively. There is a listener at the mid-point of the line joining them. Now the whistle B and the listener start moving with speed 30 m/s away from the whistle A. If speed of sound be 330 m/s, how many beats will be heard by the listener

(a) 2 (b) 4
(c) 6 (d) 8

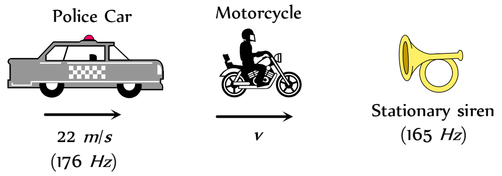
15. A source producing sound of frequency 170 Hz is approaching a stationary observer with a velocity 17 ms^{-1}. The apparent change in the wavelength of sound heard by the observer is (speed of sound in air = 340 ms^{-1})

[EAMCET (Engg.) 2000]

(a) 0.1m (b) 0.2m
(c) 0.4m (d) 0.5m

16. A police car moving at 22 m/s, chases a motorcyclist. The police man sounds his horn at 176 Hz, while both of them move towards a stationary siren of frequency 165 Hz. Calculate the speed of the motorcycle, if it is given that he does not observes any beats

[IIT-JEE (Screening) 2003]



(a) 33 m/s (b) 22 m/s
(c) Zero (d) 11 m/s

17. An observer moves towards a stationary source of sound with a speed 1/5th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively[CBSE PMT

(a) $1.2\,f, \lambda$ (b) $f, 1.2\lambda$
(c) $0.8f, 0.8\lambda$ (d) $1.2f, 1.2\lambda$

18. A light pointer fixed to one prong of a tuning fork touches a vertical plate. The fork is set vibrating and the plate is allowed to fall freely. If eight oscillations are counted when the plate falls through 10 cm, the frequency of the tuning fork is [IIT 1977; KCET 2002]
[IIT 1995; BCECE 2005]

(a) 360 Hz (b) 280 Hz
(c) 560 Hz (d) 56 Hz

19. Oxygen is 16 times heavier than hydrogen. Equal volumes of hydrogen and oxygen are mixed. The ratio of speed of sound in the mixture to that in hydrogen is [KCET 2004]

(a) $\sqrt{\frac{1}{8}}$ (2) $\sqrt{\frac{32}{17}}$
(c) $\sqrt{8}$ (d) $\sqrt{\frac{2}{17}}$

20. The equation of displacement of two waves are given as $y_1 = 10\sin\left(3\pi t + \frac{\pi}{3}\right)$; $y_2 = 5(\sin 3\pi t + \sqrt{3}\cos 3\pi t)$. Then what is the ratio of their amplitudes

[AIIMS 1997; Haryana PMT 2000]

(a) 1 : 2 (b) 2 : 1
(c) 1 : 1 (d) None of these

21. The equation $y = A\cos^2\left(2\pi\, nt - 2\pi\frac{x}{\lambda}\right)$ represents a wave with

(a) Amplitude $A/2$, frequency $2n$ and wavelength $\lambda/2$

(b) Amplitude $A/2$, frequency $2n$ and wavelength λ [RPET 1996]

(c) Amplitude A, frequency $2n$ and wavelength 2λ

(d) Amplitude A, frequency n and wavelength λ

22. In a wave motion $y = a\sin(kx - \omega t)$, y can represent

[IIT-JEE 1999]

(a) Electric field (b) Magnetic field
(c) Displacement (d) Pressure

23. Consider ten identical sources of sound all giving the same frequency but having phase angles which are random. If the average intensity of each source is I_0, the average of resultant intensity I due to all these ten sources will be

[MP PMT 1990]

(a) $I = 100\, I_0$ (b) $I = 10\, I_0$

(c) $I = I_0$ (d) $I = \sqrt{10}\, I_0$

24. Ten tuning forks are arranged in increasing order of frequency in such a way that any two nearest tuning forks produce 4 *beats/sec*. The highest frequency is twice of the lowest. Possible highest and the lowest frequencies are

[MP PMT 1990; MHCET 2002]

(a) 80 and 40 (b) 100 and 50

(c) 44 and 22 (d) 72 and 36

25. 41 forks are so arranged that each produces 5 *beats per sec* when sounded with its near fork. If the frequency of last fork is double the frequency of first fork, then the frequencies of the first and last fork are respectively

[MP PET 1997; KCET 2002]

(a) 200, 400 (b) 205, 410

(c) 195, 390 (d) 100, 200

26. Two identical wires have the same fundamental frequency of 400 *Hz*. when kept under the same tension. If the tension in one wire is increased by 2% the number of beats produced will be

(a) 4 (b) 2

(c) 8 (d) 1

27. 25 tunning forks are arranged in series in the order of decreasing frequency. Any two successive forks produce 3 beats/sec. If the frequency of the first turning fork is the octave of the last fork, then the frequency of the 21st fork is

[Kerala (Engg.) 2001]

(a) 72 *Hz* (b) 288 *Hz*

(c) 84 *Hz* (d) 87 *Hz*

28. 16 tunning forks are arranged in the order of increasing frequencies. Any two successive forks give 8 beats per sec when sounded together. If the frequency of the last fork is twice the first, then the frequency of the first fork is

[CBSE PMT 2000; MP PET 2001]

(a) 120 (b) 160

(c) 180 (d) 220

29. Two identical straight wires are stretched so as to produce 6 beats per second when vibrating simultaneously. On changing the tension in one of them, the beat frequency remains unchanged. Denoting by T_1, T_2, the higher and the lower initial tensions in the strings, then it could be said that while making the above change in tension[IIT 1991]

(a) T_2 was decreased (b) T_2 was increased

(c) T_1 was increased (d) T_1 was kept constant

30. The frequency of a stretched uniform wire under tension is in resonance with the fundamental frequency of a closed tube. If the tension in the wire is increased by 8 *N*, it is in resonance with the first overtone of the closed tube. The initial tension in the wire is

(a) 1 *N* (b) 4 *N*

(c) 8 *N* (d) 16 *N*

31. A metal wire of linear mass density of 9.8 *g/m* is stretched with a tension of 10 *kg* weight between two rigid supports 1 *metre* apart. The wire passes at its middle point between the poles of a permanent magnet, and it vibrates in resonance when carrying an alternating current of frequency *n*. The frequency *n* of the alternating source is

[AIEEE 2003]

(a) 25 *Hz* (b) 50 *Hz*

(c) 100 *Hz* (d) 200 *Hz*

32. A wire of density 9×10^{3} kg /m^3 is stretched between two clamps 1 m apart and is subjected to an extension of 4.9×10^{-4} m. The lowest frequency of transverse vibration in the wire is ($Y = 9 \times 10^{10}$ N / m^2)[UPSEAT 200

(a) 40 *Hz* (b) 35 *Hz*

(c) 30 *Hz* (d) 25 *Hz*

33. A man is watching two trains, one leaving and the other coming in with equal speeds of 4 *m*/sec. If they sound their whistles, each of frequency 240 *Hz*, the number of beats heard by the man (velocity of sound in air = 320 *m/sec*) will be equal to

MP PET 1999; RPMT 2000; BHU 2004, 05]

(a) 6 (b) 3

(c) 0 [JIPMER 1999] (d) 12

34. An open pipe is in resonance in its 2nd harmonic with tuning fork of frequency f_1. Now it is closed at one end. If the frequency of the tuning fork is increased slowly from f_1 then again a resonance is obtained with a frequency f_2. If in this case the pipe vibrates n^{th} harmonics then

[IIT-JEE (Screening) 2005]

(a) $n = 3,\ f_2 = \frac{3}{4} f_1$ (b) $n = 3,\ f_2 = \frac{5}{4} f_1$

(c) $n = 5,\ f_2 = \frac{5}{4} f_1$ (d) $n = 5,\ f_2 = \frac{3}{4} f_1$

35. Two speakers connected to the same source of fixed frequency are placed 2.0 *m* apart in a box. A sensitive microphone placed at a distance of 4.0*m* from their midpoint along the perpendicular bisector shows maximum response. The box is slowly rotated until the speakers are in line with the microphone. The distance between the midpoint of the speakers and the microphone remains unchanged. Exactly five maximum responses are observed in the microphone in doing this. The wavelength of the sound wave is

(a) 0.2 *m* (b) 0.4 *m*

(c) 0.6 *m* (d) 0.8 *m*

36. A wire of $9.8 \times 10^{-3}\, kgm^{-1}$ passes over a frictionless light pulley fixed on the top of a frictionless inclined plane which makes an angle of 30° with the horizontal. Masses *m* and *M* are tied at the two ends of wire such that *m* rests on the plane and *M* hangs freely vertically downwards. The entire system is in equilibrium and a transverse wave propagates along the wire with a velocity of 100 ms^{-1}.

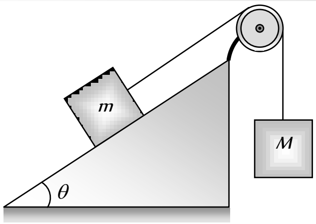
Chose the correct option [EAMCET (Engg.) 2000]

(a) $m = 20\,kg$

(b) $m = 5\,kg$

(c) $m = 2\,kg$

(d) $m = 7\,kg$

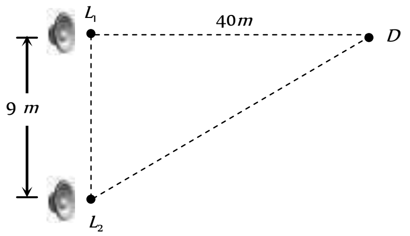


37. A man standing in front of a mountain beats a drum at regular intervals. The rate of drumming is generally increased and he finds that the echo is not heard distinctly when the rate becomes 40 per minute. He then moves nearer to the mountain by 90 *m* and finds that echo is again not heard when the drumming rate becomes 60 per minute. The distance between the mountain and the initial position of the man is

(a) 205 *m* (b) 300 *m*

(c) 180 *m* (d) 270 *m*

38. Two loudspeakers L_1 and L_2 driven by a common oscillator and amplifier, are arranged as shown. The frequency of the oscillator is gradually increased from zero and the detector at *D* records a series of maxima and minima. If the speed of sound is 330 *ms* then the frequency at which the first maximum is observed is



(a) 165 *Hz* (b) 330 *Hz*

(c) 496 *Hz* (d) 660 *Hz*

39. The displacement due to a wave moving in the positive *x*-direction is given by $y = \frac{1}{(1 + x^2)}$ at time $t = 0$ and by $y = \frac{1}{[1 + (x-1)^2]}$ at $t = 2$ seconds, where *x* and *y* are in *metres*. The velocity of the wave in *m/s* is

(a) 0.5 (b) 1

(c) 2 (d) 4

40. A person speaking normally produces a sound intensity of 40 *dB* at a distance of 1 *m*. If the threshold intensity for reasonable audibility is 20 *dB*, the maximum distance at which he can be heard clearly is

(a) 4 *m* (b) 5 *m*

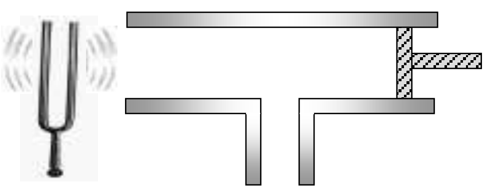
(c) 10 *m* (d) 20 *m*

41. A string of length *L* and mass *M* hangs freely from a fixed point. Then the velocity of transverse waves along the string at a distance *x* from the free end is

(a) $\sqrt{gL}$ (b) $\sqrt{gx}$

(c) gL (d) gx

42. Vibrating tuning fork of frequency *n* is placed near the open end of a long cylindrical tube. The tube has a side opening and is fitted with a movable reflecting piston. As the piston is moved through 8.75 *cm*, the intensity of sound changes from a maximum to minimum. If the speed of sound is 350 *m/s*. Then *n* is



(a) 500 *Hz* (b) 1000 *Hz*

(c) 2000 *Hz* (d) 4000 *Hz*

43. A stone is hung in air from a wire which is stretched over a sonometer. The bridges of the sonometer are *L cm* apart when the wire is in unison with a tuning fork of frequency *N*. When the stone is completely immersed in water, the length between the bridges is *l cm* for re-establishing unison, the specific gravity of the material of the stone is

(a) $\frac{L^2}{L^2 + l^2}$ (b) $\frac{L^2 - l^2}{L^2}$

(c) $\frac{L^2}{L^2 - l^2}$ (d) $\frac{L^2 - l^2}{L^2}$

44. The displacement of a particle in string stretched in *X* direction is represented by *y*. Among the following expressions for *y*, those describing wave motions are

[IIT 1987]

(a) $\cos kx \sin \omega t$ (b) $k^2x^2 - \omega^2t^2$

(c) $\cos(kx + \omega t)$ (d) $\cos(k^2x^2 - \omega^2t^2)$

45. Three waves of equal frequency having amplitudes 10 μm, 4 μm and 7 μm arrive at a given point with successive phase difference of $\frac{\pi}{2}$. The amplitude of the resulting wave in μm is given by

(a) 7 (b) 6

(c) 5 (d) 4

46. There are three sources of sound of equal intensity with frequencies 400, 401 and 402 *vib/sec*. The number of beats heard per second is

[MNR 1980; J & K CET 2005]

(a) 0 (b) 1

(c) 2 (d) 3

47. A tuning fork of frequency 340*Hz* is vibrated just above the tube of 120 *cm* height. Water is poured slowly in the tube. What is the minimum height of water necessary for the resonance (speed of sound in the air = 340 *m/sec*)

[CBSE PMT 1999; UPSEAT 1999]

(a) 15 *cm* (b) 25 *cm*

(c) 30 *cm* (d) 45 *cm*

48. An organ pipe is closed at one end has fundamental frequency of 1500 *Hz*. The maximum number of overtones generated by this pipe which a normal person can hear is :

[AIIMS 2004]

(a) 14 (b) 13

(c) 6 (d) 9

49. In Melde's experiment, the string vibrates in 4 loops when a 50 *gram* weight is placed in the pan of weight 15 *gram*. To make the string to vibrates in 6 loops the weight that has to be removed from the pan is [MH CET 2004]

(a) 0.0007 *kg wt* (b) 0.0021 *kg wt*

(c) 0.036 *kg wt* (d) 0.0029 *kg wt*

50. A racing car moving towards a cliff, sounds its horn. The driver observes that the sound reflected from the cliff has a pitch one octave higher than the actual sound of the horn. If v is the velocity of sound, then the velocity of the car is

[KCET 2002; CBSE PMT 2004]

(a) $v/\sqrt{2}$ (b) $v/2$

(c) $v/3$ (d) $v/4$

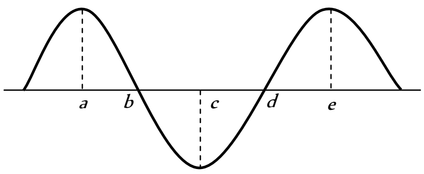
51. An earthquake generates both transverse (*S*) and longitudinal (*P*) sound waves in the earth. The speed of *S* waves is about 4.5 *km*/s and that of *P* waves is about 8.0 *km/s*. A seismograph records *P* and *S* waves from an earthquake. The first *P* wave arrives 4.0 *min* before the first *S* wave. The epicenter of the earthquake is located at a distance about **[AIIMS 2003]**

(a) 25 *km* (b) 250 *km*

(c) 2500 *km* (d) 5000 *km*

GQ Graphical Questions

1. The rope shown at an instant is carrying a wave travelling towards right, created by a source vibrating at a frequency n. Consider the following statements



I. The speed of the wave is $4n\times ab$

II. The medium at a will be in the same phase as d after $\frac{4}{3n}$ s

III. The phase difference between b and e is $\frac{3\pi}{2}$

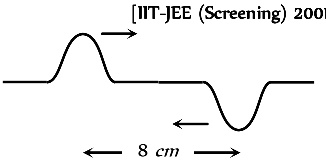
Which of these statements are correct **[AMU 2001]**

(a) I, II and III (b) II only

(c) I and III (d) III only

2. Two pulses in a stretched string whose centres are initially 8 *cm* apart are moving towards each other as shown in the figure. The speed of each pulse is 2 *cm/s*. After 2 seconds, the total energy of the pulses will be

[IIT-JEE (Screening) 2001]



(a) Zero

(b) Purely kinetic

(c) Purely potential

(d) Partly kinetic and partly potential

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Two persons on the surface of moon cannot talk to each other.
Reason : There is no atmosphere on moon.

2. Assertion : Transverse waves are not produced in liquids and gases.
Reason : Light waves are transverse waves.

3. Assertion : Sound waves cannot propagate through vacuum but light waves can.
Reason : Sound waves cannot be polarised but light waves can be polarised. [AIIMS 1998]

4. Assertion : The velocity of sound increases with increase in humidity.
Reason : Velocity of sound does not depend upon the medium.

5. Assertion : Ocean waves hitting a beach are always found to be nearly normal to the shore.
Reason : Ocean waves are longitudinal waves.

6. Assertion : Compression and rarefaction involve changes in density and pressure.
Reason : When particles are compressed, density of medium increases and when they are rarefied, density of medium decreases.

7. Assertion : Transverse waves travel through air in an organ pipe.
Reason : Air possesses only volume elasticity.

8. Assertion : Sound would travel faster on a hot summer day than on a cold winter day.
Reason : Velocity of sound is directly proportional to the square of its absolute temperature.

9. Assertion : The basic of Laplace correction was that, exchange of heat between the region of compression and rarefaction in air is not possible.
Reason : Air is a bad conductor of heat and velocity of sound in air is large.

10. Assertion : Particle velocity and wave velocity both are independent of time.
Reason : For the propagation of wave motion, the medium must have the properties of elasticity and inertia.

11. Assertion : When we start filling an empty bucket with water, the pitch of sound produced goes on decreasing.
Reason : The frequency of man voice is usually higher than that of woman.

12. Assertion : A tuning fork is made of an alloy of steel, nickel and chromium.
Reason : The alloy of steel, nickel and chromium is called elinvar.

13. Assertion : The change in air pressure effect the speed of sound.
Reason : The speed of sound in a gas is proportional to square root of pressure.

14. Assertion : Solids can support both longitudinal and transverse waves but only longitudinal waves can propagate in gases.
Reason : For the propagation of transverse waves, medium must also neccessarly have the property of rigidity.

15. Assertion : Under given conditions of pressure and temperature, sound travels faster in a monoatomic gas than in diatomic gas.
Reason : Opposition for wave to travel is more in diatomic gas than monoatomic gas.

16. Assertion : The speed of sound in solids is maximum though their density is large.
Reason : The coefficient of elasticity of solid is large.

17. Assertion : On a rainy day sound travel slower than on a dry day.
Reason : When moisture is present in air the density of air increases.

18. Assertion : To hear distinct beats, difference in frequencies of two sources should be less than 10.
Reason : More the number of beats per sec more difficult to hear them.

19. Assertion : Sound produced by an open organ pipe is richer than the sound produced by a closed organ pipe.
Reason : Outside air can enter the pipe from both ends, in case of open organ pipe.

20. Assertion : It is not possible to have interference between the waves produced by two violins.
Reason : For interference of two waves the phase difference between the waves must remain constant.

21. Assertion : Beats can also be observed by two light sources as in sound.
Reason : Light sources have constant phase deference.

22. Assertion : In the case of a stationary wave, a person hear a loud sound at the nodes as compared to the antinodes.
Reason : In a stationary wave all the particles of the medium vibrate in phase.

23. Assertion : Velocity of particles, while crossing mean position (in stationary waves) varies from maximum at antinodes to zero at nodes.
Reason : Amplitude of vibration at antinodes is maximum and at nodes, the amplitude is zero, And all particles between two successive nodes cross the mean position together.

24. Assertion : Where two vibrating tuning forks having frequencies 256 *Hz* and 512 *Hz* are held near each other, beats cannot be heard.
Reason : The principle of superposition is valid only if the frequencies of the oscillators are nearly equal.

25. Assertion : The fundamental frequency of an open organ pipe increases as the temperature is increased.
Reason : As the temperature increases, the velocity of sound increases more rapidly than length of the pipe.

26. Assertion : Sound travel faster in solids than gases.

Reason : Solid possess greater density than gases. [AIIMS 2000]

27. Assertion : Like sound, light can not propagate in vacuum.

Reason : Sound is a square wave. It propagates in a medium by a virtue of damping oscillation. [AIIMS 2000]

28. Assertion : Speed of wave $= \dfrac{\text{Wave length}}{\text{Time period}}$

Reason : Wavelength is the distance between two nearest particles in phase. [AIIMS 2002]

29. Assertion : The flash of lightening is seen before the sound of thunder is heard.

Reason : Speed of sound is greater than speed of light [AIIMS 2002]

30. Assertion : When a beetle moves along the sand with in a few tens of centimeters of a sand scorpion the scorpion immediately turn towards the beetle and dashes to it

Reason : When a beetle disturbs the sand, it sends pulses along the sands surface one set of pulses is longitudinal while other set is transverse. [AIIMS 2003]

31. Assertion : The reverberation time dependent on the the shape of enclosure, position of source and observer.

Reason : The unit of absorption coefficient in *mks* system is metric sabine. [EAMCET 2004]

Answers

Basics of Mechanical Waves

1	d	2	c	3	a	4	a	5	d
6	d	7	a	8	c	9	c	10	a
11	a	12	a	13	d	14	c	15	a
16	b	17	c	18	b	19	d	20	a
21	b	22	b	23	b	24	d	25	b
26	a	27	d	28	c	29	b	30	d
31	c	32	a	33	b	34	d	35	b
36	b	37	b	38	a	39	c	40	d
41	d	42	d	43	c	44	a	45	d
46	c	47	b	48	d	49	b	50	a
51	d	52	c	53	c	54	c	55	b
56	a	57	a	58	a	59	a	60	a
61	d	62	c	63	a	64	c	65	d
66	c	67	c	68	a	69	d	70	a
71	b	72	b	73	b	74	d	75	c
76	b	77	d	78	b	79	b	80	b
81	d	82	b	83	b	84	b	85	d
86	d	87	a	88	c	89	a	90	a
91	a	92	d	93	d	94	d		

Progressive Waves

1	d	2	c	3	b	4	c	5	d
6	d	7	c	8	d	9	c	10	c
11	c	12	c	13	c	14	b	15	b
16	abcd	17	b	18	b	19	d	20	bc
21	a	22	b	23	a	24	a	25	a
26	a	27	acd	28	d	29	a	30	a
31	b	32	d	33	b	34	d	35	d
36	d	37	a	38	a	39	b	40	b
41	d	42	c	43	b	44	c	45	a
46	a	47	d	48	a	49	b	50	d
51	d	52	abc	53	a	54	a	55	b
56	d	57	b	58	d	59	c	60	a
61	b	62	a	63	d	64	a	65	b
66	b	67	b	68	b	69	d	70	b
71	a	72	b	73	d	74	ac	75	c
76	b	77	b	78	c	79	b	80	a

Interference and Superposition of Waves

1	b	2	d	3	a	4	d	5	b
6	d	7	d	8	bc	9	c	10	c
11	a	12	b	13	c	14	d	15	b
16	c	17	a	18	a	19	b	20	c
21	a	22	b	23	a	24	c	25	d
26	b								

Beats

1	c	2	d	3	c	4	a	5	d
6	b	7	c	8	a	9	d	10	b
11	c	12	b	13	a	14	c	15	c
16	c	17	c	18	b	19	c	20	a
21	d	22	c	23	d	24	c	25	c
26	d	27	a	28	c	29	b	30	a
31	c	32	a	33	a	34	a	35	d
36	b	37	a	38	a	39	a	40	b
41	a	42	c	43	d	44	b	45	a
46	c	47	a	48	b	49	b	50	b
51	b								

Stationary Waves

1	c	2	c	3	c	4	c	5	b
6	a	7	b	8	d	9	a	10	a
11	b	12	d	13	b	14	d	15	d
16	abc	17	a	18	d	19	a	20	a
21	a	22	b	23	c	24	b	25	a
26	c	27	d	28	c	29	b	30	d
31	b	32	a	33	b	34	a	35	a
36	a	37	a	38	d	39	d		

Vibration of String

1	c	2	d	3	c	4	c	5	c
6	b	7	b	8	d	9	a	10	c
11	d	12	c	13	c	14	a	15	a
16	d	17	a	18	a	19	c	20	b
21	d	22	c	23	a	24	b	25	a
26	b	27	b	28	b	29	c	30	c
31	b	32	a	33	d	34	b	35	d
36	c	37	d	38	a	39	d	40	b
41	a	42	a	43	d	44	d	45	d
46	c	47	a	48	b	49	d	50	c
51	d	52	b						

Organ Pipe (Vibration of Air Column)

1	c	2	a	3	c	4	d	5	c
6	acd	7	d	8	a	9	b	10	c
11	b	12	c	13	b	14	b	15	b
16	a	17	b	18	a	19	c	20	a
21	b	22	a	23	a	24	b	25	c
26	a	27	a	28	b	29	a	30	d
31	c	32	a	33	b	34	b	35	b
36	b	37	b	38	c	39	b	40	b
41	b	42	b	43	a	44	c	45	a
46	c	47	a	48	d	49	b	50	c
51	a	52	a	53	b				

Doppler's Effect

1	d	2	b	3	a	4	b	5	c
6	b	7	c	8	b	9	a	10	a
11	b	12	a	13	d	14	c	15	b
16	a	17	a	18	c	19	d	20	a
21	d	22	a	23	a	24	b	25	c
26	b	27	c	28	d	29	b	30	d
31	a	32	c	33	d	34	d	35	a
36	b	37	c	38	d	39	a	40	c
41	a	42	c	43	a	44	d	45	d
46	b	47	b	48	b	49	b	50	a
51	a	52	c	53	d	54	b	55	a
56	c	57	c	58	d	59	c	60	a
61	c	62	b	63	a	64	a	65	b

Musical Sound

1	d	2	a	3	a	4	c	5	b
6	c	7	a	8	d	9	d	10	d
11	d	12	c	13	d	14	c	15	b
16	c	17	b	18	a	19	d	20	b
21	c	22	d	23	b	24	a	25	b
26	d	27	d	28	b	29	b	30	a
31	d	32	a						

Critical Thinking Questions

1	abcd	2	bc	3	c	4	a	5	c
6	b	7	b	8	c	9	b	10	d
11	b	12	abc	13	b	14	b	15	a
16	b	17	a	18	d	19	a	20	c
21	a	22	abcd	23	b	24	d	25	a
26	a	27	c	28	a	29	b	30	a
31	b	32	b	33	a	34	c	35	b
36	a	37	d	38	b	39	a	40	c
41	b	42	b	43	c	44	ac	45	c
46	b	47	d	48	c	49	c	50	c
51	c								

Graphical Questions

1	c	2	b	3	a	4	b	5	d
6	c	7	d	8	d	9	c	10	c
11	c	12	c	13	c	14	b	15	bd
16	d	17	b	18	d				

Assertion and Reason

1	a	2	b	3	b	4	c	5	c
6	a	7	e	8	c	9	c	10	e
11	d	12	b	13	e	14	a	15	c
16	a	17	d	18	b	19	b	20	a
21	d	22	c	23	a	24	c	25	a
26	b	27	d	28	b	29	c	30	a
31	e								

Answers and Solutions

Basics of Mechanical Waves

1. (d) Air is more rarer for sound to travel as compared to vacuum.

2. (c)

3. (a)

4. (a) $v = n\lambda = 2 \times 5 = 10$ *cm/sec*

5. (d) $v = n\lambda \Rightarrow \lambda = \frac{v}{n} = \frac{330}{256} = 1.29m$

6. (d) Time lost in covering the distance of 2 km by the sound waves $t = \frac{d}{v} = \frac{2000}{330} = 6.06\ sec \approx 6\ sec$

7. (a) $v_{max} = a\omega = a \times 2\pi n = 0.1 \times 2\pi \times 300 = 60\pi\ cm/\sec$

8. (c) Audiable range of frequency is 20Hz to 20kHz

9. (c) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Rightarrow 1.6\pi = \frac{2\pi}{\lambda} \times 40 \Rightarrow \lambda = 50\ cm = 0.5m$

$\Rightarrow v = n\lambda \Rightarrow 330 = 0.5 \times n \Rightarrow n = 660\ Hz$

10. (a) $\lambda = \frac{v}{n}; n \approx 50{,}000\ Hz$, $v = 330$ *m/sec* $\Rightarrow \lambda = \frac{330}{50000} m$

$= 6.6 \times 10^{-5} cm \approx 5 \times 10^{-5} cm$

11. (a)

12. (a) $\lambda = \frac{v}{n} = \frac{1.7 \times 1000}{4.2 \times 10^6} = 4 \times 10^{-4}\ m$

13. (d) Since maximum audible frequency is 20,000 Hz, hence $\lambda_{min} = \frac{v}{n_{max}} = \frac{340}{20{,}000} \approx 20\ mm$

14. (c) Velocity of sound in gas $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{\frac{\gamma T}{M}}$

$\Rightarrow \frac{v_{N_2}}{v_{He}} = \sqrt{\frac{\gamma_{N_2}}{\gamma_{He}} \times \frac{M_{He}}{M_{H_2}}} = \sqrt{\frac{\frac{7}{5} R \times 4}{\frac{5}{3} R \times 28}} = \frac{\sqrt{3}}{5}$

15. (a) Time required for a point to move from maximum displacement to zero displacement is $t = \frac{T}{4} = \frac{1}{4n}$

$\Rightarrow n = \frac{1}{4t} = \frac{1}{4 \times 0.170} = 1.47\ Hz$

16. (b) Wave number is the reciprocal of wavelength and is written as $\bar{n} = \frac{1}{\lambda}$.

17. (c) $\lambda = \frac{v}{n} = \frac{340}{200} = 1.7\ m$

18. (b)

19. (d) $v \propto \lambda \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{2/3}{3/10} = \frac{20}{9}$

20. (a) The time taken by the stone to reach the lake

$t_1 = \sqrt{\left(\frac{2h}{g}\right)} = \sqrt{\left(\frac{2 \times 500}{10}\right)} = 10\ sec$ (Using $h = ut + \frac{1}{2}gt^2$)

Now time taken by sound from lake to the man

$t_2 = \frac{h}{v} = \frac{500}{340} \approx 1.5 \sec$

$\Rightarrow$ Total time $= t_1 + t_2 = 10 + 1.5 = 11.5 \sec$.

21. (b) When medium changes, velocity and wavelength changes but frequency remains constant.

22. (b) $t = \sqrt{\frac{2h}{g}} + \frac{h}{v} = \sqrt{\frac{2 \times 19.6}{9.8}} + \frac{19.6}{v} = 2.06$

$\Rightarrow v = 326.7\ m/s$

23. (b) $v \propto \sqrt{T} \Rightarrow \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} \Rightarrow 2 = \sqrt{\frac{T_2}{(273+0)}}$

$\Rightarrow T_2 = 273 \times 4 = 1092\ K = 819^o C$

24. (d) Velocity of sound in steel is maximum out of the given materials water and air. In vacuum sound cannot travel, it's speed is zero.

25. b) Distance between a compression and the nearest rarefaction is $\frac{\lambda}{2} = 1m$. Hence $n = \frac{v}{\lambda} = \frac{360}{2} = 180\ Hz$.

26. (a) $v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow \frac{v_{O_2}}{v_{H_2}} = \sqrt{\frac{\rho_{H_2}}{\rho_{o_2}}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

27. (d) Speed of sound in gases is $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow T \propto M$

(Because v, γ-constant). Hence $\frac{T_{H_2}}{T_{O_2}} = \frac{M_{H_2}}{M_{O_2}}$

$\Rightarrow \frac{T_{H_2}}{(273+100)} = \frac{2}{32} \Rightarrow T_{H_2} = 23.2K = -249.7°C$

28. (c) If the temperature changes then velocity of wave and its wavelength changes. Frequency amplitude and time period remains constant.

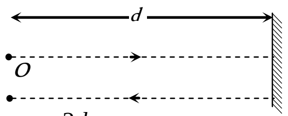
29. (b)

30. (d)

31. (c) Path difference $\Delta = \frac{\lambda}{2\pi} \times \phi \Rightarrow 1 = \frac{\lambda}{2\pi} \times \frac{\pi}{2} \Rightarrow \lambda = 4m$

Hence $v = n\lambda = 120 \times 4 = 480\ m/s$

32. (a) Suppose the distance between shooter and reflecting surface is d. Hence time interval for hearing echo is



$t = \frac{2d}{v} \Rightarrow 8 = \frac{2d}{350} \Rightarrow d = 1400\,m$.

33. (b) $\text{Time} = \frac{\text{Distance}}{\text{Velocity}} = \frac{1000}{330} = 3.03\ \text{sec}$.

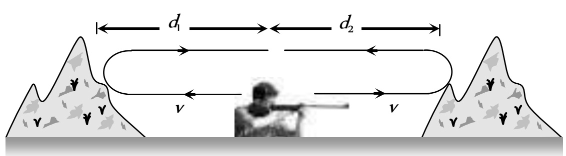
Sound will be heard after 3.03 sec. So his watch is set 3*sec*, slower.

34. (d) $v = \sqrt{\frac{\gamma P}{\rho}}$; as P changes, ρ also changes. Hence $\frac{P}{\rho}$ remains constant so speed remains constant.

35. (b) Speed of sound in gases is given by

$v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$

36. (b)



$2d_1 + 2d_2 = v \times t_1 + v \times t_2 \Rightarrow 2(d_1 + d_2) = v(t_1 + t_2)$

$d_1 + d_2 = \frac{v(t_1+t_2)}{2} = \frac{340 \times (1.5+3.5)}{2} = 850\ m$.

37. (b) By using $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{T}$

$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{T+600}{T}} = \sqrt{3} \Rightarrow T = 300\,K = 27^o\,C$

38. (a) Velocity of sound is independent of frequency. Therefore it is same (v) for frequency n and $4n$.

39. (c) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \sqrt{T}$

i.e. if v is doubled then T becomes four times,

hence $T_2 = 4T_1 = 4(273+27) = 1200K = 927°C$

40. (d) $n = \frac{3600}{60} = 60\ Hz \Rightarrow \lambda = \frac{v}{n} = \frac{960}{60} = 16\,m$

41. (d) Speed do sound, doesn't depend up on pressure and density medium.

42. (d) If d is the distance between man and reflecting surface of sound then for hearing echo

$2d = v \times t \Rightarrow d = \frac{340 \times 1}{2} = 170\,m$

43. (c) $n = \frac{54}{60} Hz, \lambda = 10\,m \Rightarrow v = n\lambda = 9\,m/s$.

44. (a) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$. Since M is minimum for H_2 so sound velocity is maximum in H_2.

45. (d) $2d = v \times t$, where v = velocity of sound = 332 m/s

t = Persistence of hearing = $\frac{1}{10}$ sec.

$\Rightarrow d = \frac{v \times t}{2} = \frac{332 \times \frac{1}{10}}{2} = 16.5\ m$

46. (c) Since solid has both the properties (rigidity and elasticity)

47. (b) If d is the distance between man and reflecting surface of sound then for hearing echo

$2d = v \times t \Rightarrow d = \frac{330 \times 1.5}{2} = 247.5\ m$

48. (d) Speed of sound $v \propto \sqrt{T}$ and it is independent of pressure.

49. (b) Frequency of wave is

$n = \frac{3600}{2 \times 60} Hz \Rightarrow \lambda = \frac{v}{n} = \frac{760}{30} = 25.3\ m.$

50. (a) Speed of sound $v = \sqrt{\frac{\gamma P}{d}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}}$ ($\because P$ - constant)

51. (d) $\lambda = \frac{v}{n} = \frac{352}{384}$; during 1 vibration of fork sound will travel $\frac{352}{384}\,m$ during 36 vibration of fork sound will travel $\frac{352}{384} \times 36 = 33\ m$

52. (c) At given temperature and pressure

$v \propto \frac{1}{\sqrt{\rho}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{4}{1}} = 2:1$

53. (c) $v \propto \sqrt{T} \Rightarrow \sqrt{\frac{T_2}{T_1}} = \frac{v_2}{v_1} \Rightarrow T_2 = T_1\left(\frac{v_2}{v_1}\right)^2$

$\Rightarrow T_2 = 273 \times 4 = 1092K$

54. (c) $\bar{n} = \frac{1}{\lambda} = \frac{1}{6000\times10^{-10}} = 1.66\times10^{6} m^{-1}$

55. (b) $v \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{v_{H_2}}{v_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{H_2}}} = \sqrt{\frac{32}{2}} \Rightarrow \frac{v_{H_2}}{v_{O_2}} = \frac{4}{1}$

56. (a) The minimum distance between compression and rarefaction of the wire $l = \frac{\lambda}{4}$ $\therefore$ Wave length $\lambda = 4l$

Now by $v = n\lambda \Rightarrow n = \frac{360}{4\times1} = 90\ \sec^{-1}$.

57. (a) $v_{sound} \propto \frac{1}{\sqrt{\rho}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{4}{1}} = 2 \Rightarrow v_2 = \frac{v_1}{2} = \frac{v_s}{2}$

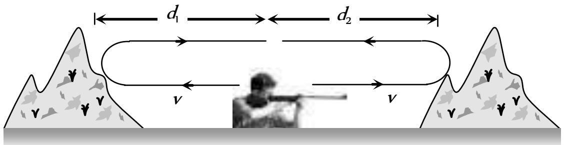
58. (a) Suppose the distance between two fixed points is d then $t = \frac{d}{v}$ also $v \propto \sqrt{T} \Rightarrow \frac{t_1}{t_2} = \frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}}$

$\Rightarrow \frac{2}{t_2} = \sqrt{\frac{303}{283}} \Rightarrow t_2 = 1.9\ sec.$

59. (a) The density of moist air (*i.e.* air mixed with water vapours) is less than the density of dry air

Hence from $v = \sqrt{\frac{\gamma P}{\rho}} \Rightarrow v_{moist\ air} > v_{dry\ air}$

60. (a) Total time taken for both the echoes $t = t_1 + t_2 = 2\ sec$



but $t = \frac{2d_1}{v} + \frac{2d_2}{v} \Rightarrow t = \frac{2}{v}(d_1 + d_2)$

$\Rightarrow (d_1 + d_2) = \frac{v\times t}{2} = \frac{340\times2}{2} = 340m.$

61. (d) Frequency of sound does not change with medium, because it is characteristics of source.

62. (c) Since $v = \sqrt{\frac{\gamma RT}{M}}$ *i.e.,* $v \propto \sqrt{T}$

63. (a) Frequency of waves remains same, *i.e.* 60 *Hz*

and wavelength $\lambda = \frac{v}{n} = \frac{330}{60\times10^3} = 5.5\ mm.$

64. (c) Path difference $\Delta = \frac{\lambda}{2\pi}\times\phi = \frac{\lambda}{2\pi}\times\frac{\pi}{3} = \frac{\lambda}{6}$

65. (d) Interference, diffraction and reflection occurs in both transverse and longitudinal waves. Polarisation occurs only in transverse waves.

66. (c) Water waves are transverse as well as longitudinal in nature.

67. (c)

68. (a) In transverse waves medium particles vibrate perpendicular to the direction of propagation of wave.

69. (d)

70. (a) Wave on a plucked string is stationary wave. Light waves are EM waves. Water waves are transverse as well as longitudinal.

71. (b)

72. (b) Transverse wave can propagate in solids but not in liquids and gases.

73. (b) Because sound waves in gases are longitudinal.

74. (d)

75. (c) Since distance between two consecutive crests is λ, so

$\phi = \frac{2\pi}{\lambda}\times\lambda = 2\pi.$

76. (b) The distance between two points *i.e.* path difference between them $\Delta = \frac{\lambda}{2\pi}\times\phi = \frac{\lambda}{2\pi}\times\frac{\pi}{3} = \frac{\lambda}{6} = \frac{v}{6n}$ $(\because v = n\lambda) \Rightarrow$

$\Delta = \frac{360}{6\times500} = 0.12\,m = 12\,cm$

77. (d) Sound waves are longitudinal in nature so they can not be polarised

78. (b)

79. (b) Ultrasonic waves are those of higher frequencies than maximum audible range frequencies (audible range of frequencies is 20 *Hz* to 20000 *Hz*)

80. (b)

81. (d) Infrasonic waves have frequency less than (20 *Hz*) audible sound and wavelength more than audible sound.

82. (b) SONAR emits ultrasonic waves.

83. (b) EM waves do not requires medium for their propagation.

84. (b)

85. (d)

86. (d) $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow \frac{T_N}{T_0} = \frac{M_N}{M_0} \Rightarrow \frac{T_N}{273+55} = \frac{14}{16} = \frac{7}{8}$

$\Rightarrow T_N = 287K = 14°C$

87. (a) We know that at night amount of carbon dioxide in atmosphere increases which raises the density of atmosphere. Since intensity is directly proportional to density, intensity of sound is more at night.

88. (c) $n = \frac{v}{\lambda} = \frac{300}{0.6\times10^{-2}} Hz = \frac{3}{6}\times10^4 Hz = 50{,}000 Hz$

$\Rightarrow$ Wave is ultrasonic.

89. (a) $v = \sqrt{\frac{K}{\rho}}$ $\therefore$ $K = v^2\rho = 2.86\times10^{10} N/m^3$

90. (a) $n = \frac{v}{\lambda} \propto v \Rightarrow \frac{n_{MW}}{n_{US}} \approx \frac{3\times10^8}{3\times10^2} \approx 10^6 : 1$

91. (a) Intensity $\propto \frac{1}{(\text{Distance})^2} \Rightarrow \frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

92. (d) $v = \frac{\sin i}{\sin r} = \frac{v_1}{v_2}$

$\Rightarrow \sin r = \sin 30°\times\frac{2u}{u} \Rightarrow \sin r = \frac{1}{2}\times2\times1 \Rightarrow r = 90°$

93. (d) Number of waves per minute = 54

$\therefore$ Number of waves per second = 54/60

Now $v = n\lambda \Rightarrow n = \frac{54}{60}\times10 = 9\,m/s.$

94. (d) If d is the distance of rock from SONAR then

$$2d = vt \Rightarrow d = \frac{v \times t}{2} = \frac{1600 \times 1}{2} = 800m$$

Progressive Waves

1. (d) Comparing given equation with standard equation of progressive wave. The velocity of wave

$$v = \frac{\omega (\text{Co-efficient of } t)}{k (\text{Co-efficient of } x)} = \frac{200\pi}{0.5\pi} = 400\ cm/s$$

2. (c) Comparing with $y = a\cos(\omega t + kx - \phi)$,

We get $k = \frac{2\pi}{\lambda} = 0.02 \Rightarrow \lambda = 100\ cm$

Also, it is given that phase difference between particles $\Delta\phi = \frac{\pi}{2}$. Hence path difference between them

$$\Delta = \frac{\lambda}{2\pi} \times \Delta\phi = \frac{\lambda}{2\pi} \times \frac{\pi}{2} = \frac{\lambda}{4} = \frac{100}{4} = 25\ cm$$

3. (b) Phase difference between two successive crest is 2π. Also, phase difference $(\Delta\phi) = \frac{2\pi}{T}$ time interval (Δt)

$$\Rightarrow 2\pi = \frac{2\pi}{T} \times 0.2 \Rightarrow \frac{1}{T} = 5\sec^{-1} \Rightarrow n = 5\ Hz$$

4. (c) Comparing with the standard equation,

$y = A\sin\frac{2\pi}{\lambda}(vt - x)$, we have

$v = 200\ cm/\sec$, $\lambda = 200\ cm$; $\therefore n = \frac{v}{\lambda} = 1\ \sec^{-1}$

5. (d) Let the phase of second particle be ϕ. Hence phase difference between two particles is $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

$$\Rightarrow \left(\phi - \frac{\pi}{3}\right) = \frac{2\pi}{60} \times 15 \Rightarrow \phi - \frac{\pi}{3} = \frac{\pi}{2} \Rightarrow \phi = \frac{5\pi}{6}$$

6. (d) The given equation can be written as $y = 4\sin\left(4\pi t - \frac{\pi x}{16}\right)$

$$\Rightarrow (v) = \frac{\text{Co-efficient of } t(\omega)}{\text{Co-efficient of } x(K)}$$

$\Rightarrow v = \frac{4\pi}{\pi/16} = 64\ cm/sec$ along $+x$ direction.

7. (c) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{628}{31.4} = 20\ cm/sec$

8. (d) $y_1 = a\sin(\omega t - kx)$

and $y_2 = a\cos(\omega t - kx) = a\sin\left(\omega t - kx + \frac{\pi}{2}\right)$

Hence phase difference between these two is $\frac{\pi}{2}$.

9. (c) $I \propto a^2 \propto \frac{1}{d^2} \Rightarrow a \propto \frac{1}{d}$

10. (c) $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \left(\frac{0.06}{0.03}\right)^2 = \frac{4}{1}$

11. (c) After reflection from rigid support, a wave suffers a phase change of π.

12. (c) The given equation representing a wave travelling along $-y$ direction (because '+' sign is given between t term and x term). On comparing it with $x = A\sin(\omega t + ky)$

We get $k = \frac{2\pi}{\lambda} = 12.56 \Rightarrow \lambda = \frac{2 \times 3.14}{12.56} = 0.5\ m$

13. (c) Comparing with $y = a\sin(\omega t - kx) \Rightarrow a = \frac{10}{\pi}, \omega = 200\pi$

$\therefore v_{max} = a\omega = \frac{10}{\pi} \times 2000\pi = 200 m/\sec$

and $\omega = \frac{2\pi}{T} \Rightarrow 200\pi = \frac{2\pi}{T} \Rightarrow T = 10^{-3}$ *sec*

14. (b) Comparing the given equation with $y = a\cos(\omega t - kx)$

We get $k = \frac{2\pi}{\lambda} = \pi \Rightarrow \lambda = 2cm$

15. (b) Comparing the given equation with $y = a\sin(\omega t - kx)$, We get $a = Y$, $\omega = 2\pi f$, $k = \frac{2\pi}{\lambda}$. Hence maximum particle velocity $(v_{max})_{particle} = a\omega = Y_0 \times 2\pi f$ and wave velocity $(v)_{wave} = \frac{\omega}{k} = \frac{2\pi f}{2\pi/\lambda} = f\lambda$

$\because (v_{max})_{Particle} = 4v_{Wave} \Rightarrow Y_0 \times 2\pi f = 4f\lambda \Rightarrow \lambda = \frac{\pi Y_0}{2}$.

16. (a,b,c,d) On comparing the given equation with $y = a\sin(\omega t + kx)$, it is clear that wave is travelling in negative x-direction.

It's amplitude $a = 10$ m and $\omega = 60$, $k = 2$. Hence frequency $n = \frac{\omega}{2\pi} = \frac{60}{2\pi} = \frac{30}{\pi} Hz$

$k = \frac{2\pi}{\lambda} = 2 \Rightarrow \lambda = \pi\ m$ and $v = \frac{\omega}{k} = \frac{60}{2} = 30\ m/s$

17. (b) $\because y = a\cos\left(\frac{2\pi}{\lambda}vt + \frac{2\pi x}{\lambda}\right) = 0.5\cos(4\pi t + 2\pi x)$

18. (b) $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{100}{50} = 2\ m/\sec$.

19. (d) $y = f(x^2 - vt^2)$ doesn't follows the standard wave equation.

20. (b,c) Standard wave equation which travel in negative x-direction is $y = A\sin(\omega t + kx + \phi_0)$

For the given wave $\omega = 2\pi n = 15\pi$, $k = \frac{2\pi}{\lambda} = 10\pi$

Now $v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{\omega}{k} = \frac{15\pi}{10\pi} = 1.5$ *m/sec*

and $\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = 0.2$ *m.*

21. (a) $v_{max} = a\omega = 3 \times 10 = 30$

22. (b) $y_1 = a_1\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$ and

$y_2 = a_2 \cos\left(\omega t - \frac{2\pi x}{\lambda} + \phi\right) = a_2 \sin\left(\omega t - \frac{2\pi x}{\lambda} + \phi + \frac{\pi}{2}\right)$

So phase difference $= \phi + \frac{\pi}{2}$ and $\Delta = \frac{\lambda}{2\pi}\left(\phi + \frac{\pi}{2}\right)$

23. (a) Both waves are moving opposite to each other .

24. (a) The velocity of wave

$v = \frac{\omega\,(\text{Co - efficient of } t)}{k\,(\text{Co - efficient of } x)} = \frac{10}{1} = 10\ m/s$

25. (a) $v = \frac{\text{Co - efficient of } t}{\text{Co - efficient of } x} = \frac{7\pi}{0.04} = 175\ m/s$.

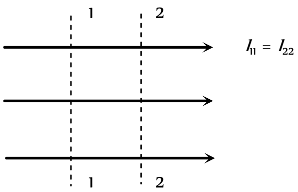
26. (a) The given equation is $y = 10\sin(0.01\pi x - 2\pi t)$

Hence $\omega =$ coefficient of $t = 2\pi$

$\Rightarrow$ Maximum speed of the particle $v_{\max} = a\omega = 10 \times 2\pi$

$= 10 \times 2 \times 3.14 = 62.8 \approx 63$ *cm/s*

27. (a,c,d) For a travelling wave, the intensity of wave remains constant if it is a plane wave.



Intensity of wave is inversely proportional to the square of the distance from the source if the wave is spherical

$\left(I = \frac{P}{4\pi r^2}\right)$

Intensity of spherical wave on the spherical surface centred at source always remains same. Here total intensity means power P.

28. (d) On comparing the given equation with standard equation $y = a\sin\frac{2\pi}{\lambda}(vt - x)$. It is clear that wave speed $(v)_{wave} = v$ and maximum particle velocity $(v_{\max})_{particle} = a\omega = y_0 \times$ co-efficient of $t = y_0 \times \frac{2\pi v}{\lambda}$

$\because\ (v_{\max})_{particle} = 2(\omega)_{wave} \Rightarrow \frac{a \times 2\pi v}{\lambda} = 2v \Rightarrow \lambda = \pi y_0$

29. (a) Given $y = A\sin(kx - \omega t)$

$\Rightarrow v = \frac{dy}{dt} = -A\omega\cos(kx - \omega t)$; $\Rightarrow v_{\max} = A\omega$

30. (a) Comparing with $y = (x, t) = a\sin(\omega t - kx)$

$k = \frac{2\pi}{\lambda} = 0.01\pi \Rightarrow \lambda = 200\ m.$

31. (b)

32. (d) Comparing the given equation with standard equation $y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \Rightarrow T = 0.04\ sec \Rightarrow v = \frac{1}{T} = 25 Hz$

Also $(A)_{\max} = \omega^2 a = \left(\frac{2\pi}{T}\right)^2 \times a = \left(\frac{2\pi}{0.04}\right)^2 \times 3$

$= 7.4 \times 10^{4}$ *cm/sec*.

33. (b) From the given equation amplitude $a = 0.04 m$

Frequency $= \frac{\text{Co–efficient of t}}{2\pi} = \frac{\pi/5}{2\pi} = \frac{1}{10} Hz$

Wave length $\lambda = \frac{2\pi}{\text{Co–efficient } of\ x} = \frac{2\pi}{\pi/9} = 18 m.$

Wave speed $v = \frac{\text{Co - efficient of } t}{\text{Co - efficient of } x} = \frac{\pi/5}{\pi/9} = 1.8 m/s.$

34. (d)

35. (d) Compare the given equation with $y = a\cos(\omega t + k\phi)$

$\Rightarrow \omega = 2\pi n = 2000 \Rightarrow n = \frac{1000}{\pi} Hz$

36. (d) $y = A\sin(at - bx + c)$ represents equation of simple harmonic progressive wave as it describes displacement of any particle (x) at any time (t). or It represents a wave because it satisfies wave equation $\frac{\partial^2 y}{\partial t^2} = v^2\frac{\partial^2 y}{\partial x^2}$.

37. (a) Here $\omega = 2\pi n = 2\pi \Rightarrow n = 1$

38. (a) Compare the given equation with $y = a\sin(\omega t + kx)$. We get

$\omega = 2\pi n = 100 \Rightarrow n = \frac{50}{\pi} Hz$

39. (b) Compare with $y = a\sin(\omega t - kx)$

We have $k = \frac{2\pi}{\lambda} = 62.4 \Rightarrow \lambda = \frac{2\pi}{62.4} = 0.1$

40. (b) Maximum velocity of the particle

$v_{\max} = a\omega = 0.5 \times 10\pi = 5\pi\ cm/sec$

41. (d) On reflection from fixed end (denser medium) a phase difference of π is introduced.

42. (c) Maximum particle velocity $v_{\max} = \omega a$ and wave velocity

$v = \frac{\omega}{k} \Rightarrow \frac{v_{\max}}{v} = \frac{\omega a}{\omega/k} = ka$. From the given equation $k = \text{Co - efficient of } x = 6 micron = 6 \times 10^{-6} m$

$\Rightarrow \frac{v_{\max}}{v} = ka = 6 \times 10^{-6} \times 60 = 3.6 \times 10^{-4}$

43. (b) $\omega = 314$, $k = 1.57$ and $v = \frac{\omega}{k} = \frac{314}{1.57} = 200$ *m/s.*

44. (c) $v = \frac{\text{Co - efficient of } t}{\text{Co - efficient of } x} = \frac{40}{1} = 40\ m/s$

45. (a) $n = \frac{\omega}{2\pi} = \frac{400\pi}{2\pi} = 200\ Hz$ (As $\omega = 400\pi$)

46. (a) Beats period $= \frac{1}{30 - 20} = 0.1\ sec$

$\Delta\phi = \frac{2\pi}{T}\Delta t = \frac{2\pi}{0.1} \times 0.6 = 2\pi \times 6 = 12\ \pi$ or Zero.

47. (d) Path difference $\Delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times \frac{\pi}{2} = \frac{\lambda}{4}$

$\because \Delta = 0.8\ m \Rightarrow \frac{\lambda}{4} = 0.8 \Rightarrow \lambda = 3.2\ m.$

$\therefore\ v = n\lambda = 120 \times 3.2 = 384$ *m/s*

48. (a) $v = \frac{\text{co-efficient of } t}{\text{co-efficient of } x} = \frac{2\pi/0.01}{2\pi/0.3} = 30\, m/s$

49. (b) Comparing with $y = a\sin 2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right] \Rightarrow \lambda = 40\ cm$

50. (d) $v = \frac{\omega}{k} = \frac{\text{Co - efficient of } t}{\text{Co - efficient of } x} = \frac{2}{0.01} = 200\ cm/\sec$.

51. (d) From the given equation $k = 0.2\pi$

$\Rightarrow \frac{2\pi}{\lambda} = 0.2\pi \Rightarrow \lambda = 10\ cm$

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{10} \times 2 = \frac{2\pi}{5} = 72^o$

52. (a,b,c) $I = 2\pi n^2 a^2 \rho v \Rightarrow I \propto n^2 a^2 v$

53. (a) comparing the given equation with $y = a\sin(\omega t - kx)$

$\omega = 200,\ k = 1$ so $v = \frac{\omega}{k} = 200\ m/s$

54. (a) $v = \frac{\omega}{k} = \frac{2\pi}{2\pi} = 1\ m/s$

55. (b) By comparing it with standard equation

$y = a\cos(\omega t - kx) \Rightarrow k = \frac{2\pi}{\lambda} = \pi \Rightarrow \lambda = 2cm$

56. (d) Compare the given equation with

$y = a\sin(\omega t + kx) \Rightarrow \omega = 2\pi n = 100 \Rightarrow n = \frac{50}{\pi} Hz$

$k = \frac{2\pi}{\lambda} = 1 \Rightarrow \lambda = 2\pi$ and $v = \omega/k = 100\ m/s$

Since '+' is given between t terms and x term, so wave is travelling in negative x-direction.

57. (b) Given $A\omega = 4v \Rightarrow A2\pi n = 4n\lambda \Rightarrow \lambda = \frac{\pi A}{2}$

58. (d) $v = \frac{\omega}{k} = \frac{100}{1/10} = 1000\ m/s$

59. (c) A wave travelling in positive x-direction may be represented as $y = A\sin\frac{2\pi}{\lambda}(vt - x)$. On putting values

$y = 0.2\sin\frac{2\pi}{60}(360t - x) \Rightarrow y = 0.2\sin 2\pi\left(6t - \frac{x}{60}\right)$

60. (a) $v = \frac{\omega}{k} = \frac{7\pi}{0.4\pi} = 17.5\ m/s$

61. (b) $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{I_1}{I_2} = \frac{25}{100} = \frac{1}{4}$

62. (a) From the given equation $k = \frac{2\pi}{\lambda}$ = Co-efficient of x

$= \frac{\pi}{4} \Rightarrow \lambda = 8m$

63. (d) $y = 4\sin 2\pi\left(\frac{t}{0.02} - \frac{x}{100}\right)$.

Comparing this equation with $y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

$v = \frac{\text{Co-efficient of } t}{\text{Co-efficient of } x} = \frac{1/0.02}{1/100}$

64. (a) Comparing the given equation with $y = a\sin(\omega t - kx)$

We get $\omega = 3000\pi \Rightarrow n = \frac{\omega}{2\pi} = 1500\,Hz$

and $k = \frac{2\pi}{\lambda} = 12\pi \Rightarrow \lambda = \frac{1}{6}m$

So, $v = n\lambda \Rightarrow v = 1500 \times \frac{1}{6} = 250\ m/s$

65. (b) Positive sign in the argument of sin indicating that wave is travelling in negative x-direction.

66. (b) Comparing the given equation with $y = a\cos(\omega t - kx)$

$a = 25,\ \omega = 2\pi n = 2\pi \Rightarrow n = 1Hz$

67. (b) $v = \frac{\omega}{k} = \frac{600}{2} = 300 m/\sec$.

68. (b) $v = \frac{\text{Co–efficent of } t}{\text{Co–efficent of } x} = \frac{\omega}{k} = \frac{100}{20} = 5\, m/s.$

69. (d) Comparing with standard wave equation

$y = a\sin\frac{2\pi}{\lambda}(vt - x)$, we get, $v = 200\, m/s.$

70. (b) Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

$\Rightarrow \frac{\pi}{2} = \frac{2\pi}{\lambda} \times 0.8 \Rightarrow \lambda = 4 \times 0.8 = 3.2\,m$

Velocity $v = n\lambda = 120 \times 3.2 = 384\, m/s.$

71. (a) Comparing the given equation with standard equation

We get $\omega = 2\pi n = 200\pi \Rightarrow n = 100\ Hz$

$k = \frac{20\pi}{17} \Rightarrow \lambda = \frac{2\pi}{k} = \frac{2\pi}{20\pi/17} = 1.7\,m$

and $v = \frac{\omega}{k} = \frac{200\pi}{20\pi/17} = 170\, m/s.$

72. (b) Given, $y = 0.5\sin(20x - 400t)$

Comparing with $y = a\sin(\omega t - kx)$

Gives velocity of wave $v = \frac{\omega}{k} = \frac{400}{20} = 20\, m/s.$

73. (d) $v = n\lambda \Rightarrow \lambda = 10\ cm$

Phase difference $\frac{2\pi}{\lambda} \times$ Path difference $\frac{2\pi}{10} \times 2.5 = \frac{\pi}{2}$

74. (a, c) $v_{max} = a\omega = \frac{v}{10} = \frac{10}{10} =$ m/sec

$\Rightarrow a\omega = a \times 2\pi n = 1 \Rightarrow n = \frac{10^3}{2\pi}$ $(\because a = 10^{-3}\,m)$

Since $v = n\lambda \Rightarrow \lambda = \frac{v}{n} = \frac{10}{10^3/2\pi} = 2\pi \times 10^{-2}\ m$

75. (c) Total energy is conserved.

76. (b) $v = \frac{\text{Co–efficent of } t}{\text{Co–efficent of } x} = \frac{1/2}{1/4} = 2\, m/s$

Hence $d = vt = 2 \times 8 = 16m$

77. (b) $y_1 = 10^{-6}\sin[100t + (x/50) + 0.5]$

$y_2 = 10^{-6}\sin\left[100\,t + \left(\frac{x}{50}\right) + \left(\frac{\pi}{2}\right)\right]$

Phase difference ϕ

$= [100t + (x/50) + 1.57] - [100t + (x/50) + 0.5]$

$= 1.07$ *radians.*

78. (c) Resultant amplitude

$A_R = 2A\cos\left(\frac{\theta}{2}\right) = 2\times(2a)\cos\left(\frac{\theta}{2}\right) = 4a\cos\left(\frac{\theta}{2}\right)$

79. (b) The particle will come after a time $\frac{T}{4}$ to its mean position.

80. (a) Maximum particle velocity $= a\omega = 2\times 2 = 4$ units.

Interference and Superposition of Waves

1. (b) With path difference $\frac{\lambda}{2}$, waves are out of phase at the point of observation.

2. (d) $A_{max} = \sqrt{A^2 + A^2} = A\sqrt{2}$, frequency will remain same *i.e.* ω.

3. (a) Phase difference is 2π means constrictive interference so resultant amplitude will be maximum.

4. (d) Resultant amplitude

$A = \sqrt{a^2 + a^2 + 2aa\cos\phi} = \sqrt{4a^2\cos^2\left(\frac{\phi}{2}\right)}$

$\because\ I \propto A^2 \Rightarrow I \propto 4a^2$

5. (b) $A^2 = a^2 = a^2 + a^2 + 2a^2\cos\theta \Rightarrow \cos\theta = -\frac{1}{2} \Rightarrow \theta = \frac{2\pi}{3}$

6. (d) $\lambda = \frac{v}{n} = \frac{350}{350} = 1\,m = 100\ cm$

Also path difference (Δx) between the waves at the point of observation is $AP - BP = 25cm$. Hence

$\Rightarrow \Delta\phi = \frac{2\pi}{\lambda}(\Delta x) = \frac{2\pi}{1}\times\left(\frac{25}{100}\right) = \frac{\pi}{2}$

$\Rightarrow A = \sqrt{(a_1)^2 + (a_2)^2} = \sqrt{(0.3)^2 + (0.4)^2} = 0.5\ mm$

7. (d) Path difference $(\Delta x) = 50\,cm = \frac{1}{2}m$

$\therefore$ Phase difference $\Delta\phi = \frac{2\pi}{\lambda}\times\Delta x \Rightarrow \phi = \frac{2\pi}{1}\times\frac{1}{2} = \pi$

Total phase difference $= \pi - \frac{\pi}{3} = \frac{2\pi}{3}$

$\Rightarrow A = \sqrt{a^2 + a^2 + 2a^2\cos(2\pi/3)} = a$

8. (b,c) Because in general phase velocity = wave velocity. But in case of complex waves (many waves together) phase velocity $\neq$ wave velocity.

$\therefore$ If two waves have same λ, v; then they have same frequency too

9. (c) If two waves of nearly equal frequency superpose, they give beats if they both travel in straight line and $I_{min} = 0$ if they have equal amplitudes.

10. (c) Resultant amplitude = $\sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

$= \sqrt{0.3^2 + 0.4^2 + 2\times 0.3\times 0.4\times\cos\frac{\pi}{2}} = 0.5\ cm$

11. (a) In the same phase $\phi = 0$ so resultant amplitude $= a_1 + a_2 = 2A + A = 3A$

12. (b) $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{16} \Rightarrow \frac{a_1}{a_2} = \frac{1}{4}$

13. (c) For interference, two waves must have a constant phase relation ship. Equation '1' and '3' and '2' and '4' have a constant phase relationship of $\frac{\pi}{2}$ out of two choices. Only one S_1 emitting '2' and S_2 emitting '4' is given so only (c) option is correct.

14. (d) This is a case of destructive interference.

15. (b) $a_1 = 5,\ a_2 = 10 \Rightarrow \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \left(\frac{5+10}{5-10}\right)^2 = \frac{9}{1}$

16. (c) For the given super imposing waves

$a_1 = 3,\ a_2 = 4$ and phase difference $\phi = \frac{\pi}{2}$

$\Rightarrow A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2} = \sqrt{(3)^2 + (4)^2} = 5$

17. (a) Phase difference between the two waves is

$\phi = (\omega t - \beta_2) = (\omega t - \beta_1) = (\beta_1 - \beta_2)$

$\therefore$ Resultant amplitude $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\beta_1 - \beta_2)}$

18. (a) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \left(\frac{2+1}{2-1}\right)^2 = 9/1$

19. (b) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\frac{\sqrt{I_1}}{\sqrt{I_2}}-1}\right)^2 = \left(\frac{\sqrt{\frac{9}{4}}+1}{\sqrt{\frac{9}{4}}-2}\right)^2 = \frac{25}{1}$

20. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \left(\frac{\frac{4}{3}+1}{\frac{4}{3}-1}\right)^2 = \frac{49}{1}$

21. (a) The resultant amplitude is given by

$A_R = \sqrt{A^2 + A^2 + 2AA\cos\theta} = \sqrt{2A^2(1+\cos\theta)}$

$= 2A\cos\theta/2 \qquad (\because H\cos\theta = 2\cos^2\theta/2)$

22. (b) $\frac{I_{max}}{I_{min}} = \frac{\left(\frac{\sqrt{I_1}}{\sqrt{I_2}}+1\right)^2}{\left(\frac{\sqrt{I_1}}{\sqrt{I_2}}-1\right)^2} = \frac{\left(\sqrt{\frac{9}{1}}+1\right)^2}{\left(\sqrt{\frac{9}{1}}-1\right)^2} = \frac{4}{1}$

23. (a) Since $\phi = \frac{\pi}{2} \Rightarrow A = \sqrt{a_1^2 + a_2^2} = \sqrt{(4)^2 + (3)^2} = 5$

24. (c) $A = \sqrt{(a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi)}$

Putting $a_1 = a_2 = a$ and $\phi = \frac{\pi}{3}$, we get $A = \sqrt{3}a$

25. (d) $y = \frac{1}{\sqrt{a}}\sin\omega t \pm \frac{1}{\sqrt{b}}\sin\left(\omega t + \frac{\pi}{2}\right)$

Here phase difference = $\frac{\pi}{2}$ $\therefore$ The resultant amplitude

$$= \sqrt{\left(\frac{1}{\sqrt{a}}\right)^2 + \left(\frac{1}{\sqrt{b}}\right)^2} = \sqrt{\frac{1}{a} + \frac{1}{b}} = \sqrt{\frac{a+b}{ab}}$$

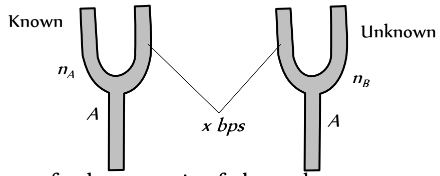
26. (b) Superposition of waves does not alter the frequency of resultant wave and resultant amplitude

$\Rightarrow a^2 = a^2 + a^2 + 2a^2\cos\phi = 2a^2(1 + \cos\phi)$

$\Rightarrow \cos\phi = -1/2 = \cos 2\pi/3 \therefore \phi = 2\pi/3$

Beats

1. (c) Suppose two tuning forks are named *A* and *B* with frequencies $n_A = 256\, Hz$ (known), n_B = ? (unknown), and beat frequency x = 4 *bps*.



Frequency of unknown tuning fork may be

$n_B = 256 + 4 = 260\, Hz$

or $= 256 - 4 = 252\, Hz$

It is given that on sounding waxed fork *A* (fork of frequency 256 *Hz*) and fork *B*, number of beats (beat frequency) increases. It means that with decrease in frequency of *A*, the difference in new frequency of *A* and the frequency of *B* has increased. This is possible only when the frequency of *A* while decreasing is moving away from the frequency of *B*.

This is possible only if n_B = 260 *Hz*.

Alternate method : It is given $n_A = 256\, Hz, n_B = ?$ and x = 4 *bps*

Also after loading *A* (*i.e.* $n_A \downarrow$), beat frequency (*i.e.* x) increases ($\uparrow$).

Apply these informations in two possibilities to known the frequency of unknown tuning fork.

$n_A \downarrow - n_B = x\uparrow$ ... (i)

$n_B - n_A \downarrow = x\uparrow$ ... (ii)

It is obvious that equation (i) is wrong (ii) is correct so

$n_B = n_A + x = 256 + 4 = 260\ Hz$.

2. (d)

3. (c)

4. (a) Suppose n_A = known frequency = 100 *Hz*, n_B = ?

x = 2 = Beat frequency, which is decreasing after loading (*i.e.* $x\downarrow$)

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B \downarrow = x\downarrow$ ... (i) ⟶ Wrong

$n_B \downarrow - n_A = x\downarrow$ ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 100 + 2 = 102\ Hz$.

5. (d) n_A = Known frequency = 256, n_B = ?

x = 2 *bps*, which is decreasing after loading (*i.e.* $x\downarrow$) known tuning fork is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow$ ... (i) ⟶ Correct

$n_B - n_A\downarrow = x\downarrow$ ... (ii) ⟶ Wrong

$\Rightarrow n_B = n_A - x = 256 - 2 = 254\ Hz$.

6. (b) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 4 *bps*, which is decreasing after loading (*i.e.* $x\downarrow$) also known tuning fork is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow$ ... (i) ⟶ Correct

$n_B - n_A\downarrow = x\downarrow$ ... (ii) ⟶ Wrong

$\Rightarrow n_B = n_A - x = 256 - 4 = 252\ Hz$.

7. (c) Time interval between two consecutive beats

$T = \frac{1}{n_1 - n_2} = \frac{1}{260 - 256} = \frac{1}{4}$ sec so, $t = \frac{1}{16} = \frac{T}{4}$ sec

By using time difference = $\frac{T}{2\pi} \times$ Phase difference

$\Rightarrow \frac{T}{4} = \frac{T}{2\pi} \times \phi \Rightarrow \phi = \frac{\pi}{2}$

8. (a) The time interval between successive maximum intensities will be $\frac{1}{n_1 \sim n_2} = \frac{1}{454 - 450} = \frac{1}{4}$ sec.

9. (d) n_A = Known frequency = 341 *Hz*, n_B = ?

x = 6 *bps*, which is decreasing (*i.e.* $x\downarrow$) after loading (from 6 to 1 *bps*)

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow$ ... (i) ⟶ Wrong

$n_B\downarrow - n_A = x\downarrow$ ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 341 + 6 = 347\ Hz$.

10. (b) $T = \frac{1}{258 - 256} = 0.5$ sec

11. (c) Suppose n_A = known frequency = 100 *Hz*, n_B = ?

x = 5 *bps*, which remains unchanged after loading

Unknown tuning fork is loaded so $n_B\downarrow$

Hence $n_A - n_B \downarrow = x$ ... (i)

$n_B \downarrow - n_A = x$ ... (ii)

From equation (i), it is clear that as n_B decreases, beat frequency. (*i.e.* $n_A - (n_B)_{new}$) can never be x again.

From equation (ii), as $n_B\downarrow$, beat frequency (*i.e.* $(n_B)_{new} - n_A$) decreases as long as $(n_B)_{new}$ remains greater than n_A, If $(n_B)_{new}$ become lesser than n_A the beat frequency will increase again and will be x. Hence this is correct.

So, $n_B = n_A + x = 100 + 5 = 105\ Hz$.

12. (b) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 6 *bps*, which remains the same after loading.

Unknown tuning fork *F* is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x$ ... (i) ⟶ Wrong

$n_B\downarrow - n_A = x$ ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 256 + 6 = 262\ Hz.$

13. (a) Probable frequencies of tuning fork be $n+4$ or $n-4$

Frequency of sonometer wire $n \propto \frac{1}{l}$

$\therefore \frac{n+4}{n-4} = \frac{100}{95}$ or $95(n+4) = 100(n-4)$

or $95n + 380 = 100n - 400$ or $5n = 780$ or $n = 156$

14. (c) After filling frequency increases, so n_A decreases ($\downarrow$). Also it is given that beat frequency increases (*i.e.*, $x\uparrow$)

Hence $n_A\downarrow - n_B = x\uparrow$ ... (i) ⟶ Correct

$n_B - n_A\uparrow = x\uparrow$ ... (ii) ⟶ Wrong

$\Rightarrow n_A = n_B + x = 512 + 5 = 517\ Hz.$

15. (c) Intensity $\propto$ (amplitude)^2

as $A_{\max} = 2a_o$ (a_o = amplitude of one source) so $I_{\max} = 4I_o$.

16. (c) Number of beats per second $= n_1 \sim n_2$

$\omega_1 = 2000\pi = 2\pi n_1 \Rightarrow n_1 = 1000$

and $\omega_2 = 2008\pi = 2\pi n_2 \Rightarrow n_2 = 1004$

Number of beats heard per sec $= 1004 - 1000 = 4$

17. (c) The tuning fork whose frequency is being tested produces 2 beats with oscillator at 514 *Hz*, therefore, frequency of tuning fork may either be 512 or 516. With oscillator frequency 510 it gives 6 *beats/sec*, therefore frequency of tuning fork may be either 516 or 504.

Therefore, the actual frequency is 516 *Hz* which gives 2 *beats/sec* with 514 *Hz* and 6 *beats/sec* with 510 *Hz*.

18. (b) If suppose n_s = frequency of string $= \frac{1}{2l}\sqrt{\frac{T}{m}}$

n_f = Frequency of tuning fork = 480 *Hz*

x = Beats heard per second = 10

as tension T increases, so n_s increases ($\uparrow$)

Also it is given that number of beats per sec decreases (*i.e.* $x\downarrow$)

Hence $n_s\uparrow - n_f = x\downarrow$ ... (i) ⟶ Wrong

$n_f - n_s\uparrow = x\downarrow$ ... (ii) ⟶ Correct

$\Rightarrow n_s = n_f - x = 480 - 10 = 470\ Hz.$

19. (c) It is given that

n_A = Unknown frequency = ?

n_B = Known frequency = 256 *Hz*

x = 3 *bps*, which remains same after loading

Unknown tuning fork *A* is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x$ ... (i) ⟶ Correct

$n_B - n_A\downarrow = x$ ... (ii) ⟶ Wrong

$\Rightarrow n_A = n_B + x = 256 + 3 = 259\ Hz.$

20. (a) Frequency of the source = 100 $\pm$ 5 = 105 *Hz* or 95 *Hz*.

Second harmonic of the source = 210 *Hz* or 190 *Hz*.

As the second harmonic gives 5 *beats/sec* with sound of frequency 205 *Hz*, the second harmonic should be 210 *Hz*.

$\Rightarrow$ Frequency of the source = 105 *Hz*.

21. (d) For producing beats, their must be small difference in frequency.

22. (c) n_A = Known frequency = 256 *Hz*, n_B = ?

x = 4 *beats per sec* which is decreasing (4 *bps* to $\frac{5}{2}bps$) after loading (*i.e.* $x\downarrow$)

Unknown tuning fork *B*, is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow$ ... (i) ⟶ Wrong

$n_B\downarrow - n_A = x\downarrow$ ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 256 + 4 = 260\ Hz.$

23. (d) $n_A\downarrow - n_B = x\uparrow$ ... (i) ⟶ Wrong

$n_B - n_A\downarrow = x\uparrow$ ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 200 + 5 = 205\ Hz.$

24. (c) $n_A - n_B\downarrow = x$ (same) ... (i) ⟶ Wrong

$n_B\downarrow - n_A = x$ (same) ... (ii) ⟶ Correct

$\Rightarrow n_B = n_A + x = 320 + 4 = 324\ Hz.$

25. (c) Beat period $T = \frac{1}{n_1 \sim n_2} = \frac{1}{384 - 380} = \frac{1}{4}\sec$. Hence minimum time interval between maxima and minima $t = \frac{T}{2} = \frac{1}{8}\sec$.

26. (d) $\frac{I_{\max}}{I_{\min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \frac{(5+3)^2}{(5-3)^2} = \frac{16}{1}$

27. (a) $n_1 = \frac{v}{\lambda_1} = \frac{v}{0.50}$ and $n_2 = \frac{v}{\lambda_2} = \frac{v}{0.51}$

$\Delta n = n_1 - n_2 = v\left[\frac{1}{0.05} - \frac{1}{0.51}\right] = 12$

$\Rightarrow v = \frac{12 \times 0.51 \times 0.50}{0.01} = 306\ m/s$

28. (c) $n_1 = \frac{316}{2\pi}$ and $n_2 = \frac{310}{2\pi}$ Number of beats heard per second $= n_1 - n_2 = \frac{316}{2\pi} - \frac{310}{2\pi} = \frac{3}{\pi}$

29. (b) Beat frequency $= \frac{2}{0.4} = 5Hz$

30. (a) Since source of frequency x gives 8 beats per second with frequency 250 *Hz*, it's possible frequency are 258 or 242. As source of frequency x gives 12 beats per second with a frequency 270 *Hz*, it's possible frequencies 282 or 258 *Hz*. The only possible frequency of x which gives 8 beats with frequency 250 *Hz* also 12 beats per second with 258 *Hz*.

31. (c) $n_1 = \frac{1000\pi}{2\pi} = 500Hz$ and $n_2 = \frac{998\pi}{2\pi} = 499\ Hz$

Hence beat frequency $= n_1 - n_2 = 1$

32. (a) $v_0 = 332$ *m/s*. Velocity sound at $t°C$ is $v_t = (v_0 + 0.61\,t)$

$\Rightarrow v_{20} = v_0 + 0.61 \times 20 = 344.2\ m/s$

$\Rightarrow \Delta n = v_{20}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = 344.2\left(\frac{100}{50} - \frac{100}{51}\right) = 14$

33. (a) Persistence of hearing is 10 *sec*.

34. (a)

35. (d) n_A = ?, n_B = 384 *Hz*

x = 6 *bps*, which is decreasing (from 6 to 4) *i.e.* $x\downarrow$

Tuning fork *A* is loaded so $n_A\downarrow$

Hence $n_A\downarrow - n_B = x\downarrow$ ⟶ Correct

$n_B - n_A\downarrow = x\downarrow$ ⟶ Wrong

$\Rightarrow n_A = n_B + x = 384 + 6 = 390$ *Hz*.

36. (b) For hearing beats, difference of frequencies should be approximately 10 *Hz*.

37. (a) $n \propto \frac{1}{l} \Rightarrow n_1 l_1 = n_2 l_2 \Rightarrow (n+4)49 = (n-4)50 \Rightarrow n = 396$

38. (a) No of beats, $x = \Delta n = \frac{30}{3} = 10\ Hz$

$\Rightarrow$ Also $\Delta n = v\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right] = v\left[\frac{1}{5} - \frac{1}{6}\right]$=10$\Rightarrow v = 300$ *m/s*

39. (a) $\Delta n = v\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right] = 396\left[\frac{1}{0.99} - \frac{1}{1}\right] = 3.96 \approx 4.$

40. (b) n_A = Known frequency = 288 *cps*, n_B = ?

x = 4 *bps*, which is decreasing (from 4 to 2) after loading *i.e.* $x\downarrow$

Unknown fork is loaded so $n_B\downarrow$

Hence $n_A - n_B\downarrow = x\downarrow$ ⟶ Wrong

$n_B\downarrow - n_A\downarrow = x\downarrow$ ⟶ Correct

$\Rightarrow n_B = n_A + x = 288 + 4 = 292$ *Hz*.

41. (a) Frequency = $\frac{\text{Number of beats}}{\text{Time}} = \frac{2}{0.04} = 50\ Hz$

42. (c) No. of beats = frequency difference = $\frac{4}{0.25} = 16$

43. (d) Suppose n_P = frequency of piano = ? $(n_P \propto \sqrt{T})$

n_f = Frequency of tuning fork $= 256 Hz$

x = Beat frequency = 5 *bps*, which is decreasing (5⟶2) after clanging the tension of piano wire

Also, tension of piano wire is increasing so $n_P\downarrow$

Hence $n_P\uparrow - n_f = x\downarrow$ ⟶ Wrong

$n_f - n_P\uparrow = x\downarrow$ ⟶ Correct

$\Rightarrow n_P = n_f - x = 256 - 5$ *Hz*.

44. (b) With temperature rise frequency of tuning fork decreases. Because, the elastic properties are modified when temperature is changed

also, $n_t = n_0(1 - 0.00011t)$

where n_t = frequency at $t°C$, n_0 = frequency at $0°C$

45. (a) $n_x = 300 Hz$, $n_y = ?$

x = beat frequency = 4 *Hz*, which is decreasing (4⟶2) after increasing the tension of the string *y*.

Also tension of wire *y* increasing so $n_y\uparrow$ $(\because n \propto \sqrt{T})$

Hence $n_x - n_y\uparrow = x\downarrow$ ⟶ Correct

$n_y\uparrow - n_x = x\downarrow$ ⟶ Wrong

$\Rightarrow n_y = n_x - x = 300 - 4 = 296 Hz$

46. (c) Let n be the frequency of fork *C* then

$n_A = n + \frac{3n}{100} = \frac{103n}{100}$ and $n_B = n - \frac{2n}{100} = \frac{98}{100}$

but $n_A - n_B = 5 \Rightarrow \frac{5n}{100} = 5 \Rightarrow n = 100\,Hz$

$\therefore n_A = \frac{(103)(100)}{100} = 103\,Hz$

47. (a)

48. (b) From the given equations of progressive waves $\omega_1 = 500\pi$ and $\omega_2 = 506\pi$ $\therefore n_1 = 250$ and $n_2 = 253$

So beat frequency $= n_2 - n_1 = 253 - 250 = 3$ *beats per sec*

$\therefore$ Number of beats per min = 180.

49. (b)

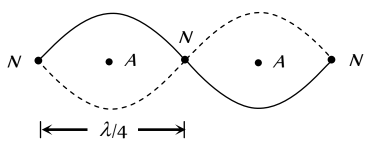
50. (b) Frequency $= \frac{360}{60} \times 60 = 360 Hz.$

51. (b) $v = n\lambda \Rightarrow \lambda = \frac{v}{n} = \frac{340}{170} \Rightarrow \lambda = 2$

Distance separating the position of minimum intensity = $\frac{\lambda}{2} = \frac{2}{2} = 1\ m$

Stationary Waves

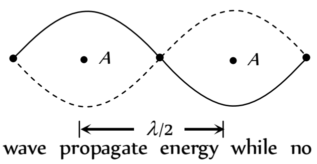
1. (c) The distance between the nearest node and antinode in a stationary wave is $\frac{\lambda}{4}$



2. (c) At nodes pressure change (strain) is maximum

3. (c) Both the sides of a node, two antinodes are present with separation $\frac{\lambda}{2}$

So phase difference between then $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2} = \pi$



4. (c) Progressive wave propagate energy while no propagation of energy takes place in stationary waves.

5. (b)

6. (a) Comparing given equation with standard equation

$y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda}$ gives us $\frac{2\pi}{\lambda} = \frac{\pi}{15} \Rightarrow \lambda = 30$

Distance between nearest node and antinodes = $\frac{\lambda}{4} = \frac{30}{4} = 7.5$

7. (b) On comparing the given equation with standard equation $y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda} \Rightarrow \frac{2\pi x}{\lambda} = \frac{\pi x}{3} \Rightarrow \lambda = 6$

Separation between two adjacent nodes = $\frac{\lambda}{2} = 3\ cm$

8. (d)

9. (a) On comparing the given equation with standard equation $y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda}$]

We get $\frac{2\pi}{\lambda} = \frac{\pi}{20} \Rightarrow \lambda = 40$

Separation between two consecutive nodes = $\frac{\lambda}{2} = \frac{40}{2} = 20\ cm$

10. (a)

11. (b) Since the point $x = 0$ is a node and reflection is taking place from point $x = 0$. This means that reflection must be taking place from the fixed end and hence the reflected ray must suffer an additional phase change of π or a path change of $\frac{\lambda}{2}$.

So, if $y_{\text{incident}} = a\cos(kx - \omega t)$

$\Rightarrow y_{\text{reflected}} = a\cos(-kx - \omega t + \pi) = -a\cos(\omega t + kx)$

12. (d) Particles have kinetic energy maximum at mean position.

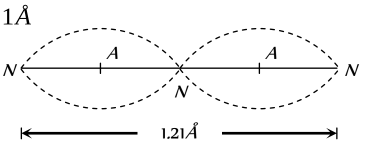
13. (b) On comparing the given equation with standard equation $\frac{2\pi}{\lambda} = 5 \Rightarrow \lambda = \frac{6.28}{5} = 1.256m$

14. (d)

15. (d)

16. (a,b,c) Standing waves can be produced only when two similar type of waves (same frequency and speed, but amplitude may be different) travel in opposite directions.

17. (a) $\lambda = 1.21 Å$



18. (d) $\frac{\lambda}{4} = 20 \Rightarrow \lambda = 80\ cm$, also $\Delta\phi = \frac{\lambda}{2\pi}.\Delta x$

$\Rightarrow \Delta\phi = \frac{60}{80}\times 2\pi = \frac{3\pi}{2}$

19. (a) Required distance $= \frac{\lambda}{4} = \frac{v/n}{4} = \frac{1200}{4\times 300} = 1\ m$

20. (a) Waves *A* and *B* satisfied the conditions required for a standing wave.

21. (a) By comparing given equation with $y = a\sin(\omega t)\cos kx$

$\Rightarrow v = \frac{\omega}{k} = \frac{100}{0.01} = 10^4\ m/s$

22. (b) At fixed end node is formed and distance between two consecutive nodes $\frac{\lambda}{2} = 10\ cm \Rightarrow \lambda = 20\ cm$

$\Rightarrow v = n\lambda = 20\ m/sec$

23. (c) $a\cos(kx + \omega t)$

hence $y_{\text{reflected}} = a\cos(-kx + \omega t + \pi) = -a\cos(kx - \omega t)$

24. (b) Distance between the consecutive node $= \frac{\lambda}{2}$,

but $\lambda = \frac{v}{n} = \frac{20}{n}$ so $\frac{\lambda}{2} = \frac{10}{n}$

25. (a) Energy is not carried by stationary waves

26. (c) On comparing the given equation with standard equation $\Rightarrow \frac{2\pi}{\lambda} = \frac{\pi}{3} \Rightarrow \lambda = 6\ cm$. Hence, distance between two consecutive nodes $\Rightarrow \lambda = 3\ cm$

27. (d) Minimum time interval between two instants when the string is flat = $\frac{T}{2} = 0.5\text{ sec} \Rightarrow T = 1\text{ sec}$

Hence $\lambda = v\times T = 10\times 1 = 10\,m$.

28. (c)

29. (b) Distance between two nodes = $\frac{\lambda}{2} = \frac{v}{2n} = \frac{16}{2n} = \frac{8}{n}$

30. (d)

31. (b) In stationary wave all the particles in one particular segment (*i.e.,* between two nodes) vibrates in the same phase.

32. (a) If $y_{incident} = a\sin(\omega t - kx)$ and $y_{stationary} = a\sin(\omega t)\cos kx$ then it is clear that frequency of both is same (ω)

33. (b)

34. (a) On comparing the given equation with standard equation $\frac{2\pi}{\lambda} = \frac{\pi}{4} \Rightarrow \lambda = 8$

Hence distance between two consecutive nodes $\frac{\lambda}{2} = 4$

35. (a)

36. (a) Waves $Z_1 = A\sin(kx - \omega t)$ is travelling towards positive *x*-direction.

Wave $Z_2 = A\sin(kx + \omega t)$, is travelling towards negative *x*-direction.

Wave $Z_3 = A\sin(ky - \omega t)$ is travelling towards positive *y* direction.

Since waves Z_1 and Z_2 are travelling along the same line so they will produce stationary wave.

37. (a) When two waves of equal frequency and travelling in opposite direction superimpose, then the stationary wave is produced. Hence Z_1 and Z_2 produces stationary wave.

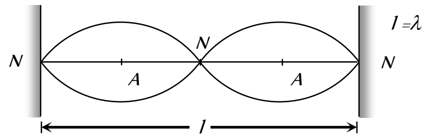
38. (d) The distance between adjacent nodes $x = \frac{\lambda}{2}$

Also $k = \frac{2\pi}{\lambda}$. Hence $x = \frac{\pi}{k}$.

39. (d) $y = 5\sin\left(\frac{2\pi x}{3}\right)\cos 20\pi t$, comparing with equation $y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{2\pi vt}{\lambda} \Rightarrow \lambda = 3$, distance between two adjacent nodes $= \lambda/2 = 1.5cm$.

Vibration of String

1. (c)



2. (d) $n \propto \frac{1}{l} \Rightarrow \frac{n_2}{n_1} = \frac{l_1}{l_2} \Rightarrow n_2 = \frac{l_1}{l_2} n_1 = \frac{1 \times 256}{1/4} = 1024 Hz$

3. (c) String vibrates in five segment so $\frac{5}{2}\lambda = l \Rightarrow \lambda = \frac{2l}{5}$

Hence $n = \frac{v}{\lambda} = 5 \times \frac{v}{2l} = 5 \times \frac{20}{2 \times 10} = 5\ Hz$

4. (c) Here $\frac{\lambda}{2} = 5.0\, cm \quad \Rightarrow \lambda = 10\ cm$

Hence $n = \frac{v}{\lambda} = \frac{200}{10} = 20\ Hz.$

5. (c)

6. (b) As we know plucking distance from one end $= \frac{l}{2p}$

$\Rightarrow\ 25 = \frac{100}{2p}\ \Rightarrow\ p = 2$. Hence frequency of vibration

$n = \frac{p}{2l}\sqrt{\frac{T}{m}} = \frac{2}{2 \times 1}\sqrt{\frac{20}{5 \times 10^{-4}}} = 200 Hz.$

7. (b) To produce 5 *beats/sec.* Frequency of one wire should be increase up to 505 Hz. *i.e.* increment of 1% in basic frequency.

$n \propto \sqrt{T}$ or $T \propto n^2 \Rightarrow \frac{\Delta T}{T} = 2\frac{\Delta n}{n}$

$\Rightarrow$ percentage change in Tension = 2 (1%) = 2%

8. (d) $y = 0.021 \sin(x + 30t) \Rightarrow v = \frac{\omega}{k} = \frac{30}{1} = 30\, m/s$.

Using, $v = \sqrt{\frac{T}{m}} \Rightarrow 30 = \sqrt{\frac{T}{1.3 \times 10^{-4}}} \Rightarrow T = 0.117\ N$

9. (a) $n \propto \sqrt{T}$

10. (c) $n \propto \sqrt{T}$

11. (d) $n \propto \sqrt{T}$

$\Rightarrow n_1 : n_2 : n_3 : n_4 = \sqrt{1} : \sqrt{4} : \sqrt{9} : \sqrt{16} = 1 : 2 : 3 : 4$

12. (c) Let the frequency of tunning fork be N

As the frequency of vibration string $\propto \frac{1}{\text{length of string}}$

For sonometer wire of length 20 *cm*, frequency must be (N + 5) and that for the sonometer wire of length 21*cm*, the frequency must be (N – 5) as in each case the tunning fork produces 5 beats/sec with sonometer wire

Hence $n_1 l_1 = n_2 l_2 \Rightarrow (N + 5) \times 20 = (N - 5) \times 21$

$\Rightarrow N = 205 Hz.$

13. (c) $\lambda = \frac{2l}{p}$ (p = Number of loops)

14. (a) String will vibrate in 7 loops so it will have 8 nodes 7 antinodes.

Number of harmonics = Number of loops = Number of antinodes $\Rightarrow$ Number of antinodes = 7

Hence number of nodes = Number of antinodes + 1

$= 7 + 1 = 8$

15. (a)

16. (d) $n \propto \frac{1}{l}\sqrt{T} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{l}{l'} = \sqrt{4} \times \frac{1}{2} = 1 \Rightarrow n' = n$

17. (a) Sonometer is used to produce resonance of sound source with stretched vibrating string.

18. (a) $n \propto \frac{1}{l} \Rightarrow \frac{l_2}{l_1} = \frac{n_1}{n_2} \Rightarrow l_2 = l_1\left(\frac{n_1}{n_2}\right) = 50 \times \frac{270}{1000} = 13.5 cm$

19. (c) $n \propto \sqrt{T} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}} \Rightarrow \frac{n}{2n} = \sqrt{\frac{10}{T_2}} \Rightarrow T_2 = 40 N$

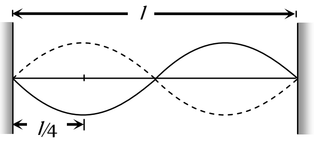
20. (b) $n \propto \sqrt{T}$

21. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \frac{\sqrt{T}}{l}$

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{n_2}{n_1}\right)^2 \left(\frac{l_2}{l_1}\right)^2 = (2)^2 \left(\frac{3}{4}\right)^2 = \frac{9}{4}$

22. (c) $v = \sqrt{\frac{T}{m}} \Rightarrow v = \sqrt{\frac{60.5}{(0.035/7)}} = 110\ m/s$

23. (a) Second harmonic means 2 loops in a total length



Hence plucking distance from one end $= \frac{l}{2p} = \frac{l}{2 \times 2} = \frac{l}{4}$.

24. (b) $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{T}{\pi r^2 \rho}}$

$v \propto \frac{\sqrt{T}}{r} \Rightarrow \frac{v_A}{v_B} = \sqrt{\frac{T_A}{T_B}} \cdot \frac{r_B}{r_A} = \sqrt{\frac{1}{2}} \cdot \frac{1}{2} = \frac{1}{2\sqrt{2}}$

25. (a) The frequency of vibration of a string $n = \frac{p}{2l}\sqrt{\frac{T}{m}}$

Also number of loops = Number of antinodes.

Hence, with 5 antinodes and hanging mass of 9 *kg*.

We have p = 5 and T = 9g $\Rightarrow n_1 = \frac{5}{2l}\sqrt{\frac{9g}{m}}$

With 3 antinodes and hanging mass M

We have p = 3 and T = Mg $\Rightarrow n_2 = \frac{3}{2l}\sqrt{\frac{Mg}{m}}$

$\because\ n_1 = n_2 \Rightarrow \frac{5}{2l}\sqrt{\frac{9g}{m}} = \frac{3}{2l}\sqrt{\frac{Mg}{m}} \Rightarrow M = 25\ kg.$

26. (b) $n \propto \frac{\sqrt{T}}{l} \Rightarrow l \propto \sqrt{T}$ (As n = constant)

$\Rightarrow \frac{l_2}{l_1} = \sqrt{\frac{T_2}{T_1}} = l_1\sqrt{\frac{169}{100}} \Rightarrow l_2 = 1.3 l_1 = l_1 + 30\%$ of l_1

27. (b) $n_1 l_1 = n_2 l_2 \Rightarrow 250 \times 0.6 = n_2 \times 0.4 \Rightarrow n_2 = 375 Hz$

28. (b) In fundamental mode of vibration wavelength is maximum $\Rightarrow$ $l = \frac{\lambda}{2} = 40\, cm \Rightarrow \lambda = 80\, cm$

29. (c) $n_1 l_1 = n_2 l_2 \Rightarrow 800 \times 50 = 1000 \times l_2 \Rightarrow l_2 = 40\ cm$

30. (c) $n \propto \sqrt{T} \Rightarrow \frac{\Delta n}{n} = \frac{\Delta T}{2T}$

If tension increases by 2%, then frequency must increases by 1%.

If initial frequency $n_1 = n$ then final frequency $n_2 - n_1 = 5$

$\Rightarrow \frac{101}{100} n - n = 5 \Rightarrow n = 500 Hz.$

Short trick : If you can remember then apply following formula to solve such type of problems.

Initial frequency of each wire (n)

$= \frac{\text{(Number of beats heard per sec)} \times 200}{\text{(per centage change in tension of the wire)}}$

Here $n = \frac{5 \times 200}{2} = 500 Hz$

31. (b) First overtone of string A = Second overtone of string B.

$\Rightarrow$ Second harmonic of A = Third harmonic of B

$\Rightarrow n_2 = n_3 \Rightarrow [2(n_1)]_A = [3(n_1)]_B$ ($\because n_1 = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}$)

$\Rightarrow 2\left[\frac{1}{2 l_A r_A}\sqrt{\frac{T}{\pi \rho}}\right] = 3\left[\frac{1}{2 l_B r_B}\sqrt{\frac{T}{\pi \rho}}\right]$

$\frac{l_A}{l_B} = \frac{2}{3}\frac{r_B}{r_A} \Rightarrow \frac{l_A}{l_B} = \frac{2}{3} \times \frac{r_B}{(2r_B)} = \frac{1}{3}$

32. (a) Fundamental frequency in case of string is

$n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \frac{\sqrt{T}}{l} \Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} \times \frac{l}{l'}$

putting $T' = T + 0.44T = \frac{144}{100}T$ and $l' = l - 0.4l = \frac{3}{5}l$

We get $\frac{n'}{n} = \frac{2}{1}$.

33. (d) Frequency in a stretched string is given by

$n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} = \frac{1}{l}\sqrt{\frac{T}{\pi d^2 \rho}}$ (d = Diameter of string)

$\Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1}\sqrt{\frac{T_1}{T_2} \times \left(\frac{d_2}{d_1}\right)^2 \times \left(\frac{\rho_2}{\rho_1}\right)}$

$= \frac{35}{36}\sqrt{\frac{8}{1} \times \left(\frac{1}{4}\right)^2 \times \frac{2}{1}} = \frac{35}{36} \Rightarrow n_2 = \frac{36}{35} \times 360 = 370$

Hence beat frequency = $n_2 - n_1 = 10$

34. (b) Frequency of first overtone or second harmonic (n_2) $= 320\ Hz$. So, frequency of first harmonic

$n_1 = \frac{n_2}{2} = \frac{320}{2} = 160 Hz$

35. (d) Similar to Q. 30

Initial frequency of each wire (n)

$= \frac{\text{(Number of beats heared per sec)} \times 200}{\text{(per centage change in tension of the wire)}}$

$= \frac{(3/2) \times 200}{1} = 300 \sec^{-1}$

36. (c) $n \propto \frac{1}{l} \Rightarrow \frac{\Delta n}{n} = -\frac{\Delta l}{l}$

If length is decreased by 2% then frequency increases by 2% *i.e.,* $\frac{n_2 - n_1}{n_1} = \frac{2}{100}$

$\Rightarrow n_2 - n_1 = \frac{2}{100} \times n_1 = \frac{2}{100} \times 392 = 7.8 \approx 8.$

37. (d) Observer receives sound waves (music) which are longitudinal progressive waves.

38. (a) Because both tuning fork and string are in resonance condition.

39. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1}\sqrt{\frac{T_1}{T_2}} = \frac{1}{4}\sqrt{\frac{1}{4}} = \frac{1}{8}$

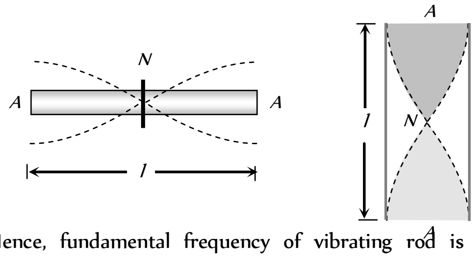
$\Rightarrow n_2 = 8 n_1 = 8 \times 200 = 1600 Hz$

40. (b) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n_1 l_1 = n_2 l_2 = n_3 l_3 = k$

$l_1 + l_2 + l_3 = l \Rightarrow \frac{k}{n_1} + \frac{k}{n_2} + \frac{k}{n_3} = \frac{k}{n}$

$\Rightarrow \frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + ...$

41. (a) If a rod clamped at middle, then it vibrates with similar fashion as open organ pipe vibrates as shown.



Hence, fundamental frequency of vibrating rod is given by $n_1 = \frac{v}{2l} \Rightarrow 2.53 = \frac{v}{4 \times 1} \Rightarrow v = 5.06\ km/sec.$

42. (a) Change in amplitude does not produce change in frequency, $\left(n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}\right)$.

43. (d) Mass per unit length $m = \frac{2 \times 10^{-4}}{0.5} kg/m = 4 \times 10^{-4} kg/m$

Frequency of 2nd harmonic $n_2 = 2n_1$

$= 2 \times \frac{1}{2l}\sqrt{\frac{T}{m}} = \frac{1}{0.5}\sqrt{\frac{20}{4 \times 10^{-4}}} = 447.2 Hz$

44. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \sqrt{T}$ For octave, $n' = 2n$

$\Rightarrow \frac{n'}{n} = \sqrt{\frac{T'}{T}} = 2 \Rightarrow T' = 4T = 16 kg\text{-}wt$

45. (d) Fundamental frequency $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}}$

where m = Mass per unit length of wire

$\Rightarrow n \propto = \frac{1}{lr} \Rightarrow \frac{n_1}{n_2} = \frac{r_2}{r_1} \times \frac{l_2}{l_1} = \frac{r}{2r} \times \frac{2L}{L} = \frac{1}{1}$

46. (c) $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} \propto \sqrt{\frac{T}{r^2 \rho}}$

$\Rightarrow \frac{n_1}{n_2} = \sqrt{\left(\frac{T_1}{T_2}\right)\left(\frac{r_2}{r_1}\right)^2\left(\frac{\rho_2}{\rho_1}\right)} = \sqrt{\left(\frac{1}{2}\right)\left(\frac{2}{1}\right)^2\left(\frac{1}{2}\right)} = 1$

$\therefore\ n_1 = n_2$

47. (a) $n = \frac{p}{2l}\sqrt{\frac{T}{m}} \propto \sqrt{T} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}}$

$\Rightarrow \frac{260}{n_2} = \sqrt{\frac{50.7g}{(50.7 - 0.0075 \times 10^3)g}} \Rightarrow n_2 \approx 240$

48. (b) Given equation of stationary wave is

$y = \sin 2\pi x \cos 2\pi t$, comparing it with standard equation $y = 2A \sin\frac{2\pi x}{\lambda}\cos\frac{2\pi x}{\lambda}$

We have $\frac{2\pi x}{\lambda} = 2\pi x \Rightarrow \lambda = 1m$

Minimum distance of string (first mode) $L_{\min} = \frac{\lambda}{2} = \frac{1}{2}m$

49. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} \Rightarrow n \propto \frac{\sqrt{T}}{lr} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{T_1}{T_2}} \times \frac{l_2}{l_1} \times \frac{r_2}{r_1}$

$= \sqrt{\frac{T}{3T}} \times \frac{3l}{l} \times \frac{2r}{r} = 3\sqrt{3} \Rightarrow n_2 = \frac{n}{3\sqrt{3}}$

50. (c) For string $\lambda = \frac{2l}{p}$

where p = No. of loops = Order of vibration

Hence for forth mode $p = 4 \Rightarrow \lambda = \frac{l}{2}$

Hence $v = n\lambda = 500 \times \frac{2}{2} = 500\ Hz$

51. (d) $n = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} \Rightarrow n \propto \frac{\sqrt{T}}{r}$

$\Rightarrow \frac{n_2}{n_1} = \frac{r_1}{r_2}\sqrt{\frac{T_2}{T_1}} = \frac{1}{2} \times \sqrt{\frac{1}{2}} = \frac{1}{2\sqrt{2}}$

52. (b) In case of sonometer frequency is given by

$n = \frac{p}{2l}\sqrt{\frac{T}{m}} \Rightarrow \frac{n_2}{n_1} = \frac{l_1}{l_2} \Rightarrow n_2 = \frac{25}{16} \times 256 = 400\ Hz$

Organ Pipe (Vibration of Air Column)

1. (c) $\lambda_1 = 2l, \lambda_2 = 2l + 2\Delta l \Rightarrow n_1 = \frac{v}{2l}$ and $n_2 = \frac{v}{2l + 2\Delta l}$

$\Rightarrow$ No. of beats $= n_1 - n_2 = \frac{v}{2}\left(\frac{1}{l} - \frac{1}{l + \Delta l}\right) = \frac{v\Delta l}{2l^2}$

2. (a) Fundamental frequency of open pipe is double that of the closed pipe.

3. (c) If is given that

First over tone of closed pipe = First over tone of open pipe $\Rightarrow$ $3\left(\frac{v}{4l_1}\right) = 2\left(\frac{v}{2l_2}\right)$; where l_1 and l_2 are the lengths of closed and open organ pipes hence $\frac{l_1}{l_2} = \frac{3}{4}$

4. (d) First overtone for closed pipe = $\frac{3v}{4l}$

Fundamental frequency for open pipe = $\frac{v}{2l}$

First overtone for open pipe = $\frac{2v}{2l}$.

5. (c) For closed pipe in general $n = \frac{v}{4l}(2N - 1) \Rightarrow n \propto \frac{1}{l}$

i.e. if length of air column decreases frequency increases.

6. (a,c,d) Fundamental frequency of closed pipe $n = \frac{v}{4l}$

where $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow v \propto \frac{1}{\sqrt{M}}$

$\because\ M_{H_2} < M_{air} \Rightarrow v_{H_2} > v_{air}$

Hence fundamental frequency with H_2 will be more as compared to air. So option (a) is correct.

Also $n \propto \frac{1}{l}$, hence if l decreases n increases so option (c) is correct.

It is well known that $(n)_{Open} = 2(n)_{Closed}$ hence option (d) is correct.

7. (d) For closed pipe $n_1 = \frac{v}{4l} \Rightarrow l = \frac{v}{4n} = \frac{332}{4 \times 166} = 0.5m$

8. (a) Fundamental frequency of open pipe

$n_1 = \frac{v}{2l} = \frac{350}{2 \times 0.5} = 350\ Hz$.

9. (b) For closed pipe $n_1 = \frac{v}{4l} = \frac{330}{4}\ Hz$

Second note = $3n_1 = \frac{3 \times 300}{4}\ Hz$.

10. (c) $n_{\text{closed}} = \frac{v}{4l}, n_{\text{open}} = \frac{v}{2l} \Rightarrow n_{\text{open}} = 2n_{\text{closed}} = 2f$

11. (b) Minimum audible frequency = 20 Hz.

$\Rightarrow \frac{v}{4l} = 20 \Rightarrow l = \frac{336}{4 \times 20} = 4.2\ m$

12. (c) First overtone of closed organ pipe $n_1 = \frac{3v}{4l_1}$

Third overtone of open organ pipe $n_2 = \frac{4v}{2l_2}$

$n_1 = n_2$ (Given) $\Rightarrow \frac{3v}{4l_1} = \frac{4v}{2l_2} \Rightarrow \frac{l_1}{l_2} = \frac{3}{8}$

13. (b) For closed pipe $n_1 = \frac{v}{4l} \Rightarrow 250 = \frac{v}{4\times 0.2} \Rightarrow v = 200 m/s$

14. (b) $n_{\text{open}} = \frac{v}{2l_{\text{open}}}$

$n_{\text{closed}} = \frac{v}{4l_{\text{closed}}} = \frac{v}{4l_{\text{open}}/2} = \frac{v}{2l_{\text{open}}}$

$\left(\text{As } l_{closed} = \frac{l_{open}}{2}\right)$, *i.e.* frequency remains unchanged.

15. (b) For closed pipe second note = $\frac{3v}{4l} = \frac{3\times 330}{4\times 1.5} = 165\ Hz$.

16. (a) Fundamental frequency of open pipe

$n_1 = \frac{v}{2l} = \frac{330}{2\times 0.3} = 550\ Hz$

First harmonic = $2\times n_1 = 1100\ Hz$. = 1.1 *kHz*

17. (b) For first pipe $n_1 = \frac{v}{4l_1}$ and for second pipe $n_2 = \frac{v}{4l_2}$

So, number of beats = $n_2 - n_1 = 4$

$\Rightarrow 4 = \frac{v}{4}\left(\frac{1}{l_2} - \frac{1}{l_1}\right) \Rightarrow 16 = 300\left(\frac{1}{l_2} - \frac{1}{1}\right) \Rightarrow l_2 = 94.9\ cm$

18. (a) Maximum pressure at closed end will be atmospheric pressure adding with acoustic wave pressure

So $\rho_{\max} = \rho_A + \rho_0$ and $\rho_{\min} = \rho_A - \rho_0$

Thus $\frac{\rho_{\max}}{\rho_{\min}} = \frac{\rho_A + \rho_0}{\rho_A - \rho_0}$

19. (c) $n_1 - n_2 = 10$ .....(i)

Using $n_1, = \frac{v}{4l_1}$ and $n_2 = \frac{v}{4l_2}$

$\Rightarrow \frac{n_1}{n_2} = \frac{l_2}{l_1} = \frac{26}{25}$ .....(ii)

After solving these equation $n_1 = 260 Hz$, $n_2 = 250\ Hz$

20. (a) Let l_1 and l_2 be the length's of closed and open pipes respectively. (Neglecting end correction)

$l_1 = \frac{\lambda_1}{4} \Rightarrow \lambda_1 = 4l_1$ and $l_2 = \frac{\lambda_2}{2} \Rightarrow \lambda_2 = 2l_2$

Given $n_1 = n_2$ so $\frac{v}{\lambda_1} = \frac{v}{\lambda_2} \Rightarrow \frac{v}{4l_1} = \frac{v}{2l_2} = \frac{l_1}{l_2} = \frac{1}{2}$

21. (b) Distance between two consecutive nodes

$= \frac{\lambda}{2} = 46 - 16 = 30 \Rightarrow \lambda = 60\ cm = 0.6m$

$\therefore\ v = n\lambda = 500\times 0.6 = 300\ m/s$.

22. (a) For closed pipe $n = \frac{v}{4l} \Rightarrow n = \frac{332}{4\times 42} = 2Hz$.

23. (a) For shortest length of pipe mode of vibration must be fundamental *i.e.,* $n = \frac{v}{4l} \Rightarrow l = \frac{v}{4n}$.

24. (b) $n_{\text{Closed}} = \frac{1}{2}(n_{\text{Open}}) = \frac{1}{2}\times 320 = 160\ Hz$

25. (c) Frequency of 2^{nd} overtone $n_3 = 5n_1 = 5\times 50 = 250\ Hz$.

26. (a) $\Delta n = n_1 - n_2 \Rightarrow 10 = \frac{v}{2l_1} - \frac{v}{2l_2} = \frac{v}{2}\left[\frac{1}{l_1} - \frac{1}{l_2}\right]$

$\Rightarrow 10 = \frac{v}{2}\left[\frac{1}{0.25} - \frac{1}{0.255}\right] \Rightarrow v = 255 m/s.$

27. (a) Fundamental frequency $n = \frac{v}{2l}$

$\Rightarrow 350 = \frac{350}{2l} \Rightarrow l = \frac{1}{2}m = 50 cm.$

28. (b) $\Delta n = n_1 - n_2 \Rightarrow 4 = \frac{v}{2l_1} - \frac{v}{2l_2} = \frac{v}{2}\left[\frac{1}{1.00} - \frac{1}{1.025}\right]$

$\Rightarrow 8 = [1 - 0.975] \Rightarrow v = \frac{8}{0.025} \approx 328 m/s.$

29. (a) In closed pipe only odd harmonics are present

30. (d) Fundamental frequency of open organ pipe $= \frac{v}{2l}$

Frequency of third harmonic of closed pipe $= \frac{3v}{4l}$

$\therefore \frac{3v}{4l} = 100 + \frac{v}{2l} \Rightarrow \frac{3v}{4l} - \frac{2v}{4l} = \frac{v}{4l} = 100 \Rightarrow \frac{v}{2l} = 200 Hz.$

31. (c) $n_A = \frac{v}{2l}; n_B = \frac{v}{4l} \Rightarrow n_A/n_B = 2:1$

32. (a) Due to rise in temperature, the speed of sound increases. Since $n = \frac{v}{\lambda}$ and λ remains unchanged, hence n increases.

33. (b)

34. (b)

35. (b) In closed organ pipe. If $y_{incident} = a\sin(\omega t - kx)$

then $y_{reflected} = a\sin(\omega t + kx + \pi) = -a\sin(\omega t + kx)$

Superimposition of these two waves give the required stationary wave.

36. (b) $v = 330\ m/s$; $n = 165\ Hz$. Distance between two successive nodes = $\frac{\lambda}{2} = \frac{v}{2n} = \frac{330}{2\times 165} = 1m$

37. (b) At the middle of pipe, node is formed.

38. (c) For closed organ pipe $n_1 : n_2 : n_3 .... = 1:3:5:.....$

39. (b) First tone of open pipe = first overtone of closed pipe $\Rightarrow \frac{v}{2l_0} = \frac{3v}{4l_c} \Rightarrow l_c = \frac{3\times 2\times 0.5}{4} = 0.75m$

40. (b) Only odd harmonics are present.

41. (b) Distance between six successive node

$= \frac{5\lambda}{2} = 85cm \Rightarrow \lambda = \frac{2\times 85}{5} = 34\ cm = 0.34\ m$

Therefore speed of sound in gas

$= n\lambda = 1000\times 0.34 = 340\ m/s$

42. (b) Let the base frequency be n for closed pipe then notes are $n, 3n, 5n.....$

$\therefore$ note $3n = 255 \Rightarrow n = 85$, note $5n = 85\times 5 = 425$

note $7n = 7\times 85 = 595$

43. (a) $l_2 = 3l_1 = 3\times 24.7 = 74.1 cm$

44. (c) Frequency of p *th* harmonic

$n = \frac{pv}{2l} \Rightarrow p = \frac{2ln}{v} = \frac{2 \times 0.33 \times 1000}{330} = 2$

45. (a) For closed pipe $l_1 = \frac{v}{4n}; l_2 = \frac{3v}{4n} \Rightarrow v = 2n(l_2 - l_1)$

$\Rightarrow n = \frac{v}{2(l_2 - l_1)} = \frac{330}{2 \times (0.49 - 0.16)} = 500\,Hz$

46. (c) Number of beats per second,

$n = \frac{16}{20} = \frac{4}{5} \Rightarrow n = n_1 - n_2 = \frac{v}{4}\left(\frac{1}{l_1} - \frac{1}{l_2}\right)$

$\Rightarrow \frac{4}{5} = \frac{v}{4}\left(\frac{1}{1} - \frac{1}{1.01}\right) = \frac{0.01v}{4 \times 1.01}$

$v = \frac{16 \times 101}{5} = 323.2\,ms^{-1}$

47. (a) In open organ pipe both even and odd harmonics are produced.

48. (d) Using $\lambda = 2(l_2 - l_1) \Rightarrow v = 2n(l_2 - l_1)$

$\Rightarrow 2 \times 512(63.2 - 30.7) = 33280 cm/s$

Actual speed of sound $v_0 = 332 m/s = 33200 cm/s$

Hence error $= 33280 - 33200 = 80 cm/s$

49. (b) Initially number of beats per second = 5

$\therefore$ Frequency of pipe = 200 $\pm$ 5 = 195 Hz or 205 Hz ...(i)

Frequency of second harmonics of the pipe = $2n$ and number of beats in this case = 10

$\therefore$ $2n$ = 420 $\pm$ 10 $\Rightarrow$ 410 Hz or 430 Hz

$\Rightarrow n$ = 205 Hz or 215 Hz ... (ii)

From equation (i) and (ii) it is clear that n = 205 Hz

50. (c) In case of open pipe, $n = \frac{N}{2l}$ where N = order of harmonics = order of mode of vibration $\Rightarrow N = \frac{n \times 2l}{v}$

$= \frac{480}{330} \times 2 \times 1 = 3$ (Here v = 330 m/s)

51. (a) In first overtone of organ pipe open at one end,

end, $n_c = \frac{3v}{4l_c}$ .....(i)

Third harmonic or second overtone of organ pipe open at both

end, $n_0 = \frac{3v}{2l_0}$ .....(ii)

given $n_c = n_o \Rightarrow \frac{3v}{4l_c} = \frac{3v_0}{2l_0} \Rightarrow \frac{l_c}{l_o} = \frac{1}{2}$.

52. (a) For end correction x, $\frac{l_2 + x}{l_1 + x} = \frac{3\lambda/4}{\lambda/4} = 3$

$x = \frac{l_2 - 3l_1}{2} = \frac{70.2 - 3 \times 22.7}{2} = 1.05\,cm$

53. (b) For open tube, $n_0 = \frac{v}{2l}$

For closed tube length available for resonance is

$l' = l \times \frac{25}{100} = \frac{l}{4}$ $\therefore$ Fundamental frequency of water filled tube $n = \frac{v}{4l'} = \frac{v}{4 \times (l/4)} = \frac{v}{l} = 2n_0 \Rightarrow \frac{n}{n_0} = 2$

Doppler's Effect

1. (d)

2. (b) $n' = n\left(\frac{v}{v - v_O}\right) = 450\left(\frac{340}{340 - 34}\right) = 500\ cycles/\sec$

3. (a) $n' = n\left(\frac{v}{v - v_s}\right) \Rightarrow \lambda' = \lambda\left(\frac{v - v_S}{v}\right)$

$\Rightarrow \lambda' = 120\left(\frac{330 - 60}{330}\right) = 98\,cm.$

4. (b) $n' = n\left(\frac{v}{v - v_S}\right) = 600\left(\frac{330}{300}\right) = 660\ cps$

5. (c) Both listeners, hears the same frequencies.

6. (b)

7. (c) $n' = n\left(\frac{v + v_O}{v}\right) \Rightarrow 2n = n\left(\frac{v + v_0}{v}\right) \Rightarrow \frac{v + v_0}{v} = 2$

$\Rightarrow v_O = v = 332\ m/sec$

8. (b) Apparent frequency in this case $n' = \frac{n(v + v_O)}{v}$

$\because \frac{v + v_0}{v} > 1 \Rightarrow \frac{n'}{n} > 1$ *i.e.* $n' > n$.

9. (a) Wave number = $\frac{1}{\lambda}$ but $\frac{1}{\lambda'} = \frac{1}{\lambda}\left(\frac{v}{v - v_s}\right)$ and $v_S = \frac{v}{3}$

$\therefore$ (W.N.)' = (W.N.) $\left(\frac{v}{v - v/3}\right) = 256 \times \frac{v}{2v/3}$

$= \frac{3}{2} \times 256 = 384$

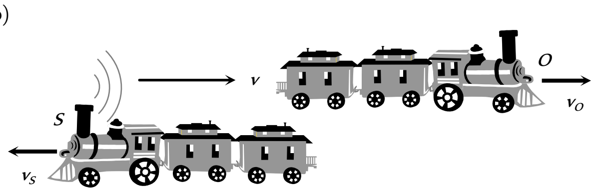
10. (a) By Doppler's formula $n' = \frac{nv}{(v - v_S)}$

Since, source is moving towards the listener so $n' > n$.

If n = 100 then n' = 102.5

$\Rightarrow 102.5 = \frac{100 \times 320}{(320 - v_S)} \Rightarrow v_s = 8\ m/\sec$

11. (b)

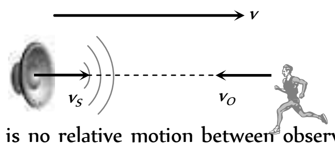


$n' = n\left(\frac{v - v_O}{v + v_S}\right) = 750\left(\frac{330 - 180\times\frac{5}{18}}{330 + 108\times\frac{5}{18}}\right) = 625\ Hz$

12. (a) By using $n' = n\left(\frac{v}{v - v_S}\right)$

$2n = n\left(\frac{v - v_O}{v - 0}\right) \Rightarrow v_O = -v = -$ (Speed of sound)

Negative sign indicates that observer is moving opposite to the direction of velocity of sound, as shown



13. (d) Since there is no relative motion between observer and source, therefore there is no apparent change in frequency.

14. (c)

15. (b)

16. (a) $n' = n\left(\frac{v}{v - v_S}\right) \Rightarrow \frac{n'}{n} = \frac{v}{v - v_S} \Rightarrow \frac{v}{v - v_S} = 3 \Rightarrow v_s = \frac{2v}{3}$

17. (a) $n' = n\left(\frac{v}{v - v_S}\right) = n\left(\frac{v}{v - v/10}\right) \Rightarrow \frac{n'}{n} = \frac{10}{9}$

18. (c) $n' = n\left(\frac{v}{v - v_S}\right) = 1200\times\left(\frac{350}{350 - 50}\right) = 1400$ *cps*

19. (d) $n' = n\left(\frac{v}{v - v_S}\right) = 1200\left(\frac{400}{400 - 100}\right) = 1600\ Hz$

20. (a) $n' = \frac{v}{v - v_S}\times n = \left(\frac{330}{330 - 110}\right)\times 150 = 225\ Hz$

21. (d) Doppler's effect is applicable for both light and sound waves.

22. (a) When source is approaching the observer, the frequency heard

$n_a = \left(\frac{v}{v - v_S}\right)\times n = \left(\frac{340}{340 - 20}\right)\times 1000 = 1063 Hz$

When source is receding, the frequency heard

$n_r = \left(\frac{v}{v + v_S}\right)\times n = \frac{340}{340 + 20}\times 1000 = 944$

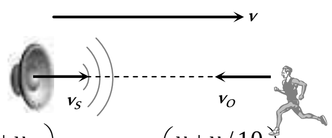
$\Rightarrow n_a : n_r = 9 : 8$

Short tricks : $\frac{n_a}{n_r} = \frac{v + v_S}{v - v_S} = \frac{340 + 20}{340 - 20} = \frac{9}{8}$.

23. (a) By using $\frac{n_{\text{approaching}}}{n_{\text{receding}}} = \frac{v + v_s}{v - v_s}$

$\Rightarrow \frac{1000}{n_r} = \frac{350 + 50}{350 - 50} \Rightarrow n_r = 750 Hz.$

24. (b) When source and listener both are moving towards each other then, the frequency heard



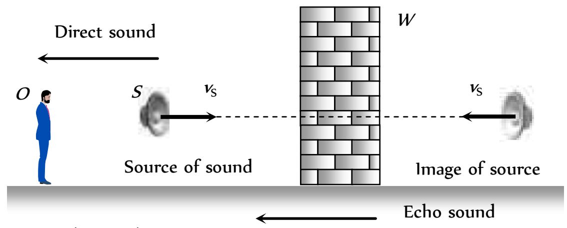
$n' = n\left(\frac{v + v_O}{v - v_S}\right) \Rightarrow n' = f\left(\frac{v + v/10}{v - v/10}\right) = 1.22\,f.$

25. (c) For source $v_s = r\omega = 0.70\times 2\pi\times 5 = 22$ *m/sec*

Minimum frequency is heard when the source is receding the man. It is given by $n_{\min} = n\frac{v}{v + v_S}$

$= 1000\times\frac{352}{352 + 22} = 941\ Hz$

26. (b) For direct sound source is moving away from the observes so frequency heard in this case



$n_1 = n\left(\frac{v}{v + v_s}\right) = 500\left(\frac{332}{332 + 2}\right) = 500\left(\frac{332}{334}\right) Hz$

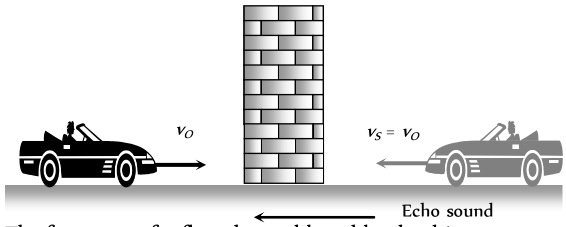
The other sound is echo, reaching the observer from the wall and can be regarded as coming from the image of source formed by reflection at the wall. This image is approaching the observer in the direction of sound.

Hence for reflected sound, frequency heard by the observer is

$n_2 = n\left(\frac{v}{v - v_S}\right) = 500\left(\frac{332}{332 - 2}\right) = 500\left(\frac{332}{330}\right) Hz$

Beats frequency $= n_2 - n_1 = 500\times 332\left(\frac{1}{330} - \frac{1}{334}\right) = 6.$

27. (c) Similar to previous question



The frequency of reflected sound heard by the driver

$n' = n\left(\frac{v - (-v_O)}{v - v_S}\right) = n\left(\frac{v + v_O}{v - v_S}\right)$

$= 124\left[\frac{330 + (72\times 5/18)}{330 - (72\times 5/18)}\right] = 140$ *vibration/sec.*

28. (d) By using $n' = n\frac{v}{v - v_S} \Rightarrow \frac{n_1}{n} = \left(\frac{V}{V - S}\right)$

29. (b) In this case Doppler's effect is not applicable.

30. (d) The apparent frequency heard by the observer is given by

$n' = \frac{v}{v - v_S} n = \frac{330}{330 - 33}\times 450 = \frac{330}{297}\times 450 = 500\ \ Hz$

31. (a) $n' = n\left(\frac{v - v_O}{v}\right) = \left(\frac{330 - 33}{330}\right)\times 100 = 90\ \ Hz$

32. (c) When train is approaching frequency heard by the observer is

$n_a = n\left(\frac{v}{v - v_S}\right) \Rightarrow 219 = n\left(\frac{340}{340 - v_S}\right)$ ....(i) when train is receding (goes away), frequency heard by the observer is

$$n_r = n\left(\frac{v}{v+v_S}\right) \Rightarrow 184 = n\left(\frac{340}{340+v_S}\right) \quad ...(ii)$$

On solving equation (i) and (ii) we get $n = 200Hz$

and $v_S = 29.5 m/s$.

33. (d) Frequency is decreasing (becomes half), it means source is going away from the observes. In this case frequency observed by the observer is

$$n' = n\left(\frac{v}{v+v_S}\right) \Rightarrow \frac{n}{2} = n\left(\frac{v}{v+v_S}\right) \Rightarrow v_S = v$$

34. (d) Observer hears two frequencies

(i) n_1 which is coming from the source directly

(ii) n_2 which is coming from the reflection image of source

so, $n_1 = 680\left(\frac{340}{340-1}\right)$ and $n_2 = 680\left(\frac{340}{340+1}\right)$

$\Rightarrow n_1 - n_2 = 4$ *beats*

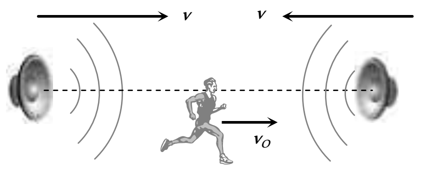
35. (a) From the figure, it is clear that

Frequency of reflected sound heard by the driver.

$$n' = n\left[\frac{v-(-v_o)}{v-v_s}\right] = n\left[\frac{v+v_o}{v-v_s}\right] = n\left[\frac{v+v_{car}}{v-v_{car}}\right]$$

$$= 600\left[\frac{330+30}{330-30}\right] = 720\ Hz.$$

36. (b) Observer is moving away from siren 1 and towards the siren 2.



Hearing frequency of sound emitted by siren 1

$$n_1 = n\left(\frac{v-v_0}{v}\right) = 330\left(\frac{330-2}{330}\right) = 328Hz$$

Hearing frequency of sound emitted by siren 2

$$n_2 = n\left(\frac{v+v_O}{v}\right) = 330\left(\frac{330+2}{330}\right) = 332Hz$$

Hence, beat frequency $= n_2 - n_1 = 332 - 328 = 4$.

37. (c) $n' = n\left(\frac{v}{v-v_S}\right) = \frac{2000 \times 1220}{(1220-40)} = 2068\ Hz$

38. (d) $n' = n\left(\frac{v+v_O}{v-v_S}\right)n \Rightarrow 400 = n\left(\frac{360+40}{360-40}\right) \Rightarrow n = 320\ cps$

39. (a) $n' = n\left(\frac{v}{v+v_S}\right) = 500 \times \left(\frac{330}{300+50}\right) = 434.2Hz$

40. (c) Since there is no relative motion between the listener and source, hence actual frequency will be heard by listener.

41. (a) $n' = n\left(\frac{v}{v-v_S}\right) \Rightarrow n' = 500\left(\frac{330}{330-30}\right) = 550\ Hz$.

42. (c) $n' = n\left(\frac{v}{v-v_S}\right) = 90\left(\frac{v}{v-\frac{v}{10}}\right) = 100\ \frac{Vibration}{sec}$

43. (a) The linear velocity of Whistle

$$v_S = r\omega = 1.2 \times 2\pi \frac{400}{60} = 50\ m/s$$

When Whistle approaches the listener, heard frequency will be maximum and when listener recedes away, heard frequency will be minimum

So, $n_{max} = n\left(\frac{v}{v-v_S}\right) = 500\left(\frac{340}{290}\right) = 586Hz$

$$n_{min} = n\left(\frac{v}{v+v_S}\right) = 500\left(\frac{340}{390}\right) = 436Hz$$

44. (d) By using $n' = n\left(\frac{v}{v-v_S}\right)$

$$\Rightarrow f_1 = n\left(\frac{v}{v-v_S}\right) = n\left(\frac{340}{340-34}\right) = \frac{340}{306}n$$

and $f_2 = n\left(\frac{340}{340-17}\right) = n\left(\frac{340}{323}\right) \Rightarrow \frac{f_1}{f_2} = \frac{323}{306} = \frac{19}{18}$

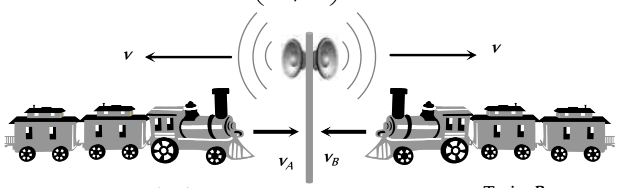
45. (d) No change in frequency.

46. (b) $n' = n\left(\frac{v-v_O}{v+v_S}\right) = n\left(\frac{340-10}{340+10}\right) = 1950 \Rightarrow n = 2068\ Hz$

47. (b) $n' = n\left(\frac{v+v_O}{v-v_S}\right) = 240\left(\frac{340+20}{340-20}\right) = 270\ Hz$.

48. (b) In both the cases observer is moving towards, the source.

Hence by using $n' = n\left(\frac{v+v_0}{v}\right)$



When passenger is sitting in train *A*, then

$$5.5 = 5\left(\frac{v+v_A}{v}\right) \quad ...(i)$$

when passenger is sitting in train *B*, then

$$6 = 5\left(\frac{v+v_B}{v}\right) \quad ...(ii)$$

On solving equation (i) and (ii) we get $\frac{v_B}{v_A} = 2$

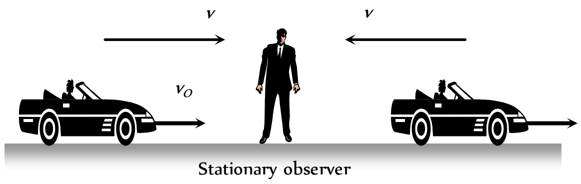
49. (b) Minimum frequency will be heard, when whistle moves away from the listener.

$n_{min} = n\left(\frac{v}{v+v_s}\right)$ where $v = r\omega = 0.5 \times 10 = 1\ m/s$

$$\Rightarrow n_{min} = 385\left(\frac{340}{340+10}\right) = 374Hz.$$

50. (a) $n' = n\left(\frac{v}{v+v_S}\right) = 800\left(\frac{330}{330+30}\right) = 733.33\ Hz$.

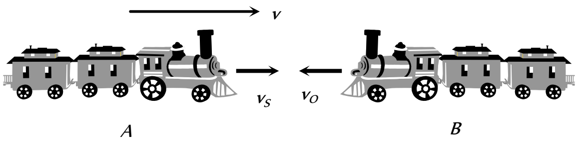
51. (a) $n_{Before} = \frac{v}{v-v_c}n$ and $n_{After} = \frac{v}{v+v_c}.n$



$\frac{n_{Before}}{n_{After}} = \frac{11}{9} = \left(\frac{v+v_c}{v-v_c}\right) \Rightarrow v_c \Rightarrow \frac{v}{10}$

52. (c) By using $n' = \left(\frac{v}{v-v_S}\right) \Rightarrow 2n = n\left(\frac{v}{v-v_S}\right) \Rightarrow v_S = \frac{v}{2}$

53. (d) The frequency of whistle heard by passenger in the train *B*, is



$n' = n\left(\frac{v+v_0}{v-v_s}\right) = 600\left(\frac{340+15}{340-20}\right) \approx 666\ Hz$

54. (b) At point *A*, source is moving away from observer so apparent frequency $n_1 < n$ (actual frequency) At point *B* source is coming towards observer so apparent frequency $n_2 > n$ and point *C* source is moving perpendicular to observer so $n_3 = n$

Hence $n_2 > n_3 > n_1$

55. (a) $n' = n\left[\frac{v+v_O}{v-v_S}\right]$; Here $v = 332\ m/s$ and $v_0 = v_s = 50\ m/s$

$\Rightarrow 435 = n\left[\frac{332+50}{332-50}\right] \Rightarrow n = 321.12\ sec^{-1} \approx 320\ sec^{1}$

56. (c) Since apparent frequency is lesser than the actual frequency, hence the relative separation between source and listener should be increasing.

57. (c)

58. (d) $n' = n\left(\frac{v+v_0}{v-v_s}\right) = n\left(\frac{v+v/2}{v-v/2}\right) = 3n$

59. (c) When engine approaches towards observer $n' = n\left(\frac{v}{v-v_S}\right)$

when engine going away from observer $n'' = \left(\frac{v}{v+v_S}\right)n$

$\therefore \frac{n'}{n''} = \frac{v+v_S}{v-v_S} \Rightarrow \frac{5}{3} = \frac{340+v_S}{340-v_S} \Rightarrow v_S = 85\ m/s$.

60. (a) Frequency heard by the observer

$n' = n\left(\frac{v+v_0}{v}\right) = 240\left(\frac{330+11}{330}\right) = 248 Hz.$

61. (c) According the concept of sound image

$n' = \frac{v+v_{person}}{v-v_{person}}.272 = \frac{345+5}{345-5}\times 272 = 280\ Hz$

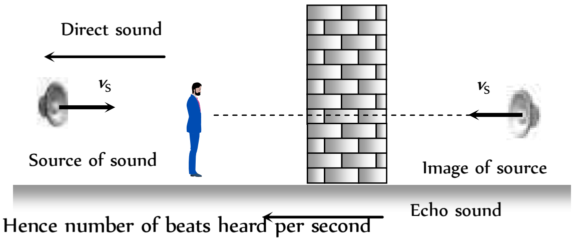
Δn = Number of beats = 280 − 272 = 8 Hz

62. (b) According the concept of sound image

$n' = \frac{v+v_B}{v-v_B}\times n = \frac{355+5}{355-5}\times 165 = 170\ Hz$

Number of beats $= n' - n = 170 - 165 = 5$

63. (a) The observer will hear two sound, one directly from source and other from reflected image of sound



Hence number of beats heard per second

$= \left(\frac{v}{v-v_S}\right)n - \left(\frac{v}{v+v_S}\right)n$

$= \frac{2nvv_S}{v^2 - v_S^2} = \frac{2\times 256\times 330\times 5}{335\times 325} = 7.8\ Hz$

64. (a) When a listener moves towards a stationary source apparent frequency

$n' = \left(\frac{v+v_O}{v}\right) n = 200$ .....(i)

When listener moves away from the same source

$n'' = \frac{(v-v_O)}{v}n = 160$ .....(ii)

From (i) and (ii)

$\frac{v+v_O}{v-v_O} = \frac{200}{160} \Rightarrow \frac{v+v_O}{v-v_O} = \frac{5}{4} \Rightarrow v = 360 m/\sec$

65. (b) When observer moves towards stationary source then apparent frequency

$n' = \left[\frac{v+v_O}{v}\right]n = \left[\frac{v+v/5}{v}\right]n = \frac{6}{5}n = 1.2n$

Increment in frequency = 0.2 n so percentage change in frequency $= \frac{0.2n}{n}\times 100$ = 20%.

Musical Sound

1. (d)

2. (a) Intensity $= \frac{\text{Power}}{\text{Area}} = \frac{4}{4\pi\times(200)^2} = 7.9\times 10^{-6}\ W/m^2$

3. (a) Intensity $\propto$ (Amplitude)

4. (c) $I = 2\pi^2 a^2 n^2\ v\rho \Rightarrow I \propto a^2 n^2 \Rightarrow \frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 \times \left(\frac{n_1}{n_2}\right)^2$

$= \left(\frac{1}{2}\right)^2 \times \left(\frac{1}{1/4}\right)^2 \Rightarrow I_2 = \frac{I_1}{4}$

5. (b) $L = 10\log_{10}\left(\frac{I}{I_0}\right) = 30 \Rightarrow \frac{I}{I_0} = 10^3$

6. (c)

7. (a) The quality of sound depends upon the number of harmonics present. Due to different number of harmonics present in two sounds, the shape of the resultant wave is also different.

8. (d) The sounds of different source are said to differ in quality. The number of overtones and their relative intensities determines the quality of any musical sound.

9. (d)

10. (d) $\text{Energy density} \propto (\text{amplitude})^2$

11. (d) Energy $\propto a^2n^2 \Rightarrow \frac{a_B}{a_A} = \frac{n_A}{n_B}$ ($\because$ energy is same)

$\Rightarrow \frac{a_B}{a_A} = \frac{8}{1}$

12. (c) Loudness depends upon intensity while pitch depends upon frequency.

13. (d) Reverberation time $T = \frac{kV}{\alpha S} \Rightarrow T \propto V$.

14. (c) $I \propto \frac{1}{r^2} \Rightarrow \frac{I_2}{I_1} = \frac{r_1^2}{r_2^2} \Rightarrow \frac{I_2}{1\times 10^{-2}} = \frac{2^2}{10^2} = \frac{4}{100}$

$\Rightarrow I_2 = \frac{4\times 10^{-2}}{100} = 4\times 10^{-4}\ \mu W/m^2$

15. (b) After passing the 3 meter intensity is given by

$I_3 = \frac{90}{100}\times\frac{90}{100}\times\frac{90}{100}\times I = 72.9\%\text{ of } I$

So, the intensity is 72.9 decibel.

16. (c)

17. (b)

18. (a) $P \propto I$

$L_1 = 10\log_{10}\left(\frac{I_1}{I_0}\right)$ and $L_2 = 10\log_{10}\left(\frac{I_2}{I_0}\right)$

So $L_2 - L_1 = 10\log_{10}\left(\frac{I_2}{I_1}\right)$

$= 10\log_{10}\left(\frac{P_2}{P_1}\right) = 10\log_{10}\left(\frac{400}{20}\right) = 10\log_{10} 20$

$= 10\log(2\times 10) = 10(0.301+1) = 13dB$

19. (d) $I \propto \frac{1}{r^2} \Rightarrow \frac{\Delta I}{I} = -2\frac{\Delta r}{r} = -2\times 2 = -4\%$

Hence intensity is decreased by 4%.

20. (b) Musical interval is the ratio of frequencies $= \frac{320}{240} = \frac{4}{3}$

21. (c)

22. (d) By using $L = \log_{10}\frac{I}{I_0}$

$L_2 - L_1 = \log_{10}\frac{I_2}{I_0} - \log_{10}\frac{I_1}{I_0}$

$5 - 1 = \log_{10}\frac{I_2}{I_1} \Rightarrow 4 = \log_{10}\frac{I_2}{I_1} \Rightarrow \frac{I_2}{I_1} = 10^4$

$\Rightarrow \frac{a_2^2}{a_1^2} = 10^4 \Rightarrow \frac{a_2}{a_1} = \frac{10^2}{1} \Rightarrow \frac{a_1}{a_2} = \frac{1}{10^2}$

23. (b)

24. (a) Pitch of mosquito is higher among all given options.

25. (b) The frequency of note 'Sa' is 256 Hz while that of note 'Re' and 'Ga' respectively are 288 Hz and 320 Hz.

26. (d)

27. (d) Indian classical vocalists don't like harmoniuim because it uses tempered scale.

28. (b)

29. (b) $I \propto \frac{1}{r^2} \Rightarrow \frac{I_2}{I_1} = \frac{r_1^2}{r_2^2} = \frac{2^2}{(40)^2} = \frac{1}{400} \Rightarrow I_1 = 400 I_2$

Intensity level at point 1, $L_1 = 10\log_{10}\left(\frac{I_1}{I_0}\right)$

and intensity at point 2, $L_2 = 10\log_{10}\left(\frac{I_2}{I_0}\right)$

$\therefore L_1 - L_2 = 10\log\frac{I_1}{I_2} = 10\log_{10}(400)$

$\Rightarrow L_1 - L_2 = 10\times 2.602 = 26$

$L_2 = L_1 - 26 = 80 - 26 = 54\ dB$

30. (a) Intensity $\propto \frac{1}{(\text{Distance})^2} \Rightarrow \frac{I_1}{I_2} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$.

31. (d)

32. (a) The pitch depends upon the frequency of the source. As the two waves have different amplitude therefore they having different intensity. While quality depends on number of harmonics/overtone produced and their relative intensity. Assuming that their frequencies are the same.

Critical Thinking Questions

1. (a,b,c,d) $y = 0.02\cos(10\pi x)\cos\left(50\pi t + \frac{\pi}{2}\right)$

At node, amplitude = 0

$\Rightarrow \cos(10\pi x) = 0 \Rightarrow 10\pi x = \frac{\pi}{2}, \frac{3\pi}{2}$

$\Rightarrow x = \frac{1}{20} = 0.05\ m,\ 0.15m$ .....

At antinode, amplitude is maximum

$\Rightarrow \cos(10\pi x) = \pm 1 \Rightarrow x = 0, \pi, 2\pi ...$

$\Rightarrow x = 0,\ 0.1m,\ 0.2m$ ...

Now $\lambda = 2\times$ Distance between two nodes or antinodes

$= 2\times 0.1 = 0.2\ m$ and $\frac{2\pi v t}{\lambda} = 50\pi t$

$v = 25\lambda = 25\times 0.2 = 5m/\sec$.

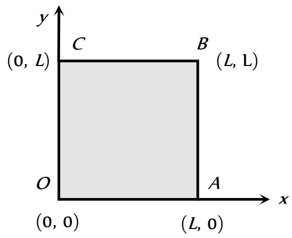
2. (b,c) Since the edges are clamped, displacement of the edges $u(x, y) = 0$ for line –

OA i.e. $y = 0$, $0 \le x \le L$

AB i.e. $x = L$, $0 \le y \le L$

BC i.e. $y = L$, $0 \le x \le L$

OC i.e. $x = 0$, $0 \le y \le L$



The above conditions are satisfied only in alternatives (b) and (c).

Note that $u(x,y)=0$, for all four values e.g. in alternative (d), $u(x,y)=0$ for $y=0, y=L$ but it is not zero for $x=0$ or $x=L$. Similarly in option (a). $u(x,y)=0$ at $x=L, y=L$ but it is not zero for $x=0$ or $y=0$, while in options (b) and (c), $u(x,y)=0$ for $x=0, y=0, x=L$ and $y=L$

3. (c) Energy $(E) \propto$ (Amplitude)^2 (Frequency)^2

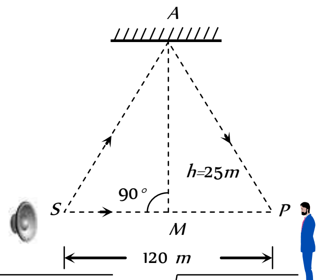
Amplitude is same in both the cases, but frequency 2ω in the second case is two times the frequency (ω) in the first case. Hence $E_2 = 4E_1$.

4. (a) Let S be source of sound and P the person or listner.

The waves from S reach point P directly following the path SMP and being reflected from the ceiling at point A following the path SAP. M is mid-point of SP (*i.e.* $SM = MP$) and $\angle SMA = 90^o$

Path difference between waves $\Delta x = SAP - SMP$

We have $SAP = SA + AP = 2(SA)$



$= 2\sqrt{[(SM)^2 + (MA)^2]} = 2\sqrt{(60^2 + 25^2)} = 130\ m$

$\therefore$ Path difference = SAP – SMP $= 130 - 120 = 10\ m$

Path difference due to reflection from ceiling = $\frac{\lambda}{2}$

$\therefore$ Effective path difference $\Delta x = 10 + \frac{\lambda}{2}$

For constructive interference

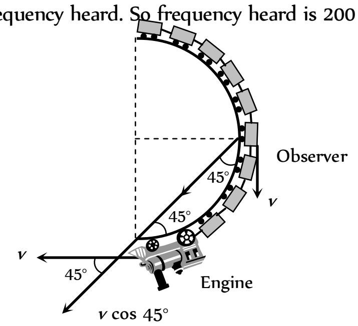
$$\Delta x = 10 + \frac{\lambda}{2} = n\lambda \Rightarrow (2n-1)\frac{\lambda}{2} = 10 (n = 1,\ 2,\ 3....)$$

$\therefore$ Wavelength $\lambda = \frac{2\times 10}{(2n-1)} = \frac{20}{2n-1}$. The possible wavelength are $\lambda = 20,\ \frac{20}{3},\ \frac{20}{5},\ \frac{20}{7},\ \frac{20}{9}, ...$

$= 20\ m,\ 6.67\ m,\ 4m,\ 2.85\,m,\ \ 2.22\ m, ...$

5. (c) The situation is shown in the fig.

Both the source (engine) and the observer (Person in the middle of the train) have the same speed, but their direction of motion is right angles to each other. The component of velocity of observer towards source is $v\cos 45°$ and that of source along the time joining the observer and source is also $v\cos 45°$. There is number relative motion between them, so there is no change in frequency heard. So frequency heard is 200 *Hz*.



6. (b) Velocity of sound increases if the temperature increases. So with $v = n\lambda$, if v increases n will increase

at $27^o C, v_1 = n\lambda$, at $31^o C$, $v_2 = (n+x)\lambda$

Now using $v \propto \sqrt{T}$ $\left(\because v = \sqrt{\frac{\gamma RT}{M}}\right)$

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \frac{n+x}{n}$$

$$\Rightarrow \frac{300+x}{300} = \sqrt{\frac{(273+31)}{(273+27)}} = \sqrt{\frac{304}{300}} = \sqrt{\frac{300+4}{300}}$$

$$\Rightarrow 1 + \frac{x}{300} = \left(1+\frac{4}{300}\right)^{1/2} = \left(1 + \frac{1}{2}\times\frac{4}{300}\right) \Rightarrow x = 2.$$

$[\because (1+x)^n = 1 + nx]$

7. (b) Let *x* be the end correction then according to question.

$$\frac{v}{4(l_1+x)} = \frac{3v}{4(l_2+x)} \Rightarrow x = 2.5\ cm = 0.025\ m.$$

8. (c) Frequency of first over tone of closed pipe = Frequency of first over tone of open pipe

$$\Rightarrow \frac{3v}{4L_1} = \frac{v}{L_2} \Rightarrow \frac{3}{4L_1}\sqrt{\frac{\gamma P}{\rho_1}} = \frac{1}{L_2}\sqrt{\frac{\gamma P}{\rho_2}} \quad \left[\because v = \sqrt{\frac{\gamma P}{\rho}}\right]$$

$$\Rightarrow L_2 = \frac{4L_1}{3}\sqrt{\frac{\rho_1}{\rho_2}} = \frac{4L}{3}\sqrt{\frac{\rho_1}{\rho_2}}$$

9. (b) For string, $\frac{\text{Mass}}{\text{Length}} = m = \frac{10^{-2}}{0.4} = 2.5\times 10^{-2} kg/m$

$\therefore$ Velocity $v = \sqrt{\frac{T}{m}} = \sqrt{\frac{16}{2.5\times 10^{-2}}} = 8m/s$

For constructive interference between successive pulses.

$$\Delta t_{\min} = \frac{2l}{v} = \frac{2(0.4)}{8} = 0.1\sec$$

(After two reflections, the wave pulse is in same phase as it was produced since in one reflection it's phase changes by π, and If at this moment next identical pulse is produced, then constructive interference will be obtained.

10. (d) Frequency of vibration in tight string

$$n = \frac{p}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \sqrt{T} \Rightarrow \frac{\Delta n}{n} = \frac{\Delta T}{2T} = \frac{1}{2}\times(4\%) = 2\%$$

$\Rightarrow$ Number of beats = $\Delta n = \frac{2}{100}\times n = \frac{2}{100}\times 100 = 2$

11. (b) When the source approaches the observer

Apparent frequency $n' = \frac{v}{v - v_s}.n = n\left[\frac{1}{1-\frac{v_s}{v}}\right]$

$= n\left[1 - \frac{v_s}{v}\right]^{-1} = n\left[1 + \frac{v_s}{v}\right]$

(Neglecting higher powers because $v_s << v$)

When the source recedes the observed apparent frequency $n'' = n\left[1 - \frac{v_s}{v}\right]$

Given $n' - n'' = \frac{2}{100}n,\ v = 300\ m/\sec$

$$\therefore \frac{2}{100}n = n\left[1+\frac{v_s}{v}\right] - n\left[1 - \frac{v_s}{v}\right] = n\left[2\frac{v_s}{v}\right]$$

$$\Rightarrow \frac{2}{100} = 2\frac{v_s}{v} \Rightarrow v_s = \frac{v}{100} = \frac{300}{100} = 3\ m/\sec.$$

12. (a,b,c) Number of waves striking the surface per second (or the frequency of the waves reaching surface of the moving target) $n' = \frac{(c+v)}{\lambda} = \frac{\nu(c+v)}{c}$

Now these waves are reflected by the moving target

(Which now act as a source). Therefore apparent frequency of reflected second $n'' = \left(\frac{c}{c-v}\right)n' = \nu\left(\frac{c+v}{c-v}\right)$

The wavelength of reflected wave $= \frac{c}{n''} = \frac{c(c-v)}{\nu(c+v)}$

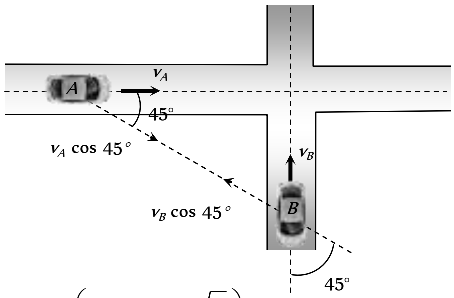
The number of beats heard by stationary listener $= n'' - \nu = \nu\left(\frac{c+v}{c-v}\right) - \nu = \frac{2\nu v}{(c-v)}$

Hence option (a) (b) and (c) are correct.

13. (b) Here $v_A = 72km/hr = 20m/\sec$

$v_B = 36km/hr = 10m/\sec$

$$n' = n\left(\frac{v + v_B \cos 45^o}{v - v_A \cos 45^o}\right)$$



$$\Rightarrow \; n' = 280\left(\frac{340 + 10/\sqrt{2}}{340 - 20/\sqrt{2}}\right) = 298\ Hz$$

14. (b) For observer note of B will not change due to zero relative motion.

Observed frequency of sound produced by A

$= 660\,\frac{(330-30)}{330} = 600\ Hz$

$\therefore$ No. of beats = 600 – 596 = 4

15. (a) $\lambda = \frac{v}{n} = \frac{340}{170} = 2m,\; n' = \frac{340}{340-17}\times 170 \Rightarrow n' = 178.9 Hz$

Now $\lambda' = \frac{v}{n'} = \frac{340}{178.9} = 1.9$

$\Rightarrow \lambda - \lambda' = 2 - 1.9 = 0.1$

16. (b) n_1 = Frequency of the police car horn observer heard by motorcyclist

n_2 = Frequency of the siren heard by motorcyclist.

v = Speed of motor cyclist

$n_1 = \frac{330 - v}{330 - 22}\times 176$; $n_2 = \frac{330 + v}{330}\times 165$

$\because\; n_1 - n_2 = 0 \Rightarrow v = 22\ m/s$.

17. (a) $n' = \frac{v + v_0}{v}.n = \frac{v + \frac{v}{5}}{v}.f = \frac{6}{5}f = 1.2f$ and since the source is stationary, so wave length remains unchanged for observer.

18. (d) Time of fall = $\sqrt{\frac{2h}{g}} = \sqrt{\frac{2\times 10}{1000}} = \frac{1}{\sqrt{50}}$

In this time number of oscillations are eight.

So time for 1 oscillation = $\frac{1}{8\sqrt{50}}$

Frequency = $8\sqrt{50}\ Hz$ = 56 Hz

19. (a) Density of mixture $= \rho_{\text{mix}} = \frac{V_{O_2}\rho_{O_2} + V_{H_2}\rho_{H_2}}{V_{O_2} + V_{H_2}}$

$= \frac{V(\rho_{O_2} + \rho_{H_2})}{2V} = \frac{\rho_{O_2} + \rho_{H_2}}{2}$ (since $V_{O_2} = V_{H_2} = V$)

$= \frac{\rho_{H_2} + 16\rho_{H_2}}{2} = 8.5\rho_{H_2} \Rightarrow v \propto \frac{1}{\sqrt{\rho}}$

$\Rightarrow \frac{V_{\text{mix}}}{V_{H_2}} = \sqrt{\frac{\rho_{H_2}}{\rho_{\text{mxn}}}} = \sqrt{\frac{\rho_{H_2}}{8.5\rho_{H_2}}} \approx \sqrt{\frac{1}{8}}$

20. (c) $y_1 = 10\sin\left(3\pi t + \frac{\pi}{3}\right)$ ...(i)

and $y_2 = 5[\sin 3\pi t + \sqrt{3}\cos 3\pi t]$

$= 5\times 2\left[\frac{1}{2}\times \sin 3\pi t + \frac{\sqrt{3}}{2}\times \cos 3\pi t\right]$

$= 10\left[\cos\frac{\pi}{3}\sin 3\pi t + \sin\frac{\pi}{3}\cos \pi t\right]$

$= 10\left[\sin\left(3\pi t + \frac{\pi}{t}\right)\right]$ ... (ii)

($\because$ sin(A + B) = sin$A$ cos$B$ + cos$A$ sin$B$)

Comparing equation (i) and (ii) we get ratio of amplitude 1 : 1.

21. (a) The given equation can be x written as

$y = \frac{A}{2}\cos\left(4\pi n t - \frac{4\pi x}{\lambda}\right) + \frac{A}{2}\quad \left(\because \cos^2\theta = \frac{1 + \cos 2\theta}{2}\right)$

Hence amplitude $= \frac{A}{2}$ and frequency $= \frac{\omega}{2\pi} = \frac{4\pi n}{2\pi} = 2n$

and wave length $= \frac{2\pi}{k} = \frac{2\pi}{4\pi/\lambda} = \frac{\lambda}{2}$.

22. (a,b,c,d) In case of sound wave, y can represent pressure and displacement, while in case of an electromagnetic wave it represents electric and magnetic fields.

(In general y is any general physical quantity which is made to oscillate at one place and these oscillations are propagated to other places also).

23. (b) In case of interference of two waves resultant intensity

$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

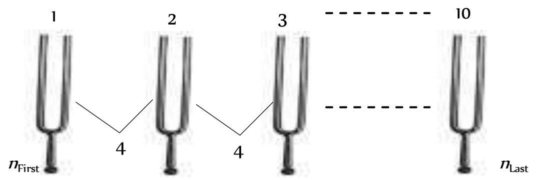
If ϕ varies randomly with time, so $(\cos\phi)_{av} = 0$

$\Rightarrow I = I_1 + I_2$

For n identical waves, $I = I_0 + I_0 + ... = nI_0$

here $I = 10I_0$.

24. (d)



Using $n_{Last} = n_{First} + (N - 1)x$

where N = Number of tuning fork in series

x = beat frequency between two successive forks

$\Rightarrow 2n = n + (10 - 1)\times 4 \Rightarrow n = 36\ Hz$

$\therefore\; n_{First} = 36\ Hz$ and $n_{Last} = 2\times n_{First} = 72\ Hz$

25. (a) Similar to previous question

$n_{last} = n_{first} + (N - 1)x$

$2n = n + (41 - 1)\times 5$

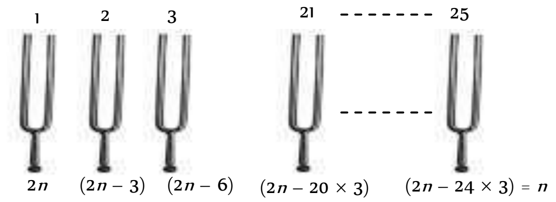
$\Rightarrow n_{first} = 200\ Hz$ and $n_{last} = 400\ Hz$

26. (a) $n \propto \sqrt{T} \Rightarrow \frac{\Delta n}{n} = \frac{1}{2}\frac{\Delta T}{T}$

Beat frequency $= \Delta n = \left(\frac{1}{2}\frac{\Delta T}{T}\right)n = \frac{1}{2} \times \frac{2}{100} \times 400 = 4$

27. (c) According to the question frequencies of first and last tuning forks are $2n$ and n respectively.

Hence frequency in given arrangement are as follows



$\Rightarrow 2n - 24 \times 3 = n \Rightarrow n = 72\ Hz$

So, frequency of 21st tuning fork

$n_{21} = (2 \times 72 - 20 \times 3) = 84 Hz$

28. (a) Using $n_{last} = n_{first} + (N-1)x$

$\Rightarrow 2n = n + (16 - 1) \times 8 \Rightarrow n = 120\ Hz$

29. (b) Using $n = \frac{1}{2l}\sqrt{\frac{T}{m}}$;

As $T_1 > T_2 \Rightarrow n_1 > n_2$ giving $n_1 - n_2 = 6$

The beat frequency of 6 will remain fixed when

(i) n_1 remains same but n_2 is increased to a new value $(n_2' - n_2 = 12)$ by increasing tension T_2.

(ii) n_2 remains same but n_1 is decreased to a new value $(n_1 - n_1' = 12)$ by decreasing tension T_1.

30. (a) According to problem

$\frac{1}{2L}\sqrt{\frac{T}{m}} = \frac{v}{4L}$ .....(i)

and $\frac{1}{2L}\sqrt{\frac{T+8}{m}} = \frac{3v}{4L}$ .....(ii)

Dividing equation (i) and (ii), $\sqrt{\frac{T}{T+8}} = \frac{1}{3} \Rightarrow T = 1N$

31. (b) In condition of resonance, frequency of a.c. will be equal to natural frequency of wire

$n = \frac{1}{2l}\sqrt{\frac{T}{m}} = \frac{1}{2 \times 1}\sqrt{\frac{10 \times 9.8}{9.8 \times 10^{-3}}} = \frac{100}{2} = 50\ Hz$

32. (b) For wire if

M = mass, ρ = density, A = Area of cross section

V = volume, l = length, Δl = change in length

Then mass per unit length $m = \frac{M}{l} = \frac{Al\rho}{l} = A\rho$

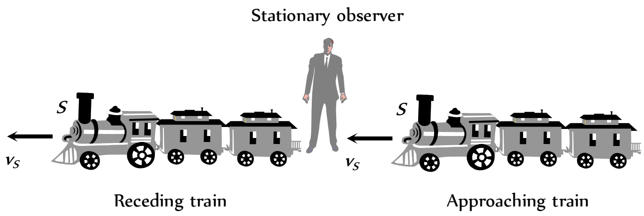
And Young's modules of elasticity $y = \frac{T/A}{\Delta l/l}$

$\Rightarrow T = \frac{Y\Delta lA}{l}$. Hence lowest frequency of vibration

$n = \frac{1}{2l}\sqrt{\frac{T}{m}} = \frac{1}{2l}\sqrt{\frac{y\left(\frac{\Delta l}{l}\right)A}{A\rho}} = \frac{1}{2l}\sqrt{\frac{y\Delta l}{l\rho}}$

$\Rightarrow n = \frac{1}{2 \times 1}\sqrt{\frac{9 \times 10^{10} \times 4.9 \times 10^{-4}}{1 \times 9 \times 10^{3}}} = 35 Hz$

33. (a)



Frequency of sound heard by the man from approaching train

$n_a = n\left(\frac{v}{v - v_s}\right) = 240\left(\frac{320}{320 - 4}\right) = 243\ Hz$

Frequency of sound heard by the man from receding train

$n_r = n\left(\frac{v}{v + v_s}\right) = 240\left(\frac{320}{320 + 4}\right) = 237 Hz$

Hence, number of beats heard by man per sec

$= n_a - n_r = 243 - 237 = 6$

Short trick : Number of beats heard per sec

$= \frac{2nvv_S}{v^2 - v_S^2} = \frac{2nvv_S}{(v - v_S)(v + v_S)} = \frac{2 \times 240 \times 320 \times 4}{(320-4)(320+4)} = 6$

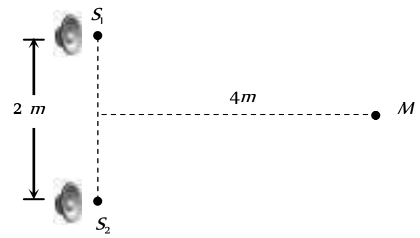
34. (c) Open pipe resonance frequency $f_1 = \frac{2v}{2L}$

Closed pipe resonance frequency $f_2 = \frac{nv}{4L}$

$f_2 = \frac{n}{4} f_1$ (where n is odd and $f_2 > f_1$) $\therefore n = 5$

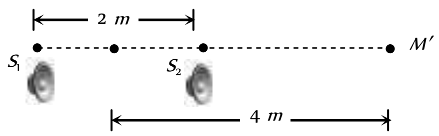
35. (b) Initially $S_1M = S_2M$

$\Rightarrow$ Path Difference $(\Delta x) = S_1M - S_2M = 0$.



Finally when the box is rotated

Path Difference $= S_1M' - S_2M' \Rightarrow \Delta x = 5 - 3 = 2m$



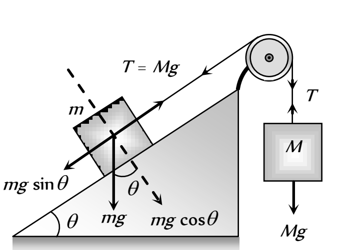
For maxima

Path Difference = (Even multiple) $\frac{\lambda}{2} \Rightarrow \Delta x = (2n)\frac{\lambda}{2}$

For 5 maximum responses

$\Rightarrow 2 = 2(5)\frac{\lambda}{2}$ $\left\{\because \Delta x = (2n)\frac{\lambda}{2}\right\}$ $\Rightarrow \lambda = \frac{2}{5} = 0.4m$.

36. (a) $v = \sqrt{\frac{T}{\mu}}$



For equilibrium $Mg = mg\sin 30 = T$

$\Rightarrow M = \frac{m}{2} \Rightarrow 100 = \sqrt{\frac{Mg}{9.8\times 10^{-3}}} = \sqrt{\frac{M(9.8)}{9.8\times 10^{-3}}}$

$\Rightarrow 100 = \sqrt{M(1000)} \Rightarrow M = 10kg$ and $m = 20kg$

37. (d) For not hearing the echo the time interval between the beats of drum must be equal to time of echo.

$\Rightarrow t_1 = \frac{2d}{v} = \frac{60}{40} = \frac{3}{2}$ ......(i)

and $t_2 = \frac{2(d-90)}{v} = \frac{60}{60} = 1$

$\Rightarrow 2d - 180 = v$ ......(ii)

Form (i), we get $2d = \frac{3}{2}v$. Substituting in (ii), we get

$\Rightarrow \frac{3}{2}v - 180 = v \Rightarrow 180 = \frac{v}{2} \Rightarrow v = 360ms^{-1}$

$\Rightarrow \frac{2(d)}{360} = \frac{3}{2} \Rightarrow d = 270m$.

38. (b) Path difference between the wave reaching at D

$\Delta x = L_2P - L_1P = \sqrt{40^2 + 9^2} - 40 = 41 - 40 = 1m$

For maximum $\Delta x = (2n)\frac{\lambda}{2}$

For first maximum $(n = 1)$ $\Rightarrow 1 = 2(1)\frac{\lambda}{2} \Rightarrow \lambda = 1m$

$\Rightarrow n = \frac{v}{\lambda} = 330Hz$.

39. (a) In a wave equation, x and t must be related in the form $(x - vt)$.

We rewrite the given equations $y = \frac{1}{1+(x-vt)^2}$

For $t = 0$, this becomes $y = \frac{1}{(1+x^2)}$, as given

For $t = 2$, this becomes $y = \frac{1}{[1+(x-2v)^2]} = \frac{1}{[1+(x-1)^2]}$

$\Rightarrow 2v = 1$ or $v = 0.5m/s$.

40. (c) $dB = 10\log_{10}\left(\frac{I}{I_0}\right)$; where $I_0 = 10^{-12}Wm^{-2}$

Since $40 = 10\log_{10}\left(\frac{I_1}{I_0}\right) \Rightarrow \frac{I_1}{I_0} = 10^4$ ....(i)

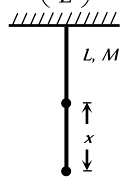
Also $20 = 10\log_{10}\left(\frac{I_2}{I_0}\right) \Rightarrow \frac{I_2}{I_0} = 10^2$ ....(ii)

$\Rightarrow \frac{I_2}{I_1} = 10^{-2} = \frac{r_1^2}{r_2^2} \Rightarrow r_2^2 = 100r_1^2 \Rightarrow r_2 = 10m$

$\{\because r_1 = 1m\}$

41. (b) Velocity $v = \sqrt{\frac{T}{m}}$; where T = weight of part of rope hanging below the point under consideration $= \left(\frac{M}{L}\right)xg$

$\Rightarrow v = \sqrt{\frac{\left(\frac{M}{L}\right)xg}{\left(\frac{M}{L}\right)}} = \sqrt{xg}$.



42. (b) When the piston is moved through a distance of 8.75cm, the path difference produced is $2\times 8.75\,cm = 17.5\,cm$. This must be equal to $\frac{\lambda}{2}$ for maximum to change to minimum. $\therefore$

$\frac{\lambda}{2} = 17.5\ cm \Rightarrow \lambda = 35cm = 0.35m$

So, $v = n\lambda \Rightarrow n = \frac{v}{\lambda} = \frac{350}{0.35} = 1000Hz$

43. (c) Frequency of vib. is stretched string $n = \frac{1}{2(\text{Length})}\sqrt{\frac{T}{m}}$

When the stone is completely immersed in water, length changes but frequency doesn't ($\because$ unison reestablished)

Hence length $\propto \sqrt{T} \Rightarrow \frac{L}{l} = \sqrt{\frac{T_{air}}{T_{water}}} = \sqrt{\frac{V\rho g}{V(\rho-1)g}}$

(Density of stone = ρ and density of water =1)

$\Rightarrow \frac{L}{l} = \sqrt{\frac{\rho}{\rho-1}} \Rightarrow \rho = \frac{L^2}{L^2 - l^2}$

44. (a,c) $y = \cos kx \sin\omega t$ and $y = \cos(kx + \omega t)$ represent wave motion, because they satisfies the wave equation $\frac{\partial^2}{\partial t^2} = v^2\frac{\partial^2 y}{\partial x^2}$.

45. (c) The wave 1 and 3 reach out of phase. Hence resultant phase difference between them is π.

$\therefore$ Resultant amplitude of 1 and 3 = $10 - 7 = 3$ μm

This wave has phase difference of $\frac{\pi}{2}$ with 4 μm

$\therefore$ Resultant amplitude = $\sqrt{3^2 + 4^2} = 5$ μm

46. (b) Let $n-1$ (= 400), n (= 401) and $n+1$ (= 402) be the frequencies of the three waves. If a be the amplitude of each then

$y = a\sin 2\pi(n-1)t,\ \ y = a\sin 2\pi nt$ and

$y_3 = a\sin 2\pi(n+1)t$

Resultant displacement due to all three waves is

$$y = y_1 + y_2 + y_3$$

$$= a\sin 2\pi nt + a[\sin 2\pi(n-1)t + \sin 2\pi(n+1)t]$$

$$= a\sin 2\pi nt + a[2\sin 2\pi nt\cos 2\pi t]$$

$$\left[\text{Using} \sin C + \sin D = 2\sin\frac{C+C}{2}\cos\frac{C-D}{2}\right]$$

$$\Rightarrow y = a(1+\cos 2\pi t)\sin 2\pi nt$$

This is the resultant wave having amplitude $=(1+\cos 2\pi t)$

For maximum amplitude $\cos 2\pi t = 1 \Rightarrow 2\pi t = 2m\pi$ where m = 0, 1, 2, 3, ...

$\Rightarrow t$ = 0, 1, 2, 3 ...

Hence time interval between two successive maximum is 1 *sec*. So beat frequency = 1

Also for minimum amplitude ($2\cos 2\pi t$) = 0

$$\Rightarrow \cos 2\pi t = -\frac{1}{2}$$

$$\Rightarrow 2\pi t = 2m\pi + \frac{2\pi}{3} \Rightarrow t = +\frac{1}{3}$$

$$\Rightarrow t = \frac{1}{3}, \frac{4}{3}, \frac{7}{3}, \frac{10}{3}, ...\quad \text{(for } m = 0, 1, 2, ..)$$

Hence time interval between two successive minima is 1 *sec* so, number of beats per second = 1

Note : PET/PMT Aspirants can remember result only.

47. (d) Because the tuning fork is in resonance with air column in the pipe closed at one end, the frequency is $n = \frac{(2N-1)v}{4l}$ where

N = 1, 2, 3 .... corresponds to different mode of vibration

putting n = 340*Hz*, v = 340 *m/s*, the length of air column in the pipe can be

$$l = \frac{(2N-1)340}{4\times 340} = \frac{(2N-1)}{4}m = \frac{(2N-1)\times 100}{4}cm$$

For N = 1, 2, 3, ... we get l = 25 *cm*, 75 *cm*, 125 *cm* ...

As the tube is only 120 *cm* long, length of air column after water is poured in it may be 25 *cm* or 75 *cm* only, 125 *cm* is not possible, the corresponding length of water column in the tube will be (120 – 25) *cm* = 95 *cm* or (120 – 75) *cm* = 45 *cm*.

Thus minimum length of water column is 45 *cm*.

48. (c) Critical hearing frequency for a person is 20,000*Hz*.

If a closed pipe vibration in N^{th} mode then frequency of vibration $n = \frac{(2N-1)v}{4l} = (2N-1)n_1$

(where n_1 = fundamental frequency of vibration)

Hence 20,000 $=(2N-1)\times 1500 \Rightarrow N = 7.1 \approx 7$

Also, in closed pipe

Number of over tones = (No. of mode of vibration) –1

= 7 – 1 = 6.

49. (c) Frequency of vibration of string is given by

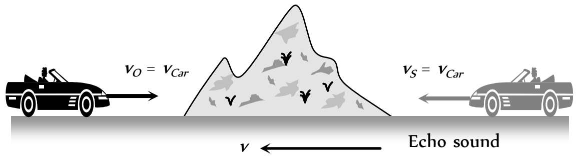
$$n = \frac{p}{2l}\sqrt{\frac{T}{m}} \Rightarrow p\sqrt{T} = \text{constant} \Rightarrow \frac{p_1}{p_2} = \sqrt{\frac{T_2}{T_1}}$$

Hence $\frac{4}{6} = \sqrt{\frac{T_2}{(50+15)gm\text{-}force}} \Rightarrow T_2 = 28.8\ gm\text{-}f$

Hence weight removed from the pan

$= T_1 - T_2 = 65 - 28.8 = 3.62$ *gm-force* = 0.036 *kg-f*.

50. (c) Frequency of reflected sound heard by driver $n' = n\left(\frac{v+v_O}{v-v_S}\right)$



It is given that $n' = 2n$

Hence, $2n = n\left(\frac{v+v_{car}}{v-v_{car}}\right) \Rightarrow v_{car} = v/3.$

51. (c) Suppose d = distance of epicenter of Earth quake from point of observation

v_s = Speed of *S*-wave and v_p = Speed of *P*-wave then $d = v_P t_P = v_S t_S$ or $8\,t_P = 4.5\,t_S$

$$\Rightarrow t_P = \frac{45}{8}t_S,\ \text{given that } t_S - t_P = 240$$

$$\Rightarrow t_S - \frac{4.5}{8}t_S = 240 \Rightarrow t_S = \frac{240\times 8}{3.5} = 548.5\,s$$

$$\therefore d = v_S t_S = 4.5\times 548.5 = 2468.6 \approx 2500\,km$$

Graphical Questions

1. (c) Speed = $n\lambda = n(4ab) = 4n \times ab$ $\left(\text{As}\, ab = \frac{\lambda}{4}\right)$

Path difference between b and e is $\frac{3\lambda}{4}$

So the phase difference = $\frac{2\pi}{\lambda}$. Path difference

$= \frac{2\pi}{\lambda} \cdot \frac{3\lambda}{4} = \frac{3\pi}{2}$

2. (b) After 2 sec the pulses will overlap completely. The string becomes straight and therefore does not have any potential energy and its entire energy must be kinetic.

3. (a) When the train is approaching the stationary observer frequency heard by the observer $n' = \frac{v + v_0}{v} n$

when the train is moving away from the observer then frequency heard by the observer $n'' = \frac{v - v_0}{v} n$

it is clear that n' and n'' are constant and independent of time. Also and $n' > n''$.

4. (b) Equation of *A, B, C* and *D* are

$y_A = A \sin \omega t$, $y_B = A \sin(\omega t + \pi/2)$

$y_C = A \sin(\omega t - \pi/2)$, $y_D = A \sin(\omega t - \pi)$

It is clear that wave C lags behind by a phase angle of $\pi/2$ and the wave B is ahead by a phase angle at $\pi/2$.

5. (d) Points B and F are in same phase ass they are λ distance apart.

6. (c) The particle velocity is maximum at B and is given by $\frac{dy}{dt} = (v_p)_{max} = \omega A$

Also wave velocity is $\frac{dx}{dt} = v = \frac{\omega}{k}$

So slope $\frac{dy}{dx} = \frac{(v_p)_{max}}{v} = kA$

7. (d) When pulse is reflected from a rigid support, the pulse is inverted both lengthwise and sidewise

8. (d) Given equation $y = y_0 \sin(\omega t - \phi)$

at $t = 0$, $y = -y_0 \sin\phi$

this is the case with curve marked *D*.

9. (c) We know frequency $n = \frac{p}{2l}\sqrt{\frac{T}{\pi r^2 \rho}} \Rightarrow n \propto \frac{1}{\sqrt{\rho}}$

i.e., graph between n and $\sqrt{\rho}$ will be hyperbola.

10. (c) Energy density (E) $= \frac{I}{v} = 2\pi^2 \rho n^2 A^2$

$v_{max} = \omega A = 2\pi n A \Rightarrow E \propto (v_{max})^2$

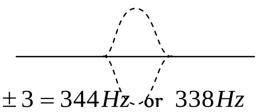
i.e., graph between E and v_{max} will be a parabola symmetrical about E axis.

11. (c) Here $A = 0.05 m$, $\frac{5\lambda}{2} = 0.025 \Rightarrow \lambda = 0.1 m$

Now standard equation of wave

$y = A \sin \frac{2\pi}{\lambda}(vt - x) \Rightarrow y = 0.05 \sin 2\pi(33t - 10x)$

12. (c) After two seconds each wave travel a distance of 2.5 × 2 = 5 *cm i.e.* the two pulses will meet in mutually opposite phase and hence the amplitude of resultant will be zero.



13. (c) $n_Q = 341 \pm 3 = 344 Hz$ or $338 Hz$

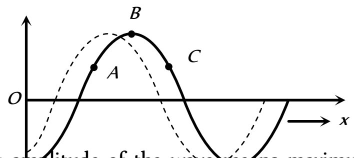
on waxing *Q*, the number of beats decreases hence $n_Q = 344 Hz$

14. (b) For observer approaching a stationary source

$n' = \frac{v + v_0}{v} . n$ and given $v_0 = at \Rightarrow n' = \left(\frac{an}{v}\right) t + n$

this is the equation of straight line with positive intercept n and positive slope $\left(\frac{n}{v}\right)$.

15. (b,d) Since A is moving upwards, therefore, after an elemental time interval the wave will be as shown dotted in following fig. It means, the wave is travelling leftward. Therefore, (a) is wrong.



Displacement amplitude of the wave means maximum possible displacement of medium particles due to propagation of the wave, which is equal to the displacement at B at the instant shown in fig. Hence (b) is correct.

From figure, it is clear that C is moving downwards at this instant. Hence (c) is wrong.

The phase difference between two points will be equal to $\frac{\pi}{2}$ if distance between them is equal to $\frac{\lambda}{4}$. Between A and C, the distance is less than $\frac{\lambda}{2}$. It may be equal to $\frac{\lambda}{4}$. Hence, phase difference between these two points may be equal to $\frac{\pi}{2}$.

16. (d) Intensity $\propto a^2\omega^2$

here $\frac{a_A}{a_B} = \frac{2}{1}$ and $\frac{\omega_A}{\omega_B} = \frac{1}{2} \Rightarrow \frac{I_A}{I_B} = \left(\frac{2}{1}\right)^2 \times \left(\frac{1}{2}\right)^2 = \frac{1}{1}$

17. (b) At $t = 0$ and $x = \frac{\pi}{2k}$. The displacement

$y = a_0 \sin\left(\omega x_0 - k \times \frac{\pi}{2x}\right) = -a_0 \sin\frac{\pi}{2} = -a_0$

from graph. Point of maximum displacement (a) in negative direction is *Q*.

18. (d) Particle velocity $(v_p) = -v \times$ Slope of the graph at that point

At point 1 : Slope of the curve is positive, hence particle velocity is negative or downward (↓)

At point 2 : Slope negative, hence particle velocity is positive or upwards (↑)

At point 3 : Again slope of the curve is positive, hence particle velocity is negative or downward (↓)

Assertion and Reason

1. (a) Sound waves require material medium to travel. As there is no atmosphere (vacuum) on the surface of moon, therefore the sound waves cannot reach from one person to another.

2. (b) Transverse waves travel in the form of crests and troughs involving change in shape of the medium. As liquids and gases do not possess the elasticity of shape, therefore, transverse waves cannot be produced in liquid and gases. Also light wave is one example of transverse wave.

3. (b) Sound waves cannot propagate through vacuum because sound waves are mechanical waves. Light waves can propagate through vacuum because light waves are electromagnetic waves. Since sound waves are longitudinal waves, the particles moves in the direction of propagation, therefore these waves cannot be polarised.

4. (c) Velocity of sound in gas medium is $v = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{\gamma p}{\rho}}$

γ is ratio of its principal heat capacities (C_P / C_v). For moist air ρ is less than that for dry air and γ is slightly greater.

∴ velocity of sound increases with increase in humidity.

5. (c) Ocean waves are transverse waves travelling in concentric circles of ever increasing radius. When they hit the shore, their radius of curvature is so large that they can be treated as plane waves. Hence they hit the shore nearly normal to the shore.

6. (a) A compression is a region of medium in which particles come closer *i.e.*, distance between the particles becomes less than the normal distance between them. Thus there is a temporary decrease in volume and a consequent increase in density of medium. Similarly in rarefaction, particle get farther apart and a consequent decrease in density.

7. (e) Since transverse wave can propagate through medium which posses elasticity of shape. Air posses only volume elasticity therefore transverse wave cannot propagate through air.

8. (c) The velocity of sound in a gas is directly proportional to the square root of its absolute temperature (as $v = \sqrt{\frac{\gamma RT}{M}}$). Since temperature of a hot day is more than cold winter day, therefore sound would travel faster on a hot summer day than on a cold winter day.

9. (c) According to Laplace, the changes in pressure and volume of a gas, when sound waves propagated through it, are not isothermal, but adiabatic. A gas is a bad conductor of heat. It does not allow the free exchange of heat between compressed layer, rarefied layer and surrounding.

10. (e) The velocity of every oscillating particle of the medium is different of its different positions in one oscillation but the velocity of wave motion is always constant *i.e.*, particle velocity vary with respect to time, while the wave velocity is independent of time.

Also for wave propagation medium must have the properties of elasticity and inertia.

11. (d) A bucket can be treated as a pipe closed at one end. The frequency of the note produced $= \frac{v}{4L}$, here L equal to depth of water level from the open end. As the bucket is filled with water L decreases, hence frequency increases. Therefore, frequency or pitch of sound produced goes on increasing.

Also, the frequency of woman voice is usually higher than that of man.

12. (b) A tuning fork is made of a material for which elasticity does not change. Since the alloy of nickel, steel and chromium (elinvar) has constant elasticity, therefore it is used for the preparation of tuning fork.

13. (e) Speed of sound in cases in independent of pressure because $v = \sqrt{\frac{\gamma P}{\rho}}$. At constant temperature, if P changes then ρ also changes in such a way that the ratio $\frac{P}{\rho}$ remains constant hence there is no effect of the pressure change on the speed of sound.

14. (a) For the propagation of transverse waves, medium must have the property of rigidity. Because gases have no rigidity, (they do not posses shear elasticity), hence transverse waves cannot be produced is gases. On the other hand, the solids possess both volume and shear elasticity and likewise both the longitudinal and transverse waves can be transmitted through them.

15. (c) Velocity of sound in a gas $v = \sqrt{\frac{\gamma P}{\rho}}$. For monoatomic gas $\gamma = 1.67$; for diatomic $\gamma = 1.40$. Therefore v is larger in case of monoatomic gas compared to its values in diatomic gas.

16. (a) The velocity of sound in solid is given by, $v = \sqrt{E/\rho}$.

Though ρ is large for solids, but their coefficient of elasticity E is much larger (compared to that of liquids and gases). That is why v is maximum in case of solid.

17. (d) When moisture is present in air, the density of air decreases. It is because the density of water vapours is less than that of dry air. The velocity of sound is inversely proportional to the square root of density, hence sound travel faster in moist air than in the dry air. Therefore, on a rainy day sound travels faster than on a dry day.

18. (b) According to the property of persistence of hearing, the impression of a sound heard persists on our mind for $\frac{1}{10}$ *sec*.

Therefore, number of beats per *sec* should be less than 10. Hence difference in frequencies of two sources must be less than 10.

19. (b) Sound produced by an open organ pipe is richer because it contains all harmonics and frequency of fundamental note in an open organ pipe is twice the fundamental frequency in a closed organ pipe of same length.

Reason is also correct, but it is not explaining the assertion.

20. (a) Since the initial phase difference between the two waves coming from different violins changes, therefore, the waves produced by two different violins does not interfere because two waves interfere only when the phase difference between them remain constant throughout.

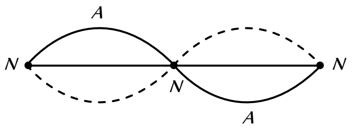
21. (d) As emission of light from atom is a random and rapid phenomenon. The phase at a point due to two independent light source will change rapidly and randomly. Therefore,

instead of beats, we shall get uniform intensity. However if light sources are LASER beams of nearly equal frequencies, it may possible to observe the phenomenon of beats in light.

22. (c) The person will hear the loud sound at nodes than at antinodes. We know that at anti-nodes the displacement is maximum and pressure change is minimum while at nodes the displacement is zero and pressure change is maximum. The sound is heard due to variation of pressure.

Also in stationary waves particles in two different segment vibrates in opposite phase.

23. (a) Stationary wave



A node is a place of zero amplitude and an antinode is a place of maximum amplitude.

24. (c) The principle of superposition does not state that the frequencies of the oscillation should be nearly equal. For beats to be heard the condition is that difference in frequencies of the two oscillations should not be more than 10 times per seconds for a normal human ear to recognise it. Hence we cannot hear beats in the case of two tuning forks vibrating at frequencies 256 *Hz* and 512 *Hz* respectively.

25. (a) The fundamental frequency of an open organ pipe is $n = \frac{v}{2l}$.

As temperature increases, both v and l increase but v increases more rapidly than l. Hence, the fundamental frequency increases as the temperature increases.

26. (b) Since, velocity of sound,

$$v = \sqrt{\frac{E}{\rho}}$$

As, the elasticity of solid is large than that of gases. Hence, it is obvious that velocity of sound is greater in solids than in gases.

27. (d)

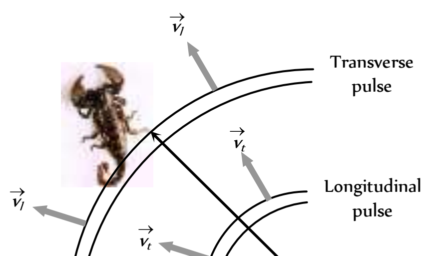
28. (b) Velocity of wave $= \frac{\text{Distance travelled by wave } (\lambda)}{\text{Time period } (T)}$

Wavelength is also defined as the distance between two nearest points in phase.

29. (c) Speed of light is greater than that of sound, hence flash of lightening is seen before the sound of thunder.

30. (a) A beetle motion sends fast longitudinal pulses and slower transverse waves along the sends surface. The sand scorpion first intercept the longitudinal pulses and learns the direction of the beetle; it is in the direction of which ever leg is disturbed earliest by the pulses. The scorpion then senses the time interval (Δt) between that first interception and the interception of slower transverse waves and uses it to determine the distance of the beetle. The distance is given by

$$\Delta t = \frac{d}{v_t} - \frac{d}{v_l}$$

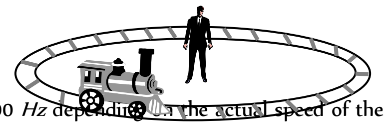


31. (e)

Waves and Sound

SET Self Evaluation Test -17

1. An engine is moving on a circular track with a constant speed. It is blowing a whistle of frequency 500 *Hz*. The frequency received by an observer standing stationary at the centre of the track is



(a) 500 *Hz*
(b) More than 500 *Hz*
(c) Less than 500 *Hz*
(d) More or less than 500 *Hz* depending on the actual speed of the engine

2. In a resonance tube, the first resonance is obtained when the level of water in the tube is at 16*cm* from the open end. Neglecting end correction, the next resonance will be obtained when the level of water from the open end is

(a) 24*cm* (b) 32*cm*
(c) 48*cm* (d) 64*cm*

3. To raise the pitch of a stringed musical instrument the player can

(a) Loosen the string (b) Tighten the string
(c) Shorten the string (d) Both (b) and (c)

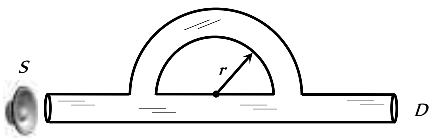
4. A wave travelling along positive *x*-axis is given by $y = A\sin(\omega t - kx)$. If it is reflected from rigid boundary such that 80% amplitude is reflected, then equation of reflected wave is

(a) $y = A\sin(\omega t + kx)$ (b) $y = -0.8A\sin(\omega t + kx)$
(c) $y = 0.8A\sin(\omega t + kx)$ (d) $y = A\sin(\omega t + 0.8\,kx)$

5. The frequency of the first harmonic of a string stretched between two points is 100 *Hz*. The frequency of the third overtone is

(a) 200 *Hz* (b) 300 *Hz*
(c) 400 *Hz* (d) 600 *Hz*

6. A sound wave of wavelength 32 *cm* enters the tube at *S* as shown in the figure. Then the smallest radius *r* so that a minimum of sound is heard at detector *D* is



(a) 7*cm* (b) [illegible]
(c) 21*cm* (d) 28 *cm*

7. A stretched wire of length 110 *cm* is divided into three segments whose frequencies are in ratio 1 : 2 : 3. Their lengths must be

(a) 20 *cm* ; 30 *cm* ; 60 *cm*
(b) 60 *cm* ; 30 *cm* ; 20 *cm*
(c) 60 *cm* ; 20 *cm* ; 30 *cm*
(d) 30 *cm* ; 60 *cm* ; 20 *cm*

8. Unlike a laboratory sonometer, a stringed instrument is seldom plucked in the middle. Supposing a sitar string is plucked at about $\frac{1}{4}$ *th* of its length from the end. The most prominent harmonic would be

(a) Eighth (b) Fourth
(c) Third (d) Second

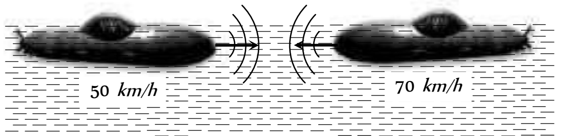
9. If n_1, n_2, n_3......... are the frequencies of segments of a stretched string, the frequency *n* of the string is given by

(a) $n = n_1 + n_2 + n_3 + ...$ (b) $n = \sqrt{n_1 \times n_2 \times n_3 \times ....}$
(c) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + ...$ (d) None of these

10. The equation of stationary wave along a stretched string is given by $y = 5\sin\frac{\pi x}{3}\cos 40\pi t$ where *x* and *y* are in centimetre and *t* in second. The separation between two adjacent nodes is :

(a) 6 *cm* (b) 4 *cm*
(c) 3 *cm* (d) 1.5 *cm*

11. An Indian submarine and an enemy submarine move towards each other during maneuvers in motionless water in the Indian ocean. The Indian submarine moves at 50 *km/h*, and the enemy submarine at 70 *km/h*. The Indian sub sends out a sonar signal (sound wave in water) at 1000 *Hz*. Sonar waves travel at 5500 *km/h*. What is the frequency detected by the Indian submarine



(a) 1.02 *kHz* (b) 2 *kHz*
(c) 2.5 *kHz* (d) 4.7 *kHz*

12. Two trains, one coming towards and another going away from an observer both at 4 *m/s* produce whistle simultaneously of frequency 300 *Hz*. Find the number of beats produced

(a) 5 (b) 6
(c) 7 (d) 12

13. A source of sound emits $200\pi W$ power which is uniformly distributed over a sphere of 10 *m* radius. What is the loudness of sound on the surface of a sphere

(a) 200 *dB* (b) 200 π *dB*
(c) 120 *dB* (d) 120 π *dB*

14. When a wave travels in a medium, the particle displacement is given by $y(x, t) = 0.03\sin\pi(2t - 0.01x)$ where *y* and *x* are meters and *t* in seconds. The phase difference, at a given instant of time between two particle 25 *m*. apart in the medium, is

(a) $\frac{\pi}{8}$ (b) $\frac{\pi}{4}$

(c) $\frac{\pi}{2}$ (d) π

15. A sine wave has an amplitude A and wavelength λ. Let V be the wave velocity and v be the maximum velocity of a particle in the medium. Then **[KCET 2001]**

(a) $V = v \text{ if } \lambda = \frac{3A}{2\pi}$ (b) $V = v \text{ if } A = 2\pi\lambda$

(c) $V = v \text{ if } A = \frac{\lambda}{2\pi}$ (d) V can not be equal to v

16. A pipe open at both ends produces a note of frequency f_1. When the pipe is kept with $\frac{3}{4}$ *th* of its length it water, it produced a note of frequency f_2. The ratio $\frac{f_1}{f_2}$ is

[KCET 1998]

(a) $\frac{3}{4}$ (b) $\frac{4}{3}$

(c) $\frac{1}{2}$ (d) 2

17. A man fires a bullet standing between two cliffs. First echo is heard after 3 seconds and second echo is heard after 5 seconds. If the velocity of sound is 330 *m/s*, then the distance between the cliffs is

(a) 1650 *m* (b) 1320 *m*

(c) 990 *m* (d) 660 *m*

18. The equation for spherical progressive wave is (where r is the distance from the source) **[CPMT 2002]**

(a) $y = a\sin(\omega t - kx)$ (b) $y = \frac{a}{\sqrt{r}}\sin(\omega t - kx)$

(c) $y = \frac{a}{2}\sin(\omega t - kx)$ (d) $y = \frac{a}{r}\sin(\omega t - kx)$

19. A tuning fork A produces 4 *beats/sec* with another tuning fork B of frequency 320 *Hz*. On filing the fork A, 4 *beats/sec* are again heard. The frequency of fork A, after filing is

[KCET (Engg./Med.) 1999]

(a) 324 *Hz* (b) 320 *Hz*

(c) 316 *Hz* (d) 314 *Hz*

20. The number of beats produced per second by two vibrations: $x_1 = x_0 \sin 646\pi t$ and $x_2 = x_0 \sin 652\pi t$ is

[UPSEAT 2005]

(a) 2 (b) 3

(c) 4 (d) 6

21. 50 tuning forks are arranged in increasing order of their frequencies such that each gives 4 beats/sec with its previous tuning fork. If the frequency of the last fork is octave of the first, then the frequency of the first tuning fork is **[DPMT 2005]**

(a) 200 *Hz* (b) 204 *Hz*

(c) 196 *Hz* (d) None of these

22. The fundamental frequency of a closed pipe is 220 *Hz*. If $\frac{1}{4}$ of the pipe is filled with water, the frequency of the first overtone of the pipe now is

[EAMCET (Med.) 2000]

(a) 220 *Hz* (b) 440 *Hz*

(c) 880 *Hz* (d) 1760 *Hz*

23. A glass tube 1.5 *m* long and open at both ends, is immersed vertically in a water tank completely. A tuning fork of 660 *Hz* is vibrated and kept at the upper end of the tube and the tube is gradually raised out of water. The total number of resonances heard before the tube comes out of water, taking velocity of sound air 330 *m/sec* is

[EAMCET (Engg.) 1999]

(a) 12 **[AFMC 2000]** (b) 6

(c) 8 (d) 4

24. In the 5^{th} overtone of an open organ pipe, these are (N-stands for nodes and A-for antinodes)

(a) 2N, 3A (b) 3N, 4A

(c) 4N, 5A (d) 5N, 4A

25. An engine approaches a hill with a constant speed. When it is at a distance of 0.9 *km* it blows a whistle, whose echo is heard by the driver after 5 *sec*. If speed of sound in air is 330 *m/s*, the speed of engine is

(a) 10 *m/s* (b) 20 *m/s*

(c) 30 *m/s* (d) 40 *m/s*

Answers and Solutions

(SET -17)

1. (a) Since there is no relative motion between the source and listener, So apparent frequency equals original frequency.

2. (c) Next resonance length after the fundamental is $3l_1 = 3 \times 16 = 48 cm$.

3. (d) Higher pitch means higher frequency

Frequency of a stringed system is given by

$$n = \frac{p}{2l}\sqrt{\frac{T}{m}} \Rightarrow n \propto \frac{\sqrt{T}}{l}$$

Hence, to get higher frequency (higher pitch) tension should be increase and length should be shorten.

4. (b) On getting reflected from a rigid boundary the wave suffers

Hence if $y_{incident} = A\sin(\omega t - kx)$

then $y_{reflected} = (0.8A)\ \sin\{\omega t - k(-x) + \pi\}$

$= -0.8A\sin(\omega t + kx)$ an additional phase change of π.

5. (c) Third overtone is the fourth harmonic i.e., $n_4 = 4n_1 = 4 \times 100 = 400$ Hz

6. (b) Path difference $(\pi r - 2r) = \frac{\lambda}{2} = \frac{32}{2} = 16$,

$$r = \frac{16}{\pi - 2} = 14 cm.$$

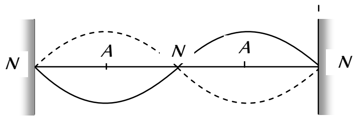
7. (b) $l_1 + l_2 + l_3 = 110\ cm$ and $n_1 l_1 = n_2 l_2 = n_3 l_3$

$n_1 : n_2 : n_3 :: 1 : 2 : 3$

$\because \frac{n_1}{n_2} = \frac{1}{2} = \frac{l_2}{l_1} \Rightarrow l_2 = \frac{l_1}{2}$ and $\frac{n_1}{n_3} = \frac{1}{3} = \frac{l_3}{l_1} \Rightarrow l_3 = \frac{l_1}{3}$

$\therefore l_1 + \frac{l_1}{2} + \frac{l_1}{3} = 110$ so $l_1 = 60cm, l_2 = 30cm, l_3 = 20cm$.

8. (d) When plucked at one fourth it gives two loops, and hence 2nd harmonic is produced.



9. (c) For a vibrating string

$n_1 l_1 = n_2 l_2 = n_3 l_3 ..... =$ constant = k (say) = nl

Also $l_1 + l_2 + l_3 + l_4 + ... = 1$

$$\frac{k}{n_1} + \frac{k}{n_2} + \frac{k}{n_3} + \frac{k}{n_4} + ... = \frac{k}{n} \Rightarrow \frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3} + ...$$

10. (c) Given $y = 5\sin\frac{\pi x}{3}\cos 40\pi t$

Comparing with $y = 2a\cos\frac{2\pi vt}{\lambda}\sin\frac{2\pi x}{\lambda} \Rightarrow \lambda = 6\ cm.$

$\therefore$ The separation between adjacent nodes $= \frac{\lambda}{2} = 3\ cm.$

11. (a) Frequency detected by Indian submarine

$$n' = n\left[\frac{v + v_{sub}}{v - v_{sub}}\right] = 1000\left[\frac{5500 + 50}{5500 - 50}\right] \approx 1.02 kHz.$$

12. (c) $\Delta n = \left[\frac{v}{v - u} - \frac{v}{v + u}\right] n = \frac{2uv}{v^2 - u^2} n$

$$= \frac{2 \times 4 \times 332}{(332)^2 - (4)^2} \times 300 \approx 7$$

13. (c) Intensity $= \frac{\text{power}}{\text{area}} = \frac{200\pi}{2\pi \times 10^{-2}} = 1\ Watt/m$

Now $L = 10\log_{10}\frac{I}{I_0} = 10\log_{10}\left(\frac{1}{10^{-12}}\right)$

$= 10\log_{10} 10^{12} = 120\ dB$

14. (b) $y(x, t) = 0.03\sin\pi(2t - 0.01x) = 0.03\sin(2\pi t - 0.01\pi x)$

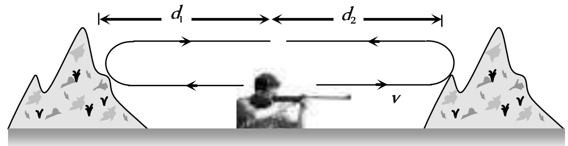
$$k = 0.01\pi = \frac{2\pi}{\lambda} \Rightarrow \Delta\phi = \frac{2\pi}{\lambda}\Delta x = 0.01\pi \times 25 = \frac{\pi}{4}$$

15. (c) Let wave velocity (V) = maximum particle velocity $\Rightarrow$ $n\lambda = \omega A = 2\pi\ nA \Rightarrow A = \frac{\lambda}{2\pi}$

16. c) For open pipe $f_1 = \frac{v}{2l}$ and for closed pipe

$$f_2 = \frac{v}{4 \times \left(\frac{l}{4}\right)} = \frac{v}{l} = 2f_1 \Rightarrow \frac{f_1}{f_2} = \frac{1}{2}$$

17. (b)



$$2(d_1 + d_2) = v(t_1 + t_2) \Rightarrow d_1 + d_2 = \frac{330 \times (3 + 5)}{2} = 1320\ m$$

18. (d) For spherical wave intensity $(I) \propto \frac{1}{(\text{Distancer})^2}$

also $I \propto a^2 \Rightarrow a \propto \frac{1}{r}$. Hence equation of a cylindrical wave is $y = \frac{1}{r}\sin(\omega t - kx)$

19. (a) n_A = ?, n_B = Known frequency = 320 *Hz*

x = 4 *bps*, which remains same after filing.

Unknown fork *A* is filed so $n_A\uparrow$

Hence $n_A\uparrow - n_B = x$ ⟶ Wrong

$n_B - n_A\uparrow = x$ ⟶ Correct

$\Rightarrow$ $n_A = n_B - x = 320 - 4 = 316$ *Hz.*

This is the frequency before filing.

But in question frequency after filing is asked which must be greater than 316 *Hz*, such that it produces 4 *beats per sec.* Hence it is 324 *Hz*.

20. (b) From the given equation $\omega_1 = 2\pi n_1 = 646\pi \Rightarrow n_1 = 323$

and $\omega_2 = 2\pi n_2 = 652\pi \Rightarrow n_2 = 326$

Hence, beat frequency $= 326 - 323 = 3$

21. (c) Frequencies of tuning forks is given by

$$n_{\text{last}} = n_{\text{first}} + (N - 1)x$$

$$2n = n + (50 - 1) \times 4 \Rightarrow n = 196 Hz.$$

***

22. (c) Fundamental frequency of closed pipe

$$n = \frac{v}{4l} = 220\ Hz \Rightarrow v = 220 \times 4l$$

If $\frac{1}{4}$ of the pipe is filled with water then remaining length of air column is $\frac{3l}{4}$

Now fundamental frequency = $\frac{v}{4\left(\frac{3l}{4}\right)} = \frac{v}{3l}$ and

First overtone = $3\times$ fundamental frequency

$$= \frac{3v}{3l} = \frac{v}{l} = \frac{220 \times 4l}{l} = 880\ Hz.$$

23. (b) Suppose N resonance occurred before tube coming out.

Hence by using $l = \frac{(2N-1)v}{4n}$

$$\Rightarrow 1.5 = \frac{(2N-1)\times 330}{4 \times 660} \Rightarrow N \approx 6.$$

24. (c) In open organ pipe 5^{th} overtone corresponds to 4^{th} harmonic mode.

Also in open pipe, Number of nodes = Order of mode of vibration and number of antinodes = (Number of nodes + 1). Here number of nodes = 4, Number of antinodes = 4 + 1 =5.

25. (c) If the speed of engine is v, the distance traveled by engine in 5 *sec* will be $5v$, and hence the distance traveled by sound in reaching the hill and coming back to the moving driver = 900 + (900 – $5v$) = 1800 – $5v$

So the time interval between original sound and it's echo $t = \frac{(1800 - 5v)}{330} = 5 \Rightarrow v = 30\ m/s.$

Chapter

19

Current Electricity

Electric Current

(1) The time rate of flow of charge through any cross-section is called current. $i = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$. If flow is uniform then $i = \frac{Q}{t}$. Current is a scalar quantity. It's S.I. unit is *ampere* (*A*) and C.G.S. unit is *emu* and is called *biot* (*Bi*), or *ab ampere*. 1*A* = (1/10) *Bi* (*ab amp.*)

(2) *Ampere* of current means the flow of 6.25 × 10^{18} *electrons/sec* through any cross-section of the conductor.

(3) The conventional direction of current is taken to be the direction of flow of positive charge, *i.e.* field and is opposite to th gative cha

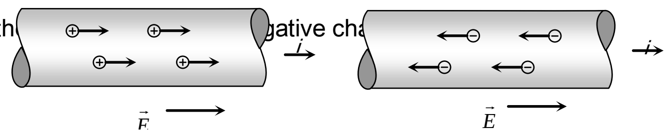


Fig. 19.1

(4) The net charge in a current carrying conductor is zero.

(5) For a given conductor current does not change with change in cross-sectional area. In the following figure $i_1 = i_2 = i_3$

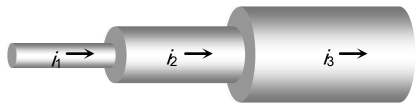


Fig. 19.2

(6) **Current due to translatory motion of charge :** If n particle each having a charge q, pass through a given area in time t then $\boldsymbol{i = \frac{nq}{t}}$

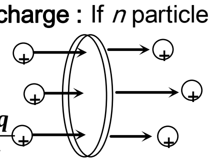
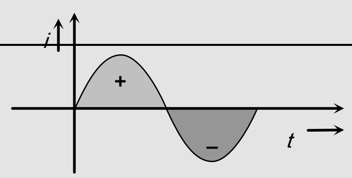
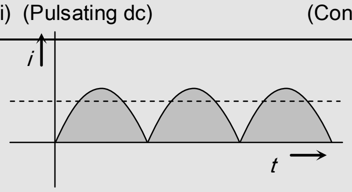
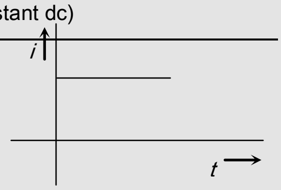


Fig. 19.3

If n particles each having a charge q pass per second per unit area, the current associated with cross-sectional area A is $\boldsymbol{i = nqA}$

If there are n particle per unit volume each having a charge q and moving with velocity v, the current thorough, cross section A is $\boldsymbol{i = nqvA}$

Table : 19.1 Types of current

Alternating current (ac)	Direct current (dc)
(i) 	(i) (Pulsating dc)  (Constant dc) 

Magnitude and direction both varies with time ac → Rectifier → dc	dc → Inverter → ac
(ii) Shows heating effect only	(ii) Shows heating effect, chemical effect and magnetic effect of current
(iii) It's symbol is —(~)—	(iii) It's symbol is $+\|\|-$

(7) **Current due to rotatory motion of charge** : If a point charge *q* is moving in a circle of radius *r* with speed *v* (frequency ν, angular speed ω and time period *T*) then corresponding current $i = q\nu = \frac{q}{T} = \frac{qv}{2\pi r} = \frac{q\omega}{2\pi}$

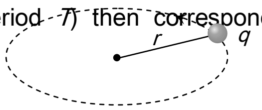


Fig. 19.4

(8) **Current carriers :** The charged particles whose flow in a definite direction constitutes the electric current are called current carriers. In different situation current carriers are different.

(i) Solids : In solid conductors like metals current carriers are free electrons.

(ii) Liquids : In liquids current carriers are positive and negative ions.

(iii) Gases : In gases current carriers are positive ions and free electrons.

(iv) Semi conductor : In semi conductors current carriers are holes and free electrons.

Current Density (*J*)

Current density at any point inside a conductor is defined as a vector having magnitude equal to current per unit area surrounding that point. Remember area is normal to the direction of charge flow (or current passes) through that point.

(1) Current density at point *P* is given by $\vec{J} = \frac{di}{dA}\vec{n}$

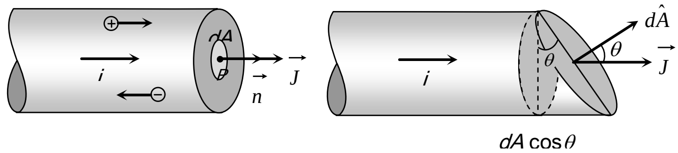


Fig. 19.5

(2) If the cross-sectional area is not normal to the current, but makes an angle θ with the direction of current then

$$J = \frac{di}{dA\cos\theta} \Rightarrow di = JdA\cos\theta = \vec{J}.\vec{dA} \Rightarrow i = \int \vec{J}\cdot\vec{dA}$$

(3) If current density $\vec{J}$ is uniform for a normal cross-section $\vec{A}$ then $J = \frac{i}{A}$

(4) Current density $\vec{J}$ is a vector quantity. It's direction is same as that of $\vec{E}$. It's S.I. unit is *amp/m*^{2} and dimension $[L^{-2}A]$.

(5) In case of uniform flow of charge through a cross-section normal to it as $i = nqvA \Rightarrow J = \frac{i}{A} = nqv$.

(6) Current density relates with electric field as $\vec{J} = \sigma\vec{E} = \frac{\vec{E}}{\rho}$; where σ = conductivity and ρ = resistivity or specific resistance of substance.

Drift Velocity

Drift velocity is the average uniform velocity acquired by free electrons inside a metal by the application of an electric field which is responsible for current through it. Drift velocity is very small it is of the order of 10^{-4} *m/s* as compared to thermal speed ($\simeq 10^5\ m/s$) of electrons at room temperature.

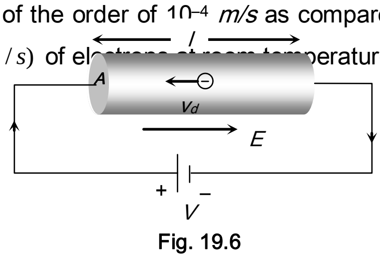


Fig. 19.6

If suppose for a conductor

n = Number of electron per unit volume of the conductor

A = Area of cross-section

V = potential difference across the conductor

E = electric field inside the conductor

i = current, J = current density, ρ = specific resistance, σ = conductivity $\left(\sigma = \frac{1}{\rho}\right)$ then current relates with drift velocity as $\boldsymbol{i = neAv_d}$ we can also write

$$\boldsymbol{v_d = \frac{i}{neA} = \frac{J}{ne} = \frac{\sigma E}{ne} = \frac{E}{\rho ne} = \frac{V}{\rho l n e}}.$$

(1) The direction of drift velocity for electron in a metal is opposite to that of applied electric field (*i.e.* current density $\vec{J}$).

$v_d \propto E$ *i.e.*, greater the electric field, larger will be the drift velocity.

(2) When a steady current flows through a conductor of non-uniform cross-section drift velocity varies inversely with area of cross-section $\left(v_d \propto \frac{1}{A}\right)$

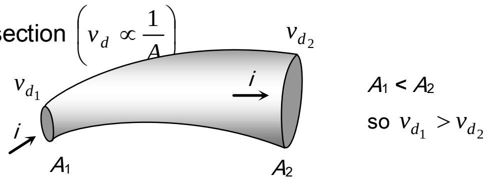


Fig. 19.7

(3) If diameter (d) of a conductor is doubled, then drift velocity of electrons inside it will not change.

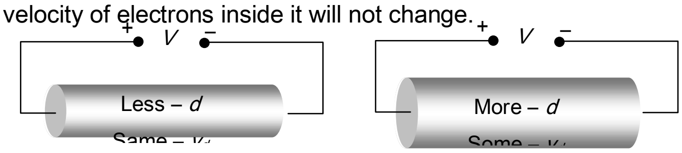


Fig. 19.8

(1) **Relaxation time (τ) :** The time interval between two successive collisions of electrons with the positive ions in the metallic lattice is defined as relaxation time $\tau = \frac{\text{mean free path}}{\text{r.m.s. velocity of electrons}} = \frac{\lambda}{v_{rms}}$. With rise in temperature v_{rms} increases consequently τ decreases.

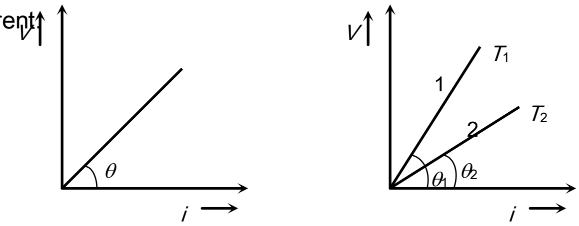
(2) **Mobility :** Drift velocity per unit electric field is called mobility of electron *i.e.* $\mu = \frac{v_d}{E}$. It's unit is $\frac{m^2}{volt - \sec}$.

Ohm's Law

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remains some, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.* $\boldsymbol{i \propto V} \Rightarrow \boldsymbol{V = iR}$ where R is a proportionality constant, known as electric resistance.

(1) Ohm's law is not a universal law, the substances, which obey ohm's law are known as ohmic substance.

(2) Graph between V and i for a metallic conductor is a straight line as shown. At different temperatures V-i curves are different.



(A) Slope of the line $= \tan\theta = \frac{V}{i} = R$

(B) Here $\tan\theta_1 > \tan\theta_2$ So $R_1 > R_2$

Fig. 19.9

(3) The device or substances which don't obey ohm's law *e.g.* gases, crystal rectifiers, thermoionic valve, transistors etc. are known as non-ohmic or non-linear conductors. For these V-i curve is not linear.

Static resistance $R_{st} = \frac{V}{i} = \frac{1}{\tan\theta}$

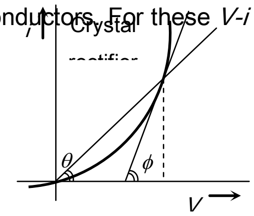


Fig. 19.10

Dynamic resistance $R_{dyn} = \frac{\Delta V}{\Delta I} = \frac{1}{\tan\phi}$

Resistance

(1) The property of substance by virtue of which it opposes the flow of current through it, is known as the resistance.

(2) **Formula of resistance :** For a conductor if l = length of a conductor A = Area of cross-section of conductor, n = No. of free electrons per unit volume in conductor, τ = relaxation time then resistance of conductor $\boldsymbol{R = \rho \frac{l}{A} = \frac{m}{ne^2\tau} \cdot \frac{l}{A}}$; where ρ = resistivity of the material of conductor

(3) **Unit and dimension :** It's S.I. unit is *Volt/Amp.* or *Ohm* (Ω). Also 1 *ohm* $= \frac{1 volt}{1 Amp} = \frac{10^8 \, emu \text{ of potential}}{10^{-1} emu \text{ of current}}$ = 10^9 *emu* of resistance. It's dimension is $[ML^2T^{-3}A^{-2}]$.

(4) **Dependence of resistance :** Resistance of a conductor depends upon the following factors.

(i) Length of the conductor : Resistance of a conductor is directly proportional to it's length *i.e.* $R \propto l$ and inversely proportional to it's area of cross-section *i.e.* $\boldsymbol{R \propto \frac{1}{A}}$

(ii) Temperature : For a conductor

$$\textbf{Resistance} \propto \textbf{temperature}.$$

If R_0 = resistance of conductor at 0°*C*

R_t = resistance of conductor at *t*°*C*

and α, β = temperature co-efficient of resistance

then $R_t = R_0(1 + \alpha t + \beta t^2)$ for $t > 300°C$ and

$\boldsymbol{R_t = R_0(1 + \alpha t)}$ for $t \le 300°C$ or $\alpha = \frac{R_t - R_0}{R_0 \times t}$

If R_1 and R_2 are the resistances at t_1°*C* and t_2°*C* respectively then $\frac{R_1}{R_2} = \frac{1 + \alpha t_1}{1 + \alpha t_2}$.

The value of α is different at different temperature. Temperature coefficient of resistance averaged over the temperature range t_1°*C* to t_2°*C* is given by $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$ which gives $R_2 = R_1 [1 + \alpha (t_2 - t_1)]$. This formula gives an approximate value.

Table 19.2 : Variation of resistance of some electrical material with temperature

Material	Temp. coefficient of resistance (α)	Variation of resistance with temperature rise
Metals	Positive	Increases
Solid non-metal	Zero	Independent
Semi-conductor	Negative	Decreases
Electrolyte	Negative	Decreases
Ionised gases	Negative	Decreases
Alloys	Small positive value	Almost constant

Resistivity (ρ), Conductivity (σ) and Conductance (C)

(1) **Resistivity :** From $R = \rho \frac{l}{A}$; If l = 1*m*, A = 1 m^2 then $\boldsymbol{R = \rho}$ *i.e.* resistivity is numerically equal to the resistance of a substance having unit area of cross-section and unit length.

(i) Unit and dimension : It's S.I. unit is *ohm* × *m* and dimension is $[ML^3T^{-3}A^{-2}]$

(ii) It's formula : $\rho = \frac{m}{ne^2\tau}$

(iii) Resistivity is the intrinsic property of the substance. It is independent of shape and size of the body (*i.e.* l and A).

(iv) For different substances their resistivity is also different *e.g.* ρ_{silver} = minimum = 1.6 × 10^{-8} Ω-*m* and $\rho_{fused\ quartz}$ = maximum ≈ 10^{16} Ω-*m*

$$\underset{(\text{Maximum for fused quartz})}{\rho_{insulator}} > \rho_{alloy} > \rho_{semi\text{-}conductor} > \underset{(\text{Minimum for silver})}{\rho_{conductor}}$$

(v) Resistivity depends on the temperature. For metals $\rho_t = \rho_0(1 + \alpha\Delta t)$ *i.e.* resitivity increases with temperature.

(vi) Resistivity increases with impurity and mechanical stress.

(vii) Magnetic field increases the resistivity of all metals except iron, cobalt and nickel.

(viii) Resistivity of certain substances like selenium, cadmium, sulphides is inversely proportional to intensity of light falling upon them.

(2) **Conductivity :** Reciprocal of resistivity is called conductivity (σ) *i.e.* $\sigma = \frac{1}{\rho}$ with unit *mho/m* and dimensions $[M^{-1}L^{-3}T^{3}A^{2}]$.

(3) **Conductance :** Reciprocal of resistance is known as conductance. $C = \frac{1}{R}$ It's unit is $\frac{1}{\Omega}$ or Ω^{-1} or "Siemen".

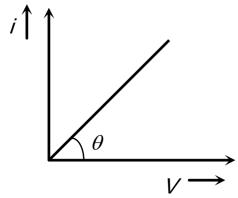


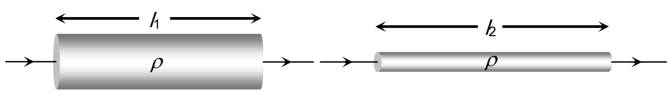
Fig. 19.11

Stretching of Wire

If a conducting wire stretches, it's length increases, area of cross-section decreases so resistance increases but volume remain constant.

Suppose for a conducting wire before stretching it's length = l_1, area of cross-section = A_1, radius = r_1, diameter = d_1, and resistance $R_1 = \rho \frac{l_1}{A_1}$

Before stretching After stretching



Volume remains constant *i.e.* $A_1l_1 = A_2l_2$

Fig. 19.12

After stretching length = l_2, area of cross-section = A_2, radius = r_2, diameter = d_2 and resistance $= R_2 = \rho \frac{l_2}{A_2}$

Ratio of resistances before and after stretching

$$\frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \left(\frac{l_1}{l_2}\right)^2 = \left(\frac{A_2}{A_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^4 = \left(\frac{d_2}{d_1}\right)^4$$

(1) If length is given then $R \propto l^2 \Rightarrow \frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2$

(2) If radius is given then $R \propto \frac{1}{r^4} \Rightarrow \frac{R_1}{R_2} = \left(\frac{r_2}{r_1}\right)^4$

Electrical Conducting Materials For Specific Use

(1) **Filament of electric bulb :** Is made up of tungsten which has high resistivity, high melting point.

(2) **Element of heating devices (such as heater, geyser or press) :** Is made up of nichrome which has high resistivity and high melting point.

(3) **Resistances of resistance boxes (standard resistances) :** Are made up of alloys (manganin, constantan or nichrome) these materials have moderate resistivity which is practically independent of temperature so that the specified value of resistance does not alter with minor changes in temperature.

(4) **Fuse-wire :** Is made up of tin-lead alloy (63% tin + 37% lead). It should have low melting point and high resistivity. It is used in series as a safety device in an electric circuit and is designed so as to melt and thereby open the circuit if the current exceeds a predetermined value due to some fault. The function of a fuse is independent of its length.

Safe current of fuse wire relates with it's radius as $\boldsymbol{i} \propto \boldsymbol{r}^{3/2}$.

(5) **Thermistors** : A thermistor is a heat sensitive resistor usually prepared from oxides of various metals such as nickel, copper, cobalt, iron etc. These compounds are also semi-conductor. For thermistors α is very high which may be positive or negative. The resistance of thermistors changes very rapidly with change of temperature.

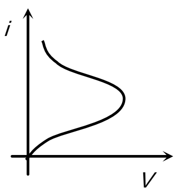


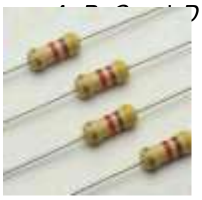
Fig. 19.13

Thermistors are used to detect small temperature change and to measure very low temperature.

Colour Coding of Resistance

To know the value of resistance colour code is used. These code are printed in form of set of rings or strips. By reading the values of colour bands, we can estimate the value of resistance.

The carbon resistance has normally four coloured rings or bands A, B, C and D as shown in following figure.



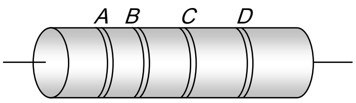


Fig. 19.14

Colour band *A* and *B* : Indicate the first two significant figures of resistance in *ohm*.

Band *C* : Indicates the decimal multiplier *i.e.* the number of zeros that follows the two significant figures *A* and *B*.

Band *D* : Indicates the tolerance in percent about the indicated value or in other words it represents the percentage accuracy of the indicated value.

The tolerance in the case of gold is ± 5% and in silver is ± 10%. If only three bands are marked on carbon resistance, then it indicate a tolerance of 20%.

Table 19.3 : Colour code for carbon resistance

Letters as an aid to memory	Colour	Figure (*A*, *B*)	Multiplier (C)
B	Black	0	10^0
B	Brown	1	10^1
R	Red	2	10^2
O	Orange	3	10^3
Y	Yellow	4	10^4
G	Green	5	10^5
B	Blue	6	10^6
V	Violet	7	10^7
G	Grey	8	10^8
W	White	9	10^9

To remember the sequence of colour code following sentence should kept in memory.

B B R O Y Great Britain Very Good Wife.

Grouping of Resistance

(1) **Series grouping**

(i) Same current flows through each resistance but potential difference distributes in the ratio of resistance *i.e.* $V \propto R$

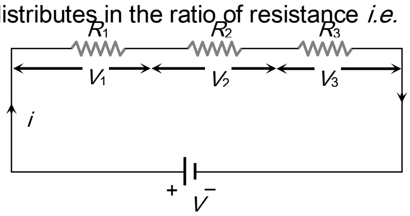


Fig. 19.15

(ii) $R_{eq} = R_1 + R_2 + R_3$ equivalent resistance is greater than the maximum value of resistance in the combination.

(iii) If *n* identical resistance are connected in series $R_{eq} = nR$ and potential difference across each resistance $V' = \frac{V}{n}$

(2) **Parallel grouping**

(i) Same potential difference appeared across each resistance but current distributes in the reverse ratio of their resistance *i.e.* $i \propto \frac{1}{R}$

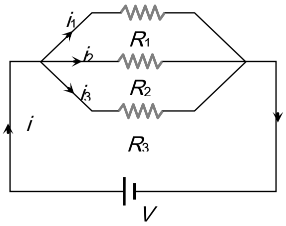


Fig. 19.16

(ii) Equivalent resistance is given by $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

or $R_{eq} = (R_1^{-1} + R_2^{-1} + R_3^{-1})^{-1}$ or $R_{eq} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_2 R_1}$

Equivalent resistance is smaller than the minimum value of resistance in the combination.

(iv) If two resistance in parallel

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{\text{Multiplication}}{\text{Addition}}$$

(v) Current through any resistance

$$i' = i \times \left[\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right]$$

Where *I* = required current (branch current),

i = main current

$$i_1 = i\left(\frac{R_2}{R_1 + R_2}\right)$$

and $i_2 = i\left(\frac{R_1}{R_1 + R_2}\right)$

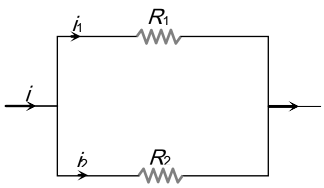
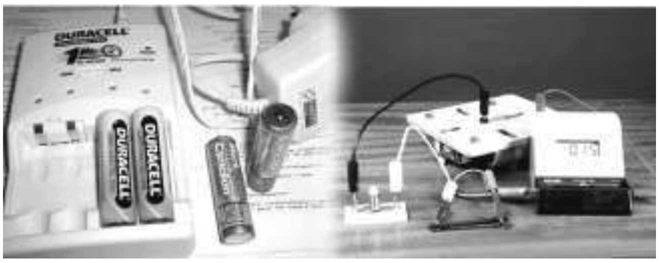


Fig. 19.17

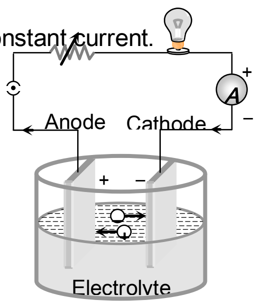
(vi) In *n* identical resistance are connected in parallel

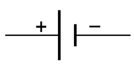
$R_{eq} = \frac{R}{n}$ and current through each resistance $i' = \frac{i}{n}$

Cell



The device which converts chemical energy into electrical energy is known as electric cell. Cell is a source of constant emf but not constant current.





Symbol of cell

Fig. 19.18

(1) **Emf of cell (*E*) :** The potential difference across the terminals of a cell when it is not supplying any current is called it's emf.

(2) **Potential difference (*V*) :** The voltage across the terminals of a cell when it is supplying current to external resistance is called potential difference or terminal voltage. Potential difference is equal to the product of current and resistance of that given part *i.e.* *V* = *iR*.

(3) **Internal resistance (*r*) :** In case of a cell the opposition of electrolyte to the flow of current through it is called internal resistance of the cell. The internal resistance of a cell depends on the distance between electrodes ($r \propto d$), area of electrodes [$r \propto (1/A)$] and nature, concentration ($r \propto C$) and temperature of electrolyte [$r \propto$ (1/ temp.)].

A cell is said to be ideal, if it has zero internal resistance.

Cell in Various Positions

(1) **Closed circuit :** Cell supplies a constant current in the circuit.

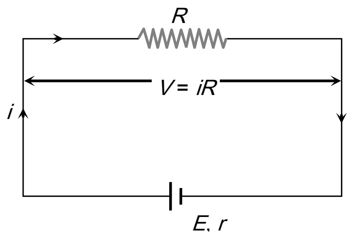


Fig. 19.19

(i) Current given by the cell $i = \frac{E}{R + r}$

(ii) Potential difference across the resistance $V = iR$

(iii) Potential drop inside the cell = *ir*

(iv) Equation of cell $E = V + ir$ ($E > V$)

(v) Internal resistance of the cell $r = \left(\frac{E}{V} - 1\right) \cdot R$

(vi) Power dissipated in external resistance (load)

$$P = Vi = i^2 R = \frac{V^2}{R} = \left(\frac{E}{R+r}\right)^2 .R$$

Power delivered will be maximum when $R = r$ so $P_{max} = \frac{E^2}{4r}$.

This statement in generalised from is called "*maximum power transfer theorem*".

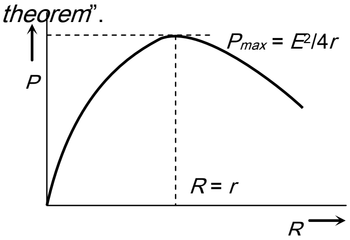


Fig. 19.20

(vii) When the cell is being charged *i.e.* current is given to the cell then $E = V - ir$ and $E < V$.

(2) **Open circuit :** When no current is taken from the cell it is said to be in open circuit

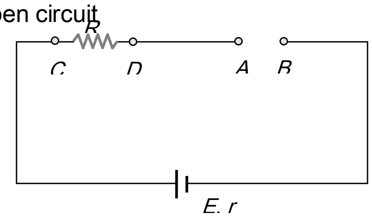


Fig. 19.21

(i) Current through the circuit $i = 0$

(ii) Potential difference between A and B, $V_{AB} = E$

(iii) Potential difference between C and D, $V_{CD} = 0$

(3) **Short circuit :** If two terminals of cell are join together by a thick conducting wire

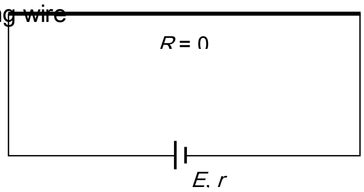


Fig. 19.22

(i) Maximum current (called short circuit current) flows momentarily $i_{sc} = \frac{E}{r}$

(ii) Potential difference $V = 0$

Grouping of Cells

Group of cell is called a battery.

In series grouping of cell's their emf's are additive or subtractive while their internal resistances are always additive. If dissimilar plates of cells are connected together their emf's are added to each other while if their similar plates are connected together their emf's are subtractive.

$E_{eq} = E_1 + E_2$ $\qquad$ $E_{eq} = E_1 - E_2$ $(E_1 > E_2)$

$r_{eq} = r_1 + r_2$ $\qquad$ $r_{eq} = r_1 + r_2$

Fig. 19.23

(1) **Series grouping :** In series grouping anode of one cell is connected to cathode of other cell and so on. If n identical cells are connected in series

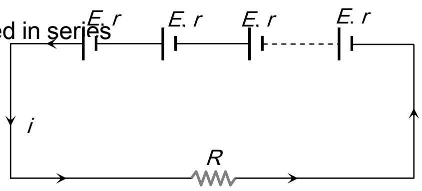


Fig. 19.24

(i) Equivalent emf of the combination $E_{eq} = nE$

(ii) Equivalent internal resistance $r_{eq} = nr$

(iii) Main current = Current from each cell $= i = \frac{nE}{R + nr}$

(iv) Potential difference across external resistance $V = iR$

(v) Potential difference across each cell $V' = \frac{V}{n}$

(vi) Power dissipated in the external circuit $= \left(\frac{nE}{R+nr}\right)^2 . R$

(vii) Condition for maximum power $R = nr$ and $P_{\max} = n\left(\frac{E^2}{4r}\right)$

(viii) This type of combination is used when *nr* << *R*.

(2) **Parallel grouping :** In parallel grouping all anodes are connected at one point and all cathode are connected together at other point. If *n* identical cells are connected in parallel

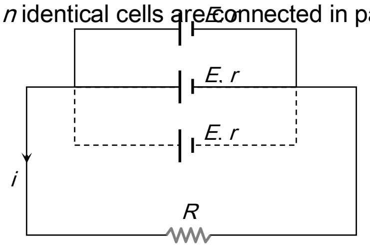


Fig. 19.25

(i) Equivalent emf $E_{eq} = E$

(ii) Equivalent internal resistance $R_{eq} = r/n$

(iii) Main current $i = \frac{E}{R + r/n}$

(iv) potential difference across external resistance = p.d. across each cell = $V = iR$

(v) Current from each cell $i' = \frac{i}{n}$

(vi) Power dissipated in the circuit $P = \left(\frac{E}{R + r/n}\right)^2 . R$

(vii) Condition for max. power is $R = r/n$ and $P_{\max} = n\left(\frac{E^2}{4r}\right)$

(viii) This type of combination is used when *nr* >> *R*

(3) **Mixed Grouping :** If *n* identical cell's are connected in a row and such *m* row's are connected in parallel as shown.

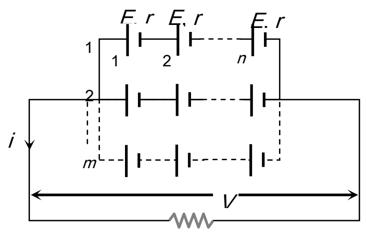


Fig. 19.26

(i) Equivalent emf of the combination $E_{eq} = nE$

(ii) Equivalent internal resistance of the combination $r_{eq} = \frac{nr}{m}$

(iii) Main current flowing through the load $i = \frac{nE}{R + \frac{nr}{m}} = \frac{mnE}{mR + nr}$

(iv) Potential difference across load $V = iR$

(v) Potential difference across each cell $V' = \frac{V}{n}$

(vi) Current from each cell $i' = \frac{i}{n}$

(vii) Condition for maximum power $R = \frac{nr}{m}$ and $P_{\max} = (mn)\frac{E^2}{4r}$

(viii) Total number of cell = *mn*

Kirchoff's Laws

(1) **Kirchoff's first law :** This law is also known as junction rule or current law (*KCL*). According to it the algebraic sum of currents meeting at a junction is zero *i.e.* $\Sigma i = 0$.

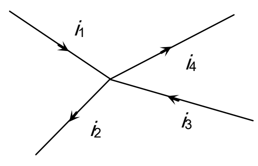


Fig. 19.27

In a circuit, at any junction the sum of the currents entering the junction must equal the sum of the currents leaving the junction. $i_1 + i_3 = i_2 + i_4$

(ii) This law is simply a statement of "*conservation of charge*".

(2) **Kirchoff's second law :** This law is also known as loop rule or voltage law (KVL) and according to it "the algebraic sum of the changes in potential in complete traversal of a mesh (closed loop) is zero", *i.e.* $\Sigma V = 0$

(i) This law represents "*conservation of energy*".

(ii) If there are n meshes in a circuit, the number of independent equations in accordance with loop rule will be $(n-1)$.

(3) **Sign convention for the application of Kirchoff's law :** For the application of Kirchoff's laws following sign convention are to be considered

(i) The change in potential in traversing a resistance in the direction of current is $-iR$ while in the opposite direction $+iR$

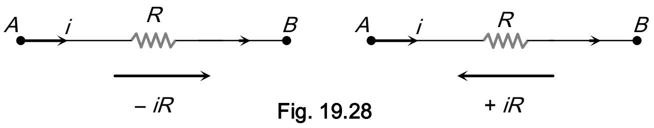


Fig. 19.28

(ii) The change in potential in traversing an emf source from negative to positive terminal is $+E$ while in the opposite direction $-E$ irrespective of the direction of current in the circuit.

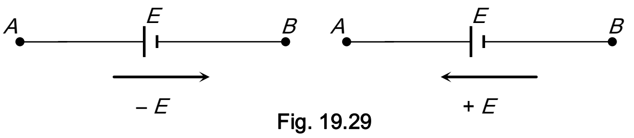


Fig. 19.29

(iii) The change in potential in traversing a capacitor from the negative terminal to the positive terminal is $+\frac{q}{C}$ while in opposite direction $-\frac{q}{C}$.

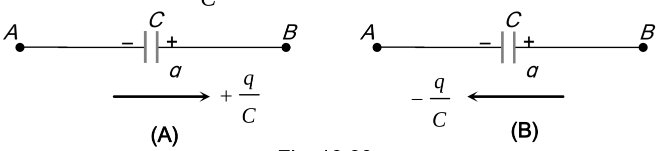


Fig. 19.30

(iv) The change in voltage in traversing an inductor in the direction of current is $-L\frac{di}{dt}$ while in opposite direction it is $+L\frac{di}{dt}$.

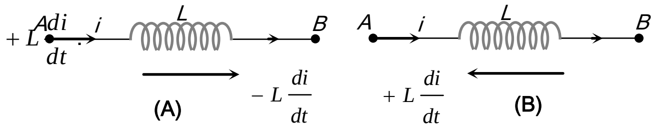
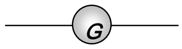


Fig. 19.31

Different Measuring Instruments

(1) **Galvanometer :** It is an instrument used to detect small current passing through it by showing deflection. Galvanometers are of different types *e.g.* moving coil galvanometer, moving magnet galvanometer, hot wire galvanometer. In dc circuit usually moving coil galvanometer are used.

(i) **It's symbol :**  ; where G is the total internal resistance of the galvanometer.

(ii) **Full scale deflection current :** The current required for full scale deflection in a galvanometer is called full scale deflection current and is represented by i_g.

(iii) **Shunt :** The small resistance connected in parallel to galvanometer coil, in order to control current flowing through the galvanometer is known as shunt.

Table 19.4 : Merits and demerits of shunt

Merits of shunt	Demerits of shunt

To protect the galvanometer coil from burning It can be used to convert any galvanometer into ammeter of desired range.	Shunt resistance decreases the sensitivity of galvanometer.

(2) **Ammeter :** It is a device used to measure current and is always connected in series with the 'element' through which current is to be measured.

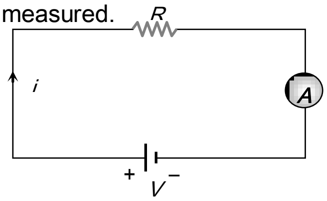


Fig. 19.32

(i) The reading of an ammeter is always lesser than actual current in the circuit.

(ii) Smaller the resistance of an ammeter more accurate will be its reading. An ammeter is said to be ideal if its resistance *r* is zero.

(iii) **Conversion of galvanometer into ammeter** : A galvanometer may be converted into an ammeter by connecting a low resistance (called shunt *S*) in parallel to the galvanometer *G* as shown in figure.

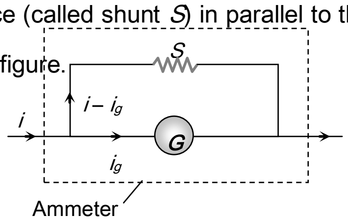


Fig. 19.33

(a) Equivalent resistance of the combination $= \frac{GS}{G+S}$

(b) *G* and *S* are parallel to each other hence both will have equal potential difference *i.e.* $i_g G = (i - i_g)S$; which gives

Required shunt $\boldsymbol{S = \frac{i_g}{(i - i_g)} G}$

(c) To pass *n*th part of main current (*i.e.* $i_g = \frac{i}{n}$) through the galvanometer, required shunt $\boldsymbol{S = \frac{G}{(n-1)}}$.

(3) **Voltmeter :** It is a device used to measure potential difference and is always put in parallel with the 'circuit element' across which potential difference is to be measured.

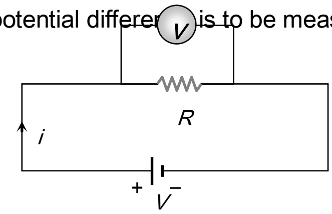


Fig. 19.34

(i) The reading of a voltmeter is always lesser than true value.

(ii) Greater the resistance of voltmeter, more accurate will be its reading. A voltmeter is said to be ideal if its resistance is infinite, *i.e.,* it draws no current from the circuit element for its operation.

(iii) **Conversion of galvanometer into voltmeter** : A galvanometer may be converted into a voltmeter by connecting a large resistance *R* in series with the galvanometer as shown in the figure.

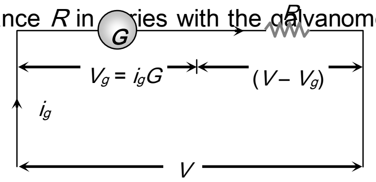


Fig. 19.35

(a) Equivalent resistance of the combination = *G* + *R*

(b) According to ohm's law $V = i_g(G + R)$; which gives

Required series resistance $\boldsymbol{R = \frac{V}{i_g} - G = \left(\frac{V}{V_g} - 1\right) G}$

(c) If n^{th} part of applied voltage appeared across galvanometer (*i.e.* $V_g = \frac{V}{n}$) then required series resistance $\boldsymbol{R = (n-1)\,G}$.

(4) **Wheatstone bridge :** Wheatstone bridge is an arrangement of four resistance which can be used to measure one of them in terms of rest. Here arms AB and BC are called ratio arm and arms AC and BD are called conjugate arms

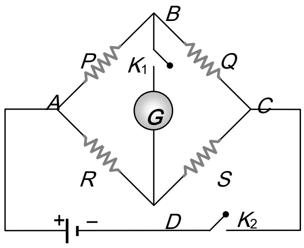


Fig. 19.36

(i) **Balanced bridge :** The bridge is said to be balanced when deflection in galvanometer is zero *i.e.* no current flows through the galvanometer or in other words $V_B = V_D$. In the balanced condition $\frac{P}{Q} = \frac{R}{S}$, on mutually changing the position of cell and galvanometer this condition will not change.

(ii) **Unbalanced bridge :** If the bridge is not balanced current will flow from D to B if $V_D > V_B$ *i.e.* $(V_A - V_D) < (V_A - V_B)$ which gives $PS > RQ$.

(iii) **Applications of wheatstone bridge :** Meter bridge, post office box and Carey Foster bridge are instruments based on the principle of wheatstone bridge and are used to measure unknown resistance.

(5) **Meter bridge :** In case of meter bridge, the resistance wire AC is 100 cm long. Varying the position of tapping point B, bridge is balanced. If in balanced position of bridge $AB = l$, BC $(100 - l)$ so that $\frac{Q}{P} = \frac{(100-l)}{l}$. Also $\frac{P}{Q} = \frac{R}{S} \Rightarrow S = \frac{(100-l)}{l}R$

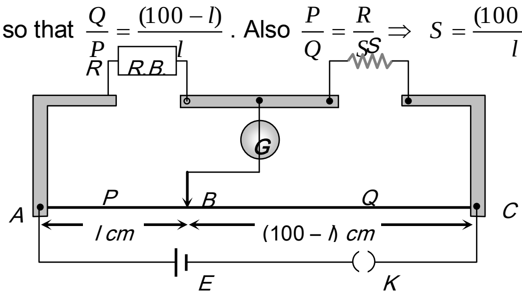


Fig. 19.37

Potentiometer

Potentiometer is a device mainly used to measure emf of a given cell and to compare emf's of cells. It is also used to measure internal resistance of a given cell.

(1) **Circuit diagram :** Potentiometer consists of a long resistive wire AB of length L (about 6m to 10 m long) made up of mangnine or constantan and a battery of known voltage e and internal resistance r called supplier battery or driver cell. Connection of these two forms primary circuit.

One terminal of another cell (whose emf E is to be measured) is connected at one end of the main circuit and the other terminal at any point on the resistive wire through a galvanometer G. This forms the secondary circuit. Other details are as follows

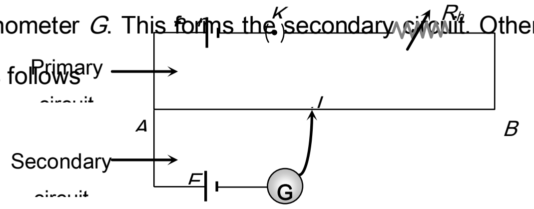


Fig. 19.38

J = Jockey

K = Key

R = Resistance of potentiometer wire,

ρ = Specific resistance of potentiometer wire.

R_h = Variable resistance which controls the current through the wire AB

(i) The specific resistance (ρ) of potentiometer wire must be high but its temperature coefficient of resistance (α) must be low.

(ii) All higher potential points (terminals) of primary and secondary circuits must be connected together at point A and all lower potential points must be connected to point B or jockey.

(iii) The value of known potential difference must be greater than the value of unknown potential difference to be measured.

(iv) The potential gradient must remain constant. For this the current in the primary circuit must remain constant and the jockey must not be slided in contact with the wire.

(v) The diameter of potentiometer wire must be uniform everywhere.

(2) **Potential gradient (x) :** Potential difference (or fall in potential) per unit length of wire is called potential gradient *i.e.* $x = \frac{V}{L}\frac{volt}{m}$ where $V = iR = \left(\frac{e}{R + R_h + r}\right).R$.

So $\boldsymbol{x = \frac{V}{L} = \frac{iR}{L} = \frac{i\rho}{A} = \frac{e}{(R + R_h + r)}.\frac{R}{L}}$

(i) Potential gradient directly depends upon

(a) The resistance per unit length (R/L) of potentiometer wire.

(b) The radius of potentiometer wire (*i.e.* Area of cross-section)

(c) The specific resistance of the material of potentiometer wire (*i.e.* ρ)

(d) The current flowing through potentiometer wire (i)

(ii) potential gradient indirectly depends upon

(a) The emf of battery in the primary circuit (*i.e.* e)

(b) The resistance of rheostat in the primary circuit (*i.e.* R_h)

(3) **Working :** Suppose jocky is made to touch a point J on wire then potential difference between A and J will be $V = xl$

At this length (l) two potential difference are obtained

(i) V due to battery e and

(ii) E due to unknown cell

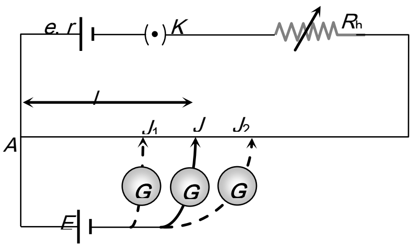


Fig. 19.39

If $V > E$ then current will flow in galvanometer circuit in one direction

If $V < E$ then current will flow in galvanometer circuit in opposite direction

If $V = E$ then no current will flow in galvanometer circuit this condition to known as null deflection position, length l is known as balancing length.

In balanced condition $\boldsymbol{E = xl}$

or $\boldsymbol{E = xl = \frac{V}{L}l = \frac{iR}{L}l = \left(\frac{e}{R + R_h + r}\right).\frac{R}{L} \times l}$

If V is constant then $L \propto l$ $\Rightarrow \frac{x_1}{x_2} = \frac{L_1}{L_2} = \frac{l_1}{l_2}$

(6) **Standardization of potentiometer :** The process of determining potential gradient experimentally is known as standardization of potentiometer.

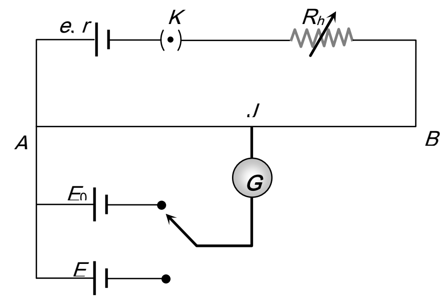


Fig. 19.40

Let the balancing length for the standard emf E_0 is l_0 then by the principle of potentiometer $E_0 = xl_0 \Rightarrow x = \frac{E_0}{l_0}$

(7) **Sensitivity of potentiometer :** A potentiometer is said to be more sensitive, if it measures a small potential difference more accurately.

(i) The sensitivity of potentiometer is assessed by its potential gradient. The sensitivity is inversely proportional to the potential gradient.

(ii) In order to increase the sensitivity of potentiometer

(a) The resistance in primary circuit will have to be decreased.

(b) The length of potentiometer wire will have to be increased so that the length may be measured more accuracy.

Table 19.5 : Difference between voltmeter and potentiometer

Voltmeter	Potentiometer
It's resistance is high but finite	Its resistance is infinite
It draws some current from source of emf	It does not draw any current from the source of unknown emf
The potential difference measured by it is lesser than the actual potential difference	The potential difference measured by it is equal to actual potential difference
Its sensitivity is low	Its sensitivity is high
It is a versatile instrument	It measures only emf or potential difference
It is based on deflection method	It is based on zero deflection method

Application of Potentiometer

(1) **To determine the internal resistance of a primary cell**

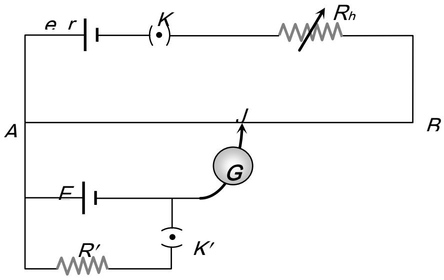


Fig. 19.41

(i) Initially in secondary circuit key K' remains open and balancing length (l_1) is obtained. Since cell E is in open circuit so it's emf balances on length l_1 *i.e.* $E = xl_1$ .... (i)

(ii) Now key K' is closed so cell E comes in closed circuit. If the process of balancing repeated again then potential difference V balances on length l_2 *i.e.* $V = xl_2$ .... (ii)

(iii) By using formula internal resistance $r = \left(\frac{E}{V} - 1\right).R'$

$$r = \left(\frac{l_1 - l_2}{l_2}\right).R'$$

(2) **Comparison of emf's of two cell :** Let l_1 and l_2 be the balancing lengths with the cells E_1 and E_2 respectively then $E_1 = xl_1$ and $E_2 = xl_2$ $\Rightarrow \frac{E_1}{E_2} = \frac{l_1}{l_2}$

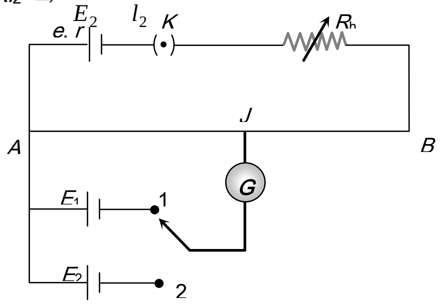
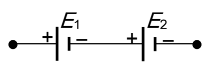
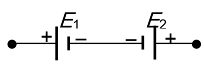


Fig. 19.42

Let $E_1 > E_2$ and both are connected in series. If balancing length is l_1 when cell assist each other and it is l_2 when they oppose each other as shown then :





$(E_1 + E_2) = xl_1$ $\qquad$ $(E_1 - E_2) = xl_2$

$$\Rightarrow \frac{E_1 + E_2}{E_1 - E_2} = \frac{l_1}{l_2} \quad \text{or} \quad \frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$$

(3) **Comparison of resistances :** Let the balancing length for resistance R_1 (when XY is connected) is l_1 and let balancing length for resistance $R_1 + R_2$ (when YZ is connected) is l_2.

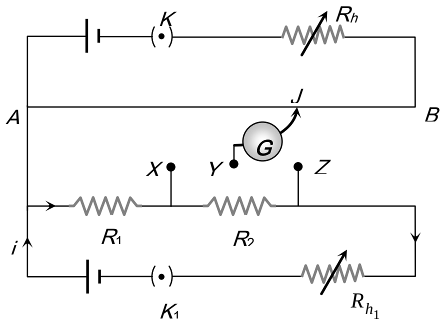


Fig. 19.43

Then $iR_1 = xl_1$ and $i(R_1 + R_2) = xl_2$ $\Rightarrow$ $\frac{R_2}{R_1} = \frac{l_2 - l_1}{l_1}$

(4) **To determine thermo emf**

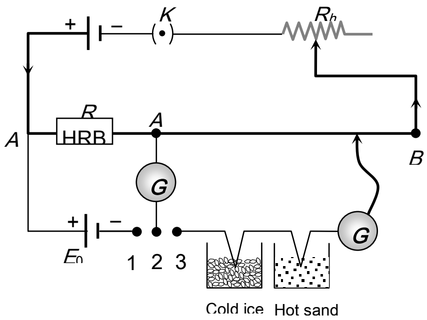


Fig. 19.44

(i) The value of thermo-emf in a thermocouple for ordinary temperature difference is very low (10^{-6} *volt*). For this the potential gradient x must be also very low (10^{-4} *V/m*). Hence a high resistance (R) is connected in series with the potentiometer wire in order to reduce current.

(ii) The potential difference across R must be equal to the emf of standard cell *i.e.* $iR = E_0$ $\therefore$ $i = \frac{E_0}{R}$

(iii) The small thermo emf produced in the thermocouple $e = xl$

(iv) $x = i\rho = \frac{iR}{L}$ $\therefore$ $e = \frac{iRl}{L}$ where L = length of potentiometer wire, ρ = resistance per unit length, l = balancing length for e

(5) **Calibration of ammeter :** Checking the correctness of ammeter readings with the help of potentiometer is called calibration of ammeter.

(i) In the process of calibration of an ammeter the current flowing in a circuit is measured by an ammeter and the same current is also measured with the help of potentiometer. By comparing both the values, the errors in the ammeter readings are determined.

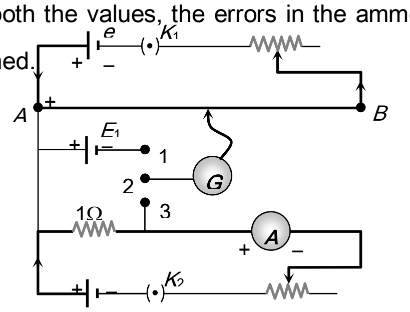


Fig. 19.45

(ii) For the calibration of an ammeter, 1 Ω standard resistance coil is specifically used in the secondary circuit of the potentiometer, because the potential difference across 1 Ω is equal to the current flowing through it *i.e.* $V = i$.

(iii) If the balancing length for the emf E_0 is l_0 then $E_0 = xl_0$

$\Rightarrow x = \frac{E_0}{l_0}$ (Process of standardisation)

(iv) Let i' current flows through 1Ω resistance giving potential difference as $V' = i'(1) = xl_1$ where l_1 is the balancing length. So error can be found as $\Delta i = i - i' = i - xl_1 = i - \frac{E_0}{l_0} \times l_1$

(6) **Calibration of voltmeter**

(i) Practical voltmeters are not ideal, because these do not have infinite resistance. The error of such practical voltmeter can be found by comparing the voltmeter reading with calculated value of p.d. by potentiometer.

(ii) If l_0 is balancing length for E_0 the emf of standard cell by connecting 1 and 2 of bi-directional key, then $x = E_0/l_0$.

(iii) The balancing length l_1 for unknown potential difference V is given by (by closing 2 and 3) $V' = xl_1 = (E_0 / l_0)l_1$.

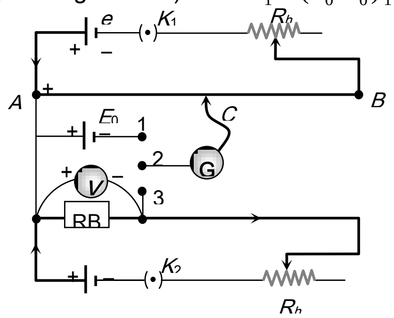


Fig. 19.46

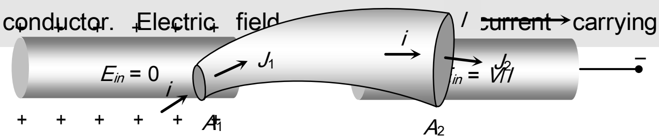
If the voltmeter reading is V then the error will be (V – V) which may be +ve, – ve or zero.

Tips & Tricks

✍ Human body, though has a large resistance of the order of $k\Omega$ (say 10 $k\Omega$), is very sensitive to minute currents even as low as a few mA. Electrocution, excites and disorders the nervous system of the body and hence one fails to control the activity of the body.

✍ dc flows uniformly throughout the cross-section of conductor while ac mainly flows through the outer surface area of the conductor. This is known as skin effect.

✍ It is worth noting that electric field inside a charged conductor is zero, but it is non zero inside a current carrying conductor and is given by $E = \frac{V}{l}$ where V = potential difference across the conductor and l = length of the conductor. Electric field / current carrying



conductor is zero.

✍ For a given conductor $JA = i$ = constant so that $J \propto \frac{1}{A}$ *i.e.*, $J_1A_1 = J_2A_2$; this is called equation of continuity

✍ The drift velocity of electrons is small because of the frequent collisions suffered by electrons.

✍ The small value of drift velocity produces a large amount of electric current, due to the presence of extremely large number of free electrons in a conductor.

The propagation of current is almost at the speed of light and involves electromagnetic process. It is due to this reason that the electric bulb glows immediately when switch is on.

✍ In the absence of electric field, the paths of electrons between successive collisions are straight line while in presence of electric field the paths are generally curved.

✍ Free electron density in a metal is given by $n = \frac{N_A x\, d}{A}$ where N_A = Avogadro number, x = number of free electrons per atom, d = density of metal and A = Atomic weight of metal.

✍ In the absence of radiation loss, the time in which a fuse will melt does not depends on it's length but varies with radius as $t \propto r^4$.

✍ If length (l) and mass (m) of a conducting wire is given then $R \propto \frac{l^2}{m}$.

✍ Macroscopic form of Ohm's law is $R = \frac{V}{i}$, while it's microscopic form is J = σ E.

✍ After stretching if length increases by n times then resistance will increase by n^2 times *i.e.* $R_2 = n^2 R_1$. Similarly if radius be reduced to $\frac{1}{n}$ times then area of cross-section decreases $\frac{1}{n^2}$ times so the resistance becomes n^4 times *i.e.* $R_2 = n^4 R_1$.

✍ After stretching if length of a conductor increases by x% then resistance will increases by $2x$ % (valid only if x < 10%)

✍ Decoration of lightning in festivals is an example of series grouping whereas all household appliances connected in parallel grouping.

✍ Using n conductors of equal resistance, the number of possible combinations is 2^{n-1}.

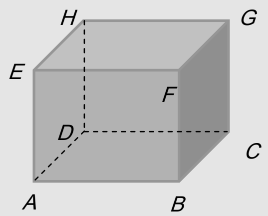
✍ If the resistance of n conductors are totally different, then the number of possible combinations will be 2^n.

✍ If n identical resistances are first connected in series and then in parallel, the ratio of the equivalent resistance is given by $\frac{R_p}{R_s} = \frac{n^2}{1}$.

✍ If a wire of resistance R, cut in n equal parts and then these parts are collected to form a bundle then equivalent resistance of combination will be $\frac{R}{n^2}$.

✍ If equivalent resistance of R_1 and R_2 in series and parallel be R_s and R_p respectively then $R_1 = \frac{1}{2}\left[R_s + \sqrt{R_s^2 - 4R_sR_p}\right]$ and $R_2 = \frac{1}{2}\left[R_s - \sqrt{R_s^2 - 4R_sR_p}\right]$.

✍ If a skeleton cube is made with 12 equal resistance each having resistance R then the net resistance across

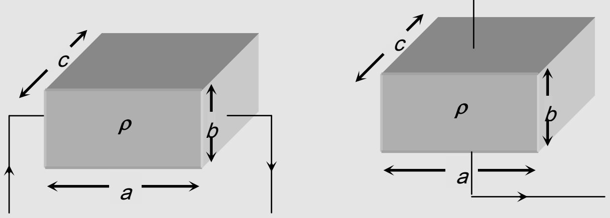


The longest diagonal (EC or AG) $= \frac{5}{6}R$

The diagonal of face (*e.g. AC, ED, ...*) $= \frac{3}{4}R$

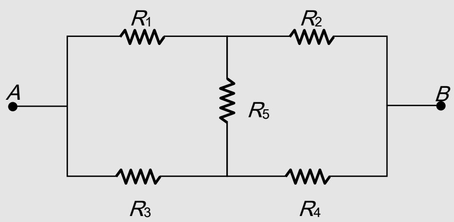
A side (*e.g. AB, BC.....*) $= \frac{7}{12}R$

✍ Resistance of a conducting body is not unique but depends on it's length and area of cross-section *i.e.* how the potential difference is applied. See the following figures

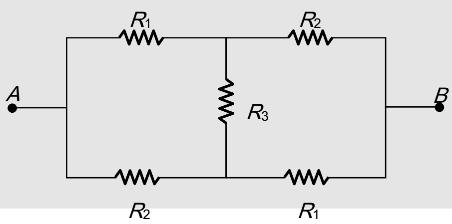


Length = a	Length = b
Area of cross-section = $b \times c$	Area of cross-section = $a \times c$
Resistance $R = \rho\left(\frac{a}{b \times c}\right)$	Resistance $R = \rho\left(\frac{b}{a \times c}\right)$

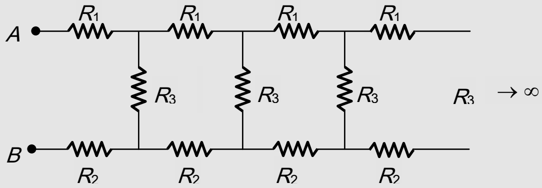
✍ Some standard results for equivalent resistance



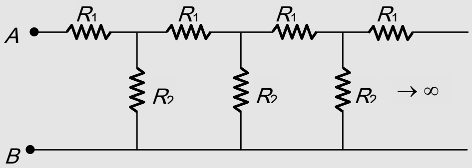
$$R_{AB} = \frac{R_1R_2(R_3+R_4)+(R_1+R_2)R_3R_4+R_5(R_1+R_2)(R_3+R_4)}{R_5(R_1+R_2+R_3+R_4)+(R_1+R_3)(R_2+R_4)}$$



$$R_{AB} = \frac{2R_1R_2 + R_3(R_1+R_2)}{2R_3 + R_1 + R_2}$$



$$R_{AB} = \frac{1}{2}(R_1+R_2) + \frac{1}{2}\left[(R_1+R_2)^2 + 4R_3(R_1+R_2)\right]^{1/2}$$



$$R_{AB} = \frac{1}{2}R_1\left[1 + \sqrt{1 + 4\left(\frac{R_2}{R_1}\right)}\right]$$

✍ It is a common misconception that "current in the circuit will be maximum when power consumed by the load is maximum."

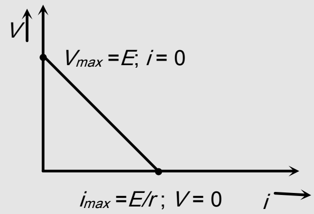
Actually current $i = E/(R+r)$ is maximum (= E/r) when R = min = 0 with $P_L = (E/r)^2 \times 0 = 0$ min. while power consumed by the load $E^2R/(R+r)^2$ is maximum (= $E^2/4r$) when $R = r$ and $i = (E/2r) \neq \max(= E/r)$.

✍ Emf is independent of the resistance of the circuit and depends upon the nature of electrolyte of the cell while potential difference depends upon the resistance between the two points of the circuit and current flowing through the circuit.

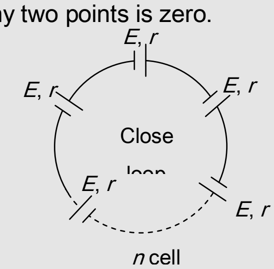
✍ Whenever a cell or battery is present in a branch there must be some resistance (internal or external or both) present in that branch. In practical situation it always happen because we can never have an ideal cell or battery with zero resistance.

✍ In series grouping of identical cells. If one cell is wrongly connected then it will cancel out the effect of two cells *e.g.* If in the combination of n identical cells (each having emf E and internal resistance r) if x cell are wrongly connected then equivalent emf $E_{eq} = (n-2x)E$ and equivalent internal resistance $r_{eq} = nr$.

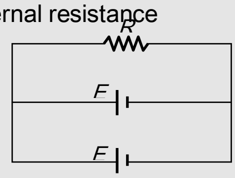
✍ Graphical view of open circuit and closed circuit of a cell.

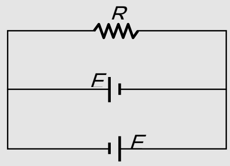


✍ If n identical cells are connected in a loop in order, then emf between any two points is zero.



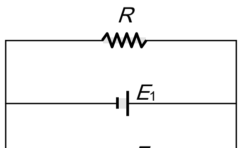
✍ In parallel grouping of two identical cell having no internal resistance





$E_{eq} = E$ $\qquad$ $E_{eq} = 0$

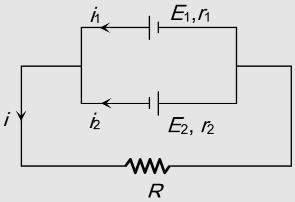
☞ When two cell's of different emf and no internal resistance are connected in parallel then equivalent emf is



indeterminate, note that connecting a wire with a cell with no resistance is equivalent to short circuiting. Therefore the total current that will be flowing will be infinity.

✍ In the parallel combination of non-identical cell's if they are connected with reversed polarity as shown then equivalent emf

$$E_{eq} = \frac{E_1r_2 - E_2r_1}{r_1 + r_2}$$



✍ Wheatstone bridge is most sensitive if all the arms of bridge have equal resistances *i.e.* $P = Q = R = S$

✍ If the temperature of the conductor placed in the right gap of metre bridge is increased, then the balancing length decreases and the jockey moves towards left.

✍ In Wheatstone bridge to avoid inductive effects the battery key should be pressed first and the galvanometer key afterwards.

✍ The measurement of resistance by Wheatstone bridge is not affected by the internal resistance of the cell.

✍ In case of zero deflection in the galvanometer current flows in the primary circuit of the potentiometer, not in the galvanometer circuit.

✍ A potentiometer can act as an ideal voltmeter.

Ordinary Thinking

Objective Questions

Electric Conduction, Ohm's Law and Resistance

1. Current of 4.8 amperes is flowing through a conductor. The number of electrons per second will be **[CPMT 1986]**

(a) 3×10^{19} (b) 7.68×10^{21}

(c) 7.68×10^{20} (d) 3×10^{20}

2. When the current i is flowing through a conductor, the drift velocity is v. If $2i$ current is flowed through the same metal but having double the area of cross-section, then the drift velocity will be

(a) $v/4$ (b) $v/2$

(c) v (d) $4v$

3. When current flows through a conductor, then the order of drift velocity of electrons will be **[CPMT 1986]**

(a) $10^{10}\ m/\sec$ (b) $10^{-2}\ cm/\sec$

(c) $10^{4}\ cm/\sec$ (d) $10^{-1}\ cm/\sec$

4. Every atom makes one free electron in copper. If 1.1 ampere current is flowing in the wire of copper having 1 mm diameter, then the drift velocity (approx.) will be (Density of copper $= 9 \times 10^3\ kg\ m^{-3}$ and atomic weight = 63) **[CPMT 1989]**

(a) $0.3\ mm/\sec$ (b) $0.1\ mm/\sec$

(c) $0.2\ mm/\sec$ (d) $0.2\ cm/\sec$

5. Which one is not the correct statement **[NCERT 1978]**

(a) $1\ volt \times 1\ coulomb = 1\ joule$

(b) $1\ volt \times 1\ ampere = 1\ joule/second$

(c) $1\ volt \times 1\ watt = 1\ H.P.$

(d) Watt-hour can be expressed in eV

6. If a 0.1 % increase in length due to stretching, the percentage increase in its resistance will be **[MNR 1990; MP PMT 1996; UPSEAT 1999; MP PMT 2000]**

(a) 0.2 % (b) 2 %

(c) 1 % (d) 0.1 %

7. The specific resistance of manganin is $50 \times 10^{-8}\ ohm \times m$.

The resistance of a cube of length $50\ cm$ will be

(a) $10^{-6}\ ohm$ (b) $2.5 \times 10^{-5}\ ohm$

(c) $10^{-8}\ ohm$ (d) $5 \times 10^{-4}\ ohm$

8. The resistivity of iron is $1 \times 10^{-7}\ ohm - m$. The resistance of a iron wire of particular length and thickness is 1 *ohm*. If the length and the diameter of wire both are doubled, then the resistivity in $ohm - m$ will be [CPMT 1983; DPMT 1999]

(a) 1×10^{-7} (b) 2×10^{-7}

(c) 4×10^{-7} (d) 8×10^{-7}

9. The temperature coefficient of resistance for a wire is $0.00125/°C$. At 300K its resistance is 1 *ohm*. The temperature at which the resistance becomes 2 *ohm* is

[IIT 1980; MP PET 2002; KCET 2003; MP PMT 2001; Orissa JEE 2002]

(a) 1154 K (b) 1100 K

(c) 1400 K (d) 1127 K

10. When the length and area of cross-section both are doubled, then its resistance [MP PET 1989]

(a) Will become half (b) Will be doubled

(c) Will remain the same (d) Will become four times

11. The resistance of a wire is 20 *ohms*. It is so stretched that the length becomes three times, then the new resistance of the wire will be

(a) 6.67 *ohms* (b) 60.0 *ohms*

(c) 120 *ohms* (d) 180.0 *ohms*

12. The resistivity of a wire [MP PMT 1984; DPMT 1982]

(a) Increases with the length of the wire

(b) Decreases with the area of cross-section

(c) Decreases with the length and increases with the cross-section of wire

(d) None of the above statement is correct

13. *Ohm*'s law is true

(a) For metallic conductors at low temperature

(b) For metallic conductors at high temperature

(c) For electrolytes when current passes through them

(d) For diode when current flows

14. The example for non-*ohm*ic resistance is [MP PMT 1978]

(a) Copper wire (b) Carbon resistance

(c) Diode (d) Tungsten wire

15. Drift velocity v_d varies with the intensity of electric field as per the relation [CPMT 1981; BVP 2003]

(a) $v_d \propto E$ (b) $v_d \propto \frac{1}{E}$

(c) $v_d = \text{constant}$ (d) $v_d \propto E^2$

16. On increasing the temperature of a conductor, its resistance increases because [CPMT 1982]

(a) Relaxation time decreases

(b) Mass of the electrons increases

(c) Electron density decreases

(d) None of the above

17. In a conductor 4 *coulombs* of charge flows for 2 *seconds*. The value of electric current will be [CPMT 1984]

(a) 4 *volts* (b) 4 *amperes*

(c) 2 *amperes* (d) 2 *volts*

18. The specific resistance of a wire is ρ, its volume is $3\,m^3$ and its resistance is 3 *ohms*, then its length will be

[CPMT 1984]

(a) $\sqrt{\frac{1}{\rho}}$ (b) $\frac{3}{\sqrt{\rho}}$

(c) $\frac{1}{\rho}\sqrt{3}$ (d) $\rho\sqrt{\frac{1}{3}}$

19. 62.5×10^{18} electrons per second are flowing through a wire of area of cross-section $0.1\,m^2$, the value of current flowing will be

(a) 1 A (b) 0.1 A

(c) 10 A (d) 0.11 A

20. A piece of wire of resistance 4 *ohms* is bent through $180°$ at its mid point and the two halves are twisted together, then the resistance is [CPMT 1971]

(a) 8 *ohms* (b) 1 *ohm*

(c) 2 *ohms* (d) 5 *ohms*

[MP PET 1989]

21. When a piece of aluminium wire of finite length is drawn through a series of dies to reduce its diameter to half its original value, its resistance will become

[NCERT 1974; AIIMS 1997; MH CET 2000; UPSEAT 2001; CBSE PMT 2002]

(a) Two times (b) Four times

(c) Eight times (d) Sixteen times

22. A wire 100 cm long and 2.0 mm diameter has a resistance of 0.7 *ohm*, the electrical resistivity of the material is

(a) $4.4 \times 10^{-6}\, ohm \times m$ (b) $2.2 \times 10^{-6}\, ohm \times m$

(c) $1.1 \times 10^{-6}\, ohm \times m$ (d) $0.22 \times 10^{-6}\, ohm \times m$

23. A certain wire has a resistance R. The resistance of another wire identical with the first except having twice its diameter is

(a) $2R$ (b) $0.25R$

(c) $4R$ (d) $0.5R$

24. In hydrogen atom, the electron makes 6.6×10^{15} revolutions per second around the nucleus in an orbit of radius $0.5 \times 10^{-10}\,m$. It is equivalent to a current nearly

(a) 1 A (b) 1 mA

(c) 1 μA (d) $1.6 \times 10^{-19}\,A$

25. A wire of length 5 m and radius 1 mm has a resistance of 1 *ohm*. What length of the wire of the same material at the same temperature and of radius 2 mm will also have a resistance of 1 *ohm*

(a) 1.25 m (b) 2.5 m

(c) 10 m (d) 20 m

26. When there is an electric current through a conducting wire along its length, then an electric field must exist

(a) Outside the wire but normal to it

(b) Outside the wire but parallel to it

(c) Inside the wire but parallel to it

(d) Inside the wire but normal to it

27. Through a semiconductor, an electric current is due to drift of

(a) Free electrons

(b) Free electrons and holes

(c) Positive and negative ions

(d) Protons

28. In an electrolyte 3.2×10^{18} bivalent positive ions drift to the right per second while 3.6×10^{18} monovalent negative ions drift to the left per second. Then the current is

(a) 1.6 amp to the left (b) 1.6 amp to the right
(c) 0.45 amp to the right (d) 0.45 amp to the left

29. A metallic block has no potential difference applied across it, then the mean velocity of free electrons is T = absolute temperature of the block)

(a) Proportional to T
(b) Proportional to $\sqrt{T}$
(c) Zero
(d) Finite but independent of temperature

30. The specific resistance of all metals is most affected by

(a) Temperature (b) Pressure
(c) Degree of illumination (d) Applied magnetic field

31. The positive temperature coefficient of resistance is for

(a) Carbon (b) Germanium
(c) Copper (d) An electrolyte

32. The fact that the conductance of some metals rises to infinity at some temperature below a few Kelvin is called

(a) Thermal conductivity (b) Optical conductivity
(c) Magnetic conductivity (d) Superconductivity

33. Dimensions of a block are $1\,cm\times1\,cm\times100\,cm$. If specific resistance of its material is $3\times10^{-7}\,ohm-m$, then the resistance between the opposite rectangular faces is [MP PET 1993]

(a) $3\times10^{-9}\,ohm$ (b) $3\times10^{-7}\,ohm$
(c) $3\times10^{-5}\,ohm$ (d) $3\times10^{-3}\,ohm$

34. In the above question, the resistance between the square faces is

(a) $3\times10^{-9}\,ohm$ (b) $3\times10^{-7}\,ohm$
(c) $3\times10^{-5}\,ohm$ (d) $3\times10^{-3}\,ohm$

35. There is a current of 20 amperes in a copper wire of 10^{-6} square metre area of cross-section. If the number of free electrons per cubic metre is 10^{29}, then the drift velocity is

(a) $125\times10^{-3}\,m/sec$ (b) $12.5\times10^{-3}\,m/sec$
(c) $1.25\times10^{-3}\,m/sec$ (d) $1.25\times10^{-4}\,m/sec$

36. The electric intensity E, current density j and specific resistance k are related to each other by the relation [DPMT 2001]

(a) $E=j/k$ (b) $E=jk$
(c) $E=k/j$ (d) $k=jE$

37. The resistance of a wire of uniform diameter d and length L is R. The resistance of another wire of the same material but diameter $2d$ and length $4L$ will be [CPMT 1984; MP PET 2002]

(a) $2R$ (b) R
(c) $R/2$ (d) $R/4$

38. There is a current of 1.344 *amp* in a copper wire whose area of cross-section normal to the length of the wire is $1\,mm^2$. If the number of free electrons per cm^3 is 8.4×10^{22}, then the drift velocity would be [CPMT 1990]

(a) 1.0 mm/sec (b) 1.0 m/sec
(c) 0.1 mm/sec (d) 0.01 mm/sec

39. It is easier to start a car engine on a hot day than on a cold day. This is because the internal resistance of the car battery

(a) Decreases with rise in temperature
(b) Increases with rise in temperature
(c) Decreases with a fall in temperature
(d) Does not change with a change in temperature

40. 5 *amperes* of current is passed through a metallic conductor. The charge flowing in one minute in coulombs will be [MP PET 1984]

(a) 5 (b) 12
(c) 1/12 (d) 300

41. Two wires of the same material are given. The first wire is twice as long as the second and has twice the diameter of the second. The resistance of the first will be [MP PMT 1993]

(a) Twice of the second (b) Half of the second
(c) Equal to the second (d) Four times of the second

42. An electric wire is connected across a cell of e.m.f. *E*. The current I is measured by an ammeter of resistance *R*. According to *ohm*'s law

(a) $E=I^2R$ (b) $E=IR$
(c) $E=R/I$ (d) $E=I/R$

43. The resistances of a wire at temperatures $t°C$ and $0°C$ are related by [MP PMT 1993]

(a) $R_t=R_0(1+\alpha t)$ (b) $R_t=R_0(1-\alpha t)$
(c) $R_t=R_0^2(1+\alpha t)$ (d) $R_t=R_0^2(1-\alpha t)$

44. An electric wire of length '*l*' and area of cross-section a has a resistance *R ohms*. Another wire of the same material having same length and area of cross-section 4*a* has a resistance of [MP PET 1993]

(a) 4*R* (b) *R*/4
(c) *R*/16 (d) 16*R*

45. For which of the following the resistance decreases on increasing the temperature [MP PET 1993]

(a) Copper (b) Tungsten
(c) Germanium (d) Aluminium

46. If n, e, τ and m respectively represent the density, charge relaxation time and mass of the electron, then the resistance of a wire of length l and area of cross-section A will be [CPMT 1992]

(a) $\frac{ml}{ne^2\tau A}$ (b) $\frac{m\tau^2A}{ne^2l}$
(c) $\frac{ne^2\tau A}{2ml}$ (d) $\frac{ne^2A}{2m\tau l}$

47. The relaxation time in conductors [DPMT 2003]

(a) Increases with the increase of temperature
(b) Decreases with the increase of temperature
(c) It does not depend on temperature
(d) All of sudden changes at 400 K

48. Which of the following statement is correct

(a) Liquids obey fully the *ohm*'s law
(b) Liquids obey partially the *ohm*'s law
(c) There is no relation between current and p.d. for liquids

(d) None of the above

49. A certain piece of silver of given mass is to be made like a wire. Which of the following combination of length (L) and the area of cross-sectional (A) will lead to the smallest resistance [MP PMT 1995; CBSE PMT 1997]

(a) L and A

(b) $2L$ and $A/2$

(c) $L/2$ and $2A$

(d) Any of the above, because volume of silver remains same

50. The resistance of a wire is $10\,\Omega$. Its length is increased by 10% by stretching. The new resistance will now be

[CPMT 2000; Pb PET 2004]

(a) $12\,\Omega$ (b) $1.2\,\Omega$

(c) $13\,\Omega$ (d) $11\,\Omega$

51. Resistance of tungsten wire at $150°C$ is $133\,\Omega$. Its resistance temperature coefficient is $0.0045/°C$. The resistance of this wire at $500°C$ will be [DPMT 2004]

(a) $180\,\Omega$ (b) $225\,\Omega$

(c) $258\,\Omega$ (d) $317\,\Omega$

52. A metal wire of specific resistance $64\times10^{-6}\,ohm-cm$ and length 198 *cm* has a resistance of 7 *ohm*, the radius of the wire will be [MP PET 1994]

(a) 2.4 *cm* (b) 0.24 *cm*

(c) 0.024 *cm* (d) 24 *cm*

53. A copper wire of length 1 *m* and radius 1 *mm* is joined in series with an iron wire of length 2 *m* and radius 3 *mm* and a current is passed through the wires. The ratio of the current density in the copper and iron wires is

[MP PMT 1994]

(a) 18 : 1 (b) 9 : 1

(c) 6 : 1 (d) 2 : 3

54. For a metallic wire, the ratio V/i ($V =$ the applied potential difference, i = current flowing) is [MP PMT 1994; BVP 2003]

(a) Independent of temperature

(b) Increases as the temperature rises

(c) Decreases as the temperature rises

(d) Increases or decreases as temperature rises, depending upon the metal

55. The resistance of a wire is R. If the length of the wire is doubled by stretching, then the new resistance will be

[Roorkee 1992; AFMC 1995; KCET 1993; AMU (Med.) 1999; CBSE PMT 1999; MP PET 2001; UPSEAT 2001]

(a) $2R$ (b) $4R$

(c) R (d) $\frac{R}{4}$

56. Which of the following has a negative temperature coefficient

(a) C (b) Fe

(c) Mn (d) Ag

57. The reciprocal of resistance is [AFMC 1995]

(a) Conductance (b) Resistivity

(c) Voltage (d) None of the above

58. A solenoid is at potential difference 60 V and current flows through it is 15 *ampere*, then the resistance of coil will be

[AFMC 1995]

(a) $4\,\Omega$ (b) $8\,\Omega$

(c) $0.25\,\Omega$ (d) $2\,\Omega$

59. All of the following statements are true except

[Manipal MEE 1995]

(a) Conductance is the reciprocal of resistance and is measured in *Siemens*

(b) *Ohm*'s law is not applicable at very low and very high temperatures

(c) *Ohm*'s law is applicable to semiconductors

(d) *Ohm*'s law is not applicable to electron tubes, discharge tubes and electrolytes

60. A potential difference of V is applied at the ends of a copper wire of length l and diameter d. On doubling only d, drift velocity

(a) Becomes two times (b) Becomes half

(c) Does not change (d) Becomes one fourth

61. If the resistance of a conductor is 5 Ω at 50°C and 7 Ω at 100°C then the mean temperature coefficient of resistance of the material is

(a) 0.008/°C (b) 0.006/°C

(c) 0.004/°C (d) 0.001/°C

62. The resistance of a discharge tube is

[AFMC 1996; CBSE PMT 1999]

(a) *Ohm*ic (b) Non-*ohm*ic

(c) Both (a) and (b) (d) Zero

63. We are able to obtain fairly large currents in a conductor because

(a) The electron drift speed is usually very large

(b) The number density of free electrons is very high and this can compensate for the low values of the electron drift speed and the very small magnitude of the electron charge

(c) The number density of free electrons as well as the electron drift speeds are very large and these compensate for the very small magnitude of the electron charge

(d) The very small magnitude of the electron charge has to be divided by the still smaller product of the number density and drift speed to get the electric current

64. A platinum resistance thermometer has a resistance of $50\,\Omega$ at $20°C$. When dipped in a liquid the resistance becomes $76.8\,\Omega$. The temperature coefficient of resistance for platinum is $\alpha = 3.92\times10^{-3}/°C$. The temperature of the liquid is

(a) $100°C$ (b) $137°C$

(c) $167°C$ (d) $200°C$

[AFMC 1995]

65. In a wire of circular cross-section with radius r, free electrons travel with a drift velocity V when a current I flows through the wire. What is the current in another wire of half the radius and of the same material when the drift velocity is $2V$

[MP PET 1997]

(a) $2I$ (b) I

(c) $I/2$ (d) $I/4$

66. The resistivity of a wire depends on its [MP PMT/PET 1998]

(a) Length (b) Area of cross-section

(c) Shape (d) Material

67. The conductivity of a superconductor is

[Similar to KCET 1993; MP PMT/PET 1998]

(a) Infinite (b) Very large

(c) Very small (d) Zero

68. In a neon discharge tube 2.9×10^{18} Ne^+ ions move to the right each *second* while 1.2×10^{18} electrons move to the left per *second*. Electron charge is $1.6 \times 10^{-19} C$. The current in the discharge tube

(a) 1 A towards right (b) 0.66 A towards right

(c) 0.66 A towards left (d) Zero

69. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity/ quantities constant along the length of the conductor is/are

[KCET 1994, IIT 1997 Cancelled; CBSE PMT 2001]

(a) Current, electric field and drift speed

(b) Drift speed only

(c) Current and drift speed

(d) Current only

70. The resistivity of alloys $= R_{alloy}$; the resistivity of constituent metals R_{metal}. Then, usually [KCET 1994]

(a) $R_{alloy} = R_{metal}$

(b) $R_{alloy} < R_{metal}$

(c) There is no simple relation between R_{alloy} and R_{metal}

(d) $R_{alloy} > R_{metal}$

71. Two wires A and B of same material and same mass have radius $2r$ and r. If resistance of wire A is $34\,\Omega$, then resistance of B will be

(a) $544\,\Omega$ (b) $272\,\Omega$

(c) $68\,\Omega$ (d) $17\,\Omega$

72. Two rods of same material and length have their electric resistance in ratio $1:2$. When both rods are dipped in water, the correct statement will be [RPMT 1997]

(a) A has more loss of weight

(b) B has more loss of weight

(c) Both have same loss of weight

(d) Loss of weight will be in the ratio $1:2$

73. $20\,\mu A$ current flows for 30 *seconds* in a wire, transfer of charge will be [RPMT 1997]

(a) $2 \times 10^{-4} C$ (b) $4 \times 10^{-4} C$

(c) $6 \times 10^{-4} C$ (d) $8 \times 10^{-4} C$

74. σ_1 and σ_2 are the electrical conductivities of *Ge* and *Na* respectively. If these substances are heated, then

(a) Both σ_1 and σ_2 increase

(b) σ_1 increases and σ_2 decreases

(c) σ_1 decreases and σ_2 increases

(d) Both σ_1 and σ_2 decrease

75. 1.6 *mA* current is flowing in conducting wire then the number of electrons flowing per *second* is [RPMT 1999]

(a) 10^{11} (b) 10^{16}

(c) 10^{19} (d) 10^{15}

76. A current I is passing through a wire having two sections P and Q of uniform diameters d and $d/2$ respectively. If the mean drift velocity of electrons in sections P and Q is denoted by v_P and v_Q respectively, then [MP PET 1999] [Roorkee 1999]

(a) $v_P = v_Q$ (b) $v_P = \frac{1}{2} v_Q$

(c) $v_P = \frac{1}{4} v_Q$ (d) $v_P = 2\, v_Q$

77. If an electric current is passed through a nerve of a man, then man

(a) Begins to laugh

(b) Begins to weep

(c) Is excited

(d) Becomes insensitive to pain

78. The resistance of a coil is 4.2 Ω at 100° C and the temperature coefficient of resistance of its material is 0.004/° C. Its resistance at 0° C is [KCET 1999]

(a) 6.5 Ω (b) 5 Ω

(c) 3 Ω (d) 4 Ω

79. Masses of three wires of copper are in the ratio of 1 : 3 : 5 and their lengths are in the ratio of $5:3:1$. The ratio of their electrical resistances are [AFMC 2000]

(a) 1 : 3 : 5 (b) 5 : 3 : 1

(c) 1 : 15 : 125 (d) 125 : 15 : 1

80. Conductivity increases in the order of [RPET 1997] [AFMC 2000]

(a) *Al, Ag, Cu* (b) *Al, Cu, Ag*

(c) *Cu, Al, Ag* (d) *Ag, Cu, Al*

81. A uniform wire of resistance R is uniformly compressed along its length, until its radius becomes n times the original radius. Now resistance of the wire becomes

[KCET 2000]

(a) $\frac{R}{n^4}$ (b) $\frac{R}{n^2}$

(c) $\frac{R}{n}$ (d) nR

82. The resistance of a conductor is 5 *ohm* at 50°C and 6 *ohm* at 100°C. Its resistance at 0°C is [KCET 2000]

(a) 1 *ohm* (b) 2 *ohm*

(c) 3 *ohm* (d) 4 *ohm*

83. If an electron revolves in the path of a circle of radius of 0.5×10^{-10} *m* at frequency of 5×10^{15} *cycles/s* the electric current in the circle is (Charge of an electron = 1.6×10^{-19} C)

[EAMCET 2000]

(a) 0.4 mA (b) 0.8 mA

(c) 1.2 mA (d) 1.6 mA

84. Equal potentials are applied on an iron and copper wire of same length. In order to have the same current flow in the two wires, the ratio r (iron)/r (copper) of their radii must be (Given that specific resistance of iron = 1.0×10^{-7} *ohm–m* and specific resistance of copper = 1.7×10^{-8} *ohm-m*)

[MP PMT 2000]

(a) About 1.2 (b) About 2.4

(c) About 3.6 (d) About 4.8

85. An electron (charge = 1.6×10^{-19} *coulomb*) is moving in a circle of radius 5.1×10^{-11} m at a frequency of 6.8×10^{15} *revolutions/sec*. The equivalent current is approximately

[MP PET 2000]

(a) 5.1×10^{-3} *amp* (b) 6.8×10^{-3} *amp*

(c) 1.1×10^{-3} *amp* (d) 2.2×10^{-3} *amp*

86. A rod of a certain metal is 1.0 m long and 0.6 cm in diameter. Its resistance is 3.0×10^{-3} *ohm*. Another disc made of the same metal is 2.0 cm in diameter and 1.0 mm thick. What is the resistance between the round faces of the disc

(a) 1.35×10^{-8} *ohm* (b) 2.70×10^{-7} *ohm*

(c) 4.05×10^{-6} *ohm* (d) 8.10×10^{-5} *ohm*

87. At what temperature will the resistance of a copper wire become three times its value at $0^\circ C$ (Temperature coefficient of resistance for copper = 4×10^{-3} *per* $^\circ C$)

[MP PET 2000]

(a) $400^\circ C$ (b) $450^\circ C$

(c) $500^\circ C$ (d) $550^\circ C$

88. An electron revolves 6×10^{15} *times/sec* in circular loop. The current in the loop is [MNR 1995; UPSEAT 2000]

(a) 0.96 mA (b) 0.96 μA

(c) 28.8 A (d) None of these

89. The charge of an electron is 1.6×10^{-19} C. How many electrons strike the screen of a cathode ray tube each *second* when the beam current is 16 mA [AMU (Med.) 2000]

(a) 10^{17} (b) 10^{19}

(c) 10^{-19} (d) 10^{-17}

90. If potential $V = 100 \pm 0.5\, Volt$ and current $I = 10 \pm 0.2$ *amp* are given to us. Then what will be the value of resistance

(a) $10 \pm 0.7\, ohm$ (b) $5 \pm 2\, ohm$

(c) $0.1 \pm 0.2 ohm$ (d) None of these

91. A nichrome wire 50 cm long and one square *millimetre* cross-section carries a current of $4A$ when connected to a $2V$ battery. The resistivity of nichrome wire in *ohm metre* is

[EAMCET 2001]

(a) 1×10^{-6} (b) 4×10^{-7}

(c) 3×10^{-7} (d) 2×10^{-7}

92. If an observer is moving with respect to a stationary electron, then he observes [DCE 2001]

(a) Only magnetic field (b) Only electric field

(c) Both (a) and (b) (d) None of the above

93. Calculate the amount of charge flowing in 2 *minutes* in a wire of resistance 10 Ω when a potential difference of 20 V is applied between its ends [Kerala (Engg.) 2001]

(a) 120 C (b) 240 C

(c) 20 C (d) 4 C

94. If a wire of resistance R is melted and recasted to half of its length, then the new resistance of the wire will be

[KCET (Med.) 2001]

(a) $R/4$ (b) $R/2$

(c) R (d) $2R$

95. The drift velocity does not depend upon [BHU 2001]

(a) Cross-section of the wire (b) Length of the wire

(c) Number of free electrons (d) Magnitude of the current

96. There is a current of 40 *ampere* in a wire of $10^{-6}\, m^2$ area of cross-section. If the number of free electron per m^3 is 10^{29}, then the drift velocity will be [Pb. PMT 2001]

(a) 1.25×10^{3} m/s (b) 2.50×10^{-3} m/s

(c) 25.0×10^{-3} m/s (d) 250×10^{-3} m/s

[MP PET 2000]

97. At room temperature, copper has free electron density of 8.4×10^{28} per m^3. The copper conductor has a cross-section of 10^{-6} m^2 and carries a current of 5.4 A. The electron drift velocity in copper is [UPSEAT 2002]

(a) 400 m/s (b) 0.4 m/s

(c) 0.4 mm/s (d) 72 m/s

98. The resistance of a 5 cm long wire is 10 Ω. It is uniformly stretched so that its length becomes 20 cm. The resistance of the wire is

(a) 160 Ω (b) 80 Ω

(c) 40 Ω (d) 20 Ω

99. The resistance of an incandescent lamp is [KCET 2002]

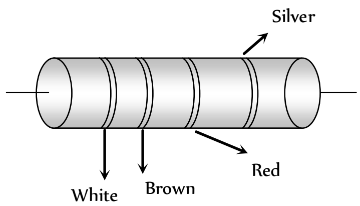
(a) Greater when switched off

(b) Smaller when switched on

(c) Greater when switched on

(d) The same whether it is switched off or switched on

100. In the figure a carbon resistor has bands of different colours on its body as mentioned in the figure. The value of the resistance is



(a) 2.2 $k\Omega$

(b) 3.3 $k\Omega$ [RPET 2001]

(c) 5.6 $k\Omega$

(d) 9.1 $k\Omega$

101. By increasing the temperature, the specific resistance of a conductor and a semiconductor [AIEEE 2002]

(a) Increases for both

(b) Decreases for both

(c) Increases, decreases

(d) Decreases, increases

102. Which of the following is vector quantity [AFMC 2002]

(a) Current density (b) Current

(c) Wattless current (d) Power

103. Masses of 3 wires of same metal are in the ratio 1 : 2 : 3 and their lengths are in the ratio 3 : 2 : 1. The electrical resistances are in ratio [CPMT 2002]

(a) 1 : 4 : 9 (b) 9 : 4 : 1

(c) 1 : 2 : 3 (d) 27 : 6 : 1

104. A current of 1 *mA* is flowing through a copper wire. How many electrons will pass a given point in one *second*

[$e = 1.6 \times 10^{-}$ *Coulomb*] [RPMT 2000; MP PMT 2002]

(a) 6.25×10^{19} (b) 6.25×10^{15}

(c) 6.25×10^{31} (d) 6.25×10^{8}

105. The drift velocity of free electrons in a conductor is '*v*' when a current '*i*' is flowing in it. If both the radius and current are doubled, then drift velocity will be [BHU 2002]

(a) v (b) $\frac{v}{2}$

(c) $\frac{v}{4}$ (d) $\frac{v}{8}$

106. A wire of radius *r* has resistance *R*. If it is stretched to a radius of $\frac{3r}{4}$, its resistance becomes [BHU 2002]

(a) $\frac{9R}{16}$ (b) $\frac{16R}{9}$

(c) $\frac{81R}{256}$ (d) $\frac{256R}{81}$

107. The resistance of a conductor increases with [CBSE PMT 2002]

(a) Increase in length

(b) Increase in temperature

(c) Decrease in cross–sectional area

(d) All of these

108. A copper wire has a square cross-section, 2.0 *mm* on a side. It carries a current of 8 *A* and the density of free electrons is $8 \times 10^{28}\ m^{-3}$. The drift speed of electrons is equal to [AMU (Med.) 2002]

(a) 0.156×10^{-3} *m.s* (b) 0.156×10^{-2} *m.s*

(c) 3.12×10^{-3} *m.s* (d) 3.12×10^{-2} *m.s*

109. Two wires of same material have length L and $2L$ and cross–sectional areas $4A$ and A respectively. The ratio of their specific resistance would be [MHCET 2002]

(a) 1 : 2 (b) 8 : 1

(c) 1 : 8 (d) 1 : 1

110. When a current flows through a conductor its temperature [MHCET 2002]

(a) May increase or decrease

(b) Remains same

(c) Decreases

(d) Increases

111. What length of the wire of specific resistance $48 \times 10^{-8}\ \Omega\ m$ is needed to make a resistance of $4.2\ \Omega$ (diameter of wire = 0.4 *mm*) [CBSE PMT 2000; Pb. PMT 2002]

(a) 4.1 *m* (b) 3.1 *m*

(c) 2.1 *m* (d) 1.1 *m*

112. A strip of copper and another of germanium are cooled from room temperature to 80 *K*. The resistance of [AIEEE 2003]

(a) Each of these increases

(b) Each of these decreases

(c) Copper strip increases and that of germanium decreases

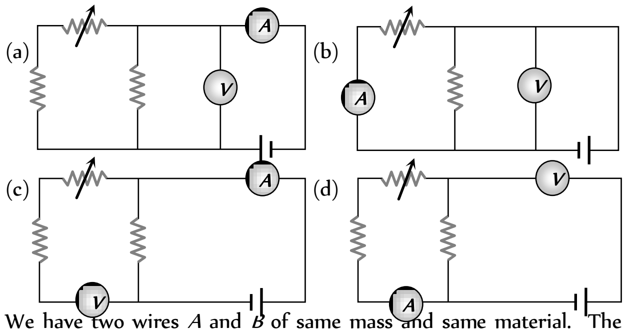
(d) Copper strip decreases and that of germanium increases

113. The length of a given cylindrical wire is increased by 100 %. Due to the consequent decrease in diameter the change in the resistance of the wire will be [AIEEE 2003]

(a) 300 % (b) 200 %

(c) 100 % (d) 50 %

114. Express which of the following setups can be used to verify Ohm's law [IIT-JEE (Screening) 2003]



115. We have two wires *A* and *B* of same mass and same material. The diameter of the wire *A* is half of that *B*. If the resistance of wire *A* is 24 *ohm* then the resistance of wire *B* will be

(a) 12 *Ohm* (b) 3.0 *Ohm*

(c) 1.5 *Ohm* (d) None of the above

116. In a hydrogen discharge tube it is observed that through a given cross-section 3.13×10^{15} electrons are moving from right to left and 3.12×10^{15} protons are moving from left to right. What is the electric current in the discharge tube and what is its direction

(a) $1 mA$ towards right (b) $1 mA$ towards left

(c) $2 mA$ towards left (d) $2 mA$ towards right

117. A steady current *i* is flowing through a conductor of uniform cross-section. Any segment of the conductor has [MP PET 1996]

(a) Zero charge

(b) Only positive charge

(c) Only negative charge

(d) Charge proportional to current *i*

118. The length of the wire is doubled. Its conductance will be [Kerala PMT 2004]

(a) Unchanged (b) Halved

(c) Quadrupled (d) 1/4 of the original value

119. A source of e.m.f. $E = 15\ V$ and having negligible internal resistance is connected to a variable resistance so that the current in the circuit increases with time as $i = 1.2\ t + 3$. Then, the total charge that will flow in first five second will be

(a) 10 *C* (b) 20 *C*

(c) 30 *C* (d) 40 *C*

120. The new resistance of wire of $R\,\Omega$, whose radius is reduced half, is [J & K CET

(a) 16 *R* (b) 3 *R*

(c) 2*R* (d) *R*

121. A resistance *R* is stretched to four times its length. Its new resistance will be [ISM Dhanbad 1994; UPSEAT 2003]

(a) 4 *R* (b) 64 *R*

(c) $R/4$ (d) 16 R

122. What is the resistance of a carbon resistance which has bands of colours brown, black and brown [DCE 1999]

(a) 100 Ω (b) 1000 Ω

(c) 10 Ω (d) 1 Ω

123. The lead wires should have [Pb. PMT 2000]

(a) Larger diameter and low resistance

(b) Smaller diameter and high resistance

(c) Smaller diameter and low resistance

(d) Larger diameter and high resistance

124. The alloys constantan and manganin are used to make standard resistance due to they have

[MH CET 2000; NCERT 1990]

(a) Low resistivity

(b) High resistivity

(c) Low temperature coefficient of resistance

(d) Both (b) and (c)

125. When a potential difference is applied across the ends of a linear metallic conductor [MP PET 1997]

(a) The free electrons are accelerated continuously from the lower potential end to the higher potential end of the conductor

(b) The free electrons are accelerated continuously from the higher potential end to the lower potential end of the conductor

(c) The free electrons acquire a constant drift velocity from the lower potential end to the higher potential end of the conductor

(d) The free electrons are set in motion from their position of rest

126. The electric resistance of a certain wire of iron is *R*. If its length and radius are both doubled, then [CBSE PMT 2004]

(a) The resistance will be doubled and the specific resistance will be halved

(b) The resistance will be halved and the specific resistance will remain unchanged

(c) The resistance will be halved and the specific resistance will be doubled

(d) The resistance and the specific resistance, will both remain unchanged

127. A wire of diameter 0.02 *metre* contains 10^{28} free electrons per cubic metre. For an electrical current of 100 *A*, the drift velocity of the free electrons in the wire is nearly

[UPSEAT 2004]

(a) 1×10^{-19} *m/s* (b) 5×10^{-10} *m/s*

(c) 2×10^{-4} *m/s* (d) 8×10^{3} *m/s*

128. The following four wires are made of the same material and are at the same temperature. Which one of them has highest electrical resistance [UPSEAT 2004]

(a) Length = 50 *cm*, diameter = 0.5 *mm*

(b) Length = 100 *cm*, diameter = 1 *mm*

(c) Length = 200 *cm*, diameter = 2 *mm*

(d) Length = 300 *cm*, diameter = 3 *mm*

129. The colour sequence in a carbon resistor is red, brown, orange and silver. The resistance of the resistor is

[DCE 2004]

(a) $21 \times 10^{3} \pm 10\%$ (b) $23 \times 10^{1} \pm 10$

(c) $21 \times 10^{3} \pm 5\%$ (d) $12 \times 10^{3} \pm 5\%$

130. A thick wire is stretched so that its length become two times. Assuming that there is no change in its density, then what is the ratio of change in resistance of wire to the initial resistance of wire

(a) 2 : 1 (b) 4 : 1

(c) 3 : 1 (d) 1 : 4

131. The length of the resistance wire is increased by 10%. What is the corresponding change in the resistance of wire

[MH CET 2004]

(a) 10% (b) 25%

(c) 21% (d) 9%

132. The electric field *E*, current density *J* and conductivity σ of a conductor are related as [Kerala PMT 2005]

(a) $\sigma = E/j$ (b) $\sigma = j/E$

(c) $\sigma = jE$ (d) $\sigma = 1/jE$

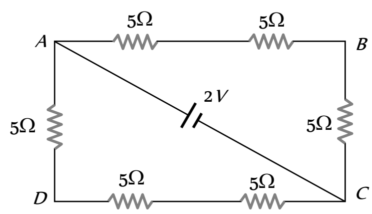
133. Two wires that are made up of two different materials whose specific resistance are in the ratio 2 : 3, length 3 : 4 and area 4 : 5. The ratio of their resistances is [Kerala PMT 2005]

(a) 6 : 5 (b) 6 : 8

(c) 5 : 8 (d) 1 : 2

Grouping of Resistances

1. The potential difference between points A and B of adjoining figure is [CPMT 1991]



(a) $\frac{2}{3}V$

(b) $\frac{8}{9}V$

(c) $\frac{4}{3}V$

(d) 2 V

2. Two resistors of resistance R_1 and R_2 having $R_1 > R_2$ are connected in parallel. For equivalent resistance R, the correct statement is [CPMT 1978; KCET (Med.) 2000]

(a) $R > R_1 + R_2$ (b) $R_1 < R < R_2$

(c) $R_2 < R < (R_1 + R_2)$ (d) $R < R_1$

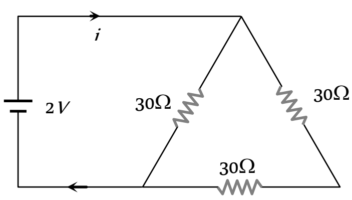
3. A wire of resistance R is divided in 10 equal parts. These parts are connected in parallel, the equivalent resistance of such connection will be [CPMT 1973, 91]

(a) 0.01 *R* (b) 0.1 *R*

(c) 10 *R* (d) 100 *R*

4. The current in the adjoining circuit will be

[IIT 1983; CPMT 1991, 92; MH CET 2002; Pb. PMT 2001; Kerala PMT 2004]



(a) $\frac{1}{45}$ *ampere*

(b) $\frac{1}{15}$ *ampere*

(c) $\frac{1}{10}$ *ampere*

(d) $\frac{1}{5}$ *ampere*

5. There are 8 equal resistances *R*. Two are connected in parallel, such four groups are connected in series, the total resistance of the system will be [MP PMT 1987]

(a) $R/2$ (b) $2R$

(c) $4R$ (d) $8R$

6. Three resistances of one *ohm* each are connected in parallel. Such connection is again connected with $2/3\,\Omega$ resistor in series. The resultant resistance will be [MP PMT 1985]

(a) $\frac{5}{3}\Omega$ (b) $\frac{3}{2}\Omega$

(c) 1Ω (d) $\frac{2}{3}\Omega$

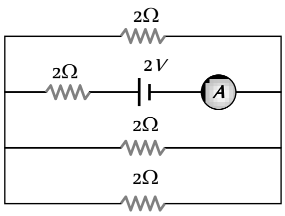
7. The lowest resistance which can be obtained by connecting 10 resistors each of 1/10 *ohm* is

[MP PMT 1984; EAMCET 1994]

(a) $1/250\,\Omega$ (b) $1/200\,\Omega$

(c) $1/100\,\Omega$ (d) $1/10\,\Omega$

8. The reading of the ammeter as per figure shown is



(a) $\frac{1}{8}A$

(b) $\frac{3}{4}A$

(c) $\frac{1}{2}A$

(d) 2 A

9. Three resistors each of 2 *ohm* are connected together in a triangular shape. The resistance between any two vertices will be

[CPMT 1983; MP PET 1990; MP PMT 1993; DCE 2004]

(a) 4/3 *ohm* (b) 3/4 *ohm*

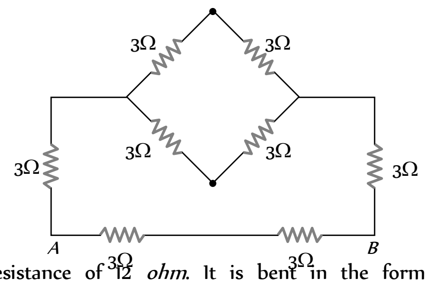
(c) 3 *ohm* (d) 6 *ohm*

10. There are n similar conductors each of resistance R. The resultant resistance comes out to be x when connected in parallel. If they are connected in series, the resistance comes out to be

(a) x/n^2 (b) n^2x

(c) x/n (d) nx

11. Equivalent resistance between *A* and *B* will be [CPMT 1981]



(a) 2 *ohm*

(b) 18 *ohm*

(c) 6 *ohm*

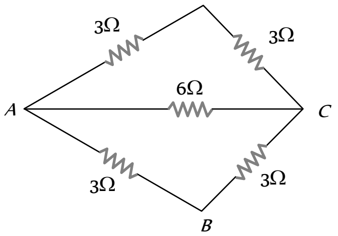
(d) 3.6 *ohm*

12. A wire has a resistance of 12 *ohm*. It is bent in the form of equilateral triangle. The effective resistance between any two corners of the triangle is

(a) 9 *ohms* (b) 12 *ohms*

(c) 6 *ohms* (d) 8/3 *ohms*

13. The effective resistance between the points A and B in the figure is [MP PET 1994]



(a) $5\,\Omega$

(b) $2\,\Omega$

(c) $3\,\Omega$

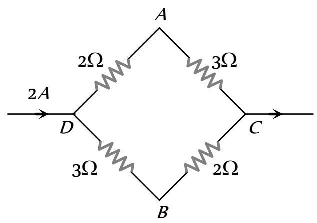
(d) $4\,\Omega$

14. Three resistances of magnitude 2, 3 and 5 *ohm* are connected in parallel to a battery of 10 volts and of negligible resistance. The potential difference across $3\,\Omega$ resistance will be

(a) 2 *volts* (b) 3 *volts*

(c) 5 *volts* (d) 10 *volts*

15. A current of 2 A flows in a system of conductors as shown. The potential difference $(V_A - V_B)$ will be [CPMT 1975, 76]



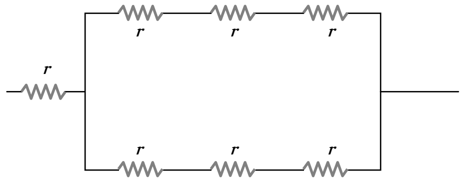
(a) $+2\,V$

(b) $+1\,V$

(c) $-1\,V$

(d) $-2\,V$

16. Referring to the figure below, the effective resistance of the network is [NCERT 1973, 75]



(a) $2r$

(b) $4r$

(c) $10\,r$

(d) $5r/2$

17. Two resistances are joined in parallel whose resultant is $\frac{6}{8}$ *ohm*. One of the resistance wire is broken and the effective resistance becomes $2\,\Omega$. Then the resistance in *ohm* of the wire that got broken was

[DPMT 2004] [CPMT 1976; DPMT 1982]

(a) 3/5 (b) 2

(c) 6/5 (d) 3

18. Given three equal resistors, how many different combination of all the three resistors can be made [NCERT 1970]

(a) Six (b) Five

(c) Four (d) Three

19. Lamps used for household lighting are connected in

(a) Series (b) Parallel

(c) Mixed circuit (d) None of the above

20. The equivalent resistance of resistors connected in series is always [CPMT 1984;

(a) Equal to the mean of component resistors

(b) Less than the lowest of component resistors

(c) In between the lowest and the highest of component resistors

(d) Equal to sum of component resistors

21. A cell of negligible resistance and e.m.f. 2 volts is connected to series combination of 2, 3 and 5 *ohm*. The potential difference in volts between the terminals of 3 *ohm* resistance will be

(a) 0.6 (b) 2/3

(c) 3 (d) 6

22. Four wires of equal length and of resistances 10 *ohms* each are connected in the form of a square. The equivalent resistance between two opposite corners of the square is [NCERT 1977]

(a) 10 ohm (b) 40 ohm

(c) 20 ohm (d) 10/4 ohm

23. Two resistors are connected (a) in series (b) in parallel. The equivalent resistance in the two cases are 9 ohm and 2 ohm respectively. Then the resistances of the component resistors are

(a) 2 ohm and 7 ohm (b) 3 ohm and 6 ohm

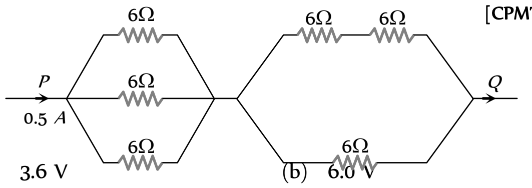
(c) 3 ohm and 9 ohm (d) 5 ohm and 4 ohm

24. Resistors of 1, 2, 3 *ohm* are connected in the form of a triangle. If a 1.5 volt cell of negligible internal resistance is connected across 3 *ohm* resistor, the current flowing through this resistance will be

(a) 0.25 *amp* (b) 0.5 *amp*

(c) 1.0 *amp* (d) 1.5 *amp*

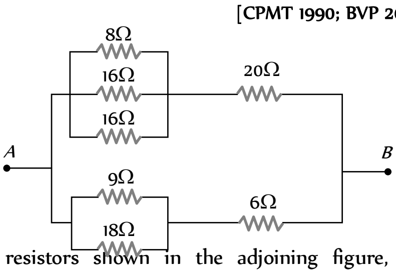
25. Resistances of 6 *ohm* each are connected in the manner shown in adjoining figure. With the current 0.5 *ampere* as shown in figure, the potential difference $V_P - V_Q$ is [CPMT 1989]



(a) 3.6 V (b) 6.0 V

(c) 3.0 V (d) 7.2 V

26. The equivalent resistance of the arrangement of resistances shown in adjoining figure between the points *A* and *B* is [CPMT 1990; BVP 2003]



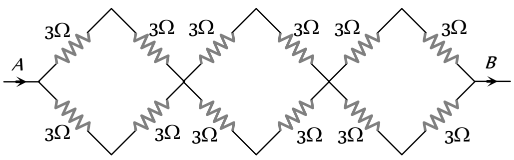
(a) 6 *ohm*

(b) 8 *ohm*

(c) 16 *ohm*

(d) 24 *ohm*

27. In the network of resistors shown in the adjoining figure, the equivalent resistance between *A* and *B* is



(a) 54 *ohm* (b) 18 *ohm*

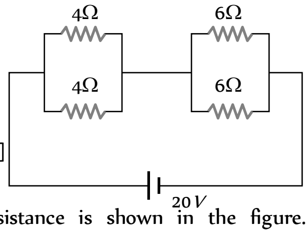
(c) 36 *ohm* (d) 9 *ohm*

28. A wire is broken in four equal parts. A packet is formed by keeping the four wires together. The resistance of the packet in comparison to the resistance of the wire will be [MP PET 1985; AFMC 2005]

(a) Equal (b) One fourth

(c) One eight (d) $\frac{1}{16}th$

29. Four resistances are connected in a circuit in the given figure. The electric current flowing through 4 *ohm* and 6 *ohm* resistance is respectively [MP PET 1993]



(a) 2 *amp* and 4 *amp*

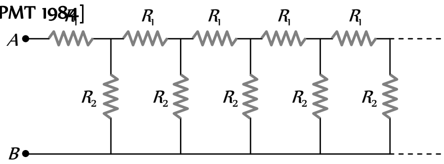
(b) 1 *amp* and 2 *amp*

(c) 1 *amp* and 1 *amp* [CPMT 1984]

(d) 2 *amp* and 2 *amp*

30. An infinite sequence of resistance is shown in the figure. The resultant resistance between *A* and *B* will be, when $R_1 = 1\,ohm$ and $R_2 = 2\,ohm$ [MP PET 1993]

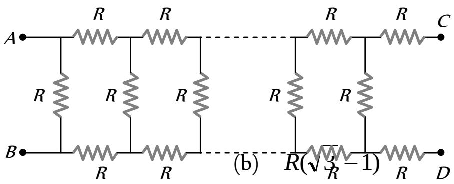
[CPMT 1984]



(a) Infinity (b) 1Ω

(c) 2Ω (d) 1.5Ω

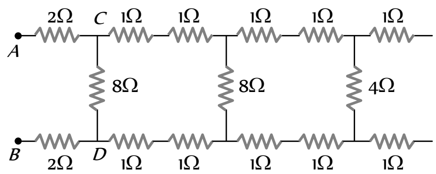
31. In the figure, the value of resistors to be connected between *C* and *D* so that the resistance of the entire circuit between *A* and *B* does not change with the number of elementary sets used is



(a) *R* (b) $R(\sqrt{3}-1)$

(c) 3 *R* (d) $R(\sqrt{3}+1)$

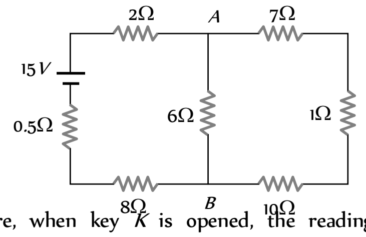
32. In the figure shown, the total resistance between *A* and *B* is



(a) 12Ω (b) 4Ω

(c) 6Ω (d) 8Ω

33. The current from the battery in circuit diagram shown is [IIT 1989]



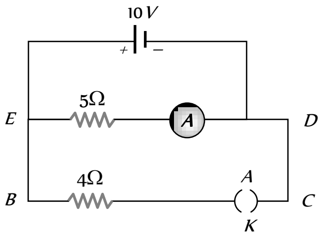
(a) 1 *A*

(b) 2 *A*

(c) 1.5 *A*

(d) 3 *A*

34. In the given figure, when key *K* is opened, the reading of the ammeter *A* will be



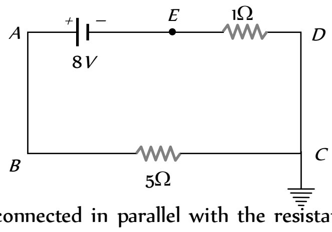
(a) 50 *A*

(b) 2 A

(c) 0.5 A

(d) $\frac{10}{9}A$

35. In the given circuit, the potential of the point E is [MP PMT 2003]



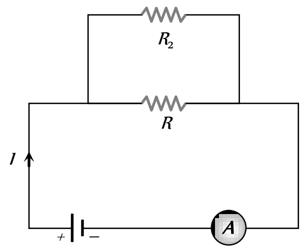
(a) Zero

(b) $-8\,V$

(c) $-4/3\,V$

(d) 4/3 V

36. If a resistance R_2 is connected in parallel with the resistance R in the circuit shown, then possible value of current through R and the possible value of R_2 will be



(a) $\frac{I}{3}, R$

(b) $I, 2R$

(c) $\frac{I}{3}, 2R$

(d) $\frac{I}{2}, R$

37. Four wires *AB, BC, CD, DA* of resistance 4 *ohm* each and a fifth wire *BD* of resistance 8 *ohm* are joined to form a rectangle *ABCD* of which *BD* is a diagonal. The effective resistance between the points *A* and *B* is [MP PMT 1994]

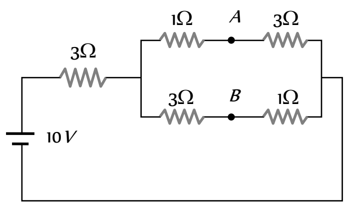
(a) 24 *ohm*

(b) 16 *ohm*

(c) $\frac{4}{3}ohm$

(d) $\frac{8}{3}ohm$

38. A battery of e.m.f. 10 V is connected to resistance as shown in figure. The potential difference $V_A - V_B$ between the points A and B is



(a) $-2V$

(b) $2V$

(c) $5V$

(d) $\frac{20}{11}V$

39. Three resistances, each of 1 *ohm*, are joined in parallel. Three such combinations are put in series, then the resultant resistance will be

(a) 9 *ohm*

(b) 3 *ohm*

(c) 1 *ohm*

(d) $\frac{1}{3}ohm$

40. A student has 10 resistors of resistance 'r'. The minimum resistance made by him from given resistors is [AFMC 1995]

(a) 10 r

(b) $\frac{r}{10}$

(c) $\frac{r}{100}$

(d) $\frac{r}{5}$

41. Two wires of same metal have the same length but their cross-sections are in the ratio $3:1$. They are joined in series. The resistance of the thicker wire is $10\,\Omega$. The total resistance of the combination will be [CBSE PMT 1995]

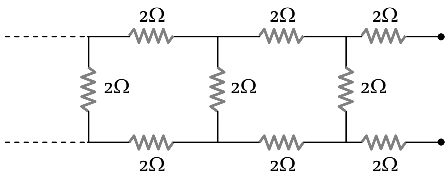
(a) $40\,\Omega$

(b) $\frac{40}{3}\Omega$

(c) $\frac{5}{2}\Omega$

(d) $100\,\Omega$

42. The equivalent resistance of the following infinite network of resistances is [AIIMS 1995]



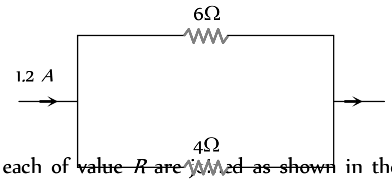
(a) Less than $4\,\Omega$

(b) $4\,\Omega$

(c) More than $4\,\Omega$ but less than $12\,\Omega$

(d) $12\,\Omega$

43. In the figure given below, the current passing through $6\,\Omega$ resistor is [Manipal MEE 1995]



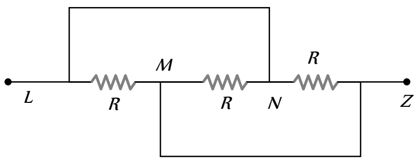
(a) 0.40 *ampere*

(b) 0.48 *ampere*

(c) 0.72 *ampere*

(d) 0.80 *ampere*

44. Three equal resistances each of value R are joined as shown in the figure. The equivalent resistance between M and N is [MP PET 1995]



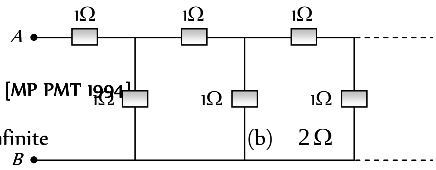
(a) R

(b) $2R$

(c) $\frac{R}{2}$ [MP PMT 1994]

(d) $\frac{R}{3}$

45. The equivalent resistance between points A and B of an infinite network of resistances each of $1\,\Omega$ connected as shown, is



[MP PMT 1994]

(a) Infinite

(b) $2\,\Omega$

(c) $\frac{1+\sqrt{5}}{2}\Omega$

(d) Zero

46. A copper wire of resistance R is cut into ten parts of equal length. Two pieces each are joined in series and then five such combinations are joined in parallel. The new combination will have a resistance

(a) R

(b) $\frac{R}{4}$

(c) $\frac{R}{5}$

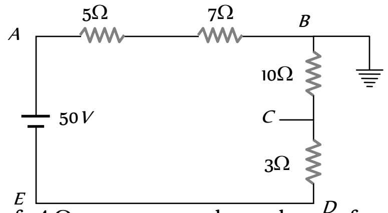
(d) $\frac{R}{25}$

47. A wire has resistance 12Ω. It is bent in the form of a circle. The effective resistance between the two points on any diameter is equal to [JIPMER 1999]

(a) 12Ω (b) 6Ω

(c) 3Ω (d) 24Ω

48. In the circuit shown, the point '*B*' is earthed. The potential at the point '*A*' is



(a) 14 *V*

(b) 24 *V*

(c) 26 *V*

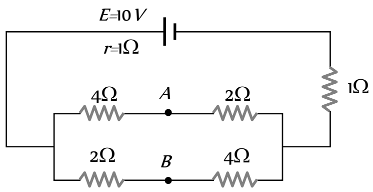
(d) 50 *V*

49. Three resistors each of 4Ω are connected together to form a network. The equivalent resistance of the network cannot be

(a) 1.33Ω (b) 3.0Ω

(c) 6.0Ω (d) 12.0Ω

50. In the circuit shown below, the cell has an e.m.f. of 10 *V* and internal resistance of 1 *ohm*. The other resistances are shown in the figure. The potential difference $V_A - V_B$ is [MP PMT 1997]



(a) 6 *V*

(b) 4 *V*

(c) 2 *V*

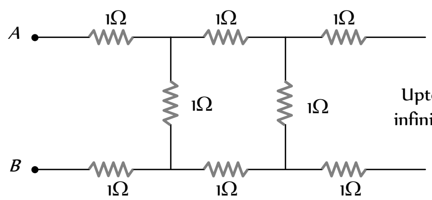
(d) -2 *V*

51. *A* wire of resistance *R* is cut into '*n*' equal parts. These parts are then connected in parallel. The equivalent resistance of the combination will be [MP PMT/PET 1998; BHU 2005]

(a) nR (b) $\frac{R}{n}$

(c) $\frac{n}{R}$ (d) $\frac{R}{n^2}$

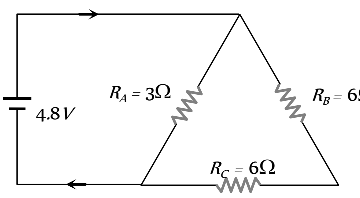
52. The resistance between the terminal points *A* and *B* of the given infinitely long circuit will be [MP PMT/PET 1998]



(a) $(\sqrt{3}-1)$ (b) $(1-\sqrt{3})$

(c) $(1+\sqrt{3})$ (d) $(2+\sqrt{3})$

53. The current in the given circuit is [CBSE PMT 1999]



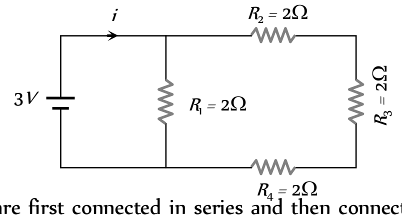
(a) 8.31 *A*

(b) 6.82 *A*

(c) 4.92 *A*

(d) 2 *A*

54. What is the current (i) in the circuit as shown in figure [AIIMS 1998]



(a) 2 *A*

(b) 1.2 *A*

(c) 1 *A*

(d) 0.5 *A*

55. *n* equal resistors are first connected in series and then connected in parallel. What is the ratio of the maximum to the minimum resistance [KCET 1994]

(a) n (b) $\frac{1}{n^2}$

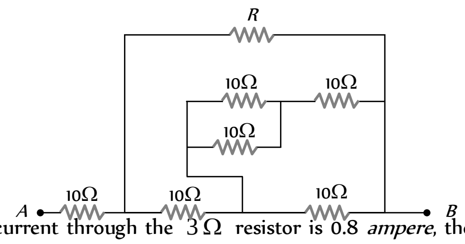
(c) n^2 (d) $\frac{1}{n}$

56. A uniform wire of 16Ω is made into the form of a square. Two opposite corners of the square are connected by a wire of resistance 16Ω. The effective resistance between the other two opposite corners is [EAMCET (Med.) 1995]

(a) 32Ω (b) 20Ω

(c) 8Ω (d) 4Ω

57. For what value of *R* the net resistance of the circuit will be 18 *ohms*



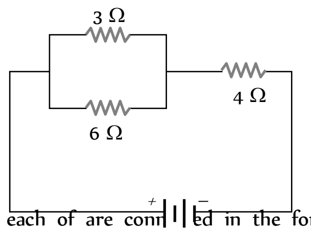
(a) 8Ω

(b) 10Ω

(c) 16Ω

(d) 24Ω

58. In the figure, current through the 3Ω resistor is 0.8 *ampere*, then potential drop through 4Ω resistor is [CBSE PMT 1993; AFMC 1999; MP PMT 2004]



(a) 9.6 *V*

(b) 2.6 *V*

(c) 4.8 *V*

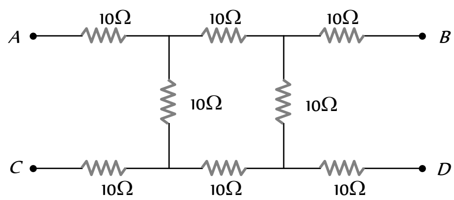
(d) 1.2 *V*

59. Three resistances 4Ω each of are connected in the form of an equilateral triangle. The effective resistance between two corners is

(a) 8Ω (b) 12Ω

(c) $\frac{3}{8}\Omega$ (d) $\frac{8}{3}\Omega$

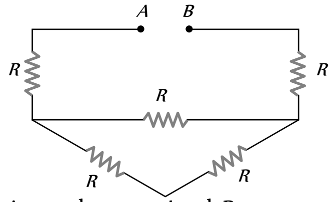
60. What will be the equivalent resistance between the two points *A* and *D* [CBSE PMT 1996]



(a) $10\,\Omega$ (b) $20\,\Omega$

(c) $30\,\Omega$ (d) $40\,\Omega$

61. What is the equivalent resistance between A and B in the figure below if $R = 3\,\Omega$ [SCRA 1996]



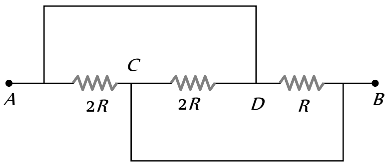
(a) $9\,\Omega$

(b) $12\,\Omega$

(c) $15\,\Omega$

(d) None of these

62. What is the equivalent resistance between A and B [BHU 1997; MP PET 2001]



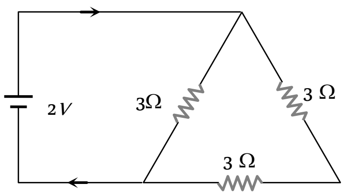
(a) $\frac{2}{3}R$

(b) $\frac{3}{2}R$

(c) $\frac{R}{2}$

(d) $2R$

63. The current in the following circuit is [CBSE PMT 1997]



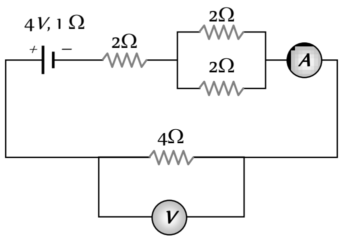
(a) $\frac{1}{8}A$

(b) $\frac{2}{9}A$

(c) $\frac{2}{3}A$

(d) $1A$

64. What is the equivalent resistance of the circuit [KCET 1998]



(a) $6\,\Omega$

(b) $7\,\Omega$

(c) $8\,\Omega$

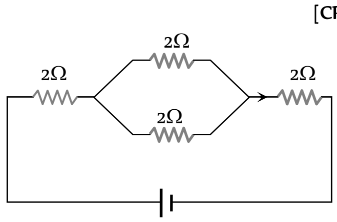
(d) $9\,\Omega$

65. 10 wires (same length, same area, same material) are connected in parallel and each has 1Ω resistance, then the equivalent resistance will be [RPMT 1999]

(a) $10\,\Omega$ (b) $1\,\Omega$

(c) $0.1\,\Omega$ (d) $0.001\,\Omega$

66. The equivalent resistance of the circuit shown in the figure is [CPMT 1999]



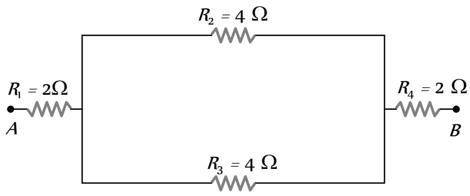
(a) $8\,\Omega$

(b) $6\,\Omega$

(c) $5\,\Omega$

(d) $4\,\Omega$

67. In the given figure, the equivalent resistance between the points A and B is [AIIMS 1999]



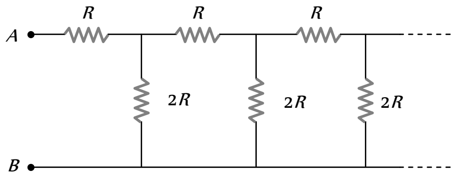
(a) $8\,\Omega$

(b) $6\,\Omega$

(c) $4\,\Omega$

(d) $2\,\Omega$

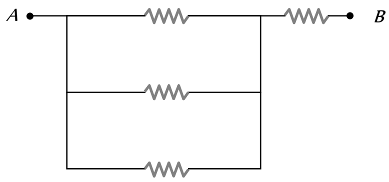
68. An infinite ladder network is arranged with resistances R and $2R$ as shown. The effective resistance between terminals A and B is



(a) ∞ (b) R

(c) $2R$ (d) $3R$

69. If all the resistors shown have the value 2 *ohm* each, the equivalent resistance over AB is [JIPMER 1999]



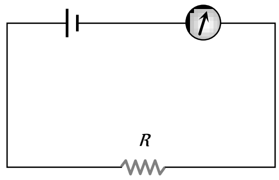
(a) 2 *ohm*

(b) 4 *ohm*

(c) $1\frac{2}{3}$ *ohm*

(d) $2\frac{2}{3}$ *ohm*

70. A battery of *emf* 10 V and internal resistance $3\,\Omega$ is connected to a resistor as shown in the figure. If the current in the circuit is 0.5 A, then the resistance of the resistor will be



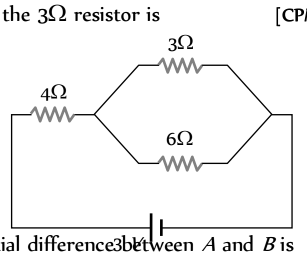
(a) $19\,\Omega$

(b) $17\,\Omega$

(c) $10\,\Omega$

(d) $12\,\Omega$

71. The potential drop across the 3Ω resistor is [CPMT 2000]



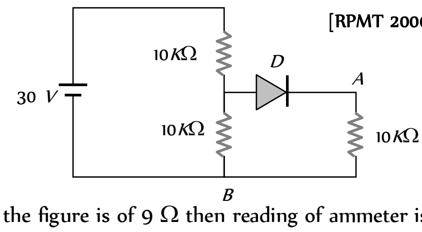
(a) 1 V

(b) 1.5 V

(c) 2 V

(d) 3 V

72. In the given figure, potential difference between A and B is [RPMT 2000]



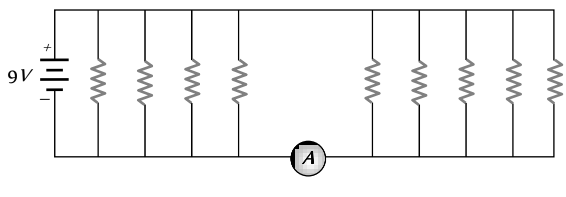
(a) 0

(b) 5 *volt*

(c) 10 *volt*

(d) 15 *volt*

73. If each resistance in the figure is of $9\,\Omega$ then reading of ammeter is



(a) 5 *A* (b) 8 *A*

(c) 2 *A* (d) 9 *A*

74. Four resistances 10 Ω, 5 Ω, 7 Ω and 3 Ω are connected so that they form the sides of a rectangle *AB, BC, CD* and *DA* respectively. Another resistance of 10 Ω is connected across the diagonal *AC*. The equivalent resistance between *A* and *B* is

(a) 2 Ω (b) 5 Ω

(c) 7 Ω (d) 10 Ω

75. Two wires of equal diameters, of resistivities ρ_1 and ρ_2 and lengths l and l, respectively, are joined in series. The equivalent resistivity of the combination is

[EAMCET (Engg.) 2000]

(a) $\dfrac{\rho_1 l_1 + \rho_2 l_2}{l_1 + l_2}$ (b) $\dfrac{\rho_1 l_2 + \rho_2 l_1}{l_1 - l_2}$

(c) $\dfrac{\rho_1 l_2 + \rho_2 l_1}{l_1 + l_2}$ (d) $\dfrac{\rho_1 l_1 - \rho_2 l_2}{l_1 - l_2}$

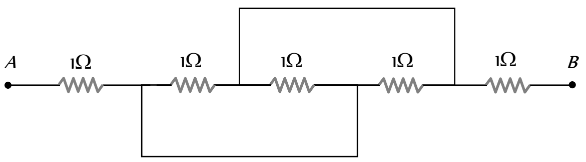
76. Four resistances of 100 Ω each are connected in the form of square. Then, the effective resistance along the diagonal points is

(a) 200 Ω (b) 400 Ω

(c) 100 Ω (d) 150 Ω

77. Equivalent resistance between the points *A* and *B* is (in Ω)

[AMU (Engg.) 2000]



(a) $\dfrac{1}{5}$ (b) $1\dfrac{1}{4}$

(c) $2\dfrac{1}{3}$ (d) $3\dfrac{1}{2}$

78. Two wires of the same material and equal length are joined in parallel combination. If one of them has half the thickness of the other and the thinner wire has a resistance of 8 *ohms*, the resistance of the combination is equal to

[AMU (Engg.) 2000]

(a) $\dfrac{5}{8}$ *ohms* (b) $\dfrac{8}{5}$ *ohms*

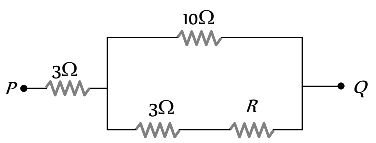
(c) $\dfrac{3}{8}$ *ohms* (d) $\dfrac{8}{3}$ *ohms*

79. In the circuit shown here, what is the value of the unknown resistor *R* so that the total resistance of the circuit between points *P* and *Q* is also equal to *R* [MP PET 2001]

(a) 3 *ohms*

(b) $\sqrt{39}$ *ohms*

(c) $\sqrt{69}$ *ohms*



(d) 10 *ohms*

80. A uniform wire of resistance 9 Ω is cut into 3 equal parts. They are connected in the form of equilateral triangle *ABC*. A cell of e.m.f. 2 *V* and negligible internal resistance is connected across *B* and *C*. Potential difference across *AB* is

[Kerala (Engg.) 2001]

(a) 1 *V* (b) 2 *V*

(c) 3 *V* (d) 0.5 *V*

81. [EAMCET (Med.) 2000] The resistors of resistances 2 Ω, 4 Ω and 8 Ω are connected in parallel, then the equivalent resistance of the combination will be [KCET 2001]

(a) $\dfrac{8}{7}\Omega$ (b) $\dfrac{7}{8}\Omega$

(c) $\dfrac{7}{4}\Omega$ (d) $\dfrac{4}{9}\Omega$

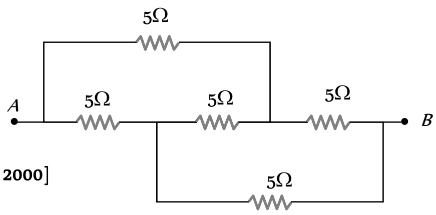
82. Effective resistance between *A* and *B* is [UPSEAT 2001]

(a) 15 Ω

(b) 5 Ω

(c) $\dfrac{5}{2}\Omega$

(d) 20 Ω [MH CET 2000]



83. The effective resistance of two resistors in parallel is $\dfrac{12}{7}\Omega$. If one of the resistors is disconnected the resistance becomes 4 Ω. The resistance of the other resistor is [MH CET 2002]

(a) 4 Ω (b) 3 Ω

(c) $\dfrac{12}{7}\Omega$ (d) $\dfrac{7}{12}\Omega$

84. Two resistance wires on joining in parallel the resultant resistance is $\dfrac{6}{5}$ *ohms*. One of the wire breaks, the effective resistance is 2 *ohms*. The resistance of the broken wire is

[MP PET 2001, 2002]

(a) $\dfrac{3}{5}$ *ohm* (b) 2 *ohm*

(c) $\dfrac{6}{5}$ *ohm* (d) 3 *ohm*

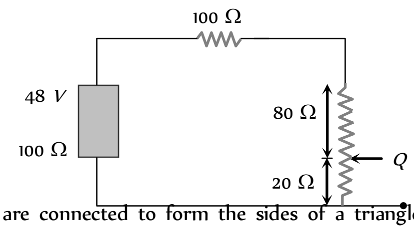
85. In the circuit, the potential difference across *PQ* will be nearest to

(a) 9.6 *V*

(b) 6.6 *V*

(c) 4.8 *V*

(d) 3.2 *V*



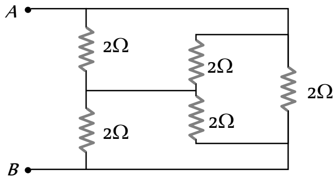
86. Three resistors are connected to form the sides of a triangle *ABC*, the resistance of the sides *AB, BC* and *CA* are 40 *ohms*, 60 *ohms* and 100 *ohms* respectively. The effective resistance between the points *A* and *B* in *ohms* will be

[JIPMER 2002]

(a) 32 (b) 64

(c) 50 (d) 200

87. Find the equivalent resistance across *AB* [Orissa JEE 2002]



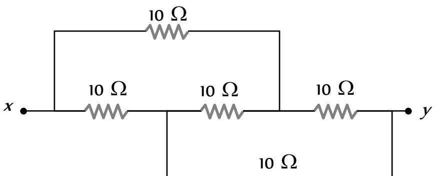
(a) 1 Ω

(b) 2 Ω

(c) 3 Ω

(d) 4 Ω

88. The equivalent resistance between *x* and *y* in the circuit shown is



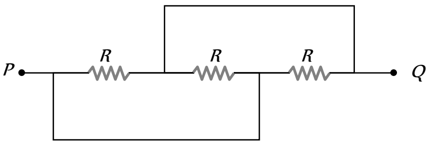
(a) 10 Ω

(b) 40 Ω

(c) 20 Ω

(d) $\frac{5}{2}$ Ω

89. The equivalent resistance between the points *P* and *Q* of the circuit given is [Pb. PMT 2002]



(a) $\frac{R}{4}$

(b) $\frac{R}{3}$

(c) 4 *R*

(d) 2 *R*

90. Two wires of the same dimensions but resistivities ρ_1 and ρ_2 are connected in series. The equivalent resistivity of the combination is

(a) $\rho_1 + \rho_2$ (b) $\frac{\rho_1 + \rho_2}{2}$

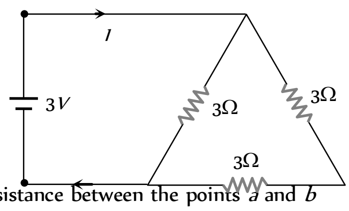
(c) $\sqrt{\rho_1 \rho_2}$ (d) $2(\rho_1 + \rho_2)$

91. Three unequal resistors in parallel are equivalent to a resistance 1 *ohm*. If two of them are in the ratio 1 : 2 and if no resistance value is fractional, the largest of the three resistances in *ohms* is

(a) 4 (b) 6

(c) 8 (d) 12

92. A 3*volt* battery with negligible internal resistance is connected in a circuit as shown in the figure. The current *I*, in the circuit will be



(a) 1/3 *A*

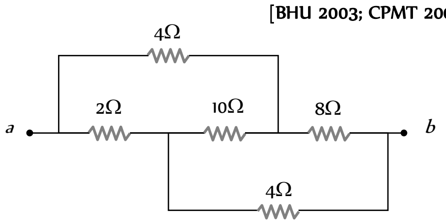
(b) 1 *A*

(c) 1.5 *A*

(d) 2 *A*

93. Find the equivalent resistance between the points *a* and *b*

[BHU 2003; CPMT 2004]



(a) 2 Ω

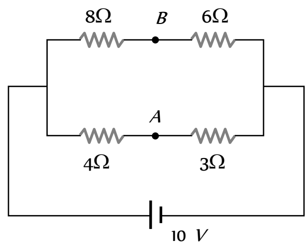
(b) 4 Ω

(c) 8 Ω

(d) 16 Ω

94. The potential difference between point *A* & *B* is

[BHU 2003; CPMT 2004; MP PMT 2005]



(a) $\frac{20}{7}$ *V*

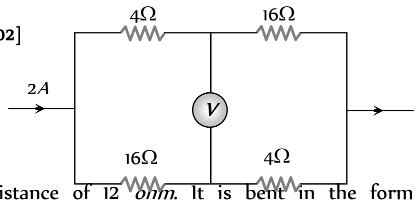
(b) $\frac{40}{7}$ *V*

(c) $\frac{10}{7}$ *V*

(d) 0

95. In the circuit shown below, The reading of the voltmeter *V* is

[MP PMT 2002]



(a) 12 *V*

(b) 8 *V*

(c) 20 *V*

(d) 16 *V*

96. A wire has a resistance of 12 *ohm*. It is bent in the form of equilateral triangle. The effective resistance between any two corners of the triangle is

(a) 9 *ohms* (b) 12 *ohms*

(c) 6 *ohms* (d) 8/3 *ohms*

97. A series combination of two resistors 1 Ω each is connected to a 12 *V* battery of internal resistance 0.4 Ω. The current flowing through it will be [MH CET (Med.) 1999]

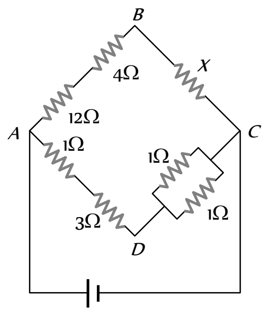
(a) 3.5 *A* (b) 5 *A*

(c) 6 *A* (d) 10 *A*

[KCET 2003]

98. In the circuit shown in the adjoining figure, the current between *B* and *D* is zero, the unknown resistance is of

[CPMT 1986]



(a) 4 Ω

[EAMCET 2003]

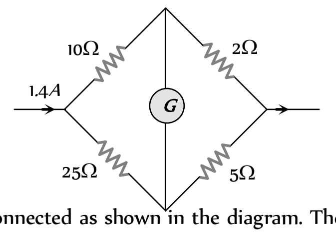
(b) 2 Ω

(c) 3 Ω

(d) *emf* of a cell is required to find the value of *X*

[AIEEE 2003]

99. In the circuit shown in the figure, the current flowing in 2 Ω resistance [CPMT 1989; MP PMT 2004]



(a) 1.4 *A*

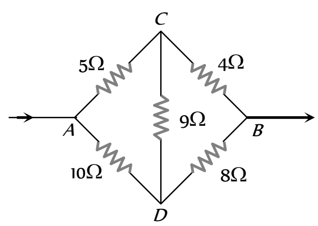
(b) 1.2 *A*

(c) 0.4 *A*

(d) 1.0 *A*

100. Five resistors are connected as shown in the diagram. The equivalent resistance between *A* and *B* is

[MP PMT 1996]



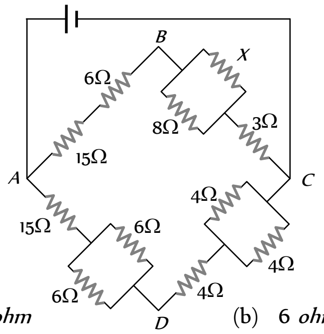
(a) 6 *ohm*

(b) 9 *ohm*

(c) $12\,ohm$

(d) $15\,ohm$

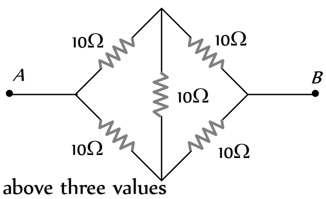
101. In the figure given the value of X resistance will be, when the p.d. between B and D is zero [MP PET 1993]



(a) 4 *ohm* (b) 6 *ohm*

(c) 8 *ohm* (d) 9 *ohm*

102. The effective resistance between points A and B is [NCERT 1974; MP PMT 2000]



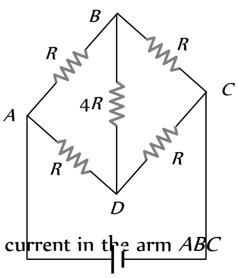
(a) $10\,\Omega$

(b) $20\,\Omega$

(c) $40\,\Omega$

(d) None of the above three values

103. Five resistors of given values are connected together as shown in the figure. The current in the arm *BD* will be [MP PMT 1995]



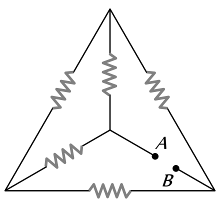
(a) Half the current in the arm *ABC*

(b) Zero

(c) Twice the current in the arm *ABC*

(d) Four times the current in the arm *ABC*

104. In the network shown in the figure, each of the resistance is equal to $2\,\Omega$. The resistance between the points A and B is [CBSE PMT 1995]



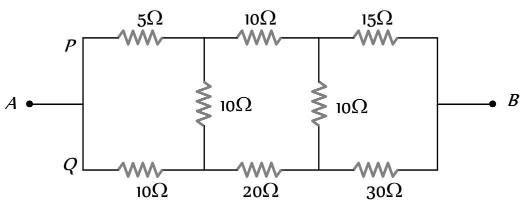
(a) $1\,\Omega$

(b) $4\,\Omega$

(c) $3\,\Omega$

(d) $2\,\Omega$

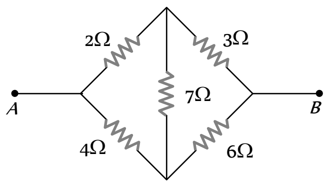
105. In the arrangement of resistances shown below, the effective resistance between points A and B is [MP PMT 1997; RPET 2001]



(a) $20\,\Omega$ (b) $30\,\Omega$

(c) $90\,\Omega$ (d) $110\,\Omega$

106. Five resistances are connected as shown in the figure. The effective resistance between the points A and B is [MP PMT 1999; KCET 2001; BHU 2001, 05]



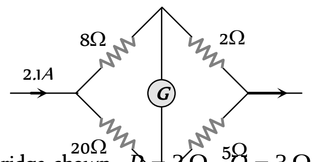
(a) $\frac{10}{3}\,\Omega$

(b) $\frac{20}{3}\,\Omega$

(c) $15\,\Omega$

(d) $6\,\Omega$

107. In the given figure, when galvanometer shows no deflection, the current (in ampere) flowing through $5\,\Omega$ resistance will be



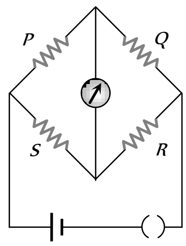
(a) 0.5

(b) 0.6

(c) 0.9

(d) 1.5

108. In the Wheatstone's bridge shown, $P = 2\,\Omega$, $Q = 3\,\Omega$, $R = 6\,\Omega$ and $S = 8\,\Omega$. In order to obtain balance, shunt resistance across 'S' must be [SCRA 1998]



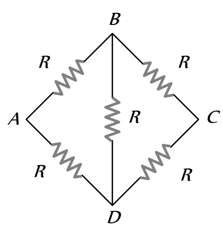
(a) $2\,\Omega$

(b) $3\,\Omega$

(c) $6\,\Omega$

(d) $8\,\Omega$

109. Five equal resistances each of value R are connected in a form shown alongside. The equivalent resistance of the network



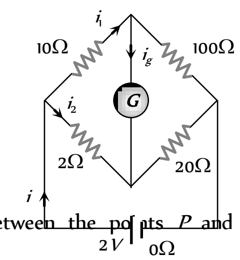
(a) Between the points B and D is R

(b) Between the points B and D is $\frac{R}{2}$

(c) Between the points A and C is R

(d) Between the points A and C is $\frac{R}{2}$

110. In the circuit shown below the resistance of the galvanometer is 20 Ω. In which case of the following alternatives are the currents arranged strictly in the decreasing order



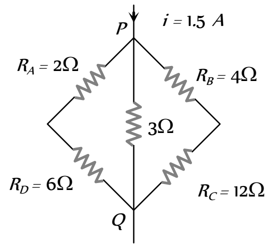
(a) i, i_1, i_2, i_g

(b) i, i_2, i_1, i_g

(c) i, i_2, i_g, i_1

(d) i, i_1, i_g, i_2

111. Potential difference between the points P and Q in the electric circuit shown is [KCET 1999]



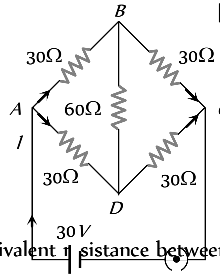
(a) 4.5 V

(b) 1.2 V

(c) 2.4 V

(d) 2.88 *V*

112. The current between *B* and *D* in the given figure is [RPET 2000; DCE 2001]



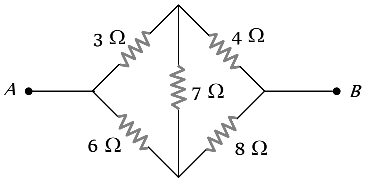
(a) 1 *amp*

(b) 2 *amp*

(c) Zero

(d) 0.5 *amp*

113. In the given figure, equivalent resistance between *A* and *B* will be



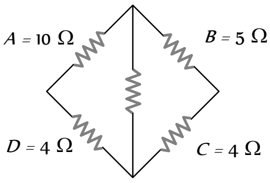
(a) $\frac{14}{3}\ \Omega$

(b) $\frac{3}{14}\ \Omega$

(c) $\frac{9}{14}\ \Omega$

(d) $\frac{14}{9}\ \Omega$

114. In a typical Wheatstone network, the resistances in cyclic order are *A* = 10 Ω, *B* = 5 Ω, *C* = 4 Ω and *D* = 4 Ω for the bridge to be balanced [KCET 2000]



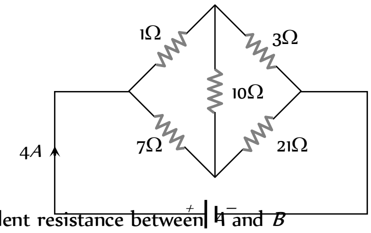
(a) 10 Ω should be connected in parallel with *A*

(b) 10 Ω should be connected in series with *A*

(c) 5 Ω should be connected in series with *B*

(d) 5 Ω should be connected in parallel with *B*

115. In the circuit shown in figure, the current drawn from the battery is 4*A*. If 10 Ω resistor is replaced by 20 Ω resistor, then current drawn from the circuit will be [KCET 2000; CBSE PMT 2001]



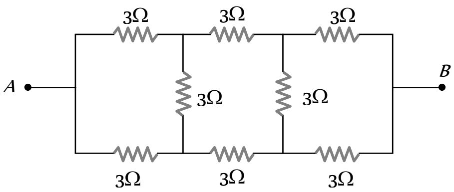
(a) 1 *A*

(b) 2 *A*

(c) 3 *A*

(d) 0 *A*

116. Calculate the equivalent resistance between *A* and *B* [UPSEAT 2001]



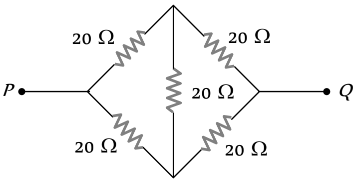
(a) $\frac{9}{2}\Omega$

(b) 3 Ω

(c) 6 Ω

(d) $\frac{5}{3}\Omega$

117. The equivalent resistance between *P* and *Q* in the given figure, is



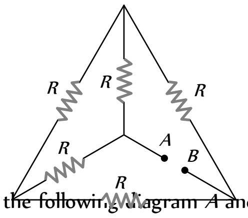
(a) 50 Ω

(b) 40 Ω

(c) 30 Ω

(d) 20 Ω

118. If each of the resistance of the network shown in the figure is *R*, the equivalent resistance between *A* and *B* is [KCET 2002]



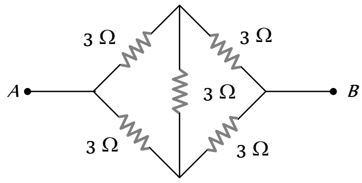
(a) 5 *R*

(b) 3 *R*

(c) *R* [CBSE PMT 2000]

(d) *R*/2

119. The equivalent resistance of the following diagram *A* and *B* is



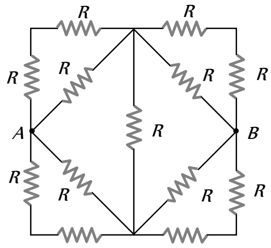
(a) $\frac{2}{3}\Omega$

(b) 9 Ω

(c) 6 Ω

(d) None of these

120. Thirteen resistances each of resistance *R ohm* are connected in the circuit as shown in the figure below. The effective resistance between *A* and *B* is [KCET 2003]



(a) $2R\,\Omega$

(b) $\frac{4R}{3}\ \Omega$

(c) $\frac{2R}{3}\ \Omega$

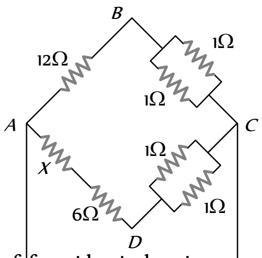
(d) $R\,\Omega$

121. In a Wheatstone's bridge all the four arms have equal resistance *R*. If the resistance of the galvanometer arm is also *R*, the equivalent resistance of the combination as seen by the battery is

(a) $\frac{R}{2}$ (b) *R*

(c) 2 *R* (d) $\frac{R}{4}$

122. For what value of unknown resistance *X*, the potential difference between *B* and *D* will be zero in the circuit shown in the figure



(a) 4 Ω

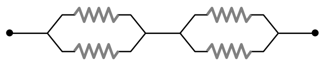
(b) 6 Ω

(c) 2 Ω

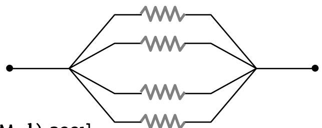
(d) 5 Ω

123. Which arrangement of four identical resistances should be used to draw maximum energy from a cell of voltage *V* [MP PMT 2004]

(a)

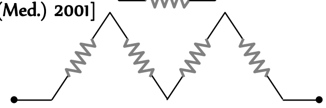


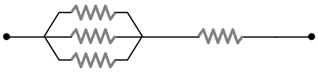
(b)



[MH CET (Med.) 2001]

(c)



(d) 

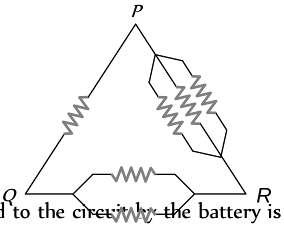
124. An unknown resistance R_1 is connected in series with a resistance of 10 Ω. This combinations is connected to one gap of a metre bridge while a resistance R_2 is connected in the other gap. The balance point is at 50 *cm*. Now, when the 10 Ω resistance is removed the balance point shifts to 40 *cm*. The value of R_1 is (in *ohm*)

(a) 60 (b) 40
(c) 20 (d) 10

125. A wire has a resistance of 6 Ω. It is cut into two parts and both half values are connected in parallel. The new resistance is ....

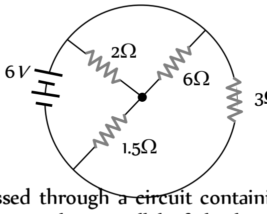
(a) 12 Ω (b) 1.5 Ω
(c) 3 Ω (d) 6 Ω

126. Six equal resistances are connected between points *P*, *Q* and *R* as shown in the figure. Then the net resistance will be maximum between [IIT-JEE (Screening) 2004]



(a) *P* and *Q*
(b) *Q* and *R*
(c) *P* and *R*
(d) Any two points

127. The total current supplied to the circuit by the battery is [AIEEE 2004]



(a) 1 *A*
(b) 2 *A*
(c) 4 *A*
(d) 6 *A*

128. An electric current is passed through a circuit containing two wires of the same material, connected in parallel. If the lengths and radii of the wires are in the ratio of 4/3 and 2/3, then the ratio of the currents passing through the wire will be [AIEEE 2004]

(a) 3 (b) 1/3
(c) 8/9 (d) 2

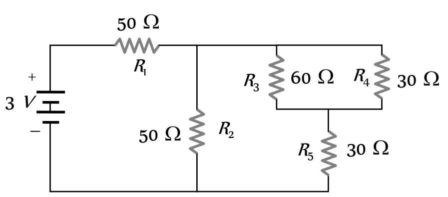
129. If a rod has resistance 4 Ω and if rod is turned as half cycle then the resistance along diameter [BCECE 2004]

(a) 1.56 Ω (b) 2.44 Ω
(c) 4 Ω (d) 2 Ω

130. If three resistors of resistance 2Ω, 4Ω and 5 Ω are connected in parallel then the total resistance of the combination will be [Pb. PMT 2004]

(a) $\frac{20}{19}\Omega$ (b) $\frac{19}{20}\Omega$
(c) $\frac{19}{10}\Omega$ (d) $\frac{10}{19}\Omega$

131. In circuit shown below, the resistances are given in ohms and the battery is assumed ideal with emf equal to 3 *volt*. The voltage across the resistance R_4 is [UPSEAT 2004; Kerala PMT 2004]

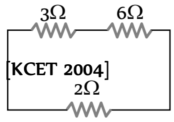


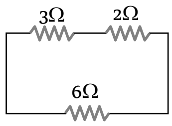
(a) 0.4 *V*
(b) 0.6 *V*
(c) 1.2 *V*
(d) 1.5 *V*

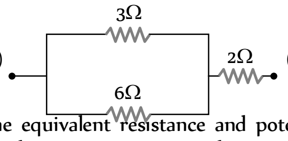
132. A parallel combination of two resistors, of 1 Ω each, is connected in series with a 1.5 Ω resistor. The total combination is connected across a 10 *V* battery. The current flowing in the circuit is

(a) 5 *A* (b) 20 *A*
(c) 0.2 *A* (d) 0.4 *A*

133. [KCET 2004] If you are provided three resistances 2 Ω, 3 Ω and 6 Ω. How will you connect them so as to obtain the equivalent resistance of 4 Ω

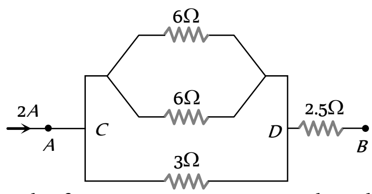
(a) 

(b) 

(c) 

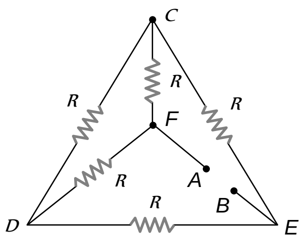
(d) None of these

134. The equivalent resistance and potential difference between *A* and *B* for the circuit is respectively [Pb. PMT 2003]



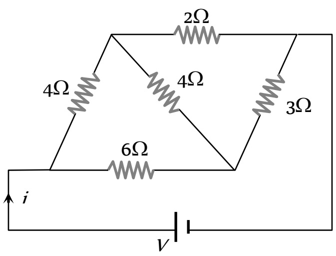
(a) 4 Ω, 8 *V*
(b) 8 Ω, 4 *V*
(c) 2 Ω, 2 *V*
(d) 16 Ω, 8 *V*

135. Five equal resistances each of resistance *R* are connected as shown in the figure. *A* battery of *V* volts is connected between *A* and *B*. The current flowing in *AFCEB* will be [CBSE PMT 2004]



(a) $\frac{3V}{R}$
(b) $\frac{V}{R}$
(c) $\frac{V}{2R}$
(d) $\frac{2V}{R}$

136. For the network shown in the figure the value of the current i is



(a) $\frac{9V}{35}$
(b) $\frac{5V}{18}$
(c) $\frac{5V}{9}$
(d) $\frac{18V}{5}$

137. When a wire of uniform cross-section a, length *l* and resistance *R* is bent into a complete circle, resistance between any two of diametrically opposite points will be [CBSE PMT 2005]

(a) $\frac{R}{4}$ (b) $\frac{R}{8}$
(c) $4R$ (d) $\frac{R}{2}$

138. The current in a simple series circuit is 5.0 *amp*. When an additional resistance of 2.0 *ohms* is inserted, the current drops to 4.0 *amp*. The original resistance of the circuit in ohms was

(a) 1.25 (b) 8

(c) 10 (d) 20

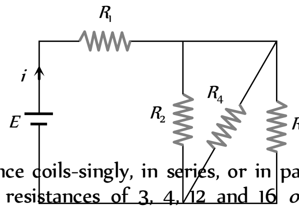
139. In the circuit given $E = 6.0\ V$, $R_1 = 100\ ohms$, $R_2 = R_3 = 50\ ohms$, $R_4 = 75\ ohms$. The equivalent resistance of the circuit, in ohms, is

(a) 11.875

(b) 26.31

(c) 118.75

(d) None of these



140. By using only two resistance coils-singly, in series, or in parallel one should be able to obtain resistances of 3, 4, 12 and 16 *ohms*. The separate resistances of the coil are [KCET 2005]

(a) 3 and 4 (b) 4 and 12

(c) 12 and 16 (d) 16 and 3

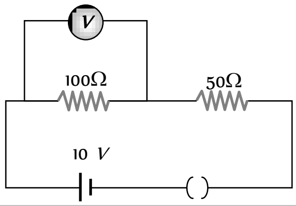
141. In the given circuit, the voltmeter records 5 *volts*. The resistance of the voltmeter in *ohms* is [KCET 2005]

(a) 200

(b) 100

(c) 10

(d) 50



Kirchhoff's Law, Cells

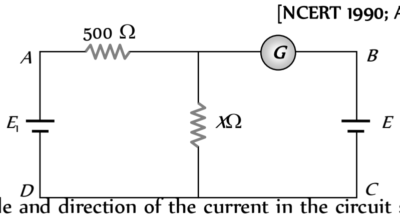
1. In the adjoining circuit, the battery E_1 has an $e.m.f.$ of $12\,volt$ and zero internal resistance while the battery E has an $e.m.f.$ of $2\,volt$. If the galvanometer G reads zero, then the value of the resistance X in *ohm* is [NCERT 1990; AIEEE 2005]

(a) 10

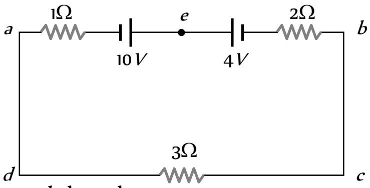
(b) 100

(c) 500

(d) 200



2. The magnitude and direction of the current in the circuit shown will be [CPMT 1986, 88]



(a) $\frac{7}{3}$ *A* from *a* to *b* through *e*

(b) $\frac{7}{3}$ *A* from *b* to *a* through *e*

(c) 1*A* from *b* to *a* through *e*

(d) 1*A* from *a* to *b* through *e*

3. A cell of $e.m.f.$ $1.5\,V$ having a finite internal resistance is connected to a load resistance of $2\,\Omega$. For maximum power transfer the internal resistance of the cell should be [BIT 1988]

(a) 4 *ohm* (b) 0.5 *ohm*

(c) 2 *ohm* (d) None of these

4. By a cell a current of 0.9 A flows through 2 *ohm* resistor and 0.3 A through 7 *ohm* resistor. The internal resistance of the cell is [KCET 2003]

(a) $0.5\,\Omega$ (b) $1.0\,\Omega$

(c) 1.[KCET 2005] (d) $2.0\,\Omega$

5. The e.m.f. of a cell is E volts and internal resistance is r *ohm*. The resistance in external circuit is also r *ohm*. The p.d. across the cell will be [CPMT 1985; NCERT 1973]

(a) *E*/2 (b) 2*E*

(c) 4*E* (d) *E*/4

6. A cell of e.m.f. E is connected with an external resistance R, then p.d. across cell is V. The internal resistance of cell will be [MNR 1987; Kerala P

(a) $\frac{(E-V)R}{E}$ (b) $\frac{(E-V)R}{V}$

(c) $\frac{(V-E)R}{V}$ (d) $\frac{(V-E)R}{E}$

7. Two cells, e.m.f. of each is E and internal resistance r are connected in parallel between the resistance R. The maximum energy given to the resistor will be, only when [MNR 1988; MP PET 2000; UPSEAT 2001]

(a) $R = r/2$ (b) $R = r$

(c) $R = 2r$ (d) $R = 0$

8. Kirchhoff's first law *i.e.* $\Sigma i = 0$ at a junction is based on the law of conservation of [CBSE PMT 1997; AIIMS 2000; MP PMT 2002; RPMT 2001; DPMT 2005]

(a) Charge (b) Energy

(c) Momentum (d) Angular momentum

9. Kirchhoff's second law is based on the law of conservation of [RPET 2003; MH CET 2001]

(a) Charge (b) Energy

(c) Momentum (d) Sum of mass and energy

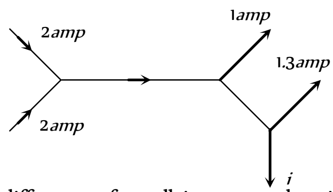
10. The figure below shows currents in a part of electric circuit. The current *i* is [CPMT 1981; RPET 1999]

(a) 1.7 *amp*

(b) 3.7 *amp*

(c) 1.3 *amp*

(d) 1 *amp*



11. The terminal potential difference of a cell is greater than its e.m.f. when it is

(a) Being discharged

(b) In open circuit

(c) Being charged

(d) Being either charged or discharged

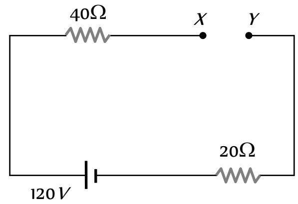
12. In the circuit shown, potential difference between *X* and *Y* will be

(a) Zero

(b) 20 *V*

(c) 60 *V*

(d) 120 *V*



13. In the above question, potential difference across the $40\,\Omega$ resistance will be

(a) Zero (b) 80 V

(c) 40 V (d) 120 V

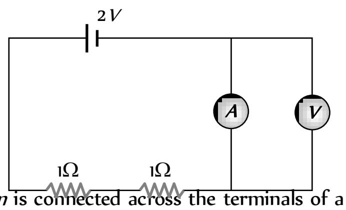
14. In the circuit shown, A and V are ideal ammeter and voltmeter respectively. Reading of the voltmeter will be

(a) 2 V

(b) 1 V

(c) 0.5 V

(d) Zero



15. When a resistance of 2 *ohm* is connected across the terminals of a cell, the current is 0.5 *amperes*. When the resistance is increased to 5 *ohm*, the current is 0.25 *amperes*. The internal resistance of the cell is

(a) $0.5\,ohm$ (b) $1.0\,ohm$

(c) $1.5\,ohm$ (d) $2.0\,ohm$

[MP PMT 1996]

16. The terminal potential difference of a cell when short-circuited is (E = E.M.F. of the cell)

(a) E (b) $E/2$

(c) Zero (d) $E/3$

17. A primary cell has an e.m.f. of 1.5 volts, when short-circuited it gives a current of 3 amperes. The internal resistance of the cell is

(a) 4.5 ohm (b) 2 ohm

(c) 0.5 ohm (d) 1/4.5 ohm

[CPMT 1976, 83]

18. A 50 V battery is connected across a 10 *ohm* resistor. The current is 4.5 *amperes*. The internal resistance of the battery is

(a) Zero (b) 0.5 *ohm*

(c) 1.1 *ohm* (d) 5.0 *ohm*

[CPMT 1985; BHU 1997; Pb. PMT 2001]

19. The potential difference in open circuit for a cell is 2.2 *volts*. When a 4 *ohm* resistor is connected between its two electrodes the potential difference becomes 2 *volts*. The internal resistance of the cell will be

[MP PMT 1984; SCRA 1994; CBSE PMT 2002]

(a) 1 *ohm* (b) 0.2 *ohm*

(c) 2.5 *ohm* (d) 0.4 *ohm*

20. A new flashlight cell of e.m.f. 1.5 *volts* gives a current of 15 *amps*, when connected directly to an ammeter of resistance $0.04\,\Omega$. The internal resistance of cell is [MP PET 1994]

(a) $0.04\,\Omega$ (b) $0.06\,\Omega$

(c) $0.10\,\Omega$ (d) $10\,\Omega$

21. A cell whose e.m.f. is 2 V and internal resistance is $0.1\,\Omega$, is connected with a resistance of $3.9\,\Omega$. The voltage across the cell terminal will be

[CPMT 1990; MP PET 1993; CBSE PMT 1999; AFMC 1999; Pb. PMT 2000; AIIMS 2001]

(a) $0.50\,V$ (b) $1.90\,V$

(c) $1.95\,V$ (d) $2.00\,V$

22. The reading of a high resistance voltmeter when a cell is connected across it is 2.2 V. When the terminals of the cell are also connected to a resistance of $5\,\Omega$ the voltmeter reading drops to 1.8 V. Find the internal resistance of the cell

(a) $1.2\,\Omega$ (b) $1.3\,\Omega$

(c) $1.1\,\Omega$ (d) $1.4\,\Omega$

[KCET 2003; MP PMT 2003]

23. When cells are connected in parallel, then

[MNR 1983]

(a) The current decreases (b) The current increases

(c) The e.m.f. increases (d) The e.m.f. decreases

24. The internal resistance of a cell depends on

(a) The distance between the plates

(b) The area of the plates immersed

(c) The concentration of the electrolyte

(d) All the above

25. n identical cells each of e.m.f. E and internal resistance r are connected in series. An external resistance R is connected in series to this combination. The current through R is

[DPMT 2002]

(a) $\dfrac{nE}{R+nr}$ (b) $\dfrac{nE}{nR+r}$

(c) $\dfrac{E}{R+nr}$ (d) $\dfrac{nE}{R+r}$

26. A cell of internal resistance r is connected to an external resistance R. The current will be maximum in R, if

[CPMT 1982]

(a) $R=r$ (b) $R<r$

(c) $R>r$ (d) $R=r/2$

27. To get the maximum current from a parallel combination of n identical cells each of internal resistance r in an external resistance R, when

[DPMT 1999]

(a) $R>>r$ (b) $R<<r$

(c) $R=r$ (d) None of these

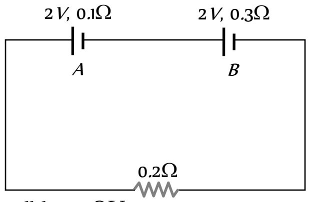
28. Two identical cells send the same current in $2\,\Omega$ resistance, whether connected in series or in parallel. The internal resistance of the cell should be

[NCERT 1982; Kerala PMT 2002]

(a) $1\,\Omega$ (b) $2\,\Omega$

(c) $\dfrac{1}{2}\,\Omega$ (d) $2.5\,\Omega$

29. The internal resistances of two cells shown are $0.1\,\Omega$ and $0.3\,\Omega$. If $R=0.2\,\Omega$, the potential difference across the cell



(a) B will be zero

(b) A will be zero

(c) A and B will be 2 V

(d) A will be $>2V$ and B will be $<2V$

30. A torch battery consisting of two cells of 1.45 *volts* and an internal resistance $0.15\,\Omega$, each cell sending currents through the filament of the lamps having resistance 1.5 *ohms*. The value of current will be [MP PET 19

(a) 16.11 *amp* (b) 1.611 *amp*

(c) 0.1611 *amp* (d) 2.6 *amp*

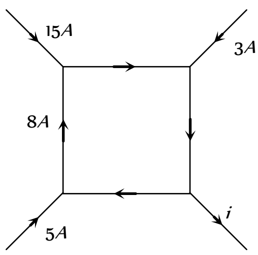
31. The electromotive force of a primary cell is 2 *volts*. When it is short-circuited it gives a current of 4 *amperes*. Its internal resistance in *ohms* is [MP PET 1995]

(a) 0.5 (b) 5.0

(c) 2.0 (d) 8.0

32. The figure shows a network of currents. The magnitude of currents is shown here. The current i will be

[MP PMT 1995]



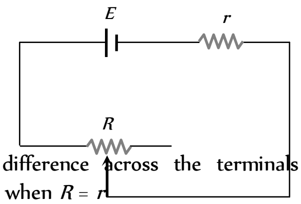
(a) 3 A

(b) 13 A

(c) 23 A

(d) – 3 A

33. A battery of e.m.f. E and internal resistance r is connected to a variable resistor R as shown here. Which one of the following is true



(a) Potential difference across the terminals of the battery is maximum when $R = r$

(b) Power delivered to the resistor is maximum when $R = r$

(c) Current in the circuit is maximum when $R = r$

(d) Current in the circuit is maximum when $R >> r$

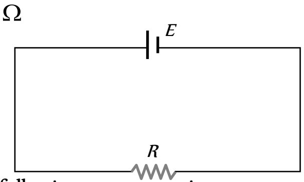
34. A dry cell has an e.m.f. of 1.5 V and an internal resistance of $0.05\,\Omega$. The maximum current obtainable from this cell for a very short time interval is [Haryana CEE 1996]

(a) 30 A (b) 300 A

(c) 3 A (d) 0.3 A

35. Consider the circuit given here with the following parameters

E.M.F. of the cell = 12 V. Internal resistance of the cell $= 2\,\Omega$. Resistance $R = 4\,\Omega$



Which one of the following statements in true

(a) Rate of energy loss in the source is = 8 W

(b) Rate of energy conversion in the source is 16 W

(c) Power output in is = 8 W

(d) Potential drop across R is = 16 V

36. A current of two amperes is flowing through a cell of e.m.f. 5 *volts* and internal resistance 0.5 *ohm* from negative to positive electrode. If the potential of negative electrode is 10 V, the potential of positive electrode will be [MP PMT 1997]

(a) 5 V (b) 14 V

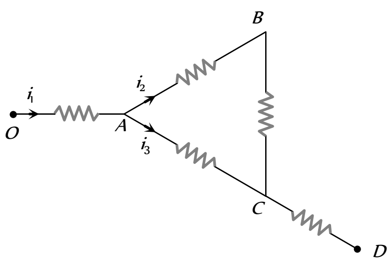
(c) 15 V (d) 16 V

37. 100 cells each of e.m.f. 5 V and internal resistance 1 *ohm* are to be arranged so as to produce maximum current in a 25 *ohms* resistance. Each row is to contain equal number of cells. The number of rows should be [MP PMT 1997]

(a) 2 (b) 4

(c) 5 (d) 10

38. The current in the arm CD of the circuit will be [MP PMT/PET 1998; MP PMT 2000; DPMT 2000]



(a) $i_1 + i_2$

(b) $i_2 + i_3$

(c) $i_1 + i_3$

(d) $i_1 - i_2 + i_3$

39. When a resistance of 2 *ohm* is connected across the terminals of a cell, the current is 0.5 A. When the resistance is increased to 5 *ohm*, the current is 0.25 A. The e.m.f. of the cell is [MP PET 1999, 2000; Pb. PMT 2002; MP PMT 2000]

(a) 1.0 V [MP PMT 1995] (b) 1.5 V

(c) 2.0 V (d) 2.5 V

40. Two non-ideal identical batteries are connected in parallel. Consider the following statements [MP PMT 1999]

(i) The equivalent e.m.f. is smaller than either of the two e.m.f.s

(ii) The equivalent internal resistance is smaller than either of the two internal resistances

(a) Both (i) and (ii) are correct

(b) (i) is correct but (ii) is wrong

(c) (ii) is correct but (i) is wrong

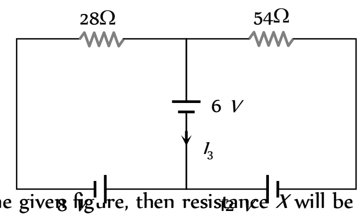
(d) Both (i) and (ii) are wrong

41. If six identical cells each having an e.m.f. of 6 V are connected in parallel, the e.m.f. of the combination is [EAMCET (Med.) 1995; Pb. PMT 1999; CPMT 2000]

(a) 1 V (b) 36 V

(c) $\frac{1}{6}V$ (d) 6 V

42. Consider the circuit shown in the figure. The current I_3 is equal to



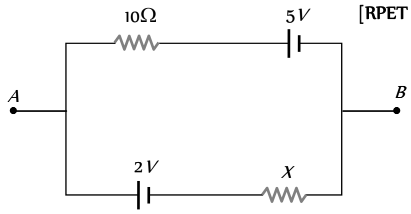
(a) 5 *amp*

(b) 3 *amp*

(c) $-3\,amp$

(d) $-5/6\,amp$

43. If $V_{AB} = 4V$ in the given figure, then resistance X will be [RPET 1997]



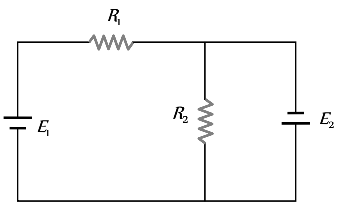
(a) $5\,\Omega$

(b) $10\,\Omega$

(c) $15\,\Omega$

(d) $20\,\Omega$

44. Two resistances R_1 and R_2 are joined as shown in the figure to two batteries of e.m.f. E_1 and E_2. If E_2 is short-circuited, the current through R_1 is [NDA 1995]



(a) E_1 / R_1

(b) E_2 / R_1

(c) E_2 / R_2

(d) $E_1 /(R_2 + R_1)$

45. A storage battery has e.m.f. 15 *volts* and internal resistance 0.05 *ohm*. Its terminal voltage when it is delivering 10 *ampere* is

(a) 30 *volts* (b) 1.00 *volts*

(c) 14.5 *volts* (d) 15.5 *volts*

46. The number of dry cells, each of e.m.f. 1.5 *volt* and internal resistance 0.5 *ohm* that must be joined in series with a resistance of 20 *ohm* so as to send a current of 0.6 *ampere* through the circuit is

(a) 2 (b) 8

(c) 10 (d) 12

47. *Emf* is most closely related to [DCE 1999]

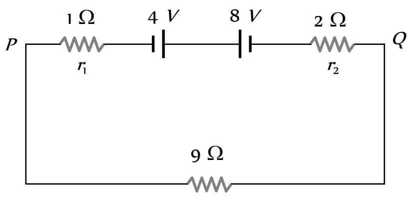
(a) Mechanical force (b) Potential difference

(c) Electric field (d) Magnetic field

48. For driving a current of 2 *A* for 6 *minutes* in a circuit, 1000 *J* of work is to be done. The e.m.f. of the source in the circuit is

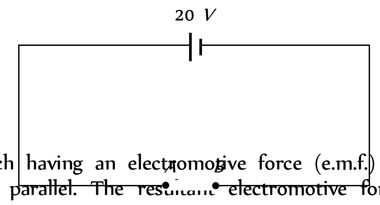
(a) 1.38 *V* (b) 1.68 *V*
(c) 2.04 *V* (d) 3.10 *V*

49. Two batteries of e.m.f. 4 *V* and 8 *V* with internal resistances 1 Ω and 2 Ω are connected in a circuit with a resistance of 9 Ω as shown in figure. The current and potential difference between the points *P* and *Q* are [AFMC 1999]



(a) $\frac{1}{3}A$ and $3V$
(b) $\frac{1}{6}A$ and $4V$
(c) $\frac{1}{9}A$ and $9V$
(d) $\frac{1}{2}A$ and $12V$

50. In the shown circuit, what is the potential difference across *A* and *B*



(a) 50 *V*
(b) 45 *V*
(c) 30 *V*
(d) 20 *V*

51. Four identical cells each having an electromotive force (e.m.f.) of 12 *V*, are connected in parallel. The resultant electromotive force (e.m.f.) of the combination is [CPMT 1999]

(a) 48 *V* (b) 12 *V*
(c) 4 *V* (d) 3 *V*

52. Electromotive force is the force, which is able to maintain a constant

(a) Current (b) Resistance
(c) Power (d) Potential difference

53. A cell of *emf* 6 *V* and resistance 0.5 *ohm* is short circuited. The current in the cell is [JIPMER 1999]

(a) 3 *amp* (b) 12 *amp*
(c) 24 *amp* (d) 6 *amp*

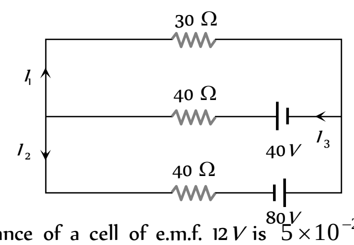
54. A storage cell is charged by 5 *amp* D.C. for 18 *hours*. Its strength after charging will be [JIPMER 1999]

(a) 18 *AH* (b) 5 *AH*
(c) 90 *AH* (d) 15 *AH*

55. A battery having e.m.f. 5 *V* and internal resistance 0.5 Ω is connected with a resistance of 4.5 Ω then the voltage at the terminals of battery is [RPMT 2000]

(a) 4.5 *V* (b) 4 *V*
(c) 0 *V* (d) 2 *V*

56. In the given circuit the current I_1 is [DCE 2000]

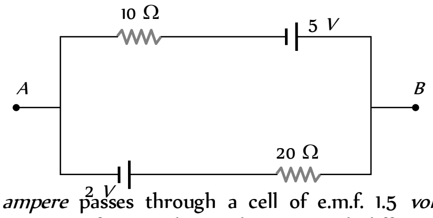


(a) 0.4 *A*
(b) – 0.4 *A*
(c) 0.8 *A*
(d) – 0.8 *A*

57. The internal resistance of a cell of e.m.f. 12 *V* is $5\times10^{-2}\,\Omega$. It is connected across an unknown resistance. Voltage across the cell, when a current of 60 *A* is drawn from it, is [CBSE PMT 2000]

(a) 15 *V* (b) 12 *V*
(c) 9 *V* (d) 6 *V*

58. The current in the given circuit is [CPMT 1999] [AIIMS 2000; MH CET 2003]



(a) 0.1 *A*
(b) 0.2 *A*
(c) 0.3 *A*
(d) 0.4 *A*

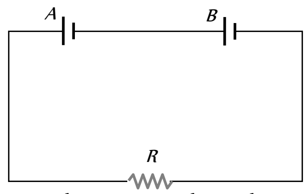
59. A current of 2.0 *ampere* passes through a cell of e.m.f. 1.5 *volts* having internal resistance of 0.15 *ohm*. The potential difference measured, in *volts*, across both the ends of the cell will be

(a) 1.35 (b) 1.50
(c) 1.00 (d) 1.20

60. A battery has e.m.f. 4 *V* and internal resistance *r*. When this battery is connected to an external resistance of 2 *ohms*, a current of 1 *amp*. flows in the circuit. [AIIMS 1999] How much current will flow if the terminals of the battery are connected directly [MP PET 2001]

(a) 1 *amp* (b) 2 *amp*
(c) 4 *amp* (d) Infinite

61. Two batteries *A* and *B* each of e.m.f. 2 *V* are connected in series to an external resistance *R* = 1 *ohm*. If the internal resistance of battery *A* is 1.9 *ohms* and that of *B* is 0.9 *ohm*, what is the potential difference between the terminals of battery *A*



(a) 2 *V*
(b) 3.8 *V* [Pb. PMT 1999]
(c) Zero
(d) None of the above

62. When a resistor of 11 Ω is connected in series with an electric cell, the current flowing in it is 0.5 *A*. Instead, when a resistor of 5 Ω is connected to the same electric cell in series, the current increases by 0.4 *A*. The internal resistance of the cell is

(a) 1.5 Ω (b) 2 Ω
(c) 2.5 Ω (d) 3.5 Ω

63. The internal resistance of a cell is the resistance of [BHU 1999, 2000; AIIMS 2001]

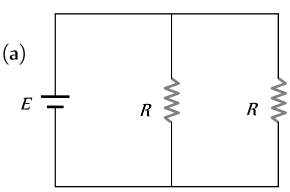
(a) Electrodes of the cell
(b) Vessel of the cell
(c) Electrolyte used in the cell
(d) Material used in the cell

64. How much work is required to carry a 6 μC charge from the negative terminal to the positive terminal of a 9 *V* battery [KCET (Med.) 2001]

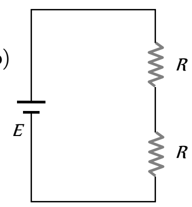
(a) $54\times10^{-3}\,J$ (b) $54\times10^{-6}\,J$
(c) $54\times10^{-9}\,J$ (d) $54\times10^{-12}\,J$

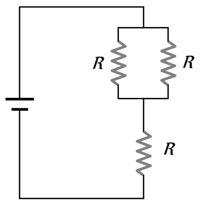
65. Consider four circuits shown in the figure below. In which circuit power dissipated is greatest (Neglect the internal resistance of the power supply) [Orissa JEE 2002]

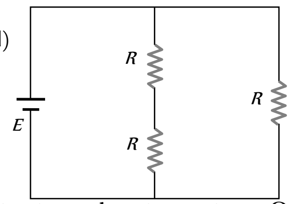
(a)



(b)



(c) 

(d) 

66. The *emf* of a battery is 2 *V* and its internal resistance is 0.5 Ω. The maximum power which it can deliver to any external circuit will be [AMU (Med.) 2002]

(a) 8 *Watt* (b) 4 *Watt*

(c) 2 *Watt* (d) None of the above

67. Kirchoff's I law and II law of current, proves the [CBSE PMT 1993; BHU 2002; AFMC 2003]

(a) Conservation of charge and energy

(b) Conservation of current and energy

(c) Conservation of mass and charge

(d) None of these

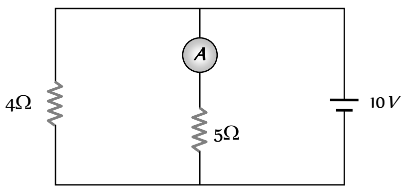
68. In the circuit, the reading of the ammeter is (assume internal resistance of the battery be zero)

(a) $\frac{40}{29}A$

(b) $\frac{10}{9}A$

(c) $\frac{5}{3}A$

(d) 2 *A*

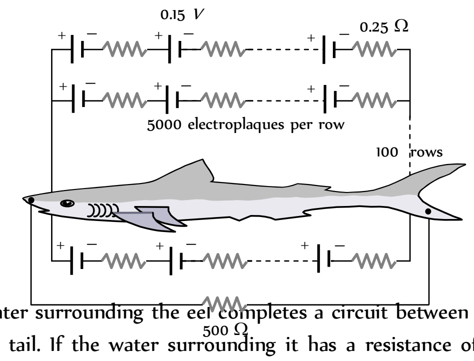


69. In the above question, if the internal resistance of the battery is 1 *ohm*, then what is the reading of ammeter

(a) 5/3 *A* (b) 40/29 *A*

(c) 10/9 *A* (d) 1 *A*

70. Eels are able to generate current with biological cells called electroplaques. The electroplaques in an eel are arranged in 100 rows, each row stretching horizontally along the body of the fish containing 5000 electroplaques. The arrangement is suggestively shown below. Each electroplaques has an emf of 0.15 *V* and internal resistance of 0.25 Ω [AIIMS 2004]



The water surrounding the eel completes a circuit between the head and its tail. If the water surrounding it has a resistance of 500 Ω, the current an eel can produce in water is about

(a) 1.5 *A* (b) 3.0 *A*

(c) 15 *A* (d) 30 *A*

71. Current provided by a battery is maximum when [AFMC 2004]

(a) Internal resistance equal to external resistance

(b) Internal resistance is greater than external resistance

(c) Internal resistance is less than external resistance

(d) None of these

72. A battery is charged at a potential of 15 *V* for 8 *hours* when the current flowing is 10 *A*. The battery on discharge supplies a current of 5 *A* for 15 *hours*. The mean terminal voltage during discharge is 14 *V*. The "*Watt-hour*" efficiency of the battery is

(a) 82.5% (b) 80 %

(c) 90% (d) 87.5%

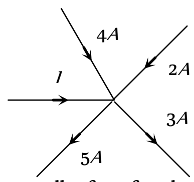
73. In the given current distribution what is the value of *I* [Orissa PMT 2004]

(a) 3*A*

(b) 8 *A*

(c) 2*A*

(d) 5*A*



74. A capacitor is connected to a cell of emf *E* having some internal resistance *r*. The potential difference across the [CPMT 2004; MP PMT 2005]

(a) Cell is < *E* (b) Cell is *E*

(c) Capacitor is > *E* (d) Capacitor is < *E*

75. When the resistance of 9 Ω is connected at the ends of a battery, its potential difference decreases from 40 *volt* to 30 *volt*. The internal resistance of the battery is [DPMT 2003]

(a) 6 Ω (b) 3 Ω

(c) 9 Ω (d) 15 Ω

76. The maximum power drawn out of the cell from a source is given by (where *r* is internal resistance) [DCE 2002]

(a) $E^2/2r$ (b) $E^2/4r$

(c) E^2/r (d) $E^2/3r$

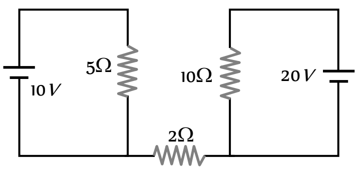
77. Find out the value of current through 2Ω resistance for the given circuit [IIT-JEE (Screening) 2005]

(a) 5 *A*

(b) 2 *A*

(c) Zero

(d) 4 *A*



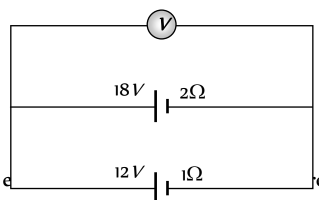
78. Two batteries, one of emf 18 *volts* and internal resistance 2Ω and the other of emf 12 *volt* and internal resistance 1Ω, are connected as shown. The voltmeter *V* will record a reading of

(a) 15 *volt*

(b) 30 *volt*

(c) 14 *volt*

(d) 18 *volt*



79. Two sources of equal e … esistance *R*. The internal resistances of the two sources are R_1 and

$R_2\,(R_2 > R_1)$. If the potential difference across the source having internal resistance R_2 is zero, then

[AIEEE 2005]

(a) $R = R_1R_2/(R_1 + R_2)$

(b) $R = R_1R_2/(R_2 - R_1)$

(c) $R = R_2 \times (R_1 + R_2)/(R_2 - R_1)$

(d) $R = R_2 - R_1$

80. An energy source will supply a constant current into the load if its internal resistance is [AIEEE 2005]

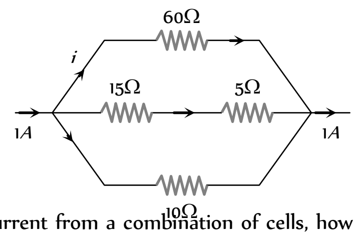
(a) Zero

(b) Non-zero but less than the resistance of the load

(c) Equal to the resistance of the load

(d) Very large as compared to the load resistance

81. The magnitude of *i* in ampere unit is [KCET 2005]



(a) 0.1

(b) 0.3

(c) 0.6

(d) None of these

82. To draw maximum current from a combination of cells, how should the cells be grouped [AFMC 2005]

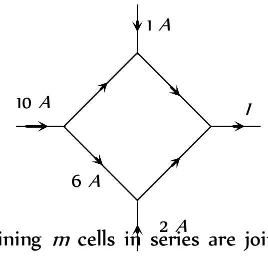
(a) Series

(b) Parallel

(c) Mixed

(d) Depends upon the relative values of external and internal resistance

83. The figure shows a network of currents. The magnitude of currents is shown here. The current *I* will be [BCECE 2005]



(a) 3 *A*

(b) 9 *A*

(c) 13 *A*

(d) 19 *A*

84. The *n* rows each containing *m* cells in series are joined in parallel. Maximum current is taken from this combination across an external resistance of 3Ω resistance. If the total number of cells used are 24 and internal resistance of each cell is 0.5 Ω then [J & K CET 2005]

(a) $m = 8, n = 3$ (b) $m = 6, n = 4$

(c) $m = 12, n = 2$ (d) $m = 2, n = 12$

85. A cell of constant e.m.f. first connected to a resistance R_1 and then connected to a resistance R_2. If power delivered in both cases is then the internal resistance of the cell is

[Orissa JEE 2005]

(a) $\sqrt{R_1R_2}$ (b) $\sqrt{\dfrac{R_1}{R_2}}$

(c) $\dfrac{R_1 - R_2}{2}$ (d) $\dfrac{R_1 + R_2}{2}$

Different Measuring Instruments

1. In meter bridge or Wheatstone bridge for measurement of resistance, the known and the unknown resistances are interchanged. The error so removed is

[MNR 1988; MP PET 1995]

(a) End correction

(b) Index error

(c) Due to temperature effect

(d) Random error

2. A galvanometer can be converted into an ammeter by connecting

[MP PMT 1987, 93; CPMT 1973, 75, 96, 2000; MP PET 1994; AFMC 1993, 95; RPET 2000; DCE 2000]

(a) Low resistance in series

(b) High resistance in parallel

(c) Low resistance in parallel

(d) High resistance in series

3. A cell of internal resistance $1.5\,\Omega$ and of e.m.f. 1.5 volt balances 500 *cm* on a potentiometer wire. If a wire of $15\,\Omega$ is connected between the balance point and the cell, then the balance point will shift [MP PMT 1985]

(a) To zero (b) By 500 *cm*

(c) By 750 *cm* (d) None of the above

4. $10^{-3}\,amp$ is flowing through a resistance of $1000\,\Omega$. To measure the correct potential difference, the voltmeter is to be used of which the resistance should be [MP PMT 1985]

(a) $0\,\Omega$ (b) $500\,\Omega$

(c) $1000\,\Omega$ (d) $>> 1000\,\Omega$

5. A galvanometer of $100\,\Omega$ resistance gives full scale deflection when 10 *mA* of current is passed. To convert it into 10 *A* range ammeter, the resistance of the shunt required will be

(a) $-10\,\Omega$ (b) $1\,\Omega$

(c) $0.1\,\Omega$ (d) $0.01\,\Omega$

6. $50\,\Omega$ and $100\,\Omega$ resistors are connected in series. This connection is connected with a battery of 2.4 *volts*. When a voltmeter of $100\,\Omega$ resistance is connected across $100\,\Omega$ resistor, then the reading of the voltmeter will be

[MP PMT 1985]

(a) 1.6 *V* (b) 1.0 *V*

(c) 1.2 *V* (d) 2.0 *V*

7. A 2 *volt* battery, a $15\,\Omega$ resistor and a potentiometer of 100 cm length, all are connected in series. If the resistance of potentiometer wire is $5\,\Omega$, then the potential gradient of the potentiometer wire is [AIIMS 1982]

(a) 0.005 *V/cm* (b) 0.05 *V/cm*

(c) 0.02 *V/cm* (d) 0.2 *V/cm*

8. An ammeter gives full scale deflection when current of 1.0 A is passed in it. To convert it into 10 A range ammeter, the ratio of its resistance and the shunt resistance will be

[MP PMT 1985]

(a) 1 : 9 (b) 1 : 10

(c) 1 : 11 (d) 9 : 1

9. By ammeter, which of the following can be measured [MP PET 1981; DPMT 2001]

(a) Electric potential (b) Potential difference
(c) Current (d) Resistance

10. The resistance of 1 A ammeter is $0.018\,\Omega$. To convert it into 10 A ammeter, the shunt resistance required will be [MP PET 1982]

(a) $0.18\,\Omega$ (b) $0.0018\,\Omega$
(c) $0.002\,\Omega$ (d) $0.12\,\Omega$

11. For measurement of potential difference, potentiometer is preferred in comparison to voltmeter because [MP PET 1983]

(a) Potentiometer is more sensitive than voltmeter
(b) The resistance of potentiometer is less than voltmeter
(c) Potentiometer is cheaper than voltmeter
(d) Potentiometer does not take current from the circuit

12. In order to pass 10% of main current through a moving coil galvanometer of 99 *ohm*, the resistance of the required shunt is [MP PET 1990, 99; MP PMT 1994; RPET 2001; KCET 2003, 05]

(a) $9.9\,\Omega$ (b) $10\,\Omega$
(c) $11\,\Omega$ (d) $9\,\Omega$

13. An ammeter of 5 *ohm* resistance can read 5 *mA*. If it is to be used to read 100 volts, how much resistance is to be connected in series [MP PET 1991; MP PMT 1996; MP PMT 2000]

(a) $19.9995\,\Omega$ (b) 199.995Ω
(c) $1999.95\,\Omega$ (d) $19995\,\Omega$

14. The potential gradient along the length of a uniform wire is $10\,volt/metre$. B and C are the two points at $30\,cm$ and $60\,cm$ point on a meter scale fitted along the wire. The potential difference between B and C will be [CPMT 1986]

(a) $3\,volt$ (b) $0.4\,volt$
(c) $7\,volt$ (d) $4\,volt$

15. $100\,mA$ current gives a full scale deflection in a galvanometer of $2\,\Omega$ resistance. The resistance connected with the galvanometer to convert it into a voltmeter to measure $5\,V$ is

(a) $98\,\Omega$ (b) $52\,\Omega$
(c) $50\,\Omega$ (d) $48\,\Omega$

16. When a $12\,\Omega$ resistor is connected with a moving coil galvanometer then its deflection reduces from 50 divisions to 10 divisions. The resistance of the galvanometer is [CPMT 2002; DPMT 2003]

(a) $24\,\Omega$ (b) $36\,\Omega$
(c) $48\,\Omega$ (d) $60\,\Omega$

17. A galvanometer can be used as a voltmeter by connecting a [AFMC 1993; MP PMT 1993, 95; CBSE PMT 2004]

(a) High resistance in series (b) Low resistance in series
(c) High resistance in parallel (d) Low resistance in parallel

18. The tangent galvanometer, when connected in series with a standard resistance can be used as [MP PET 1994]

(a) An ammeter
(b) A voltmeter
(c) A wattmeter
(d) Both an ammeter and a voltmeter

19. In Wheatstone's bridge $P = 9$ *ohm*, $Q = 11$ *ohm*, $R = 4$ *ohm* and $S = 6$ *ohm*. How much resistance must be put in parallel to the resistance S to balance the bridge [DPMT 1999]

(a) 24 *ohm* (b) $\frac{44}{9}$ *ohm*
(c) 26.4 *ohm* (d) 18.7 *ohm*

20. A Daniel cell is balanced on 125 cm length of a potentiometer wire. Now the cell is short-circuited by a resistance 2 *ohm* and the balance is obtained at 100 cm. The internal resistance of the Daniel cell is [UPSEAT 2002]

(a) 0.5 *ohm* (b) 1.5 *ohm*
(c) 1.25 *ohm* (d) 4/5 *ohm*

21. Sensitivity of potentiometer can be increased by [MP PET 1994]

(a) Increasing the e.m.f. of the cell
(b) Increasing the length of the potentiometer wire
(c) Decreasing the length of the potentiometer wire
(d) None of the above

22. A potentiometer is an ideal device of measuring potential difference because

(a) It uses a sensitive galvanometer
(b) It does not disturb the potential difference it measures
(c) It is an elaborate arrangement
(d) It has a long wire hence heat developed is quickly radiated

23. A battery of 6 volts is connected to the terminals of a three metre long wire of uniform thickness and resistance of the order of 100 Ω. The difference of potential between two points separated by 50 cm on the wire will be [CPMT 1984; CBSE PMT 2004]

(a) 1 V (b) 1.5 V
(c) 2 V (d) 3 V

24. A galvanometer of 10 *ohm* resistance gives full scale deflection with 0.01 ampere of current. It is to be converted into an ammeter for measuring 10 ampere current. The value of shunt resistance required will be [MP PET 1984] [MNR 1994; UPSEAT 2000]

(a) $\frac{10}{999}$ *ohm* (b) 0.1 *ohm*
(c) 0.5 *ohm* (d) 1.0 *ohm*

25. A potentiometer is used for the comparison of e.m.f. of two cells E_1 and E_2. For cell E_1 the no deflection point is obtained at 20 cm and for E_2 the no deflection point is obtained at 30 cm. The ratio of their e.m.f.'s will be [MP PET 1984]

(a) 2/3 (b) 1/2
(c) 1 (d) 2

26. Potential gradient is defined as [MP PET 1994]

(a) Fall of potential per unit length of the wire
(b) Fall of potential per unit area of the wire
(c) Fall of potential between two ends of the wire

(d) Potential at any one end of the wire

27. In an experiment of meter bridge, a null point is obtained at the centre of the bridge wire. When a resistance of 10 *ohm* is connected in one gap, the value of resistance in other gap is

(a) 10Ω (b) 5Ω

(c) $\frac{1}{5}\Omega$ (d) 500Ω

28. If the length of potentiometer wire is increased, then the length of the previously obtained balance point will

(a) Increase (b) Decrease

(c) Remain unchanged (d) Become two times

29. In potentiometer a balance point is obtained, when

(a) The e.m.f. of the battery becomes equal to the e.m.f. of the experimental cell

(b) The p.d. of the wire between the +*ve* end to jockey becomes equal to the e.m.f. of the experimental cell

(c) The p.d. of the wire between +*ve* point and jockey becomes equal to the e.m.f. of the battery

(d) The p.d. across the potentiometer wire becomes equal to the e.m.f. of the battery

30. In the experiment of potentiometer, at balance, there is no current in the

(a) Main circuit

(b) Galvanometer circuit

(c) Potentiometer circuit

(d) Both main and galvanometer circuits

31. If in the experiment of Wheatstone's bridge, the positions of cells and galvanometer are interchanged, then balance points will

(a) Change

(b) Remain unchanged

(c) Depend on the internal resistance of cell and resistance of galvanometer

(d) None of these

32. The resistance of a galvanometer is 90 *ohms*. If only 10 percent of the main current may flow through the galvanometer, in which way and of what value, a resistor is to be used

(a) 10 *ohms* in series (b) 10 *ohms* in parallel

(c) 810 *ohms* in series (d) 810 *ohms* in parallel

33. Two cells when connected in series are balanced on $8m$ on a potentiometer. If the cells are connected with polarities of one of the cell is reversed, they balance on $2m$. The ratio of e.m.f.'s of the two cells is

(a) $3:5$ (b) $5:3$

(c) $3:4$ (d) $4:3$

34. A voltmeter has a resistance of G *ohms* and range V *volts*. The value of resistance used in series to convert it into a voltmeter of range nV volts is

[MP PMT 1999; MP PET 2002; DPMT 2004; MH CET 2004]

(a) nG (b) $(n-1)G$

(c) $\frac{G}{n}$ (d) $\frac{G}{(n-1)}$

35. Which of the following statement is wrong [MP PET 1994]

(a) Voltmeter should have high resistance

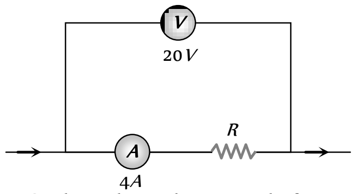
(b) Ammeter should have low resistance

(c) Ammeter is placed in parallel across the conductor in a circuit

(d) Voltmeter is placed in parallel across the conductor in a circuit

36. In the diagram shown, the reading of voltmeter is 20 V and that of ammeter is 4 A. The value of R should be (Consider given ammeter and voltmeter are not ideal) [RPMT 1997]

[MP PET 1994]



(a) Equal to 5Ω

(b) Greater from 5Ω

(c) Less than 5Ω

(d) Greater or less than 5Ω depends on the material of R

37. A moving coil galvanometer has a resistance of 50Ω and gives full scale deflection for 10 mA. How could it be converted into an ammeter with a full scale deflection for 1A

[MP PMT 1996]

(a) $50/99\Omega$ in series (b) $50/99\Omega$ in parallel

(c) 0.01Ω in series (d) 0.01Ω in parallel

38. The current flowing through a coil of resistance 900 *ohms* is to be reduced by 90%. What value of shunt should be connected across the coil [Roorkee 1992]

(a) 90Ω (b) 100Ω

(c) 9Ω (d) 10Ω

39. A galvanometer of resistance 25Ω gives full scale deflection for a current of 10 *milliampere*, is to be changed into a voltmeter of range 100 V by connecting a resistance of 'R' in series with galvanometer. The value of resistance R in Ω is

[MP PET 1994]

(a) 10000 (b) 10025

(c) 975 (d) 9975

40. In a potentiometer circuit there is a cell of e.m.f. 2 *volt*, a resistance of 5 *ohm* and a wire of uniform thickness of length 1000 *cm* and resistance 15 *ohm*. The potential gradient in the wire is [MP PET 1996]

(a) $\frac{1}{500}V/cm$ (b) $\frac{3}{2000}V/cm$

(c) $\frac{3}{5000}V/cm$ (d) $\frac{1}{1000}V/cm$

41. The resistance of a galvanometer is 25 *ohm* and it requires $50\,\mu A$ for full deflection. The value of the shunt resistance required to convert it into an ammeter of 5 *amp* is

[MP PMT 1994; BHU 1997]

(a) $2.5\times10^{-4}\,ohm$ (b) $1.25\times10^{-3}\,ohm$

(c) 0.05 *ohm* (d) 2.5 *ohm*

42. Which is a *wrong* statement [MP PMT 1994]

(a) The Wheatstone bridge is most sensitive when all the four resistances are of the same order

(b) In a balanced Wheatstone bridge, interchanging the positions of galvanometer and cell affects the balance of the bridge

(c) Kirchhoff's first law (for currents meeting at a junction in an electric circuit) expresses the conservation of charge

(d) The rheostat can be used as a potential divider

43. A voltmeter having a resistance of 998 *ohms* is connected to a cell of e.m.f. 2 *volt* and internal resistance 2 *ohm*. The error in the measurement of e.m.f. will be [MP PMT 1994]

(a) $4\times10^{-1}\,volt$ (b) $2\times10^{-3}\,volt$

(c) $4\times10^{-3}\,volt$ (d) $2\times10^{-1}\,volt$

44. For comparing the e.m.f.'s of two cells with a potentiometer, a standard cell is used to develop a potential gradient along the wires. Which of the following possibilities would make the experiment unsuccessful [MP PMT 1994]

(a) The e.m.f. of the standard cell is larger than the E e.m.f.'s of the two cells
(b) The diameter of the wires is the same and uniform throughout
(c) The number of wires is ten
(d) The e.m.f. of the standard cell is smaller than the e.m.f.'s of the two cells

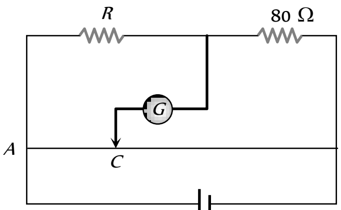
45. Which of the following is correct [BHU 1995]

(a) Ammeter has low resistance and is connected in series
(b) Ammeter has low resistance and is connected in parallel
(c) Voltmeter has low resistance and is connected in parallel
(d) None of the above

46. An ammeter with internal resistance $90\,\Omega$ reads 1.85 A when connected in a circuit containing a battery and two resistors 700 Ω and $410\,\Omega$ in series. Actual current will be [Roorkee 1995]

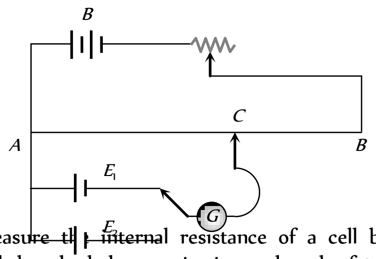
(a) 1.85 A (b) Greater than $1.85\,A$
(c) Less than 1.85 A (d) None of these

47. AB is a wire of uniform resistance. The galvanometer G shows no current when the length AC = 20 cm and CB = 80 cm. The resistance R is equal to [MP PMT 1995; RPET 2001]



(a) $2\,\Omega$
(b) $8\,\Omega$
(c) $20\,\Omega$
(d) $40\,\Omega$

48. The circuit shown here is used to compare the e.m.f. of two cells E_1 and $E_2 (E_1 > E_2)$. The null point is at C when the galvanometer is connected to E_1. When the galvanometer is connected to E_2, the null point will be [MP PMT 1995]

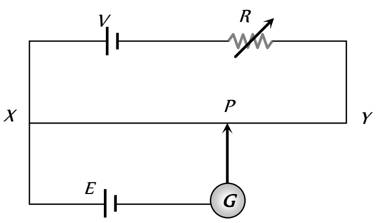


(a) To the left of C
(b) To the right of C
(c) At C itself
(d) Nowhere on AB

49. In an experiment to measure the internal resistance of a cell by potentiometer, it is found that the balance point is at a length of 2 m when the cell is shunted by a $5\,\Omega$ resistance; and is at a length of 3 m when the cell is shunted by a $10\,\Omega$ resistance. The internal resistance of the cell is, then [Haryana CEE 1996]

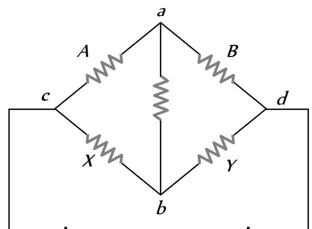
(a) $1.5\,\Omega$ (b) $10\,\Omega$
(c) $15\,\Omega$ (d) $1\,\Omega$

50. A potentiometer circuit shown in the figure is set up to measure e.m.f. of a cell E. As the point P moves from X to Y the galvanometer G shows deflection always in one direction, but the deflection decreases continuously until Y is reached. In order to obtain balance point between X and Y it is necessary to



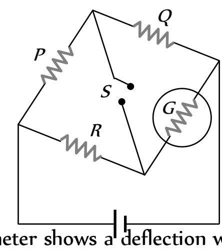
(a) Decreases the resistance R
(b) Increase the resistance R
(c) Reverse the terminals of battery V
(d) Reverse the terminals of cell E

51. In the Wheatstone's bridge (shown in figure) $X = Y$ and $A > B$. The direction of the current between ab will be



(a) From a to b
(b) From b to a
(c) From b to a through c
(d) From a to b through c

52. The figure shows a circuit diagram of a 'Wheatstone bridge' to measure the resistance G of the galvanometer. The relation $\frac{P}{Q} = \frac{R}{G}$ will be satisfied only when

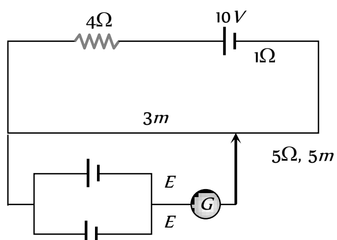


(a) The galvanometer shows a deflection when switch S is closed
(b) The galvanometer shows a deflection when switch S is open
(c) The galvanometer shows no change in deflection whether S is open or closed
(d) The galvanometer shows no deflection

53. The resistance of a galvanometer is 50 $ohms$ and the current required to give full scale deflection is $100\,\mu A$. In order to convert it into an ammeter, reading upto 10A, it is necessary to put a resistance of [MP PMT 1997; AIIMS 1999]

(a) $5 \times 10^{-3}\,\Omega$ in parallel (b) $5 \times 10^{-4}\,\Omega$ in parallel
(c) $10^5\,\Omega$ in series (d) $99{,}950\,\Omega$ in series

54. A resistance of $4\,\Omega$ and a wire of length 5 $metres$ and resistance $5\,\Omega$ are joined in series and connected to a cell of e.m.f. 10 V and internal resistance $1\,\Omega$. A parallel combination of two identical cells is balanced across 300 cm of the wire. The e.m.f. E of each cell is [MP PMT 199



(a) 1.5 V
(b) 3.0 V
(c) 0.67 V
(d) 1.33 V

55. The resistivity of a potentiometer wire is $40 \times 10^{-8}\ ohm - m$ and its area of cross-section is $8 \times 10^{-6}\,m^2$. If 0.2 amp current is flowing through the wire, the potential gradient will be

(a) $10^{-2}\, volt/m$ (b) $10^{-1}\, volt/m$

(c) $3.2\times 10^{-2}\, volt/m$ (d) $1\, volt/m$

56. If only 2% of the main current is to be passed through a galvanometer of resistance *G*, then the resistance of shunt will be

(a) $\frac{G}{50}$ (b) $\frac{G}{49}$

(c) $50\,G$ (d) $49\,G$

57. The resistance of an ideal voltmeter is

[EAMCET (Med.) 1995; MP PMT/PET 1998; Pb. PMT 1999; CPMT 2000]

(a) Zero (b) Very low

(c) Very large (d) Infinite

58. A 100 *V* voltmeter of internal resistance $20\,k\Omega$ in series with a high resistance *R* is connected to a 110 *V* line. The voltmeter reads 5 *V*, the value of *R* is [MP PET 1999]

(a) $210\,k\Omega$ (b) $315\,k\Omega$

(c) $420\,k\Omega$ (d) $440\,k\Omega$

59. Constantan wire is used in making standard resistances because its

(a) Specific resistance is low

(b) Density is high

(c) Temperature coefficient of resistance is negligible

(d) Melting point is high

60. The net resistance of a voltmeter should be large to ensure that

(a) It does not get overheated

(b) It does not draw excessive current

(c) It can measure large potential difference

(d) It does not appreciably change the potential difference to be measured

61. A galvanometer has resistance of $7\,\Omega$ and gives a full scale deflection for a current of 1.0 *A*. How will you convert it into a voltmeter of range 10 *V* [MP PMT 1999]

(a) $3\,\Omega$ in series (b) $3\,\Omega$ in parallel

(c) $17\,\Omega$ in series (d) $30\,\Omega$ in series

62. A potentiometer consists of a wire of length 4 *m* and resistance $10\,\Omega$. It is connected to a cell of e.m.f. 2 *V*. The potential difference per unit length of the wire will be

[CBSE PMT 1999; AFMC 2001]

(a) 0.5 V/m (b) $2\,V/m$

(c) $5\,V/m$ (d) $10\,V/m$

63. In a meter bridge, the balancing length from the left end (standard resistance of one *ohm* is in the right gap) is found to be 20 *cm*. The value of the unknown resistance is

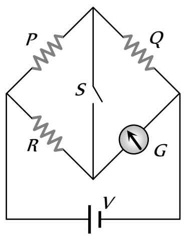
[CBSE PMT 1999; Pb PMT 2004]

(a) $0.8\,\Omega$ (b) $0.5\,\Omega$

(c) $0.4\,\Omega$ (d) $0.25\,\Omega$

64. In the circuit shown $P\neq R$, the reading of the galvanometer is same with switch *S* open or closed. Then

[IIT-JEE (Screening) 1999]



(a) $I_R = I_G$

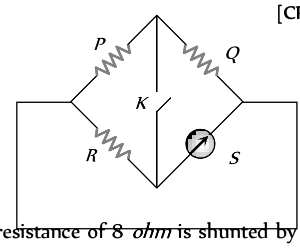
(b) $I_P = I_G$

(c) $I_Q = I_G$ [MP PMT/PET 1998]

(d) $I_Q = I_R$

65. In the following Wheatstone bridge $P/Q = R/S$. If key *K* is closed, then the galvanometer will show deflection

[CPMT 1999]



(a) In left side

(b) In right side

(c) No deflection

(d) In either side

66. A galvanometer having a resistance of 8 *ohm* is shunted by a wire of resistance 2 *ohm*. If the total current is 1 *amp*, the part of it passing through the shunt will be

[CBSE PMT 1998]

(a) 0.25 *amp* [MP PET 1999] (b) 0.8 *amp*

(c) 0.2 *amp* (d) 0.5 *amp*

67. A potentiometer wire has length 10 *m* and resistance $20\,\Omega$. A 2. 5 *V* battery of negligible internal resistance is connected across the wire with an $80\,\Omega$ series resistance. The potential gradient on the wire will be [KCET 1994]

[MP PMT 1999]

(a) $5\times 10^{-5}\, V/mm$ (b) $2.5\times 10^{-4}\, V/cm$

(c) $0.62\times 10^{-4}\, V/mm$ (d) $1\times 10^{-5}\, V/mm$

68. An ammeter whose resistance is $180\,\Omega$ gives full scale deflection when current is 2 *mA*. The shunt required to convert it into an ammeter reading 20 *mA* (in *ohms*) is

[EAMCET (Engg.) 1995]

(a) 18 (b) 20

(c) 0.1 (d) 10

69. A galvanometer whose resistance is $120\,\Omega$ gives full scale deflection with a current of 0.05 *A* so that it can read a maximum current of 10 *A*. A shunt resistance is added in parallel with it. The resistance of the ammeter so formed is

[Bihar MEE 1995]

(a) $0.06\,\Omega$ (b) $0.006\,\Omega$

(c) $0.6\,\Omega$ (d) $6\,\Omega$s

70. In a potentiometer experiment, the galvanometer shows no deflection when a cell is connected across 60 *cm* of the potentiometer wire. If the cell is shunted by a resistance of $6\,\Omega$, the balance is obtained across 50 *cm* of the wire. The internal resistance of the cell is [SCRA 1994]

(a) $0.5\,\Omega$ (b) $0.6\,\Omega$

(c) $1.2\,\Omega$ (d) $1.5\,\Omega$

71. A voltmeter of resistance $1000\,\Omega$ gives full scale deflection when a current of 100 *mA* flow through it. The shunt resistance required across it to enable it to be used as an ammeter reading 1 *A* at full scale deflection is [SCRA 1994]

(a) $10000\,\Omega$ (b) $9000\,\Omega$

(c) $222\,\Omega$ (d) $111\,\Omega$

72. The resistance of 10 *metre* long potentiometer wire is 1*ohm/meter*. A cell of e.m.f. 2.2 *volts* and a high resistance box are connected in series to this wire. The value of resistance taken from resistance box for getting potential gradient of 2.2 *millivolt/metre* will be[RPET 1997]

(a) $790\,\Omega$ (b) $810\,\Omega$

(c) $990\,\Omega$ (d) $1000\,\Omega$

73. We have a galvanometer of resistance $25\,\Omega$. It is shunted by a $2.5\,\Omega$ wire. The part of total current that flows through the galvanometer is given as

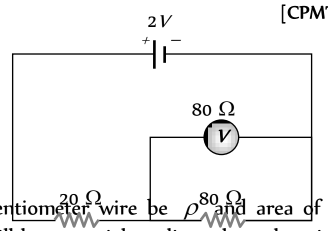
[AFMC 1998; MH CET 1999; Pb. PMT 2002]

(a) $\frac{I}{I_0}=\frac{1}{11}$ (b) $\frac{I}{I_0}=\frac{1}{10}$

(c) $\frac{I}{I_0}=\frac{3}{11}$ (d) $\frac{I}{I_0}=\frac{4}{11}$

74. In the adjoining circuit, the e.m.f. of the cell is 2 *volt* and the internal resistance is negligible. The resistance of the voltmeter is 80 *ohm*. The reading of the voltmeter will be

[CPMT 1991]



(a) 0.80 *volt*

(b) 1.60 *volt*

(c) 1.33 *volt*

(d) 2.00 *volt*

75. If the resistivity of a potentiometer wire be ρ and area of cross-section be *A*, then what will be potential gradient along the wire

(a) $\frac{I\rho}{A}$ (b) $\frac{I}{A\rho}$

(c) $\frac{IA}{\rho}$ (d) $IA\rho$

76. A voltmeter has resistance of 2000 *ohms* and it can measure upto 2*V*. If we want to increase its range to 10 *V*, then the required resistance in series will be

[CPMT 1997, SCRA 1994]

(a) $2000\,\Omega$ (b) $4000\,\Omega$

(c) $6000\,\Omega$ (d) $8000\,\Omega$

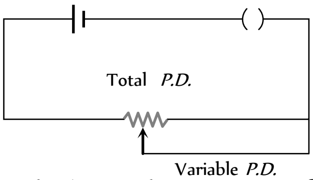
77. For a cell of e.m.f. 2*V*, a balance is obtained for 50 *cm* of the potentiometer wire. If the cell is shunted by a $2\,\Omega$ resistor and the balance is obtained across 40 *cm* of the wire, then the internal resistance of the cell is [SCRA 1998]

(a) $0.25\,\Omega$ (b) $0.50\,\Omega$

(c) $0.80\,\Omega$ (d) $1.00\,\Omega$

78. The arrangement as shown in figure is called as

[CPMT 1999]



(a) Potential divider

(b) Potential adder

(c) Potential substracter

(d) Potential multiplier

79. A potentiometer wire of length $1\,m$ and resistance 10 Ω is connected in series with a cell of *emf* 2 *V* with internal resistance 1 Ω and a resistance box including a resistance *R*. If potential difference between the ends of the wire is 1 *mV*, the value of *R* is [KCET 1999]

(a) 20000 Ω (b) 19989 Ω

(c) 10000 Ω (d) 9989 Ω

80. In a balanced Wheatstone's network, the resistances in the arms *Q* and *S* are interchanged. As a result of this

[KCET 1999]

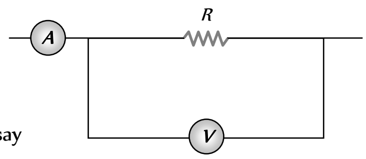
(a) Network is not balanced

(b) Network is still balanced

(c) Galvanometer shows zero deflection

(d) Galvanometer and the cell must be interchanged to balance

81. The ammeter *A* reads 2 *A* and the voltmeter *V* reads 20 *V*. the value of resistance *R* is (Assuming finite resistance's of ammeter and voltmeter) [JIPMER 1999; MP PMT 2004]



(a) Exactly 10 *ohm*

(b) Less than 10 *ohm*

(c) More than 10 *ohm*

(d) We cannot definitely say

82. The resistance of a galvanometer coil is *R*. What is the shunt resistance required to convert it into an ammeter of range 4 times

(a) $\frac{R}{5}$ (b) $\frac{R}{4}$

(c) $\frac{R}{3}$ (d) 4 *R*

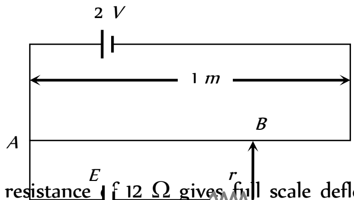
[RPET 1996]

83. If an ammeter is connected in parallel to a circuit, it is likely to be damaged due to excess [BHU 2000; BCECE 2004]

(a) Current (b) Voltage

(c) Resistance (d) All of these

84. In the given figure, battery *E* is balanced on 55 *cm* length of potentiometer wire but when a resistance of 10 Ω is connected in parallel with the battery then it balances on 50 *cm* length of the potentiometer wire then internal resistance *r* of the battery is



(a) 1 Ω

(b) 3 Ω

(c) 10 Ω

(d) 5 Ω

85. A galvanometer with a resistance of 12 Ω gives full scale deflection when a current of 3 *mA* is passed. It is required to convert it into a voltmeter which can read up to 18 *V*. the resistance to be connected is [Pb. PMT 2000]

(a) 6000 Ω (b) 5988 Ω

(c) 5000 Ω (d) 4988 Ω

86. The resistance of an ideal ammeter is [KCET 2000]

(a) Infinite (b) Very high

(c) Small (d) Zero

87. A galvanometer of 25 Ω resistance can read a maximum current of 6*mA*. It can be used as a voltmeter to measure a maximum of 6 *V* by connecting a resistance to the galvanometer. Identify the correct choice in the given answers [EAMCET (Med.) 2000]

(a) 1025 Ω in series (b) 1025 Ω in parallel

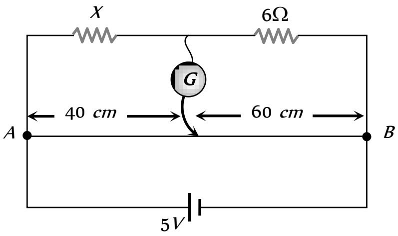
(c) 975 Ω in series (d) 975 Ω in parallel

88. A galvanometer has a resistance of 25 *ohm* and a maximum of 0.01 *A* current can be passed through it. In order to change it into an ammeter of range 10 *A*, the shunt resistance required is

(a) 5/999 *ohm* (b) 10/999 *ohm*
(c) 20/999 *ohm* (d) 25/999 *ohm*

89. In the circuit shown, a *meter* bridge is in its balanced state. The *meter* bridge wire has a resistance 0.1 *ohm/cm*. The value of unknown resistance *X* and the current drawn from the battery of negligible resistance is [AMU (Engg.) 2000]

(a) 6 Ω, 5 *amp*
(b) 10 Ω, 0.1 *amp*
(c) 4 Ω, 1.0 *amp*
(d) 12 Ω, 0.5 *amp*



90. A galvanometer has 30 divisions and a sensitivity 16 $\mu A/\text{div}$. It can be converted into a voltmeter to read 3 *V* by connecting

(a) Resistance nearly 6 $k\Omega$ in series
(b) $6k\Omega$ in parallel
(c) 500Ω in series
(d) It cannot be converted

91. Voltmeters *V* and *V* are connected in series across a *D.C.* line. *V* reads 80 *volts* and has a per *volt* resistance of 200 *ohms*. *V* has a total resistance of 32 *kilo ohms*. The line voltage is

(a) 120 *volts* (b) 160 *volts*
(c) 220 *volts* (d) 240 *volts*

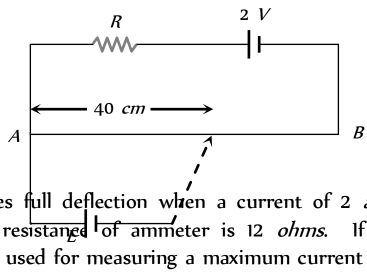
92. A potentiometer having the potential gradient of 2 *mV/cm* is used to measure the difference of potential across a resistance of 10 *ohm*. If a length of 50 *cm* of the potentiometer wire is required to get the null point, the current passing through the 10 *ohm* resistor is (in *mA*)

[AMU (Med.) 2000]

(a) 1 (b) 2
(c) 5 (d) 10

93. *AB* is a potentiometer wire of length 100 *cm* and its resistance is 10 *ohms*. It is connected in series with a resistance *R* = 40 *ohms* and a battery of e.m.f. 2 *V* and negligible internal resistance. If a source of unknown e.m.f. *E* is balanced by 40 *cm* length of the potentiometer wire, the value of *E* is [MP PET 2001]

(a) 0.8 *V*
(b) 1.6 *V*
(c) 0.08 *V*
(d) 0.16 *V*



94. An ammeter gives full deflection when a current of 2 *amp.* flows through it. The resistance of ammeter is 12 *ohms*. If the same ammeter is to be used for measuring a maximum current of 5 *amp.*, then the ammeter must be connected with a resistance of

(a) 8 *ohms* in series (b) 18 *ohms* in series
(c) 8 *ohms* in parallel (d) 18 *ohms* in parallel

95. In a circuit 5 percent of total current passes through a galvanometer. If resistance of the galvanometer is *G* then value of the shunt is [MP PET 2001]

(a) 19 *G* (b) 20 *G*
(c) $\frac{G}{20}$ (d) $\frac{G}{19}$

[MP PET 2000]

96. A voltmeter having resistance of 50 × 10 *ohm* is used to measure the voltage in a circuit. To increase the range of measurement 3 times the additional series resistance required is

(a) 10 *ohm* (b) 150 *k.ohm*
(c) 900 *k.ohm* (d) 9 × 10 *ohm*

97. In a potentiometer experiment two cells of e.m.f. *E* and *E* are used in series and in conjunction and the balancing length is found to be 58 *cm* of the wire. If the polarity of *E* is reversed, then the balancing length becomes 29 *cm*. The ratio $\frac{E_1}{E_2}$ of the e.m.f. of the two cells is

[Kerala (Engg.) 2001]

(a) 1 : 1 (b) 2 : 1
(c) 3 : 1 (d) 4 : 1

98. A milliammeter of range 10 *mA* has a coil of resistance 1 Ω. To use it as voltmeter of range 10 *volt*, the resistance that must be connected in series with it, will be [Kerala PMT 2005] [KCET 2001]

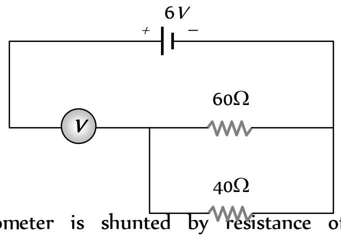
(a) 999 Ω (b) 99 Ω
(c) 1000 Ω (d) None of these

99. A voltmeter has a range 0-*V* with a series resistance *R*. With a series resistance 2*R*, the range is 0-V'. The correct relation between *V* and *V* is [CPMT 2001]

(a) $V' = 2V$ [UPSEAT 2000] (b) $V' > 2V$
(c) $V' >> 2V$ (d) $V' < 2V$

100. The measurement of voltmeter in the following circuit is [AFMC 2001]

(a) 2.4 *V*
(b) 3.4 *V*
(c) 4.0 *V*
(d) 6.0 *V*



101. A 36 Ω galvanometer is shunted by resistance of 4Ω. The percentage of the total current, which passes through the galvanometer is [UPSEAT 2002]

(a) 8 % (b) 9 %
(c) 10 % (d) 91 %

102. An ammeter and a voltmeter of resistance *R* are connected in series to an electric cell of negligible internal resistance. Their readings are *A* and *V* respectively. If another resistance *R* is connected in parallel with the voltmeter

[EAMCET 2000; KCET 2002]

(a) Both *A* and *V* will increase
(b) Both *A* and *V* will decrease
(c) *A* will decrease and *V* will increase
(d) *A* will increase and *V* will decrease [MP PET 2001]

103. A wire of length 100 *cm* is connected to a cell of *emf* 2 *V* and negligible internal resistance. The resistance of the wire is 3 Ω. The additional resistance required to produce a potential drop of 1 *milli volt* per *cm* is [Kerala PET 2002]

(a) 60 Ω (b) 47 Ω
(c) 57 Ω (d) 35 Ω

104. A galvanometer of resistance 20 Ω is to be converted into an ammeter of range 1 *A*. If a current of 1 *mA* produces full scale deflection, the shunt required for the purpose is [Kerala PET 2002]

(a) 0.01 Ω (b) 0.05 Ω

(c) 0.02 Ω (d) 0.04 Ω

105. There are three voltmeters of the same range but of resistances 10000Ω, 8000Ω and 4000Ω respectively. The best voltmeter among these is the one whose resistance is

(a) 10000 Ω (b) 8000 Ω

(c) 4000 Ω (d) All are equally good

106. If an ammeter is to be used in place of a voltmeter then we must connect with the ammeter a [AIEEE 2002; AFMC 2002]

(a) Low resistance in parallel

(b) High resistance in parallel

(c) High resistance in series

(d) Low resistance in series

107. A 10 *m* long wire of 20Ω resistance is connected with a battery of 3 *volt* e.m.f. (negligible internal resistance) and a 10 Ω resistance is joined to it is series. Potential gradient along wire in volt per meter is [MP PMT 2003]

(a) 0.02 (b) 0.3

(c) 0.2 (d) 1.3

108. A potentiometer has uniform potential gradient across it. Two cells connected in series (i) to support each other and (ii) to oppose each other are balanced over $6m$ and $2m$ respectively on the potentiometer wire. The e.m.f.'s of the cells are in the ratio of

(a) 1 : 2 (b) 1 : 1

(c) 3 : 1 (d) 2 : 1

109. The material of wire of potentiometer is [MP PMT 2002]

(a) Copper (b) Steel

(c) Manganin (d) Aluminium

110. To convert a galvanometer into a voltmeter, one should connect a

(a) High resistance in series with galvanometer

(b) Low resistance in series with galvanometer

(c) High resistance in parallel with galvanometer

(d) Low resistance in parallel with galvanometer

111. To convert a 800 *mV* range *milli voltmeter* of resistance 40 Ω into a galvanometer of 100 *mA* range, the resistance to be connected as shunt is [CBSE PMT 2002]

(a) 10 Ω (b) 20 Ω

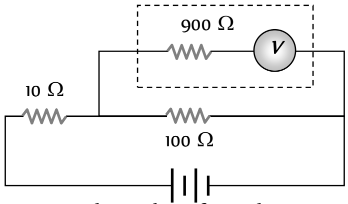
(c) 30 Ω (d) 40 Ω

112. A 100 *ohm* galvanometer gives full scale deflection at 10 *mA*. How much shunt is required to read 100 *mA* [MP PET 2002]

(a) 11.11 *ohm* (b) 9.9 *ohm*

(c) 1.1 *ohm* (d) 4.4 *ohm*

113. The potential difference across the 100Ω resistance in the following circuit is measured by a voltmeter of 900 Ω resistance. The percentage error made in reading the potential difference is [Kerala PET 2002]



(a) $\frac{10}{9}$

(b) 0.1

(c) 1.0

(d) 10.0

114. A cell of internal resistance 3 *ohm* and *emf* 10 *volt* is connected to a uniform wire of length 500 *cm* and resistance 3 *ohm*. The potential gradient in the wire is [MP PET 2003]

(a) 30 *mV/cm* (b) 10 *mV/cm*

(c) 20 *mV/cm* (d) 4 *mV/cm*

115. An ammeter of 100 Ω resistance gives full deflection for the current of 10^{-5} *amp*. Now the shunt resistance required to convert it into ammeter of 1 *amp*. range, will be [RPET 2003]

(a) 10^{-4} Ω (b) 10^{-5} Ω

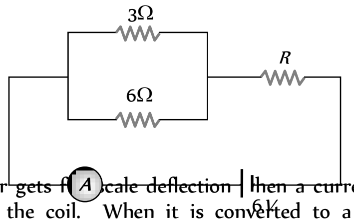
(c) 10^{-3} Ω (d) 10^{-1} Ω

116. A galvanometer of resistance 36 Ω is changed into an ammeter by using a shunt of 4 Ω. The fraction f of total current passing through the galvanometer is [BCECE 2003]

(a) $\frac{1}{40}$ (b) $\frac{1}{4}$

(c) $\frac{1}{140}$ (d) $\frac{1}{10}$

117. If the ammeter in the given circuit reads 2 *A*, the resistance *R* is [MP PMT 2002]



(a) 1 *ohm*

(b) 2 *ohm*

(c) 3 *ohm*

(d) 4 *ohm*

118. A 50 *ohm* galvanometer gets full scale deflection when a current of 0.01 *A* passes through the coil. When it is converted to a 10 *A* ammeter, the shunt resistance is [Orissa JEE 2003]

[CBSE PMT 2002]

(a) 0.01 Ω (b) 0.05 Ω

(c) 2000 Ω (d) 5000 Ω

119. Resistance in the two gaps of a *meter* bridge are 10 *ohm* and 30 *ohm* respectively. If the resistances are interchanged the balance point shifts by [Orissa JEE 2003]

(a) 33.3 *cm* (b) 66.67 *cm*

(c) 25 *cm* (d) 50 *cm*

120. A potentiometer has uniform potential gradient. The specific resistance of the material of the potentiometer wire is 10^{-7} *ohm–meter* and the current passing through it is 0.1 *ampere*; cross-section of the wire is 10^{-6} m^2. The potential gradient along the potentiometer wire is [KCET 2003]

(a) 10^{-4} *V/m* (b) 10^{-6} *V/m*

(c) 10^{-2} *V/m* (d) 10^{-8} *V/m*

121. Two resistances of 400 Ω and 800 Ω are connected in series with 6 *volt* battery of negligible internal resistance. A voltmeter of resistance 10,000 Ω is used to measure the potential difference across 400 Ω. The error in the measurement of potential difference in *volts* approximately is [AMU (Med.) 2002]

(a) 0.01 (b) 0.02

(c) 0.03 (d) 0.05

122. A galvanometer, having a resistance of 50 Ω gives a full scale deflection for a current of 0.05 *A*. The length in *meter* of a resistance wire of area of cross-section 2.97×10^{-2} *cm* that can be used to convert the galvanometer into an ammeter which can read a maximum of 5 *A* current is (Specific resistance of the wire = $5 \times 10^{-7}\ \Omega m$)

(a) 9 (b) 6
(c) 3 (d) 1.5

123. An ammeter reads upto 1 *ampere*. Its internal resistance is 0.81 *ohm*. To increase the range to 10 *A* the value of the required shunt is [AIEEE 2003]

(a) 0.09 Ω (b) 0.03 Ω
(c) 0.3 Ω (d) 0.9 Ω

124. The length of a wire of a potentiometer is 100 *cm*, and the *emf* of its standard cell is *E volt*. It is employed to measure the *e.m.f* of a battery whose internal resistance is 0.5 Ω. If the balance point is obtained at l = 30 *cm* from the positive end, the e.m.f. of the battery is [AIEEE 2003]

(a) $\frac{30E}{100}$

(b) $\frac{30E}{100.5}$

(c) $\frac{30E}{(100-0.5)}$

(d) $\frac{30(E-0.5i)}{100}$, where i is the current in the potentiometer

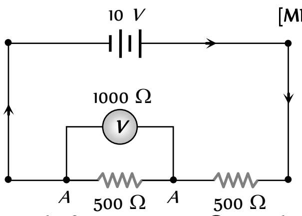
125. Resistance of 100 *cm* long potentiometer wire is 10Ω, it is connected to a battery (2 *volt*) and a resistance *R* in series. A source of 10 *mV* gives null point at 40 *cm* length, then external resistance *R* is

(a) 490 Ω (b) 790 Ω
(c) 590 Ω (d) 990 Ω

126. The e.m.f. of a standard cell balances across 150 *cm* length of a wire of potentiometer. When a resistance of 2 Ω is connected as a shunt with the cell, the balance point is obtained at 100 *cm*. The internal resistance of the cell is [MP PET 1993]

(a) 0.1 Ω (b) 1 Ω
(c) 2 Ω (d) 0.5 Ω

127. What is the reading of voltmeter in the following figure [MP PMT 2004]



(a) 3 *V*
(b) 2 *V*
(c) 5 *V*
(d) 4 *V*

128. The current flowing in a coil of resistance 90 Ω is to be reduced by 90%. What value of resistance should be connected in parallel with it [MP PMT 2004]

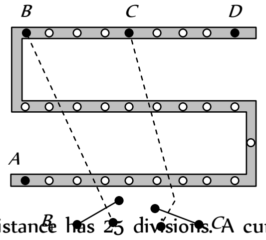
(a) 9 Ω (b) 90 Ω
(c) 1000 Ω (d) 10 Ω

129. The maximum current that can be measured by a galvanometer of resistance 40 Ω is 10 *mA*. It is converted into a voltmeter that can read upto 50 *V*. The resistance to be connected in series with the galvanometer is ... (in *ohm*) [KCET 2004]

(a) 5040 (b) 4960
(c) 2010 (d) 4050

[EAMCET 2003]

130. For the post office box arrangement to determine the value of unknown resistance the unknown resistance should be connected between [IIT-JEE (Screening) 2004]



(a) *B* and *C*
(b) *C* and *D*
(c) *A* and *D*
(d) B_1 and C_1

131. A galvanometer of 50 *ohm* resistance has 25 divisions. A current of 4×10^{-4} *ampere* gives a deflection of one division. To convert this galvanometer into a voltmeter having a range of 25 *volts*, it should be connected with a resistance of [CBSE PMT 2004]

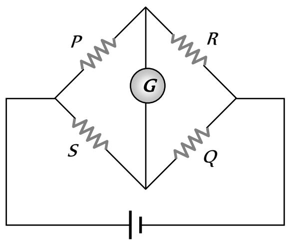
(a) 2500 Ω as a shunt (b) 2450 Ω as a shunt
(c) 2550 Ω in series (d) 2450 Ω in series

132. In a metre bridge experiment null point is obtained at 20 *cm* from one end of the wire when resistance *X* is balanced against another resistance *Y*. If *X* < *Y*, then where will be the new position of the null point from the same end, if one decides to balance a resistance of 4*X* against *Y* [AIEEE 2004]

[MP PMT 2003]

(a) 50 *cm* (b) 80 *cm*
(c) 40 *cm* (d) 70 *cm*

133. In the circuit given, the correct relation to a balanced Wheatstone bridge is [Orissa PMT 2004]



(a) $\frac{P}{Q}=\frac{R}{S}$

(b) $\frac{P}{Q}=\frac{S}{R}$

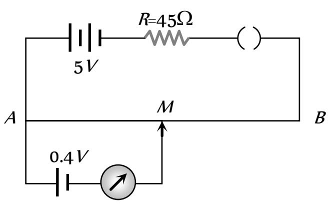
(c) $\frac{P}{R}=\frac{S}{Q}$

(d) None of these

134. A galvanometer coil of resistance 50 Ω, show full deflection of $100\mu A$. The shunt resistance to be added to the galvanometer, to work as an ammeter of range 10 *mA* is [Pb PET 2000]

(a) 5 Ω in parallel (b) 0.5 Ω in series
(c) 5 Ω in series (d) 0.5 Ω in parallel

135. In given figure, the potentiometer wire *AB* has a resistance of 5 Ω and length 10 *m*. The balancing length *AM* for the emf of 0.4 *V* is



(a) 0.4 *m*
(b) 4 *m*
(c) 0.8 *m*
(d) 8 *m*

136. A potentiometer consists of a wire of length 4 *m* and resistance 10 Ω. It is connected to cell of emf 2 *V*. The potential difference per unit length of the wire will be [Pb. PET 2002]

(a) 0.5 *V/m* (b) 10 *V/m*
(c) 2 *V/m* (d) 5 *V/m*

137. A voltmeter essentially consists of [UPSEAT 2004]

(a) A high resistance, in series with a galvanometer
(b) A low resistance, in series with a galvanometer
(c) A high resistance in parallel with a galvanometer
(d) A low resistance in parallel with a galvanometer

138. In a potentiometer experiment the balancing with a cell is at length 240 *cm*. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 *cm*. The internal resistance of the cell is

(a) 4 Ω (b) 2 Ω
(c) 1 Ω (d) 0.5 Ω

139. With a potentiometer null point were obtained at 140 *cm* and 180 *cm* with cells of emf 1.1 *V* and one unknown *X* volts. Unknown emf is [DCE 2002]

(a) 1.1 *V* (b) 1.8 *V*
(c) 2.4 *V* (d) 1.41 *V*

140. A moving coil galvanometer of resistance 100Ω is used as an ammeter using a resistance 0.1Ω. The maximum deflection current in the galvanometer is 100μA. Find the minimum current in the circuit so that the ammeter shows maximum deflection

(a) 100.1 *mA* (b) 1000.1 *mA*
(c) 10.01 *mA* (d) 1.01 *mA*

141. Two resistances are connected in two gaps of a metre bridge. The balance point is 20 *cm* from the zero end. A resistance of 15 *ohms* is connected in series with the smaller of the two. The null point shifts to 40 *cm*. The value of the smaller resistance in ohms is

(a) 3 (b) 6
(c) 9 (d) 12

142. If resistance of voltmeter is 10000Ω and resistance of ammeter is 2Ω then find *R* when voltmeter reads 12 *V* and ammeter reads 0.1 *A*

(a) 118 Ω (b) 120 Ω
(c) 124 Ω (d) 114Ω

143. Potentiometer wire of length 1 *m* is connected in series with 490 Ω resistance and 2 *V* battery. If 0.2 *mV/cm* is the potential gradient, then resistance of the potentiometer wire is

(a) 4.9 Ω (b) 7.9 Ω
(c) 5.9 Ω (d) 6.9 Ω

CT Critical Thinking

Objective Questions

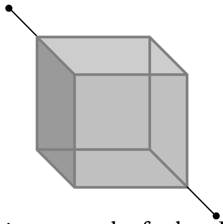
1. In an electrical cable there is a single wire of radius 9 *mm* of copper. Its resistance is $5\,\Omega$. The cable is replaced by 6 different insulated copper wires, the radius of each wire is $3\,mm$. Now the total resistance of the cable will be [CPMT 1988]

(a) $7.5\,\Omega$ (b) $45\,\Omega$
(c) $90\,\Omega$ (d) $270\,\Omega$

2. Two uniform wires A and B are of the same metal and have equal masses. The radius of wire A is twice that of wire B. The total resistance of *A* and B when connected in parallel is

(a) $4\,\Omega$ when the resistance of wire A is $4.25\,\Omega$
(b) $5\,\Omega$ when the resistance of wire A is $4.25\,\Omega$
(c) $4\,\Omega$ when the resistance of wire B is $4.25\,\Omega$
(d) $4\,\Omega$ when the resistance of wire B is $4.25\,\Omega$

3. Twelve [DCE 2002, AIEEE 2005] wires of equal length and same cross-section are connected in the form of a cube. If the resistance of each of the wires is R, then the effective resistance between the two diagonal ends would be [J & K CET 2004]

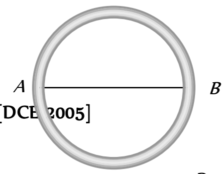


(a) 2 R
(b) 12 R
(c) $\frac{5}{6}R$
(d) 8 R

4. You are given several identical resistances each of value $R = 10\,\Omega$ [IIT-JEE (Screening) 2005] and each capable of carrying maximum current of 1 ampere. It is required to make a suitable combination of these resistances to produce a resistance of $5\,\Omega$ which can carry a current of 4 amperes. The minimum number of resistances of the type R that will be required for this job [CBSE PMT 1990]

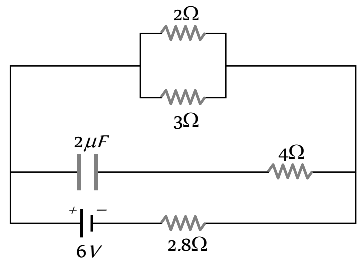
(a) 4 [KCET 2005] (b) 10
(c) 8 (d) 20

5. The resistance of a wire is $10^{-6}\,\Omega$ per metre. It is bend in the form of a circle of diameter $2\,m$. [BCECE 2005] A wire of the same material is connected across its diameter. The total resistance across its diameter *AB* will be



(a) $\frac{4}{3}\pi \times 10^{-6}\,\Omega$ (b) $\frac{2}{3}\pi \times 10^{-6}\,\Omega$
(c) $0.88 \times 10^{-6}\,\Omega$ (d) $14\pi \times 10^{-6}\,\Omega$

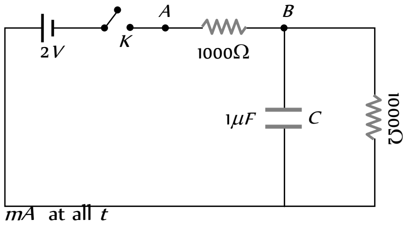
6. In the figure shown, the capacity of the condenser C is $2\,\mu F$. The current in $2\,\Omega$ resistor is [IIT 1982]



(a) 9 A (b) 0.9 A

(c) $\frac{1}{9}A$ (d) $\frac{1}{0.9}A$

7. When the key K is pressed at time $t = 0$, which of the following statements about the current I in the resistor AB of the given circuit is true [CBSE PMT 1995]



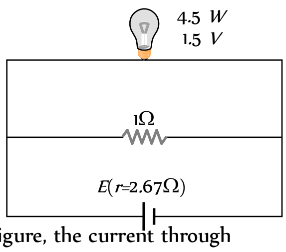
(a) I = 2 mA at all t

(b) I oscillates between 1 mA and 2mA

(c) I = 1 mA at all t

(d) At $t = 0$, I = 2 mA and with time it goes to 1 mA

8. A torch bulb rated as 4.5 W, 1.5 V is connected as shown in the figure. The $e.m.f.$ of the cell needed to make the bulb glow at full intensity is [MP PMT 1999]



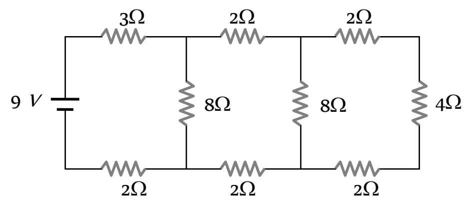
(a) 4.5 V

(b) 1.5 V

(c) 2.67 V

(d) 13.5 V

9. In the circuit shown in the figure, the current through [IIT 1998]



(a) The 3Ω resistor is 0.50A (b) The 3Ω resistor is 0.25 A

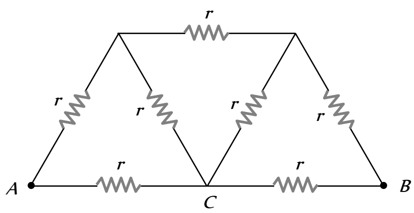
(c) The 4Ω resistor is 0.50A (d) The 4Ω resistor is 0.25 A

10. There are three resistance coils of equal resistance. The maximum number of resistances you can obtain by connecting them in any manner you choose, being free to use any number of the coils in any way is [ISM Dhanbad 1994]

(a) 3 (b) 4

(c) 6 (d) 5

11. In the circuit shown, the value of each resistance is r, then equivalent resistance of circuit between points A and B will be



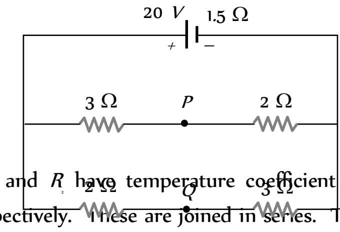
(a) (4/3) r

(b) $3r/2$

(c) $r/3$

(d) $8r/7$

12. If in the circuit shown below, the internal resistance of the battery is 1.5 Ω and V_P and V_Q are the potentials at P and Q respectively, what is the potential difference between the points P and Q



(a) Zero

(b) 4 $volts$ ($V_P > V_Q$)

(c) 4 $volts$ ($V_Q > V_P$)

(d) 2.5 $volts$ ($V_Q > V_P$)

13. Two wires of resistance R_1 and R_2 have temperature coefficient of resistance α_1 and α_2, respectively. These are joined in series. The effective temperature coefficient of resistance is

(a) $\frac{\alpha_1 + \alpha_2}{2}$ (b) $\sqrt{\alpha_1 \alpha_2}$

(c) $\frac{\alpha_1 R_1 + \alpha_2 R_2}{R_1 + R_2}$ (d) $\frac{\sqrt{R_1 R_2 \alpha_1 \alpha_2}}{\sqrt{R_1^2 + R_2^2}}$

14. Two cells of equal $e.m.f.$ and of internal resistances r_1 and $r_2 (r_1 > r_2)$ are connected in series. On connecting this combination to an external resistance R, it is observed that the potential difference across the first cell becomes zero. The value of R will be

[MP PET 1985; KCET 2005; Kerala PMT 2005]

(a) $r_1 + r_2$ (b) $r_1 - r_2$

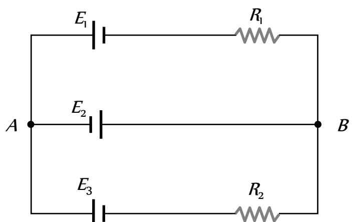
(c) $\frac{r_1 + r_2}{2}$ (d) $\frac{r_1 - r_2}{2}$

15. When connected across the terminals of a cell, a voltmeter measures 5 V and a connected ammeter measures 10 A of current. A resistance of 2 $ohms$ is connected across the terminals of the cell. The current flowing through this resistance will be

(a) 2.5 A (b) 2.0 A

(c) 5.0 A (d) 7.5 A

16. In the circuit shown here, $E_1 = E_2 = E_3 = 2$ V and $R_1 = R_2 = 4$ $ohms$. The current flowing between points A and B through battery E_2 is



(a) Zero

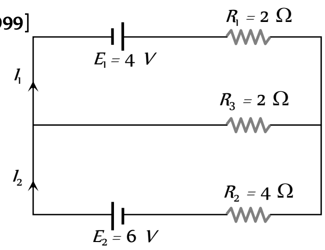
(b) 2 amp from A to B

(c) 2 amp from B to A

(d) None of the above

17. In the circuit shown below E_1 = 4.0 V, R_1 = 2 Ω, E_2 = 6.0 V, R_2 = 4 Ω and R_3 = 2 Ω. The current I_1 is [MP PET 2003]

[Similar to CBSE PMT 1999; RPET 1999]



(a) 1.6 A

(b) 1.8 A

(c) 1.25 A

(d) 1.0 A

18. A microammeter has a resistance of $100\,\Omega$ and full scale range of $50\,\mu A$. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination

[SCRA 1996; AMU (Med.) 2001; Roorkee 2000]

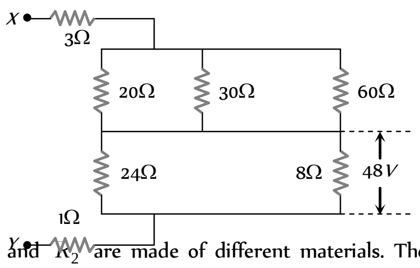
(a) 50 *V* range with $10\,k\Omega$ resistance in series

(b) 10 *V* range with $200\,k\Omega$ resistance in series

(c) 10 *mA* range with $1\,\Omega$ resistance in parallel

(d) 10 *mA* range with $0.1\,\Omega$ resistance in parallel

19. The potential difference across 8 *ohm* resistance is 48 *volt* as shown in the figure. The value of potential difference across *X* and *Y* points will be [MP PET 1996]



(a) 160 *volt*

(b) 128 *volt*

(c) 80 *volt*

(d) 62 *volt*

20. Two resistances R_1 and R_2 are made of different materials. The temperature coefficient of the material of R_1 is α and of the material of R_2 is $-\beta$. The resistance of the series combination of R_1 and R_2 will not change with temperature, if R_1/R_2 equals

(a) $\frac{\alpha}{\beta}$ (b) $\frac{\alpha+\beta}{\alpha-\beta}$

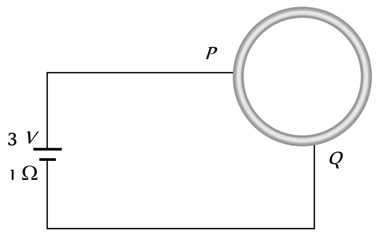
(c) $\frac{\alpha^2+\beta^2}{\alpha\beta}$ (d) $\frac{\beta}{\alpha}$

21. An ionization chamber with parallel conducting plates as anode and cathode has 5×10^7 electrons and the same number of singly-charged positive ions per cm^3. The electrons are moving at 0.4 *m/s*. The current density from anode to cathode is $4\,\mu A/m^2$. The velocity of positive ions moving towards cathode is

(a) 0.4 *m/s* (b) 16 *m/s*

(c) Zero (d) 0.1 *m/s*

22. A wire of resistance 10 Ω is bent to form a circle. *P* and *Q* are points on the circumference of the circle dividing it into a quadrant and are connected to a Battery of 3 *V* and internal resistance 1 Ω as shown in the figure. The currents in the two parts of the circle are



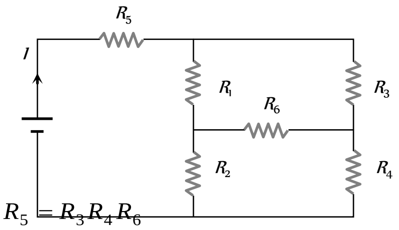
(a) $\frac{6}{23}A$ and $\frac{18}{23}A$

(b) $\frac{5}{26}A$ and $\frac{15}{26}A$

(c) $\frac{4}{25}A$ and $\frac{12}{25}A$

(d) $\frac{3}{25}A$ and $\frac{9}{25}A$

23. In the given circuit, it is observed that the current *I* is independent of the value of the resistance R_6. Then the resistance values must satisfy [IIT-JEE (Screening) 2001]



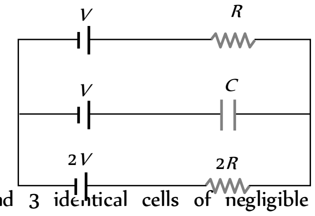
(a) $R_1R_2R_5 = R_3R_4R_6$

(b) $\frac{1}{R_5}+\frac{1}{R_6}=\frac{1}{R_1+R_2}+\frac{1}{R_3+R_4}$

(c) $R_1R_4 = R_2R_3$

(d) $R_1R_3 = R_2R_4 = R_5R_6$

24. In the given circuit, with steady current, the potential drop across the capacitor must be [IIT-JEE (Screening) 2001]



(a) *V*

(b) $V/2$

(c) $V/3$

(d) $2V/3$

25. A wire of length *L* and 3 identical cells of negligible internal resistances are connected in series. Due to current, the temperature of the wire is raised by Δ *T* in a time *t*. A number *N* of similar cells is now connected in series with a wire of the same material and cross–section but of length 2 *L*. The temperature of the wire is raised by the same amount Δ *T* in the same time *t*. the value of *N* is

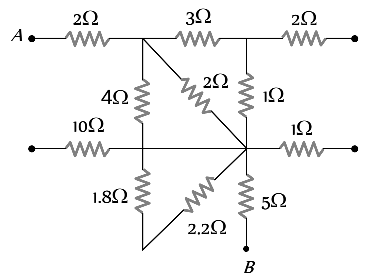
[MP PMT 1997]

[IIT-JEE (Screening) 2001]

(a) 4 (b) 6

(c) 8 (d) 9

26. What is the equivalent resistance between the points *A* and *B* of the network [AMU (Engg.) 2001]



(a) $\frac{57}{7}\Omega$

(b) 8 Ω

(c) 6 Ω

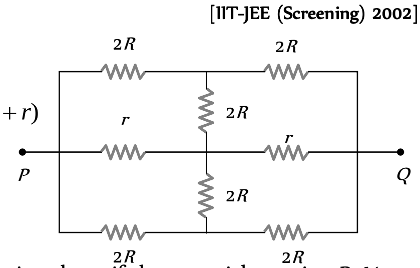
[CBSE PMT 1992]

(d) $\frac{57}{5}\Omega$

27. The effective resistance between points *P* and *Q* of the electrical circuit shown in the figure is

[Roorkee 1999]

[IIT-JEE (Screening) 2002]



(a) $2Rr/(R+r)$

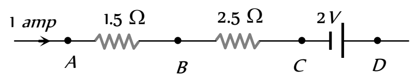
(b) $8R(R+r)/(3R+r)$

(c) $2r+4R$

(d) $5R/2+2r$

28. In the circuit element given here, if the potential at point *B*, V_B = 0, then the potentials of *A* and *D* are given as

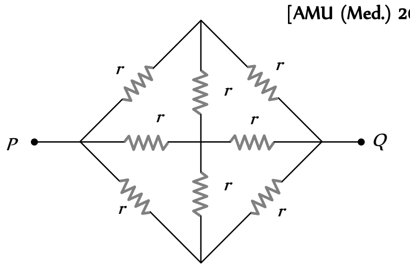
[AMU (Med.) 2002]



(a) $V_A = -1.5\,V, V_D = +2\,V$ (b) $V_A = +1.5\,V, V_D = +2\,V$

(c) $V_A = +1.5\,V, V_D = +0.5\,V$ (d) $V_A = +1.5\,V, V_D = -0.5\,V$

29. The equivalent resistance between the points P and Q in the network given here is equal to (given $r = \frac{3}{2}\Omega$) [AMU (Med.) 2002]



(a) $\frac{1}{2}\Omega$

(b) $1\,\Omega$

(c) $\frac{3}{2}\Omega$

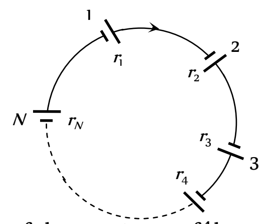
(d) $2\,\Omega$

30. The current in a conductor varies with time t as $I = 2t + 3t^2$ where I is in *ampere* and t in *seconds*. Electric charge flowing through a section of the conductor during $t = 2$ *sec* to $t = 3$ *sec* is

(a) 10 C (b) 24 C

(c) 33 C (d) 44 C

31. A group of N cells whose *emf* varies directly with the internal resistance as per the equation $E = 1.5\,r$ are connected as shown in the figure below. The current I in the circuit is [KCET 2003]



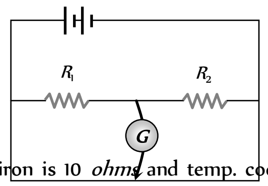
(a) 0.51 *amp*

(b) 5.1 *amp*

(c) 0.15 *amp*

(d) 1.5 *amp*

32. In the shown arrangement of the experiment of the meter bridge if AC corresponding to null deflection of galvanometer is x, what would be its value if the radius of the wire AB is doubled



(a) x

(b) $x/4$

(c) $4x$

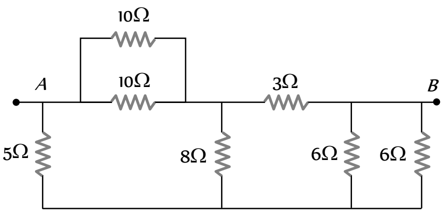
(d) $2x$

33. The resistance of a wire of iron is 10 *ohms* and temp. coefficient of resistivity is $5\times10^{-3}/°C$. At 20°C it carries 30 *milliamperes* of current. Keeping constant potential difference between its ends, the temperature of the wire is raised to $120°C$. The current in *milliamperes* that flows in the wire is

(a) 20 (b) 15

(c) 10 (d) 40

34. Seven resistances are connected as shown in the figure. The equivalent resistance between A and B is [MP PET 2000]



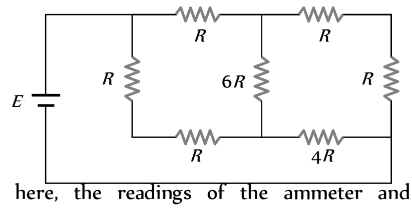
(a) $3\,\Omega$

(b) $4\,\Omega$

(c) $4.5\,\Omega$

(d) $5\,\Omega$

35. A battery of internal resistance 4Ω is connected to the network of resistances as shown. In order to give the maximum power to the network, the value of R (in Ω) should be



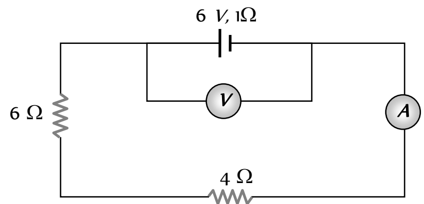
(a) 4/9

(b) 8/9

(c) 2

(d) 18

36. In the circuit shown here, the readings of the ammeter and voltmeter are [Kerala PMT 2002]



(a) 6 A, 60 V

(b) 0.6 A, 6 V

(c) 6/11 A, 60/11 V

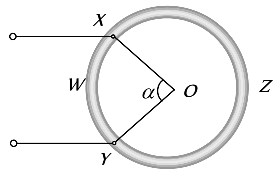
(d) 11/6 A, 11/60 V

37. Length of a hollow tube is $5\,m$, it's outer diameter is 10 *cm* and thickness of it's wall is 5 *mm*. If resistivity of the material of the tube is $1.7\times10^{-8}\,\Omega\times m$ then resistance of tube will be [Orissa JEE 2003]

(a) $5.6\times10^{-}\,\Omega$ (b) $2\times10^{-}\,\Omega$

(c) $4\times10^{-}\,\Omega$ (d) None of these

38. A wire of resistor R is bent into a circular ring of radius r. Equivalent resistance between two points X and Y on its circumference, when angle XOY is α, can be given by



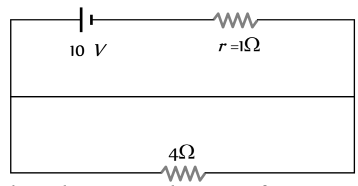
(a) $\frac{R\alpha}{4\pi^2}(2\pi-\alpha)$

(b) $\frac{R}{2\pi}(2\pi-\alpha)$

(c) $R\,(2\pi-\alpha)$

(d) $\frac{4\pi}{R\alpha}(2\pi-\alpha)$ [IIT-JEE (Screening) 2003]

39. Potential difference across the terminals of the battery shown in figure is (r = internal resistance of battery)



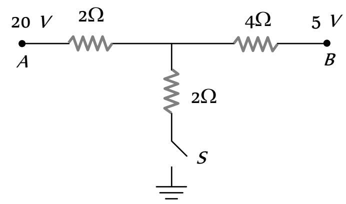
(a) 8 V

(b) 10 V

(c) 6 V

(d) Zero

40. As the switch S is closed in the circuit shown in figure, current passed through it is [MP PMT 1994]



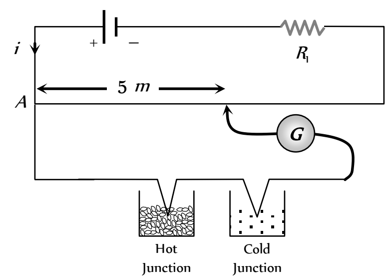
(a) 4.5 A

(b) 6.0 A

(c) 3.0 A

(d) Zero

41. In the following circuit a 10 m long potentiometer wire with resistance 1.2 *ohm/m*, a resistance R_1 and an accumulator of emf 2 V are connected in series. When the emf of thermocouple is 2.4 mV then the deflection in galvanometer is zero. The current supplied by the accumulator will be [IIT 1995]



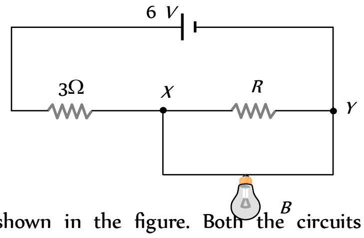
(a) 4×10^{-4}

(b) $8 \times 10^{\cdot}$ *A*

(c) $4 \times 10^{\cdot}$ *A*

(d) $8 \times 10^{\cdot}$ *A*

42. In the following circuit, bulb rated as 1.5 *V*, 0.45 *W*. If bulbs glows with full intensity then what will be the equivalent resistance between *X* and *Y*



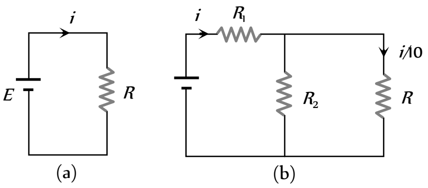
(a) 0.45 Ω

(b) 1 Ω

(c) 3 Ω

(d) 5 Ω

43. Consider the circuits shown in the figure. Both the circuits are taking same current from battery but current through *R* in the second circuit is $\frac{1}{10}$ *th* of current through *R* in the first circuit. If *R* is 11 Ω, the value of *R*



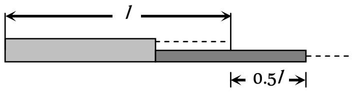
(a) 9.9 Ω

(b) 11 Ω

(c) 8.8 Ω

(d) 7.7 Ω

44. In order to quadruple the resistance of a uniform wire, a part of its length was uniformly stretched till the final length of the entire wire was 1.5 times the original length, the part of the wire was fraction equal to



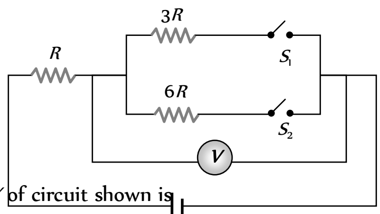
(a) 1 / 8

(b) 1 / 6

(c) 1 / 10

(d) 1 / 4

45. In the circuit shown in figure reading of voltmeter is *V* when only *S* is closed, reading of voltmeter is *V* when only *S* is closed and reading of voltmeter is *V* when both *S* and *S* are closed. Then



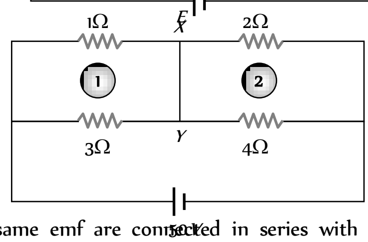
(a) *V* > *V* > *V*

(b) *V* > *V* > *V*

(c) *V* > *V* > *V*

(d) *V* > *V* > *V*

46. Current through wire *XY* of circuit shown is



(a) 1 *A*

(b) 4 *A*

(c) 2 *A*

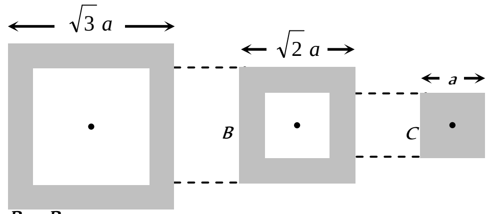
(d) 3 *A*

47. 12 cells each having same emf are connected in series with some cells wrongly connected. The arrangement is connected in series with an ammeter and two cells which are in series. Current is 3 *A* when cells and battery aid each other and is 2 *A* when cells and battery oppose each other. The number of cells wrongly connected is

(a) 4 (b) 1

(c) 3 (d) 2

48. Following figure shows cross-sections through three long conductors of the same length and material, with square cross-section of edge lengths as shown. Conductor *B* will fit snugly within conductor *A*, and conductor *C* will fit snugly within conductor *B*. Relationship between their end to end resistance is



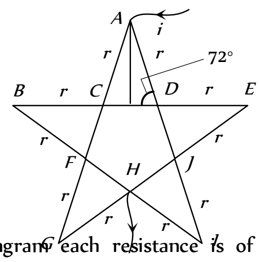
(a) *R* = *R* = *R*

(b) *R* > *R* > *R*

(c) *R* < *R* < *R*

(d) Information is not sufficient

49. In the following star circuit diagram (figure), the equivalent resistance between the points *A* and *H* will be



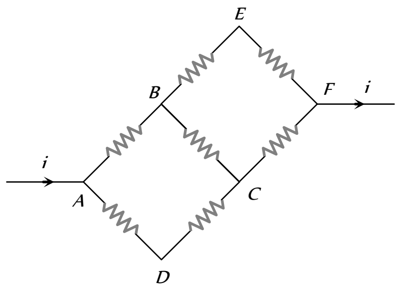
(a) 1.944 *r*

(b) 0.973 *r*

(c) 0.486 *r*

(d) 0.243 *r*

50. In the adjoining circuit diagram each resistance is of 10 Ω. The current in the arm AD will be



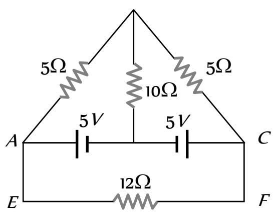
(a) $\frac{2i}{5}$

(b) $\frac{3i}{5}$

(c) $\frac{4i}{5}$

(d) $\frac{i}{5}$

51. In the circuit of adjoining figure the current through 12 Ω resister will be



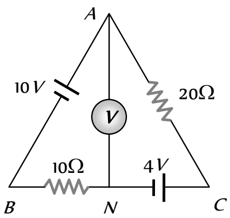
(a) 1 *A*

(b) $\frac{1}{5}$ *A*

(c) $\frac{2}{5}$ *A*

(d) 0 *A*

52. The reading of the ideal voltmeter in the adjoining diagram will be



(a) 4 *V*

(b) 8 *V*

(c) 12 *V*

(d) 14 *V*

53. The resistance of the series combination of two resistance is *S*. When they are joined in parallel the total resistance is *P*. If *S* = *nP*, then the minimum possible value of *n* is

[AIEEE 2004]

(a) 4 (b) 3

(c) 2 (d) 1

54. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 *divisions per milliampere* and voltage sensitivity is 2 *divisions per millivolt*. In order that each division reads 1 *volt*, the resistance in ohms needed to be connected in series with the coil will be [AIEEE 2005]

(a) 99995 (b) 9995

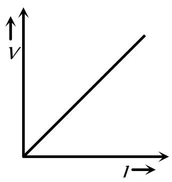
(c) 10^3 (d) 10^5

Graphical Questions

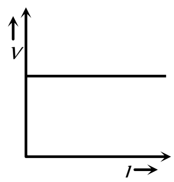
1. Which of the adjoining graphs represents *ohmic* resistance

[CPMT 1981; DPMT 2002]

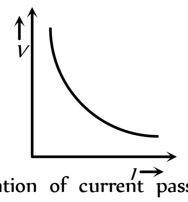
(a)



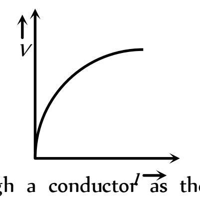
(b)



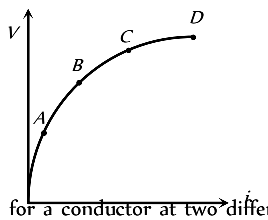
(c)



(d)



2. Variation of current passing through a conductor as the voltage applied across its ends as varied is shown in the adjoining diagram. If the resistance (*R*) is determined at the points *A*, *B*, *C* and *D*, we will find that [CPMT 1988]



(a) $R_C = R_D$

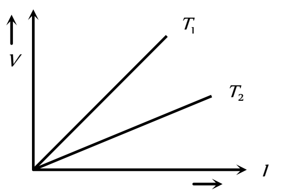
(b) $R_B > R_A$

(c) $R_C > R_B$

(d) None of these

3. The voltage *V* and current *I* graph for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is

[MP PET 1996; KCET 2002]



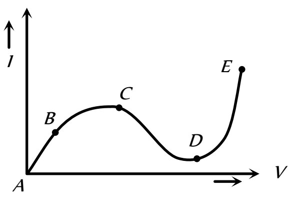
(a) $T_1 > T_2$

(b) $T_1 \approx T_2$

(c) $T_1 = T_2$

(d) $T_1 < T_2$

4. From the graph between current *I* and voltage *V* shown below, identify the portion corresponding to negative resistance



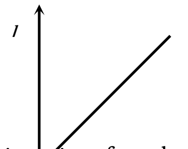
(a) *AB*

(b) *BC*

(c) *CD*

(d) *DE*

5. *I-V* characteristic of a copper wire of length *L* and area of cross-section *A* is shown in figure. The slope of the curve becomes



(a) More if the experiment is performed at higher temperature

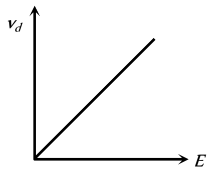
(b) More if a wire of steel of same dimension is used

(c) More if the length of the wire is increased

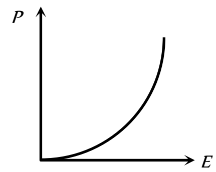
(d) Less if the length of the wire is increased

6. *E* denotes electric field in a uniform conductor, *I* corresponding current through it, v_d drift velocity of electrons and *P* denotes thermal power produced in the conductor, then which of the following graph is incorrect

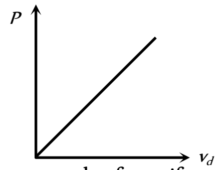
(a)



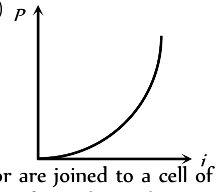
(b)



(c)

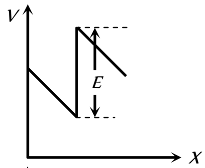


(d)

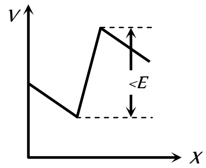


7. The two ends of a uniform conductor are joined to a cell of e.m.f. *E* and some internal resistance. Starting from the midpoint *P* of the conductor, we move in the direction of current and return to *P*. The potential *V* at every point on the path is plotted against the distance covered (*x*). Which of the following graphs best represents the resulting curve

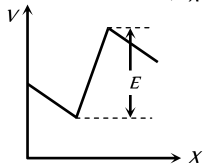
(a)



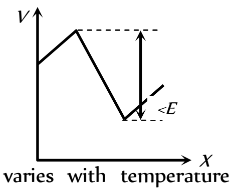
(b)



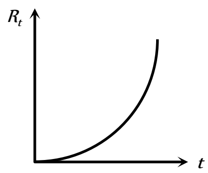
(c)



(d)



8. The resistance R_t of a conductor varies with temperature *t* as shown in the figure. If the variation is represented by $R_t = R_0[1 + \alpha t + \beta t^2]$, then [CPMT 1988]



(a) α and β are both negative

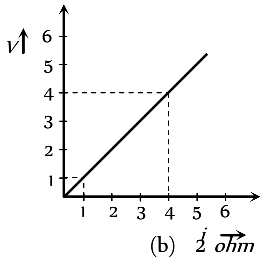
(b) α and β are both positive

(c) α is positive and β is negative

[CBSE PMT 1997]

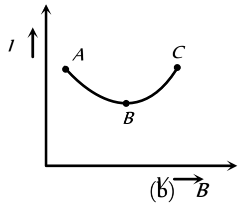
(d) α is negative and β are positive

9. Variation of current and voltage in a conductor has been shown in the diagram below. The resistance of the conductor is.



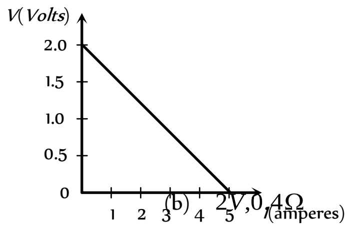
(a) 4 *ohm* (b) 2 *ohm*
(c) 3 *ohm* (d) 1 *ohm*

10. Resistance as shown in figure is negative at [CPMT 1997]



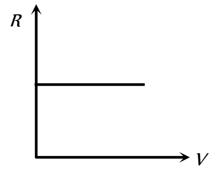
(a) *A* (b) *B*
(c) *C* (d) None of these

11. For a cell, the graph between the potential difference (*V*) across the terminals of the cell and the current (*I*) drawn from the cell is shown in the figure. The e.m.f. and the internal resistance of the cell are

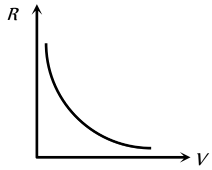


(a) $2V, 0.5\Omega$ (b) $2V, 0.4\Omega$
(c) $> 2V, 0.5\Omega$ (d) $> 2V, 0.4\Omega$

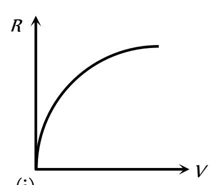
12. The graph which represents the relation between the total resistance *R* of a multi range moving coil voltmeter and its full scale deflection *V* is



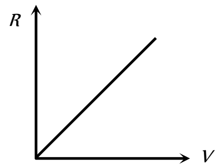
(i)



(ii)



(iii)

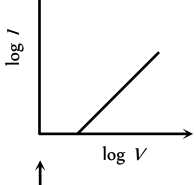


(iv)

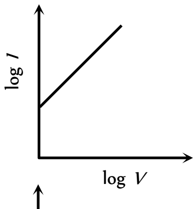
(a) (i) (b) (ii)
(c) (iii) (d) (iv)

13. When a current I is passed through a wire of constant resistance, it produces a potential difference *V* across its ends. The graph drawn between log I and log V will be

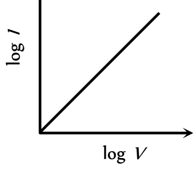
(a)



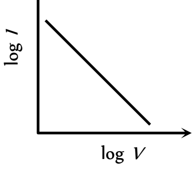
(b)



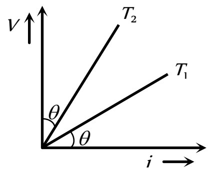
(c)



(d)



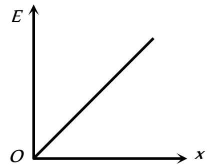
14. The *V-i* graph for a conductor at temperature T_1 and T_2 are as shown in the figure. $(T_2 - T_1)$ is proportional to



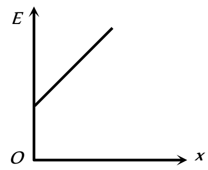
(a) $\cos 2\theta$
(b) $\sin\theta$
(c) $\cot 2\theta$
(d) $\tan\theta$

15. A cylindrical conductor has uniform cross-section. Resistivity of its material increase linearly from left end to right end. If a constant current is flowing through it and at a section distance *x* from left end, magnitude of electric field intensity is *E*, which of the following graphs is correct

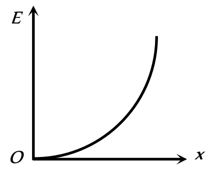
(a)



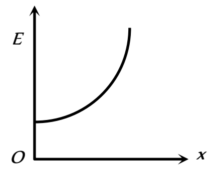
(b)



(c)



(d)

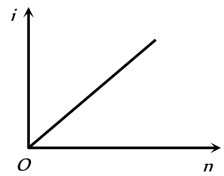


16. The *V-i* graph for a conductor makes an angle θ with *V*-axis. Here *V* denotes the voltage and *i* denotes current. The resistance of conductor is given by

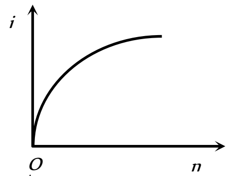
(a) $\sin\theta$ (b) $\cos\theta$
(c) $\tan\theta$ (d) $\cot\theta$

17. A battery consists of a variable number '*n*' of identical cells having internal resistances connected in series. The terminals of battery are short circuited and the current *i* is measured. Which of the graph below shows the relation ship between *i* and *n*

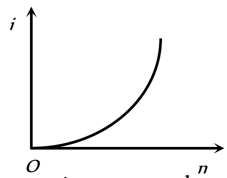
(a)



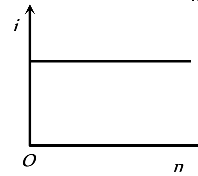
(b)



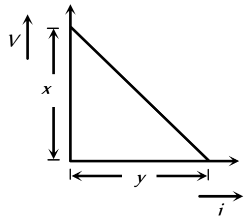
(c)

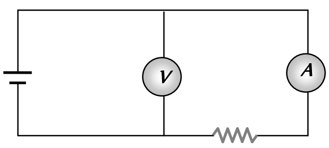


(d)



18. In an experiment, a graph was plotted of the potential difference *V* between the terminals of a cell against the circuit current *i* by varying load rheostat. Internal conductance of the cell is given by

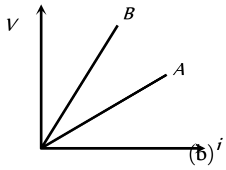




(a) xy (b) $\frac{y}{x}$

(c) $\frac{x}{y}$ (d) $(x - y)$

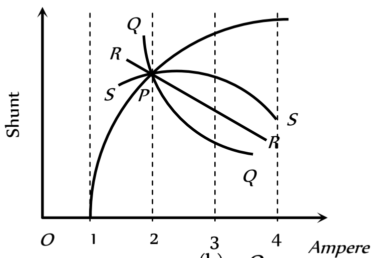
19. V-i graphs for parallel and series combination of two identical resistors are as shown in figure. Which graph represents parallel combination



(a) A (b) B

(c) A and B both (d) Neither A nor B

20. The ammeter has range 1 *ampere* without shunt. the range can be varied by using different shunt resistances. The graph between shunt resistance and range will have the nature



(a) P (b) Q

(c) R (d) S

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

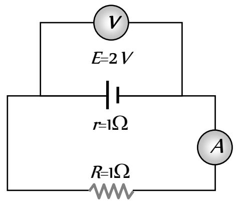
(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : The resistivity of a semiconductor increases with temperature.
Reason : The atoms of a semiconductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity [AIIMS 2003]

2. Assertion : In a simple battery circuit the point of lowest potential is positive terminal of the battery
Reason : The current flows towards the point of the higher potential as it flows in such a circuit from the negative to the positive terminal. [AIIMS 2002]

3. Assertion : The temperature coefficient of resistance is positive for metals and negative for p-type semiconductor.
Reason : The effective charge carriers in metals are negatively charged whereas in p-type semiconductor they are positively charged. [AIIMS 1996]

4. Assertion : In the following circuit emf is $2V$ and internal resistance of the cell is $1\ \Omega$ and $R = 1\Omega$, then reading of the voltmeter is $1V$.



Reason : $V = E - ir$ where $E = 2V$, $i = \frac{2}{2} = 1A$ and $R = 1\ \Omega$ [AIIMS 1995]

5. Assertion : There is no current in the metals in the absence of electric field.
Reason : Motion of free electron are randomly. [AIIMS 1994]

6. Assertion : Electric appliances with metallic body have three connections, whereas an electric bulb has a two pin connection.
Reason : Three pin connections reduce heating of connecting wires.

7. Assertion : The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.
Reason : On increasing temperature, conductivity of metallic wire decreases.

8. Assertion : The electric bulbs glows immediately when switch is on.
Reason : The drift velocity of electrons in a metallic wire is very high.

9. Assertion : Bending a wire does not effect electrical resistance.
Reason : Resistance of wire is proportional to resistivity of material.

10. Assertion : In meter bridge experiment, a high resistance is always connected in series with a galvanometer.
Reason : As resistance increases current through the circuit increases.

11. Assertion : Voltameter measures current more accurately than ammeter.
Reason : Relative error will be small if measured from voltameter.

12. Assertion : Electric field outside the conducting wire which carries a constant current is zero.
Reason : Net charge on conducting wire is zero.

13. Assertion : The resistance of super-conductor is zero.
Reason : The super-conductors are used for the transmission of electric power.

14. Assertion : A potentiometer of longer length is used for accurate measurement.
Reason : The potential gradient for a potentiometer of longer length with a given source of e.m.f. becomes small.

15. Assertion : The e.m.f. of the driver cell in the potentiometer experiment should be greater than the e.m.f. of the cell to be determined.
Reason : The fall of potential across the potentiometer wire should not be less than the e.m.f. of the cell to be determined.

16. Assertion : A person touching a high power line gets stuck with the line.

Reason : The current carrying wires attract the man towards it.

17. Assertion : The connecting wires are made of copper.

Reason : The electrical conductivity of copper is high.

Answers

Electric Conduction, Ohm's Law and Resistance

1	a	2	c	3	b	4	b	5	c
6	a	7	a	8	a	9	d	10	c
11	d	12	d	13	a	14	c	15	a
16	a	17	c	18	b	19	c	20	b
21	d	22	b	23	b	24	b	25	d
26	c	27	b	28	b	29	b	30	a
31	c	32	d	33	b	34	d	35	c
36	b	37	b	38	c	39	a	40	d
41	b	42	b	43	a	44	b	45	c
46	a	47	b	48	b	49	c	50	a
51	c	52	c	53	b	54	b	55	b
56	a	57	a	58	a	59	c	60	c
61	a	62	b	63	b	64	c	65	c
66	d	67	a	68	b	69	d	70	d
71	a	72	a	73	c	74	b	75	b
76	c	77	c	78	c	79	d	80	b
81	a	82	d	83	b	84	b	85	c
86	b	87	c	88	a	89	a	90	d
91	a	92	c	93	b	94	a	95	b
96	b	97	c	98	a	99	c	100	d
101	c	102	a	103	d	104	b	105	b
106	d	107	d	108	a	109	d	110	d
111	d	112	d	113	a	114	a	115	c
116	a	117	a	118	b	119	c	120	a
121	d	122	a	123	a	124	d	125	c
126	b	127	c	128	a	129	a	130	c
131	c	132	b	133	c				

Grouping of Resistances

1	c	2	d	3	a	4	c	5	b
6	c	7	c	8	b	9	a	10	b
11	d	12	d	13	b	14	d	15	b
16	d	17	c	18	c	19	b	20	d
21	a	22	a	23	b	24	b	25	c
26	b	27	d	28	d	29	d	30	c
31	b	32	d	33	a	34	b	35	c
36	d	37	d	38	b	39	c	40	b
41	a	42	c	43	b	44	d	45	c
46	d	47	c	48	b	49	b	50	d
51	d	52	c	53	d	54	a	55	c
56	d	57	c	58	c	59	d	60	c
61	d	62	c	63	d	64	c	65	c
66	c	67	b	68	c	69	d	70	b
71	a	72	c	73	a	74	b	75	a
76	c	77	c	78	b	79	c	80	a
81	a	82	b	83	b	84	d	85	d
86	a	87	a	88	a	89	b	90	b
91	b	92	c	93	b	94	d	95	a
96	d	97	b	98	b	99	d	100	a
101	c	102	a	103	b	104	d	105	a
106	a	107	b	108	d	109	bc	110	b
111	d	112	c	113	a	114	a	115	d
116	a	117	d	118	c	119	d	120	c
121	b	122	b	123	b	124	c	125	b
126	a	127	c	128	b	129	c	130	a
131	a	132	a	133	c	134	a	135	b
136	b	137	a	138	b	139	c	140	b
141	b								

Kirchhoff's Law, Cells

1	b	2	d	3	c	4	a	5	a
6	b	7	a	8	a	9	b	10	a
11	c	12	d	13	a	14	d	15	b
16	c	17	c	18	c	19	d	20	b
21	c	22	c	23	b	24	d	25	a
26	a	27	b	28	b	29	a	30	b
31	a	32	c	33	b	34	a	35	a
36	b	37	a	38	b	39	b	40	c
41	d	42	d	43	d	44	a	45	c
46	c	47	b	48	a	49	a	50	d
51	b	52	d	53	b	54	c	55	a
56	b	57	c	58	a	59	d	60	b
61	c	62	c	63	c	64	b	65	a
66	c	67	a	68	d	69	b	70	a
71	a	72	d	73	c	74	b	75	b
76	b	77	c	78	c	79	d	80	d
81	a	82	d	83	c	84	c	85	a

Different Measuring Instruments

1	a	2	c	3	d	4	d	5	c
6	c	7	a	8	d	9	c	10	c
11	d	12	c	13	d	14	a	15	d
16	c	17	a	18	b	19	c	20	a
21	b	22	b	23	a	24	a	25	a
26	a	27	a	28	a	29	b	30	b
31	b	32	b	33	b	34	b	35	c
36	c	37	b	38	b	39	d	40	b

41	a	42	b	43	c	44	d	45	a
46	b	47	c	48	a	49	b	50	a
51	b	52	c	53	b	54	b	55	a
56	b	57	d	58	c	59	c	60	d
61	a	62	a	63	d	64	a	65	d
66	b	67	a	68	b	69	c	70	c
71	d	72	c	73	a	74	c	75	a
76	d	77	b	78	a	79	b	80	a
81	c	82	c	83	a	84	a	85	b
86	d	87	c	88	d	89	c	90	a
91	d	92	d	93	d	94	c	95	d
96	a	97	c	98	a	99	d	100	d
101	c	102	d	103	c	104	c	105	a
106	c	107	c	108	d	109	c	110	a
111	a	112	a	113	c	114	b	115	c
116	d	117	a	118	b	119	d	120	c
121	d	122	c	123	a	124	a	125	b
126	b	127	d	128	d	129	b	130	c
131	d	132	a	133	c	134	d	135	d
136	a	137	a	138	b	139	d	140	a
141	c	142	a	143	a				

Critical Thinking Questions

1	a	2	a	3	c	4	c	5	c
6	b	7	d	8	d	9	d	10	b
11	d	12	d	13	c	14	b	15	b
16	b	17	b	18	b	19	a	20	d
21	d	22	a	23	c	24	c	25	b
26	b	27	a	28	d	29	b	30	b
31	d	32	a	33	a	34	b	35	c
36	c	37	a	38	a	39	d	40	a
41	a	42	b	43	a	44	a	45	b
46	c	47	b	48	a	49	b	50	a
51	d	52	b	53	a	54	b		

Graphical Questions

1	a	2	d	3	a	4	c	5	d
6	c	7	b	8	b	9	d	10	a
11	b	12	d	13	a	14	c	15	b
16	d	17	d	18	b	19	a	20	b

Assertion and Reason

1	d	2	d	3	b	4	a	5	a
6	c	7	b	8	c	9	a	10	c
11	a	12	a	13	b	14	a	15	a
16	d	17	a						

Answers and Solutions

Electric Conduction, Ohm's Law and Resistance

1. (a) Number of electrons flowing per second

$\frac{n}{t} = \frac{i}{e} = 4.8/1.6 \times 10^{-19} = 3 \times 10^{19}$

2. (c) $v_d = \frac{J}{ne} \Rightarrow v_d \propto J$ (current density)

$J_1 = \frac{i}{A}$ and $J_2 = \frac{2i}{2A} = \frac{i}{A} = J_1$; $\therefore (v_d)_1 = (v_d)_2 = v$

3. (b) Order of drift velocity $= 10^{-4} m/sec = 10^{-2} cm/sec$

4. (b) Density of $Cu = 9 \times 10^3 kg/m^3$ (mass of 1 m^3 of Cu)

$\because$ 6.0 × 10^{23} atoms has a mass = 63 × 10^{-3} kg

$\therefore$ Number of electrons per m^3 are

$= \frac{6.0 \times 10^{23}}{63 \times 10^{-3}} \times 9 \times 10^3 = 8.5 \times 10^{28}$

Now drift velocity $= v_d = \frac{i}{neA}$

$= \frac{1.1}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times \pi \times (0.5 \times 10^{-3})^2}$

$= 0.1 \times 10^{-3} m/sec$

5. (c) Because 1 $H.P.$ = 746 J/s = 746 $watt$

6. (a) $R \propto l^2 \Rightarrow \frac{\Delta R}{R} = \frac{2\Delta l}{l} \Rightarrow \frac{\Delta R_0}{R}\% = 2 \times 0.1 = 0.2\%$

7. (a) $R = \frac{\rho l}{A} = 50 \times 10^{-8} \times \frac{50 \times 10^{-2}}{(50 \times 10^{-2})^2} = 10^{-6}\Omega$

8. (a) Resistivity of some material is its intrinsic property and is constant at particular temperature. Resistivity does not depend upon shape.

9. (d) $\frac{\rho_1}{\rho_2} = \frac{(1+\alpha t_1)}{(1+\alpha t_2)} \Rightarrow \frac{1}{2} = \frac{(1+0.00125 \times 27)}{(1+0.00125 \times t)}$

$\Rightarrow t = 854°C \Rightarrow T = 1127K$

10. (c) $R_1 \propto \frac{l}{A} \Rightarrow R_2 \propto \frac{2l}{2A}$ *i.e.* $R_2 \propto \frac{l}{A}$

$\therefore R_1 = R_2$

11. (d) In case of stretching of wire $R \propto l^2$

$\Rightarrow$ If length becomes 3 times so Resistance becomes 9 times *i.e.* $R' = 9 \times 20 = 180\Omega$

12. (d) Resistivity is the property of the material. It does not depend upon size and shape.

13. (a) Because with rise in temperature resistance of conductor increase, so graph between V and i becomes non linear.

14. (c) Because V-i graph of diode is non-linear.

15. (a) $v_d = \frac{e}{m} \times \frac{V}{l}\tau$ or $v_d = \frac{e}{m} \cdot \frac{El}{l}\tau$ (Since $V = El$)

$\therefore v_d \propto E$

16. (a) Resistance of conductor depends upon relation as $R \propto \frac{1}{\tau}$.

With rise in temperature *rms* speed of free electron inside the conductor increase, so relaxation time decrease and hence resistance increases

17. (c) $i = \frac{q}{t} = \frac{4}{2} = 2\,ampere$

18. (b) Volume $= Al = 3 \Rightarrow A = \frac{3}{l}$

Now $R = \rho\frac{l}{A} \Rightarrow 3 = \frac{\rho \times l}{3/l} = \frac{\rho l^2}{3} \Rightarrow l^2 = \frac{9}{\rho} = \frac{3}{\sqrt{\rho}}$

19. (c) $i = \frac{ne}{t} = \frac{62.5 \times 10^{18} \times 1.6 \times 10^{-19}}{1} = 10\,ampere$

20. (b) In twisted wire, two halves each of resistance 2Ω are in parallel, so equivalent resistance will be $\frac{2}{2} = 1\Omega$.

21. (d) In stretching of wire $R \propto \frac{1}{r^4}$

22. (b) $R = \frac{\rho L}{A} \Rightarrow 0.7 = \frac{\rho \times 1}{\frac{22}{7}(1 \times 10^{-3})^2}$

$\rho = 2.2 \times 10^{-6}$ *ohm-m.*

23. (b) $R \propto \frac{1}{A} \Rightarrow R \propto \frac{1}{r^2} \propto \frac{1}{d^2}$ [d = diameter of wire]

24. (b) $i = qv = 1.6 \times 10^{-19} \times 6.6 \times 10^{15} = 10.56 \times 10^{-4} A = 1mA$

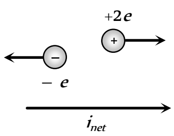
25. (d) $R \propto \frac{l}{r^2} \Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{r_2^2}{r_1^2} \Rightarrow \frac{1}{1} = \frac{5}{l_2} \times \left(\frac{2}{1}\right)^2 \Rightarrow l_2 = 20m$

26. (c)

27. (b) In semiconductors charge carries are free electrons and holes

28. (b) Net current $i_{net} = i_{(+)} + i_{(-)}$

$= \frac{n_{(+)}q_{(+)}}{t} + \frac{n_{(-)}q_{(-)}}{t}$



$= \frac{n_{(+)}}{t} \times 2e + \frac{n_{(-)}}{t} \times e$

= 3.2 × 10^{18} × 2 × 1.6 × 10^{-19} + 3.6 × 10^{18} × 1.6 × 10^{-19}

= 1.6 A (towards right)

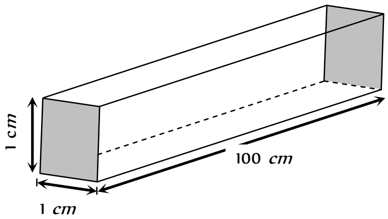
29. (b) In the absence of external electric field mean velocity of free electron (V_-) is given by $V_{rms} = \sqrt{\frac{3KT}{m}} \Rightarrow V_{rms} \propto \sqrt{T}$

30. (a) With rise in temperature specific resistance increases

31. (c) For metallic conductors, temperature co-efficient of resistance is positive.

32. (d)

33. (b) Length l = 1 cm $= 10^{-2} m$



Area of cross-section A = 1 cm × 100 cm

= 100 cm^2 = 10^{-2} m^2

Resistance R = 3 × 10^{-7} × $\frac{10^{-2}}{10^{-2}}$ = 3 × 10^{-7} Ω

34. (d) In the above question for calculating equivalent resistance between two opposite square faces.

l = 100 cm = 1 m, A = 1 cm^2 = 10^{-4} m^2, so resistance R = 3 × 10^{-7} × $\frac{1}{10^{-4}}$ = 3 × 10^{-3} Ω

35. (c) $v_d = \frac{i}{nAe} = \frac{20}{10^{29} \times 10^{-6} \times 1.6 \times 10^{-19}} = 1.25 \times 10^{-3} m/s$

36. (b) Specific resistance $k = \frac{E}{j}$

37. (b) $R \propto \frac{l}{A} \propto \frac{l}{d^2} \Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2} \times \left(\frac{d_2}{d_1}\right)^2 = \frac{L}{4L}\left(\frac{2d}{d}\right)^2 = 1$

$\Rightarrow R_2 = R_1 = R.$

38. (c) $v_d = \frac{i}{nAe} = \frac{1.344}{10^{-6} \times 1.6 \times 10^{-19} \times 8.4 \times 10^{22}}$

$= \frac{1.344}{10 \times 1.6 \times 8.4} = 0.01 cm/s = 0.1 mm/s$

39. (a) Internal resistance $\propto \frac{1}{\text{Temperature}}$

40. (d) Charge = Current × Time = 5 × 60 = 300 C

41. (b) By $R = \rho l / A$

42. (b)

43. (a)

44. (b) $R = \frac{\rho l}{a}$ for first wire and $R' = \frac{\rho l}{4a} = \frac{R}{4}$ for second wire.

45. (c) For semiconductors, resistance decreases on increasing the temperature.

46. (a) $R = \rho \frac{l}{A} = \frac{n}{ne^2 \tau} \cdot \frac{l}{A}$

47. (b) Because as temperature increases, the resistivity increases and hence the relaxation time decreases for conductors $\left(\tau \propto \frac{1}{\rho}\right)$.

48. (b) In VI graph, we will not get a straight line in case of liquids.

49. (c) $R = \rho \frac{l}{A}$

50. (a) Since $R \propto l^2 \Rightarrow$ If length is increased by 10%, resistance is increases by almost 20%

Hence new resistance $R' = 10 + 20\%$ of 10

$= 10 + \frac{20}{100} \times 10 = 12\,\Omega.$

51. (c) $\frac{R_{150}}{R_{500}} = \frac{[1 + \alpha(150)]}{[1 + \alpha(500)]}$. Putting $R_{150} = 133\Omega$ and $\alpha = 0.0045/°C$, we get $R_{500} = 258\Omega$

52. (c) $R = \rho \frac{l}{A} \Rightarrow 7 = \frac{64 \times 10^{-6} \times 198}{\frac{22}{7} \times r^2} \Rightarrow r = 0.024 cm$

53. (b) Current density $J = \frac{i}{A} = \frac{i}{\pi r^2} \Rightarrow \frac{J_1}{J_2} = \frac{i_1}{i_2} \times \frac{r_2^2}{r_1^2}$

But the wires are in series, so they have the same current, hence $i_1 = i_2$. So $\frac{J_1}{J_2} = \frac{r_2^2}{r_1^2} = 9:1$

54. (b) As $\frac{V}{i} = R$ and $R \propto$ temperature

55. (b) $R \propto l^2 \Rightarrow$ If l doubled then R becomes 4 times.

56. (a) Temperature coefficient of a semiconductor is negative.

57. (a) The reciprocal of resistance is called conductance

58. (a) $\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$

59. (c) Ohm's Law is not obeyed by semiconductors.

60. (c) Drift velocity $v_d = \frac{V}{\rho l n e}$; v_d does not depend upon diameter.

61. (a) Using $R_{T_2} = R_{T_1}[1 + \alpha(T_2 - T_1)]$

$\Rightarrow R_{100} = R_{50}[1 + \alpha(100 - 50)]$

$\Rightarrow 7 = 5[1 + (\alpha \times 50)] \Rightarrow \alpha = \frac{(7-5)}{250} = 0.008/^o C$

62. (b) This is because of secondary ionisation which is possible in the gas filled in it.

63. (b)

64. (c) $\frac{R_1}{R_2} = \frac{(1 + \alpha t_1)}{(1 + \alpha t_2)} \Rightarrow \frac{50}{76.8} = \frac{(1 + 3.92 \times 10^{-3} \times 20)}{(1 + 3.92 \times 10^{-3} t)}$

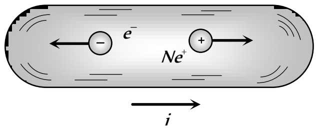
$\Rightarrow t = 167°C$

65. (c) From $v_d = \frac{i}{neA} \Rightarrow i \propto v_d A \Rightarrow i \propto v_d r^2$

66. (d) Resistivity depends only on the material of the conductor.

67. (a) A particular temperature, the resistance of a superconductor is zero $\Rightarrow G = \frac{1}{R} = \frac{1}{0} = \infty$

68. (b) Net current $i = i_+ + i_- = \frac{(n_+)(q_+)}{t} + \frac{(n_-)(q_-)}{t}$



$\Rightarrow i = \frac{(n_+)}{t} \times e + \frac{(n_-)}{t} \times e$

$= 2.9 \times 10^{18} \times 1.6 \times 10^{-19} + 1.2 \times 10^{18} \times 1.6 \times 10^{-19}$

$\Rightarrow i = 0.66\, A$

69. (d) If E be electric field, then current density $j = \sigma E$

Also we know that current density $j = \frac{i}{A}$

Hence j is different for different area of cross-sections. When j is different, then E is also different. Thus E is not constant. The drift velocity v_d is given by $v_d = \frac{j}{ne}$ = different for different j values. Hence only current i will be constant.

70. (d)

71. (a) $R = \rho \frac{l}{A}$ and mass m = volume (V) × density (d) = ($A\, l$) d

Since wires have same material so ρ and d is same for both.

Also they have same mass $\Rightarrow Al$ = constant $\Rightarrow l \propto \frac{1}{A}$

$\Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \left(\frac{A_2}{A_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^4$

$\Rightarrow \frac{34}{R_2} = \left(\frac{r}{2r}\right)^4 \Rightarrow R_2 = 544\,\Omega$

72. (a) $R = \rho \frac{l}{A} \Rightarrow \frac{R_1}{R_2} = \frac{A_2}{A_1} (\rho, L \text{ constant}) \Rightarrow \frac{A_1}{A_2} = \frac{R_2}{R_1} = 2$

Now, when a body dipped in water, loss of weight $= V\sigma_L g = AL\sigma_L g$

So, $\frac{(\text{Loss of weight})_1}{(\text{Loss of wight})_2} = \frac{A_1}{A_2} = 2$; so A has more loss of weight.

73. (c) $Q = it = 20 \times 10^{-6} \times 30 = 6 \times 10^{-4}\, C$

74. (b) Ge is semiconductor and Na is a metal. The conductivity of semiconductor increases and that of the metals decreases with the rise in temperature.

75. (b) $i = \frac{ne}{t} \Rightarrow n = \frac{it}{e} = \frac{1.6 \times 10^{-3} \times 1}{1.6 \times 10^{-19}} = 10^{16}$.

76. (c) Drift velocity $v_d = \frac{i}{neA} \Rightarrow v_d \propto \frac{1}{A}$ or $v_d \propto \frac{1}{d^2}$

$\Rightarrow \frac{v_P}{v_Q} = \left(\frac{d_Q}{d_P}\right)^2 = \left(\frac{d/2}{d}\right)^2 = \frac{1}{4} \Rightarrow v_P = \frac{1}{4} v_Q$.

77. (c) Human body, though has a large resistance of the order, of $K\Omega$ (say $10 k\Omega$), is very sensitive to minute currents even as low as a few mA. Electrons, excites and disorders the nervous system of the body and hence one fails to control the activity of the body.

78. (c) $R_t = R_0(1 + \alpha t)$

$\Rightarrow 4.2 = R_0(1 + 0.004 \times 100) = 1.4 R_0 \Rightarrow R_0 = 3\Omega$.

79. (d) $R \propto \frac{l^2}{m} \Rightarrow R_1 : R_2 : R_3 = \left(\frac{l_1}{m_1}\right)^2 : \left(\frac{l_2}{m_2}\right)^2 : \left(\frac{l_3}{m_3}\right)^2$

$= \frac{25}{1} : \frac{9}{3} : \frac{1}{5} = 25 : 3 : \frac{1}{5} \Rightarrow 125 : 15 : 1$.

80. (b)

81. (a) $\frac{R_1}{R_2} = \left(\frac{r_2}{r_1}\right)^4 \Rightarrow \frac{R}{R_2} = \left(\frac{nr}{r}\right)^4 \Rightarrow R_2 = \frac{R}{n^4}$.

82. (d) $\frac{R_1}{R_2} = \frac{(1 + \alpha t_1)}{(1 + \alpha t_2)} \Rightarrow \frac{5}{6} = \frac{(1 + \alpha \times 50)}{(1 + \alpha \times 100)} \Rightarrow \alpha = \frac{1}{200}$ per ^oC

Again by $R_t = R_0(1 + \alpha t)$

$\Rightarrow 5 = R_0\left(1 + \frac{1}{200} \times 50\right) \Rightarrow R_0 = 4\Omega$.

83. (b) $i = \frac{Q}{T} = Q\nu = 1.6 \times 10^{-19} \times 5 \times 10^{15} = 0.8 mA$.

84. (b) $\frac{r_{\text{iron}}}{r_{\text{Copper}}} = \sqrt{\frac{\rho_{\text{iron}}}{\rho_{\text{copper}}}} = \sqrt{\frac{1 \times 10^{-7}}{1.7 \times 10^{-8}}} \approx 2.4$.

85. (c) $i = e\nu = 1.6 \times 10^{-19} \times 6.8 \times 10^{15} = 1.1 \times 10^{-3}\, amp.$

86. (b) Resistivity of the material of the rod

$\rho = \frac{RA}{l} = \frac{3 \times 10^{-3} \pi (0.3 \times 10^{-2})^2}{1} = 27 \times 10^{-9} \pi\, \Omega \times m$

Resistance of disc $R = \frac{(\text{Thickness})}{(\text{Area of cross section})}$

$= 27 \times 10^{-9} \pi \times \frac{(10^{-3})}{\pi \times (1 \times 10^{-2})^2} = 2.7 \times 10^{-7}\Omega$.

87. (c) By using $R_t = R_0(1 + \alpha t)$

$3 \times R_0 = R_0(1 + 4 \times 10^{-3}\, t) \Rightarrow t = 500^o C$.

88. (a) $i = 6 \times 10^{15} \times 1.6 \times 10^{-19} = 0.96 mA$.

89. (a) $i = \frac{ne}{t} \Rightarrow 16 \times 10^{-3} = \frac{n \times 1.6 \times 10^{-19}}{1} \Rightarrow n = 10^{17}$

90. (d) $R = \frac{V}{i} = \frac{100 \pm 0.5}{10 \pm 0.2} = 10 \pm 0.25\,\Omega$.

91. (a) $R = \frac{V}{i} = \rho \frac{l}{A} \Rightarrow \frac{2}{4} = \rho \frac{50 \times 10^{-2}}{(1 \times 10^{-3})^2} \Rightarrow \rho = 1 \times 10^{-6}\Omega m$.

92. (c)

93. (b) $i = \frac{V}{R} = \frac{Q}{t} \Rightarrow Q = \frac{Vt}{R} = \frac{20 \times 2 \times 60}{10} = 240\, C$.

94. (a) $R \propto l^2 \Rightarrow \frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2 \Rightarrow \frac{R}{R_2} = \left(\frac{l}{l/2}\right)^2 = 4 \Rightarrow R_2 = \frac{R}{4}$.

95. (b)

96. (b) $V_d = \frac{i}{neA} = \frac{40}{10^{29} \times 10^{-6} \times 1.6 \times 10^{-19}}$

$= 2.5 \times 10^{-3}\, m/sec$.

97. (c) $V_d = \frac{i}{nAe} = \frac{5.4}{8.4 \times 10^{28} \times 10^{-6} \times 1.6 \times 10^{-19}}$

$= 0.4 \times 10^{-3}\, m/sec = 0.4 mm/sec$.

98. (a) $\frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2 \Rightarrow \frac{10}{R_2} = \left(\frac{5}{20}\right)^2 = \frac{1}{16} = R_2 = 160\Omega$.

99. (c) $R \propto \frac{1}{\tau}$; where τ = Relaxation time.

When lamp is switched on, temperature of filament increase, hence τ decrease so R increases

100. (d) $R = 91 \times 10^2 \approx 9.1 k\Omega$.

101. (c)

102. (a)

103. (d) $R \propto \frac{l^2}{m} \Rightarrow R_1 : R_2 : R_3 = \frac{l_1^2}{m_1} : \frac{l_2^2}{m_2} : \frac{l_3^2}{m_3}$

$\Rightarrow R_1 : R_2 : R_3 = \frac{9}{1} : \frac{4}{2} : \frac{1}{3} = 27 : 6 : 1$.

104. (b) $n = \frac{1 \times 10^{-3}}{1.6 \times 10^{-19}} = 6.25 \times 10^{15}$.

105. (b) $v_d = \frac{i}{ne\pi r^2} \Rightarrow v_d \propto \frac{i}{r^2} \Rightarrow \frac{v}{v'} = \frac{i_1}{i_2} \times \left(\frac{r_2}{r_1}\right)^2 \Rightarrow v' = \frac{v}{2}$.

106. (d) $\frac{R_1}{R_2} = \left(\frac{r_2}{r_1}\right)^4 \Rightarrow \frac{R}{R_2} = \left(\frac{3r/4}{r}\right)^4 = \frac{81}{256} = R_2 = \frac{256}{81} R$

107. (d)

108. (a) $v_d = \frac{i}{nAe} = \frac{8}{8 \times 10^{28} \times (2 \times 10^{-3})^2 \times 1.6 \times 10^{-19}}$

$= 0.156 \times 10^{-3}\, m/sec$.

109. (d) Specific resistance doesn't depend upon length and area.

110. (d) Heating effect of current.

111. (d) $l = \frac{R\pi r^2}{\rho} = \frac{4.2 \times 3.14 \times (0.2 \times 10^{-3})^2}{48 \times 10^{-8}} = 1.1 m$

112. (d) For conductors, resistance $\propto$ Temperature and for semi-conductor, resistance $\propto \frac{1}{\text{Temperature}}$

113. (a) If suppose initial length $l_1 = 100$ then $l_2 = 100 + 100 = 200$

$\frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2 = \left(\frac{100}{200}\right)^2 \Rightarrow R_2 = 4R_1$

$\frac{\Delta R}{R} \times 100 = \frac{R_2 - R_1}{R_1} \times 100 = \frac{4R_1 - R_1}{R_1} \times 100 = 300\%$.

114. (a) Ammeter is always connected in series and Voltmeter is always connected in parallel.

115. (c) Same mass, same material *i.e.* volume is same or Al = constant

Also, $R = \rho \frac{l}{A} \Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \left(\frac{A_2}{A_1}\right)^2 \left(\frac{d_2}{d_1}\right)^4$

$\Rightarrow \frac{24}{R_2} = \left(\frac{d}{d/2}\right)^4 = 16 \Rightarrow R_2 = 1.5\Omega$.

116. (a) $I = n_e q_e + n_p q_p = 1 mA$ towards right

117. (a) As steady current is flowing through the conductor, hence the number of electrons entering from one end and outgoing from the other end of any segment is equal. Hence charge will be zero.

118. (b) Conductance $C = \frac{1}{R} = \frac{A}{\rho l} \Rightarrow C \propto \frac{1}{l}$

119. (c) $i = \frac{dQ}{dt} \Rightarrow dQ = idt \Rightarrow Q = \int_{t_1}^{t_2} i dt = \int_0^5 (1.2t + 3) dt$

$= \left[\frac{1.2t^2}{2} + 3t\right]_0^5 = 30C$

120. (a) In stretching, $\frac{R_2}{R_1} = \left(\frac{r_1}{r_2}\right)^4 \Rightarrow \frac{R_2}{R} = \left(\frac{2}{1}\right)^4 \Rightarrow R_2 = 16R$

121. (d) $R' = n^2 R \Rightarrow R' = 16R$

122. (a)

Significant figures		Multiplier
Brown	Black	Brown
1	0	10^1

$\therefore R = 10 \times 10^1 = 100\ \Omega$

123. (a)

124. (d)

125. (c)

126. (b) $R \propto \frac{l}{r^2} \Rightarrow \frac{R_2}{R_1} = \frac{l_2}{l_1} \times \frac{r_1^2}{r_2^2} = \left(\frac{2}{1}\right) \times \left(\frac{1}{2}\right)^2 = \frac{1}{2}$

$\Rightarrow R_2 = \frac{R_1}{2}$, specific resistance doesn't depend upon length, and radius.

127. (c) By using $v_d = \frac{i}{neA} = \frac{100}{10^{28} \times 1.6 \times 10^{-19} \times \frac{\pi}{4} \times (0.02)^2}$

$= 2 \times 10^{-4}\, m/\text{sec}$

128. (a) $R \propto \frac{l}{r^2}$. For highest resistance $\frac{l}{r^2}$ should be maximum, which is correct for option (a)

129. (a) Red, brown, orange, silver red and brown represents the first two significant figures.

Significant figures		Multiplier	Tolerance
Red	Brown	Orange	Silver
2	1	10^3	± 10%

$\therefore R = 21 \times 10^3 \pm 10\%$

130. (c) In stretching $R \propto l^2 \Rightarrow \frac{R_2}{R_1} = \frac{l_2^2}{l_1^2} \Rightarrow \frac{R_2}{R_1} = \left(\frac{2}{1}\right)^2$

$\Rightarrow R_2 = 4R_1$. Change in resistance $= R_2 - R_1 = 3R_1$

Now, $\frac{\text{Change in resistance}}{\text{Original resistance}} = \frac{3R_1}{R_1} = \frac{3}{1}$

131. (c) $\frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2$, If $l_1 = 100$ then $l = 110$

$\Rightarrow \frac{R_1}{R_2} = \left(\frac{100}{110}\right)^2 \Rightarrow R_2 = 1.21 R_1$

% change $\frac{R_2 - R_1}{R_1} \times 100 = 21\%$

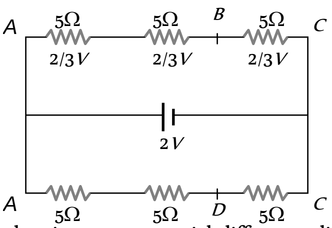
132. (b)

133. (c) Resistance $= \rho \frac{l}{A}$

$\therefore \frac{R_1}{R_2} = \frac{\rho_1}{\rho_2} \times \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \frac{2}{3} \times \frac{3}{4} \times \frac{5}{4} = \frac{5}{8}$

Grouping of Resistances

1. (c) The given circuit can be redrawn as follows



For identical resistances, potential difference distributes equally among all. Hence potential difference across each resistance is $\frac{2}{3}V$, and potential difference between A and B is $\frac{4}{3}V$.

2. (d) Equivalent resistance of parallel resistors is always less than any of the member of the resistance system.

3. (a) Each part will have a resistance $r = R/10$

Let equivalent resistance be r_R, then

$\frac{1}{r_R} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r}$.......... .10 times

$\therefore \frac{1}{r_R} = \frac{10}{r} = \frac{10}{R/10} = \frac{100}{R} \Rightarrow r_R = \frac{R}{100} = 0.01R$

4. (c) $R_{\text{equivalent}} = \frac{(30+30)30}{(30+30)+30} = \frac{60 \times 30}{90} = 20\Omega$

$\therefore i = \frac{V}{R} = \frac{2}{20} = \frac{1}{10}$ *ampere*

5. (b) Resistance of parallel group $= \frac{R}{2}$

$\therefore$ Total equivalent resistance $= 4 \times \frac{R}{2} = 2R$

6. (c) Resistance of 1 *ohm* group $= \frac{R}{n} = \frac{1}{3}\Omega$

This is in series with $\frac{2}{3}\Omega$ resistor.

$\therefore$ Total resistance $= \frac{2}{3} + \frac{1}{3} = \frac{3}{3}\Omega = 1\Omega$

7. (c) Lowest resistance will be in the case when all the resistors are connected in parallel.

$\frac{1}{R} = \frac{1}{0.1} + \frac{1}{0.1}$....... 10 times

$\frac{1}{R} = 10 + 10$....... 10 times

$\frac{1}{R} = 100$ *i.e.* $R = \frac{1}{100}\Omega$

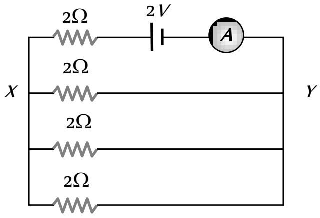
8. (b) Resistance across $XY = \frac{2}{3}\Omega$

Total resistance

$= 2 + \frac{2}{3} = \frac{8}{3}\Omega$

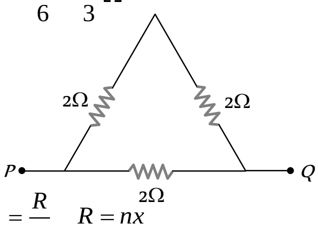
Current through ammeter

$= \frac{2}{8/3} = \frac{6}{8} = \frac{3}{4}A$



9. (a) Equivalent resistance of the combination

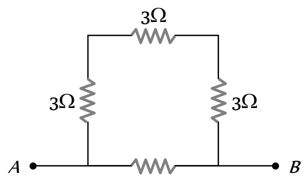
$= \frac{(2+2) \times 2}{2+2+2} = \frac{8}{6} = \frac{4}{3}\Omega$



10. (b) In parallel, $x = \frac{R}{n}$ $R = nx$

In series, $R + R + R$ .... n times $= nR = n(nx) = n x$

11. (d) The circuit reduces to



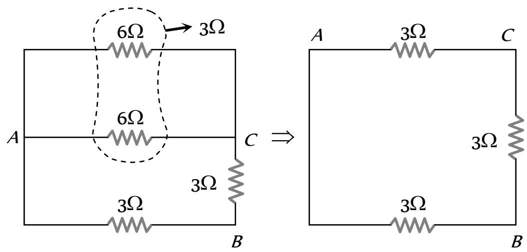
$R_{AB} = \frac{9 \times 6}{9+6} = \frac{9 \times 6}{15} = \frac{18}{5} = 3.6\Omega$

12. (d) As resistance $\propto$ Length

Resistance of each arm $= \frac{12}{3} = 4\Omega$

$\Rightarrow R_{\text{effective}} = \frac{4 \times 8}{4+8} = \frac{8}{3}\Omega$

13. (b) Given circuit is equivalent to



So the equivalent resistance between points A and B is equal to $R=\frac{6\times3}{6+3}=2\Omega$

14. (d) Potential difference across all resistors in parallel combination is same.

15. (b) Current through each arm DAC and DBC = 1A

$V_D-V_A=2$ and $V_D-V_B=3 \Rightarrow V_A-V_B=+1V$

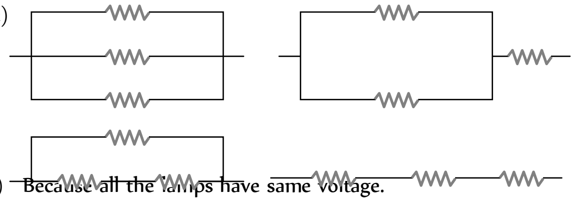
16. (d) $R = r+\frac{3r}{2}=\frac{5r}{2}$

17. (c) If resistances are R_1 and R_2 then $\frac{R_1R_2}{R_1+R_2}=\frac{6}{8}$ .....(i)

Suppose R_2 is broken then $R_1=2\Omega$ .....(ii)

On solving equations (i) and (ii) we get $R_2=6/5\,\Omega$

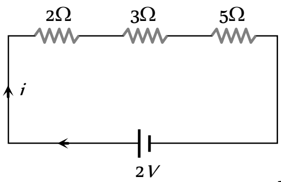
18. (c)



19. (b) Because all the lamps have same voltage.

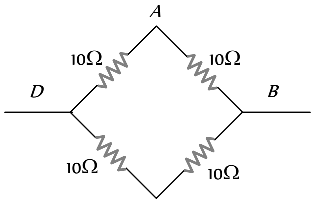
20. (d) $R_{\text{series}}=R_1+R_2+R_3+......$

21. (a) Current supplied by cell $i=\frac{2}{2+3+5}=\frac{1}{5}A$



So potential difference across 3 will be $V=\frac{3\times1}{5}=0.6V$

22. (a) According to the problem, we arrange four resistance as follows



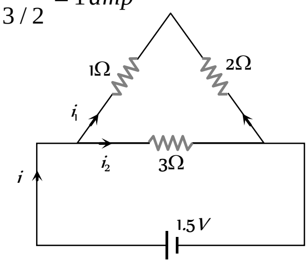
Equivalent resistance $=\frac{20\times20}{40}=10\Omega$

23. (b) $R_1+R_2=9$ and $\frac{R_1R_2}{R_1+R_2}=2 \Rightarrow R_1R_2=18$

$R_1-R_2=\sqrt{(R_1+R_2)^2-4R_1R_2}=\sqrt{81-72}=3$

$R_1=6\Omega, R_2=3\Omega$

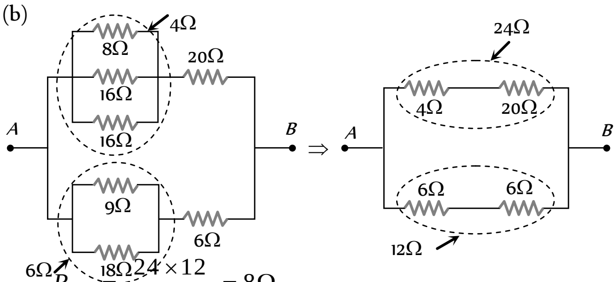
24. (b) $i_1+i_2=\frac{1.5}{3/2}=1\,amp$



$\frac{i_1}{i_2}=\frac{3}{3} \Rightarrow i_1=i_2 \quad \therefore\ i_2=0.5A=i_1$

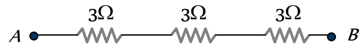
25. (c) $V_p-V_q=\left(\frac{6}{3}+\frac{12\times6}{12+6}\right)(0.5)=(2+4)(0.5)=3V$

26. (b)



$R_{AB}=\frac{24\times12}{(24+12)}=8\Omega$

27. (d) The network can be redrawn as follows



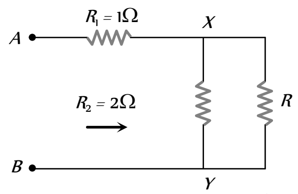
$\Rightarrow R_{eq}=9\Omega$

28. (d) Let the resistance of the wire be R, then we know that resistance is proportional to the length of the wire. So each of the four wires will have $R/4$ resistance and they are connected in parallel. So the effective resistance will be

$\frac{1}{R_1}=\left(\frac{4}{R}\right)4 \Rightarrow R_1=\frac{R}{16}$

29. (d) Equivalent resistance $=\frac{4\times4}{4+4}+\frac{6\times6}{6+6}=5ohm$ So the current in the circuit $=\frac{20}{5}=4$ *ampere* Hence the current flowing through each resistance = 2 *ampere.*

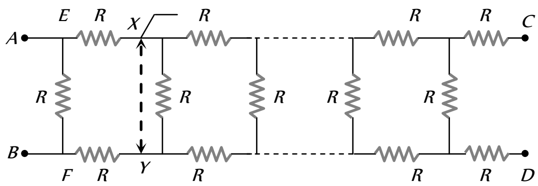
30. (c) Let the resultant resistance be R. If we add one more branch, then the resultant resistance would be the same because this is an infinite sequence.

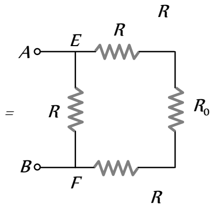


$\therefore \frac{RR_2}{R+R_2}+R_1=R \Rightarrow 2R+R+2=R^2+2R$

$\Rightarrow R^2-R-2=0 \Rightarrow R=-1$ or $R=2ohm$

31. (b) Cut the series from XY and let the resistance towards right of XY be R_0 whose value should be such that when connected across AB does not change the entire resistance. The combination is reduced to as shown below.





The resistance across $EF, = R_{EF} = (R_0 + 2R)$

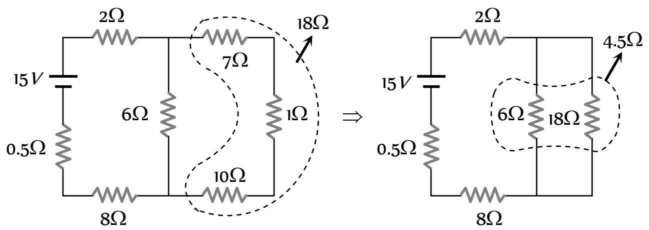
Thus $R_{AB} = \frac{(R_0 + 2R)R}{R_0 + 2R + R} = \frac{R_0 R + 2R^2}{R_0 + 3R} = R_0$

$\Rightarrow R_0^2 + 2RR_0 - 2R^2 + 0 \Rightarrow R_0 = R(\sqrt{3} - 1)$

32. (d) The last two resistance are out of circuit. Now 8Ω is in parallel with $(1 + 1 + 4 + 1 + 1)\Omega$.

$\therefore R = 8\Omega \| \; 8\Omega = \frac{8}{2} = 4\Omega \Rightarrow R_{AB} = 4 + 2 + 2 = 8\Omega$

33. (a) The given circuit can be simplified as follows

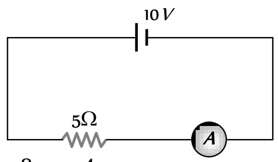


On further solving equivalent resistance $R = 15\,\Omega$

Hence current from the battery $i = \frac{15}{15} = 1A$

34. (b) The circuit will be as shown

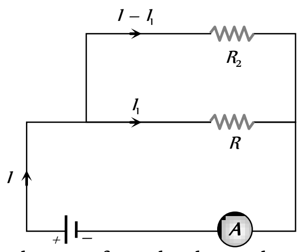
$i = \frac{10}{5} = 2A$



35. (c) The current in the circuit $= \frac{8}{5+1} = \frac{4}{3}$

Now $V_C - V_E = \frac{4}{3} \times 1 \Rightarrow V_E = -\frac{4}{3} V$

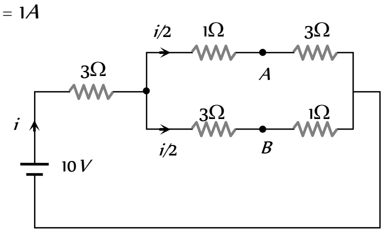
36. (d) According to the figure, $(I - I_1)R_2 = I_1 R$



Only two values satisfying the above relation are $\frac{I}{2}$ and R

37. (d) Effective resistance between the points A and B is $R = \frac{32}{12} = \frac{8}{3}\Omega$

38. (b) $R_{eq} = 5\Omega$, Current $i = \frac{10}{5} = 2A$ and current in each branch = $1A$



Potential difference between C and A,

$V_C - V_A = 1 \times 1 = 1V$ ....(i)

Potential difference between C and B,

$V_C - V_B = 1 \times 3 = 3V$ ......(ii)

On solving (i) and (ii) $V_A - V_B = 2\,volt$

Shot Trick : $(V_A - V_B) = \frac{i}{2}(R_2 - R_1) = \frac{2}{2}(3 - 1) = 2V$

39. (c) $\frac{1}{R} = \frac{1}{1} + \frac{1}{1} + \frac{1}{1} = \frac{3}{1} \Rightarrow R = \frac{1}{3} ohm$

Now such three resistance are joined in series, hence total $R = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1 ohm$

40. (b) To obtain minimum resistance, all resistors must be connected in parallel.

Hence equivalent resistance of combination $= \frac{r}{10}$

41. (a) For same material and same length

$\frac{R_2}{R_1} = \frac{A_1}{A_2} = \frac{3}{2} \Rightarrow R_2 = 3R_1$

Resistance of thick wire $R_1 = 10\Omega$

$\therefore$ Resistance of thin wire $R_2 = 30\Omega$

Total resistance in series = 10 + 30 = 40 Ω

42. (c) Similar to Q. No. 30

$R = 2 + 2 + \frac{2 \times R}{2 + R} \Rightarrow 2R + R^2 = 8 + 4R + 2R$

$\Rightarrow R^2 - 4R - 8 = 0 \Rightarrow R = \frac{4 \pm \sqrt{16 + 32}}{2} = 2 \pm 2\sqrt{3}$

R cannot be negative, hence $R = 2 + 2\sqrt{3} = 5.46\Omega$

43. (b) P.d. across the circuit $= 1.2 \times \frac{6 \times 4}{6 + 4} = 2.88\,volt$

Current through 6 *ohm* resistance $= \frac{2.88}{6} = 0.48\,A$

44. (d) Three resistances are in parallel.

$\therefore \frac{1}{R'} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R}$

The equivalent resistance $R' = \frac{R}{3}\Omega$

45. (c) Similar to Q. No. 30. By formula $R = R_1 + \frac{R_2 \times R}{R_2 + R}$

$\therefore R = 1 + \frac{1 \times R}{1 + R} \Rightarrow R^2 + R = 1 + R + R$

$\Rightarrow R^2 - R - 1 = 0$ or $R = \frac{1 \pm \sqrt{1 + 4}}{2} = \frac{1 \pm \sqrt{5}}{2}$

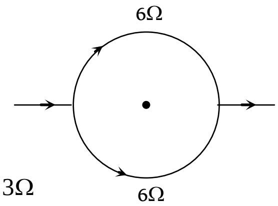
Since R cannot be negative, hence $R = \frac{1 + \sqrt{5}}{2}\Omega$

46. (d) $R \propto l$

Hence every new piece will have a resistance $\frac{R}{10}$. If two pieces are connected in series, then their resistance $= \frac{2R}{10} = \frac{R}{5}$

If 5 such combinations are joined in parallel, then net resistance $= \frac{R}{5\times 5} = \frac{R}{25}$

47. (c)



$R_{eq} = \frac{6}{2} = 3\Omega$

48. (b) Current in the given circuit $i = \frac{50}{(5+7+10+3)} = 2A$

Potential difference between A and B $V_A - V_B = 2\times 12$

$\Rightarrow V_A - 0 = 24V \Rightarrow V_A = 24\ V$

49. (b) If all are in series then $R_{eq} = 12\,\Omega$

If all are in parallel then $R_{eq} = \frac{4}{3}\Omega = 1.33\,\Omega$

If two are in series then parallel with third, $R_{eq} = \frac{8}{3} = 2.6\,\Omega$

If two are in parallel then series with third, $R_{eq} = 6\,\Omega$

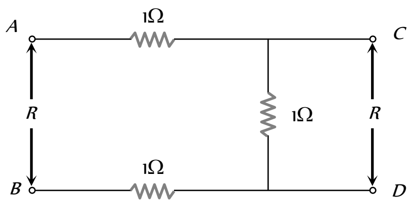
50. (d) Equivalent external resistance of the given circuit $R_{eq} = 4\,\Omega$

Current given by the cell $i = \frac{E}{R_{eq}+r} = \frac{10}{(4+1)} = 2\ A$

Hence, $(V_A - V_B) = \frac{i}{2}\times(R_2 - R_1) = \frac{2}{2}(2-4) = -2\ V.$

51. (d) Resistance of each part will be $\frac{R}{n}$; such n parts are joined in parallel so $R_{eq} = \frac{R}{n^2}$.

52. (c) Let equivalent resistance between A and B be R, then equivalent resistance between C and D will also be R.



$R' = \frac{R}{R+1} + 2 = R$ or $R^2 - 2R - 2 = 0$

$\therefore\ R = \frac{2\pm\sqrt{4+8}}{2} = \sqrt{3}+1$

53. (d) 6Ω and 6Ω are in series, so effective resistance is 12Ω which is in parallel with 3Ω, so

$\frac{1}{R} = \frac{1}{3} + \frac{1}{12} = \frac{15}{36} \Rightarrow R = \frac{36}{15}$

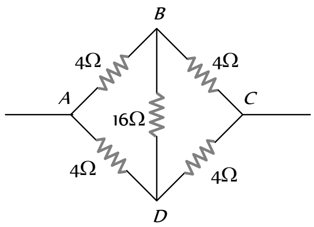
$\therefore\ I = \frac{V}{R} = \frac{4.8\times 15}{36} = 2\ A$

54. (a) Equivalent resistance of the circuit $R = \frac{3}{2}\Omega$

$\therefore$ Current through the circuit $i = \frac{V}{R} = \frac{3}{3/2} = 2A$

55. (c) $R_{max} = nR$ and $R_{min} = R/n \Rightarrow \frac{R_{max}}{R_{min}} = n^2$

56. (d) According to the principle of Wheatstone's bridge, the effective resistance between the given points is 4Ω.



57. (c)

58. (c) Current through 6Ω resistance in parallel with 3Ω resistance = 0.4 A

So total current = 0.8 + 0.4 = 1.2 A

Potential drop across $4\Omega = 1.2\times 4 = 4.8\ V$

59. (d) Two resistances in series are connected parallel with the third. Hence $\frac{1}{R_p} = \frac{1}{4} + \frac{1}{8} = \frac{3}{8} \Rightarrow R_p = \frac{8}{3}\Omega$

60. (c) Resistances at C and B are not in the circuit. Use laws of resistances in series and parallel excluding the two resistance.

61. (d) After simplifying the network, equivalent resistance obtained between A and B is 8Ω.

62. (c) The circuit consists of three resistances (2R, 2R and R) connected in parallel.

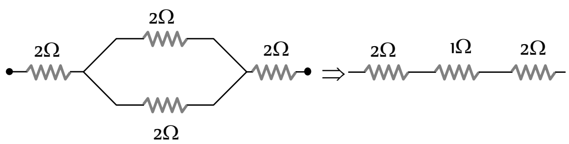
63. (d) Resistance across the battery is

$\frac{1}{R_p} = \frac{1}{3} + \frac{1}{6} = \frac{2+1}{6} = \frac{3}{6} \Rightarrow R_p = 2\Omega \Rightarrow I = \frac{2}{2} = 1\ A$

64. (c) The voltmeter is assumed to have infinite resistance. Hence (1 + 2 + 1) + 4 = 8Ω.

65. (c) $R' = \frac{R}{n} = \frac{1}{10} = 0.1\Omega$

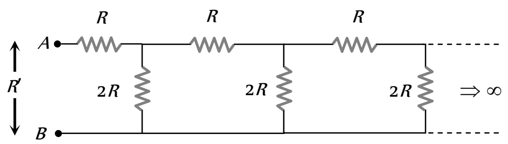
66. (c) The given circuit can be redrawn as follows

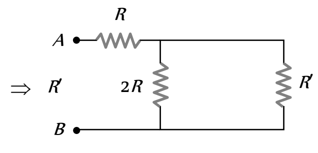


$\Rightarrow\ R_{eq} = 5\Omega$.

67. (b) $R_{AB} = R_1 + \frac{R_2R_3}{R_2+R_3} + R_4 = 2 + \frac{4\times 4}{4+4} + 2 = 6\Omega$.

68. (c) Let equivalent resistance between A and B is R', so given circuit can be reduced as follows





$R' = R + \dfrac{2R \times R'}{(2R + R')} \Rightarrow R'^2 - RR' - 2R^2 = 0$

On solving the equation we get $R' = 2R$.

69. (d) $R_{AB} = \dfrac{R}{3} + R = \dfrac{2}{3} + 2 = \dfrac{8}{3} = 2\dfrac{2}{3}\Omega$.

70. (b) $i = \dfrac{E}{R+r} \Rightarrow 0.5 = \dfrac{10}{R+3} \Rightarrow 10 = 0.5R + 1.5 \Rightarrow R = 17\Omega$.

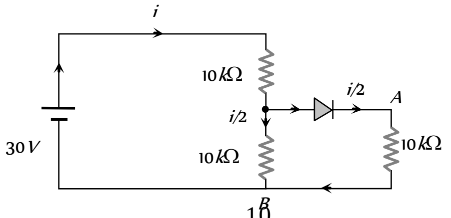
71. (a) Equivalent resistance $R = 4 + \dfrac{3 \times 6}{3+6} = 6\Omega$ and main current

$i = \dfrac{E}{R} = \dfrac{3}{6} = 0.5A$

Now potential difference across the combination of 3Ω and 6Ω, $V = 0.5 \times \left(\dfrac{3 \times 6}{3+6}\right) = 1 Volt$

The same potential difference, also develops across 3Ω resistance.

72. (c)



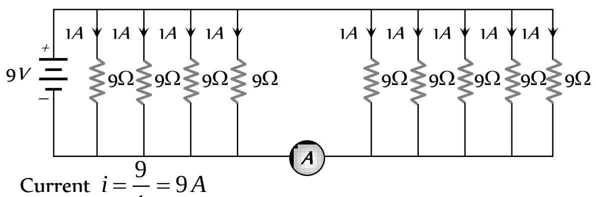
Equivalent resistance $R = 10 + \dfrac{10}{2} = 15\,k\Omega$

Current $i = \dfrac{30}{15} = 2 \times 10^{-3} A$

Hence, potential difference between A and B

$V = \left(\dfrac{2 \times 10^{-3}}{2}\right) \times 10 \times 10^3 = 10\,Volt$

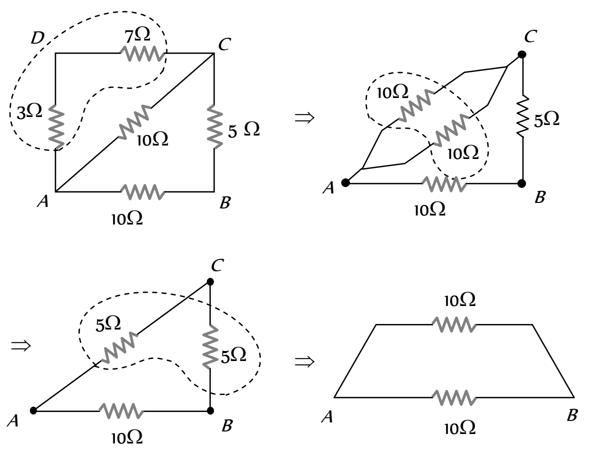
73. (a) Equivalent resistance $R = \dfrac{9}{9} = 1\Omega$



Current $i = \dfrac{9}{1} = 9A$

Current passes through the ammeter = 5A.

74. (b) The figure can be drawn as follows

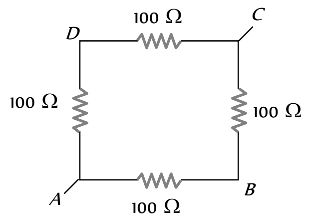


$\Rightarrow R_{AB} = 5\Omega$.

75. (a) $R_1 = \dfrac{\rho_1 l_1}{A}$ and $R_2 = \dfrac{\rho_2 l_2}{A}$. In series $R_{eq} = R_1 + R_2$

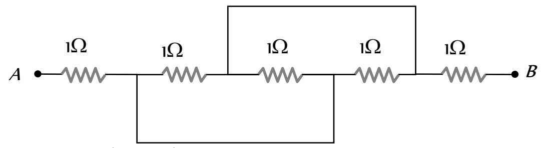
$\dfrac{\rho_{eq.}(l_1 + l_2)}{A} = \dfrac{\rho_1 l_1}{A} + \dfrac{\rho_2 l_2}{A} \Rightarrow \rho_{eq} = \dfrac{\rho_1 l_1 + \rho_2 l_2}{l_1 + l_2}$.

76. (c) The figure can be drawn as follows



$R_{AC} = \dfrac{200 \times 200}{200 + 200} = 100\Omega$.

77. (c)



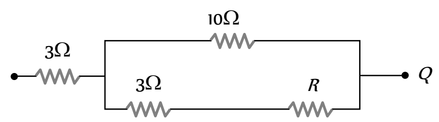
$R_{AB} = 2 + \dfrac{1}{3} = 2\dfrac{1}{3}\Omega$.

78. (b) ρ – same, l – same, $A_2 = \dfrac{1}{4}A_1$ (as $r_2 = \dfrac{r_1}{2}$)

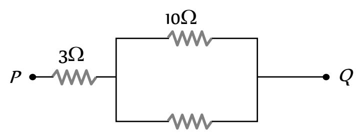
By using $R = \rho\dfrac{l}{A} \Rightarrow \dfrac{R_1}{R_2} = \dfrac{A_2}{A_1} \Rightarrow \dfrac{R_1}{8} = \dfrac{1}{4} \Rightarrow R_1 = 2\Omega$

Hence, $R_{eq} = \dfrac{R_1 R_2}{R_1 + R_2} = \dfrac{2 \times 8}{(2+8)} = \dfrac{8}{5}\Omega$.

79. (c) The given circuit can be simplified as follows



⇒

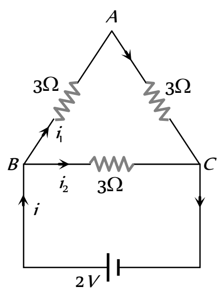


$R = 3 + \dfrac{10 \times (3 + R)}{10 + 3 + R} = 3 + \dfrac{30 + 10R}{13 + R}$

$R = \dfrac{39 + 3R + 30 + 10R}{13 + R} = \dfrac{69 + 13R}{13 + R}$

$13R + R^2 = 69 + 13R \Rightarrow R = \sqrt{69}\Omega$.

80. (a) The circuit can be drawn as follows



Equivalent resistance $R = \frac{3\times(3+3)}{3+(3+3)} = 2\Omega$

Current $i = \frac{2}{2} = 1A$. So, $i_1 = 1\times\left(\frac{3}{3+6}\right) = \frac{1}{3}A$.

Potential difference between A and $B = \frac{1}{3}\times 3 = 1 volt$.

81. (a) $\frac{1}{R_{eq}} = \frac{1}{2}+\frac{1}{4}+\frac{1}{8} = \frac{4+2+1}{8} \Rightarrow R_{eq} = \frac{8}{7}\Omega$.

82. (b) The given figure is balance wheat stone bridge.

83. (b) $\frac{7}{12} = \frac{1}{4}+\frac{1}{R} \Rightarrow R = 3\Omega$

84. (d) Suppose resistance of wires are R_1 and R_2 then $\frac{6}{5} = \frac{R_1R_2}{R_1+R_2}$. If R_2 breaks then $R_1 = 2\Omega$

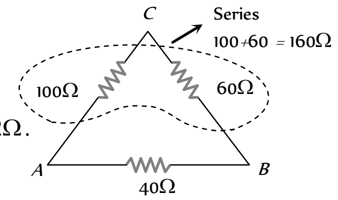
Hence, $\frac{6}{5} = \frac{2\times R_2}{2+R_2} \Rightarrow R_2 = 3\Omega$.

85. (d) Potential difference across PQ *i.e.* p.d. across the resistance of 20Ω, which is $V = i\times 20$

and $i = \frac{48}{(100+100+80+20)} = 0.16A$

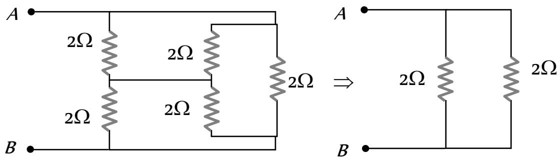
$\therefore\ V = 0.16\times 20 = 3.2V$.

86. (a)



$R = \frac{160\times 40}{160+40} = 32\Omega$.

87. (a)



$R_{AB} = \frac{2\times 2}{2+2} = 1\Omega$.

88. (a) Given circuit is a balance Wheatstone bridge circuit.

89. (b) All of three resistance are in parallel So, $R' = R/n = \frac{R}{3}$.

90. (b) $R_{eq} = R_1 + R_2 \Rightarrow \frac{\rho_{eff.}2l}{A} = \frac{\rho_1 l}{A}+\frac{\rho_2 l}{A} \Rightarrow \rho_{eff.} = \frac{\rho_1+\rho_2}{2}$.

91. (b) Two resistance are in ratio 1 : 2 and third resistance is R

So, $\frac{1}{x}+\frac{1}{2x}+\frac{1}{R} = 1 \Rightarrow x = \frac{3}{2}\left(\frac{R}{R-1}\right)$

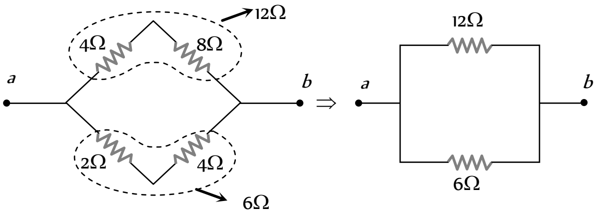
As, resistance is not fractional $\Rightarrow \frac{R}{R-1} = 2$

$\Rightarrow x = 3, R = 2, 2x = 6$

Hence, the value of largest resistance = 6Ω.

92. (c) $R = \frac{(3+3)\times 3}{(3+3)+3} = 2\Omega \Rightarrow i = \frac{3}{2} = 1.5A$.

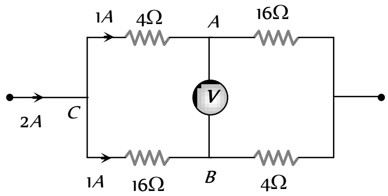
93. (b) Given circuit is a balanced Wheatstone bridge circuit, hence it can be redrawn as follows



$R_{AB} = \frac{12\times 6}{(12+6)} = 4\Omega$.

94. (d) The given circuit is a balanced wheatstone bridge circuit. Hence potential difference between A and B is zero.

95. (a) In the following circuit potential difference between C and A is $V_C - V_A = 1\times 4 = 4$ ......(i)



C and B is $V_C - V_B = 1\times 16 = 16$ ......(ii)

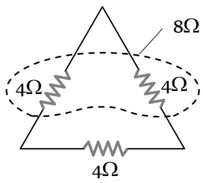
On solving equations (i) and (ii) we get

$V_A - V_B = 12V$.

96. (d) As resistance ∝ Length

$\therefore$ Resistance of each arm $= \frac{12}{3} = 4\,\Omega$

$\therefore\ R_{effective} = \frac{4\times 8}{4+8} = \frac{8}{3}\Omega$



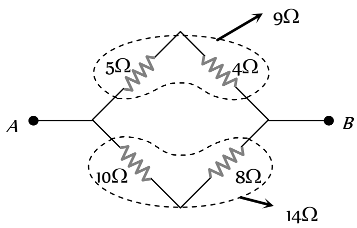
97. (b) $i = \frac{12}{(1+1)+0.4} = 5A$.

98. (b) By balanced Wheatstone bridge condition $\frac{16}{X} = \frac{4}{0.5}$

$\Rightarrow X = \frac{8}{4} = 2\,\Omega$

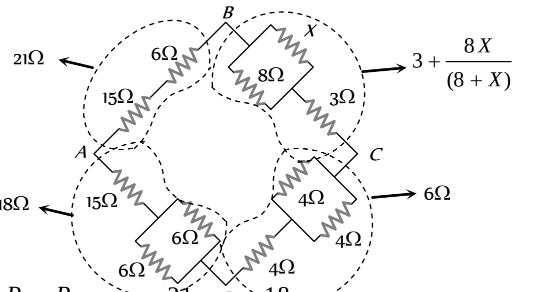
99. (d) Current through $2\Omega = 1.4\left\{\frac{(25+5)}{(10+2)+(25+5)}\right\} = 1A$

100. (a) Since the given bridge is balanced, hence there will be no current through 9Ω resistance. This resistance has no effect and must be ignored in the calculations.



$$R_{AB} = \frac{9\times 18}{27} = 6\,\Omega$$

101. (c) Potential difference between B and D is zero, it means Wheatstone bridge is in balanced condition



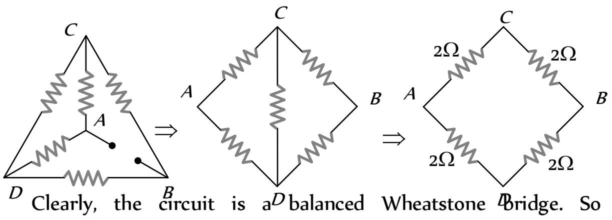
So $\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{21}{3+\frac{8X}{(8+X)}} = \frac{18}{6} \Rightarrow X = 8\Omega$

102. (a) This is a balanced Wheatstone bridge. Therefore no current will flow from the diagonal resistance $10\,\Omega$

$\therefore$ Equivalent resistance $= \frac{(10+10)\times(10+10)}{(10+10)+(10+10)} = 10\,\Omega$

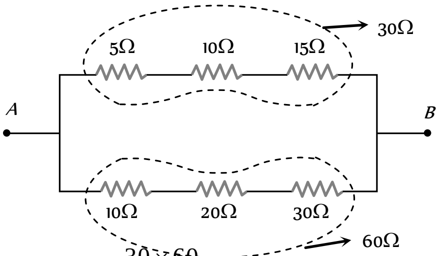
103. (b) This is a balanced Wheatstone bridge circuit. So potential at B and D will be same and no current flows through $4R$ resistance.

104. (d) The equivalent circuits are as shown below



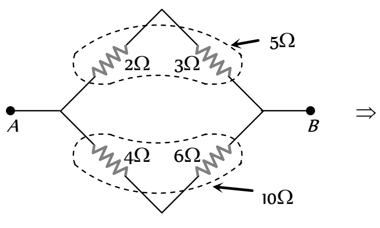
Clearly, the circuit is a balanced Wheatstone bridge. So effective resistance between A and B is $2\,\Omega$.

105. (a) By the concept of balanced Wheatstore bridge, the given circuit can be redrawn as follows



$\Rightarrow R_{AB} = \frac{30\times 60}{(30+60)} = 20\ \Omega$

106. (a) The given circuit is a balanced Wheatstone bridge type, hence it can be simplified as follows



$\Rightarrow \quad R_{AB} = \frac{10}{3}\Omega$

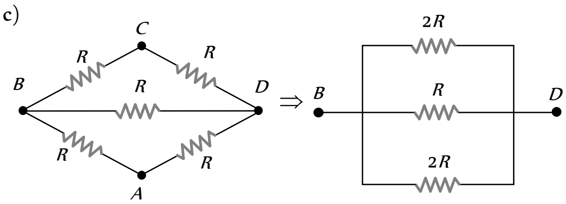
107. (b) Let current through $5\,\Omega$ resistance be i. Then

$$i\times 25 = (2.1 - i)10 \Rightarrow i = \frac{10}{35}\times 2.1 = 0.6\,A$$

108. (d) Let the value of shunt be r. Hence the equivalent resistance of branch containing S will be $\frac{Sr}{S+r}$

In balance condition, $\frac{P}{Q} = \frac{Sr/(S+r)}{R}$. This gives $r = 8\Omega$

109. (b, c)



$$\frac{1}{R_{BD}} = \frac{1}{2R} + \frac{1}{R} + \frac{1}{2R} \Rightarrow R_{BD} = \frac{R}{2}$$

Between A and C circuit becomes equivalent to balanced Wheatstone bridge so $R_{AC} = R$.

110. (b) $i \propto \frac{1}{R}$

111. (d) Equivalent resistance between P and Q

$$\frac{1}{R_{PQ}} = \frac{1}{(6+2)} + \frac{1}{3} + \frac{1}{(4+12)} \Rightarrow R_{PQ} = \frac{48}{25}\Omega$$

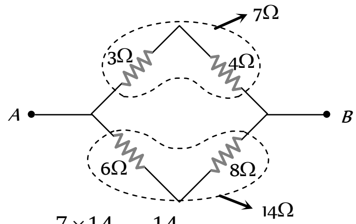
Current between P and Q; $i = 1.5A$

So, potential difference between P and Q

$$V_{PQ} = 1.5\times\frac{48}{25} = 2.88\,V.$$

112. (c) Given circuit is a balanced Wheatstone bridge i.e. potential difference between B and D is zero. Hence, no current flows between B and D.

113. (a) The given circuit is a balanced Wheatstone bridge, hence it can be redrawn as follows



$$\Rightarrow \quad R_{eq} = \frac{7\times 14}{(7+14)} = \frac{14}{3}\Omega.$$

114. (a) For a balance Wheatstone bridge.

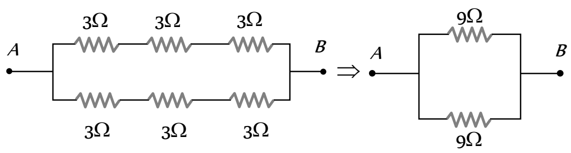
$$\frac{A}{B} = \frac{D}{C} \Rightarrow \frac{10}{5} \neq \frac{4}{4}\,(\text{Unbalanced})$$

$$\frac{A'}{B} = \frac{D}{C} \Rightarrow \frac{A'}{5} = \frac{4}{4} \Rightarrow A' = 5\Omega$$

$A'(5\Omega)$ is obtained by connecting a $10\,\Omega$ resistance in parallel with A.

115. (d) Given circuit is a balanced Wheatstone bridge circuit. So there will be no change in equivalent resistance. Hence no further current will be drawn.

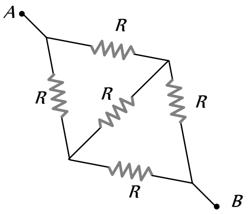
116. (a) No current flow through vertical resistances



$R_{AB} = \frac{9}{2}\Omega$.

117. (d) The given circuit is a balanced Wheatstone bridge.

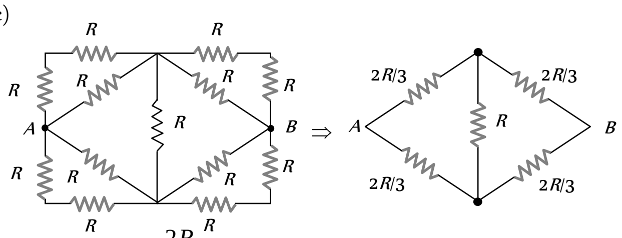
118. (c) The given circuit can be redrawn as follows



Equivalent resistance between *A* to *B* is *R*.

119. (d) Equivalent resistance of the given circuit is 3Ω.

120. (c)



Hence $R_{eq} = \frac{2R}{3}$.

121. (b)

122. (b) For balanced Wheatstone bridge $\frac{P}{Q} = \frac{R}{S}$

$\Rightarrow \frac{12}{(1/2)} = \frac{x+6}{(1/2)} \Rightarrow x = 6\Omega$

123. (b) For maximum energy equivalent resistance of combination should be minimum.

124. (c) For first balancing condition $\frac{10+R_1}{R_2} = \frac{50}{50}$

$\Rightarrow R_2 = 10 + R_1$. For second balancing condition $\frac{R_1}{R_2} = \frac{40}{60} \Rightarrow \frac{R_1}{10+R_1} = \frac{2}{3} \Rightarrow R_1 = 20\Omega$

125. (b) Given $R = 6\Omega$. When resistor is cut into two equal parts and connected in parallel, then

$R_{eq} = \frac{R/2}{2} = \frac{R}{4} = \frac{6}{4} = 1.5\,\Omega$

126. (a) Resistance between *P* and *Q*

$$R_{PQ} = R \,||\, \left(\frac{R}{3} + \frac{R}{2}\right) = \frac{R \times \frac{5}{6}R}{R + \frac{5}{6}R} = \frac{5}{11}R$$

Resistance between *Q* and *R*

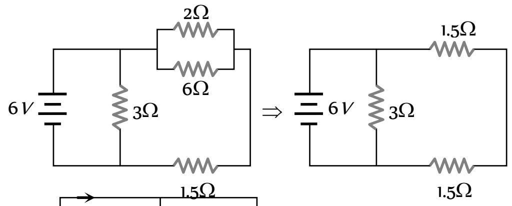
$$R_{QR} = \frac{R}{2} \,||\, \left(R + \frac{R}{3}\right) = \frac{\frac{R}{2} \times \frac{4R}{3}}{\frac{R}{2} + \frac{4R}{3}} = \frac{4}{11}R$$

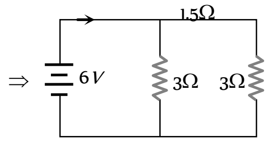
Resistance between *P* and *R*

$$R_{PR} = \frac{R}{3} \,||\, \left(\frac{R}{2} + R\right) = \frac{\frac{R}{3} \times \frac{3R}{2}}{\frac{R}{3} + \frac{3R}{2}} = \frac{3}{11}R$$

Hence it is clear that R_{PQ} is maximum.

127. (c) Given circuit can be redrawn as follows

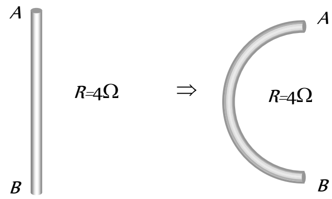




$\Rightarrow i = \frac{6}{1.5} = 4\,A$

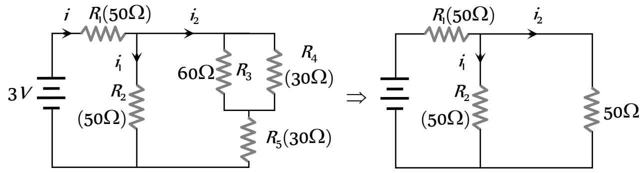
128. (b) $\frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{l_2}{l_1} \times \left(\frac{r_1}{r_2}\right)^2 = \frac{3}{4}\left(\frac{2}{3}\right)^2 = \frac{1}{3}$

129. (c)



130. (a) $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20} \Rightarrow R_{eq} = \frac{20}{19}\Omega$

131. (a) Equivalent resistance of the given network $R_{eq} = 75\,\Omega$



$\therefore$ Total current through battery $i = \frac{3}{75}$

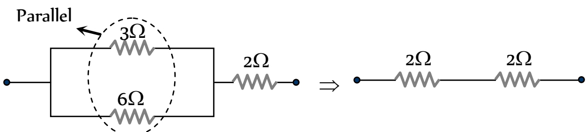
$i_1 = i_2 = \frac{3}{75 \times 2} = \frac{3}{150}$

Current through $R_4 = \frac{3}{150} \times \frac{60}{(30+60)} = \frac{3}{150} \times \frac{60}{90} = \frac{2}{150}A$

$V_4 = i_4 \times R_4 = \frac{2}{150} \times 30 = \frac{2}{5}V = 0.4\,V$

132. (a) $i = \frac{10}{1.5 + (1 \,||\, 1)} = \frac{10}{1.5 + 0.5} = 5A$

133. (c)



$R_{eq} = 4\Omega$

134. (a) The equivalent resistance between *C* and *D* is

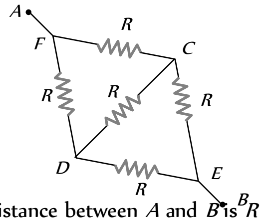
$$\frac{1}{R'}=\frac{1}{6}+\frac{1}{6}+\frac{1}{3}=\frac{2}{3} \text{ or } R'=\frac{3}{2}=1.5\,\Omega$$

Now the equivalent resistance between A and B as $R'=1.5\,\Omega$ and $2.5\,\Omega$ are connected in series, so

$$R''=1.5+2.5=4\,\Omega$$

Now by ohm's law, potential difference between A and B is given by $V_A-V_B=iR=2\times4.0=8\ volt$

135. (b) The given circuit can be redrawn as follows

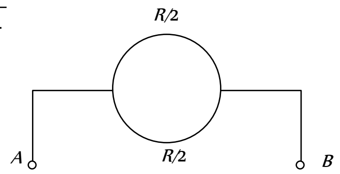


Equivalent resistance between A and B is R and current $i=\frac{V}{R}$

136. (b) The given network is a balanced Wheatstone bridge. It's equivalent resistance will be $R=\frac{18}{5}\Omega$

So current from the battery $i=\frac{V}{R}=\frac{V}{18/5}=\frac{5V}{18}$

137. (a) $\Rightarrow R_{AB}=\frac{R/2}{2}=\frac{R}{4}$



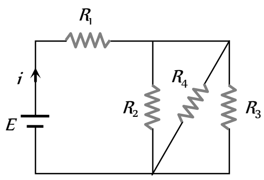
138. (b) $i\propto\frac{1}{R}\Rightarrow\frac{i_1}{i_2}=\frac{R_2}{R_1}\Rightarrow\frac{5}{4}=\frac{(R+2)}{R}\Rightarrow R=8\Omega$

139. (c) In given circuit three resistance R_2, R_4 and R_3 are parallel.

$$\frac{1}{R}=\frac{1}{R_2}+\frac{1}{R_4}+\frac{1}{R_3}$$

$$=\frac{1}{50}+\frac{1}{50}+\frac{1}{75}$$

$$=\frac{75+75+50}{50\times75}$$



$$R=\frac{50\times75}{75+75+50}=\frac{50\times75}{200}=\frac{75}{4}\Omega=18.75\Omega$$

This resistance is in series with R_1

$\therefore$

$$R_{\text{resultant}}=R_1+R=100+18.75=118.75\Omega$$

140. (b) When resistances 4Ω and 12Ω are connected in series $=4+12=16\Omega$

When these resistance are connected in parallel.

$$\frac{1}{R_P}=\frac{1}{4}+\frac{1}{12}\Rightarrow R_P=\frac{4\times12}{4+12}=\frac{4\times12}{16}=3\Omega$$

141. (b) Since voltmeter records $5\,V$, it means the equivalent. Resistance of voltmeter and 100 Ω must be 50, because in series grouping if resistances are equal, they share equal potential difference. It conclude that resistance of voltmeter must be 100 Ω.

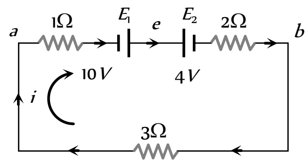
Kirchoff's Law, Cells

1. (b) For no current through galvanometer, we have

$$\left(\frac{E_1}{500+X}\right)X=E\Rightarrow\left(\frac{12}{500+X}\right)X=2\Rightarrow X=100\ \Omega$$

2. (d) Since $E_1(10\ V)>E_2(4V)$

So current in the circuit will be clockwise.



Applying Kirchoff's voltage law

$$-1\times i+10-4-2\times i-3i=0\Rightarrow i=1A(a\text{ to }b\text{ via }e)$$

$$\therefore \text{ Current }=\frac{V}{R}=\frac{10-4}{6}=1.0\ ampere$$

3. (c) For maximum power, external resistance = internal resistance.

4. (a) $0.9\,(2+r)=0.3\,(7+r)\Rightarrow 6+3r=7+r\Rightarrow r=0.5\ \Omega$

5. (a) Since both the resistors are same, therefore potential difference $=V+V=E\Rightarrow V=\frac{E}{2}$

6. (b) Let the current in the circuit $=i=\frac{V}{R}$

Across the cell, $E=V+ir\Rightarrow r=\frac{E-V}{i}=\frac{E-V}{V/R}=\left(\frac{E-V}{V}\right)R$

7. (a) For maximum energy, we have

External resistance of the circuit

= Equivalent internal resistance of the circuit *i.e.* $R=\frac{r}{2}$

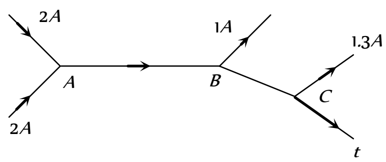
8. (a) Kirchhoff's first law is based on the law of conservation of charge.

9. (b) Kirchhoff's second law is based on the law of conservation of energy.

10. (a) According to Kirchhoff's first law

At junction A, $i_{AB}=2+2=4A$

At junction B, $i_{AB}=i_{BC}-1=3A$



At junction C, $i=i_{BC}-1.3=3-1.3=1.7\ amp$

11. (c) In charging $V>E$.

12. (d) In open circuit of a cell $V=E$

13. (a) Zero (Circuit open means no current and hence no potential difference across resistance).

14. (d) Zero (No potential difference across voltmeter).

15. (b) Let the e.m.f. of cell be E and internal resistance be r. Then

$0.5 = \frac{E}{(r+2)}$ and $0.25 = \frac{E}{(r+5)}$

On dividing, $2 = \frac{5+r}{2+r} \Rightarrow r = 1\Omega$

16. (c) In short circuiting $R = 0$, so $V = 0$

17. (c) Short circuit current $i_{SC} = \frac{E}{r} \Rightarrow 3 = \frac{1.5}{r} \Rightarrow r = 0.5\Omega$

18. (c) $i = \frac{50}{R+r} \Rightarrow r = \frac{50}{4.5} - 10 = \frac{5}{4.5} = 1.1\Omega$

19. (d) $(4+r)i = 2.2$ ......(i)

and $4i = 2 \Rightarrow i = \frac{1}{2}$

Putting the value of i in (i), we get $r = 0.4$ *ohm*.

20. (b) Let the internal resistance of cell be r, then

$i = \frac{E}{R+r} \Rightarrow 15 = \frac{1.5}{0.04+r} \Rightarrow r = 0.06\Omega$

21. (c) The voltage across cell terminal will be given by

$= \frac{E}{R+r} \times R = \frac{2}{(3.9+0.1)} \times 3.9 = 1.95V$

22. (c) $E = 2.2 volt, \quad V = 1.8 volt, \quad R = 5R$

$r = \left(\frac{E}{V} - 1\right)R = \left(\frac{2.2}{1.8} - 1\right) \times 5 = 1.1\Omega$

23. (b) In parallel, equivalent resistance is low $\left(i = \frac{E}{R + \frac{r}{n}}\right)$

24. (d) Internal resistance $\propto$ distance $\propto \frac{1}{\text{Area}} \propto$ concentration

25. (a) Total e.m.f. = nE, Total resistance $R + nr \Rightarrow i = \frac{nE}{R+nr}$

26. (a) Current through R is maximum when total internal resistance of the circuit is equal to external resistance.

27. (b) Cells are joined in parallel when internal resistance is higher then a external resistance. ($R << r$)

$i = \frac{E}{R + \frac{r}{n}}$

28. (b) In series , $i_1 = \frac{2E}{2+2r}$

In parallel, $i_2 = \frac{E}{2 + \frac{r}{2}} = \frac{2E}{4+r}$

Since $i_1 = i_2 \Rightarrow \frac{2E}{4+r} = \frac{2E}{2+2r} \Rightarrow r = 2\Omega$

29. (a) Applying Kirchhoff law

$(2+2) = (0.1+0.3+0.2)i \Rightarrow i = \frac{20}{3}A$

Hence potential difference across A

$= 2 - 0.1 \times \frac{20}{3} = \frac{4}{3}V$ (less than $2V$)

Potential difference across $B = 2 - 0.3 \times \frac{20}{3} = 0$

30. (b) Here two cells are in series.

Therefore total emf = $2E$.

Total resistance = $R + 2r$

$\therefore i = \frac{2E}{R+2r} = \frac{2 \times 1.45}{1.5 + 2 \times 0.15} = \frac{2.9}{1.8} = \frac{29}{18} = 1.611 amp$

31. (a) $E = V + ir$

After short-circuiting, $V = 0; \Rightarrow r = \frac{E}{i} = \frac{2}{4} = 0.5\Omega$

32. (c) By Kirchhoff's current law.

33. (b) For power to be maximum

External resistance = Equivalent internal resistance of the circuit

34. (a) $i = \frac{E}{r} = \frac{1.5}{0.05} = 30A$

35. (a) $i = \frac{12}{(4+2)} = 2A$

Energy loss inside the source $= i^2 r = (2)^2 \times 2 = 8W$

36. (b) $V_2 - V_1 = E - ir = 5 - 2 \times 0.5 = 4 volt$

$\Rightarrow V_2 = 4 + V_1 = 4 + 10 = 14 \, volt$

37. (a) If m = Number of rows

and n = Number of cells in a row

Then $m \times n = 100$ ......(i)

Also condition of maximum current is $R = \frac{nr}{m}$

$\Rightarrow 25 = \frac{1 \times n}{m} \Rightarrow n = 25\,m$ .....(ii)

On solving (i) and (ii) $m = 2$

38. (b) According to Kirchhoff's law $i_{CD} = i_2 + i_3$

39. (b) Since $i = \left(\frac{E}{R+r}\right)$, we get

$0.5 = \frac{E}{2+r}$ ......(i)

$0.25 = \frac{E}{5+r}$ .....(ii)

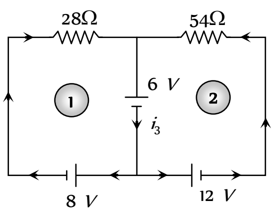
Dividing (i) by (ii), we get $2 = \frac{5+r}{2+r} \Rightarrow r = 1\Omega$

$\therefore 0.5 = \frac{E}{2+1} \Rightarrow E = 1.5V$

40. (c) Because $E_{eq} = E$ and $r_{eq} = \frac{r}{2}$

41. (d) In parallel combination $E_{eq} = E = 6V$

42. (d) Suppose current through different paths of the circuit is as follows.



After applying KVL for loop (1) and loop (2)

We get $28i_1 = -6-8 \Rightarrow i_1 = -\frac{1}{2}A$

and $54i_2 = -6-12 \Rightarrow i_2 = -\frac{1}{3}A$

Hence $i_3 = i_1 + i_2 = -\frac{5}{6}A$

43. (d) $V_{AB} = 4 = \frac{5X + 2\times 10}{X+10} \Rightarrow X = 20\Omega$

44. (a) After short circuiting, R becomes meaningless.

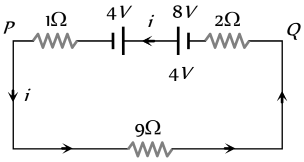
45. (c) $V = E - IR = 15 - 10\times 0.05 = 14.5V$

46. (c) In series $i = \frac{nE}{nr+R} \Rightarrow 0.6 = \frac{n\times 1.5}{n\times 0.5\times 20} \Rightarrow n = 10$

47. (b)

48. (a) $P = \frac{W}{t} = Vi \Rightarrow V = \frac{W}{it} = \frac{1000}{2\times 6\times 60} = 1.38\ V$

49. (a) Applying Kirchoff's voltage law in the given loop.



$-2i + 8 - 4 - 1\times i - 9i = 0 \Rightarrow i = \frac{1}{3}A$

Potential difference across $PQ = \frac{1}{3}\times 9 = 3V$

50. (d) Because cell is in open circuit.

51. (b) In parallel combination $E_{eq} = E = 12V$

52. (d)

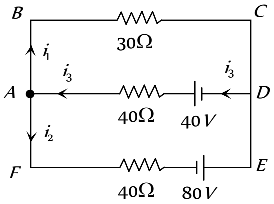
53. (b) $i = \frac{E}{r} = \frac{6}{0.5} = 12\,amp.$

54. (c) Strength = 5 × 18 = 90AH.

55. (a) $i = \frac{E}{R+r} = \frac{5}{4.5+0.5} = 1A$

$V = E - ir = 5 - 1\times 0.5 = 4.5$ Volt

56. (b) The circuit can be simplified as follows



Applying KCL at junction A

$i_3 = i_1 + i_2$ .....(i)

Applying Kirchoff's voltage law for the loop $ABCDA$

$-30i_1 - 40i_3 + 40 = 0$

$\Rightarrow -30i_1 - 40(i_1 + i_2) + 40 = 0$

$\Rightarrow 7i_1 + 4i_2 = 4$ .....(ii)

Applying Kirchoff's voltage law for the loop $ADEFA$.

$-40i_2 - 40i_3 + 80 + 40 = 0$

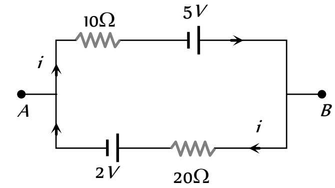
$\Rightarrow -40i_2 - 40(i_1 + i_2) = -120$

$\Rightarrow i_1 + 2i_2 = 3$ ....(iii)

On solving equation (ii) and (iii) $i_1 = -0.4A$.

57. (c) $V = E - ir = 12 - 60\times 5\times 10^{-2} = 9V$.

58. (a) Applying Kirchoff's voltage law in the loop



$-10i + 5 - 20i - 2 = 0 \Rightarrow i = 0.1A$

59. (d) $V = E - ir = 1.5 - 2\times 0.15 = 1.20\,Volt.$

60. (b) $i = \frac{E}{R+r} \Rightarrow 1 = \frac{4}{2+r} = r = 2\Omega$

Short circuit when terminals of battery connected directly then current flows which is $i_{SC} = \frac{E}{r} = \frac{4}{2} = 2A$.

61. (c) $i = \frac{2+2}{1+1.9+0.9} = \frac{4}{3.8}A$

For cell A $E = V + ir \Rightarrow V = 2 - \frac{4}{3.8}\times 1.9 = 0$.

62. (c) By using $i = \frac{E}{R+r}$

$\Rightarrow 0.5 = \frac{E}{11+r} \Rightarrow E = 5.5 + 0.5r$ .....(i)

and $0.9 = \frac{E}{5+r} \Rightarrow E = 4.5 + 0.9r$ .....(ii)

On solving these equation, we have $r = 2.5\Omega$

63. (c)

64. (b) $W = qV = 6\times 10^{-6}\times 9 = 54\times 10^{-6}\,J$.

65. (a) $P = \frac{V^2}{R_{eq}}$; for P to be maximum R_{eq} should be less. Hence option (a) is correct.

66. (c) $P_{max} = \frac{E^2}{4r} = \frac{(2)^2}{4\times 0.5} = 2\,W$

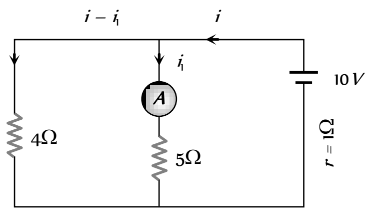
67. (a)

68. (d) Applying Kirchhoff law in the first mesh

$10 = 5\times i \Rightarrow i = \frac{10}{5} = 2\,A$

69. (b) Applying Kirchhoff law in the first mesh

$10 = 5i_1 + i$ .....(i)



Applying in the second mesh

$5i_1 = 4i - 4i_1$ ......(ii)

Solving equation (i) and (ii), we get $i_1 = \frac{40}{29}A$

70. (a) Given problem is the case of mixed grouping of cells

So total current produced $i = \dfrac{nE}{R + \frac{nr}{m}}$

Here $m = 100,\ n = 5000,\ R = 500\,\Omega$

$E = 0.15\,V$ and $r = 0.25\,\Omega$

$$\Rightarrow \quad i = \frac{5000 \times 0.15}{500 + \frac{5000 \times 0.25}{100}} = \frac{750}{512.5} \approx 1.5\,A$$

71. (a)

72. (d) Watt hour efficiency $= \dfrac{\text{Discharging energy}}{\text{Charging energy}}$

$$= \frac{14 \times 5 \times 15}{15 \times 8 \times 10} = 0.875 = 87.5\%$$

73. (c) From Kirchoff's junction Law

$\Rightarrow 4 + 2 + i - 5 - 3 = 0 \Rightarrow i = 2\,A$

74. (b) In the given case cell is in open circuit (i = 0) so voltage across the cell is equal to its e.m.f.

75. (b) The internal resistance of battery is given by

$$r = \left(\frac{E}{V} - 1\right)R = \left(\frac{40}{30} - 1\right) \times 9 = \frac{9 \times 10}{30} = 3\,\Omega$$

76. (b) $i = \dfrac{E}{r + R} \Rightarrow P = i^2 R \Rightarrow P = \dfrac{E^2 R}{(r + R)^2}$

Power is maximum when $r = R \Rightarrow P_{\max} = E^2 / 4r$

77. (c) Since the current coming out from the positive terminal is equal to the current entering the negative terminal, therefore, current in the respective loop will remain confined in the loop itself.

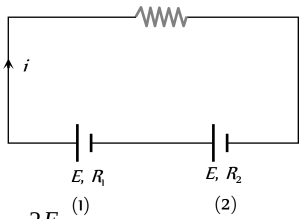
$\therefore$ current through 2Ω resistor = 0

78. (c) Reading of voltmeter

$$= E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2} = \frac{18 \times 1 + 12 \times 2}{1 + 2} = 14V$$

79. (d) $i = \dfrac{2E}{R + R_1 + R_2}$

From cell (2) $E = V + iR_2 = 0 + iR_2$

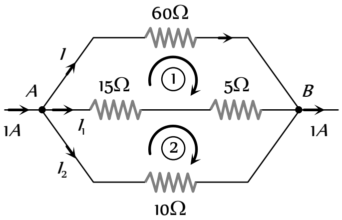


$$\Rightarrow E = \frac{2E}{R + R_1 + R_2} \times R_2 \Rightarrow R = R_2 - R_1$$

80. (d)

81. (a) Applying Kirchoff's law in following figure.

At junction A :



$i + i_1 + i_2 = 1$ .... (i)

For Loop (i)

$-60\,i + (15 + 5)i_1 = 0$

$\Rightarrow i_1 = 3i$ ...(ii)

For loop (2)

$-(15 + 5)\,i_1 + 10\,i_2 = 0$

$\Rightarrow i_2 = i_1 = (3\,i) = 6i$

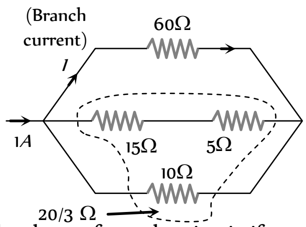
On solving equation (i), (ii) and (iii) we get $i = 0.1\,A$

Short Trick : Branch current =

$$\text{main current}\left(\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right)$$

$$\Rightarrow i = 1 \times \left[\frac{\frac{20}{3}}{\frac{20}{3} + 60}\right]$$

= 0.1 A



82. (d) Maximum current will be drawn from the circuit if resultant resistance of all internal resistances is equal to the value of external resistance if the arrangement s mixed. In series, $R >> nr$ and in parallel, the external resistance is negligible.

83. (c) On applying Kirchoff's current law $i = 13\,A$.

84. (c) Total cells = $m \times n = 24$ .... (i)

For maximum current in the circuit $R = \dfrac{mr}{n}$

$\Rightarrow 3 = \dfrac{m}{n} \times (0.5) \Rightarrow m = 6n$ ..... (ii)

On solving equation (i) and (ii), we get m = 12, n =2

85. (a) Power dissipated $= i^2 R = \left(\dfrac{E}{R + r}\right)^2 R$

$$\therefore \left(\frac{E}{R_1 + r}\right)^2 R_1 = \left(\frac{E}{R_2 + r}\right)^2 R_2$$

$\Rightarrow R_1(R_2^2 + r_2 + 2R_2 r) = R_2(R_1^2 + r^2 + 2R_1 r)$

$\Rightarrow R_2^2 R_1 + R_1 r^2 + 2R_2 r = R_1^2 R_2 + R_2 r^2 + 2R_1 R_2 r$

$\Rightarrow (R_1 - R_2)r^2 = (R_1 - R_2)r^2 = (R_1 - R_2)R_1 R_2$

$\Rightarrow r = \sqrt{R_1 R_2}$

Different Measuring Instruments

1. (a) In meter bridge experiment, it is assumed that the resistance of the L shaped plate is negligible, but actually it is not so. The error created due to this is called, end error. To remove this the resistance box and the unknown resistance must be interchanged and then the mean reading must be taken.

2. (c) To convert a galvanometer into an ammeter a low value resistance is to be connected in parallel to it called shunt.

3. (d) Balance point has some fixed position on potentiometer wire. It is not affect by the addition of resistance between balance point and cell.

4. (d) Resistance of voltmeter should be greater than the external circuit resistance. An ideal voltmeter has infinite resistance.

5. (c) $S = \dfrac{i_g G}{i - i_g} = \dfrac{100 \times 0.01}{(10 - 0.01)} = \dfrac{1}{10} = 0.1\Omega$

6. (c) Equivalent resistance of the circuit $R_{eq} = 100\Omega$

current through the circuit $i = \dfrac{2.4}{100} A$

P.D. across combination of voltmeter and 100 Ω resistance

$= \dfrac{2.4}{100} \times 50 = 1.2V$

Since the voltmeter and 100 Ω resistance are in parallel, so the voltmeter reads the same value *i.e.* 1.2 *V*.

7. (a) Potential gradient $= \dfrac{e}{(R + R_h + r)} \cdot \dfrac{R}{L}$

$= \dfrac{2}{(15 + 5 + 0)} \times \dfrac{5}{1} = 0.5 \dfrac{V}{m} = 0.005 \dfrac{V}{cm}$

8. (d) $S = \dfrac{i_g G}{(i - i_g)} \Rightarrow \dfrac{G}{S} = \dfrac{i - i_g}{i_g} = \dfrac{10 - 1}{1} = \dfrac{9}{1}$

9. (c) Ammeter is used to measure the current through the circuit.

10. (c) $S = \dfrac{i_g G}{(i - i_g)} = \dfrac{1 \times 0.018}{10 - 1} = \dfrac{0.018}{9} = 0.002\Omega$

11. (d) Potentiometer works on null deflection method. In balance condition no current flows in secondary circuit.

12. (c) Shunt resistances $S = \dfrac{i_g G}{(i - i_g)} = \dfrac{10 \times 99}{(100 - 10)} = 11\Omega$

13. (d) By using $R = \dfrac{V}{i_g} - G \Rightarrow R = \dfrac{100}{5 \times 10^{-3}} - 5 = 19{,}995\Omega$

14. (a) Potential gradient = Change in voltage per unit length

$\therefore\ 10 = \dfrac{V_2 - V_1}{30/100} \Rightarrow V_2 - V_1 = 3\,volt$

15. (d) $R = \dfrac{V}{i_g} - G = \dfrac{5}{100/10^3} - 2 = \dfrac{5000}{100} - 2 = 48\Omega$

16. (c) $i_g = \dfrac{iS}{S + G} \Rightarrow 10 = \dfrac{50 \times 12}{12 + G} \Rightarrow 12 + G = 60 \Rightarrow G = 48\Omega$

17. (a) To convert a galvanometer into a voltmeter, a high value resistance is to be connected in series with it.

18. (b)

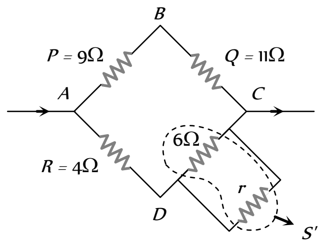
19. (c) $\dfrac{P}{Q} = \dfrac{R}{S'}$ (For balancing bridge)

$\Rightarrow S' = \dfrac{4 \times 11}{9} = \dfrac{44}{9}$

$\Rightarrow \dfrac{1}{S'} = \dfrac{1}{r} + \dfrac{1}{6}$

$\Rightarrow \dfrac{9}{44} - \dfrac{1}{6} = \dfrac{1}{r}$

$\Rightarrow r = \dfrac{132}{5} = 26.4\ \Omega$



20. (a) $r = \left(\dfrac{l_1 - l_2}{l_2}\right) R = \left(\dfrac{25}{100}\right) 2 = 0.5\ \Omega$

21. (b) The sensitivity of potentiometer can be increased by decreasing the potential gradient *i.e.* by increasing the length of potentiometer wire.

(Sensitivity $\propto \dfrac{1}{P.G.} \propto$ Length)

22. (b) In balance condition, potentiometer doesn't take the current from secondary circuit.

23. (a) Here same current is passing throughout the length of the wire, hence $V \propto R \propto l$

$\Rightarrow \dfrac{V_1}{V_2} = \dfrac{l_1}{l_2} \Rightarrow \dfrac{6}{V_2} = \dfrac{300}{50} \Rightarrow V_1 = 1\ V.$

24. (a) $S = \dfrac{i_g G}{i - i_g} = \dfrac{10 \times 0.01}{10 - 0.01} = \dfrac{10}{999} ohm$

25. (a) Ratio will be equal to the ratio of no deflection lengths *i.e.* $\dfrac{E_1}{E_2} = \dfrac{l_1}{l_2} = \dfrac{2}{3}$

26. (a) Potential gradient $= \dfrac{\text{Potential difference}}{\text{Length}}$

27. (a) Wheatstone bridge is balanced, therefore

$\dfrac{P}{Q} = \dfrac{R}{S}$ or $1 = \dfrac{10}{S} \Rightarrow S = 10\,ohm$

28. (a) When the length of potentiometer wire is increased, the potential gradient decreases and the length of previous balance point is increased.

29. (b)

30. (b)

31. (b) The actual circuit is same.

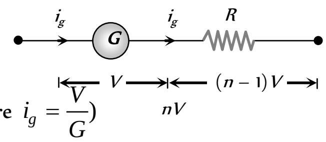
32. (b) $\because\ i_g = 10\%$ of $i = \dfrac{i}{10} \Rightarrow S = \dfrac{G}{(n-1)} = \dfrac{90}{(10-1)} = 10\Omega$

33. (b) $\dfrac{E_1}{E_2} = \dfrac{l_1 + l_2}{l_1 - l_2} = \dfrac{(8+2)}{(8-2)} = \dfrac{5}{3}$

34. (b) Suppose resistance *R* is connected in series with voltmeter as shown.

By Ohm's law

$i_g . R = (n-1)V$



$\Rightarrow R = (n-1)G$ (where $i_g = \dfrac{V}{G}$)

35. (c) Ammeter is always connected in series with circuit.

36. (c) If resistance of ammeter is *r* then

$20 = (R + r)4 \Rightarrow R + r = 5 \Rightarrow R < 5\,\Omega$

37. (b) $S = \dfrac{i_g \times G}{i - i_g} = \dfrac{10 \times 10^{-3} \times 50}{1 - 10^{-3} \times 10} = \dfrac{50}{99}\Omega$ in parallel.

38. (b) $\because\ i_g = (100 - 90)\%$ of $i = \dfrac{i}{10}$

$\Rightarrow$ Required shunt $S = \dfrac{G}{(n-1)} = \dfrac{900}{(10-1)} = 100\,\Omega$

39. (d) $R = \dfrac{V}{i_g} - G = \dfrac{100}{10 \times 10^{-3}} - 25 = 9975\,\Omega$

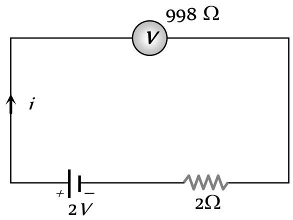
40. (b) Potential gradient $x = \dfrac{V}{L} = \dfrac{iR}{L}$

$\Rightarrow x = \frac{2}{(15+5)} \times \frac{15}{10} = \frac{3}{2000} volt/cm$

41. (a) $S = \frac{G}{\frac{i}{i_g} - 1} = \frac{25}{\frac{5}{50 \times 10^{-6}} - 1} = \frac{25}{10^5 - 1} = \frac{25}{10^5} = 2.5 \times 10^{-4} \Omega$

42. (b) In balanced Wheatstone bridge, the arms of galvanometer and cell can be interchanged without affecting the balance of the bridge.

43. (c) Error in measurement = Actual value – Measured value



Actual value = 2 V

$i = \frac{2}{998+2} = \frac{1}{500} A$

Since $E = V + ir \Rightarrow V = E - ir = 2 - \frac{1}{500} \times 2 = \frac{998}{500} V$

$\therefore$ Measured value $= \frac{998}{500} V$

$\Rightarrow$ Error $= 2 - \frac{998}{500} = 4 \times 10^{-3} volt$

44. (d) The emf of the standard cell must be greater than that of experimental cells, otherwise balance point is not obtained.

45. (a)

46. (b) In general, ammeter always reads less than the actual value because of its resistance.

47. (c) By Wheatstone bridge, $\frac{R}{80} = \frac{AC}{BC} = \frac{20}{80} \Rightarrow R = 20 \Omega$

48. (a) $E \propto l$ (balancing length)

49. (b) $r = \left(\frac{l_1 - l_2}{l_2}\right) \times R' = \left(\frac{l_1 - 2}{2}\right) \times 5$ ... (i)

and $r = \left(\frac{l_1 - 3}{3}\right) \times 10$ ... (ii)

On solving (i) and (ii) $r = 10 \Omega$

50. (a)

51. (b) In the part $c\ b\ d$,

$V_c - V_b = V_b - V_d \Rightarrow V_b = \frac{V_c + V_d}{2}$

In the part $c\ a\ d$

$V_c - V_a > V_a - V_d \Rightarrow \frac{V_c + V_d}{2} > V_a \Rightarrow V_b > V_a$

52. (c) In balance condition, no current will flow through the branch containing S.

53. (b) Resistance in parallel $S = \frac{Gi_g}{i - i_g} = \frac{50 \times 100 \times 10^{-6}}{(10 - 100 \times 10^{-6})}$

$\Rightarrow S = 5 \times 10^{-4} \Omega$

54. (b) $E = x\,l = \frac{V}{l} = \frac{iR}{L} \times l \Rightarrow E = \frac{e}{(R + R_h + r)} \times \frac{R}{L} \times l$

$\Rightarrow E = \frac{10}{(5+4+1)} \times \frac{5}{5} \times 3 = 3\ V$

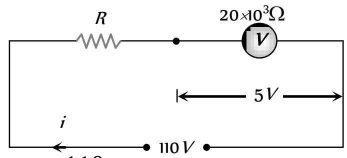
55. (a) Potential gradient $= \frac{V}{L} = \frac{iR}{L} = \frac{i\rho L}{AL} = \frac{i\rho}{A}$

$= \frac{0.2 \times 40 \times 10^{-8}}{8 \times 10^{-6}} = 10^{-2}\ V/m$

56. (b) $i_g = 2\%$ of $i = \frac{i}{50} \Rightarrow S = \frac{G}{(n-1)} = \frac{G}{(50-1)} = \frac{G}{49}$

57. (d) The resistance of an ideal voltmeter is considered as infinite.

58. (c)



Here $i = \frac{110}{20 \times 10^3 + R}$

$\because V = iR \Rightarrow 5 = \left(\frac{110}{20 \times 10^3 + R}\right) \times 20 \times 10^3$

$\Rightarrow 10^5 + 5R = 22 \times 10^5 \Rightarrow R = 21 \times \frac{10^5}{5} = 420\ K\Omega$

59. (c) Due to the negligible temperature co-efficient of resistance of constantan wire, there is no change in it's resistance value with change in temperature.

60. (d) The resistance of voltmeter is too high, so that it draws negligible current from the circuit, hence potential drop in the external circuit is also negligible.

61. (a) By connecting a series resistance

$R = \frac{V}{i_g} - G = \frac{10}{1} - 7 = 3 \Omega$

62. (a) Since potential difference for full length of wire = 2 V

$\therefore$ P.D. per unit length of wire $= \frac{2}{4} = 0.5 \frac{V}{m}$

63. (d) $\frac{X}{1} = \frac{20}{80} \Rightarrow X = \frac{1}{4} \Omega = 0.25 \Omega$.

64. (a) Reading of galvanometer remains same whether switch S is open or closed, hence no current will flow through the switch *i.e.* R and G will be in series and same current will flow through them. $I_R = I_G$.

65. (d) Pressing the key does not disturb current in all resistances as the bridge is balanced. Therefore, deflection in the galvanometer in whatever direction it was, will stay.

66. (b) $i_g S = (i - i_g) G \Rightarrow i_g (S + G) = iG$

$\Rightarrow \frac{i_g}{i} = \frac{G}{S+G} = \frac{8}{2+8} = 0.8$

67. (a) Potential gradient $x = \frac{e}{(R + R_h + r)} \cdot \frac{R}{L}$

$\Rightarrow x = \frac{2.5}{(20+80+0)} \times \frac{20}{10} = 5 \times 10^{-5} \frac{V}{mm}$

68. (b) Given $i_g = 2mA,\ i = 20mA, G = 180\Omega$

$\frac{i_g}{i} = \frac{S}{G+S} \Rightarrow 180 + S = 10S \Rightarrow S = \frac{180}{9} = 20\Omega$

69. (c) Resistance of shunted ammeter $= \frac{GS}{G+S}$

Also $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{GS}{G+S} = \frac{i_g.G}{i}$

$\Rightarrow \frac{GS}{G+S} = \frac{0.05 \times 120}{10} = 0.6\ \Omega$

70. (c) $r = \frac{(l_1 - l_2)}{l_2} \times R' = \left(\frac{60-50}{50}\right) \times 6 = 1.2\,\Omega$

71. (d) By using $\frac{i}{i_g} = 1 + \frac{G}{S}$

$\Rightarrow \frac{i}{100 \times 10^{-3}} = 1 + \frac{1000}{S} \Rightarrow S = \frac{1000}{9} = 111\Omega$

72. (c) Potential gradient $x = \frac{V}{L} = \frac{e}{(R + R_h + r)} \cdot \frac{R}{L}$

$\Rightarrow 2.2 \times 10^{-3} = \frac{2.2}{(10 + R_h)} \times 1 \Rightarrow R' = 990\,\Omega$

73. (a) $\frac{i}{i_g} = \frac{G+S}{S} \Rightarrow \frac{i_g}{i} = \frac{S}{G+S} = \frac{2.5}{27.5} = \frac{1}{11}$

74. (c) Total resistance of the circuit $= \frac{80}{2} + 20 = 60\,\Omega$

$\Rightarrow$ Main current $i = \frac{2}{60} = \frac{1}{30} A$

Combination of voltmeter and 80Ω resistance is connected in series with 20Ω, so current through 20Ω and this combination will be same $= \frac{1}{30} A$.

Since the resistance of voltmeter is also 80Ω, so this current is equally distributed in 80Ω resistance and voltmeter (*i.e.* $\frac{1}{60}$ *A* through each)

P.D. across 80Ω resistance $= \frac{1}{60} \times 80 = 1.33\ V$

75. (a) Potential gradient $x = \frac{V}{L} = \frac{iR}{L} = \frac{i\left(\frac{\rho L}{A}\right)}{L} = \frac{i\rho}{A}$

76. (d) Here $n = \frac{10}{2} = 5$

$\therefore\ R = (n-1)G = (5-1)2000 = 8000\,\Omega$

77. (b) $r = \left(\frac{l_1 - l_2}{l_1}\right) R = 0.5\,\Omega$.

78. (a)

79. (b) $V = i.R. = \frac{e}{(R + R_h + r)}.R \Rightarrow 10^{-3} = \frac{2}{(10 + R + r)} \times 10$

$\Rightarrow R = 19{,}989\Omega$.

80. (a)

81. (c) $2R > 20 \Rightarrow R > 10\Omega$.

82. (c) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{4}{1} = 1 + \frac{R}{S} \Rightarrow S = \frac{R}{3}$.

83. (a) When ammeter is connected in parallel to the circuit, net resistance of the circuit decreases. Hence more current is drawn from the battery, which damages the ammeter.

84. (a) $r = \left(\frac{l_1 - l_2}{l_2}\right) \times R' \Rightarrow r = \left(\frac{55-50}{50}\right) \times 10 = 1\Omega$.

85. (b) $R = \frac{V}{i_g} - G = \frac{18}{3 \times 10^{-3}} - 12 = 5988\,\Omega$

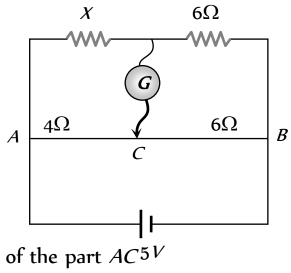
86. (d)

87. (c) $R = \frac{V}{i_g} - G = \frac{6}{6 \times 10^{-3}} - 25 = 975\Omega$ (In series).

88. (d) $i_g = i\frac{S}{G+S} \Rightarrow 0.01 = 10\frac{S}{25+S}$

$\Rightarrow 1000S = 25 + S \Rightarrow S = \frac{25}{999}\Omega$.

89. (c)



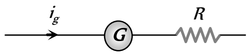
Resistance of the part *AC*

$R_{AC} = 0.1 \times 40 = 4\Omega$ and $R_{CB} = 0.1 \times 60 = 6\Omega$

In balanced condition $\frac{X}{6} = \frac{4}{6} \Rightarrow X = 4\Omega$

Equivalent resistance $R_{eq} = 5\Omega$ so current drawn from battery $i = \frac{5}{5} = 1A$.

90. (a) $(R+G)i_g = V \Rightarrow (R+G) = \frac{V}{i_g}$

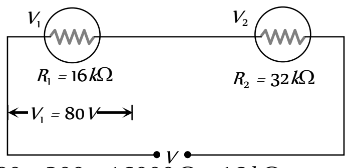


$= \frac{3}{30 \times 16 \times 10^{-6}} = 6.25k\Omega$

$\therefore$ Value of R is nearly equal to $6k\Omega$

This is connected in series in a voltmeter.

91. (d)



$R_1 = 80 \times 200 = 16000\,\Omega = 16\,k\Omega$

Current flowing through V_1 = Current flowing through V_2 = $\frac{80}{16 \times 10^3} = 5 \times 10^{-3} A$.

So, potential differences across V_2 is

$V_2 = 5 \times 10^{-3} \times 32 \times 10^3 = 160$ volt

Hence, line voltage $V = V_1 + V_2 = 80 + 160 = 240V$.

92. (d) $V = xl \Rightarrow iR = xl$

$\Rightarrow i \times 10 = \left(\frac{2 \times 10^{-3}}{10^{-2}}\right) \times 50 \times 10^{-2} = 0.1$

$\Rightarrow i = 10 \times 10^{-3} A = 10\,mA$.

93. (d) $E = \frac{e}{(R + R_h + r)}\frac{R}{L} \times l = \frac{2}{(10 + 40 + 0)} \times \frac{10}{1} \times 0.4 = 0.16V$.

94. (c) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{5}{2} = 1 + \frac{12}{S} \Rightarrow S = 8\Omega$. (In parallel).

95. (d) $\frac{i_g}{i} = \frac{S}{G+S} \Rightarrow \frac{5}{100} = \frac{S}{G+S} \Rightarrow S = \frac{G}{19}$

96. (a) $R = G(n-1) = 50 \times 10^3(3-1) = 10^5\,\Omega$.

97. (c) $\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2} = \frac{58+29}{58-29} = \frac{3}{1}$

98. (a) $R = \frac{V}{i_g} - G = \frac{10}{10 \times 10^{-3}} - 1 = 999\Omega$.

99. (d) For conversion of galvanometer (of resistances) into voltmeter, a resistance R is connected in series.

$\therefore\ i_g = \frac{V_1}{R+G}$ and $i_g = \frac{V_2}{2R+G}$

$\Rightarrow \frac{V_1}{R+G} = \frac{V_2}{2R+G} \Rightarrow \frac{V_2}{V_1} = \frac{2R+G}{R+G} = \frac{2(R+G)-G}{(R+G)}$

$= 2 - \frac{G}{(R+G)} \Rightarrow V_2 = 2V_1 - \frac{V_1 G}{(R+G)} \Rightarrow V_2 < 2V_1$

100. (d) If the voltmeter is ideal then given circuit is an open circuit, so reading of voltmeter is equal to the e.m.f. of cell *i.e.*, 6 *V*.

101. (c) $\frac{i_g}{i} = \frac{S}{G+S} = \frac{4}{36+4} = \frac{1}{10}$ *i.e.* 10%.

102. (d) After connecting a resistance R in parallel with voltmeter its effective resistance decreases. Hence less voltage appears across it *i.e.* V will decreases. Since overall resistance decreases so more current will flow *i.e.* A will increase.

103. (c) Potential gradient $x = \frac{e}{(R + R_h + r)} \cdot \frac{R}{L}$

$\Rightarrow \frac{10^{-3}}{10^{-2}} = \frac{2}{(3 + R_h + 0)} \times \frac{3}{1} \Rightarrow R_h = 57\Omega$.

104. (c) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{1}{10^{-3}} = 1 + \frac{20}{S} \Rightarrow S = \frac{20}{999} \approx 0.02\Omega$.

105. (a) Resistance of voltmeter should be high.

106. (c) If ammeter is used in place of voltmeter (*i.e.* in parallel) it may damage due to large current in circuit. Hence to control this large amount of current a high resistance must be connected in series.

107. (c) Potential gradient $x = \frac{e}{(R + R_h + r)} \cdot \frac{R}{L}$

$= \frac{3}{(20+10+0)} \times \frac{20}{10} = 0.2$

108. (d) $\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2} = \frac{(6+2)}{(6-2)} = \frac{2}{1}$

109. (c) Manganin or constantan are used for making the potentiometer wire.

110. (a)

111. (a) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{i.G}{V_g} = 1 + \frac{G}{S} \Rightarrow \frac{100 \times 10^{-3} \times 40}{800 \times 10^{-3}} = 1 + \frac{40}{S}$

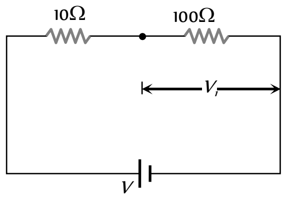
$\Rightarrow S = 10\Omega$.

112. (a) $i_g = i\frac{S}{G+S} \Rightarrow 10 \times 10^{-3} = \frac{S}{100+S} \times 100 \times 10^{-3}$

$90\,S = 1000 \Rightarrow S = \frac{1000}{90} = 11.11\,\Omega$.

113. (c) Before connecting the voltmeter, potential difference across 100Ω resistance

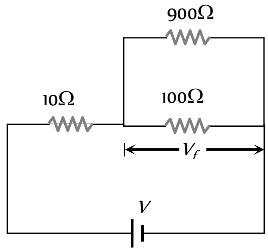
$V_i = \frac{100}{(100+10)} \times V = \frac{10}{11} V$



Finally after connecting voltmeter across 100Ω
Equivalent resistance
$\frac{100 \times 900}{(100+900)} = 90\Omega$

Final potential difference

$V_f = \frac{90}{(90+10)} \times V = \frac{9}{10} V$



% error = $\frac{V_i - V_f}{V_i} \times 100$

$= \frac{\frac{10}{11}V - \frac{9}{10}V}{\frac{10}{11}V} \times 100 = 1.0$.

114. (b) Potential gradient = $\frac{e.R}{(R+r).L} = \frac{10 \times 3}{(3+3) \times 5}$.

$= 1 V/m = 10\, mV/cm$.

115. (c) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{1}{10^{-5}} = 1 + \frac{100}{S} \Rightarrow S \approx \frac{100}{10^5} = 10^{-3}\Omega$.

116. (d) $\frac{i_g}{i} = \frac{S}{G+S} = \frac{4}{36+4} = \frac{4}{40} = \frac{1}{10}$

117. (a) $i = \frac{V}{R} \Rightarrow 2 = \frac{6}{\frac{6 \times 3}{6+3} + R} = \frac{6}{2+R} \Rightarrow R = 1\ \Omega$.

118. (b) $i_g = i\frac{S}{G+S} \Rightarrow \frac{0.01}{10} = \frac{5}{50+S} \Rightarrow S = \frac{50}{999} = 0.05\Omega$.

119. (d) $S = \left(\frac{100-l}{l}\right).R$

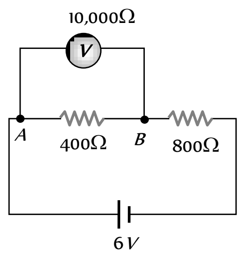
Initially, $30 = \left(\frac{100-l}{l}\right) \times 10 \Rightarrow l = 25cm$

Finally, $10 = \left(\frac{100-l}{l}\right) \times 30 \Rightarrow l = 75cm$

So, shift = 50*cm*.

120. (c) Potential gradient (x) = $\frac{i\rho}{A} = \frac{0.1 \times 10^{-7}}{10^{-6}} = 10^{-2}\ V/m$

121. (d) Before connecting voltmeter potential difference across 400Ω resistance is



$$V_i = \frac{400}{(400+800)} \times 6 = 2V$$

After connecting voltmeter equivalent resistance between A and $B = \frac{400 \times 10{,}000}{(400+10{,}000)} = 384.6\Omega$

Hence, potential difference measured by voltmeter $V_f = \frac{384.6}{(384.6+800)} \times 6 = 1.95V$

Error in measurement = $V_i - V_f = 2 - 1.95$ = 0.05 V.

122. (c) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{5}{0.05} = 1 + \frac{50}{S}$

$\Rightarrow S = \frac{50}{99} = \frac{\rho \times l}{A} \Rightarrow l = \frac{50}{99} \times \frac{2.97 \times 10^{-2} \times 10^{-4}}{5 \times 10^{-7}} = 3m$.

123. (a) $\frac{i}{i_g} = 1 + \frac{G}{S} \Rightarrow \frac{10}{1} = 1 + \frac{0.81}{S} \Rightarrow S = 0.09\Omega$.

124. (a) From the principle of potentiometer $V \propto l$

$\Rightarrow \frac{V}{E} = \frac{l}{L}$; where V = emf of battery, E = emf of standard cell, L = Length of potentiometer wire

$V = \frac{El}{L} = \frac{30E}{100}$.

125. (b) $E = \frac{e}{(R+R_h+r)} \cdot \frac{R}{L} \times l$

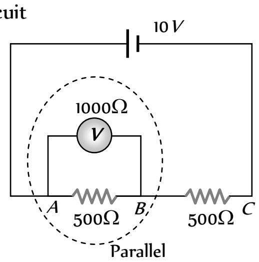
$\Rightarrow 10 \times 10^{-3} = \frac{2}{(10+R+0)} \times \frac{10}{1} \times 0.4 \Rightarrow R = 790\Omega$

126. (b) Using $r = R\left(\frac{l_1}{l_2} - 1\right) = 2\left(\frac{150}{100} - 1\right) = 1\Omega$

127. (d) Resistance between A and $B = \frac{1000 \times 500}{(1500)} = \frac{1000}{3}$

So, equivalent resistance of the circuit

$R_{eq} = 500 + \frac{1000}{3} = \frac{2500}{3}$



$\therefore$ Current drawn from the cell

$i = \frac{10}{(2500/3)} = \frac{3}{250}A$

Reading of voltmeter *i.e.*

potential difference across $AB = \frac{3}{250} \times \frac{1000}{3} = 4\ V$

128. (d) $i_g = \frac{i}{10} \Rightarrow$ Required shunt $S = \frac{G}{(n-1)} = \frac{90}{(10-1)} = 10\ \Omega$

129. (b) $i_g = \frac{50}{10 \times 10^{-3}} - 40 = 4960\ \Omega$

130. (c) Post office box is based on the principle of Wheatstone's bridge

131. (d) Full deflection current $i_g = 25 \times 4 \times 10^{-4} = 100 \times 10^{-4} A$

Using $R = \frac{V}{I_g} - G = \frac{25}{100 \times 10^{-4}} - 50 = 2450\ \Omega$ in series.

132. (a) In balancing condition, $\frac{R_1}{R_2} = \frac{l_1}{l_2} = \frac{l_1}{100 - l_1}$

$\Rightarrow \frac{X}{Y} = \frac{20}{80} = \frac{1}{4}$ .....(i)

and $\frac{4X}{Y} = \frac{l}{100-l}$ .....(ii)

$\Rightarrow \frac{4}{4} = \frac{l}{100-l} \Rightarrow l = 50\ cm$

133. (c)

134. (d) $S = \left(\frac{i_g}{i - i_g}\right) \times G = \frac{100 \times 10^{-6}}{(10 \times 10^{-3} - 100 \times 10^{-6})} \times 50 \approx 0.5\ \Omega$ (in parallel)

135. (d) $E = \frac{e}{(R+R_h+r)} \cdot \frac{R}{L} \times l \Rightarrow 0.4 = \frac{5}{(5+45+0)} \times \frac{5}{10} \times l$

$\Rightarrow l = 8\ m$

136. (a) Potential difference per unit length $= \frac{V}{L} = \frac{2}{4} = 0.5\ V/m$

137. (a)

138. (b) $r = R\left(\frac{l_1}{l_2} - 1\right) = 2\left(\frac{240}{120} - 1\right) = 2\Omega$

139. (d) $E = \frac{V}{l}$; E is constant (volt. gradient).

$\Rightarrow \frac{V_1}{l_1} = \frac{V_2}{l_2} \Rightarrow \frac{1.1}{140} = \frac{V}{180} \Rightarrow V = \frac{180 \times 1.1}{140} = 1.41V$

140. (a) $I_G \times G = (I - I_G)S \Rightarrow I = \left(1 + \frac{G}{S}\right)I_G \Rightarrow I = 100.1\ mA$

141. (c) Let S be larger and R be smaller resistance connected in two gaps of meter bridge.

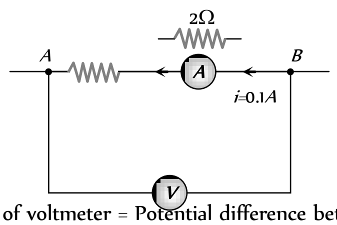
$\therefore S = \left(\frac{100-l}{l}\right)R = \frac{100-20}{20}R = 4R$ .....(i)

When 15Ω resistance is added to resistance R, then

$S = \left(\frac{100-40}{40}\right)(R+15) = \frac{6}{4}(R+15)$ .... (ii)

From equations (i) and (ii) $R = 9\Omega$

142. (a) According to following figure



Reading of voltmeter = Potential difference between A and $B = i(R+2) \Rightarrow 12 = 0.1\ (R+2) \Rightarrow R = 118\ \Omega$.

143. (a) Potential gradient $x = \frac{e}{(R+R_h+r)} \cdot \frac{R}{L}$

$\Rightarrow \frac{0.2 \times 10^{-3}}{10^{-2}} = \frac{2}{(R+490+0)} \times \frac{R}{1} \Rightarrow R = 4.9\ \Omega$.

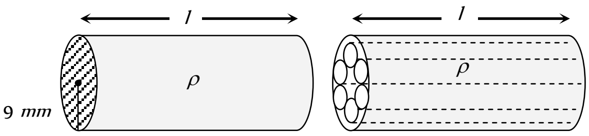
Critical Thinking Questions

1. (a) Initially : Resistance of given cable

$R = \rho \dfrac{l}{\pi \times (9 \times 10^{-3})^2}$ ....(i)

Finally : Resistance of each insulated copper wire is

$R' = \rho \dfrac{l}{\pi \times (3 \times 10^{-3})^2}$. Hence equivalent resistance of cable $R_{eq} = \dfrac{R'}{6} = \dfrac{1}{6} \times \left(\rho \dfrac{l}{\pi \times (3 \times 10^{-3})^2}\right)$ ....(ii)



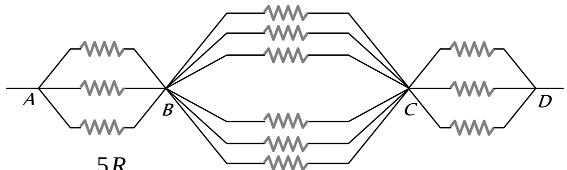
On solving equation (i) and (ii) we get $R = 7.5\ \Omega$

2. (a) $\dfrac{R_A}{R_B} = \left(\dfrac{r_B}{r_A}\right)^4 \Rightarrow \dfrac{R_A}{R_B} = \left(\dfrac{1}{2}\right)^4 = \dfrac{1}{16} \Rightarrow R_B = 16R_A$

When R_A and R_B are connected in parallel then equivalent resistance $R_{eq} = \dfrac{R_A R_B}{(R_A + R_B)} = \dfrac{16}{17} R_A$

If $R_A = 4.25\Omega$ then $R_{eq} = 4\Omega$ *i.e.* option (a) is correct.

3. (c) The given circuit can be simplified as follows



$\therefore R_{AD} = \dfrac{5R}{6}$

4. (c) Suppose *n* resistors are used for the required job. Suppose equivalent resistance of the combination is *R'* and according to energy conservation it's current rating is *i'*.

Energy consumed by the combination = *n* × (Energy consumed by each resistance)

$\Rightarrow i'^2 R' = n \times i^2 R \Rightarrow n = \left(\dfrac{i'}{i}\right)^2 \times \left(\dfrac{R'}{R}\right) = \left(\dfrac{4}{1}\right)^2 \times \left(\dfrac{5}{10}\right) = 8$

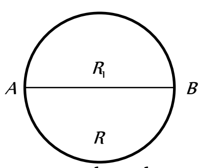
5. (c) Resistance across $AB = \dfrac{1}{R'} = \dfrac{1}{R} + \dfrac{1}{R} + \dfrac{1}{R_1}$

$R_1 = 2 \times 10^{-6}\Omega$

and $R = \pi \times 1 \times 10^{-6}\Omega$

On solving,

$R' = 0.88 \times 10^{-6}\Omega$



6. (b) No current flows through the capacitor branch in steady state. Total current supplied by the battery

$i = \dfrac{6}{2.8 + 1.2} = \dfrac{3}{2}$.

Current through 2 Ω resistor $= \dfrac{3}{2} \times \dfrac{3}{5} = 0.9A$

7. (d) At time $t = 0$ *i.e.* when capacitor is charging, current $i = \dfrac{2}{1000} = 2mA$

When capacitor is full charged, no current will pass through it, hence current through the circuit $i = \dfrac{2}{2000} = 1mA$

8. (d) Current in the bulb $= \dfrac{P}{V} = \dfrac{4.5}{1.5} = 3A$

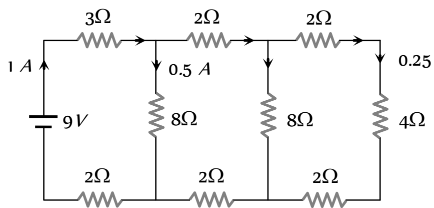
Current in 1 Ω resistance $= \dfrac{1.5}{1} = 1.5A$

Hence total current from the cell $i = 3 + 1.5 = 4.5A$

By using $E = V + ir \Rightarrow E = 1.5 + 4.5 \times (2.67) = 13.5V$

9. (d) Equivalent resistance of the circuit $R = 9\Omega$

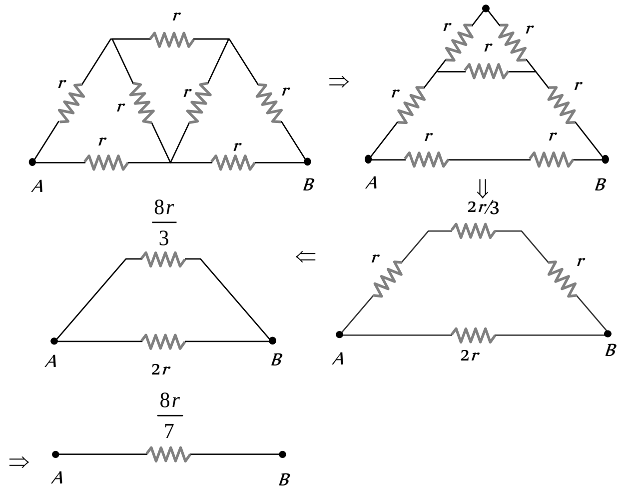
$\therefore$ Main current $i = \dfrac{V}{R} = \dfrac{9}{9} = 1A$



After proper distribution, the current through 4Ω resistance is 0.25 *A*.

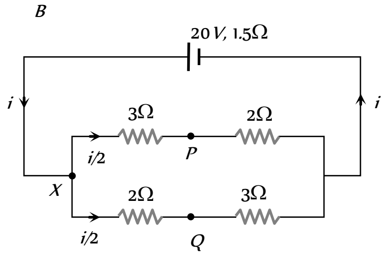
10. (b) Maximum number of resistance $= 2^{n-1} = 2^{3-1} = 4$

11. (d) The given circuit can be simplified as follows.



12. (d) $R_{eq} = \dfrac{5}{2}\Omega$

$i = \dfrac{20}{\dfrac{5}{2} + 1.5} = 5A$



Potential difference between *X* and *P*,

$V_X - V_P = \left(\dfrac{5}{2}\right) \times 3 = 7.5V$ ....(i)

$V_X - V_Q = \frac{5}{2} \times 2 = 5V$ ...(ii)

On solving (i) and (ii) $V_P - V_Q = -2.5\, volt; V_Q > V_P$.

Short Trick : $(V_P - V_Q) = \frac{i}{2}(R_2 - R_1) = \frac{5}{2}(2-3) = -2.5$

$\Rightarrow V_Q > V_P$

13. (c) $R_{t_1} = R_1(1+\alpha_1 t)$ and $R_{t_2} = R_2(1+\alpha_2 t)$

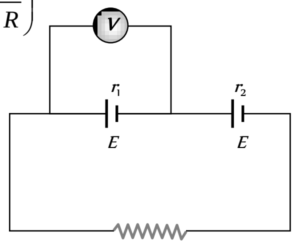
Also $R_{eq.} = R_{t_1} + R_{t_2} \Rightarrow R_{eq} = R_1 + R_2 + (R_1\alpha_1 + R_2\alpha_2)t$

$\Rightarrow R_{eq} = (R_1 + R_2)\left\{1 + \left(\frac{R_1\alpha_1 + R_2\alpha_2}{R_1 + R_2}\right).t\right\}$

So $\alpha_{eff} = \frac{R_1\alpha_1 + R_2\alpha_2}{R_1 + R_2}$

14. (b) Let the voltage across any one cell is V, then

$V = E - ir = E - r_1\left(\frac{2E}{r_1 + r_2 + R}\right)$



But $V = 0$

$\Rightarrow E - \frac{2Er_1}{r_1 + r_2 + R} = 0$

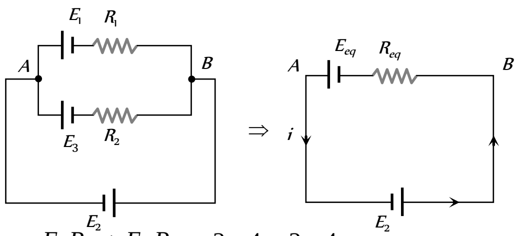
$\Rightarrow r_1 + r_2 + R = 2r_1$

$\Rightarrow R = r_1 - r_2$

15. (b) Emf $E = 5V$, Internal resistance $r = \frac{5}{10} = 0.5\Omega$

Current through the resistance $i = \frac{5}{(2+0.5)} = 2A$

16. (b) The given circuit can be redrawn

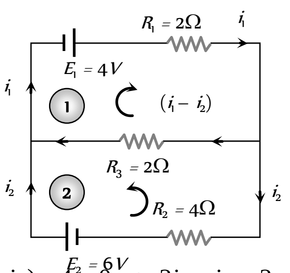


$E_{eq} = \frac{E_1R_2 + E_2R_1}{R_1 + R_2} = \frac{2\times4 + 2\times4}{4+4} = 2V$ and

$R_{eq} = \frac{4}{2} = 2\Omega$. Current $i = \frac{2+2}{2} = 2A$ from A to B through E.

17. (b) Applying Kirchhoff's law for the loops (1) and (2) as shown in figure

For loop (1)



$-2i_1 - 2(i_1 - i_2) + 4 = 0 \Rightarrow 2i_1 - i_2 = 2$ ...(i)

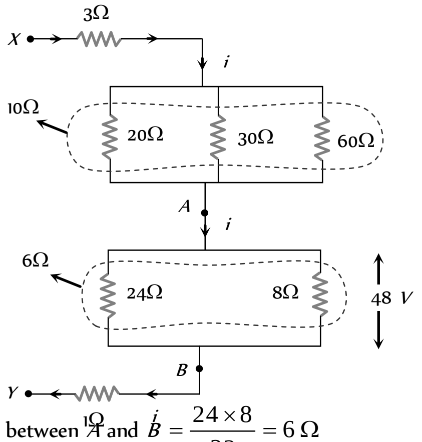
For loop (2)

$-2(i_1 - i_2) + 4i_2 - 6 = 0 \Rightarrow -i_1 + 3i_2 = 3$ ...(ii)

On solving equation (i) and (ii) $i_1 = 1.8A$.

18. (b) To convert a galvanometer into an ammeter, a shunt $S = \frac{I_g}{I - I_g}G$ is connected in parallel with it. To convert a galvanometer into a voltmeter, a resistance $R = \frac{V}{I_g} - G$ is connected in series with it.

19. (a) The given circuit can be redrawn as follows



Resistance between A and $B = \frac{24\times8}{32} = 6\,\Omega$

Current between A and B = Current between X and Y $= i = \frac{48}{6} = 8A$

Resistance between X and $Y = (3+10+6+1) = 20\,\Omega$

$\Rightarrow$ Potential difference between X and $Y = 8 \times 20 = 160\ V$

20. (d) $R_1 + R_2 = R_1(1+\alpha t) + R_2(1-\beta t)$

$\Rightarrow R_1 + R_2 = R_1 + R_2 + R_1\alpha t - R_2\beta t \Rightarrow \frac{R_1}{R_2} = \frac{\beta}{\alpha}$

21. (d) Current density of drifting electrons $j = nev$

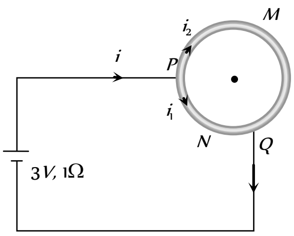
$n = 5\times10^7 cm^{-3} = 5\times10^7 \times 10^6 m^{-3}$.

$v = 0.4ms^{-1}, e = 1.6\times10^{-19}C \Rightarrow j = 3.2\times10^{-6} Am^{-2}$

Current density of ions = $(4 - 3.2) \times 10^{-6} = 0.8\times10^{-6}\ \frac{A}{m^2}$

This gives v for ions = 0.1 ms^{-1}.

22. (a) In the following figure



Resistance of part PNQ;

$R_1 = \frac{10}{4} = 2.5\Omega$ and

Resistance of part PMQ;

$R_2 = \frac{3}{4}\times10 = 7.5\Omega$

$R_{eq} = \frac{R_1R_2}{R_1+R_2} = \frac{2.5\times7.5}{(2.5+7.5)} = \frac{15}{8}\Omega$.

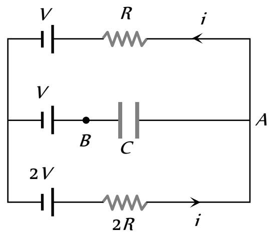
Main Current $i = \frac{3}{\frac{15}{8}+1} = \frac{24}{23}A$

So, $i_1 = i\times\left(\frac{R_2}{R_1+R_2}\right) = \frac{24}{23}\times\left(\frac{7.5}{2.5+7.5}\right) = \frac{18}{23}A$

and $i_2 = i - i_1 = \frac{24}{23} - \frac{18}{23} = \frac{6}{23}A$.

23. (c) As I is independent of R_6, no current flows through R_6 this requires that the junction of R_1 and R_2 is at the same potential as the junction of R_3 and R_4. This must satisfy the condition $\frac{R_1}{R_2} = \frac{R_3}{R_4}$, as in the Wheatstone bridge.

24. (c) Moving anticlockwise from A



$-iR - V + 2V - 2iR = 0$

or $3iR = V$ or $i = \frac{V}{3R}$

$V_A - V_B = iR + V - V = iR$

$\Rightarrow$ Potential drop across $C = \frac{V}{3}$

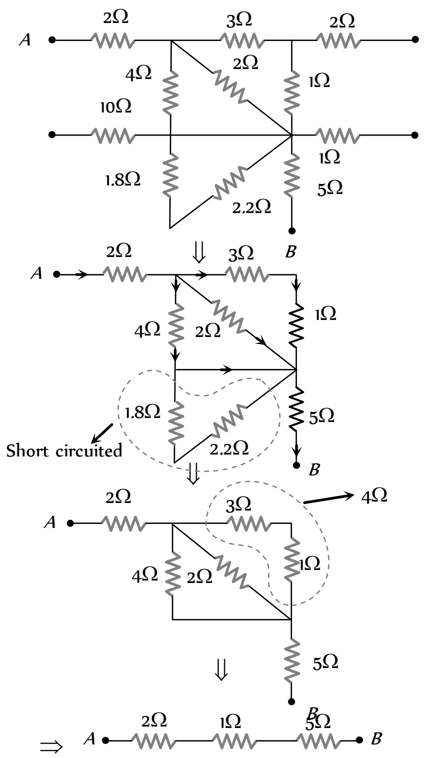
25. (b) Let R and m be the resistance and mass of the first wire, then the second wire has resistance $2R$ and mass $2m$. Let E = emf of each cell, S = specific heat capacity of the material of the wire.

For the first wire, current $i_1 = \frac{3E}{R}$ and $i_1^2 Rt = mS\Delta T$

For the second wire, $i_2 = \frac{NE}{2R}$ and $i_2^2(2R)t = 2mS\Delta T$.

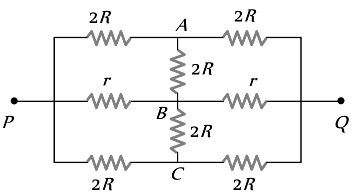
Thus, $i_1 = i_2$ or $N = 6$.

26. (b)



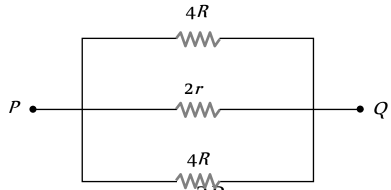
$R_{AB} = 8\Omega$.

27. (a)



In a circuit, any circuit element placed between points at the same potential can be removed, without affecting the rest of the circuit. Here, by symmetry, points A, B and C are at same potential, for any potential difference between P and Q.

The circuit can therefore be reduced as shown below



Effective resistance $R_{eq} = \frac{2Rr}{R+r}$.

28. (d) Potential difference between A and B

$V_A - V_B = 1 \times 1.5$

$\Rightarrow V_A - 0 = 1.5V \Rightarrow V_A = 1.5V$

Potential difference between B and C

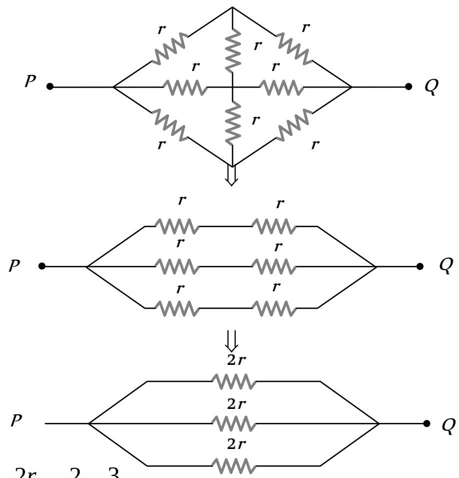
$V_B - V_C = 1 \times 2.5 = 2.5V$

$\Rightarrow 0 - V_C = 2.5V \Rightarrow V_C = -2.5V$

Potential difference between C and D

$V_C - V_D = -2V \Rightarrow -2.5 - V_D = -2 \Rightarrow V_D = -0.5V$.

29. (b) The given circuit can be simplifies as follows



$R' = \frac{2r}{3} = \frac{2}{3} \times \frac{3}{2} = 1\Omega$.

30. (b) $dQ = Idt \Rightarrow Q = \int_{t=2}^{t=3} Idt = \left[2\int_2^3 tdt + 3\int_2^3 t^2 dt\right]$

$= \left[t^2\right]_2^3 + \left[t^3\right]_2^3 = (9-4) + (27-8) = 5 + 19 = 24C$.

31. (d) $i = \frac{E_1 + E_2 + E_3 + ... + E_n}{(r_1 + r_2 + r_3 + ... + r_n)}$

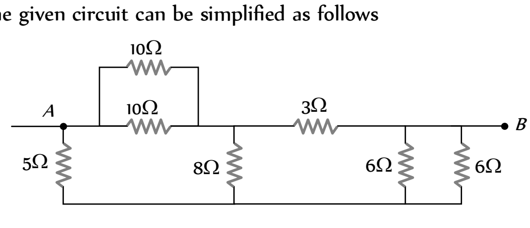
$= \frac{1.5(r_1 + r_2 + r_3 + ... + r_n)}{(r_1 + r_2 + r_3 + ... + r_n)} = 1.5A$.

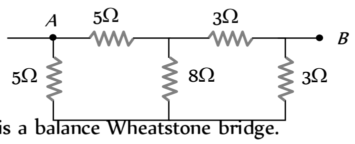
32. (a) Balancing length is independent of the cross sectional area of the wire.

33. (a) $\frac{R_1}{R_2} = \frac{(1+\alpha t_1)}{(1+\alpha t_2)} \Rightarrow \frac{10}{R_2} = \frac{(1+5\times10^{-3}\times20)}{(1+5\times10^{-3}\times120)} \Rightarrow R_2 \approx 15\Omega$

Also $\frac{i_1}{i_2} = \frac{R_2}{R_1} \Rightarrow \frac{30}{i_2} = \frac{15}{10} \Rightarrow i_2 = 20\,mA$

34. (b) The given circuit can be simplified as follows

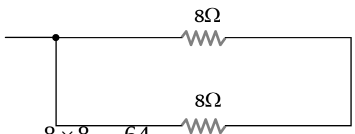




$\Rightarrow$

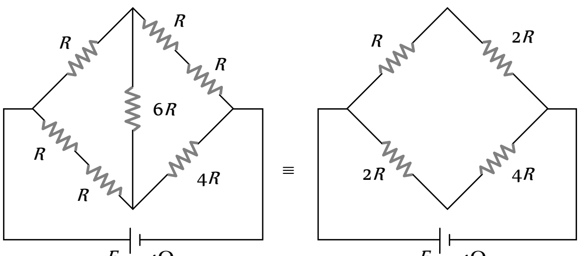
Now it is a balance Wheatstone bridge.

So,



$\Rightarrow R_{AB} = \frac{8 \times 8}{8+8} = \frac{64}{16} = 4\Omega$

35. (c) The equivalent network is

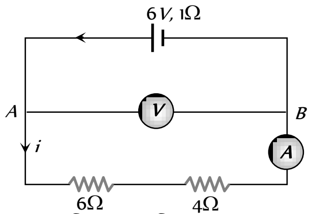


Clearly, the network of resistances is a balanced Wheatstone bridge. So R_{AB} is given by

$$\frac{1}{R_{AB}} = \frac{1}{3R} + \frac{1}{6R} = \frac{2+1}{6R} = \frac{1}{2R} \Rightarrow R_{AB} = 2R$$

For maximum power transfer $2R = 4\Omega \Rightarrow R = \frac{4}{2} = 2\Omega$

36. (c) The given circuit can be redrawn as follows



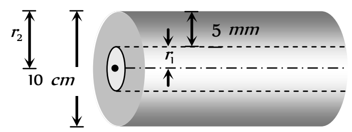
Current $i = \frac{6}{6+4+1} = \frac{6}{11} A$

P.D. between A and B, $V = \frac{6}{11} \times 10 = \frac{60}{11} V$.

37. (a) By using $R = \rho . \frac{l}{A}$; here $A = \pi(r_2^2 - r_1^2)$

Outer radius r_2 = 5cm

Inner radius r_1 = 5 – 0.5 = 4.5 cm



So $R = 1.7 \times 10^{-8} \times \frac{5}{\pi\{(5 \times 10^{-2})^2 - (4.5 \times 10^{-2})^2\}}$

$= 5.6 \times 10^{-5}\Omega$

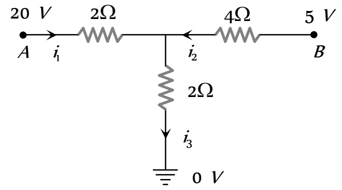
38. (a) Here $R_{XWY} = \frac{R}{2\pi r} \times (r\alpha) = \frac{R\alpha}{2\pi}$ $\left(\because \alpha = \frac{l}{r}\right)$

and $R_{XZY} = \frac{R}{2\pi r} \times r(2\pi - \alpha) = \frac{R}{2\pi}(2\pi - \alpha)$

$$R_{eq} = \frac{R_{XWY} R_{XZY}}{R_{XWY} + R_{XZY}} = \frac{\frac{R\alpha}{2\pi} \times \frac{R}{2\pi}(2\pi - \alpha)}{\frac{R\alpha}{2\pi} + \frac{R(2\pi - \alpha)}{2\pi}} = \frac{R\alpha}{4\pi^2}(2\pi - \alpha)$$

39. (d) Battery is short circuited so potential difference is zero.

40. (a) Let V be the potential of the junction as shown in figure. Applying junction law, we have



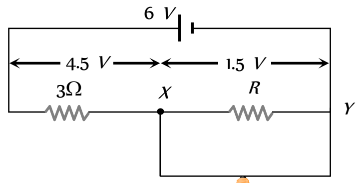
or $\frac{20 - V}{2} + \frac{5 - V}{4} = \frac{V - 0}{2}$

or 40 – 2V + 5 – V = 2V or 5V = 45 $\Rightarrow$ V = 9V

$\therefore \; i_3 = \frac{V}{2} = 4.5A$

41. (a) $E = xl = i\rho l \Rightarrow i = \frac{E}{\rho l} = \frac{E}{\rho l} = \frac{2.4 \times 10^{-3}}{1.2 \times 5} = 4 \times 10^{-4} A$.

42. (b) When bulb glows with full intensity, then voltage across it will be 1.5 V and voltage across 3 Ω resistance will be 4.5 V.



Current through 3 Ω resistance $i = \frac{4.5}{3} = 1.5A$

Same current will flow between X and Y

So $V_{XY} = iR_{XY} \Rightarrow 1.5 = 1.5R_{XY} \Rightarrow R_{XY} = 1\Omega$

43. (a) In figure (b) current through $R_2 = i - \frac{i}{10} = \frac{9i}{10}$

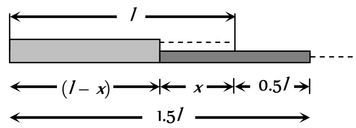
Potential difference across R_2 = Potential difference across R

$\Rightarrow R_2 \times \frac{9}{10} i = R \times \frac{i}{10}$ i.e. $R_2 = \frac{R}{9} = \frac{11}{9}\Omega$

$$R_{eq} = \frac{R_2 \times R}{(R_2 + R)} = \frac{\frac{11}{9} \times \frac{11}{1}}{\frac{11}{9} + \frac{11}{1}} = \frac{11}{10}\Omega$$

Total circuit resistance $= \frac{11}{10} + R_1 = R = 11 \Rightarrow R_1 = 9.9\Omega$

44. (a) Let l be the original length of wire and x be its length stretched uniformly such that final length is 1.5 l



Then $4R = \rho\frac{(l - x)}{A} + \rho\frac{(0.5l + x)}{A'}$ where $A' = \frac{x}{(0.5l + x)} A$

$\therefore\ 4\rho\frac{l}{A}=\rho\frac{l-x}{A}+\rho\frac{(0.5l+x)^2}{xA}$

or $4l=l-x+\frac{1}{4}\frac{l^2}{x}+\frac{x^2}{x}+\frac{lx}{x}$ or $\frac{x}{l}=\frac{1}{8}$

45. (b) In series : Potential difference $\propto R$

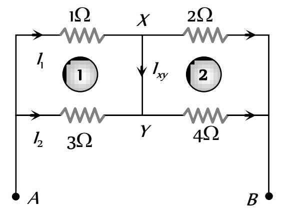
When only S_1 is closed $V_1=\frac{3}{4}E=0.75E$

When only S_2 is closed $V_2=\frac{6}{7}E=0.86E$

and when both S_1 and S_2 are closed combined resistance of $6R$ and $3R$ is $2R$

$\therefore\quad V_3=\left(\frac{2}{3}\right)E=0.67E\ \Rightarrow V_2>V_1>V_3$

46. (c)



$-i_1+0\times i_{xy}+3i_2=0$ *i.e.* $i_1=3i_2$ ......(i)

Also $-2(i_1-i_{xy})+4(i_2+i_{xy})=0$

i.e. $2i_1-4i_2=6i_{xy}$ ....(ii)

Also $V_{AB}-1\times i_1-2(i_1-i_{xy})=0\Rightarrow 50=i_1+2(i_1-i_{xy})$

$=3i_1-2i_{xy}$ .... (iii)

Solving (i), (ii) and (iii), $i_{xy}=2A$

47. (b) Let n be the number of wrongly connected cells.

Number of cells helping one another $=(12-n)$

Total e.m.f. of such cells $=(12-n)E$

Total e.m.f. of cells opposing = nE

Resultant e.m.f. of battery $=(12-n)E-nE=(12-2n)E$

Total resistance of cells = $12r$

($\because$ resistance remains same irrespective of connections of cells)

With additional cells

(a) Total e.m.f. of cells when additional cells help battery = $(12-2n)E+2E$

Total resistance = $12r+2r=14r$

$\therefore\ \frac{(12-2n)E+2E}{14r}=3$ ......(i)

(b) Similarly when additional cells oppose the battery

$\frac{(12-2n)E-2E}{14r}=2$ ......(ii)

Solving (i) and (ii), $n=1$

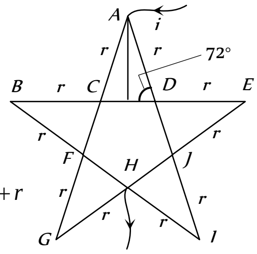
48. (a) All the conductors have equal lengths. Area of cross-section of A is $\{(\sqrt{3}\,a)^2-(\sqrt{2}\,a)^2\}=a^2$

Similarly area of cross-section of B = Area of cross-section of C = a

Hence according to formula $R=\rho\frac{l}{A}$; resistances of all the conductors are equal *i.e.* $R_A=R_B=R_C$

49. (b) Resistance of CD arm = $2r\cos 72^\circ=0.62r$

Resistance of CBFC branch



$\frac{1}{R}=\frac{1}{2r}+\frac{1}{0.62r}=\frac{1}{r}\left(\frac{2.62}{2\times 0.62}\right)$

$\frac{1}{R}=\frac{2.62}{1.24r}\qquad \therefore R=\frac{1.24r}{2.62}$

Equivalent $R'=2R+r=2\times\frac{1.24r}{2.62}+r$

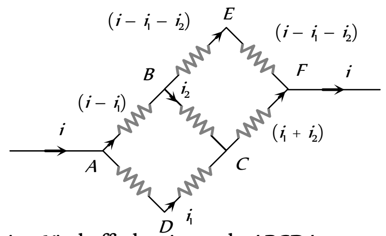
$=r\left(\frac{2.48}{2.62}+1\right)=1.946r$

Because the star circuit is symmetrical about the line AH

$\therefore$ Equivalent resistance between A and H

$\frac{1}{R_{eq}}=\frac{1}{R'}+\frac{1}{R'}\Rightarrow R_{eq}=\frac{R'}{2}=\frac{1.946}{2}r=0.973r$

50. (a)



Applying Kirchoff's law in mesh $ABCDA$

$-10(i-i_1)-10i_2+20i_1=0\ \Rightarrow\ 3i_1-i_2=i$ ....(i)

and in mesh $BEFCB$

$-20(i-i_1-i_2)+10(i_1+i_2)+10i_2=0$

$\Rightarrow\quad 3i_1+4i_2=2i$ ......(ii)

From equation (i) and (ii) $i_1=\frac{2i}{5},i_2=\frac{i}{5}\Rightarrow i_{AD}=\frac{2i}{5}$

51. (d) Let the current in 12 Ω resistance is i

Applying loop theorem in closed mesh $AEFCA$

$12i=-E+E=0\quad\therefore\ i=0$

52. (b) Current flowing in the circuit $i=\frac{E}{R}=\frac{10-4}{20+10}=\frac{1}{5}A$

P.D. across $AC=\frac{1}{5}\times 20=4V$

P.D. across $AN=4+4=8V$

53. (a) If two resistances are R_1 and R_2 then

$S=R_1+R_2$ and $P=\frac{R_1R_2}{(R_1+R_2)}$

From given condition $S=nP$ *i.e.* $(R_1+R_2)=n\left(\frac{R_1R_2}{R_1+R_2}\right)$

$\Rightarrow(R_1+R_2)^2=n\,R_1R_2\Rightarrow(R_1-R_2)^2+4R_1R_2=nR_1R_2$

So $n=4+\frac{(R_1-R_2)^2}{R_1R_2}$. Hence minimum value of n is 4.

54. (b) Voltage sensitivity $=\frac{\text{Current sensitivity}}{\text{Resistance of galvanometer G}}$

$\Rightarrow G = \frac{10}{2} = 5\,\Omega$.

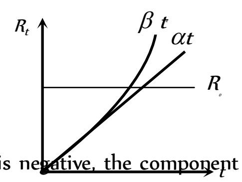
Here i_g = Full scale deflection current $= \frac{150}{10} = 15\,mA$.

V = Voltage to be measured = 150 × 1 = 150 V.

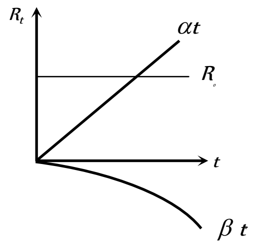
Hence $R = \frac{V}{i_g} - G = \frac{150}{15 \times 10^{-3}} - 5 = 9995\,\Omega$.

Graphical Questions

1. (a) For ohmic resistance $V \propto i \Rightarrow V = Ri$ (here R is constant)
2. (d) From the curve it is clear that slopes at points A, B, C, D have following order $A > B > C > D$.
and also resistance at any point equals to slope of the V-i curve.
So order of resistance at three points will be $R_A > R_B > R_C > R_D$
3. (a) Slope of the V-i curve at any point equal to resistance at that point. From the curve slope for T_1 > slope for T_2
$\Rightarrow R_{T_1} > R_{T_2}$. Also at higher temperature resistance will be higher so $T_1 > T_2$
4. (c) For portion CD slope of the curve is negative *i.e.* resistance be negative.
5. (d) Slope of V-i curve $= R\left(=\frac{\rho l}{A}\right)$. But in given curve axis of i and V are interchanged. So slope of given curve $= \frac{1}{R}\left(=\frac{A}{\rho l}\right)$
i.e. with the increase in length of the wire. Slope of the curve will decrease.
6. (c) $E = \frac{iR}{L} = \frac{i.\rho}{A} = \frac{neAv_d\rho}{A} \Rightarrow v_d \propto E$ (Straight line)
$P = i^2R = \left(\frac{EA}{\rho}\right)^2 R \Rightarrow P \propto E^2$ (Symmetric parabola)
Also $P \propto i^2$ (parabola)
Hence all graphs a, b, d are correct and c is incorrect.
7. (b) When we move in the direction of the current in a uniform conductor, the potential difference decreases linearly. When we pass through the cell, from it's negative to it's positive terminal, the potential increases by an amount equal to it's potential difference. This is less than it's emf, as there is some potential drop across it's internal resistance when the cell is driving current.
8. (b) Since the value of R continuously increases, both α and β must be positive.
Actually the components of the given equation are as follows



It α is positive, β is negative, the component will be shown in the following graph.



In this case, the value of R will not increase continuously. Hence the correct option is (c).

9. (d) Slope of V-i curve = resistance. Hence $R = \frac{1}{1} = 1\Omega$
10. (a) At point A the slope of the graph will be negative. Hence resistance is negative.
11. (b) E.m.f. is the value of voltage, when no current is drawn from the circuit so $E = 2V$. Also r = slope $= \frac{2}{5} = 0.4\Omega$
12. (d) For conversion of a galvanometer into a voltmeter
$\frac{V}{R+G} = i_g \Rightarrow \frac{V}{R_V} = i_g$; where $R_V = R + G$ = Total resistance
$\Rightarrow R_V = \frac{V}{i_g} \Rightarrow R_V \propto V$
13. (a) According to ohm's law $V = iR$
$\Rightarrow \log_e V = \log_e i + \log_e R \Rightarrow \log_e i = \log_e V - \log_e R$
The graph between $\log_e I$ and $\log_e V$ will be a straight line which cut $\log_e V$ axis and it's gradient will be positive.
14. (c) As we know, for conductors resistance ∝ Temperature.
From figure $R_1 \propto T_1 \Rightarrow \tan\theta \propto T_1 \Rightarrow \tan\theta = kT_1$ ... (i)
and $R_2 \propto T_2 \Rightarrow \tan(90 - \theta) \propto T_2 \Rightarrow \cot\theta = kT_2$ ....(ii)
From equation (i) and (ii) $k(T_2 - T_1) = (\cot\theta - \tan\theta)$
$(T_2 - T_1) = \left(\frac{\cos\theta}{\sin\theta} - \frac{\sin\theta}{\cos\theta}\right) = \frac{(\cos^2\theta - \sin^2\theta)}{\sin\theta\cos\theta} = 2\cot 2\theta$
$\Rightarrow (T_2 - T_1) \propto \cot 2\theta$
15. (b) Let resistivity at a distance 'x' from left end be $\rho = (\rho_0 + ax)$. Then electric field intensity at a distance 'x' from left end will be equal to $E = \frac{i\rho}{A} = \frac{i(\rho_0 + ax)}{A}$ where i is the current flowing through the conductor. It means $E \propto \rho$ or E varies linearly with distance 'x'. But at $x = 0$, E has non-zero value. Hence (b) is correct.
16. (d) At an instant approach the student will choose $\tan\theta$ will be the right answer. But it is to be seen here the curve makes the angle θ with the V-axis. So it makes an angle $(90 - \theta)$ with the i-axis.
So resistance = slope = $\tan(90 - \theta) = \cot\theta$.
17. (d) Short circuited current $i = \frac{nE}{nr} = \frac{E}{r}$ *i.e.* i doesn't depend upon n.
18. (b) Here internal resistance is given by the slope of graph *i.e.* $\frac{x}{y}$.
But conductance $= \frac{1}{\text{Resistance}} = \frac{y}{x}$
19. (a) $R_{Parallel} < R_{Series}$. From graph it is clear that slope of the line A is lower than the slope of the line B. Also slope = resistance, so line A represents the graph for parallel combination.
20. (b) To make range n times, the galvanometer resistance should be G/n, where G is initial resistance.

Assertion and Reason

1. (d) Resistivity of a semiconductor decreases with the temperature. The atoms of a semiconductor vibrate with larger amplitudes at higher temperatures thereby increasing it's conductivity not resistivity.

2. (d) It is quite clear that in a battery circuit, the point of lowest potential is the negative terminal of the battery and the current flows from higher potential to lower potential.

3. (b) The temperature co-efficient of resistance for metal is positive and that for semiconductor is negative.

In metals free electrons (negative charge) are charge carriers while in P-type semiconductors, holes (positive charge) are majority charge carriers.

4. (a) Here, $E = 2V$, $1 = \frac{2}{2} = 1A$ and $r = 1\Omega$

Therefore, $V = E - ir = 2 - 1 \times 1 = 1V$

5. (a) It is clear that electrons move in all directions haphazardly in metals. When an electric field is applied, each free electron acquire a drift velocity. There is a net flow of charge, which constitute current. In the absence of electric field this is impossible and hence, there is no current.

6. (c) The metallic body of the electrical appliances is connected to the third pin which is connected to the earth. This is a safety precaution and avoids eventual electric shock. By doing this the extra charge flowing through the metallic body is passed to earth and avoid shocks. There is nothing such as reducing of the heating of connecting wires by three pin connections.

7. (b) On increasing temperature of wire the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases. Also when temperature increases, resistivity increase and resistivity is inversely proportional to conductivity of material.

8. (c) In a conductor there are large number of free electrons. When we close the circuit, the electric field is established instantly with the speed of electromagnetic wave which cause electron drift at every portion of the circuit. Due to which the current is set up in the entire circuit instantly. The current which is set up does not wait for the electrons flow from one end of the conductor to the another end. It is due to this reason, the electric bulb glows immediately when switch is on.

9. (a) Resistance wire $R = \rho \frac{l}{A}$. where ρ is resistivity of material which does not depend on the geometry of wire. Since when wire is banded, resistivity, length and area of cross-section do not change, therefore resistance of wire also remain same.

10. (c) The resistance of the galvanometer is fixed. In meter bridge experiments, to protect the galvanometer from a high current, high resistance is connected to the galvanometer in order to protect it from damage.

11. (a) Voltameter measures current indirectly in terms of mass of ions deposited and electrochemical equivalent of the substance $\left(I = \frac{m}{Zt}\right)$. Since value of m and Z are measured to 3rd decimal place and 5th decimal place respectively. The relative error in the measurement of current by voltmeter will be very small as compared to that when measured by ammeter directly.

12. (a) When current flows through a conductor it always remains uncharged, hence no electric field is produced outside it.

13. (b) Here assertion and reason both are correct but the reason is not the correct explanation of assertion.

14. (a) Sensitivity $\propto \frac{1}{\text{Potential gradient}} \propto (\text{Length of wire})$

15. (a) If either the e.m.f. of the driver cell or potential difference across the whole potentiometer wire is lesser than the e.m.f. of the experimental cell, then balance point will not obtained.

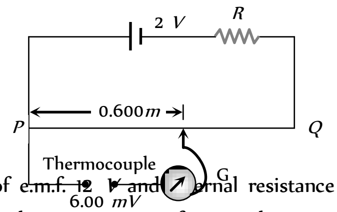
16. (d) Because there is no special attractive force that keeps a person stuck with a high power line. The actual reason is that a current of the order of 0.05 A or even less is enough to bring disorder in our nervous system. As a result of it, the affected person may lose temporarily his ability to exercise his nervous control to get himself free from the high power line.

17. (a) Due to high electrical conductivity of copper, it conducts the current without offering much resistance. The copper being diamagnetic material does not get magnetised due to current through it and hence does not disturb the current in the circuit.

Current Electricity

SET Self Evaluation Test -19

1. Figure shows a simple potentiometer circuit for measuring a small e.m.f. produced by a thermocouple. The meter wire PQ has a resistance 5 Ω and the driver cell has an e.m.f. of 2 V. If a balance point is obtained 0.600 m along PQ when measuring an e.m.f. of 6.00 mV, what is the value of resistance R

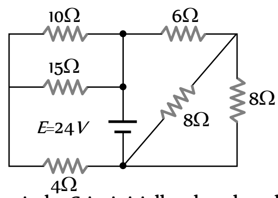


(a) 995 Ω
(b) 1995 Ω
(c) 2995 Ω
(d) None of these

2. A car has a fresh battery of e.m.f. 12 V and internal resistance of 0.05 Ω. If the starter motor draws a current of 90 A, the terminal voltage when the starter is on will be
(a) 12 V (b) 10.5 V
(c) 8.5 V (d) 7.5 V

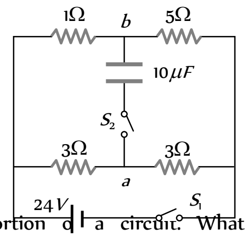
3. If the balance point is obtained at the 35 cm in a metre bridge the resistances in the left and right gaps are in the ratio of
(a) 7 : 13 (b) 13 : 7
(c) 9 : 11 (d) 11 : 9

4. Find the equivalent resistance across the terminals of source of e.m.f. 24 V for the circuit shown in figure



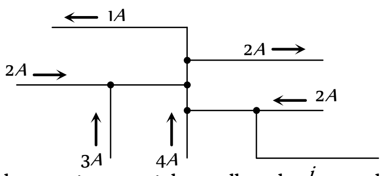
(a) 15 Ω
(b) 10 Ω
(c) 5 Ω
(d) 4 Ω

5. In the circuit shown in figure, switch S_1 is initially closed and S_2 is open. Find $V_a - V_b$



(a) 4 V
(b) 8 V
(c) 12 V
(d) 16 V

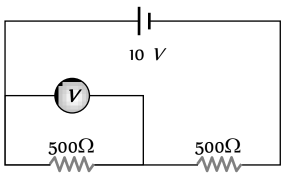
6. The figure here shows a portion of a circuit. What are the magnitude and direction of the current i in the lower right-hand wire



(a) 7 A
(b) 8 A
(c) 6 A
(d) 2 A

7. A carbon resistor has colour strips as violet, yellow brown and golden. The resistance is
(a) 641 Ω (b) 741 Ω
(c) 704 Ω (d) 407 Ω

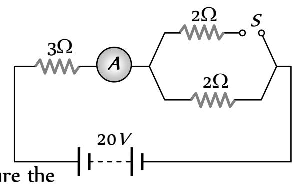
8. A voltmeter of resistance 1000 Ω is connected across a resistance of 500 Ω in the given circuit. What will be the reading of voltmeter



(a) 1 V
(b) 2 V
(c) 6 V
(d) 4 V

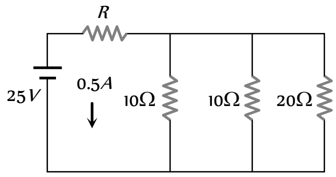
9. A beam contains 2 × 10 doubly charged positive ions per cubic centimeter, all of which are moving with a speed of 10 m/s. The current density is
(a) 6.4 A/m (b) 3.2 A/m
(c) 1.6 A/m (d) None of these

10. In the circuit shown, the reading of ammeter when switch S is open and when switch S is closed respectively are



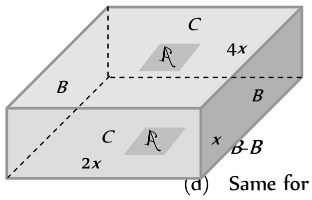
(a) 3 A and 4 A
(b) 4 A and 5 A
(c) 5 A and 6 A
(d) 6 A and 7 A

11. In the circuit as shown in figure the



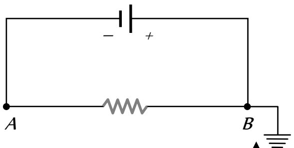
(a) Resistance R = 46 Ω
(b) Current through 20 Ω resistance is 0.1 A
(c) Potential difference across the middle resistance is 2 V
(d) All option are correct

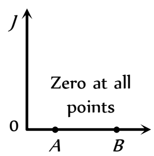
12. In figure shows a rectangular block with dimensions x, $2x$ and $4x$. Electrical contacts can be made to the block between opposite pairs of faces (for example, between the faces labelled A-A, B-B and C-C). Between which two faces would the maximum electrical resistance be obtained (A-A : Top and bottom faces, B-B : Left and right faces, C-C : Front and rear faces)

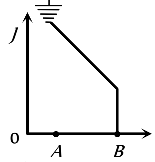


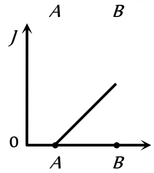
(a) A-A (b) B-B
(c) C-C (d) Same for all three pairs

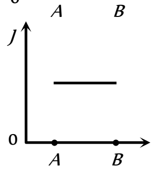
13. A battery is connected to a uniform resistance wire AB and B is earthed. Which one of the graphs below shows how the current density J varies along AB



(a)


(b)






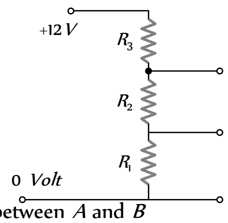
(c) (d)

14. A cylindrical metal wire of length l and cross sections area S, has resistance R, conductance G, conductivity σ and resistivity ρ. Which one of the following expressions for σ is valid

(a) $\frac{GR}{\rho}$ (b) $\frac{\rho R}{G}$

(c) $\frac{GS}{l}$ (d) $\frac{Rl}{S}$

15. A potential divider is used to give outputs of 4 V and 8 V from a 12 V source. Which combination of resistances, (R_1, R_2, R_3) gives the correct voltages ? $R_1 : R_2 : R_3$



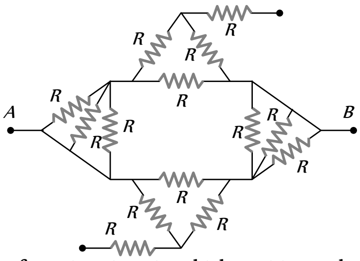
(a) 2 : 1 : 2

(b) 1 : 1 : 1

(c) 2 : 2 : 1

(d) 1 : 1 : 2

16. Find equivalent resistance between A and B



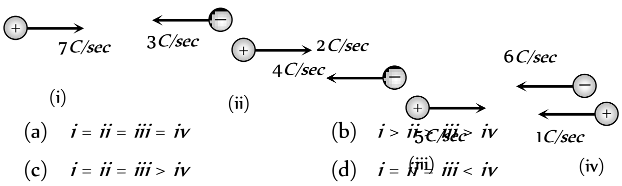
(a) R

(b) $\frac{3R}{4}$

(c) $\frac{R}{2}$

(d) $2R$

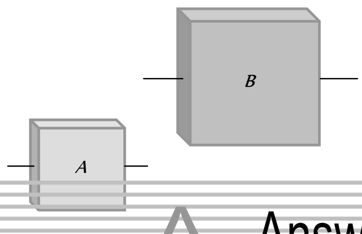
17. Following figure shows four situations in which positive and negative charges moves horizontally through a region and gives the rate at which each charge moves. Rank the situations according to the effective current through the region greatest first



(a) $i = ii = iii = iv$ (b) $i > ii > iii > iv$

(c) $i = ii = iii > iv$ (d) $i = ii = iii < iv$

18. A and B are two square plates of same metal and same thickness but length of B is twice that of A. Ratio of resistances of A and B is



(a) 4 : 1

(b) 1 : 4

(c) 1 : 1

(d) 1 : 2

19. A moving coil galvanometer is converted into an ammeter reading upto $0.03\,A$ by connecting a shunt of resistance $4r$ across it and into an ammeter reading upto $0.06\,A$ when a shunt of resistance r is connected across it. What is the maximum current which can be sent through this galvanometer if no shunt is used

(a) $0.01\,A$ (b) $0.02\,A$

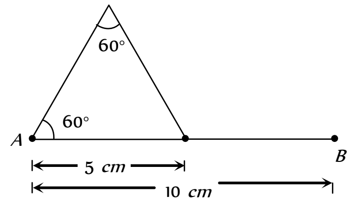
(c) $0.03\,A$ (d) $0.04\,A$

20. Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1.0 mm. Conductor B is a hollow tube of outside diameter 2.0 mm and inside diameter 1.0 mm. The resistance ratio R_A/R_B will be

(a) 1 (b) 2

(c) 3 (d) 4

21. A wire has resistance of 24 Ω is bent in the following shape. The effective resistance between A and B is



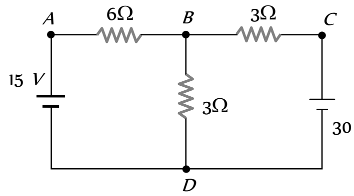
(a) 24 Ω

(b) 10 Ω

(c) $\frac{16}{3}\,\Omega$

(d) None of these

22. In the circuit shown in figure, find the current through the branch BD



(a) 5 A

(b) 0 A

(c) 3 A

(d) 4 A

23. A battery of 24 cells, each of emf 1.5 V and internal resistance 2Ω is to be connected in order to send the maximum current through a 12 Ω resistor. The correct arrangement of cells will be

(a) 2 rows of 12 cells connected in parallel

(b) 3 rows of 8 cells connected in parallel

(c) 4 rows of 6 cells connected in parallel

(d) All of these

Answers and Solutions

(SET - 19)

1. (a) The voltage per unit light of the metre wire PQ is $\left(\frac{6.00\,mV}{0.600\,m}\right)$ *i.e.* $10\,mV/m$. Hence potential difference across the metre wire is $10\,mV/m \times 1m = 10\,mV$. The current drawn from the driver cell is $i = \frac{10\,mV}{5\,\Omega} = 2\,mA$.

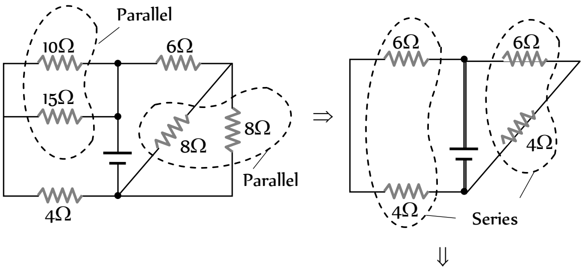
The resistance $R = \frac{(2V - 10mV)}{2\,mA} = \frac{1990\,mV}{2\,mA} = 995\,\Omega$.

2. (d) $V = E - i.r = 12 - 90 \times 0.05 = 12 - 4.5 = 7.5\,V$.

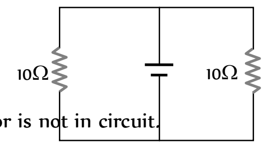
3. (a) Using Wheatstone principle $\frac{P}{Q} = \frac{R}{S} = \frac{R}{100-l}$

$$= \frac{35}{100-35} = \frac{35}{65} = \frac{7}{13}$$

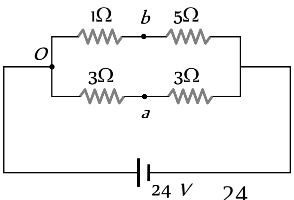
4. (c) Given circuit can be reduced to a simple circuit as shown in figures below



i.e. $R_{eq} = 5\Omega$.



5. (b) Switch S_2 is open so capacitor is not in circuit.



Current through 3Ω resistor $= \frac{24}{3+3} = 4\ A$

Let potential of point '*O*' shown in fig. is V_O

then using ohm's law

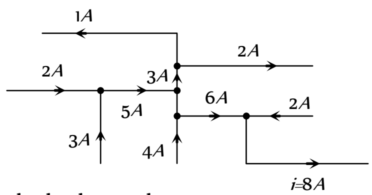
$V_O - V_a = 3 \times 4 = 12V$ ....(i)

Now current through 5Ω resistor $= \frac{24}{5+1} = 4A$

So $V_0 - V_b = 4 \times 1 = 4\ V$
.....(ii)

From equation (i) and (ii) $V_b - V_a = 12 - 4 = 8V$.

6. (b) By using Kirchoff's junction law as shown below.



7. (b) Using standard colour codes

Violet = 7, yellow = 4, brown = 1 and gold = 5 % (tolerance)

So $R = 74 \times 10^1 \pm 5\% = 740 \pm 5\%$

So its value will be nearest to $741\,\Omega$.

8. (d) Total current through the circuit

$$i = \frac{10}{\frac{1000}{3} + 500} = \frac{3}{250}A$$

Now voltmeter reading $= i_v \times R_V = \frac{2}{3} \times \frac{3}{250} \times 500 = 4V$.

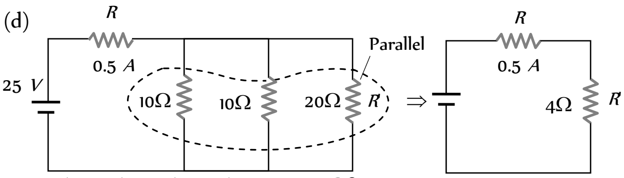
9. (a) $J = nqv = n(ze)v = \frac{2 \times 10^8 \times 2 \times 1.6 \times 10^{-19} \times 10^5}{(10^{-2})^3}$ =6.4A/m

10. (b) When switch *S* is open total current through ammeter.

$$i = \frac{20}{(3+2)} = 4A.$$

When switch is closed $i = \frac{20}{3 + (2\|\ 2)} = 5A$.

11. (d)



$$\frac{1}{R'} = \frac{1}{10} + \frac{1}{10} + \frac{1}{20} \Rightarrow R' = \frac{20}{5} = 4\ \Omega$$

Now using ohm's law $i = \frac{25}{R+R'} \Rightarrow 0.5 = \frac{25}{R+4}$

$$\Rightarrow R + 4 = \frac{25}{0.5} = 50 \Rightarrow R = 50 - 4 = 46\ \Omega$$

Current through 20Ω resistor $= \frac{0.5 \times 5}{20+5} = \frac{2.5}{25} = 0.1A$

Potential difference across middle resistor

= Potential difference across $20\Omega = 20 \times 0.1 = 2V$

12. (c) Let ρ is the resistivity of the material

Resistance for contact *A-A*

$$R_{AA} = \rho\frac{x}{2x \times 4x} = \frac{\rho}{8x}$$

Similar for contacts *B-B* and *C-C* are respectively

$$R_{BB} = \rho.\frac{2x}{x \times 4x} = \frac{\rho}{2x} = \frac{4\rho}{8x}$$

and $R_{CC} = \rho\frac{4x}{x \times 2x} = \frac{2\rho}{x} = \frac{16\rho}{8x}$

It is clear maximum resistance will be for contact *C-C*.

13. (d) Wire *AB* is uniform so current through wire *AB* at every across section will be same. Hence current density $J(= i/A)$ at every point of the wire will be same.

14. (a) Conductivity $\sigma = \frac{1}{\rho}$ .....(i)

and conductance $G = \frac{1}{R}$

$\Rightarrow GR = 1$ .....(ii)

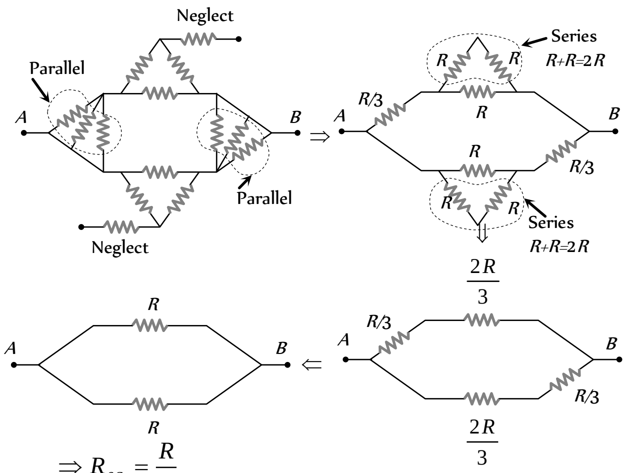
From equation (i) and (ii) $\sigma = \frac{GR}{\rho}$

15. (b) Resistors are connected in series. So current through each resistor will be same

$$\Rightarrow i = \frac{12-8}{R_3} = \frac{8-4}{R_2} = \frac{4-0}{R_1} \Rightarrow \frac{4}{R_3} = \frac{4}{R_2} = \frac{4}{R_1}$$

So, $R_1 : R_2 : R_3 :: 1 : 1 : 1$.

16. (c) Given circuit can be redrawn as follows



$\Rightarrow R_{eq} = \frac{R}{2}$

17. (c) For figure (i) $i_1 = 7A$

For figure (ii) $i_2 = 4 + 3 = 7A$

For figure (iii) $i_3 = 5 + 2 = 7A$

For figure (iv) $i_4 = 6 - 1 = 5A$

18. (c) $R_A = \frac{\rho l}{l \times t} = \frac{\rho}{t}$ and $R_B = \frac{\rho \times 2l}{2l \times t} = \frac{\rho}{t}$ *i.e.* $\frac{R_A}{R_B} = 1:1$

19. (b) $\frac{i_g}{i} = \frac{S}{G+S} \Rightarrow i_g G = (i - i_g)S$

$\therefore\ i_g G = (0.03 - i_g)4r$ .....(i)

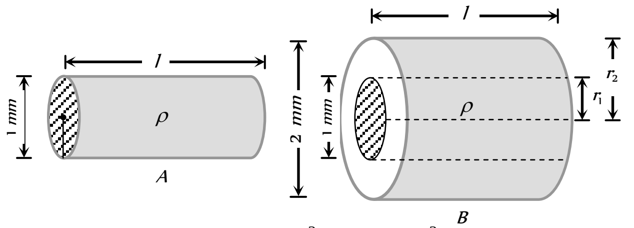
and $i_g G = (0.06 - i_g)r$ .....(ii)

From (i) and (ii)

$0.12 - 4i_g = 0.06 - i_g \Rightarrow i_g = 0.02A$.

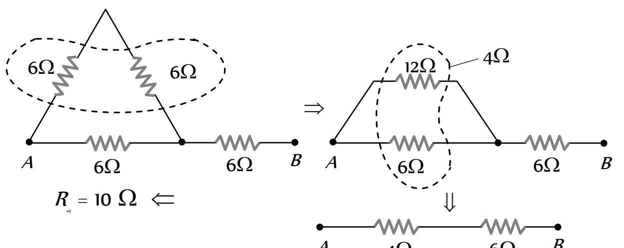
20. (c) For conductor *A*, $R_A = \frac{\rho l}{\pi r_1^2}$,

For conductor *B*, $R_B = \frac{\rho l}{\pi (r_2^2 - r_1^2)}$



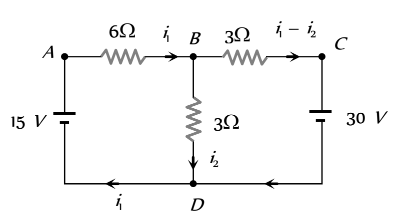
$\Rightarrow \frac{R_A}{R_B} = \frac{r_2^2 - r_1^2}{r_1^2} = \left(\frac{r_2}{r_1}\right)^2 - 1 = \left(\frac{d_2}{d_1}\right)^2 - 1 = \left(\frac{2}{1}\right)^2 - 1 = 3$

21. (b) Given resistance of each part will be



$R_{eq} = 10\ \Omega$

22. (a) The current in the circuit are assumed as shown in the fig.



Applying KVL along the loop *ABDA*, we get

$-6i_1 - 3i_2 + 15 = 0$ or $2i_1 + i_2 = 5$ .....(i)

Applying KVL along the loop *BCDB*, we get

$-3(i_1 - i_2) - 30 + 3i_2 = 0$ or $-i_1 + 2i_2 = 10$ .....(ii)

Solving equation (i) and (ii) for i_2, we get $i_2 = 5\ A$.

23. (a) Suppose *m* rows are connected in parallel and each row contains *n* identical cells (each cell having $E = 15\ V$ and $r = 2\Omega$) For maximum current in the external resistance *R*, the necessary condition is $R = \frac{nr}{m}$

$\Rightarrow 12 = \frac{n \times 2}{m} \Rightarrow n = 6m$ ..... (i)

Total cells = 24 = $n \times m$ ..... (ii)

On solving equations (i) and (ii) $n = 12$ and $m = 2$

i.e. 2 rows of 12 cells are connected in parallel.

***

Chapter

20

Heating and Chemical Effect of Current

Joules Heating

When some potential difference V is applied across a resistance R then the work done by the electric field on charge q to flow through the circuit in time t will be $W = qV = Vit = i^2Rt = \frac{V^2t}{R} Joule$. This work appears as thermal energy in the resistor.

Heat produced by the resistance R is $H = \frac{W}{J} = \frac{Vit}{4 \cdot 2} = \frac{i^2Rt}{4 \cdot 2} = \frac{V^2t}{4 \cdot 2R} Cal.$ This relation is called joules heating.

Electric Power

The rate at which electrical energy is dissipated into other forms of energy is called electrical power *i.e.* $\boldsymbol{P = \frac{W}{t} = Vi = i^2R = \frac{V^2}{R}}$

(1) **Units :** It's S.I. unit is *Joule/sec* or *Watt*

Bigger S.I. units are *KW*, *MW* and *HP*, remember 1 *HP* = 746 *Watt*

(2) **Rated values :** On electrical appliances (Bulbs, Heater, Geyser …. *etc.*). Wattage, voltage, ……. *etc.* are printed called rated values *e.g.* If suppose we have a bulb of 40 *W*, 220 *V* then rated power (P_R) = 40 *W* while rated voltage (V_R) = 220 *V*.

(3) **Resistance of electrical appliance :** If variation of resistance with temperature is neglected then resistance of any electrical appliance can be calculated by rated power and rated voltage *i.e.* by using $\boldsymbol{R = \frac{V_R^2}{P_R}}$.

(4) **Power consumed (illumination) :** An electrical appliance (Bulb, heater, …. *etc.*) consume rated power (P_R) only if applied voltage (V_A) is equal to rated voltage (V_R) *i.e.* If $V_A = V_R$ so $P_{consumed} = P_R$. If $V_A < V_R$ then $P_{consumed} = \frac{V_A^2}{R}$ also we have $R = \frac{V_R^2}{P_R}$ so $\boldsymbol{P_{Consumed}\ (Brightness) = \left(\frac{V_A^2}{V_R^2}\right) . P_R}$

(5) **Long distance power transmission :** When power is transmitted through a power line of resistance R, power-loss will be i^2R

Now if the power P is transmitted at voltage V then $P = Vi$ *i.e.* $i = (P/V)$ So, $\text{Power loss} = \frac{P^2}{V^2} \times R$

Now as for a given power and line, P and R are constant so $\text{Power loss} \propto (1/V^2)$

So if power is transmitted at high voltage, power loss will be small and vice-versa. This is why long distance power transmission is carried out at high voltage.

Electricity Consumption

(1) The price of electricity consumed is calculated on the basis of electrical energy and not on the basis of electrical power.

(2) The unit *Joule* for energy is very small hence a big practical unit is considered known as *kilowatt hour* (*KWH*) or board of trade unit (B.T.U.) or simple unit.

(3) 1 *KWH* or 1 unit is the quantity of electrical energy which dissipates in one hour in an electrical circuit when the electrical power in the circuit is 1 *KW* thus 1 *KWH* = 1000 *W* × 3600 *sec* = 3.6 × 10^6 *J*.

(4) Important formulae to calculate the no. of consumed units is $n = \frac{\text{Total } Watt \times \text{Total } Hours}{1000}$

Combination of Bulbs

(1) **Series combination**

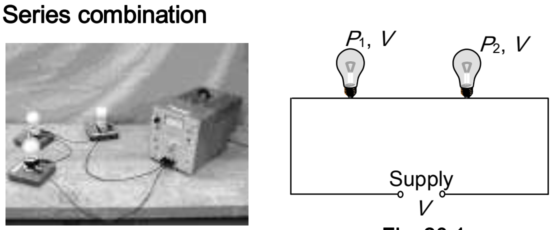


Fig. 20.1

(i) Total power consumed $\frac{1}{P_{total}} = \frac{1}{P_1} + \frac{1}{P_2} + ...$

(ii) If '*n*' bulbs are identical, $P_{total} = \frac{P}{N}$

(iii) $P_{consumed}$ (Brightness) $\propto V \propto R \propto \frac{1}{P_{rated}}$ *i.e.* in series combination bulb of lesser wattage will give more bright light and p.d. appeared across it will be more.

(2) **Parallel combination**

(i) Total power consumed $P_{total} = P_1 + P_2 + P_3 ...... + P_n$

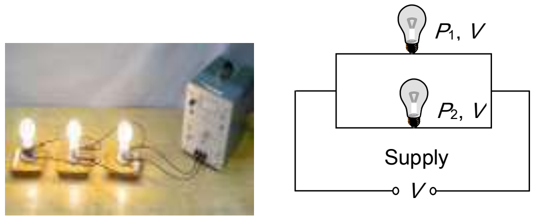


Fig. 20.2

(ii) If '*n*' identical bulbs are in parallel. $P_{total} = nP$

(iii) $P_{consumed}$ (Brightness) $\propto P_R \propto i \propto \frac{1}{R}$ *i.e.* in parallel combination, bulb of greater wattage will give more bright light and more current will pass through it.

Chemical Effect of Current

Current can produce or speed up chemical change, this ability of current is called chemical effect (shown by *dc* not by *ac*).

(1) **Electrolytes :** The liquids which allows the current to pass through them and also dissociates into ions on passing current through them are called electrolytes *e.g.* solutions of salts, acids and bases in water, *etc*.

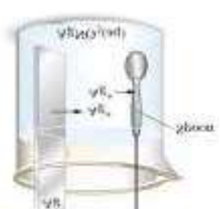
Those liquids which do not allow current to pass through them are called insulators (*e.g.* vegetable oils, distilled water *etc*.)

Solutions of cane sugar, glycerin, alcohol *etc*. are examples of non-electrolytes.

(2) **Electrolysis :** The process of decomposition of electrolyte solution into ions on passing the current through it is called electrolysis.

Practical applications of electrolysis are Electrotyping, extraction of metals from the ores, Purification of metals, Manufacture of chemicals, Production of O_2 and H_2, Medical applications and electroplating.

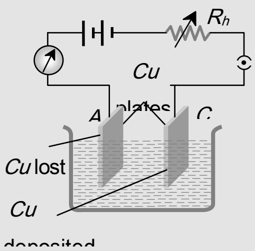
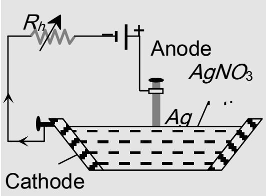
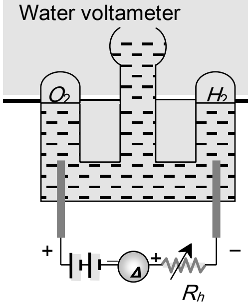
(3) **Electroplating :** It is a process of depositing a thin layer of one metal over another metal by the method of electrolysis. The articles of cheap metals are coated with precious metals like silver and gold to make their look more attractive. The



article to be electroplated is made the cathode and the metal to be deposited is made the anode. A soluble salt of the precious metal is taken as the electrolyte. (If gold is to be coated then auric chloride is used as electrolyte).

(4) **Voltameter :** The vessel in which the electrolysis is carried out is called a voltameter. It contains two electrodes and electrolyte. It is also known as electrolytic cell.

Table 20.1 : Types of voltameters

Volatameter	Anode/ cathode	Electrolyte	Deposition
Cu voltameter 	Cathode may be of any material but anode must be of *Cu*	$CuSO_4$ or $CuCl_2$	At cathode *Cu* deposited
Ag voltameter 	Cathode may be of any material but anode must be of *Ag*	$AgNO_3$	At cathode *Ag* deposited
Water voltameter 	Both electrode are made of platinum (*Pt*)	Acidulated water	H_2 and O_2 gases are collects over the cathode and anode respectively in the ratio of 2 : 1

Faraday's Law of Electrolysis

(1) **First law :** It states that the mass (*m*) of substance deposited at the cathode during electrolysis is directly proportional to the quantity of electricity (total charge *q*) passed through the electrolyte *i.e.* $m \propto q$ or ***m* = *zq* = *zit***, where the constant of proportionality *z* is called *electrochemical equivalent* (*E.C.E.*) *of the substance.*

Therefore we have $m = zit$. If q = 1 *coulomb*, then we have $m = z \times 1$ or $z = m$

Hence, the electrochemical equivalent of substance may be defined as the mass of its substance deposited at the cathode, when one *coulomb* of charge passes through the electrolyte.

S.I. unit of electrochemical equivalent of a substance is *kilogram coulomb*$^{-1}$ ($kg\text{-}C^{-1}$).

Table 20.2 : E.C.E. for certain substances

Element	Atomic weight	Atomic number	Valency	E.C.E. (*Z*) in *kg / C*
Hydrogen	1.0008	1	1	10.4×10^{-9}
Oxygen	15.999	8	2	82.9×10^{-9}
Aluminium	26.982	13	3	93.6×10^{-9}
Chromium	51.996	24	3	179.6×10^{-9}
Nickel	58.710	28	2	304.0×10^{-9}
Copper	63.546	29	2	329.4×10^{-9}
Zinc	65.380	30	2	338.7×10^{-9}
Silver	107.868	47	1	1118×10^{-9}
Gold	196.966	79	3	681.2×10^{-9}

(2) **Second law :** If same quantity of electricity is passed through different electrolytes, masses of the substance

deposited at the respective cathodes are directly proportional to their chemical equivalents *i.e.* $\boldsymbol{m \propto E \Rightarrow \frac{m_1}{m_2} = \frac{E_1}{E_2}}$

Let m be the mass of the ions of a substance liberated, whose chemical equivalent is E. Then, according to Faraday's second law of electrolysis, $m \propto E$ or m = constant $\times$ E or $\frac{m}{E} = \text{constant}$

Chemical equivalent E also known as equivalent weight in *gm i.e.* $E = \frac{\text{Atomic mass }(A)}{\text{Valancy }(V)}$

(3) **Relation between chemical equivalent and electrochemical equivalent :** Suppose that on passing same amount of electricity q through two different electrolytes, masses of the two substances liberated are m_1 and m_2. If E_1 and E_2 are their chemical equivalents, then from Faraday's second law, we have $\frac{m_1}{m_2} = \frac{E_1}{E_2}$. Also from Faraday's first law $\frac{m_1}{m_2} = \frac{z_1}{z_2}$

So $\frac{z_1}{z_2} = \frac{E_1}{E_2} \Rightarrow z \propto E$

(4) **Faraday constant :** As we discussed above $E \propto z$

$\Rightarrow E = Fz \Rightarrow z = \frac{E}{F} = \frac{A}{VF}$. '$F$' is proportionality constant called Faraday's constant.

As $z = \frac{E}{F}$ and $z = \frac{m}{Q}$ so $\frac{E}{F} = \frac{m}{Q}$ hence if Q = 1 *Faraday* then $E = m$ *i.e.* If electricity supplied to a voltameter is 1 Faraday then amount of substance liberated or deposited is (in *gm*) equal to the chemical equivalent.

Electro Chemical Cell

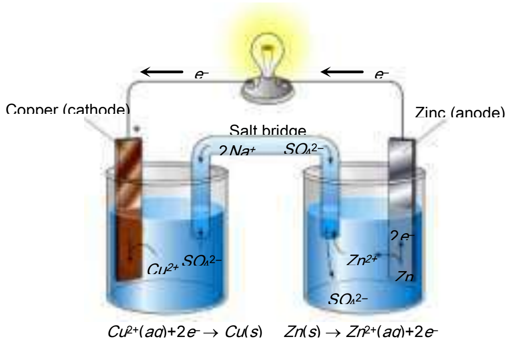


Fig. 20.4

It is an arrangement in which the chemical energy is converted into electrical energy due to chemical action taking place in it.

(1) **Primary cell :** Is that cell in which electrical energy is produced due to chemical energy. In the primary cell, chemical reaction is irreversible. This cell can not be recharged. Examples of primary cells are Voltaic cell, Daniel cell, Leclanche cell and Dry cell *etc.*

(2) **Secondary cell :** A secondary cell is that cell in which the electrical energy is first stored up as a chemical energy and when the current is taken from the cell, the chemical energy is reconverted into electrical energy. In the secondary cell chemical reactions are reversible. The secondary cells are also called storage cell or accumulator. The commonly used secondary cells is lead accumulator.

(3) **Defects In a primary cell :** In voltaic cell there are two main defects arises.

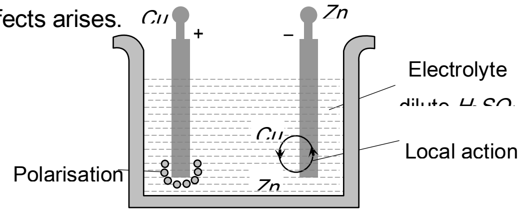


Fig. 20.5

Local action : It arises due to the presence of impurities of iron, carbon etc. on the surface of commercial *Zn* rod used as an electrode. The particles of these impurities and *Zn* in contact with sulphuric acid form minute voltaic cell in which small local electric currents are set up resulting in the wastage of *Zn* even when the cell is not sending the external current.

Removal : By amalgamating *Zn* rod with mercury (*i.e.* the surface of *Zn* is coated with *Hg*).

Polarisation : It arises, when the positive H_2 ions, which are formed by the action of *Zn* on sulphuric acid, travel towards the *Cu* rod and after transferring, the positive charge converted into H_2 gas atoms and get deposited in the form of neutral layer of a gas on the surface of *Cu* rod. This weakens the action of cell.

Removal : Either by brushing the anode the remove the layer or by using a depolariser (*i.e.* some oxidising agent MnO_2, $CuSO_4$ *etc* which may oxidise H_2 into water).

Thermo electric effect of current

If two wires of different metals are joined at their ends so as to form two junctions, then the resulting arrangement is called a "**Thermo couple**".

Seeback Effect

(1) **Definition :** When the two junctions of a thermo couple are maintained at different temperatures, then a current starts flowing through the loop known as thermo electric current. The potential difference between the junctions is called thermo electric emf which is of the order of a few micro-volts per degree temperature difference ($\mu V/^{o}C$).

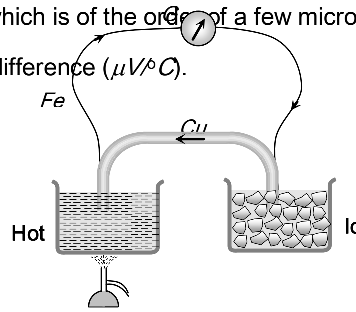


Fig. 20.6

(2) **Seebeck series :** The magnitude and direction of thermo emf in a thermocouple depends not only on the temperature difference between the hot and cold junctions but also on the nature of metals constituting the thermo couple.

(i) Seebeck arranged different metals in the decreasing order of their electron density. Few metals forming the series are as below.

Sb, *Fe*, *Cd*, *Zn*, *Ag*, *Au*, *Cr*, *Sn*, *Pb*, *Hg*, *Mn*, *Cu*, *Pt*, *Co*, *Ni*, *Bi*

(ii) Thermo electric emf is directly proportional to the distance between the two metals in series. Farther the metals in the series forming the thermo couple greater is the thermo emf. Thus maximum thermo emf is obtained for ***Sb-Bi*** thermo couple.

(iii) The current flow at the hot junction of the thermocouple is from the metal occurring later in the series towards that occurring earlier, Thus, in the ***copper-iron*** thermocouple the current flows from copper (*Cu*) to iron (*Fe*) at the hot junction. This may be remembered easily by the **hot coffee**.

(3) **Variation of thermo emf with temperature :** In a thermocouple as the temperature of the hot junction increases keeping the cold junction at constant temperature (say $0^{o}C$). The thermo emf increases till it becomes maximum at a certain temperature.

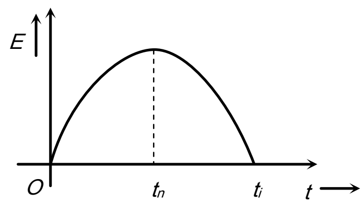


Fig. 20.7

(i) Thermo electric emf is given by the equation $E = \alpha t + \frac{1}{2}\beta t^2$ where α and β are thermo electric constant having units are $volt/^{o}C$ and $volt/^{o}C^2$ respectively (t = temperature of hot junction). For E to be maximum (at $t = t_n$)

$$\frac{dE}{dt} = 0 \;\; i.e. \;\alpha + \beta t_n = 0 \Rightarrow t_\eta = -\frac{\alpha}{\beta}$$

(ii) The temperature of hot junction at which thermo emf becomes maximum is called neutral temperature (t_n). Neutral temperature is constant for a thermo couple (*e.g.* for *Cu-Fe*, $t_n = 270^{o}C$)

(iii) Neutral temperature is independent of the temperature of cold junction.

(iv) If temperature of hot junction increases beyond neutral temperature, thermo emf start decreasing and at a particular temperature it becomes zero, on heating slightly further, the direction of emf is reversed. This temperature of hot junction is called temperature of inversion (t_i).

(v) Relation between t_n, t_i and t_c is $t_n = \frac{t_i + t_c}{2}$

(4) **Thermo electric power :** The rate of change of thermo emf with the change in the temperature of the hot junction is called thermoelectric power.

It is also given by the slope of parabolic curve representing the variation of thermo emf with temperature of the hot junction, as discussed in previous section.

The thermo electric power $\left(\frac{dE}{dt}\right)$ is also called **Seebeck coefficient**. Differentiating both sides of the equation of thermo emf with respect to t, we have thermoelectric power $P = \frac{dE}{dt} = \frac{d}{dt}(\alpha t + \frac{1}{2}\beta t^2)$

$\Rightarrow P = \alpha + \beta t$

The equation of the thermo electric power is of the type $y = mx + c$, so the graph of thermo electric power is as shown.

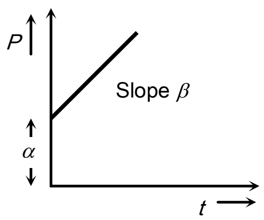


Fig. 20.8

(5) **Laws of thermoelectricity**

(i) **Law of successive temperature :** If initially temperature limits of the cold and the hot junction are t_1 and t_2, say the thermo emf is $E_{t_1}^{t_2}$. When the temperature limits are t_2 and t_3, then say the thermo emf is $E_{t_2}^{t_3}$ then $E_{t_1}^{t_2} + E_{t_2}^{t_3} = E_{t_1}^{t_3}$ where $E_{t_1}^{t_3}$ is the thermo emf when the temperature limits are $E_{t_1}^{t_3}$

(ii) **Law of intermediate metals :** Let *A*, *B* and *C* be the three metals of Seebeck series, where *B* lies between *A* and *C*. According to this law, $E_A^B + E_B^C = E_A^C$

When tin is used as a soldering metal in *Fe-Cu* thermocouple then at the junction, two different thermo couples are being formed. One is between iron and tin and the other is between tin and copper, as shown in figure

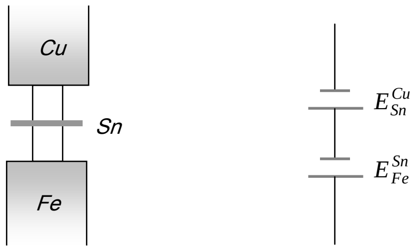


Fig. 20.9

If the soldering metal does not lie between two metals (in Seebeck series) of thermocouple then the resultant emf will be subtractive.

Peltier Effect

When current is passed through a junction of two different metals, the heat is either evolved or absorbed at the junction. This effect is known as Peltier effect. It is the reverse of Seebeck effect. (When a positive charge flows from high potential to low potential, it releases energy and when positive charge flows from low potential to high potential it absorbs energy.)

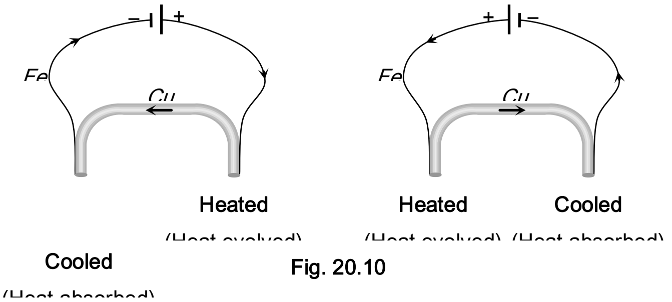


Fig. 20.10

Peltier co-efficient (π) : Heat absorbed or liberated at the junction is directly proportional to the charge passing through the junction *i.e.* $H \propto Q \Rightarrow H = \pi Q$; where π is called Peltier co-efficient. It's unit is *J/C* or *volt*.

Peltier co-efficient of a junction is the amount of heat absorbed or liberated per sec. When 1 *amp* of current is passed to the thermo couple.

It is found that $\pi = T\frac{dE}{dT} = T \times S$; where *T* is in Kelvin and $\frac{dE}{dT} = P =$ Seebeck coefficient *S*

Thomson's Effect

In Thomson's effect we deal with only metallic rod and not with thermocouple as in Peltiers effect and Seebeck's effect. (That's why sometimes it is known as homogeneous thermo electric effect. When a current flows thorough an unequally heated metal, there is an absorption or evolution of heat in the body of the metal. This is Thomson's effect.

(i) **Positive Thomson's effect :** In positive Thomson's effect it is found that hot end is at high potential and cold end is at low potential. Heat is evolved when current is passed from hotter end to the colder end and heat is absorbed when current is passed from colder end to hotter end. The metals which shows positive Thomson's effect are *Cu*, *Sn*, *Ag*, *Cd*, *Zn*... *etc*.

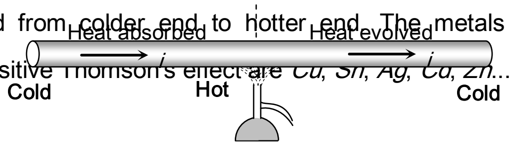


Fig. 28.11

(ii) **Negative Thomson's effect :** In the elements which show negative Thomson's effect, it is found that the hot end is at low potential and the cold end is at higher potential. Heat is evolved when current is passed from colder end to the hotter end and heat is absorbed when current flows from hotter end to colder end. The metals which shows negative. Thomson's effect are *Fe*, *Co*, *Bi*, *Pt*, *Hg* ... *etc*.

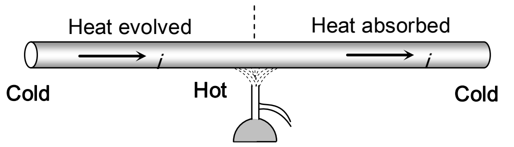


Fig. 20.12

Thomson's co-efficient : In Thomson's effect it is found that heat released or absorbed is proportional to $Q\Delta\theta$ *i.e.* $H \propto Q\Delta\theta$ $\Rightarrow$ $H = \sigma Q\Delta\theta$ where σ = Thomson's coefficient. It's unit is *Joule*/*coulomb*°*C* or *volt*/°*C* and $\Delta\theta$ = temperature difference.

If *Q* = 1 and $\Delta\theta$ = 1 then $\sigma = H$ so the amount of heat energy absorbed or evolved per second between two points of a conductor having a unit temperature difference, when a unit current is passed is known as Thomson's co-efficient for the material of a conductor.

It can be proved that Thomson co-efficient of the material of conductor $\sigma = -T\frac{d^2E}{dT^2} = -T\left(\frac{dS}{dT}\right) = T \times \beta$; where β = Thermo electric constant $= \frac{dS}{dt}$

Application of Thermo Electric Effect

(1) **To measure temperature :** A thermocouple is used to measure very high (2000°*C*) as well as very low (– 200°*C*) temperature in industries and laboratories. The thermocouple used to measure very high temperature is called pyrometer.

(2) **To detect heat radiation :** A thermopile is a sensitive instrument used for detection of heat radiation and measurement of their intensity. It is based upon Seebeck effect.

A thermoppile consists of a number of thermocouples of *Sb-Bi*, all connected in series.

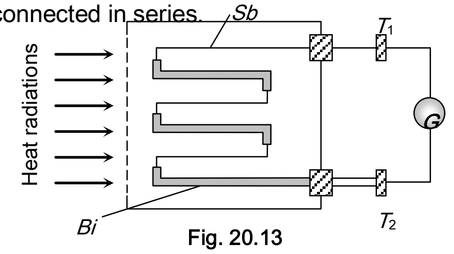


Fig. 20.13

Table 20.3: Heating effect and Thermo-electric effects

S.No.	Joule's effect	Peltier's effect	Seebeck effect	Thomson's effect
1.	Heat produced is directly proportional to the square of the current passing through a	Heat produced or absorbed at a junction is proportional to the current through the junction.	Here temperature difference of junction is used to produce thermo e.m.f. and vice versa.	Thomson's heat is proportional to the current passing through the conductor.

	conductor.			
2.	This effect is produced due to collision of free electrons with positive ions of the current carrying conductor.	This effect is produced when current is passed through junction of suitable materials.	This effect produced when junctions of a themocouple are kept at different temperatures.	This effect is produced when parts of same conductor are kept at different temperature.
3.	It is not a reversible effect.	It is a reversible effect	It is a reversible effect	It is a reversible effect
4.	Heat produced depends upon resistance (and thus temperature also) of the conductor.	Heat exchange depends upon nature of conductors and temperature of the junctions.	This effect depends upon nature of materials used to form junctions and temperature of junctions.	This effect depends upon nature of conductor and temperature difference of different parts of the conductor.
5.	It is basically a heating effect	It can be heating as well as cooling effect.	Different junctions are at different temperature.	It is heating as well as cooling effect.

This instrument is so sensitive that it can detect heat radiations from a match stick lighted at a distance of 50 *metres* from the thermopile.

(3) **Thermoelectric refrigerator :** The working of thermo-electric refrigerator is based on Peltier effect.

(4) **Thermoelectric generator :** Thermocouple can be used to generate electric power using Seebeck effect in remote areas.

(5) **Thero-couple meter :** The current to be measured passes through a resistance where heat is generated in the amount of i^2R *joule/sec*. The hot junction of the thermocouple is in contact with this resistance, and resulting thermoelectic current gives deflection in the galvanometer *G*.

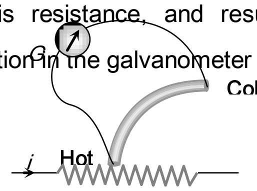
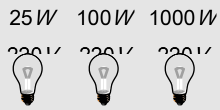


Fig. 20.14

Tips & Tricks

If $V_{Applied} < V_{Rated}$ then % drop in output power of electrical device $= \frac{(P_R - P_{consumed})}{P_R} \times 100$

✍ Different bulbs



⇒ Resistance $R_{25} > R_{100} > R_{1000}$

⇒ Thickness of filament $t_{1000} > t_{100} > t_{40}$

⇒ Brightness $B_{1000} > B_{100} > B_{25}$

✍ Time taken by heater to raise the temperature by $\Delta\theta$ of *m kg* (or *m litre*) water is given by $t = \frac{4180(\text{or } 4200) m\,\Delta\theta}{p}$

✍ Necessary series resistance to glow a bulb, if $V_{Applied} > V_{Rated}$

$$R = \left(\frac{V_{Applied} - V_{Rated}}{P_R}\right) \times V_R$$ (P_R = Rated power of bulb)

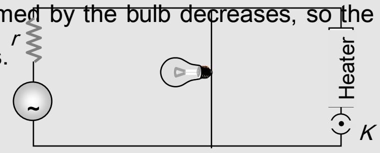
✍ When some potential difference applied across the conductor then collision of free electrons with ions of the lattice result's in conversion of electrical energy into heat energy

✍ If a heating coil of resistance R, (length l) consumed power *P*, when voltage *V* is applied to it then by keeping *V* constant if it is cut in n equal parts then resistance of each part will be R/n and from $P_{consumed} \propto \frac{1}{R}$, power consumed by each part $P' = nP$.

✍ In series a device of higher power rating consumes less power.

✍ Consider that *n* bulbs are connected in series across *V* volt supply. If one bulb gets fused and (*n* – 1) bulbs are again connected in series across same supply, the illumination will be more with (*n* – 1) bulbs then *n* bulbs but risk of fusing of bulbs will increases.

✍ When a heavy current appliance such us motor, heater or geyser is switched on, it will draw a heavy current from the source so that terminal voltage of source decreases. Hence power consumed by the bulb decreases, so the light of bulb becomes less.



✍ *If ρ is the density of the material deposited and A is the area of deposition then the thickness (d) of the layer of the material deposited in electroplating process is* $d = \frac{m}{\rho A} = \frac{Zit}{\rho A}$; *where m = deposited mass, Z = electro chemical equivalent, i = electric current.*

✍ Charging current for a secondary cell

$$= \frac{\text{e.m.f. of charger} - \text{e.m.f. of cell}}{\text{Total resistance of the circuit}}$$

✍ Efficiency of a cell is given by $\eta = \frac{R}{r+R}$ where *R* is external resistance and *r* is internal resistance.

✍ The efficiency of cell is 50% when the power dissipated in the external circuit is maximum.

✍ Thermo couple can be compared to a heat engine. It absorbs heat at the junction (source) converts heat into electric energy (which appears as the circulating electric current) and rejects the remaining heat to cold junction (Sink).

Ordinary Thinking

Objective Questions

Heating Effect of Current

1. One *kilowatt* hour is equal to **[NCERT 1974; MP PMT 2002]**

(a) 36×10^5 *joules* (b) 36×10^3 *joules*

(c) 10^3 *joules* (d) 10^5 *joules*

2. If R_1 and R_2 are respectively the filament resistances of a 200 *watt* bulb and 100 *watt* bulb designed to operate on the same voltage, then **[NCERT 1980; CPMT 1991, 97]**

(a) R_1 is two times R_2 (b) R_2 is two times R_1

(c) R_2 is four times R_1 (d) R_1 is four times R_2

3. Two electric bulbs, one of 200 *volt* 40 *watt* and the other 200 *volt* 100 *watt* are connected in a house wiring circuit

[NCERT 1971; CBSE PMT 2000]

(a) They have equal currents through them

(b) The resistance of the filaments in both the bulbs is same

(c) The resistance of the filament in 40 *watt* bulb is more than the resistance in 100 *watt* bulb

(d) The resistance of the filament in 100 *watt* bulb is more than the resistance in 40 *watt* bulb

4. The two bulbs as in the above question are connected in series to a 200 *volt* line. Then

(a) The potential drop across the two bulbs is the same

(b) The potential drop across the 40 *watt* bulb is greater than the potential drop across the 100 *watt* bulb

(c) The potential drop across the 100 *W* bulb is greater than the potential drop across the 40 *W* bulb

(d) The potential drop across both the bulb is 200 *volt*

5. Forty electric bulbs are connected in series across a 220 *V* supply. After one bulb is fused, the remaining 39 are connected again in series across the same supply. The illumination will be

[NCERT 1972; Haryana CEE 1996; DPMT 2001]

(a) More with 40 bulbs than with 39
(b) More with 39 bulbs than with 40
(c) Equal in both the cases
(d) In the ratio of $49^2 : 39^2$

6. The material of fuse wire should have [BHU 1999; MH CET 2001; CBSE PMT 2003]

(a) A high specific resistance and high melting point
(b) A low specific resistance and low melting point
(c) A high specific resistance and low melting point
(d) A low specific resistance and a high melting point

7. Two electric bulbs whose resistances are in the ratio of 1 : 2 are connected in parallel to a constant voltage source. The powers dissipated in them have the ratio [NCERT 1977; MP PMT 1994, 2000]

(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) 1 : 4

8. A heater coil is cut into two parts of equal length and one of them is used in the heater. The ratio of the heat produced by this half coil to that by the original coil is [NCERT 1972; AIEEE 2005; CBSE PMT 2005]

(a) 2 : 1 (b) 1 : 2
(c) 1 : 4 (d) 4 : 1

9. Resistance of one carbon filament and one tungsten lamp are measured individually when the lamp are lit and compared with their respective resistances when cold. Which one of the following statements will be true [NCERT 972]

(a) Resistance of the carbon filament lamp will increase but that of the tungsten will diminish when hot
(b) Resistance of the tungsten filament lamp will increase but that of carbon will diminish when hot
(c) Resistances of both the lamps will increase when hot
(d) Resistances of both the lamps will decrease when hot

10. The mechanism of the heat produced in a conductor when an electric current flows through it, can be explained on the basis of

(a) Viscosity (b) Friction
(c) Free electron theory (d) Gauss's theorem

11. Two electric bulbs whose resistances are in the ratio of 1 : 2 are connected in series. The powers dissipated in them have the ratio [NCERT 1977]

(a) 1 : 2 (b) 2 : 1
(c) 1 : 1 (d) 1 : 4

12. You are given a resistance wire of length 50 cm and a battery of negligible resistance. In which of the following cases is largest amount of heat generated

(a) When the wire is connected to the battery directly
(b) When the wire is divided into two parts and both the parts connected to the battery in parallel
(c) When the wire is divided into four parts and all the four connected to the battery in parallel
(d) When only half the wire is connected to the battery

13. What is immaterial for an electric fuse wire [MNR 1984; MP PMT 2002; CPMT 1996, 2003]

(a) Its specific resistance
(b) Its radius
(c) Its length
(d) Current flowing through it

14. The electric bulbs have tungsten filaments of same length. If one of them gives 60 *watt* and other 100 *watt*, then [NCERT 1979]

(a) 100 *watt* bulb has thicker filament
(b) 60 *watt* bulb has thicker filament
(c) Both filaments are of same thickness
(d) It is possible to get different wattage unless the lengths are different

15. Three equal resistors connected in series across a source of e.m.f. together dissipate 10 watt. If the same resistors are connected in parallel across the same e.m.f., then the power dissipated will be [CBSE PMT 1998; KCET (Engg.) 1999; MP PMT 2003]

(a) 10 *watt* (b) 30 *watt*
(c) 10/3 *watt* (d) 90 *watt*

16. How much energy in kilowatt hour is consumed in operating ten 50 watt bulbs for 10 hours per day in a month (30 days). [NCERT 1978, 80; CPMT 1991]

(a) 1500 (b) 5,000
(c) 15 (d) 150

17. (1) The product of a volt and a coulomb is a joule.
(2) The product of a volt and an ampere is a joule/second.
(3) The product of volt and watt is horse power.
(4) Watt-hour can be measured in terms of electron volt.

State if [NCERT 1978; MP PMT 2003]

(a) All four are correct
(b) (1), (2) and (4) are correct
(c) (1) and (3) are correct
(d) (3) and (4) are correct

18. A 25 *W*, 220 *V* bulb and a 100 *W*, 220 *V* bulb are connected in parallel across a 440 *V* line [CBSE PMT 2001]

(a) Only 100 *watt* bulb will fuse
(b) Only 25 *watt* bulb will fuse
(c) Both bulbs will fuse
(d) None of the bulbs will fuse

19. Two electric lamps of 40 watt each are connected in parallel. The power consumed by the combination will be [CPMT 1984]

(a) 20 *watt* (b) 60 *watt*
(c) 80 *watt* (d) 100 *watt*

20. Two heating coils, one of fine wire and the other of thick wire of the same material and of the same length are connected in series and in parallel. Which of the following statement is correct

(a) In series fine wire liberates more energy while in parallel thick wire will liberate more energy
(b) In series fine wire liberates less energy while in parallel thick wire will liberate more energy
(c) Both will liberate equally
(d) In series the thick wire will liberate more while in parallel it will liberate less energy

21. An electric bulb is rated 220 *volt* and 100 *watt*. Power consumed by it when operated on 110 *volt* is [CPMT 1986; MP PMT 1986, 94; AFMC 2000]

(a) 50 *watt* (b) 75 *watt*
(c) 90 *watt* (d) 25 *watt*

22. A 25 *watt*, 220 *volt* bulb and a 100 *watt*, 220 *volt* bulb are connected in series across a 220 *volt* lines. Which electric bulb will glow more brightly [MP PET 1999; MP PMT 1999]

(a) 25 *watt* bulb
(b) 100 *watt* bulb
(c) First 25 watt and then 100 *watt*
(d) Both with same brightness

23. A resistor R_1 dissipates the power P when connected to a certain generator. If the resistor R_2 is put in series with R_1, the power dissipated by R_1 [CPMT 1985; MNR 1998]

(a) Decreases
(b) Increases
(c) Remains the same
(d) Any of the above depending upon the relative values of R_1 and R_2

24. An electric fan and a heater are marked as 100 *watt*, 220 *volt* and 1000 *watt*, 220 volt respectively. The resistance of the heater is

(a) Zero
(b) Greater than that of the fan
(c) Less than that of the fan
(d) Equal to that of the fan

25. According to Joule's law, if the potential difference across a conductor having a material of specific resistance remains constant, then the heat produced in the conductor is directly proportional to

(a) ρ (b) ρ^2
(c) $\frac{1}{\sqrt{\rho}}$ (d) $\frac{1}{\rho}$

26. Two heater wires of equal length are first connected in series and then in parallel. The ratio of heat produced in the two cases is [MNR 1987; UPSEAT 1999; MP PMT 1996, 2000, 01; AIIMS 2000; MP PET 1999, 2002; BHU 2004; Pb PET 2004]

(a) 2 : 1 (b) 1 : 2
(c) 4 : 1 (d) 1 : 4

27. Two bulbs of equal wattage, one having carbon filament and the other having a tungsten filament are connected in series to the mains, then

(a) Both bulbs glow equally
(b) Carbon filament bulb glows more
(c) Tungsten filament bulbs glows more
(d) Carbon filament bulb glows less

28. Two identical heaters rated 220 *volt*, 1000 watt are placed in series with each other across 220 *volt* lines. If resistance do not change with temperature, then the combined power is

(a) 1000 *watt* (b) 2000 *watt*
(c) 500 *watt* (d) 4000 *watt*

29. A 25 *watt*, 220 *volt* bulb and a 100 *watt*, 220 *volt* bulb are connected in parallel across a 220 *volt* line. Which bulb will glow more brightly

(a) 25 *watt* bulb
(b) 100 *watt* bulb
(c) Both will have same brightness

(d) First 25 *watt* then 100 *watt*

30. If two bulbs of wattage 25 and 100 respectively each rated at 220 *volt* are connected in series with the supply of 440 *volt*, then which bulbs will fuse [MNR 1988]

(a) 100 *watt* bulb (b) 25 *watt* bulb
(c) None of them (d) Both of them

31. If current in an electric bulb changes by 1%, then the power will change by [AFMC 1996]

(a) 1% (b) 2%
(c) 4% (d) $\frac{1}{2}\%$

32. Two identical batteries, each of e.m.f. 2 *volt* and internal resistance 1.0 ohm are available to produce heat in an external resistance $R = 0.5\ ohm$ by passing a current through it. The maximum Joulean power that can be developed across *R* using these batteries is

[CBSE PMT 1990; BHU 1997]

(a) 1.28 *watt* (b) 2.0 *watt*
(c) $\frac{8}{9} watt$ (d) 3.2 *watt*

33. A constant voltage is applied between the two ends of a metallic wire. If both the length and the radius of the wire are doubled, the rate of heat developed in the wire

[MP PMT 1996]

(a) Will be doubled (b) Will be halved
(c) Will remain the same (d) Will be quadrupled

34. The heating coils rating at 220 *volt* and producing 50 *cal/sec* heat are available with the resistances $55\,\Omega, 110\,\Omega, 220\,\Omega$ and $440\,\Omega$. The heater of maximum power will be of

[MP PMT 1985]

(a) $440\,\Omega$ (b) $220\,\Omega$
(c) $110\,\Omega$ (d) $55\,\Omega$

35. Which of the following statement is false

(a) Heat produced in a conductor is proportional to its resistance
(b) Heat produced in a conductor is proportional to the square of the current
(c) Heat produced in a conductor is proportional to charge
(d) Heat produced in a conductor is proportional to the time for which current is passed

36. On an electric heater 220 *volt* and 1100 *watt* are marked. On using it for 4 hours, the energy consumed in *kWh* will be

(a) 2 (b) 4.4
(c) 6 (d) 8

37. An electric heater kept in vacuum is heated continuously by passing electric current. Its temperature [MP PET 1993]

(a) Will go on rising with time
(b) Will stop after sometime as it will loose heat to the surroundings by conduction
(c) Will rise for sometime and there after will start falling
(d) Will become constant after sometime because of loss of heat due to radiation

38. Heat produced in a wire of resistance R due to current flowing at constant potential difference is proportional to

[MP PET 1993]

(a) $\frac{1}{R^2}$ (b) $\frac{1}{R}$
(c) R (d) R^2

39. The power rating of an electric motor which draws a current of 3.75 *amperes* when operated at 200 *V* is about

(a) 1 H.P. (b) 500 *W*
(c) 54 *W* (d) 750 H.P.

40. An electric bulb of 100 *watt* is connected to a supply of electricity of 220 *V*. Resistance of the filament is

[EAMCET 1981, 82; MP PMT 1993, 97]

(a) $484\,\Omega$ (b) $100\,\Omega$
(c) $22000\,\Omega$ (d) $242\,\Omega$

41. A cable of resistance $10\,\Omega$ carries electric power from a generator producing 250 *kW* at 10000 *volt*. The current in the cable is

(a) 25 *A* (b) 250 *A*
(c) 100 *A* (d) 1000 *A*

42. In the above question, the power lost in the cable during transmission is

(a) 12.5 *kW* (b) 6.25 *kW*
(c) 25 *kW* (d) 3.15 *kW*

43. The heat generated through 2 *ohm* and 8 *ohm* resistances separately, when a condenser of 200 μF capacity charged to 200 *V* is discharged one by one, will be [MP PET 1993]

(a) 4 *J* and 16 *J* respectively
(b) 16 *J* and 4 *J* respectively
(c) 4 *J* and 8 *J* respectively
(d) 4 *J* and 4 *J* respectively

44. Two bulbs are in parallel and they together consume 48 *W* from a battery of 6 *V*. The resistance of each bulb is

(a) $0.67\,\Omega$ (b) $3.0\,\Omega$
(c) $4.0\,\Omega$ (d) $1.5\,\Omega$

45. The heat developed in an electric wire of resistance *R* by a current *I* for a time *t* is [MP PMT 1993; MP PET 2005]

(a) $\frac{I^2Rt}{4.2} cal$ (b)
(c) $\frac{I^2R}{4.2\,t} cal$ (d) $\frac{Rt}{4.2\,I^2} cal$

46. Two bulbs, one of 50 *watt* and another of 25 *watt* are connected in series to the mains. The ratio of the currents through them is

(a) 2 : 1
(b) 1 : 2
(c) 1 : 1
(d) Without voltage, cannot be calculated

47. The brightness of a bulb will be reduced, if a resistance is connected in

(a) Series with it
(b) Parallel with it
(c) Series or parallel with it
(d) Brightness of the bulb cannot be reduced

48. A 100 *watt* bulb working on 200 *volt* and a 200 *watt* bulb working on 100 *volt* have

(a) Resistances in the ratio of 4 : 1
(b) Maximum current ratings in the ratio of $1:4$
(c) Resistances in the ratio of 2 : 1
(d) Maximum current ratings in the ratio of 1 : 2

49. There are two electric bulbs of 40 *W* and 100 *W*. Which one will be brighter when first connected in series and then in parallel,
(a) 40 *W* in series and 100 *W* in parallel
(b) 100 *W* in series and 40 *W* in parallel
(c) 40 *W* both in series and parallel will be uniform
(d) 100 *W* both in series and parallel will be uniform

50. Two resistances R_1 and R_2 when connected in series and parallel with 120 *V* line, power consumed will be 25 *W* and 100 *W* respectively. Then the ratio of power consumed by R_1 to that consumed by R_2 will be [EAMCET 1983]
(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 4

51. A 220 *volt* and 800 *watt* electric kettle and three 220 *volt* and 100 *watt* bulbs are connected in parallel. On connecting this combination with 220 *volt* electric supply, the total current will be
(a) 0.15 *ampere* (b) 5.0 *ampere*
(c) 5.5 *ampere* (d) 6.9 *ampere*

52. You are given three bulbs of 25, 40 and 60 *watt*. Which of them has lowest resistance [NCERT 1982]
(a) 25 *watt* bulb (b) 40 *watt* bulb
(c) 60 *watt* bulb (d) Information is insufficient

53. The value of internal resistance of an ideal cell is [EAMCET 1989]
(a) Zero (b) $0.5\,\Omega$
(c) $1\,\Omega$ (d) Infinity

54. Electric power is transmitted over long distances through conducting wires at high voltage because [MP PET 1994]
(a) High voltage travels faster
(b) Power loss is large
(c) Power loss is less
(d) Generator produced electrical energy at a very high voltage

55. A coil develops heat of 800 *cal/sec*. When 20 *volts* is applied across its ends. The resistance of the coil is (1 *cal* = 4.2 *joule*)
(a) $1.2\,\Omega$ (b) $1.4\,\Omega$
(c) $0.12\,\Omega$ (d) $0.14\,\Omega$

56. Resistances R_1 and R_2 are joined in parallel and a current is passed so that the amount of heat liberated is H_1 and H_2 respectively. The ratio $\frac{H_1}{H_2}$ has the value [MP PMT 1994]
(a) $\frac{R_2}{R_1}$ (b) $\frac{R_1}{R_2}$
(c) $\frac{R_1^2}{R_2^2}$ (d) $\frac{R_2^2}{R_1^2}$

57. The internal resistance of a primary cell is 4 *ohm*. It generates a current of 0.2 *amp* in an external resistance of 21 *ohm*. The rate at which chemical energy is consumed in providing the current is
(a) $0.42\,J/s$ (b) $0.84\,J/s$
(c) $5\,J/s$ (d) $1\,J/s$

58. A heating coil is labelled 100 *W*, 220 *V*. The coil is cut in half and the two pieces are joined in parallel to the same source. The energy now liberated per second is [CBSE PMT 1995]
(a) 200 *J* (b) 400 *J*
(c) 25 *J* [MP PET 1993] (d) 50 *J*

59. Which of the following is not a correct statement [MP PET 1995]
(a) Resistivity of electrolytes decreases on increasing temperature
(b) Resistance of mercury falls on decreasing its temperature
(c) When joined in series a 40 *W* bulb glows more than a 60 *W* bulb
(d) Resistance of 40 *W* bulb is less than the resistance of 60 *W* bulb

60. Three light bulbs of 40 *W*, 60 *W* and 100 *W* are connected in series with 220 *V* source. Which one of the bulbs will glow brightest[MP PMT 1995; UI
(a) 40 *W*
(b) 60 *W*
(c) 100 *W*
(d) All with the same brightness [MP PMT 1975]

61. The energy consumed in 1 *kilowatt* electric heater in 30 *seconds* will be
(a) $6\times10^2\ J$ (b) $4.99\times10^7\ J$
(c) $9.8\times10^6\ J$ (d) $3\times10^4\ J$

62. Two bulbs of 500 *watt* and 200 *watt* are manufactured to operate on 220 *volt* line. The ratio of heat produced in 500 *W* and 200 *W*, in two cases, when firstly they are joined in parallel and secondly in series, will be [MP PET 1996; DPMT 1999]
(a) $\frac{5}{2},\frac{2}{5}$ (b) $\frac{5}{2},\frac{5}{2}$
(c) $\frac{2}{5},\frac{5}{2}$ (d) $\frac{2}{5},\frac{2}{5}$

63. A 60 *watt* bulb carries a current of 0.5 *amp*. The total charge passing through it in 1 *hour* is [MP PMT 1996]
(a) 3600 *coulomb* (b) 3000 *coulomb*
(c) 2400 *coulomb* (d) 1800 *coulomb*

64. An electric heater of resistance 6 *ohm* is run for 10 *minutes* on a 120 *volt* line. The energy liberated in this period of time is [MP PET 1994]
(a) $7.2\times10^3\ J$ (b) $14.4\times10^5\ J$
(c) $43.2\times10^4\ J$ (d) $28.8\times10^4\ J$

65. Two bulbs are working in parallel order. Bulb *A* is brighter than bulb *B*. If R_A and R_B are their resistance respectively then
(a) $R_A > R_B$ (b) $R_A < R_B$
(c) $R_A = R_B$ (d) None of these

66. Two conductors made of the same material are connected across a common potential difference. Conductor *A* has twice the diameter and twice the length of conductor *B*. The power delivered to the two conductors P_A and P_B respectively is such that P_A/P_B equals to
(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0

67. A heating coil can heat the water of a vessel from $20°C$ to $60°C$ in 30 *minutes*. [MP PMT 1994] Two such heating coils are put in series and then used to heat the same amount of water through the same temperature range. The time taken now will be (neglecting thermal capacity of the coils) [MP PMT 1997]
(a) 60 *minutes* (b) 30 *minutes*
(c) 15 *minutes* (d) 7.5 *minutes*

68. If 2.2 *kilowatt* power is transmitted through a 10 *ohm* line at 22000 *volt*, the power loss in the form of heat will be [MP PMT/PET 1998]

(a) 0.1 *watt* (b) 1 *watt*
(c) 10 *watt* (d) 100 *watt*

69. Two resistors having equal resistances are joined in series and a current is passed through the combination. Neglect any variation in resistance as the temperature changes. In a given time interval

(a) Equal amounts of thermal energy must be produced in the resistors
(b) Unequal amounts of thermal energy may be produced
(c) The temperature must rise equally in the resistors
(d) The temperature must rise unequally in the resistors

70. A $5°C$ rise in temperature is observed in a conductor by passing a current. When the current is doubled the rise in temperature will be approximately [CBSE PMT 1998]

(a) $16°C$ (b) $10°C$
(c) $20°C$ (d) $12°C$

71. *Watt-hour* meter measures [KCET 1994]

(a) Electric energy (b) Current
(c) Voltage (d) Power

72. An electric lamp is marked 60 *W*, 230 *V*. The cost of 1 *kilowatt* hour of power is *Rs.* 1.25. The cost of using this lamp for 8 hours is

(a) *Rs.* 1.20 (b) *Rs.* 4.00
(c) *Rs.* 0.25 (d) *Rs.* 0.60

73. 4 bulbs marked 40 *W*, 250 *V* are connected in series with 250 *V* mains. The total power is [EAMCET (Engg.) 1995]

(a) 10 *W* (b) 40 *W*
(c) 320 *W* (d) 160 *W*

74. Pick out the wrong statement [AMU 1995]

(a) In a simple battery circuit, the point of lowest potential is the negative terminal of the battery
(b) The resistance of an incandescent lamp is greater when the lamp is switched off
(c) An ordinary 100 *W* lamp has less resistance than a 60 *W* lamp
(d) At constant voltage, the heat developed in a uniform wire varies inversely as the length of the wire used

75. Two resistors of $6\,\Omega$ and 9Ω are connected in series to a 120 *volt* source. The power consumed by the $6\,\Omega$ resistor is [SCRA 1994]

(a) 384 *W* (b) 576 *W*
(c) 1500 *W* (d) 1200 *W*

76. Electric room radiator which operates at 225 *volts* has resistance of 50 *ohms*. Power of the radiator is approximately

(a) 100 *W* (b) 450 *W*
(c) 750 *W* (d) 1000 *W*

77. If a power of 100 *W* is being supplied across a potential difference of 200 *V*, current flowing is [AFMC 1993]

(a) 2 *A* (b) 0.5 *A*
(c) 1 *A* (d) 20 *A*

78. A current of 2 *A* passing through conductor produces 80 *J* of heat in 10 *seconds*. The resistance of the conductor is [CBSE PMT 1993]

(a) $0.5\,\Omega$ (b) $2\,\Omega$
(c) $4\,\Omega$ (d) $20\,\Omega$

79. A $4\mu F$ conductor is charged to 400 *volts* and then its plates are joined through a resistance of $1k\Omega$. The heat produced in the resistance is [CBSE PMT 1994]

(a) 0.16 *J* (b) 1.28 *J*
(c) 0.64 *J* (d) 0.32 *J*

80. A 10 *ohm* electric heater operates on a 110 *V* line. Calculate the rate at which it develops heat in watts [MP PMT 1999] [AFMC 1997]

(a) 1310 *W* (b) 670 *W*
(c) 810 *W* (d) 1210 *W*

81. A (100 *W*, 200 *V*) bulb is connected to a 160 *V* power supply. The power consumption would be [CBSE PMT 1997; JIPMER 2000]

(a) 64 *W* (b) 80 *W*
(c) 100 *W* (d) 125 *W*

82. A battery of e.m.f. 10 *V* and internal resistance 0.5 *ohm* is connected across a variable resistance *R*. The value of *R* for which the power delivered in it is maximum is given by [BHU 1998; JIPMER 2001, 02; CBSE PMT 2001]

(a) 2.0 *ohm* (b) 0.25 *ohm*
(c) 1.0 *ohm* (d) 0.5 *ohm*

83. A piece of fuse wire melts when a current of 15 *ampere* flows through it. With this current, if it dissipates 22.5 *W*, the resistance of fuse wire will be [KCET 1994] [MNR 1998]

(a) Zero (b) $10\,\Omega$
(c) 1Ω (d) $0.10\,\Omega$

84. Two wires '*A*' and '*B*' of the same material have their lengths in the ratio 1 : 2 and radii in the ratio 2 : 1. The two wires are connected in parallel across a battery. The ratio of the heat produced in '*A*' to the heat produced in '*B*' for the same time is

(a) $1:2$ (b) $2:1$
(c) $1:8$ (d) $8:1$

85. A heater draws a current of 2*A* when connected to a 250 *V* source. The rate of energy dissipation is [JIPMER 1999]

(a) 500 *W* (b) 1000 *W*
(c) 250 *W* (d) 125 *W*

86. A bulb rated at (100 *W* – 200 *V*) is used on a 100 *V* line. The current in the bulb is [JIPMER 1999]

(a) $\frac{1}{4}$ *amp* (b) 4 *amp*
(c) $\frac{1}{2}$ *amp* [SCRA 1994] (d) 2 *amp*

87. A steel wire has a resistance twice that of an aluminium wire. Both of them are connected with a constant voltage supply. More heat will be dissipated in [Roorkee 1999]

(a) Steel wire when both are connected in series
(b) Steel wire when both are connected in parallel
(c) Aluminium wire when both are connected in series
(d) Aluminium wire when both are connected in parallel

88. A current *i* passes through a wire of length *l*, radius of cross-section *r* and resistivity ρ. The rate of heat generation is [AMU (Med.) 1999]

(a) $\frac{i^2 l\rho}{\pi r^2}$ (b) $i^2\left(\frac{l\rho}{\pi r^2}\right)^2$

(c) $i^2 l\rho / r$ (d) $il\rho / r$

89. Which of the following is not equal to *watt* [DPMT 1999]

(a) $(Amp)^2 \times ohm$ (b) *Amp / Volt*

(c) *Amp* × *Volt* (d) *Joule / sec*

90. Two wires with resistances R and $2R$ are connected in parallel, the ratio of heat generated in $2R$ and R is

[DCE 1999, 2000]

(a) 1 : 2 (b) 2 : 1

(c) 1 : 4 (d) 4 : 1

91. If a high power heater is connected to electric mains, then the bulbs in the house become dim, because there is a

[BHU 1999; Pb. PMT 2000]

(a) Current drop (b) Potential drop

(c) No current drop (d) No potential drop

92. If three bulbs 60 *W*, 100 *W* and 200 *W* are connected in parallel, then

(a) 200 *W* bulb will glow more

(b) 60 *W* bulb will glow more

(c) 100 *W* bulb will glow more

(d) All the bulbs will glow equally

93. An expression for rate of heat generated, if a current of *I* ampere flows through a resistance of $R\,\Omega$, is [Pb. PMT 2000]

(a) $I^2 Rt$ (b) $I^2 R$

(c) $V^2 R$ (d) $I\,R$

94. On giving 220 *V* to a resistor the power dissipated is 40 *W* then value of resistance is [RPMT 2000]

(a) 1210 Ω (b) 2000 Ω

(c) 1000 Ω (d) None of these

95. A 60 *watt* bulb operates on 220 *V* supply. The current flowing through the bulb is [MP PMT 2000]

(a) 11/3 *amp* (b) 3/11 *amp*

(c) 3 *amp* (d) 6 *amp*

96. If two bulbs of wattage 25 and 30, each rated at 220 *volts*, are connected in series with a 440 *volt* supply, which bulb will fuse

[MP PET 2000]

(a) 25 *W* bulb (b) 30 *W* bulb

(c) Neither of them (d) Both of them

97. Two electric bulbs (60 *W* and 100 *W* respectively) are connected in series. The current passing through them is

[AMU (Med.) 2000]

(a) More in 100 *W* bulb (b) More in 60 *W* bulb

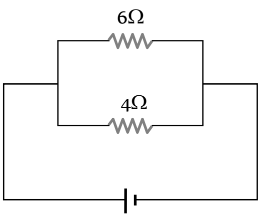
(c) Same in both (d) None of these

98. In the circuit shown below, the power developed in the 6Ω resistor is 6 watt. The power in watts developed in the 4Ω resistor is

(a) 16

(b) 9

(c) 6



(d) 4

99. Two wires *A* and *B* of same material and mass have their lengths in the ratio 1 : 2. On connecting them to the same source, the rate of heat dissipation in *B* is found to be 5 *W*. The rate of heat dissipation in *A* is [AMU (Engg.) 2000]

(a) 10 *W* (b) 5 *W*

(c) 20 *W* (d) None of these

100. If two electric bulbs have 40 *W* and 60 *W* rating at $220V$, then the ratio of their resistances will be

[BHU 1999; KCET 2001]

(a) 3 : 2 (b) 2 : 3

(c) 3 : 4 (d) 4 : 3

101. An electric bulb is designed to draw power P_0 at voltage V_0. If the voltage is *V* it draws a power *P*. Then [KCET 2001]

(a) $P = \left(\frac{V_0}{V}\right)^2 P_0$ (b) $P = \left(\frac{V}{V_0}\right)^2 P_0$

[BHU 2000]

(c) $P = \left(\frac{V}{V_0}\right) P_0$ (d) $P = \left(\frac{V_0}{V}\right) P_0$

102. Three bulbs of 40 *W*, 60 *W* and 100 *W* are arranged in series with 220 *V*. Which bulb has minimum resistance

[AFMC 2001]

(a) 40 *W* (b) 60 *W*

(c) 100 *W* (d) Equal in all bulbs

103. An electric kettle has two heating coils. When one coil is used, water in the kettle boils in 5 minutes, while when second coil is used, same water boils in 10 minutes. If the two coils, connected in parallel are used simultaneously, the same water will boil in time

(a) 3 *min* 20 *sec* (b) 5 *min*

(c) 7 *min* 30 *sec* (d) 2 *min* 30 *sec*

104. An external resistance *R* is connected to a battery of e.m.f. *V* and internal resistance *r*. The joule heat produced in resistor *R* is maximum when *R* is equal to [MP PET 2001]

(a) r (b) $\frac{r}{2}$

(c) $2r$ (d) Infinitely large

105. The amount of heat produced in a resistor when a current is passed through it can be found using [Kerala PET 2001]

(a) Faraday's Law (b) Kirchhoff's Law

(c) Laplace's Law (d) Joule's Law

106. Two wires have resistance of 2Ω and 4Ω connected to same voltage, ratio of heat dissipated at resistance is

[UPSEAT 2001]

(a) 1 : 2 (b) 4 : 3

(c) 2 : 1 (d) 5 : 2

[AMU (Med.) 2000]

107. Two electric bulbs rated P_1 watt *V* volts and P_2 watt *V* volts are connected in parallel and *V* volts are applied to it. The total power will be [MP PMT 2001; MP PET 2002]

(a) $P_1 + P_2 watt$ (b) $\sqrt{P_1 P_2}$ watt

(c) $\frac{P_1 P_2}{P_1 + P_2} watt$ (d) $\frac{P_1 + P_2}{P_1 P_2} watt$

108. n identical bulbs, each designed to draw a power p from a certain voltage supply, are joined in series across that supply. The total power which they will draw is [KCET 2002]

(a) p/n^2 (b) p/n

(c) p (d) np

109. A wire when connected to 220 V mains supply has power dissipation P_1. Now the wire is cut into two equal pieces which are connected in parallel to the same supply. Power dissipation in this case is P_2. Then $P_2 : P_1$ is [AIEEE 2002]

(a) 1 (b) 4

(c) 2 (d) 3

110. An electric bulb marked 40 W and 200 V, is used in a circuit of supply voltage 100 V. Now its power is [AIIMS 2002]

(a) 100 W (b) 40 W

(c) 20 W (d) 10 W

111. Electric bulb 50 W-100 V glowing at full power are to be used in parallel with battery 120 V, 10 Ω. Maximum number of bulbs that can be connected so that they glow in full power is

(a) 2 (b) 8

(c) 4 (d) 6

112. A bulb has specification of one kilowatt and 250 *volts*, the resistance of bulb is [MP PMT 2002]

(a) 125 Ω (b) 62.5 Ω

(c) 0.25 Ω (d) 625 Ω

113. If a 30 V, 90 W bulb is to be worked on a 120 V line, a resistance of how many ohms should be connected in series with the bulb [MP PMT 2002; KCET 2003]

(a) 10 *ohm* (b) 20 *ohm*

(c) 30 *ohm* (d) 40 *ohm*

114. A fuse wire with radius 1 *mm* blows at 1.5 *amp*. The radius of the fuse wire of the same material to blow at 3A will be [KCET 2003]

(a) $4^{1/3} mm$ (b) $3^{1/4} mm$

(c) $2^{1/2} mm$ (d) $3^{1/2} mm$

115. Three electric bulbs of rating 60 W each are joined in series and then connected to electric mains. The power consumed by these three bulbs will be [MP PET 2003; CBSE PMT 2004]

(a) 180 W (b) 60 W

(c) 20 W (d) $\frac{20}{3} W$

116. An electric bulb is rated 60 W, 220 V. The resistance of its filament is [MP PET 2003]

(a) 708 Ω (b) 870 Ω

(c) 807 Ω (d) 780 Ω

117. A 220 *volt*, 1000 W bulb is connected across a 110 volt mains supply. The power consumed will be [AIEEE 2003]

(a) 1000 W (b) 750 W

(c) 500 W (d) 250 W

118. Two bulbs of 100 W and 200 W working at 220 *volt* are joined in series with 220 *volt* supply. Total power consumed will be approximately. [Pb. PET 2003; BHU 2005]

(a) 65 *watt* (b) 33 *watt*

(c) 300 *watt* (d) 100 *watt*

119. How many calories of heat will be produced approximately in a 210 *watt* electric bulb in 5 minutes [Pb. PET 2004]

(a) 80000 *cal* (b) 63000 *cal*

(c) 1050 *cal* (d) 15000 *cal*

120. A $5^o C$ rise in the temperature is observed in a conductor by passing some current. When the current is doubled, then rise in temperature will be equal to [BHU 2004]

(a) $5^o C$ (b) $10^o C$

(c) $20^o C$ (d) $40^o C$

121. If a 2 kW boiler is used everyday for 1 hour, then electrical energy consumed by boiler in thirty days is [BHU 2004]

(a) 15 unit (b) 60 unit

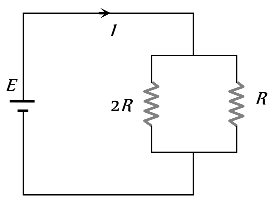
(c) 120 unit (d) 240 unit

122. What will happen when a 40 *watt*, 220 *volt* lamp and 100 *watt*, 220 *volt* lamp are connected in series across 40 *volt* supply [CPMT 2002]

(a) 100 *watt* lamp will fuse (b) 40 *watt* lamp will fuse

(c) Both lamps will fuse (d) Neither lamp will fuse

123. What is the ratio of heat generated in R and $2R$ [DCE 2003]



(a) 2 : 1

(b) 1 : 2

(c) 4 : 1

(d) 1 : 4

124. In an electric heater 4 *amp* current passes for 1 *minute* at potential difference of 250 *volt*, the power of heater and energy consumed will be respectively [DPMT 2003]

(a) 1 kW, 60 kJ (b) 0.5 kW, 30 kJ

(c) 10 kW, 600 kJ (d) None of these

125. Some electric bulbs are connected in series across a 220 V supply in a room. If one bulb is fused then remaining bulbs are connected again in series across the same supply. The illumination in the room will [J & K CET 2004]

(a) Increase (b) Decrease

(c) Remains the same (d) Not continuous

126. The resistor of resistance 'R' is connected to 25 V supply and heat produced in it is 25 J/sec. The value of R is [Orissa PMT 2004]

(a) 225Ω (b) 1Ω

(c) 25Ω (d) 50Ω

127. Three bulbs of 40 W, 60 W, 100 W are arranged in series with 220 *volt* supply which bulb has minimum resistance [Pb. PET 2000]

(a) 100 W (b) 40 W

(c) 60 W (d) Equal in all bulbs

128. If two electric bulbs have 40 W and 60 W rating at 220 V, then the ratio of their resistances will be [Pb. PET 2001]

(a) 9 : 4 (b) 4 : 3

(c) 3 : 8 (d) 3 : 2

129. A 10 V storage battery of negligible internal resistance is connected across a $50\,\Omega$ resistor. How much heat energy is produced in the resistor in 1 hour [Pb. PET 2001]

(a) 7200 J (b) 6200 J

(c) 5200 J (d) 4200 J

130. A hot electric iron has a resistance of $80\,\Omega$ and is used on a 200 V source. The electrical energy spent, if it is used for two hours, will be [Pb. PET 2002]

(a) 8000 Wh (b) 2000 Wh

(c) 1000 Wh (d) 800 Wh

131. The heat produced by a 100 *watt* heater in 2 minute will be equal to [BCECE 2004]

(a) $12\times10^3\ J$ (b) $10\times10^3\ J$

(c) $6\times10^3\ J$ (d) $3\times10^3\ J$

132. If two wires having resistance R and $2R$. Both joined in series and in parallel then ratio of heat generated in this situation, applying the same voltage, [BCECE 2004]

(a) 2 : 1 (b) 1 : 2

(c) 2 : 9 (d) 9 : 2

133. Two electric bulbs A and B are rated as 60 W and 100 W. They are connected in parallel to the same source. Then, [KCET 2004]

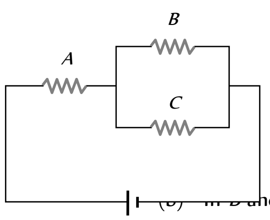
(a) Both draw the same current

(b) A draws more current than B

(c) B draws more current than A

(d) Current drawn are in the ratio of their resistances

134. Three identical resistances A, B and C are connected as shown in the given figure. The heat produced will be maximum



(a) In B (b) In B and C

(c) In A (d) Same for A, B and C

135. If $2.2\,kW$ power is transmitted through a 100Ω line at $22{,}000V$, the power loss in the form of heat will be [MP PET 2004]

(a) 0.1 W (b) 1 W

(c) 10 W (d) 100 W

136. A heater coil connected to a supply of a 220 V is dissipating some power P_1. The coil is cut into half and the two halves are connected in parallel. The heater now dissipates a power P_2. The ratio of power $P_1 : P_2$ is [AFMC 2004]

(a) 2 : 1 (b) 1 : 2

(c) 1 : 4 (d) 4 : 1

137. An electric lamp is marked 60 W, 230 V. The cost of a 1 kWh of energy is *Rs.* 1.25. The cost of using this lamp 8 *hrs* a day for 30 day is [Kerala (Med.) 2002]

(a) *Rs.* 10 (b) *Rs.* 16

(c) *Rs.* 18 (d) *Rs.* 20

138. An electric iron draws 5 *amp*, a TV set draws 3 *amp* and refrigerator draws 2 *amp* from a 220 *volt* main line. The three appliances are connected in parallel. If all the three are operating at the same time, the fuse used may be of [ISM Dhanbad 1994]

(a) 20 *amp* (b) 5 *amp*

(c) 15 *amp* (d) 10 *amp*

139. Match the List I with the List II from the combination shown. In the left side (List I) there are four different conditions and in the right side (List II), there are ratios of heat produced in each resistance for each condition : [ISM Dhanbad 1994]

	List I	List II
(I)	Two wires of same resistance are connected in series and same current is passed through them	(A) 1 : 2
(II)	Two wires of resistance R and $2R$ *ohm* are connected in series and same P.D. is applied across them	(B) 4 : 1
(III)	Two wires of same resistance are connected in parallel and same current is flowing through them	(C) 1 : 1
(IV)	Two wires of resistances in the ratio 1 : 2 are connected in parallel and same P.D. is applied across them	(D) 2 : 1

(a) $I-B; II-A; III-C; IV-D$

(b) $I-C; II-D; III-C; IV-D$

(c) $I-B; II-D; III-A; IV-C$

[MP PMT 2004]

(d) $I-A; II-B; III-D; IV-C$

140. The electric current passing through a metallic wire produces heat because of [BHU 1994]

(a) Collisions of conduction electrons with each other

(b) Collisions of the atoms of the metal with each other

(c) The energy released in the ionization of the atoms of the metal

(d) Collisions of the conduction electrons with the atoms of the metallic wires

141. The maximum current that flows through a fuse wire before it blows out varies with its radius as [SCRA 1998]

(a) $r^{3/2}$ (b) r

(c) $r^{2/3}$ (d) $r^{1/2}$

142. What is immaterial for an electric fuse wire [UPSEAT 1999]

(a) Specific resistance of the wire

(b) Radius of the wire

(c) Length of the wire

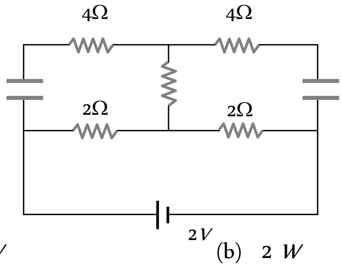
(d) Current flowing through the wire

143. The current flowing through a lamp marked as 50 W and 250 V is

(a) 5 *amp* (b) 2.5 *amp*

(c) 2 *amp* (d) 0.2 *amp*

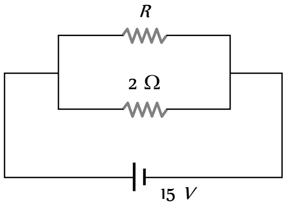
144. Find the power of the circuit [AIEEE 2002]



(a) 1.5 *W* (b) 2 *W*

(c) 1 *W* (d) None of these

145. If in the circuit, power dissipation is 150 *W*, then *R* is [AIEEE 2002]



(a) 2 Ω (b) 6 Ω

(c) 5 Ω (d) 4 Ω

146. Two resistors whose value are in ratio 2 : 1 are connected in parallel with one cell. Then ratio of power dissipated is [RPMT 2000]

(a) 2 : 1 (b) 4 : 1

(c) 1 : 2 (d) 1 : 1

147. A heater coil is cut into two equal parts and only one part is now used in the heater. The heat generated will now be [AIEEE 2005]

(a) One fourth (b) Halved

(c) Doubled (d) Four times

148. The resistance of hot tungsten filament is about 10 times the cold resistance. What will be the resistance of 100 *W* and 200 *V* lamp when not in use [AIEEE 2005]

(a) 400 Ω (b) 200 Ω

(c) 40 Ω (d) 20 Ω

149. A 5.0 *amp* current is setup in an external circuit by a 6.0 *volt* storage battery for 6.0 minutes. The chemical energy of the battery is reduced by [KCET 2005]

(a) 1.08×10^4 *J* (b) 1.08×10^4 *volt*

(c) 1.8×10^4 *J* (d) 1.8×10^4 *volt*

150. A railway compartment is lit up by thirteen lamps each taking 2.1 amp at 15 volts. The heat generated per second in each lamp will be

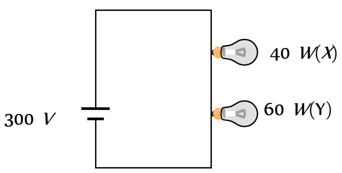
(a) 4.35 *cal* (b) 5.73 *cal*

(c) 7.5 *cal* (d) 2.5 *cal*

151. Two bulbs *X* and *Y* having same voltage rating and of power 40 watt and 60 watt respectively are connected in series across a potential difference of 300 volt, then [Orissa JEE 2005]

(a) *X* will glow brighter

(b) Resistance of *Y* is greater than *X*



(c) Heat produced in *Y* will be greater than *X*

(d) Voltage drop in *X* will be greater than *Y*

152. 3 identical bulbs are connected in series and these together dissipate a power *P*. If now the bulbs are connected in parallel, then the power dissipated will be [DPMT 2005]

(a) $\frac{P}{3}$ (b) $3P$

(c) $9P$ (d) $\frac{P}{9}$

153. A coil takes 15 *min* to boil a certain amount of water, another coil takes 20 *min* for the same process. Time taken to boil the same amount of water when both coil are connected in series

(a) 5 *min* (b) 8.6 *min*

(c) 35 *min* (d) 30 *min*

Chemical Effect of Current

1. Water can not be made conducting by adding small amount of any of the following except

(a) Sodium chloride (b) Copper sulphate

(c) Ammonium chloride (d) Sugar

2. The electrochemical equivalent Z of any element can be obtained by multiplying the electrochemical equivalent of hydrogen with

(a) Atomic weight (b) Molecular weight

(c) Chemical equivalent (d) A constant

3. A silver and zinc voltameter are connected in series and a current *i* is passed through them for a time *t* liberating *W gm* of zinc. The weight of silver deposited is nearly [NCERT 1973, 76]

(a) *W* (b) 1.7 *W*

(c) 2.4 *W* (d) 3.5 *W*

4. To deposit one gm equivalent of an element at an electrode, the quantity of electricity needed is [IIT 1984; DPMT 1982; MP PET 1998; MP PMT 1998; 2003]

(a) One *ampere* (b) 96000 *amperes*

(c) 96500 *farads* (d) 96500 *coulombs*

5. In an electrolysis experiment, a current *i* passes through two different cells in series, one containing a solution of $CuSO_4$ and the other a solution of $AgNO_3$. The rate of increase of the weight of the cathodes in the two cells will be [NCERT 1972] [J & K CET 2005]

(a) In the ratio of the densities of *Cu* and *Ag*

(b) In the ratio of the at. weights of *Cu* and *Ag*

(c) In the ratio of half the atomic weight of *Cu* to the atomic weight of *Ag*

(d) In the ratio of half the atomic weight of *Cu* to half the atomic weight of *Ag*

6. To deposit one litre of hydrogen at 22.4 atmosphere from acidulaled water, the quantity of electricity that must pass through is

(a) 1 *coulomb* (b) 22.4 *coulomb*

(c) 96500 *coulomb* (d) 193000 *coulomb*

7. The amount of substance liberated on electrodes during electrolysis when 1 coulomb of electricity is passed, is

(a) Chemical equivalent
(b) Electrochemical equivalent
(c) Equivalent weight
(d) One mol

8. For goldplating on a copper chain, the substance required in the form of solution is

(a) Copper sulphate
(b) Copper chloride
(c) Potassium cyanide
(d) Potassium aurocyanide

9. On passing the current in water voltameter, the hydrogen

(a) Liberated at anode (b) Liberated at cathode
(c) Does not liberate (d) Remains in the solution

10. In water voltameter, the electrolysis of ...... takes place [DPMT 1999]

(a) H_2O (b) H_2SO_4
(c) H_2O and H_2SO_4 both (d) H_2 and O_2

11. For depositing 1 *gm* of *Cu* in copper voltameter on passing 2 *amperes* of current, the time required will be (For copper Z = 0.00033 *gm/C*)

(a) Approx. 20 *minutes* (b) Approx. 25 *minutes*
(c) Approx. 30 *minutes* (d) Approx. 35 *minutes*

12. A battery of e.m.f. 3 volt and internal resistance 1.0 *ohm* is connected in series with copper voltameter. The current flowing in the circuit is 1.5 amperes. The resistance of voltameter will be

(a) Zero (b) 1.0 *ohm*
(c) 1.5 *ohm* (d) 2.0 *ohm*

13. According to Faraday's laws of electrolysis, the amount of decomposition is proportional to [MP PMT 1993]

(a) $\frac{1}{\text{Time for which curent passes}}$
(b) Electrochemical equivalent of the substance
(c) $\frac{1}{\text{Current}}$
(d) $\frac{1}{\text{Electrochemical equivalent}}$

14. If in a voltaic cell 5 gm of zinc is consumed, then we get how many ampere hours ? (Given that E.C.E. of *Zn* is 3.387×10^{-7} *kg/coulomb*)

(a) 2.05 (b) 8.2
(c) 4.1 (d) $5\times3.387\times10^{-7}$

15. The current flowing in a copper voltameter is 1.6 *A*. The number of Cu^{++} ions deposited at the cathode per minute are

(a) 1.5×10^{20} (b) 3×10^{20}
(c) 6×10^{20} (d) 1×10^{19}

16. In a copper voltameter experiment, current is decreased to one-fourth of the initial value but it is passed for four times the earlier duration. Amount of copper deposited will be [MP PMT 1993]

(a) Same
(b) One-fourth the previous value
(c) Four times the previous value
(d) $\frac{1}{16}th$ of the previous value

17. A certain charge liberates 0.8 *gm* of O_2. The same charge will liberate how many gm of silver [MP PET 1999]

(a) 108 *gm* (b) 10.8 *gm*
(c) 0.8 *gm* (d) $\frac{108}{0.8}gm$

18. In charging a battery of motor-car, the following effect of electric current is used [MP PET 1993; AFMC 2003]

(a) Magnetic (b) Heating
(c) Chemical (d) Induction

19. The Avogadro's number is 6×10^{23} per gm mole and electronic charge is $1.6\times10^{-19}\,C$. The Faraday's number is [DPMT 2001]

(a) $6\times10^{23}\times1.6\times10^{-19}$ (b) $\frac{6\times10^{23}}{1.6\times10^{-19}}$
(c) $\frac{2}{6\times10^{23}\times1.6\times10^{-19}}$ (d) $\frac{1.6\times10^{-19}}{6\times10^{23}}$

20. In $CuSO_4$ solution when electric current equal to 2.5 *faraday* is passed, the gm equivalent deposited on the cathode is

(a) 1 (b) 1.5
(c) 2 (d) 2.5

21. The atomic weight of silver and copper are 108 and 64. A silver voltameter and a copper voltameter are connected in series and when current is passed 10.8 *gm* of silver is deposited. The mass of copper deposited will be

(a) 6.4 *gm* (b) 12.8 *gm*
(c) 3.2 *gm* (d) 10.8 *gm*

22. Faraday's laws of electrolysis are related to [IIT 1983]

(a) The atomic number of positive ion
(b) The equivalent weight of electrolyte
(c) The atomic number of negative ion
(d) The velocity of positive ion

23. In the process of electrolysis, the current is carried out inside the electrolyte by [AMU (Engg.) 1999]

(a) Electrons
(b) Atoms
(c) Positive and negative ions
(d) All the above

24. The mass of ions deposited during a given interval of time in the process of electrolysis depends on [DPMT 2002]

(a) The current (b) The resistance
(c) The temperature (d) The electric power

25. The amount of charge required to liberate 9 *gm* of aluminium (atomic weight = 27 and valency = 3) in the process of electrolysis is (Faraday's number = 96500 *coulombs/gm* equivalent) [MP PMT 1994; MP PET 2000]

(a) 321660 *coulombs* (b) 69500 *coulombs*
(c) 289500 *coulombs* (d) 96500 *coulombs*

26. In an electroplating experiment, *m gm* of silver is deposited when 4 *ampere* of current flows for 2 *minute*. The amount (in *gm*) of silver deposited by 6 *ampere* of current for 40 *second* will be [MNR 1991; UPSEAT 200

Pb. PET 2004; Orissa JEE 2005]

(a) 4 m (b) $m/2$

(c) $m/4$ (d) 2 m

27. In electrolysis, if the duration of the passage of current is doubled, the mass liberated is [EAMCET 1979]

(a) Doubled (b) Halved

(c) Increased four times (d) Remains the same

28. A current of 16 *ampere* flows through molten $NaCl$ for 10 *minute*. The amount of metallic sodium that appears at the negative electrode would be [EAMCET 1984]

(a) 0.23 *gm* (b) 1.15 *gm*

(c) 2.3 *gm* (d) 11.5 *gm*

29. The mass of a substance liberated when a charge 'q' flows through an electrolyte is proportional to [EAMCET 1984]

(a) q (b) $1/q$

(c) q^2 (d) $1/q^2$

30. A steady current of 5 *amps* is maintained for 45 *mins*. During this time it deposits 4.572 *gms* of zinc at the cathode of a voltameter. E.C.E. of zinc is [MP PET 1994]

(a) $3.387 \times 10^{-4}\, gm/C$ (b) $3.387 \times 10^{-4}\, C/gm$

(c) $3.384 \times 10^{-3}\, gm/C$ (d) $3.394 \times 10^{-3}\, C/gm$

31. The relation between faraday constant F, electron charge e and avogadro number N is [MP PET 1995]

(a) $F = N/e$ (b) $F = Ne$

(c) $N = F^2$ (d) $F = N^2e$

32. The electrochemical equivalent of magnesium is $0.126\, mg/C$. A current of 5 A is passed in a suitable solution for 1 *hour*. The mass of magnesium deposited will be

(a) 0.0378 *gm* (b) 0.227 *gm*

(c) 0.378 *gm* (d) 2.27 *gm*

33. Two electrolytic cells containing $CuSO_4$ and $AgNO_3$ respectively are connected in series and a current is passed through them until 1 *mg* of copper is deposited in the first cell. The amount of silver deposited in the second cell during this time is approximately

[Atomic weights of copper and silver are respectively 63.57 and 107.88] [MP PMT 1996]

(a) 1.7 *mg* (b) 3.4 *mg*

(c) 5.1 *mg* (d) 6.8 *mg*

34. A current I is passed for a time t through a number of voltameters. If m is the mass of a substance deposited on an electrode and z is its electrochemical equivalent, then

[MP PMT 1997]

(a) $\frac{zIt}{m} = \text{constant}$ (b) $\frac{z}{mIt} = \text{constant}$

(c) $\frac{I}{zmt} = \text{constant}$ (d) $\frac{It}{zm} = \text{constant}$

35. For electroplating a spoon, it is placed in the voltameter at

[MP PMT/PET 1998]

(a) The position of anode

(b) The position of cathode

(c) Exactly in the middle of anode and the cathode

(d) Anywhere in the electrolyte

36. If nearly 10^5 *coulomb* liberate 1 *gm* equivalent of aluminium, then the amount of aluminium (equivalent weight 9) deposited through electrolysis in 20 minutes by a current of 50 *amp* will be

(a) 0.6 *gm* (b) 0.09 *gm*

(c) 5.4 *gm* (d) 10.8 *gm*

37. Electroplating does not help in [AIIMS 1998]

(a) Fine finish to the surface

(b) Shining appearance

(c) Metals to become hard

(d) Protect metal against corrosion

38. When a current is passed through water, acidified with a dilute sulphuric acid, the gases formed at the platinum electrodes are

(a) 1 vol. hydrogen (cathode) and 2 vol. oxygen (anode)

(b) 2 vol. hydrogen (cathode) and 1 vol. oxygen (anode)

(c) 1 vol. hydrogen (cathode) and 1 vol. oxygen (anode)

(d) 1 vol. oxygen (cathode) and 2 vol. hydrogen (anode)

39. The negative Zn pole of a Daniel cell, sending a constant current through a circuit, decreases in mass by 0.13*g* in 30 *minutes*. If the electrochemical equivalent of Zn and Cu are 32.5 and 31.5 respectively, the increase in the mass of the positive Cu pole in this time is [AIEEE 2003]

(a) 0.242 *g* (b) 0.190 *g*

(c) 0.141 *g* (d) 0.126 *g*

40. When a copper voltameter is connected with a battery of e.m.f. 12 *volts*. 2 *gms* of copper is deposited in 30 *minutes*. If the same voltameter is connected across a 6 volt battery, then the mass of copper deposited in 45 minutes would be

[SCRA 1994]

(a) 1 *gm* (b) 1.5 *gm*

(c) 2 *gm* (d 2.5 *gm*

[MP PMT 1995]

41. The value of current required to deposit 0.972 *gm* of chromium in 3 *hours* if the E.C.E. of chromium is 0.00018 *gm* per coulomb, is

(a) 1 *amp* (b) 1.5 *amp*

(c) 0.5 *amp* (d) 2 *amp*

42. The current inside a copper voltameter [Roorkee 1992]

(a) Is half the outside value

(b) Is the same as the outside value

(c) Is twice the outside value

(d) Depends on the concentration of $CuSO_4$

43. The resistance of a cell does not depend on [RPET 1996]

(a) Current drawn from the cell

(b) Temperature of electrolyte

(c) Concentration of electrolyte

(d) The e.m.f. of the cell

44. The electrochemical equivalent of a metal is $3.3 \times 10^{-7}\, kg/coulomb$. The mass of the metal liberated at the cathode when a 3 A current is passed for 2 seconds will be

(a) $19.8 \times 10^{-7}\, kg$ (b) $9.39 \times 10^{-7}\, kg$

(c) $6.6 \times 10^{-7}\, kg$ (d) $1.1 \times 10^{-7}\, kg$

45. Faraday's 2nd law states that mass deposited on the electrode is directly proportional to [DCE 1999]

(a) Atomic mass (b) Atomic mass × Velocity

(c) Atomic mass/Valency (d) Valency

46. The relation between Faraday constant (F), chemical equivalent (E) and electrochemical equivalent (Z) is [SCRA 1994; AFMC 2000]

(a) $F = EZ$ (b) $F = \frac{Z}{E}$

(c) $F = \frac{E}{Z}$ (d) $F = \frac{E}{Z^2}$

47. The electrochemical equivalent of a material in an electrolyte depends on [MP PET 2001]

(a) The nature of the material

(b) The current through the electrolyte

(c) The amount of charge passed through electrolyte

(d) The amount of material present in electrolyte

48. On passing 96500 *coulomb* of charge through a solution $CuSO_4$ the amount of copper liberated is [MP PMT 2001]

(a) 64 *gm* (b) 32 *gm*

(c) 32 *kg* (d) 64 *kg*

49. If 96500 *coulombs* of electricity liberates one gram equivalent of any substance, the time taken for a current of 0.15 *amperes* to deposite 20*mg* of copper from a solution of copper sulphate is (Chemical equivalent of copper = 32)

[Kerala (Engg.) 2002]

(a) 5 *min* 20 *sec* (b) 6 *min* 42 *sec*

(c) 4 *min* 40 *sec* (d) 5 *min* 50 *sec*

50. How much current should be passed through acidified water for 100 *s* to liberate 0.224 *litre* of H_2 [DCE 2002]

(a) 22.4 *A* (b) 19.3 *A*

(c) 9.65 *A* (d) 1 *A*

51. Who among the following scientists made the statement –"Chemical change can produce electricity" [DCE 2004]

(a) Galvani (b) Faraday

(c) Coulomb (d) Thomson

52. If a steady current of 4 *amp* maintained for 40 *minutes,* deposits 4.5 *gm* of zinc at the cathode and then the electro chemical equivalent will be [MH CET 2003]

(a) $51 \times 10^{-17}\ gm/C$ (b) $28 \times 10^{-6}\ gm/C$

(c) $32 \times 10^{-5}\ gm/C$ (d) $47 \times 10^{-5}\ gm/C$

53. The current flowing in a copper voltameter is 3.2 *A*. The number of copper ions (Cu^{2+}) deposited at the cathode per minute is

(a) 0.5×10^{20} (b) 1.5×10^{20}

(c) 3×10^{20} (d) 6×10^{20}

54. A copper voltameter is connected in series with a heater coil of resistance 0.1Ω. A steady current flows in the circuit for twenty minutes and mass of 0.99 *g* of copper is deposited at the cathode. If electrochemical equivalent of copper is 0.00033 *gm/C*, then heat generated in the coil is

[Pb. PET 2002]

(a) 750 *J* (b) 650 *J*

(c) 350 *J* (d) 250 *J*

55. E.C.E. of *Cu* and *Ag* are 7×10^{-6} and 1.2×10^{-6}. A certain current deposits 14 *gm* of *Cu*. Amount of *Ag* deposited is

[Orissa PMT 2004]

(a) 1.2 *gm* (b) 1.6 *gm*

(c) 2.4 *gm* (d) 1.8 *gm*

56. The chemical equivalent of silver is 108. If the current in a silver voltameter is 2 *Amp.*, the time required to deposit 27 *grams* of silver will be [MP PMT 2004]

(a) 8.57 *hrs* (b) 6.70 *hrs*

(c) 3.35 *hrs* (d) 12.50 *hrs*

57. Two voltameters, one of copper and another of silver, are joined in parallel. When a total charge q flows through the voltameters, equal amount of metals are deposited. If the electrochemical equivalents of copper and silver are z_1 and z_2 respectively the charge which flows through the silver voltameter is

(a) $q\frac{z_1}{z_2}$ (b) $q\frac{z_2}{z_1}$

(c) $\frac{q}{1+\frac{z_1}{z_2}}$ (d) $\frac{q}{1+\frac{z_2}{z_1}}$

58. The chemical equivalent of copper and zinc are 32 and 108 respectively. When copper and silver voltameter are connected in series and electric current is passed through for sometimes, 1.6 *g* of copper is deposited. Then, the mass of silver deposited will be

(a) 3.5 *g* (b) 2.8 *g*

(c) 5.4 *g* (d) None of these

59. Ampere hour is the unit of [Orissa JEE 2005]

(a) Quantity of charge (b) Potential

(c) Energy (d) Current

Thermo-Electricity

1. The production of e.m.f. by maintaining a difference of temperature between the two junctions of two different metals is known as

(a) Joule effect (b) Seebeck effect

(c) Peltier effect (d) Thomson effect

2. When a current passes through the junction of two different metals, evolution or absorption of heat at the junction is known as

(a) Joule effect [Pb. PET 2001] (b) Seebeck effect

(c) Peltier effect (d) Thomson effect

3. When a current passes through a wire whose different parts are maintained at different temperatures, evolution or absorption of heat all along the length of wire is known as

(a) Joule effect (b) Seebeck effect

(c) Peltier effect (d) Thomson effect

4. The thermocouple is based on the principle of

[MP PET 1984; AFMC 1998; BCECE 2003]

(a) Seebeck effect (b) Thomson effect

(c) Peltier effect (d) Joule effect

5. For a thermocouple, the neutral temperature is $270°C$ and the temperature of its cold junction is $20°C$. If there is no deflection in the galvanometer, the temperature of the hot junction should be
(a) $210°C$ (b) $540°C$
(c) $520°C$ (d) $209°C$

6. Thermocouple is a device for the measurement of
(a) Absolute temperature of a metal
(b) The temperature difference between two substances
(c) The couple acting on a wire
(d) Thermal conductivity of a substance

7. The true statement for thermo e.m.f. of a thermocouple
(a) Depends on the nature of metals
(b) Depends only on temperature of cold junction
(c) Depends only on temperature of hot junction
(d) Depends on the length of the wires used for thermocouple

8. The direction of current in an iron-copper thermocouple is [MP PET 1995]
(a) From copper to iron at the hot junction
(b) From iron to copper at the hot junction
(c) From copper to iron at cold junction
(d) No current will flow

9. Peltier coefficient for the junction of a pair of metals is proportional to [MP PMT 1993; MP PET 1997]
(a) T absolute temperature of the junction
(b) Square of absolute temperature of the junction
(c) $\frac{1}{\text{Absolute temperature of the junction}}$
(d) $\frac{1}{\text{Square of absolute temperature of the junction}}$

10. If for a thermocouple T_n is the neutral temperature, T_c is the temperature of the cold junction and T_i is the temperature of inversion, then [MP PET 2001; AIEEE 2002]
(a) $T_i = 2T_n - T_c$ (b) $T_n = T_i - 2T_c$
(c) $T_i = T_n - T_c$ (d) None of these

11. For a thermocouple, the temperature of inversion is that temperature at which thermo e.m.f. is
(a) Zero (b) Maximum
(c) Minimum (d) None of the above

12. For a given thermocouple, the thermo e.m.f. can be
(a) Zero (b) Positive
(c) Negative (d) All of the above

13. When current is passed in antimony-bismuth couple, then
(a) The junction becomes hot when the current is from bismuth to antimony
(b) The junction becomes hot when current flows from antimony to bismuth
(c) Both junctions become hot
(d) Both junctions become cold

14. A thermocouple is made of *Cu* and *Fe*. If a battery is connected in it, then
(a) Both junctions will be at the same temperature
(b) Both junctions will become hot
(c) One junction will be hotter than the other
(d) None of these

15. Thermopile is used for [AMU Engg. 2000]
(a) Collecting the heat energy
(b) The measurement of radiant heat energy
(c) The measurement of current
(d) The change of atomic energy into heat energy

16. When a current of 1 ampere is passed through a conductor whose ends are maintained at temperature difference of $1°C$, the amount of heat evolved or absorbed is called
(a) Peltier coefficient (b) Thomson coefficient
(c) Thermoelectric power (d) Thermo e.m.f.

17. In a thermocouple, the temperature that does not depend on the temperature of the cold junction is called
(a) Neutral temperature (b) Temperature of inversion
(c) Both the above (d) None of the above

18. At neutral temperature, the thermoelectric power $\left(\frac{dE}{dT}\right)$ has the value [MP PET 2003; MP PMT 2004]
(a) Zero (b) Maximum but negative
(c) Maximum but positive (d) Minimum but positive

19. In *Cu-Fe* couple, the flow of current at the temperature of inversion is
(a) From *Fe* to *Cu* through the hot junction
(b) From *Cu* to *Fe* through the hot junction
(c) Maximum
(d) None of the above

20. In Seebeck series *Sb* appears before *Bi*. In a $Sb - Bi$ thermocouple current flows from [MP PET 1994]
(a) *Sb* to *Bi* at the hot junction
(b) *Sb* to *Bi* at the cold junction
(c) *Bi* to *Sb* at the cold junction
(d) None of the above

21. Which of the following statement is correct [MP PET 1994]
(a) Both Peltier and Joule effects are reversible
(b) Both Peltier and Joule effects are irreversible
(c) Joule effect is reversible, whereas Peltier effect is irreversible
(d) Joule effect is irreversible, whereas Peltier effect is reversible

22. For a given temperature difference, which of the following pairs will generate maximum thermo e.m.f. [MP PMT 1994]
(a) Antimony-bismuth (b) Silver-gold
(c) Iron-copper (d) Lead-nickel

23. The cold junction of a thermocouple is maintained at $10°C$. No thermo e.m.f. is developed when the hot junction is maintained at $530°C$. The neutral temperature is [MP PMT 1994]
(a) $260°C$ (b) $270°C$
(c) $265°C$ (d) $520°C$

24. Which of the following is not reversible [Manipal MEE 1995; DPMT 2001]
(a) Joule effect (b) Peltier effect

(c) Seebeck effect (d) Thomson effect

25. Neutral temperature of a thermocouple is defined as the temperature at which [MP PMT 1996]

(a) The thermo e.m.f. changes sign

(b) The thermo e.m.f. is maximum

(c) The thermo e.m.f. is minimum

(d) The thermo e.m.f. is zero

26. As the temperature of hot junction of a thermo-couple is increased (while cold junction is at constant temperature), the thermo e.m.f.

(a) Increases uniformly at constant rate

(b) Increases slowly in the beginning and more rapidly at higher temperatures

(c) Increases more rapidly in the beginning but less rapidly at higher temperatures

(d) In minimum at neutral temperature

27. As the temperature of hot junction increases, the thermo e.m.f.

(a) Always increases

(b) Always decreases

(c) May increase or decrease

(d) Always remains constant

28. The e.m.f. in a thermoelectric circuit with one junction at $0°C$ and the other at $t°C$ is given by $E = At - Bt^2$. The neutral temperature is then [AMU 1995; BCECE 2004]

(a) $\frac{A}{B}$ (b) $-\frac{A}{2B}$

(c) $-\frac{B}{2A}$ (d) $\frac{A}{2B}$

29. The temperature of cold junction and neutral temperature of a thermocouple are $15^o C$ and $280^o C$ respectively. The temperature of inversion is [AMU (Engg.) 1999]

(a) $295^o C$ (b) $265^o C$

(c) $545^o C$ (d) $575^o C$

30. Above neutral temperature, thermo e.m.f. in a thermocouple [AMU (Engg.) 1999]

(a) Decreases with rise in temperature

(b) Increases with rise in temperature

(c) Remains constant

(d) Changes sign

31. Consider the following two statements A and B, and identify the correct choice out of given answers

A. Thermo e.m.f. is minimum at neutral temperature of a thermocouple

B. When two junctions made of two different metallic wires are maintained at different temperatures, an electric current is generated in the circuit. [EAMCET (Med.) 2000]

(a) A is false and B is true (b) A is true and B is false

(c) Both A and B are false (d) Both A and B are true

32. The temperature at which thermal electric power of a thermo couple becomes zero is called [MP PMT 2001]

(a) Inversion temperature (b) Neutral temperature

(c) Junction temperature (d) Null temperature

33. Thomson coefficient of a conductor is $10 \mu V/K$. The two ends of it are kept at $50^o C$ and $60^o C$ respectively. Amount of heat absorbed by the conductor when a charge of 10 C flows through it is

(a) 1000 J (b) 100 J

(c) 100 mJ (d) 1 mJ

34. For a thermocouple the neutral temperature is $270^o C$ when its cold junction is at $20^o C$. What will be the neutral temperature and the temperature of inversion when the temperature of cold junction is increased to $40^o C$ [Kerala PET 2001]

(a) $290^o C, 580^o C$ (b) $270^o C, 580^o C$

(c) $270^o C, 500^o C$ (d) $290^o C, 540^o C$

35. Two ends of a conductor are at different temperatures the electromotive force generated between two ends is [MP PMT 2001; MP PET 2002]

(a) Seebeck electro motive force (e.m.f.)

(b) Peltier electro motive force (e.m.f.)

(c) Thomson electro motive force (e.m.f.)

(d) None of these

36. The neutral temperature of a thermocouple is $350^o C$ when the cold junction is at $0^o C$. When the cold junction is immersed in a bath of $30^o C$, the inversion temperature is [MP PET 1999] [Kerala (Med.) 2002]

(a) $700^o C$ (b) $600^o C$

(c) $350^o C$ (d) $670^o C$

37. A thermoelectric refrigerator works on [JIPMER 2002]

(a) Joule effect (b) Seeback effect

(c) Peltier effect (d) Thermonic emission

38. If the temperature of cold junction of thermocouple is lowered, then the neutral temperature [JIPMER 2002]

(a) Increases

(b) Approaches inversion temperature

(c) Decreases

(d) Remains the same

39. Consider the following two statements A and B and identify the correct choice given in the answers

(A) Duddells thermo-galvanometer is suitable to measure direct current only

(B) Thermopile can measure temperature differences of the order of $10^{-3}\ ^oC$ [EAMCET 2003]

(a) Both A and B are true (b) Both A and B are false

(c) A is true but B is false (d) A is false but B is true

40. If $E = at + bt^2$, what is the temperature of inversion [DCE 2003]

(a) $-\frac{a}{2b}$ (b) $+\frac{a}{2b}$

(c) $-\frac{a}{b}$ (d) $+\frac{a}{b}$

41. Antimony and bismuth are usually used in a thermocouple, because

(a) Negative thermal e.m.f. produced

(b) Constant thermal e.m.f. produced

(c) Lower thermal e.m.f. produced

(d) Higher thermal e.m.f. produced [EAMCET 2001]

42. The smallest temperature difference that can be measured with a combination of a thermocouple of thermo e.m.f. 30μV per degree and a galvanometer of 50 *ohm* resistance, capable of measuring a minimum current of $3 \times 10^{-}$ *amp* is [MP PET 2000]

(a) 0.5 degree (b) 1.0 degree
(c) 1.5 degree (d) 2.0 degree

43. $e = \alpha t - \frac{1}{2}\beta t^2$, If temperature of cold junction is $0^o C$ then temperature of inversion is
$(\text{if}\,\alpha = 500.0 \mu V/^o C, \beta = 5.0 \mu V/\text{Square}\,^o C)$ [DCE 2001]

(a) 100 (b) 200
(c) 300 (d) 400

44. If the emf of a thermocouple, one junction of which is kept 0° *C* is given by $e = at + 1/2\ bt^2$ then the neutral temperature will be [J & K CET 2005]

(a) *a/b* (b) – *a/b*
(c) *a/2b* (d) –1/ *ab*

Critical Thinking

Objective Questions

1. The resistance of the filament of an electric bulb changes with temperature. If an electric bulb rated 220 volt and 100 watt is connected $(220 \times .8)$ *volt* sources, then the actual power would be

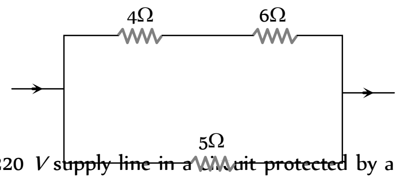
(a) $100 \times 0.8\, watt$
(b) $100 \times (0.8)^2 watt$
(c) Between 100×0.8 *watt* and 100 *watt*
(d) Between $100 \times (0.8)^2 watt$ and 100×0.8 *watt*

2. An immersion heater is rated 836 *watt*. It should heat 1 *litre* of water from $10°C$ to $40°C$ in about [AIEEE 2004]

(a) 200 *sec* (b) 150 *sec*
(c) 836 *sec* (d) 418 *sec*

3. In the circuit shown in figure, the heat produced in 5 *ohm* resistance is 10 *calories* per *second*. The heat produced in 4 resistance is [IIT 1981; UPSEAT 2002]

(a) 1 *cal / sec*
(b) 2 *cal/sec*
(c) 3 *cal / sec*
(d) 4 *cal/sec*



4. A house is served by 220 *V* supply line in a circuit protected by a 9 *ampere* fuse. The maximum number of 60 W lamps in parallel that can be turned on, is

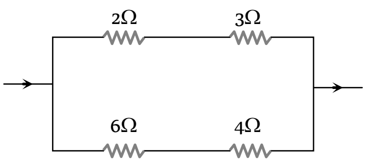
(a) 44 (b) 20
(c) 22 (d) 33

5. Water boils in an electric kettle in 15 *minutes* after switching on. If the length of the heating wire is decreased to $2/3$ of its initial value, then the same amount of water will boil with the same supply voltage in [MP PMT 1994]

(a) 15 *minutes* (b) 12 *minutes*
(c) 10 *minutes* (d) 8 *minutes*

6. In the circuit as shown in the figure, the heat produced by 6 *ohm* resistance due to current flowing in it is 60 *calorie* per *second*. The heat generated across 3 *ohm* resistance per second will be

(a) 30 *calorie*



(b) 60 *calorie*
(c) 100 *calorie*
(d) 120 *calorie*

7. The resistance of a heater coil is 110 *ohm*. A resistance *R* is connected in parallel with it and the combination is joined in series with a resistance of 11 *ohm* to a 220 *volt* main line. The heater operates with a power of 110 *watt*. The value of *R* in *ohm* is

(a) 12.22
(b) 24.42
(c) Negative
(d) That the given values are not correct

8. A 500 *W* heating unit is designed to operate from a 115 *volt* line. If the line voltage drops to 110 volt, the percentage drop in heat output will be [ISM Dhanbad 1994]

(a) 10.20% (b) 8.1%
(c) 8.6% (d) 7.6%

9. A heater of 220 *V* heats a volume of water in 5 minute time. A heater of 110 *V* heats the same volume of water in [AFMC 1993]

(a) 5 *minutes* (b) 8 *minutes*
(c) 10 *minutes* (d) 20 *minutes*

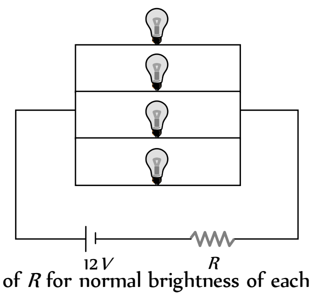
10. An electric kettle takes 4 *A* current at 220 *V*. How much time will it take to boil 1 *kg* of water from room temperature $20°C$? The temperature of boiling water is $100°C$ [CPMT 1989] [RPET 1996]

(a) 6.4 *minutes* (b) 6.3 *minutes*
(c) 12.6 *minutes* (d) 12.8 *minutes*

11. If a wire of resistance $20\,\Omega$ is covered with ice and a voltage of 210 *V* is applied across the wire, then the rate of melting of ice is

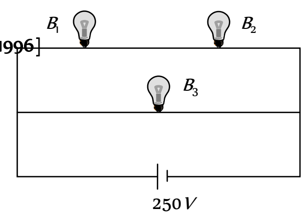
(a) $0.85\, g/s$ (b) $1.92\, g/s$
(c) $6.56\, g/s$ (d) All of these

12. Four identical electrical lamps are labelled 1.5 *V*, 0.5*A* which describes the condition necessary for them to operate at normal brightness. A 12 *V* battery of negligible internal resistance is connected to lamps as shown, then [UPSEAT 2001]



(a) The value of *R* for normal brightness of each lamp is (3/4) Ω
(b) The value of *R* for normal brightness of each lamp is (21/4) Ω
(c) Total power dissipated in circuit when all lamps are normally bright is 24 *W*
(d) Power dissipated in *R* is 21 *W* when all lamps are normally bright

13. A 100 *W* bulb B_1 and two 60-*W* bulbs B_2 and B_3, are connected to a 250 *V* source, as shown in the figure. Now W_1, W_2 and W_3 are the output powers of the bulbs B_1, B_2 and B_3 respectively. Then [MP PET 1996]

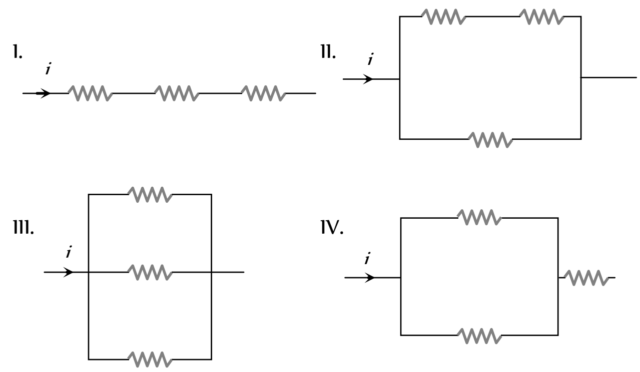


(a) $W_1 > W_2 = W_3$ (b) $W_1 > W_2 > W_3$

(c) $W_1 < W_2 = W_3$ (d) $W_1 < W_2 < W_3$

14. The three resistance of equal value are arranged in the different combinations shown below. Arrange them in increasing order of power dissipation

[IIT-JEE (Screening) 2003]



(a) III < II < IV < I (b) II < III < IV < I

(c) I < IV < III < II (d) I < III < II < IV

15. Silver and copper voltameter are connected in parallel with a battery of e.m.f. 12 *V*. In 30 *minutes*, 1 *gm* of silver and 1.8 *gm* of copper are liberated. The power supplied by the battery is

(a) 24.13 *J/sec* (b) 2.413 *J/sec*

(c) 0.2413 *J/sec* (d) 2413 *J/sec*

$(Z_{Cu} = 6.6 \times 10^{-4}\ gm/C$ and $Z_{Ag} = 11.2 \times 10^{-4}\ gm/C)$

16. A silver voltameter of resistance 2 *ohm* and a 3 *ohm* resistor are connected in series across a cell. If a resistance of 2 *ohm* is connected in parallel with the voltameter, then the rate of deposition of silver [EAMCET 1983]

(a) Decreases by 25%

(b) Increases by 25%

(c) Increases by 37.5%

(d) Decreases by 37.5%

17. The expression for thermo e.m.f. in a thermocouple is given by the relation $E = 40\,\theta - \frac{\theta^2}{20}$, where θ is the temperature difference of two junctions. For this, the neutral temperature will be

(a) $100°C$ (b) $200°C$

(c) $300°C$ (d) $400°C$

18. For copper-iron (*Cu-Fe*) couple, the thermo e.m.f. (temperature of cold junction $= 0°C$) is given by $E = (14\theta - 0.02\theta^2)\mu V$. The neutral temperature will be

(a) $350°C$ (b) 350 *K*

(c) $560°C$ (d) 560 *K*

19. One junction of a certain thermoelectric couple is at a fixed temperature T_r and the other junction is at temperature *T*. The thermo electromotive force for this is expressed by $E = K(T - T_r)\left[T_0 - \frac{1}{2}(T + T_r)\right]$. At temperature $T = \frac{1}{2}T_0$, the thermoelectric power is [MP PMT 1994]

(a) $\frac{1}{2}KT_0$ (b) KT_0

(c) $\frac{1}{2}KT_0^2$ (d) $\frac{1}{2}K(T_0 - T_r)^2$

20. The temperature of the cold junction of thermo-couple is $0°C$ and the temperature of hot junction is $T°C$. The e.m.f. is $E = 16T - 0.04T^2\,\mu$ volts. The temperature of inversion is

(a) $200°C$ (b) $400°C$

(c) $100°C$ (d) $300°C$

21. The temperature of the cold junction of a thermocouple is $0°C$ and temperature of the hot junction is $T°C$. The thermo e.m.f. is given by the relation $E = AT - \frac{1}{2}BT^2$ (where *A* = 16 and *B* = 0.08). The temperature of inversion is

(a) $100°C$ (b) $300°C$

(c) $400°C$ (d) $500°C$

22. The thermo e.m.f. of a thermo-couple is $25\mu V/°C$ at room temperature. A galvanometer of 40 ohm resistance, capable of detecting current as low as $10^{-5} A$, is connected with the thermocouple. The smallest temperature difference that can be detected by this system is [IIT 1975] [AIEEE 2003]

(a) $20°C$ (b) $16°C$

(c) $12°C$ (d) $8°C$

23. An electric bulb rated for 500 watts at 100 volts is used in a circuit having a 200-volt supply. The resistance *R* that must be put in series with the bulb, so that the bulb draws 500 *W* is

(a) $10\,\Omega$ (b) $20\,\Omega$

(c) $50\,\Omega$ (d) $100\,\Omega$

24. A thermo couple develops $200\,\mu V$ between $0°C$ and $100°C$. If it develops $64\,\mu V$ and $76\,\mu V$ respectively between $(0°C - 32°C)$ and $(32°C - 70°C)$ then what will be the thermo *emf* it develops between $70°C$ and $100°C$

(a) $65\,\mu V$ (b) $60\,\mu V$

(c) $55\,\mu V$ [AMU (Engg.) 2000] (d) $50\,\mu V$

25. A thermo couple is formed by two metals *X* and *Y* metal *X* comes earlier to *Y* in Seebeck series. If temperature of hot junction increases beyond the temperature of inversion. Then direction of current in thermocouple will so

(a) *X* to *Y* through cold junction

(b) *X* to *Y* through hot junction

(c) *Y* to *X* through cold junction

(d) Both (b) and (c)

26. Peltier co-efficient of a thermo couple is 2 *nano volts.* How much heat is developed at a junction if 2.5 *amp* current flows for 2 *minute*

(a) 6 *ergs* (b) 6×10^{-7} *ergs*

(c) 16 *ergs* (d) 6×10^{-3} *erg*

27. Resistance of a voltameter is 2Ω, it is connected in series to a battery of 10 *V* through a resistance of 3Ω. In a certain time mass deposited on cathode is 1 *gm*. Now the voltameter and the 3Ω resistance are connected in parallel with the battery. Increase in the deposited mass on cathode in the same time will be

(a) 0 (b) 1.5 *gm*

(c) 2.5 *gm* (d) 2 *gm*

28. A current of 1.5 *A* flows through a *copper* voltameter. The thickness of *copper* deposited on the electrode surface of area $50\,cm^2$ in 20 *minutes* will be (Density of *copper* = 9000 kg/m^3 and E.C.E. of *copper* = 0.00033 *g/C*)

(a) $2.6 \times 10^{-5}\,m$ (b) $2.6 \times 10^{-4}\,m$

(c) $1.3 \times 10^{-5}\,m$ (d) $1.3 \times 10^{-4}\,m$

29. An ammeter, suspected to give inaccurate reading, is connected in series with a *silver* voltameter. The ammeter indicates 0.54 *A*. A steady current passed for one hour deposits 2.0124 *gm* of *silver*. If the E.C.E. of *silver is* $1.118 \times 10^{-3}\,gmC^{-1}$, then the error in ammeter reading is

(a) + 0.04 *A* (b) + 0.02 *A*

(c) – 0.03 *A* (d) – 0.01 *A*

30. If 1 *A* of current is passed through $CuSO_4$ solution for 10 seconds, then the number of copper ions deposited at the cathode will be about

(a) 1.6×10^{19} (b) 3.1×10^{19}

(c) 4.8×10^{19} (d) 6.2×10^{19}

31. A silver and a copper voltmeters are connected in parallel across a 6 *volt* battery of negligible resistance. In half an hour, 1 *gm* of copper and 2 *gm* of silver are deposited. The rate at which energy is supplied by the battery will approximately be (Given E.C.E. of copper $= 3.294 \times 10^{-4}\,g/C$ and *E.C.E.* of silver $= 1.118 \times 10^{-3}\,g/C$)

(a) 64 *W* (b) 32 *W*

(c) 96 *W* (d) 16 *W*

32. A thermocouple of resistance $1.6\,\Omega$ is connected in series with a galvanometer of $8\,\Omega$ resistance. The thermocouple develops and e.m.f. of $10\mu V$ per degree temperature difference between two junctions. When one junction is kept at $0^o C$ and the other in a molten metal, the galvanometer reads 8 *millivolt*. The temperature of molten metal, when e.m.f. varies linearly with temperature difference, will be

(a) $960^o C$ (b) $1050^o C$

(c) $1275^o C$ (d) $1545^o C$

33. The *emf* of a thermocouple, one junction of which is kept at $0^o C$, is given by $e = at + bt^2$ the Peltier co-efficient will be

(a) $(t+273)\,(a+2bt)$ (b) $(t+273)\,(a-2bt)$

(c) $(t-273)\,(a-2bt)$ (d) $(t-273)\,(a-2bt)$

34. A coil of wire of resistance $50\,\Omega$ is embedded in a block of ice. If a potential difference of 210 *V* is applied across the coil, the amount of ice melted per second will be

(a) 4.12 *gm* (b) 4.12 *kg*

(c) 3.68 *kg* (d) 2.625 *gm*

35. The same mass of copper is drawn into two wires 1 *mm* and 2 *mm* thick. Two wires are connected in series and current is passed through them. Heat produced in the wire is in the ratio

(a) 2 : 1 (b) 1 : 16

(c) 4 : 1 (d) 16 : 1

36. The temperature of hot junction of a thermo-couple changes from $80^o C$ to $100^o C$. The percentage change in thermoelectric power is

(a) 8% (b) 10%

(c) 20% (d) 25%

37. A thermo couple uses Bismuth and Tellurium as the dissimilar metals. The sensitivity of bismuth is $-72\mu V/^o C$ and that of the tellurium is $500\mu\ V/^o C$. If the difference between hot and cold junction is $100^o C$, then the maximum output will be

(a) $50\ mV$ (b) $7.2\ mV$

(c) $42.8\ mV$ (d) $57.2\ mV$

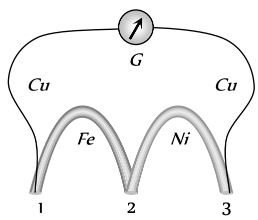
38. Three wires of copper, iron and nickel are joined to form three junctions as shown in Fig. When the temperature of junction 1 is kept $50^o C$ with the other two junctions at $0^o C$, the sensitive galvanometer gives a deflection of 14 divisions. When the temperature of junction 3 is kept $50^o C$, with the other two junctions at $0^o C$, the galvanometer gives a deflection of 11 divisions. Then the deflection given by the galvanometer, when temperature of the junction 2 is kept at $50^o C$, with the other two junctions at $0^o C$, will be

(a) 3 *div*

(b) 11 *div*

(c) 14 *div*

(d) 25 *div*



39. The wiring of a house has resistance $6\,\Omega$. A 100 *W* bulb is glowing. If a geyser of 1000 *W* is switched on, the change in potential drop across the bulb is nearly **[MNR 1998]**

(a) Nil (b) 23 *V*

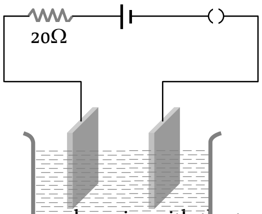
(c) 32 V (d) 12 V

40. A 12 V lead accumulator is being charged using 24 V supply with an external resistance 2Ω. The internal resistance of the accumulator is 1Ω. Find the time in which it will store 360 W-hour energy.

(a) 1 hr (b) 7.5 hr

(c) 10 hr (d) None of these

41. In a Ag voltameter 2.68 gm of silver is deposited in 10 min. The heat developed in $20\,\Omega$ resistor during the same period will be



(a) 192 kJ

(b) 192 J

(c) 200 J

(d) 132 kJ

42. The thermo e.m.f. of a thermocouple varies with the temperature θ of the hot junction as $E = a\theta + b\theta^2$ in $volts$ where the ratio a/b is $700^o C$. If the cold junction is kept at $0^o C$, then the neutral temperature is [AIEEE 2004]

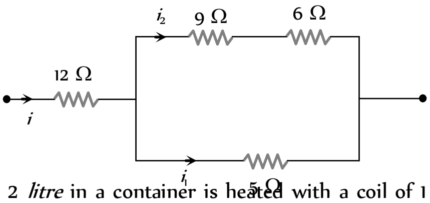
(a) $700^o C$

(b) $350^o C$

(c) $1400^o C$

(d) No neutral temperature is possible for this thermocouple

43. In the following circuit, 5 Ω resistor develops 45 J/s due to current flowing through it. The power developed per second across 12 Ω resistor is [AMU (Engg.) 1999]



(a) 16 W

(b) 192 W

(c) 36 W

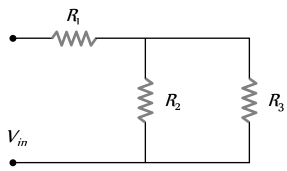
(d) 64 W

44. Water of volume 2 $litre$ in a container is heated with a coil of 1 kW at 27°C. The lid of the container is open and energy dissipates at rate of 160 J/s. In how much time temperature will rise from 27°C to 77°C [Given specific heat of water is 4.2 kJ/kg]

(a) 8 min 20 s (b) 6 min 2 s

(c) 7 min (d) 14 min

45. For ensuring dissipation of same energy in all three resistors (R_1, R_2, R_3) connected as shown in figure, their values must be related as] [AIIMS 2005]



(a) $R_1 = R_2 = R_3$

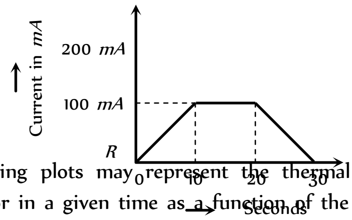
(b) $R_2 = R_3$ and $R_1 = 4R_2$

(c) $R_2 = R_3$ and $R_1 = \frac{1}{4}R_2$

(d) $R_1 = R_2 + R_3$

Graphical Questions

1. In a copper voltameter, mass deposited in 30 $second$ is m gm. If the time-current graph is as shown in figure, ECE of copper is



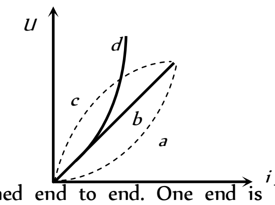
(a) m

(b) $m/2$

(c) 0.1 m

(d) 0.6 m

2. Which of the following plots may represent the thermal energy produced in a resistor in a given time as a function of the electric current [MP PMT 1999]



(a) a

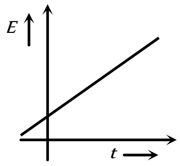
(b) b

(c) c

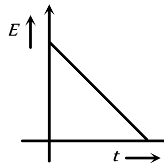
(d) d

3. Two different metals are joined end to end. One end is kept at constant temperature and the other end is heated to a very high temperature. The graph depicting the thermo e.m.f. is

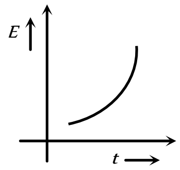
(a)



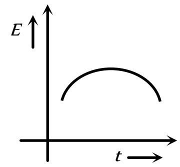
(b)



(c)

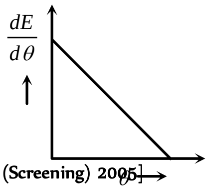


(d)

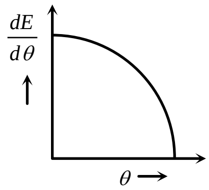


4. Which of the following graphs shows the variation of thermoelectric power with temperature difference between hot and cold junction in thermocouples

(a)

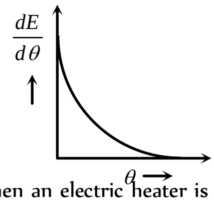


(b)

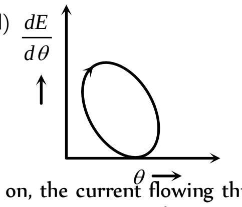


[IIT-JEE (Screening) 2005]

(c)

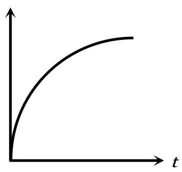


(d)

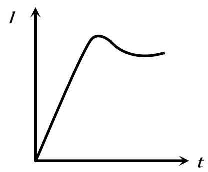


5. When an electric heater is switched on, the current flowing through it (i) is plotted against time (t). Taking into account the variation of resistance with temperature, which of the following best represents the resulting curve

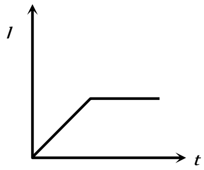
(a)



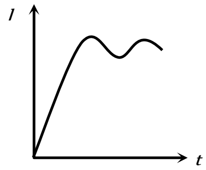
(b)



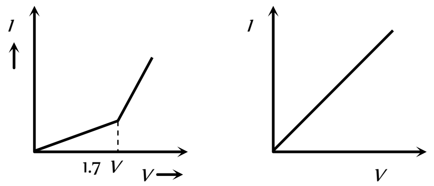
(c)



(d)



6. The V-i graphs A and B drawn for two voltameters. Identify each graph

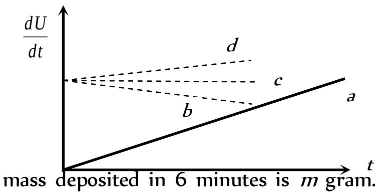


(A) (B)

(a) A for water voltameter and B for Cu voltameter
(b) A for Cu voltameter and B for water voltameter
(c) Both A and B represents Cu voltameter
(d) None of these

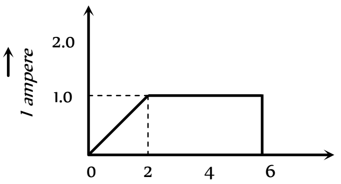
7. A constant current i is passed through a resistor. Taking the temperature coefficient of resistance into account, indicate which of the plots shown in figure best represents the rate of production of thermal energy in the resistor

(a) a
(b) b
(c) c
(d) d

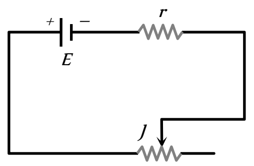


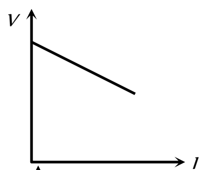
8. In a copper voltameter, mass deposited in 6 minutes is m gram. If the current-time graph for the voltameter is as shown here, then the E.C.E of the copper is

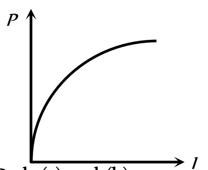
(a) $m/5$
(b) $m/300$
(c) $5m$
(d) $m/18000$

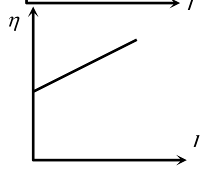


9. Battery shown in figure has e.m.f. E and internal resistance r. Current in the circuit can be varied by sliding the contact J. If at any instant current flowing through the circuit is I, potential difference between terminals of the cell is V, thermal power generated in the cell is equal to η fraction of total electrical power generated in it.; then which of the following graph is correct



(a)


(b)


(c)


(d) Both (a) and (b) are correct

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below :

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : The possibility of an electric bulb fusing is higher at the time of switching ON and OFF
Reason : Inductive effects produce a surge at the time of switch ON and OFF [AIIMS 2003]

2. Assertion : The 200 W bulbs glows with more brightness then 100 W bulbs.
Reason : A 100 W bulb has more resistance than a 200 W bulb.

3. Assertion : Fuse wire must have high resistance and low melting point.
Reason : Fuse is used for small current flow only.

4. Assertion : Two electric bulbs of 50 and 100 W are given. When connected in series 50 W bulb glows more but when connected parallel 100 W bulb glows more.
Reason : In series combination, power is directly proportional to the resistance of circuit. But in parallel combination, power is inversely proportional to the resistance of the circuit.

5. Assertion : Two bulbs of same wattage, one having a carbon filament and the other having a metallic filament are connected in series. Metallic bulbs will glow more brightly than carbon filament bulb.
Reason : Carbon is a semiconductor.

6. Assertion : An electric bulb is first connected to a dc source and then to a ac source having the same brightness in both the cases.
Reason : The peak value of voltage for an A.C. source is $\sqrt{2}$ times the root mean square voltage.

7. Assertion : Current is passed through a metallic wire, heating it red. When cold water is poured on half of its portion, then rest of the half portion become more hot.
Reason : Resistances decreases due to decrease in temperature and so current through wire increases.

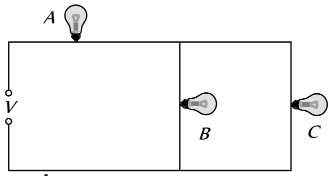
8. Assertion : Through the same current flows through the line wires and the filament of the bulb but heat produced in the filament is much higher then that in line wires.
Reason : The filament of bulbs is made of a material of high resistance and high melting point.

9. Assertion : Neutral temperature of a thermocouple does not depend upon temperature of cold junction.
Reason : Its value is constant for the given metals of the couple.

10. Assertion : In practical application, power rating of resistance is not important.
Reason : Property of resistance remain same even at high temperature.

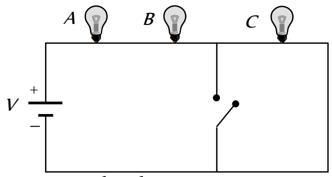
11. Assertion : Leclanche cell is used, when constant supply of electric current is not required.
Reason : The e.m.f. of a Leclanche cell falls, if it is used continuously.

12. Assertion : In the given circuit if lamp B or C fuses then light emitted by lamp A decreases.



Reason : Voltage on A decreases.

13. Assertion : If three identical bulbs are connected in series as shown in figure then on closing the switches. Bulb C short circuited and hence illumination of bulbs A and B decreases.



Reason : Voltage on A and B decreases

14. Assertion : Heat is generated continuously is an electric heater but its temperature becomes constant after some time.

Reason : At the stage when heat produced in heater is equal to the heat dissipated to its surrounding the temperature of heater becomes constant.

15. Assertion : Electric appliances with metallic body; *e.g.* heaters, presses etc, have three pin connections, whereas an electric bulb has a two pin connection. [AIIMS 1996]

Reason : Three pin connections reduce heating of connecting cables.

16. Assertion : A laser beam 0.2 W power can drill holes through a metal sheet, whereas 1000 W torch-light cannot.

Reason : The frequency of laser light is much higher then that of torch light. [AIIMS 1996]

17. Assertion : A domestic electrical appliance, working on a three pin will continue working even if the top pin is removed. [AIIMS 1995]

Reason : The third pin is used only as a safety device.

18. Assertion : In all conductors, for studying the thermoelectric behaviour or metals, lead is taken as a reference metal.

Reason : In lead, the Thomson effect is negative.

19. Assertion : The presence of water molecules makes separation of ions easier in electrolyte.

Reason : The presence of water molecules in electrolyte decreases the resistance of electrolyte.

20. Assertion : Thermocouple acts as a heat engine.

Reason : When two junctions of thermocouple are at different temperature, thermo e.m.f. is produced.

21. Assertion : When temperature of cold junction of a thermocouple is lowered, the value of neutral temperature of this thermocouple is raised.

Reason : When the difference of temperature of two junction is raised, more thermo e.m.f. is produced.

Answers

Heating Effect of Current

1	a	2	b	3	c	4	b	5	b
6	c	7	c	8	a	9	b	10	c
11	a	12	c	13	c	14	a	15	d
16	d	17	b	18	c	19	c	20	a
21	d	22	a	23	a	24	c	25	d
26	d	27	c	28	c	29	b	30	b
31	b	32	b	33	a	34	d	35	c
36	b	37	d	38	b	39	a	40	a
41	a	42	b	43	d	44	d	45	a
46	c	47	a	48	b	49	a	50	a
51	b	52	c	53	a	54	c	55	c
56	a	57	d	58	b	59	d	60	a
61	d	62	a	63	d	64	b	65	b
66	d	67	a	68	a	69	a	70	c
71	a	72	d	73	a	74	b	75	a
76	d	77	b	78	b	79	d	80	d
81	a	82	d	83	d	84	d	85	a
86	a	87	a,d	88	a	89	b	90	a
91	b	92	a	93	b	94	a	95	b
96	a	97	c	98	b	99	c	100	a
101	b	102	c	103	a	104	a	105	d
106	c	107	a	108	b	109	b	110	d
111	c	112	b	113	c	114	a	115	c
116	c	117	d	118	a	119	d	120	c
121	b	122	d	123	a	124	a	125	a
126	c	127	a	128	d	129	a	130	c
131	a	132	c	133	c	134	c	135	b
136	c	137	c	138	c	139	b	140	d
141	a	142	c	143	d	144	c	145	b
146	c	147	c	148	c	149	a	150	c
151	a	152	c	153	c				

Chemical Effect of Current

1	d	2	c	3	d	4	d	5	c
6	d	7	b	8	d	9	b	10	a
11	b	12	b	13	b	14	c	15	b
16	a	17	b	18	c	19	a	20	d
21	c	22	b	23	c	24	a	25	d
26	b	27	a	28	c	29	a	30	a
31	b	32	d	33	b	34	a	35	b
36	c	37	c	38	b	39	d	40	b
41	c	42	b	43	d	44	a	45	c
46	c	47	a	48	b	49	b	50	b
51	a	52	d	53	d	54	a	55	c

56	c	57	d	58	c	59	a		

Thermo-Electricity

1	b	2	c	3	d	4	a	5	c
6	b	7	a	8	a	9	a	10	a
11	a	12	d	13	b	14	c	15	b
16	b	17	a	18	a	19	a	20	b
21	d	22	a	23	b	24	a	25	b
26	c	27	c	28	d	29	c	30	a
31	a	32	b	33	d	34	c	35	c
36	d	37	c	38	d	39	d	40	a
41	d	42	a	43	b	44	b		

Critical Thinking Questions

1	d	2	b	3	b	4	d	5	c
6	d	7	a	8	c	9	d	10	b
11	c	12	b	13	d	14	a	15	a
16	d	17	d	18	a	19	a	20	b
21	c	22	b	23	b	24	b	25	d
26	a	27	b	28	c	29	a	30	b
31	d	32	a	33	a	34	d	35	d
36	d	37	d	38	d	39	b	40	b
41	a	42	d	43	b	44	a	45	c

Graphical Questions

1	b	2	d	3	d	4	a	5	b
6	a	7	d	8	b	9	d		

Assertion and Reason

1	a	2	a	3	c	4	a	5	d
6	e	7	a	8	a	9	b	10	d
11	a	12	a	13	d	14	a	15	c
16	c	17	a	18	c	19	b	20	b
21	d								

Answers and Solutions

Heating Effect of Current

1. (a) $1\ kWh = 1000\ W \times 3600\ sec = 36 \times 10^5\ W\text{-}sec$ (or J)

2. (b) $P \propto \frac{1}{R} \Rightarrow \frac{P_1}{P_2} = \frac{R_2}{R_1} \Rightarrow \frac{200}{100} = \frac{R_2}{R_1} \Rightarrow R_2 = 2R_1$

3. (c) $P = \frac{V^2}{R} \Rightarrow R_1 = \frac{V_1^2}{P_1} = \frac{(200)^2}{40} = 1000\Omega$

   and $R_2 = \frac{V_2^2}{P_2} = \frac{(200)^2}{100} = 400\Omega$

4. (b) When two bulbs are connected in series, the current will be same in both the bulbs. As a result potential drop will be more in the bulb of higher resistance *i.e.,* bulb of lower wattage.

5. (b) When 1 bulb fuses, the total resistance of the circuit decreases hence the current increases. Since $P = i^2R$, therefore illumination increases.

6. (c)

7. (c) We know that $\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{2}{1}$

8. (a) $P = \frac{V^2}{R} \Rightarrow P \propto \frac{1}{R}$ and $R \propto l$ $\therefore P \propto \frac{1}{l} \Rightarrow \frac{P_1}{P_2} = \frac{l_1}{l_2} = \frac{2}{1}$

9. (b) $R_{conductor} \propto$ Temperature and $R_{semiconductor} \propto \frac{1}{\text{Temperature}}$

10. (c)

11. (a) In series, current is same in both the bulbs, hence $P \propto R (P = i^2R)$ $\therefore \frac{P_1}{P_2} = \frac{R_1}{R_2} = \frac{1}{2}$

12. (c) In this case, $P = \frac{V^2}{R}$ or $P \propto \frac{1}{R}$ and R will be minimum, when divided four parts are joints in parallel to the battery.

13. (c) Length is immaterial for an electric fuse wire.

14. (a) $P_{Rated} \propto \frac{1}{R}$ and $R \propto \frac{1}{(\text{Thickness of filament})^2}$

    So $P_{Rated} \propto (\text{Thickness of filament})^2$

15. (d) In series $P_S = \frac{P}{n} \Rightarrow 10 = \frac{P}{3} \Rightarrow P = 30\ W$

    In parallel $P_P = nP = 3 \times 30 = 90\ W$

16. (d) Energy consumed in $kWh = \frac{Watt \times hour}{1000}$

    $\Rightarrow$ For 30 days, $P = \frac{10 \times 50 \times 10}{1000} \times 30 = 150 kWh$

17. (b) $W = qV$ also $P = i \times V = \frac{W}{t}$

18. (c) Because given voltage is very high,

19. (c) $P_p = nP = 2 \times 40 = 80\ W$

20. (a) In series, $P \propto R (\because i$ is same), *i.e.* in series Fine wire (high R) liberates more energy.

    In parallel, $P \propto \frac{1}{R} (V$ is same) *i.e.* thick wire (less R) liberates more energy.

21. (d) Resistance of the bulb $= \frac{V^2}{P_{Ratate}} = \frac{220 \times 220}{100} = 484\Omega$

When connected with 110 *V*, the power consumed

$$P_{Consumed} = \frac{V^2}{R} = \frac{110 \times 110}{484} = 25W$$

22. (a) The resistance of 25 *W* bulb is greater than 100 *W* bulb. So for the same current, heat produced will be more in 25 *W* bulb. So it will glow more brightly.

23. (a) Equivalent resistance in the second case $= R_1 + R_2 = R$

Now, we know that $P \propto \frac{1}{R}$

Since in the second case the resistance $(R_1 + R_2)$ is higher than that in the first case (R).

Therefore power dissipation in the second case will be decreased.

24. (c) For constant voltage, we know that $P \propto \frac{1}{R}$

So higher the power, lower will be the resistance.

25. (d) $P = \frac{V^2}{R}$ but $R = \frac{\rho l}{A}$ $\Rightarrow$ $P = \frac{V^2}{\rho l / A} = \frac{AV^2}{\rho l}$. Since $\frac{AV^2}{l}$ is constant as per given conditions So $P \propto \frac{1}{\rho}$.

26. (d) Power consumed means heat produced.

For constant potential difference $P_{\text{consumed}} = \text{Heat} \propto \frac{1}{R_{eq}}$

$$\therefore \frac{H_1}{H_2} = \frac{R_2}{R_1} = \frac{R/2}{2R} = \frac{1}{4}$$

(Since $R_2 = \frac{R.R}{R+R} = \frac{R}{2}$ and $R_1 = R + R = 2R$)

27. (c) Resistance of carbon filament decreases with temperature while that of tungsten increases with temperature

In series $P_{Consumed} \propto R$ *i.e.* tungsten bulb will glow more brightly

28. (c) Power of the combination $P_s = \frac{P}{n} = \frac{1000}{2} = 500\,W$

29. (b) For parallel combination $P_{Consumed} \propto Brightness \propto P_{Rated}$

30. (b) Resistance of 25 *W* bulb $= \frac{220 \times 220}{25} = 1936\,\Omega$

Its safe current $= \frac{220}{1936} = 0.11\ amp.$

Resistance of 100 *W* bulb $= \frac{220 \times 220}{100} = 484\,\Omega$

Its safe current $= \frac{220}{484} = 0.48\ amp.$

When connected in series to 440 *V* supply, then the current $I = \frac{440}{(1936+484)} = 0.18\,amp.$

Thus current is greater for 25 *W* bulb, so it will fuse.

31. (b) $P = i^2R \Rightarrow \frac{\Delta P}{P} = \frac{2\Delta i}{t}$ ($R \rightarrow$ Constant)

$\Rightarrow$ % change in power $= 2\times$ % change in current

$= 2 \times 1 = 2\%$

32. (b) $P_{\max} = n\left(\frac{E^2}{4\,r}\right) = 2\left(\frac{2\times 2}{4\times 1}\right) = 2\,W$

33. (a) $H \propto \frac{1}{R}$ (If *V* = constant) $\Rightarrow \frac{H_1}{H_2} = \frac{R_2}{R_1} = \frac{l_2 A_1}{l_1 A_2} = \frac{l_2 r_1^2}{l_1 r_2^2}$

$\Rightarrow H_2 = 2H_1$

34. (d) $\frac{H}{t} = \frac{V^2}{R} \Rightarrow \frac{H}{t} \propto \frac{1}{R}$

35. (c) $H = i^2Rt$ and $i = \frac{q}{t}$. Hence $H = \frac{q^2R}{t}$; $\therefore H \propto q^2$

36. (b) $E = \frac{1100 \times 4}{1000} = 4.4\ kWh$

37. (d) After some time, thermal equilibrium will reach.

38. (b) At constant p.d., heat produced $= \frac{V^2}{R}$ *i.e.* $H \propto \frac{1}{R}$

39. (a) Power $= 3.75 \times 200\,W = 750\,W \approx 1\,H.P.$

40. (a) $\frac{V^2}{R} = P \Rightarrow R = \frac{V^2}{P} = \frac{220 \times 220}{100} = 484\Omega$

41. (a) Since $P = VI \Rightarrow I = \frac{P}{V} = \frac{250000}{10000} = 25\ A$

42. (b) Power lost in cable $= 10 \times (25)^2 = 6250\,W = 6.25\ kW$

43. (d) Heat generated in both the cases will be same because the capacitor has the same energy initially

$= \frac{1}{2}CV^2 = \frac{1}{2} \times 200 \times 10^{-6} \times (200)^2 = 4\,J$

44. (d) The bulbs are connected in parallel, hence each bulb consumes $\frac{48}{2} = 24\,W$. Therefore $\frac{V^2}{R} = 24$

$\Rightarrow R = \frac{6 \times 6}{24} = 1.5\,\Omega$

45. (a)

46. (c) The bulbs are in series, hence they will have the same current through them.

47. (a) When resistance is connected in series, brightness of bulb decreases because voltage across the bulb decreases.

48. (b) $R = \frac{V^2}{P} \Rightarrow R_1 = \frac{200 \times 200}{100} = 400\,\Omega$ and $R_2 = \frac{100 \times 100}{200} = 50\,\Omega$. Maximum current rating $i = \frac{P}{V}$

So $i_1 = \frac{100}{200}$ and $i_2 = \frac{200}{100} \Rightarrow \frac{i_1}{i_2} = \frac{1}{4}$.

49. (a) $\frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{100}{40} = \frac{5}{2}$. Resistance of 40 *W* bulb is $\frac{5}{2}$ times than 100 *W*. In series, $P = i^2R$ and in parallel, $P = \frac{V^2}{R}$. So 40 *W* in series and 100 *W* in parallel will glow brighter.

50. (a) $P = \frac{V^2}{R} \Rightarrow \frac{P_P}{P_S} = \frac{R_S}{R_P} = \frac{(R_1+R_2)}{R_1R_2/(R_1+R_2)} = \frac{(R_1+R_2)^2}{R_1\,R_2}$

$\Rightarrow \frac{100}{25} = \frac{(R_1+R_2)^2}{R_1R_2} \Rightarrow \frac{R_1}{R_2} = \frac{1}{1}$

51. (b) Total power $P = (800 + 3 \times 100)$

Also $P = Vi \Rightarrow 1100 = 220 \times i \Rightarrow i = 5A$

52. (c) Because $R \propto \frac{1}{P}$

53. (a) An ideal cell has zero resistance.

54. (c) Power loss in transmission $P_L = \frac{P^2R}{V^2} \Rightarrow P_L \propto \frac{1}{V^2}$

55. (c) $H = \frac{V^2 t}{4.2\,R}$ or $\frac{H}{t} = \frac{V^2}{4.2\,R}$

$\Rightarrow 800 = \frac{20 \times 20}{4.2 \times R} \Rightarrow R = \frac{5}{42} = 0.119 \approx 0.12\,\Omega$

56. (a) Heat produced $H = \frac{V^2 t}{4.2R} = H \propto \frac{1}{R}$ Hence $\frac{H_1}{H_2} = \frac{R_2}{R_1}$

57. (d) $\frac{H}{t} = i^2 R$. Here total $R = (21 + 4) = 25\ \Omega$

$\Rightarrow$ Rate of energy consumed $= 0.2 \times 0.2 \times 25 = 1\ J/s$

58. (b) When the heating coil is cut into two equal parts and these parts are joined in parallel, the resistance of coil is reduced to one fourth, so power consumed will become 4 times *i.e.* 400 Js^{-1}.

59. (d) The resistance of 40 *W* bulb will be more and 60 *W* bulb will be less.

60. (a) In series $P_{Consumed} \propto \text{Brightness} \propto \frac{1}{P_{Rated}}$

61. (d) *E* = *P* × *t* $= 1000\,W \times 30\ sec = 3 \times 10^4\ J$

62. (a) Resistance R_1 of 500 *W* bulb $= \frac{(220)^2}{500}$

Resistance R_2 of 200 *W* bulb $= \frac{(220)^2}{200}$

When joined in parallel, the potential difference across both the bulbs will be same.

Ratio of heat produced $= \frac{V^2/R_1}{V^2/R_2} = \frac{R_2}{R_1} = \frac{5}{2}$

When joined in series, the same current will flow through both the bulbs.

Ratio of heat produced $= \frac{i^2 R_1}{i^2 R_2} = \frac{R_1}{R_2} = \frac{2}{5}$

63. (d) Charge $q = it = 0.5\,A \times 3600\,\text{sec} = 1800\ culoumb$

64. (b) $H = i^2 Rt = \frac{V^2 t}{R} = \frac{120 \times 120 \times (10 \times 60)}{6} = 14.4 \times 10^5\,joule$

65. (b) In parallel $P_{consumed} \propto \text{Brightness} \propto \frac{1}{R}$

$P_A > P_B$ (given) $\quad \therefore\ R_A < R_B$

66. (d) $R = \rho \frac{l}{A}$ and $P \propto \frac{1}{R} \Rightarrow P \propto \frac{A}{l} \Rightarrow P \propto \frac{d^2}{l} \Rightarrow\ P_A = 2P_B$

67. (a) $t_S = t_1 + t_2 = 30 + 30 = 60\ minutes$

68. (a) For power transmission power loss in line $P_L = i^2 R$

If power of electricity is *P* and it is transmitted at voltage *V*, then $P = Vi \Rightarrow i = \frac{P}{V}$

$P_L = \left(\frac{P}{V}\right)^2 R = \frac{P^2 R}{V^2} = \frac{2.2 \times 10^3 \times 2.2 \times 10^3 \times 10}{22000 \times 22000} = 0.1W$

69. (a) $P = i^2 R$ (*i* and *R* are same)

So *P* will be same for given resistors.

70. (c) Since $H \propto i^2$, so on doubling the current, the heat produced and hence the rise in temperature becomes four times.

71. (a) *Watt-hour meter* measures electric energy.

72. (d) Total energy consumed $= \frac{60 \times 8}{1000} = 0.48\ kWH$

So cost $= 0.48 \times 1.25 = 0.6\ Rs.$

73. (a) $P_S = \frac{P}{n} = \frac{40}{4} = 10\ W.$

74. (b) As temperature increases resistance of filament also increases.

75. (a) Current through the combination $i = \frac{120}{(6+9)} = 8\ A$

So, power consumed by $6\,\Omega$ resistance

$P = (8)^2 \times 6 = 384\ W$

76. (d) $P = \frac{V^2}{R} = \frac{(225)^2}{50} = 1012.5 \approx 1000\ W$

77. (b) $P = Vi \Rightarrow\ i = \frac{P}{V} = \frac{100}{200} = 0.5\ A$

78. (b) $H = i^2 Rt\ \Rightarrow\ R = \frac{H}{i^2 t} = \frac{80}{4 \times 10} = 2\,\Omega$

79. (d) Heat produced = Energy stored in capacitor

$= \frac{1}{2} CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times (400)^2 = 0.32\ J$

80. (d) $P = \frac{V^2}{R} = \frac{(110)^2}{10} = \frac{12100}{10} = 1210\ W$

81. (a) $P_{consumed} = \left(\frac{V_A}{V_R}\right)^2 \times P_R = \frac{(160)^2}{(200)^2} \times 100 = 64\ W$

82. (d) For maximum power *r* = *R*

83. (d) $P = i^2 R\ \Rightarrow\ 22.5 = (15)^2 \times R \Rightarrow\ R = 0.10\ \Omega$

84. (d) $R_1 = \rho \frac{l_1}{A_1}$ and $R_2 = \rho \frac{l_2}{A_2} \Rightarrow\ \frac{R_1}{R_2} = \frac{l_1}{l_2} . \frac{A_2}{A_1} = \frac{l_1}{l_2}\left(\frac{r_2}{r_1}\right)^2$

Given $\frac{l_1}{l_2}=\frac{1}{2}$ and $\frac{r_1}{r_2}=\frac{2}{1}$ or $\frac{r_2}{r_1}=\frac{1}{2}\Rightarrow\frac{R_1}{R_2}=\frac{1}{8}$

$\therefore$ Ratio of heats $\frac{H_1}{H_2}=\frac{V^2/R_1}{V^2/R_2}=\frac{R_2}{R_1}=\frac{8}{1}$

85. (a) $P=Vi=250\times 2=500\,W$

86. (a) $P=\frac{V^2}{R}\Rightarrow 100=\frac{(200)^2}{R}\Rightarrow R=\frac{4\times10^4}{10^2}=400\,\Omega$

Now, $i=\frac{V}{R}=\frac{100}{400}=\frac{1}{4}amp$

87. (a, d) $R_{steel}=2R_{Al}$. In series $H\propto R$ (i is Same)

So, H will be more in steel wire . In parallel $H\propto\frac{1}{R}$ (V is Same), so H will be more in aluminium wire.

88. (a) $H=i^2Rt\Rightarrow\frac{H}{t}=i^2R=\frac{i^2\rho l}{\pi r^2}$

89. (b)

90. (a) $H=\frac{V^2}{R}.t\Rightarrow\frac{H_1}{H_2}=\frac{R_2}{R_1}=\frac{R}{2R}=\frac{1}{2}$

91. (b)

92. (a) In parallel $P_{Consumed}\propto P_{Rated}$

93. (b)

94. (a) $P=\frac{V^2}{R}\Rightarrow R=\frac{V^2}{P}=\frac{(220)^2}{40}=1210\,\Omega$

95. (b) $P=Vi\Rightarrow i=\frac{P}{V}=\frac{60}{220}=\frac{3}{11}amp$

96. (a) In series, $P_{Consumed}\propto\frac{1}{P_{Rated}}\propto V_{Applied}$

i.e. more voltage appears on smaller wattage bulb, so 25 *W* bulb will fuse

97. (c) Because in series current is same.

98. (b) $P=\frac{V^2}{R}\Rightarrow\frac{P_1}{P_2}=\frac{R_2}{R_1}\Rightarrow\frac{6}{P_2}=\frac{4}{6}=\frac{2}{3}\Rightarrow P_2=9\,W$

99. (c) $\frac{H}{t}=P=\frac{V^2}{R}\Rightarrow P\propto\frac{1}{R}$ also $R\propto\frac{l}{A}\propto\frac{l^2\rho}{A.l\rho}$

$\Rightarrow R\propto\frac{l^2}{m}\Rightarrow R\propto l^2$ (for same mass)

So $\frac{P_A}{P_B}=\frac{l_B^2}{l_A^2}=\frac{4}{1}\Rightarrow P_A=20\,W$

100. (a) $P=\frac{V^2}{R}\Rightarrow\frac{R_1}{R_2}=\frac{P_2}{P_1}=\frac{60}{40}=\frac{3}{2}$

101. (b) $P\propto V^2\Rightarrow\frac{P}{P_0}=\left(\frac{V}{V_0}\right)^2\Rightarrow P=\left(\frac{V}{V_0}\right)^2P_0$

102. (c) $P=\frac{V^2}{R}\Rightarrow R\propto\frac{1}{P}$

So resistance of the 100 *W* bulb will be minimum

103. (a) In parallel $\frac{1}{t_p}=\frac{1}{t_1}+\frac{1}{t_2}\Rightarrow t_p=\frac{t_1t_2}{t_1+t_2}$

$=\frac{5\times10}{5+10}=\frac{50}{15}=3.33\min=3\,min.\,20\,sec$

104. (a) For maximum joule heat produced in resistor external resistance = Internal resistance.

105. (d)

106. (c) $H=\frac{V^2}{R}t\Rightarrow\frac{H_1}{H_2}=\frac{R_2}{R_1}=\frac{4}{2}=\frac{2}{1}$

107. (a) If resistances of bulbs are R_1 and R_2 respectively then in parallel $\frac{1}{R_P}=\frac{1}{R_1}+\frac{1}{R_2}\Rightarrow$

$\frac{1}{\left(\frac{V^2}{P_p}\right)}=\frac{1}{\left(\frac{V^2}{P_1}\right)}+\frac{1}{\left(\frac{V^2}{P_2}\right)}$

$\Rightarrow P_P=P_1+P_2$

108. (b)

109. (b) When wire is cut into two equal parts then power dissipated by each part is $2P_1$

So their parallel combination will dissipate power $P_2=2P_1+2P_1=4P_1$

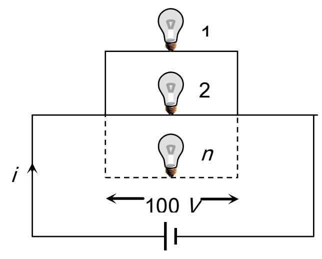
Which gives $\frac{P_2}{P_1}=4$

110. (d) $P=\frac{V^2}{R}\Rightarrow\frac{P_2}{P_1}=\frac{V_2^2}{V_1^2}$ ($\because R$ is constant)

$\Rightarrow\frac{P_2}{P_1}=\left(\frac{100}{200}\right)^2=\frac{1}{4}\Rightarrow P_2=\frac{P_1}{4}=\frac{40}{4}=10\,W$

111. (c) When each bulb is glowing at full power,

Current from each bulb $=i'=\frac{50}{100}=\frac{1}{2}A$



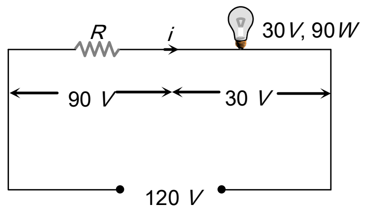
So main current $i=\frac{n}{2}A$

Also $E=V+ir \Rightarrow 120=100+\left(\frac{n}{2}\right)\times 10 \Rightarrow n=4$

112. (b) $R=\frac{V^2}{P}=\frac{(250)^2}{10^3}=62.5\,\Omega$

113. (c) Suppose resistance R is corrected in series with bulb.

Current through the bulb $i=\frac{90}{30}=3\,A$



Hence for resistance $V=iR \Rightarrow 90=3\times R \Rightarrow R=30\,\Omega$

114. (a) $i\propto r^{3/2} \Rightarrow \frac{r_2}{r_1}=\left(\frac{i_2}{i_1}\right)^{3/2}=\left(\frac{3}{1.5}\right)^{2/3}=(4)^{1/3}$

$\Rightarrow r_2=(4)^{1/3}\times r_1=4^{1/3}$ ($\because$ r_1 = 1 *mm*)

115. (c) In series $P'=\frac{P}{n}=\frac{60}{3}=20\,watts$

116. (c) $R=\frac{V^2}{P}=\frac{(220)^2}{60}=807\,\Omega$

117. (d) $\frac{P_1}{P_2}=\left(\frac{V_1}{V_2}\right)^2 \Rightarrow \frac{1000}{P_2}=\left(\frac{220}{110}\right)^2=4 \Rightarrow P_2=250\,W$

118. (a) $P_S=\frac{P_1P_2}{P_1+P_2}=\frac{100\times 200}{100+200}=\frac{200}{3}\approx 65\,watt$

119. (d) $H=\frac{V^2t}{R\times J}Calories=\frac{P\,t}{J}=\frac{210\times 5\times 60}{4.2}=15000\,cal$

120. (c) Using conservation of energy

Supplied electric energy = absorbed heat energy

$\Rightarrow i^2Rt=mST$

$\Rightarrow T\propto i^2$ (T - change in temperature)

i.e. when i is doubled T will be four times *i.e.* $5\times 4=20^oC$

121. (b) Energy $=P\times t$ = 2 × 1 × 30 = 60 *kWH* = 60 unit

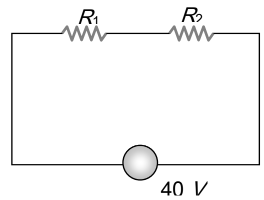
122. (d) Bulb (I) : Rated current $I_1=\frac{P}{V}=\frac{40}{220}=\frac{2}{11}amp.$

Resistance $R_1=\frac{V^2}{P}=\frac{(220)^2}{40}=1210\,\Omega$

Bulb (II) : Rated current $I_2=\frac{100}{220}=\frac{5}{11}amp$

Resistance $R_2=\frac{(220)^2}{100}=484\,\Omega$

When both are connected in series across 40 V supply



Total current through supply

$I=\frac{40}{P_1+P_2}=\frac{40}{1210+484}=\frac{40}{1254}=0.03A$

This current is less than the rated current of each bulb. So neither bulb will fuse.

Short Trick : Since $V_{Applied} < V_{Rated}$, neither bulb will fuse.

123. (a) Both R and $2R$ in parallel (V – constant)

So using $P=\frac{V^2}{R} \Rightarrow \frac{P_1}{P_2}=\frac{R_2}{R_1} \Rightarrow \frac{H_1}{H_2}=\frac{R_2}{R_1}=\frac{2}{1}$

124. (a) Power $P=Vit=250\times 4=1000\,W=1kW$

Energy = $P\times t$ = 1 *kW* × 60 *sec* = 60 *kJ*

125. (a) $P=\frac{V^2}{R} \Rightarrow P\propto \frac{1}{R}$ (V - constant)

$\therefore$ When one bulb will fuse out resistance of the series combination will be reduced.

Hence from $P_{Consumed}\propto \frac{1}{R}$ illumination will increase.

126. (c) $P=\frac{V^2}{R} \Rightarrow R=\frac{V^2}{P}=\frac{25\times 25}{25}=25\,\Omega$

127. (a) $P_{Rated}=\frac{V_{Rated}^2}{R} \Rightarrow R\propto \frac{1}{P_{Rated}}$ (V - constant)

So bulb of high power will have less resistance.

128. (d) $P_{Rated} \propto \frac{1}{R} \Rightarrow \frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{60}{40} = \frac{3}{2}$

129. (a) Energy $= \frac{V^2}{R} \times t = \frac{10 \times 10}{50} \times 3600 = 7200\,J$

130. (c) Energy $\frac{V^2}{R} t = \frac{200 \times 200 \times 2}{80} = 1000\,Wh$

131. (a) Energy $= P \times t = 100 \times 2 \times 60 = 12000\,J = 12 \times 10^3\,J$

132. (c) Heat $H = \frac{V^2 t}{R} \Rightarrow H \propto \frac{1}{R}$ (If *V*, *t* constant)

$\Rightarrow \frac{H_S}{H_P} = \frac{R_P}{R_S} = \frac{\left(\frac{R \times 2R}{3R}\right)}{(R + 2R)} = \frac{2}{9}$

133. (c) $i \propto \frac{1}{R}$ and $P \propto \frac{1}{R} \Rightarrow i \propto P$ *i.e.* in parallel bulb of higher power will draw more current.

134. (c) Resistance of *A* is greater than the resistance of combination of *B* and *C*, hence voltage drop across *A* will be greater than that across *B* or *C*. Also $H = \frac{V^2 t}{R}$

$\Rightarrow H \propto V^2$ so $H_A > (H_B = H_C)$ (*R* = constant)

135. (b) $P = Vi \Rightarrow i = \frac{2.2 \times 10^3}{22000} = \frac{1}{10} A$

Now loss of power $= i^2 R = \left(\frac{1}{10}\right)^2 \times 100$ = 1 *W*

136. (c) $P = \frac{V^2}{R}$. If resistance of heater coil is *R*, then resistance of parallel combination of two halves will be $\frac{R}{4}$

So $\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{R/4}{R} = \frac{1}{4}$

137. (c) Total *kWh* consumed $= \frac{60 \times 8 \times 30}{1000} = 14.4$

Hence cost $= 14.4 \times 1.25 = 18\,Rs$

138. (c) Current capacity of a fuse wire should be slightly greater then the total rated load current.

139. (b)

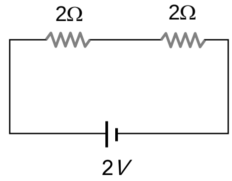
140. (d) Colliding electrons lose their kinetic energy as heat.

141. (a) It is called safe current and is proportional to $r^{3/2}$.

142. (c)

143. (d) $i = \frac{P}{V} = \frac{50}{250} = 0.2\,amp.$

144. (c) In steady state the branch containing capacitors, can be neglected. So reduced circuit is as follows



Power $P = \frac{V^2}{R} = \frac{(2)^2}{4} = 1\,W$.

145. (b) $P = \frac{V^2}{R_{eq}} \Rightarrow 150 = \frac{(15)^2}{[2R/(R+2)]} = \frac{225 \times (R+2)}{2R}$

$\Rightarrow R = \frac{450}{75} = 6\Omega$.

146. (c) $P = \frac{V^2}{R} \Rightarrow \frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{1}{2}$.

147. (c) $H = \frac{V^2 t}{R} \Rightarrow \frac{H_{Half}}{H_{Full}} = \left(\frac{R_{Full}}{R_{Half}}\right) = \frac{R}{R/2} = 2$

$\Rightarrow H_{Half} = 2 \times H_{Full}$.

148. (c) It is given $R_{Hot} = 10\,R_{Cold}$ also resistance at rated temperature $R = \frac{V^2}{P} = \frac{200 \times 200}{100} = 400\,\Omega$.

So resistance when lamp not in use.

$R_{Cold} = \frac{R_{Hot}}{10} = \frac{400}{10} = 40\,\Omega$

149. (a) The chemical energy reduced in battery

$= VIt = 6 \times 5 \times 6 \times 60\,J = 10800\,J = 1.08 \times 10^4\,J$

150. (c) The heat generated = $IVt = 2.1 \times 15 \times 1 = 31.5 J$

$= 31.5/4.2\,cal = 7.5 cal.$ $[\because 1\,cal = 4.2 J]$

151. (a) Resistance $\propto \frac{1}{\text{power}}$. Thus, 40 *W* bulb has a high resistance. Because of which there will be more potential drop across 40 *W* bulb. Thus 40 *W* bulb will glow brighter.

152. (c) When bulbs are connected in series, $P = \frac{V^2}{R'} = \frac{V^2}{3R}$

When bulbs are connected in parallel,

$P' = \frac{V^2}{R''} = \frac{V^2 \times 3}{R} = 3 \times 3P = 9P.$

153. (c) Time $t_S = t_1 + t_2 = 35$ min.

Chemical Effect of Current

1. (d) As sugar cannot be decomposed into ions and ions are responsible for conduction.

2. (c) $\because \frac{Z_1}{Z_2} = \frac{E_1}{E_2} \Rightarrow Z_2 = \left(\frac{E_2}{E_1}\right). Z_1$

3. (d) $\frac{m_{Zn}}{m_{Ag}} = \frac{E_{Zn}}{E_{Ag}} \Rightarrow m_{Ag} = W\left(\frac{E_{Ag}}{E_{Zn}}\right)$ = 3.3 *W* = 3.5 *W*

4. (d) 96500 *coulombs* of charge is needed to deposit one gram equivalent of an element at an electrode.

5. (c) As $\frac{m_{Cu}}{m_{Ag}} = \frac{E_{Cu}}{E_{Ag}} = \frac{\frac{1}{2}(\text{Atomic weight})_{Cu}}{(\text{Atomic weight})_{Ag}}$

6. (d) $V_2 = \frac{22.4 \times 1}{1} = 22.4\, litre$ at NTP

$\because$ 11.2 *litre* of H_2 is liberated by 96,500 *C*

$\therefore$ 22.4 *litre* of H_2 is liberated by 96500 × 2 = 1,93,000 *C*

7. (b) From *m* = *ZQ*, if *Q* = 1*C* ⇒ *m* = *Z*

8. (d)

9. (b) Because *H* has positive charge.

10. (a) Because H_2O is used as electrolyte.

11. (b) $m = Zit \Rightarrow 1 = 0.00033 \times 2 \times t$

$\therefore\ t = \frac{1}{0.00066 \times 60} min = \frac{100000}{3960} \approx 25\, min$

12. (b) $3 = 1.5(1 + r) \Rightarrow r = 1\Omega$

13. (b)

14. (c) $m = Zit = Zq$; $q = \frac{5 \times 10^{-3}}{3.387 \times 10^{-7}} amp\text{-}sec$

or $q = \frac{5 \times 10^{-3}}{3.387 \times 10^{-7} \times 3600} amp\text{-}hr = 4.1$

15. (b) Charge *Q* = *I t* = 1.6 × 60 = 96 *C*

Let *n* be the number of Cu^{+2} ions, then

$ne = Q \Rightarrow n = \frac{Q}{e} = \frac{96}{2 \times 1.6 \times 10^{-19}} = 3 \times 10^{20}$

16. (a) In the first case, $Zit = m$

In the second case, $Z \times \frac{i}{4} \times 4t = m$

17. (b) $\frac{\text{Mass of } O_2 \text{ ions}}{\text{Mass of } Ag \text{ ions}} = \frac{\text{Chemical equivalent of } O_2}{\text{Chemical equivalent of } Ag}$

$\Rightarrow \frac{0.8}{m} = \frac{8}{108} \Rightarrow m = 10.8\, gm$

18. (c)

19. (a) $F = Ne = 6 \times 10^{23} \times 1.6 \times 10^{-19}$

20. (d) Since 1 *faraday* deposits 1 *gm* equivalent.

21. (c) Equivalent weight of copper $= \frac{64}{2} = 32$

$\frac{\text{Equivalent weight of } Cu}{\text{Equivalent weight of } Ag} = \frac{\text{Weight of } Cu \text{ deposited}}{\text{Weight of } Ag \text{ deposited}}$

Weight of copper deposited $= \frac{10.8 \times 32}{108} = 3.2gm$

22. (b)

23. (c)

24. (a) $m \propto q \Rightarrow m \propto it$

25. (d) Equivalent weight of aluminium $= \frac{27}{3} = 9$

So 1 *faraday* = 96500 *C* are required to liberate 9 *gm* of *Al*.

26. (b) By Faraday's law, $m \propto it$.

$\therefore\ \frac{m_1}{m_2} = \frac{i_1 t_1}{i_2 t_2} \Rightarrow \frac{m}{m_2} = \frac{4 \times 120}{6 \times 40} \Rightarrow m_2 = \frac{m}{2}$

27. (a) $m \propto it$

28. (c) Amount of metallic sodium appears

$m = Zit = \left(\frac{A}{VF}\right) it$

$= \left(\frac{23}{1 \times 96500}\right) \times 16 \times 10 \times 60$ =2.3 *gm*

29. (a)

30. (a) $m = Zit \Rightarrow Z = \frac{m}{it} = \frac{4.572}{5 \times 45 \times 60} = 3.387 \times 10^{-4}\, gm/C$

31. (b) Faraday constant = 1 mole electron charge = *Ne*

$= 6.02 \times 10^{23} \times 1.6 \times 10^{-19} = 96500$

32. (d) $m = Zit = 0.126 \times 10^{-3} \times 5 \times 3600 = 2.27\, gm$

33. (b) $\frac{m_1}{m_2} = \frac{E_1}{E_2}$ (By faraday law for same current and time)

Where E_1 and E_2 are the chemical equivalents and m_1 and m_2 are the masses of copper and silver respectively.

$E = \frac{\text{Atomic weight}}{\text{Valency}}$. $E_1 = \frac{63.57}{2} = 31.79$ and

$E_2 = \frac{107.88}{1} = 107.88$

$\therefore\ \frac{1\, mg}{m_2} = \frac{31.79}{107.88} \Rightarrow m_2 = \frac{107.88}{31.79} mg = 3.4\, mg$

34. (a) $m = Zit \Rightarrow \frac{m}{Zit} = 1(\text{constant})$

35. (b) Positive ions get deposited on cathode.

36. (c) $m = Zit$ or $m \propto it$

$\therefore \frac{m_1}{m_2} = \frac{i_1t_1}{i_2t_2} \Rightarrow \frac{9}{m_2} = \frac{10^5}{50 \times 20 \times 60} \Rightarrow m_2 = 5.4\ gm$

37. (c) Electroplating only provides a thin deposition of a metal on the surface which in no way can give hardness to the metal.

38. (b)

39. (d) $m = Zit \Rightarrow \frac{m_{Cu}}{m_{Zn}} = \frac{Z_{Cu}}{Z_{Zn}}$

$m_{Cu} = m_{Zn}\frac{Z_{Cu}}{Z_{Zn}} = 0.13 \times \frac{31.5}{32.5} = 0.126\ g$

40. (b) $m = Zit \Rightarrow m = \frac{ZVt}{R} \Rightarrow m \propto Vt \Rightarrow \frac{m_1}{m_2} = \frac{V_1t_1}{V_2t_2}$

$\Rightarrow \frac{2}{m_2} = \frac{12 \times 30}{6 \times 45} \Rightarrow m_2 = 1.5\ gm$

41. (c) $i = \frac{m}{Zt} = \frac{0.972}{0.00018 \times 3 \times 3600} = 0.5\ A$

42. (b) The current through the voltameter is same as drawn from the battery outside it.

43. (d) The resistance of the cell is independent of e.m.f.

44. (a) $m = Zit = 3.3 \times 10^{-7} \times 3 \times 2 = 19.8 \times 10^{-7} kg$

45. (c) $m = zq$, z = atomic mass / valence

46. (c)

47. (a)

48. (b) 1 faraday (96500*C*) is the electricity which liberated that amount of substance which is equal to equivalent wt. So liberated amount of *Cu* is $\frac{63.5}{2}$ $= 31.25\ gm \approx 32\ gm$

49. (b) $m = Zit \Rightarrow 20 \times 10^{-3} = \left(\frac{32}{96500}\right) \times 0.15 \times t$

$= 6.7\ min = 6\ min.42\ sec$

50. (b) 22.4 *litre* H_2 = 1 mole H_2 = *N* molecules of H_2

= 2*N* atom of *H*

So charge required to liberate 22.4 *litre* of H_2 = 2*Ne* = 2*F*

Hence charge required to liberate 0.224 *litre* of H_2

$= \frac{2F}{22.4} \times 0.224 = \frac{2F}{100} = 2 \times 965\ C$

So current $i = \frac{Q}{t} = \frac{2 \times 965}{100} = 19.3\ amp$

51. (a)

52. (d) $m = Zit \Rightarrow Z = \frac{m}{it} = \frac{4.5}{4 \times 40 \times 60} = 47 \times 10^{-5}\ g/C$

53. (d) Charge supplied per minute = 3.2 × 60 = 192 *C*

Charge 2*e* liberates one Cu^{+2} ion

$\therefore$ No of Cu^{+2} ion liberate by 192 *C*

$= \frac{192}{2e} = \frac{192}{2 \times 1.6 \times 10^{-19}} = 6 \times 10^{20}$

54. (a) $m = Zit \Rightarrow i = \frac{m}{Zt} = \frac{0.99}{0.00033 \times 1200} = 2.5A$

Hence heat generated in the coil is

$H = i^2Rt = (2.5)^2 \times 0.1 \times 1200$ = 750 *J*

55. (c) $\frac{m_1}{m_2} = \frac{Z_1}{Z_2} \Rightarrow m_2 = \frac{m_1Z_2}{Z_1} = \frac{14 \times 1.2 \times 10^{-6}}{7 \times 10^{-6}}$ = 2.4 *g*

56. (c) $m = Zit \Rightarrow t = \frac{m}{Zi} = \frac{m \times F}{E \times i}$ $\left(\because Z = \frac{E}{F}\right)$

$t = \frac{27 \times 96500}{108 \times 2} = 12062.5\ \sec = \frac{12062.5}{3600}hr = 3.35\ hr$

57. (d) $m = zq \Rightarrow z \propto \frac{1}{q} \Rightarrow \frac{z_1}{z_2} = \frac{q_2}{q_1}$ ......(i)

also $q = q_1 + q_2 \Rightarrow \frac{q}{q_2} = \frac{q_1}{q_2} + 1$

$\Rightarrow q_2 = \frac{q}{1 + \frac{q_1}{q_2}}$ ......(ii)

From equation (i) and (ii) $q_2 = \frac{q}{1 + \frac{z_2}{z_1}}$

58. (c) From Faraday's law, *m/E* = constant

where *m* = mass of substance deposited, *E* = chemical equivalent.

$\therefore \frac{m_2}{m_1} = \frac{E_2}{E_1} \Rightarrow m_2 = \frac{108}{32} \times 1.6 = 5.4g$

59. (a) $q = it = \text{current} \times \text{time}$

Thermo-Electricity

1. (b) Production of e.m.f. by temperature difference is known Seeback effect.

2. (c) Production of heat at junctions due to current is known as Peltier effect.

3. (d)

4. (a)

5. (c) When there is no deflection, then this temperature is called inversion temperature. It is given by the relation

$\theta_n = \frac{\theta_i + \theta_c}{2}$

Where θ_c is temperature of cold junction $= 20^o C$ and neutral temperature $\theta_n = 270^o C$

$\therefore\ \theta_i = 2\theta_n - \theta_c = 540 - 20 = 520^o C$

6. (b)

7. (a) Thermo e.m.f. of a thermo couple depends on the nature of metals.

8. (a)

9. (a) According to the definition.

10. (a) $T_n = \frac{T_i + T_C}{2} \Rightarrow T_i = 2T_n - T_C$

11. (a)

12. (d)

13. (b) Based on Peltier effect.

14. (c) Peltier effect

15. (b) Thermopile is used for detection of heat radiation and measurement.

16. (b) $H = \sigma i t \Delta\theta \Rightarrow$ If i = 1 A, $\Delta\theta$ = 1°C, t = 1 *sec* then $H = \sigma$.

17. (a) According to Seebeck effect

18. (a) At neutral temperature, $\frac{dE}{dT} = 0$

19. (a) According to Seebeck effect.

20. (b)

21. (d)

22. (a) As a rule, more the metals are separated from each other in the thermoelectric series, the greater will be the thermo *emf.*

23. (b) $T_n = \frac{T_i + T_c}{2} = \frac{10 + 530}{2} = 270^o C$

24. (a) Joule effect is not reversible.

25. (b)

26. (c)

27. (c) The graph between thermo *emf* and temperature of hot junction is parabolic in shape.

28. (d) At neutral temperature E is maximum so

$\frac{dE}{dt} = 0 \Rightarrow \frac{d}{dt}(At - Bt^2) = 0 \Rightarrow A - 2Bt = 0 \Rightarrow t = \frac{A}{2B}$

29. (c) $t_n = \frac{t_1 + t_c}{2} \Rightarrow 280 = \frac{t_i + 15}{2} \Rightarrow t_i = 545^o C$

30. (a)

31. (a) A is false because at neutral temperature thermo emf is maximum. B is true.

32. (b) Thermo-electric power $P = \frac{dE}{d\theta}$; at t_n, $E \rightarrow$ maximum. So $P \rightarrow$ zero.

33. (d) By using $H = \sigma Q \theta$

$\Rightarrow\ H = (10 \times 10^{-6}) \times 10 \times (60 - 50) = 10^{-3} J = 1\ mJ$

34. (c) No change in neutral temperature but temperature of inversion is $t_i = 2t_n - t_c \Rightarrow t_i = 2 \times 270 - 40 = 500^o C$

35. (c)

36. (d) $t_i = 2t_n - t_c \Rightarrow t_i = 2 \times 350 - 30 = 670^o C$

37. (c)

38. (d) Neutral temperature is independent of temperature of cold junction.

39. (d)

40. (a) $E = at + bt^2$ at inversion temperature E will be minimum

Thus $\frac{dE}{dt} = 0 \Rightarrow \frac{d}{dt}[at + bt^2] = 0$

$\Rightarrow a + 2bt = 0 \Rightarrow t = -\frac{a}{2b}$

41. (d)

42. (a) $i = \frac{e}{R} \Rightarrow 3 \times 10^{-7} = \frac{(30 \times 10^{-6}) \times \theta}{50} \Rightarrow \theta = 0.5°$

43. (b) $t_n = \frac{\alpha}{\beta} = \left(\frac{500}{5}\right) = 100\,°C$

Also $t_n = \frac{t_i + t_c}{2} \Rightarrow 100 = \frac{t_i + 0}{2} \Rightarrow t_i = 200\,°C$

44. (b) At neutral temperature, thermal emf will be maximum.

$\therefore \frac{de}{dt} = a + bt$

For maximum or minima, $a + bt_n = 0$

$\therefore\ t_n = -a/b$

Critical Thinking Questions

1. (d) $P_1 = \frac{(220)^2}{R_1}$ and $P_2 = \frac{(220 \times 0.8)^2}{R_2}$

$\frac{P_2}{P_1} = \frac{(220\times 0.8)^2}{(220)^2}\times\frac{R_1}{R_2} \Rightarrow \frac{P_2}{P_1} = (0.8)^2\times\frac{R_1}{R_2}$ Here $R_2 < R_1$

(because voltage decreases from 220 $V \rightarrow$ 220 × 0.8 V

It means heat produced → decreases)

So $\frac{R_1}{R_2} > 1 \Rightarrow P_2 > (0.8)^2 P_1 \Rightarrow P_2 > (0.8)^2\times 100\,W$

Also $\frac{P_2}{P_1} = \frac{(220\times 0.8)i_2}{220\,i_1}$, Since $i_2 < i_1$ (we expect)

So $\frac{P_2}{P_1} < 0.8 \Rightarrow P_2 < (100\times 0.8)$

Hence the actual power would be between $100\times(0.8)^2 W$ and (100 × 0.8) W

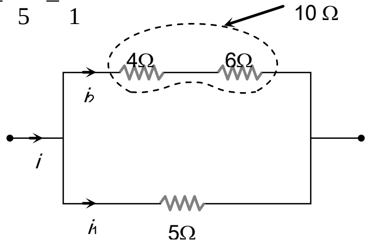
2. (b) $W = JH \Rightarrow P\times t = J\times m\,s\,\Delta\theta$

$\Rightarrow t = \frac{J\times m\times s\Delta\theta}{P}$ (For water 1 *litre* = 1*kg*)

$\Rightarrow t = \frac{4.2\times 1\times 1000\times(40-10)}{836} = 150\,sec$

Short Trick : use formula $t = \frac{4200\times m\times\Delta\theta}{P}$

3. (b) $\frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{10}{5} = \frac{2}{1}$



Also heat produced per sec *i.e.* $\frac{H}{t} = P = i^2R$

$\Rightarrow \frac{P_5}{P_4} = \left(\frac{i_1}{i_2}\right)^2\times\frac{5}{4} = \left(\frac{2}{1}\right)^2\times\frac{5}{4} = \frac{5}{1} \Rightarrow P_4 = \frac{10}{5} = 2\,cal/s$

4. (d) $220\times 9 = n(60) \Rightarrow n = 33$

5. (c) $H = \frac{V^2}{R}t$

Since supply voltage is same and equal amount of heat will produce, therefore

$\frac{R_1}{t_1} = \frac{R_2}{t_2}$ or $\frac{R_1}{R_2} = \frac{t_1}{t_2}$ .....(i)

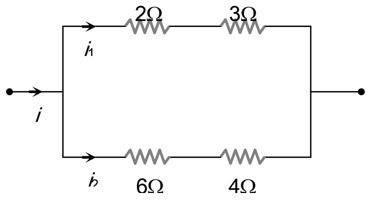
But $R \propto l \Rightarrow \frac{R_1}{R_2} = \frac{l_1}{l_2}$ .....(ii)

By (i) and (ii), $\frac{l_1}{l_2} = \frac{t_1}{t_2}$ .....(iii)

Now $l_2 = \frac{2}{3}l_1 \Rightarrow \frac{l_1}{l_2} = \frac{3}{2}$

∴ By equation (iii), $\frac{3}{2} = \frac{15}{t_2} \Rightarrow t_2 = 10$ *minutes*

6. (d)



Resistance of upper branch $R_1 = 2+3 = 5\,\Omega$

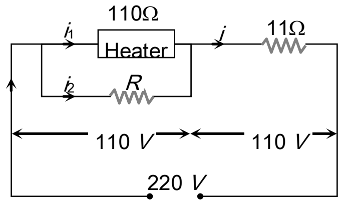
Resistance of lower branch $R_2 = 4+6 = 10\,\Omega$

Hence $\frac{i_1}{i_2} = \frac{R_2}{R_1} = \frac{10}{5} = 2$

$\frac{\text{Heat generated across } 3\,\Omega(H_1)}{\text{Heat generated across } 6\,\Omega(H_2)} = \frac{i_1^2\times 3}{i_2^2\times 6} = \frac{4}{2} = 2$

∴ Heat generated across 3 Ω = 120 *cal/sec*

7. (a) Power consumed by heater is 110 W so by using $P = \frac{V^2}{R}$



$110 = \frac{V^2}{110} \Rightarrow V = 110\,V$. Also from figure

$i_1 = \frac{110}{110} = 1A$ and $i = \frac{110}{11} = 10\,A$. So $i_2 = 10-1 = 9\,A$

Applying *Ohms* law for resistance *R*, *V= iR*

$\Rightarrow 110 = 9\times R \Rightarrow R = 12.22\,\Omega$

8. (c) $P_{consumed} = \left(\frac{V_A}{V_R}\right)^2\times P_R = \left(\frac{110}{115}\right)^2\times 500 = 457.46\;W$

So, percentage drop in power output

$= \frac{(500-457.46)}{500}\times 100 = 8.6\%$

9. (d) Heat produced $= \frac{V^2}{R}t$

i.e. when voltage is halved, heat produced becomes one-fourth. Hence time taken to heat the water becomes four times.

10. (b) Electric power consumed by kettle $P = 220 \times 4\,W$

Heat required

$H = 1000 \times 1(100 - 20) = 1000 \times 80\ cal = 4200 \times 80\ J$

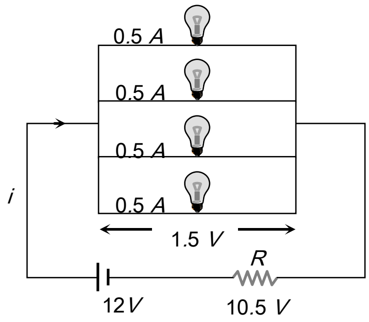
$P = \frac{H}{t} \Rightarrow H = P \times t$

$\therefore\ 220 \times 4 \times t = 4200 \times 80 \Rightarrow\ t = 6.3$ *minutes*

11. (c) $H = \frac{V^2}{R} \times t = \frac{(210)^2}{20} \times 1 = mL$

$\therefore\ \frac{(210)^2}{20} = m \times 80 \times 4.2 \Rightarrow\ m = 6.56\ g/s$

12. (b) For normal brightness of each bulb see following circuit. Current through each bulb = 0.5 *A*



So main current $i = 2A$

Also, voltage across the combination $= 1.5\,V$

So voltage across the resistance $= 10.5\,V$

Hence for resistance $V = iR\ \ \Rightarrow 10.5 = 2 \times R$

$\Rightarrow R = \frac{21}{4}\Omega$

13. (d) $P = \frac{V^2}{R}$ so $R = \frac{V^2}{P} \Rightarrow R_1 = \frac{V^2}{100}$ and $R_2 = R_3 = \frac{V^2}{60}$

Now $W_1 = \frac{(250)^2}{(R_1 + R_2)^2}.R_1$, $W_2 = \frac{(250)^2}{(R_1 + R_2)^2}.R_2$

and $W_3 = \frac{(250)^2}{R_3}$

$W_1 : W_2 : W_3 = 15 : 25 : 64$ or $W_1 < W_2 < W_3$

14. (a) Power dissipated $\propto\ R_{\text{equivalent}}$

15. (a) The current taken by the silver voltameter

$I_1 = \frac{m}{Zt} = \frac{1}{11.2 \times 10^{-4} \times 30 \times 60} = 0.496\ A$

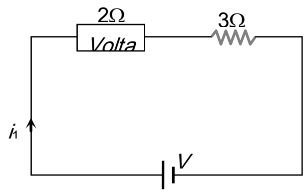
and by copper voltameter

$I_2 = \frac{1.8}{6.6 \times 10^{-4} \times 30 \times 60} = 1.515\ A$

Total current $I = (I_1 + I_2) = 2.011\ A$

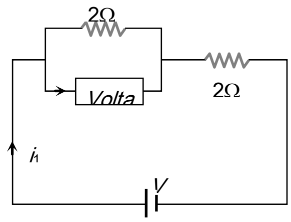
Power $P = IV = 2.011 \times 12 = 24.132\ J/\text{sec}$

16. (d) Initially current through the voltameter $i_1 = \frac{V}{(3+2)} = \frac{V}{5}$



Finally main current $i = \frac{V}{3+1} = \frac{V}{4}$

Hence current through voltameter $i_2 = \frac{V}{8}$



$\because$ Rate of deposition $(R) = \frac{m}{t} = Zi \Rightarrow R \propto i$

$\therefore$ % drop in rate $= \frac{R_2 - R_1}{R_1} \times 100 = \frac{i_2 - i_1}{i_1} \times 100$

$= \frac{\left(\frac{V}{8} - \frac{V}{5}\right)}{\frac{V}{5}} \times 100 = -37.5\%$

17. (d) Comparing the given equation with standard equation

$E = \alpha t + \frac{1}{2}\beta t^2$

$\alpha = 40$ and $\frac{1}{2}\beta = -\frac{1}{20} \Rightarrow \beta = -\frac{1}{10}$

Hence neutral temperature $t_n = -\frac{\alpha}{\beta} = \frac{-40}{-1/10}$

$\Rightarrow t_n = 400^o C$

18. (a) Comparing the given equation with standard equation $E = \alpha t + \frac{1}{2}\beta t^2$, we get $\alpha = 14$ and $\frac{1}{2}\beta = -0.02$

$\Rightarrow \beta = -0.04$

Hence neutral temperature $t_n = -\frac{\alpha}{\beta} = -\frac{14}{-0.04} = 350°C$

19. (a) We know that thermoelectric power $S = \frac{dE}{dT}$

Given $E = k(T - T_r)\left[T_0 - \frac{1}{2}(T + T_r)\right]$

By differentiating the above equation *w.r.t.* T and

Putting $T = \frac{1}{2}T_o$, we get $S = \frac{1}{2}kT_o$

20. (b) Comparing the given equation with $E = \alpha t + \frac{1}{2}\beta t^2$

We get $\alpha = 16$ and $\frac{1}{2}\beta = -0.04 \Rightarrow \beta = -0.08$

$\Rightarrow t_n = -\frac{\alpha}{\beta} = -\frac{16}{-0.08} = 200°C$

Also $t_i = 2t_n - t_c \Rightarrow t_i = 2\times(200) - 0 = 400°C$

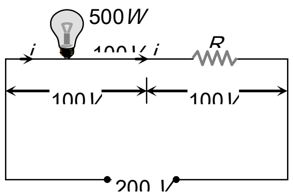
21. (c) $m = Zit \Rightarrow 20\times10^{-3} = \left(\frac{32}{96500}\right)\times 0.15\times t$

$= 6.7 min = 6 min. 42 sec.$

22. (b) $e = iR \Rightarrow 25\times10^{-6}\times\Delta\theta = 10^{-5}\times 40$

$\Delta\theta = \frac{40\times10^{-5}}{25\times10^{-6}} = \frac{400}{25} = 16°C$

23. (b)



Rated current through the circuit $i = \frac{500}{100} = 5A$

Potential difference across R, $100 = 5\times R \Rightarrow R = 20\,\Omega$

24. (b) By using $e_0^{100} = e_0^{32} + e_{32}^{70} + e_{70}^{100}$

$\Rightarrow 200 = 64 + 76 + e_{70}^{100} \Rightarrow e_{70}^{100} = 60\,\mu V$

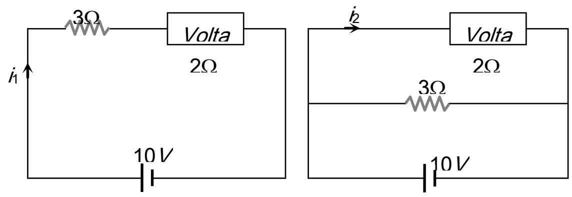
25. (d) In the normal condition current flows from X to Y through cold. While after increasing the temperature of hot junction beyond temperature of inversion. The current is reversed *i.e.* X to Y through hot junction or Y to X through cold junction.

26. (a) $H = \pi it = (2\times10^{-9})\times 2.5\times(2\times60) = 6\times10^{-7}\ J = 6\,erg$

27. (b) Remember mass of the metal deposited on cathode depends on the current through the voltameter and not on the current supplied by the battery. Hence by using $m = Zit$, we can say $\frac{m_{Parallel}}{m_{Series}} = \frac{i_{Parallel}}{i_{Series}}$

$\Rightarrow m_{Parallel} = \frac{5}{2}\times 1 = 2.5\ gm.$

Hence increase in mass = 2.5 – 1 = 1.5 *gm*



28. (c) Mass deposited $m = \text{Density}\times\text{Volume of the metal}$

$\Rightarrow m = \rho\times Ax$. Also $m = Zit$, so $Zit = \rho Ax$

$\Rightarrow x = \frac{Zit}{A\rho} = \frac{0.00033\times10^{-3}\times1.5\times20\times60}{(50\times10^{-4})\times9000} = 1.3\times10^{-5}\ m$

29. (a) $i = \frac{m}{Zt} = \frac{2.0124}{1.118\times10^{-3}\times3600} = 0.5\ A$

$\Rightarrow$ Error $= 0.54 - 0.5 = 0.04\ A$

30. (b) Total charge supplied $= 1\times10 = 10\,C$

$\because$ 2 electronic charge $(3.2\times10^{-19}\,C)$ liberates one Cu^{++} ion

$\therefore$ Number of Cu^{++} ions liberated by 10 C charge

$= \frac{1}{3.2\times10^{-19}}\times10 = 3.1\times10^{19}$

31. (d) $\because\ m = Zit$ or $i = \frac{m}{Zt}$

For silver voltmeter

$$i_1 = \frac{m_1}{Z_1 t} = \frac{2}{1.118\times10^{-3}\times1800} = 0.994\ amp$$

For copper voltameter

$$i_2 = \frac{m_2}{Z_2 t} = \frac{1}{3.294\times10^{-4}\times1800} = 1.687\ amp$$

$\therefore$ Power of circuit $= V(i_1 + i_2) = 6\times(0.994+1.687)$

$= 6\times2.681 \approx 16\ W$

32. (a) Let the temperature of molten metal is $t^o C$.

The thermo-emf $e = 10\times10^{-6}\,t\ volt$

Current in the circuit

$$i = \frac{e}{R+R_G} = \frac{10^{-5}t}{8+1.6} = \frac{10^{-5}t}{9.6}\,amp.$$

But $i = \frac{V}{R_G} = \frac{8\times10^{-3}}{8}$

$\therefore \frac{10^{-5}t}{9.6} = \frac{8\times10^{-3}}{8}$ or $t = \frac{9.6\times10^{-3}}{10^{-5}} = 960^o C$

33. (a) $\because$ Peltier coefficient $\pi = T\frac{de}{dT}$ and $t^o C = T - 273$

$\therefore e = a(T-273) + b(T-273)^2$

Differentiating *w.r.t.* T $\frac{de}{dT} = a + 2b(T-273)$

$\pi = T\frac{de}{dT} = T[a+2b(T-273)] \Rightarrow \pi = (t+273)(a+2bt)$

34. (d) $\frac{Q}{t} = \frac{V^2}{4.2\ R} = \frac{m}{t}.L$

$\therefore \frac{m}{t} = \frac{V^2}{4.2\ RL} = \frac{(210)^2}{4.2\times50\times80} \approx 2.625\ gm$

35. (d) $H = i^2RT = i^2\left(\frac{\rho l}{A}\right)t = \frac{i^2\rho Vt}{A^2}$ (V = volume, = *Al*)

$\Rightarrow H \propto \frac{1}{r^4} \Rightarrow \frac{H_1}{H_2} = \left(\frac{r_2}{r_1}\right)^4 = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$.

36. (d) Thermoelectric power $P \propto \theta$

$\Rightarrow \frac{P_{100} - P_{80}}{P_{80}}\times100 = \frac{100-80}{80}\times100$ = 25%

37. (d) The sensitivity of the thermocouple will be

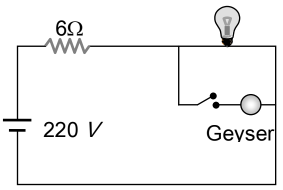
$= 500\mu V/^o C - (-72\mu V/^o C) = 572\mu V/^o C$

Therefore for a $100^o C$ temperature difference, the thermo e.m.f. will be

$E = 572\times10^{-6}\times100(volt) = 57.2\times10^{-3} = 57.2\ mV.$

38. (d) At cold junction, current flows from copper to nickel and from iron to copper, and at hot junction from nickel to iron, thus the contributions add.

39. (b) $R_{Bulb} = \frac{220^2}{100} = 484\ \Omega$, $R_{Geyser} = \frac{220^2}{1000} = 48.4\ \Omega$



(i) When only bulb is ON, $V_{Bulb} = \frac{220\times484}{490} = 217.4\ V$

(ii) When geyser is also switched ON, equivalent resistance of bulb and geyser is $R = \frac{484\times48.4}{484+48.4} = 44\ \Omega$

Voltage across the bulb $V_{Bulb} = \frac{220\times44}{50} = 193.6\ V$

Hence the potential drop is $217.4 - 193.6 = 23.8\ V$

40. (b) $i = \frac{24-12}{3} = 4\ A$, Time of charging $t = \frac{360`}{V.i}$

$\Rightarrow t = \frac{360}{12\times4} = 7.5\ hours.$

41. (a) $I = \frac{m}{Zt} = \frac{2.68}{\frac{108}{96500}\times10\times60} = \frac{2.68}{108}\times\frac{965}{6} \approx 4\ A$

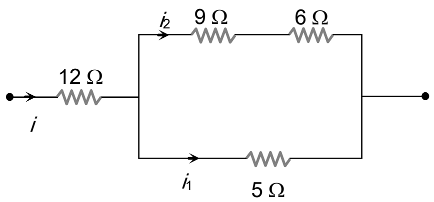
Energy $= I^2Rt = 4^2\times20\times600 = 192\ kJ.$

42. (d) Comparing with standard equation $E = \alpha t + \frac{1}{2}\beta t^2$

α = *a* and β = 2*b* $\Rightarrow t_n = -\frac{a}{2b} = -\frac{1}{2}\times700 = -350^o C$

This is not possible.

43. (b) $\frac{i_1}{i_2} = \frac{15}{5} = \frac{3}{1}$ … (i)



Also $\frac{H}{t} = i^2 R \Rightarrow 45 = (i_1)^2 \times 5$

$\Rightarrow i_1 = 3\,A$ and from equation (i) $i_2 = 1\,A$

So $i = i_1 + i_2 = 4\,A$

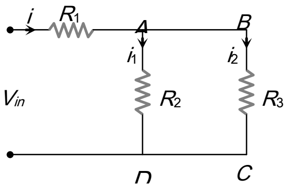
Hence power developed in $12\,\Omega$ resistance

$P = i^2 R = (4)^2 \times 12 = 192\,W$

44. (a) Heat gained by water = Heat supplied by container - heat lost $\Rightarrow$ $mS\Delta\theta$ = 1000*t* – 160*t*

$\Rightarrow t = \frac{2 \times 4.2 \times 1000 \times 50}{840}$ = 8 *min* 20 *sec*

45. (c) As the voltage in R_2 and R_3 is same therefore, according to,



$H = \frac{V^2}{R}.t, \ R_2 = R_3$

Also the energy in all resistance is same.

$\therefore \quad i^2 R_1 t = i_1^2 R_2 t$

Using $i_1 = \frac{R_3}{R_2 + R_3} i = \frac{R_3}{R_3 + R_3} i = \frac{1}{2} i$

Thus $i^2 R_1 t = \frac{i^2}{4} R_2 t$ or, $R_1 = \frac{R_2}{4}$

Graphical Questions

1. (b) Area = *it* = 2 *Coulomb* and $m = zit \Rightarrow z = \frac{m}{it} = \frac{m}{2}$

2. (d) $U \propto i^2$, hence the graph between *U* and *i* is parabolic in nature and should be above graph (*b*).

3. (d) $E = \alpha t + \frac{1}{2} \beta t^2$, graph between *E* and *t* will be a parabola, such that first emf increases and then decreases.

4. (a) Thermo electric power $P = \frac{dE}{d\theta} = \alpha + \beta\theta$

Comparing it with $y = mx + c$, option (a) is correct.

5. (b) The filament of the heater reaches its steady resistance when the heater reaches its steady temperature, which is much higher than the room temperature. The resistance at room temperature is thus much lower than the resistance at its steady state. When the heater is switched on, it draws a larger current than its steady state current. As the filament heats up, its resistance increases and current falls to steady state value.

6. (a) *Cu* voltameter with soluble electrodes obeys ohms law. In water voltameter, in the beginning when *V* is small $(< 1.7\,volt)$, very little current flows, the voltameter does not obey ohms law. As soon as *V* exceeds 1.7 *volt* (back e.m.f.) the current increases steadily according to ohms law.

7. (d) Thermal energy in resistor is $U = i^2 Rt$

where $R = R_0(1 + \alpha t) \Rightarrow U = i^2 R_0 (1 + \alpha t) t = i^2 R_0 t + i^2 R_0 t^2$

So $\frac{dU}{dt} = i^2 R_0 (1 + \alpha t)$

With the time temperature increases, hence dU/dt increases. This is best shown by curve (*d*).

8. (b) $m = Zi\,t$ and $i\,t$ = Area of given curve

= Area of triangle + Area of rectangle

$\Rightarrow i\,t = \frac{1}{2} \times (2 \times 60) \times 1 + (6 - 2) \times 60 \times 1 = 300$

$\therefore \ Z = \frac{m}{i\,t} = \frac{m}{300}$

9. (d) Terminal voltage $V = E - Ir$. Hence the graph between *V* and *i* will be a straight line having negative slope and positive intercept.

Thermal power generated in the external circuit

$P = EI - I^2 r$. Hence graph between *P* and *I* will be a parabola passing through origin.

Also at an instant, thermal power generated in the cell = $i^2 r$ and total electrical power generated in the cell = *Ei*. Hence the fraction $\eta = \frac{I^2 r}{EI} = \left(\frac{r}{E}\right) I$; so

$\eta \propto I$. It means graph between η and I will be a straight line passing through origin.

Assertion and Reason

1. (a) The possibility of an electric bulb fusing is higher at the time of switching ON and switching OFF because inductive effect produces a surge at the time of switching ON and OFF.

2. (a) The resistance, $R = \frac{V^2}{P} \Rightarrow R \propto 1/P$

i.e., higher is the wattage of a bulb, lesser is the resistance and so it will glow bright.

3. (c) Assertion is true but reason is false. Fuse wire must have high resistance because in series current remains same, therefore according to Joule's law $H = \frac{i^2 Rt}{4.2}$, heat produced is high if *R* is high. The melting point must be low so that wire may melt with increase in temperature. As the current equal to maximum safe value, flows through the fuse wire, it heats up, melts and break the circuit.

4. (a) Resistance of 50 *W* bulb is two times the resistance of 100 *W* bulb. When bulbs are connected in series, 50 *W* bulb will glow more as $P = i^2 R$ (current remains same in series). In parallel the 100 *W* bulb will glow more as $P = V^2 / R$ (potential difference remain same in parallel).

5. (d) When two bulbs are connected in series, the resistance of the circuit increases and so the voltage in each decreases, hence the brightness and the temperature also decreases. Due to decrease in temperature, the resistance of the carbon filament will slightly increase while that of metal filament will decrease. Hence, carbon filament bulb will glow more brightly $(P = i^2 R)$. Also carbon is not a semiconductor.

6. (e) Voltage of dc source is constant but in ac, peak value of voltage is $\sqrt{2}$ times the *rms.* voltage. Hence bulb will glow with more brightness when connected to an ac source of the same voltage.

7. (a) When cold water is poured on half portion of the wire, its resistance decreases due to decrease in temperature. As a result of this total resistance of circuit decreases *i.e.* current through each portion of wire increases *i.e.* rest of the half portion becomes still more hot.

8. (a) As filament of bulb and line wire are in series, hence current through both is same. Now, because $H = \frac{i^2 Rt}{4.2}$ and resistance of the filament of the bulb is much higher than that of line wires, hence heat produced in the filament is much higher than that in line wires.

9. (b) Neutral temperature is the temperature of hot junction, at which the thermo e.m.f. produced in the thermocouple becomes maximum. It is independent of cold junction and depends on the nature of materials of two metals used to form thermocouple.

10. (d) Because of heat production every resistance has a maximum power rating, the maximum power that can be dissipated without overheating the device. When this rating is exceeded, heat is produced, due to which resistance may change unpredictably.

11. (a) The e.m.f. of a Leclanche cell falls, because of the partial polarisation due to accumulation of hydrogen gas. In case, Leclanche cell is used in experiment, where current is drawn after short breaks, then during each break, hydrogen gas escapes and

Mn_2O_3 converts into MnO_2 by taking oxygen from the atmosphere. As a result, the cell regains its original e.m.f.

12. (a) When lamp *B* or *C* gets fused equivalent resistance of *B* and *C* increases. In series voltage distributes in the ratio of resistance, so voltage appears across *B* increases or in other words voltage across *A* decreases.

13. (d) When switch *S* is closed, bul*b C* is short circuited, so voltage *V* distributes only in two parts *i.e.* voltage on Bulb *A* and *B* increases as compared previously. Hence illumination of Bulb *A* and *B* increases.

14. (a)

15. (c) The electrical appliances with metallic body like heater, press *etc*. have three pin connections. Two pins are for supply line and third pin is for earth connection for safety purposes.

16. (c) A laser beam is a beam of light which is light amplification by stimulated emission of radiation.

The energy per unit area of the laser beam is very high as compared to the torch light.

17. (a) Follow hint of question 15 of this section.

18. (c) Thomson e.m.f. in lead is practically zero.

19. (b) The presence of water molecules reduces force between ions by $1/81$ times because the value of dielectric constant of water is 81. That is why the separation between ions becomes easier.

20. (b) Here reason is not the correct explanation of the assertion, which is correct.

21. (d) Here assertion and reason are not correct.

Heating and Chemical Effect of Current

SET Self Evaluation Test -20

1. An electric kettle has two coils. When one of these is switched on, the water in the kettle boils in 6 minutes. When the other coil is switched on, the water boils in 3 minutes. If the two coils are connected in series, the time taken to boil the water in the kettle is

(a) 3 *minutes* (b) 6 *minutes*
(c) 2 *minutes* (d) 9 *minutes*

2. A $3°$ rise in temperature is observed in a conductor by passing a certain current. When the current is doubled, the rise in temperature will be

(a) $15°C$ (b) $12°C$
(c) $9°C$ (d) $3°C$

3. Two indentical electric lamps marked 500 *W*, 220 *V* are connected in series and then joined to a 110 *V* line. The power consumed by each lamp is

(a) $\frac{125}{4}W$ (b) $\frac{25}{4}W$
(c) $\frac{225}{4}W$ (d) 125 *W*

4. When 1 *gm* hydrogen $(e.c.e. = 1.044\times10^{-8} kg/C$ forms water, 34 *kcal* heat is liberated. The minimum voltage required to decompose water is

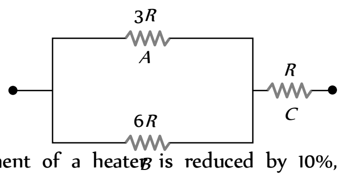
(a) 0.75 *V* (b) 3 *V*
(c) 1.5 *V* (d) 4.5 *V*

5. In how much time, one *litre* of H_2 will be collected by 5 *A* current ? (If $Z = 1\times10^{-8}\ kg/C$ and density of $H_2 = 0.09\,kg/m^3$)

(a) 30 *minutes* (b) 15 *minutes*
(c) 45 *minutes* (d) 60 *minutes*

6. The three resistances *A*, *B* and *C* have values 3*R*, 6*R* and *R* respectively. When some potential difference is applied across the network, the thermal powers dissipated by *A*, *B* and *C* are in the ratio

(a) 2 : 3 : 4
(b) 2 : 4 : 3
(c) 4 : 2 : 3
(d) 3 : 2 : 4



7. If the length of the filament of a heater is reduced by 10%, the power of the heater will

(a) Increase by about 9% (b) Increase by about 11%
(c) Increase by about 19% (d) Decrease by about 10%

8. A thermo couple develops 40 $\mu V/kelvin$. If hot and cold junctions be at 40° *C and* 20° *C* respectively then the emf develops by a thermopile using such 150 thermo couples in series shall be

(a) $150mV$ (b) $80mV$
(c) $144mV$ (d) $120mV$

9. Amount of electricity required to pass through the H_2O voltmeter so as to liberate 11.2 *litre* of hydrogen will be

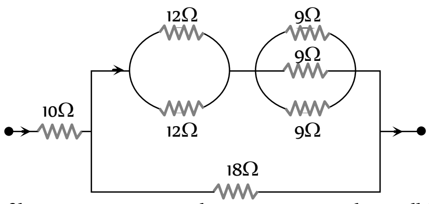
(a) 1 *Faraday* (b) $\frac{1}{2}Faraday$
(c) 2 *Faraday* (d) 3 *Faraday*

10. The resistance of the filament of a lamp increases with the increase in temperature. A lamp rated 100 *W*, 220 *V* is connected across 220 *V* power supply. If the voltage drops by 10% then the power of lamp will be

(a) 90 *W* (b) 81 *W*
(c) Between 90 *W* and 100 *W* (d) Between 81 *W* and 90 *W*

11. In the following circuit, 18Ω resistor develops $2\,J/sec$ due to current flowing through it. The power developed across 10Ω resistance is

(a) 125 *W*
(b) 10 *W*
(c) $\frac{4}{5}W$
(d) 25 *W*



12. If resistance of the filament increases with temperature, what will be power dissipated in a 220 *V*- 100 *W* lamp when connected to 110 *V* power supply

(a) 25 *W* (b) < 25 *W*
(c) > 25 *W* (d) None of these

13. Total surface area of a cathode is $0.05m^2$ and 1 *A* current passes through it for 1 *hour*. Thickness of nickle deposited on the cathode is (Given that density of nickle = $9gm/cc$ and it's E.C.E. = $3.04\times10^{-4}gm/C$)

(a) 2.4 *m* (b) $2.4\mu m$
(c) 2.4 μm (d) None of these

14. Two bulbs consume same power when operated at 200 *V* and 300 *V* respectively. When these bulbs are connected in series across a D.C. source of 500 *V*, then

(a) Ratio of potential difference across them is 3/2
(b) Ratio of potential difference across them is 9/4
(c) Ratio of power consumed across them is 4/9
(d) Ratio of power consumed across them is 2/3

AS Answers and Solutions

(SET -20)

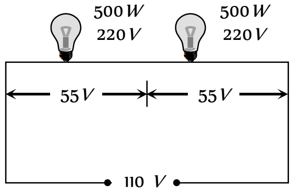
1. (d) In series $\frac{1}{P_S}=\frac{1}{P_1}+\frac{1}{P_2} \Rightarrow \frac{1}{(H_s/t_s)}=\frac{1}{(H_1/t_1)}+\frac{1}{(H_2/t_2)}$

$\because H_s = H_1 = H_2$ So $t_s = t_1 + t_2 = 6+3 = 9 min$

2. (b) $i^2Rt = C\theta = 3C;$ C = Thermal capacity

when $i_1 = 2i \Rightarrow C\theta_1 = 4i^2Rt = 4\times 3C \Rightarrow \theta_1 = 12^o C$

3. (a) Voltage across each bulb $V'=\frac{110}{2}=55W$ so, power consumed by each bulb will be



$P'=\left(\frac{55}{220}\right)^2\times 500$

$=\frac{125}{4}W$

4. (c) $m = Zit \Rightarrow it = \frac{m}{Z}=\frac{1\times 10^{-3}}{1.044\times 10^{-8}}C=\frac{10^5}{1.044}C$

Given $H = 34\,kcal$ = $4.2 \times 34 \times 10^3$ J

$\Rightarrow$ Heat generated $H = Vit = V.\frac{10^5}{1.044}$

$\Rightarrow V = \frac{4.2\times 34\times 1.044}{10^2}$ = $4.2 \times 0.34 \times 1.044 = 1.5$ V

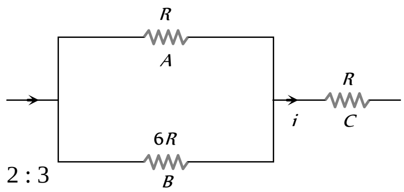
5. (a) $m = zit \Rightarrow 10^{-3}\times 0.09 = 1\times 10^{-8}\times 5\times t \Rightarrow t = 30\,min$

6. (c) Thermal power in $A = P_A = \left(\frac{2i}{3}\right)^2 3R = \frac{4}{3}i^2R$

Thermal power in $B = P_B = \left(\frac{i}{3}\right)^2 6R = \frac{2}{3}i^2R$

Thermal power in

$C = P_C = i^2R$



$\Rightarrow P_A : P_B : P_C$

$=\frac{4}{3}:\frac{2}{3}:1 = 4:2:3$

7. (b) $P \propto \frac{1}{R}$ and $R \propto l \Rightarrow P \propto \frac{1}{l}$

$\Rightarrow \frac{P_1}{P_2}=\frac{l_2}{l_1}\Rightarrow \frac{P_1}{P_2}=\frac{(100-10)}{100}=\frac{90}{100}\Rightarrow P_2 = 1.11P_1$

% change in power = $\frac{P_2-P_1}{P_1}\times 100 = 11\%$

8. (d) The temperature difference is 20°C = 20 K. So that thermo emf developed $E = \alpha\theta = 40\frac{\mu V}{K}\times 20K = 800\mu V$

Hence total emf = $150\times 800 = 12\times 10^4\,\mu V = 120mV$

9. (a) 22.4 *litre* H_2 =1 mole of H_2 = N molecules of H_2

= $2N$ atoms of H.

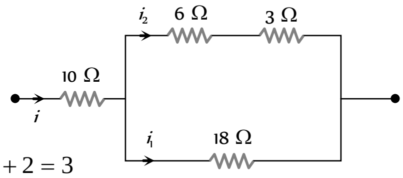
So charge required to liberate 22.4 *litre* of H_2 = $2Ne$ = $2F$.

Hence charge required to liberate 11.2 *litre* of H_2 = F.

10. (d) Let the resistance of the lamp filament be R. Then $100=\frac{(220)^2}{R}$. When then voltage drops, expected power is $P=\frac{(220\times 0.9)^2}{R'}$. Here R' will be less than R, because now the rise in temperature will be less. Therefore P is more than $\frac{(220\times 0.9)^2}{R}=81W$

But it will not be 90% of earlier value, because fall in temperature is small. Hence (d) is correct.

11. (b) The given circuit can be redrawn as follows



$\frac{i_1}{i_2}=\frac{9}{18}=\frac{1}{2}$

and $i = i_1 + i_2$

$\Rightarrow \frac{i}{i_1}=1+\frac{i_2}{i_1}=1+2=3$

From $P = i^2R \Rightarrow \frac{P_{10\Omega}}{P_{18\Omega}}=\left(\frac{i}{i_1}\right)^2\times\frac{10}{18}\Rightarrow P_{10\Omega}=10W$

12. (c) If resistance does not vary with temperature P consumed = $\left(\frac{V_A}{V_R}\right)^2\times P_R=\left(\frac{110}{220}\right)^2\times 100 = 25W$. But in second cases resistance decreases so consumed power will be more than 25 W

13. (c) Mass deposited = density × volume of the metal

$m = p\times A\times X$ .....(i)

Hence from Faraday's first law $m = Zit$ .....(ii)

So from equation (i) and (ii)

$Zit = \rho\times Ax \Rightarrow x = \frac{Zit}{\rho A}$

$=\frac{3.04\times 10^{-4}\times 10^{-3}\times 1\times 3600}{9000\times 0.05}=2.4\times 10^{-6}m = 2.4\mu m$

14. (c) $P=\frac{V^2}{R}$ $\therefore R=\frac{V^2}{P}$ or $R\propto V^2$ *i.e.* $\frac{R_1}{R_2}=\left(\frac{200}{300}\right)^2=\frac{4}{9}$

When connected in series potential drop and power consumed are in the ratio of their resistances. So, $\frac{P_1}{P_2}=\frac{V_1}{V_2}=\frac{R_1}{R_2}=\frac{4}{9}$

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Chapter
21

Magnetic Effect of Current

Oersted found that a magnetic field is established around a current carrying conductor.

Magnetic field exists as long as there is current in the wire.

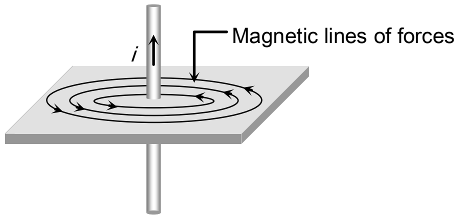


Fig. 21.1

Biot-Savart's Law

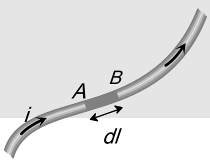
Biot-Savart's law is used to determine the magnetic field at any point due to a current carrying conductor.

This law is although for infinitesimally small conductor yet it can be used for long conductors. In order to understand the Biot-Savart's law, we need to understand the term current-element.

Current element

It is the product of current and length of infinitesimal segment of current carrying wire.

The current element is taken as a vector quantity. Its direction is same as the direction of current.



Current element *AB* = $i\vec{dl}$

According to Biot-Savart Law, magnetic field at point '*P* due to the current element $i\vec{dl}$ is given by the expression, $d\vec{B} = k\frac{i\,dl\sin\theta}{r^2}\hat{n}$ also $\vec{B} = \int d\vec{B} = \frac{\mu_0 i}{4\pi}.\int\frac{dl\sin\theta}{r^2}\hat{n}$

In C.G.S. *k* = 1 and in S.I. : $k = \frac{\mu_0}{4\pi}$

where μ_0 = Absolute permeability of air or vacuum $= 4\pi\times10^{-7}\frac{Wb}{Amp-metre}$. It's other units are

$\frac{Henry}{metre}$ or $\frac{N}{Amp^2}$ or $\frac{Tesla-metre}{Ampere}$

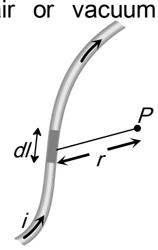


Fig. 21.2

Vectorially, $d\vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{i(\vec{dl}\times\hat{r})}{r^2} = \frac{\mu_0}{4\pi}\cdot\frac{i(\vec{dl}\times\vec{r})}{r^3}$

Direction of Magnetic Field

The direction of magnetic field is determined with the help of the following simple laws :

(1) **Maxwell's cork screw rule :** According to this rule, if we imagine a right handed

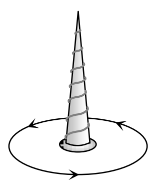


Fig. 21.3

screw placed along the current carrying linear conductor, be rotated such that the screw moves in the direction of flow of current, then the direction of rotation of the thumb gives the direction of magnetic lines of force.

(2) **Right hand thumb rule :** According to this rule if a straight current carrying conductor is held in the right hand such that the thumb of the hand represents the direction of current flow, then the direction of folding fingers will represent the direction of magnetic lines of force.

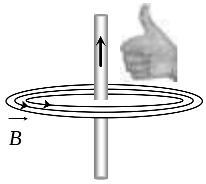


Fig. 21.4

(3) **Right hand thumb rule of circular currents :** According to this rule if the direction of current in circular conducting coil is in the direction of folding fingers of right hand, then the direction of magnetic field will be in the direction of stretched thumb.

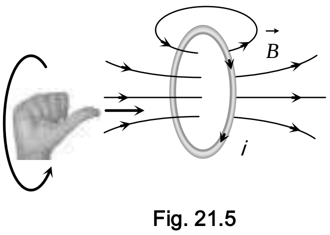


Fig. 21.5

(4) **Right hand palm rule**

If we stretch our right hand such that fingers point towards the point. At which magnetic field is required while thumb is in the direction of current then normal to the palm will show the direction of magnetic field.

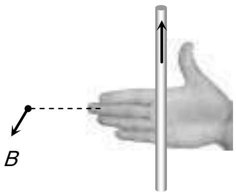


Fig. 21.6

Meaning of Cross ⊗ and dot ⊙

If magnetic field is directed perpendicular and into the plane of the paper it is represented by ⊗ (cross) while if magnetic field is directed perpendicular and out of the plane of the paper it is represented by ⊙ (dot)

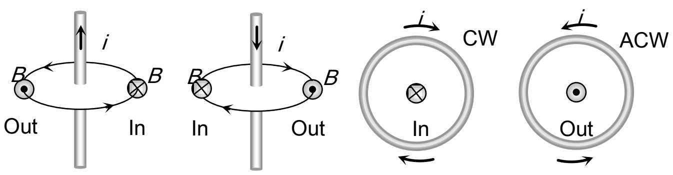


Fig. 21.7

In : Magnetic field is away from the observer or perpendicular inwards.

Out : Magnetic field is towards the observer or perpendicular outwards.

Ampere's Law

Amperes law gives another method to calculate the magnetic field due to a given current distribution.

Line integral of the magnetic field $\vec{B}$ around any closed curve is equal to μ_0 times the net current *i* threading through the area enclosed by the curve *i.e.*

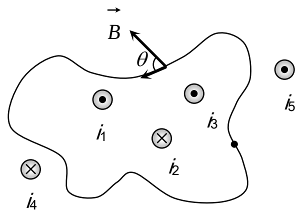


Fig. 21.8

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 \sum i = \mu_0 (i_1 + i_3 - i_2)$$

Also using $\vec{B} = \mu_0 \vec{H}$ (where $\vec{H}$ = magnetising field)

$$\oint \mu_0 \vec{H}.\vec{dl} = \mu_0 \Sigma i \Rightarrow \oint \vec{H}.\vec{dl} = \sum i$$

Total current crossing the above area is $(i_1 + i_3 - i_2)$. Any current outside the area is not included in net current. (Outward ⊙ → +*ve*, Inward ⊗ → – *ve*)

Table 21.1 : Biot-Savart's law v/s Ampere's law

Biot-Savart's law	Ampere's law
this law is valid for all current distributions	This law is valid for symmetrical current distributions
This law is the differential form of $\vec{B}$ or $\vec{H}$	Basically this law is the integral from of $\vec{B}$ or $\vec{H}$
This law is based only on the principle of magnetism	This law is based on the principle of electromagnetism.

Magnetic Field Due to Circular Current

If a coil of radius r, carrying current i then magnetic field on it's axis at a distance x from its centre given by (Application of B

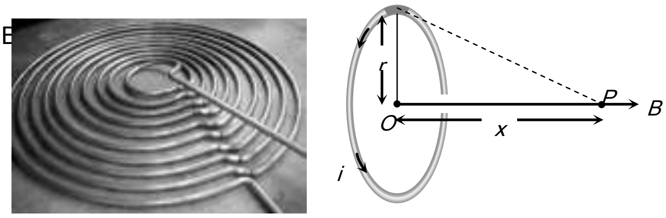


Fig. 21.9

(1) $B_{axis} = \frac{\mu_0}{4\pi} \cdot \frac{2\pi N i r^2}{(x^2 + r^2)^{3/2}}$; where N = number of turns in coil.

(2) At centre $x = 0 \Rightarrow B_{centre} = \frac{\mu_0}{4\pi} \cdot \frac{2\pi Ni}{r} = \frac{\mu_0 Ni}{2r} = B_{\max}$

(3) The ratio of magnetic field at the centre of circular coil and on it's axis is given by $\frac{\boldsymbol{B_{centre}}}{\boldsymbol{B_{axis}}} = \left(\mathbf{1} + \frac{\boldsymbol{x^2}}{\boldsymbol{r^2}}\right)^{3/2}$

(4) If $x >> r \Rightarrow B_{axis} = \frac{\mu_0}{4\pi} \cdot \frac{2\pi\, N i r^2}{x^3} = \frac{\mu_0}{4\pi} \cdot \frac{2NiA}{x^3}$

where $A = \pi r^2$ = Area of each turn of the coil.

(5) ***B-x* curve** : The variation of magnetic field due to a circular coil as the distance x varies as shown in the figure.

B varies non-linearly with distance x as shown in figure and is maximum when $x^2 = \min = 0$, *i.e.*, the point is at the centre of the coil and it is zero at $x = \pm\infty$.

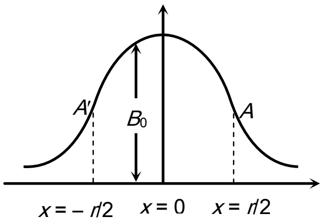


Fig. 21.10

(6) **Point of inflection** (A and A') **:** Also known as points of curvature change or points of zero curvature.

(i) At these points B varies linearly with $x \Rightarrow \frac{dB}{dx} =$ constant $\Rightarrow \frac{d^2B}{dx^2} = 0$.

(ii) These are located at $x = \pm\frac{r}{2}$ from the centre of the coil and the magnetic field at $x = \frac{r}{2}$ is $B = \frac{4\mu_0 Ni}{5\sqrt{5}\, r}$

(7) **Helmholtz coils**

(i) This is the set-up of two coaxial coils of same radius such that distance between their centres is equal to their radius.

(ii) At axial mid point O, magnetic field is given by $B = \frac{8\mu_0 Ni}{5\sqrt{5}R} = 0.716\frac{\mu_0 Ni}{R} = 1.432\,B$, where $B = \frac{\mu_0 Ni}{2R}$

(iii) Current direction is same in both coils otherwise this arrangement is not called Helmholtz's coil arrangement.

(iv) Number of points of inflextion $\Rightarrow$ Three (A, A', A'')

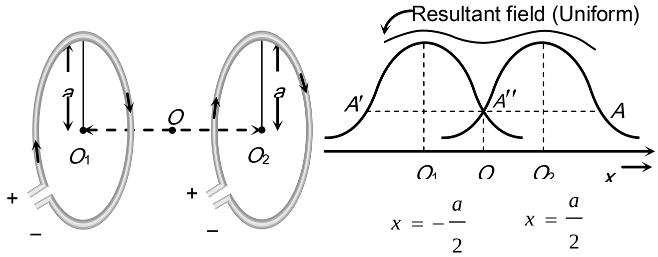
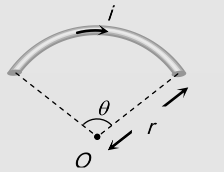
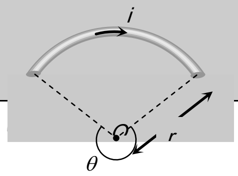
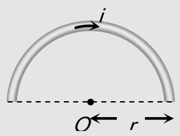
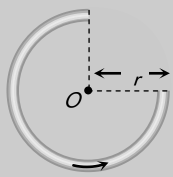
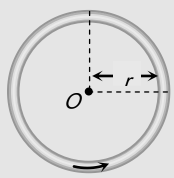
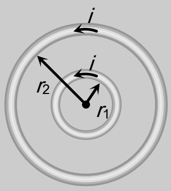
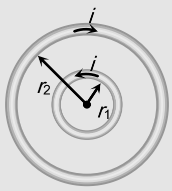
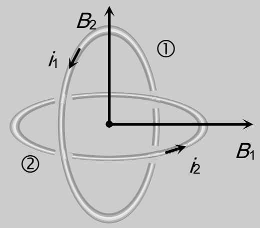
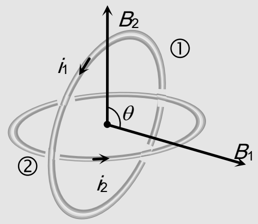
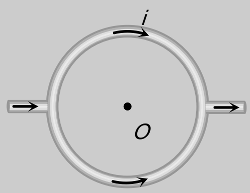
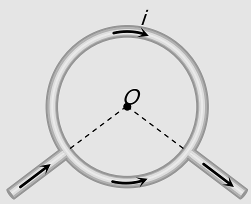


Fig. 21.11

Magnetic Field at Centre *O* in Different Conditions of Circular Current

Condition	Figure	Magnetic field
Arc subtends angle θ at the centre		$B = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{r}$
Arc subtends		

angle $(2\pi - \theta)$ at the centre		$B = \frac{\mu_0}{4\pi}\cdot\frac{(2\pi-\theta)i}{r}$
Semi-circular arc		$B = \frac{\mu_0}{4\pi}\cdot\frac{\pi i}{r} = \frac{\mu_0 i}{4r}$
Three quarter semi-circular current carrying arc		$B = \frac{\mu_0}{4\pi}\cdot\frac{\left(2\pi - \frac{\pi}{2}\right)i}{r}$ $= \frac{3\mu_0 i}{8r}$
Circular current carrying arc		$B = \frac{\mu_0}{4\pi}\frac{2\pi i}{r}$ $= \frac{\mu_0 i}{2r}$
Concentric co-planer circular loops carries current in the same direction		$B_1 = \frac{\mu_0}{4\pi}2\pi i\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$
Concentric co-planer circular loops carries current in the opposite direction		$B_2 = \frac{\mu_0}{4\pi}2\pi i\left[\frac{1}{r_1}-\frac{1}{r_2}\right]$
Concentric loops but their planes are perpendicular to each other		$B = \sqrt{B_1^2 + B_2^2}$ $= \frac{\mu_0}{2r}\sqrt{i_1^2 + i_2^2}$
Concentric loops but their planes are at an angle θ with each other		$B = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos\theta}$
Distribution of current across the diameter		$B = 0$
Distribution of current between any two points on the circumference		$B = 0$

Magnetic Field Due to a Straight Wire

Magnetic field due to a current carrying wire at a point *P* which lies at a perpendicular distance *r* from the wire as shown is given as

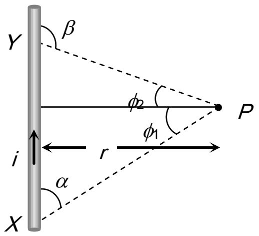


Fig. 21.12

$$B = \frac{\mu_0}{4\pi}.\frac{i}{r}(\sin\phi_1 + \sin\phi_2)$$

From figure $\alpha = (90^o - \phi_1)$

and $\beta = (90^o + \phi_2)$

Hence $B = \frac{\mu_o}{4\pi}.\frac{i}{r}(\cos\alpha - \cos\beta)$

(1) **For a wire of finite length :** Magnetic field at a point which lies on perpendicular bisector of finite length wire

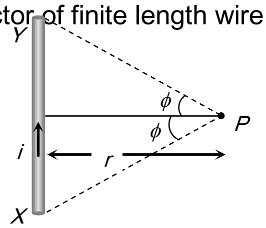


Fig. 21.13

$\phi_1 = \phi_2 = \phi$

So $B = \frac{\mu_0}{4\pi}.\frac{i}{r}(2\sin\phi)$

(2) **For a wire of infinite length :** When the linear conductor *XY* is of infinite length and the point *P* lies near the centre of the conductor $\phi_1 = \phi_2 = 90^o$.

So, $B = \frac{\mu_0}{4\pi}\frac{i}{r}[\sin 90^o + \sin 90^o]$

$= \frac{\mu_0}{4\pi}\frac{2i}{r}$

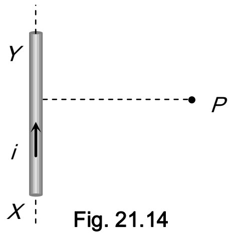


Fig. 21.14

(3) **For a wire of semi-infinite length :** When the linear conductor is of infinite length and the point *P* lies near the end *Y* or *X*. $\phi_1 = 90^o$ and $\phi_2 = 0^o$

So, $B = \frac{\mu_0}{4\pi}\frac{i}{r}[\sin 90^o + \sin 0^o]$

$= \frac{\mu_0 i}{4\pi r}$

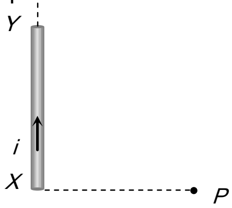


Fig. 21.15

(4) **For axial position of wire :** When point *P* lies on axial position of current carrying conductor then magnetic field at *P*

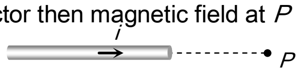


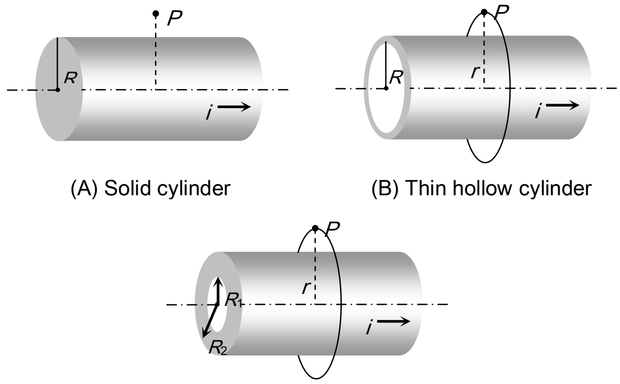
Fig. 21.16

B = 0

Magnetic Field Due to a Cylindrical Wire

Magnetic field due to a cylindrical wire is obtained by the application of Ampere's law

(1) **Outside the cylinder**



(A) Solid cylinder (B) Thin hollow cylinder

(C) Thick hollow cylinder

Fig. 21.17

In all above cases magnetic field outside the wire at *P*

$$\oint \vec{B}.\vec{dl} = \mu_0 i \Rightarrow B\int dl = \mu_0 i \Rightarrow B \times 2\pi r = \mu_0 i \Rightarrow B_{out} = \frac{\mu_0 i}{2\pi r}$$

In all the above cases $B_{surface} = \frac{\mu_0 i}{2\pi R}$

(2) **Inside the hollow cylinder :** Magnetic field inside the hollow cylinder is zero.

(A) Thin hollow cylinder (B) Thick hollow cylinder

Fig. 21.18

(3) **Inside the solid cylinder :** Current enclosed by loop (*i'*) is lesser then the total current (*i*)

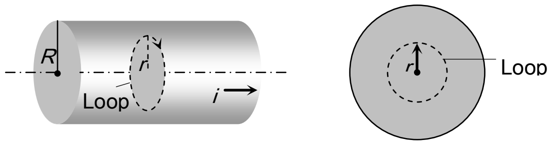


Fig. 21.19

Current density is uniform *i.e.* $J = J' \Rightarrow i' = i \times \frac{A'}{A} = i\left(\frac{r^2}{R^2}\right)$

Hence at inside point $\oint \overrightarrow{B_{in}}.\overrightarrow{dl} = \mu_0 i' \Rightarrow B = \frac{\mu_0}{2\pi}.\frac{ir}{R^2}$

(4) **Inside the thick portion of hollow cylinder :** Current enclosed by loop is given as $i' = i \times \frac{A'}{A} = i \times \frac{(r^2 - R_1^2)}{(R_2^2 - R_1^2)}$

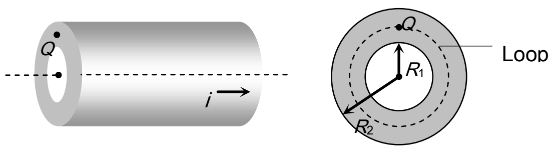


Fig. 21.20

Hence at point *Q* $\oint \vec{B}.\vec{dl} = \mu_0 i' \Rightarrow B = \frac{\mu_0 i}{2\pi r}.\frac{(r^2 - R_1^2)}{(R_2^2 - R_1^2)}$

Magnetic Field Due to an Infinite Sheet Carrying Current

The figure shows an infinite sheet of current with linear current density *j* (*A*/*m*). Due to symmetry the field line pattern above and below the sheet is uniform. Consider a square loop of side *l* as shown in the figure.

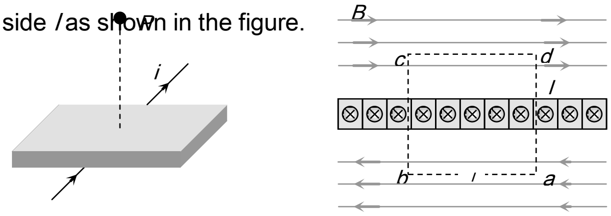


Fig. 21.21

$\int_a^b \vec{B}.\vec{dl} + \int_b^c \vec{B}.\vec{dl} + \int_c^d \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl} = \mu_0 i$ (By Ampere's law)

Since $B \perp dl$ along the path $b \to c$ and $d \to a$, therefore,

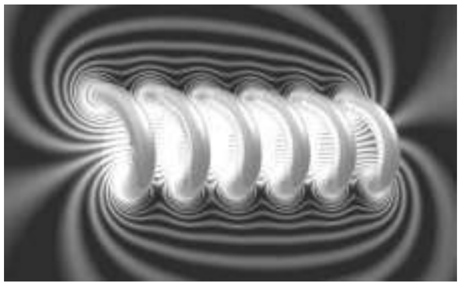
$\int_b^c \vec{B}.\vec{dl} = 0$; $\int_d^a \vec{B}.\vec{dl} = 0$

Also, $B \parallel dl$ along the path $a \to b$ and $c \to d$, thus

$\int_a^b \vec{B}.\vec{dl} + \int_d^a \vec{B}.\vec{dl} = 2Bl$

The current enclosed by the loop is $i = jl$. Therefore, according to Ampere's law $2Bl = \mu_0(jl)$ or $B = \frac{\mu_0 j}{2}$

Solenoid



A cylinderical coil of many tightly wound turns of insulated wire with generally diameter of the coil smaller than its length is called a solenoid.

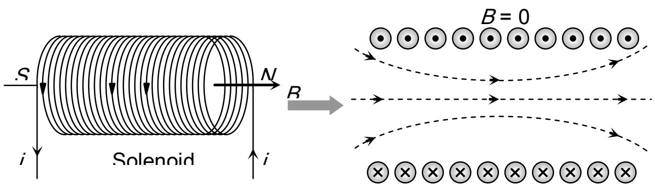


Fig. 21.22

A magnetic field is produced around and within the solenoid. The magnetic field within the solenoid is uniform and parallel to the axis of solenoid.

(1) **Finite length solenoid :**

If *N* = total number of turns, *l* = length of the solenoid, *n* = number of turns per unit length $= \frac{N}{l}$

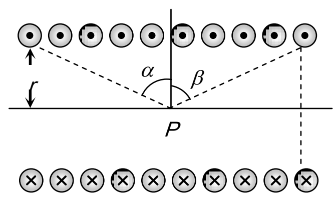


Fig. 21.23

(i) Magnetic field inside the solenoid at point *P* is given by $B = \frac{\mu_0}{4\pi}(2\pi ni)[\sin\alpha + \sin\beta]$

(ii) **Infinite length solenoid :** If the solenoid is of infinite length and the point is well inside the solenoid *i.e.* $\alpha = \beta = (\pi/2)$.

So $\quad \boldsymbol{B_{in} = \mu_0 ni}$

(iii) If the solenoid is of infinite length and the point is near one end *i.e.* $\alpha = 0$ and $\beta = (\pi/2)$ so $\boldsymbol{B_{end} = \frac{1}{2}(\mu_0 ni)}$

($B_{end} = \frac{1}{2}B_{in}$)

Toroid

A toroid can be considered as a ring shaped closed solenoid. Hence it is like an endless cylindrical solenoid.

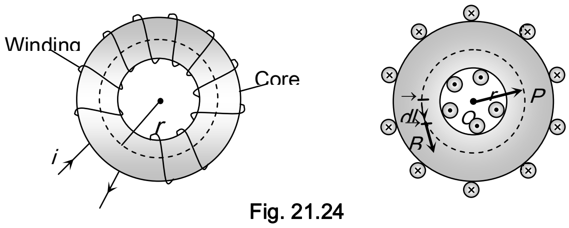


Fig. 21.24

Consider a toroid having *n* turns per unit length. Magnetic field at a point *P* in the figure is given as

$B = \frac{\mu_0 Ni}{2\pi r} = \mu_0 ni$ where $n = \frac{N}{2\pi r}$

Force On a Charged Particle in Magnetic Field

If a particle carrying a positive charge *q* and moving with velocity *v* enters a magnetic field *B* then it experiences a force *F* which is given by the expression $\vec{F} = q(\vec{v} \times \vec{B}) \Rightarrow F = qvB\sin\theta$

where $\vec{v} =$ velocity of the particle, $\vec{B} =$ magnetic field

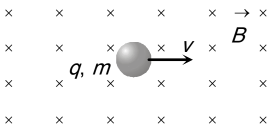


Fig. 21.25

(1) **Zero force :** Force on charged particle will be zero (*i.e.* *F* = 0) if

(i) No field *i.e.* *B* = 0 ⇒ *F* = 0

(ii) Neutral particle *i.e.* *q* = 0 ⇒ *F* = 0

(iii) Rest charge *i.e.* *v* = 0 ⇒ *F* = 0

(iv) Moving charge *i.e.* θ = 0° or θ = 180° ⇒ *F* = 0

(2) **Direction of force :** The force $\vec{F}$ is always perpendicular to both the velocity $\vec{v}$ and the field $\vec{B}$ in accordance with Right Hand Screw Rule, though $\vec{v}$ and $\vec{B}$ themselves may or may not be p[illegible]h other.

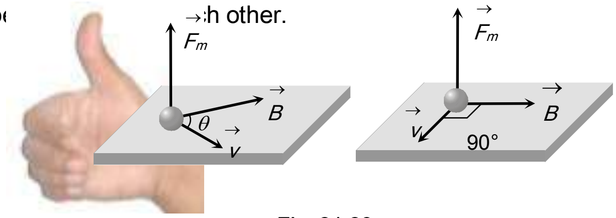


Fig. 21.26

Direction of force on charged particle in magnetic field can also be find by Fleming's Left Hand Rule (FLHR).

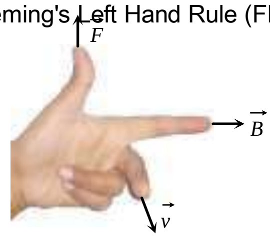


Fig. 21.27

Here, *First finger* (indicates) → Direction of magnetic field

Middle finger → Direction of motion of positive charge or direction, Opposite to the motion of negative charge.

Thumb → Direction of force

Trajectory of a Charged Particle in a Magnetic Field

(1) **Straight line :** If the direction of a $\vec{v}$ is parallel or antiparallel to $\vec{B}$, θ = 0 or θ = 180° and therefore *F* = 0. Hence the trajectory of the particle is a straight line.

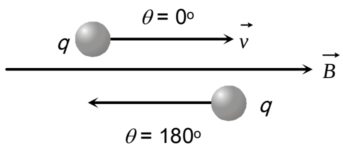


Fig. 21.28

(2) **Circular path :** If $\vec{v}$ is perpendicular to $\vec{B}$ *i.e.* θ = 90°, hence particle will experience a maximum magnetic force ***F_{max} = qvB*** which act's in a direction perpendicular to the motion of charged particle. Therefore the trajectory of the particle is a circle.

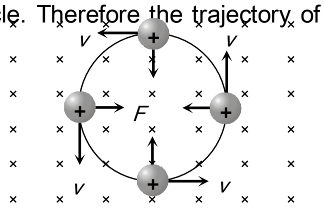


Fig. 21.29

(i) In this case path of charged particle is circular and magnetic force provides the necessary centripetal force *i.e.* $qvB = \frac{mv^2}{r}$ $\Rightarrow$ radius of path $\boldsymbol{r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mK}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}}$

where *p* = momentum of charged particle and *K* = kinetic energy of charged particle (gained by charged particle after accelerating through potential difference *V*) then $p = mv = \sqrt{2mK} = \sqrt{2mqV}$

(ii) If *T* is the time period of the particle then $T = \frac{2\pi m}{qB}$ (*i.e.*, time period (or frequency) is independent of speed of particle).

(3) **Helical path :** When the charged particle is moving at an angle to the field (other than 0°, 90°, or 180°). Particle describes a path called helix.

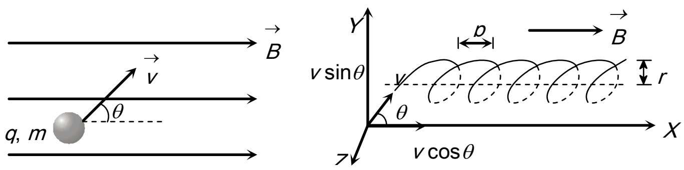


Fig. 21.30

(i) The radius of this helical path is $\boldsymbol{r = \frac{m(v\sin\theta)}{qB}}$

(ii) Time period and frequency do not depend on velocity and so they are given by $T = \frac{2\pi m}{qB}$ and $\nu = \frac{qB}{2\pi m}$

(iii) The *pitch* of the *helix*, (*i.e.*, linear distance travelled in one rotation) will be given by $p = T(v\cos\theta) = 2\pi\frac{m}{qB}(v\cos\theta)$

(iv) If pitch value is *p*, then number of pitches obtained in length *l* given as

Number of pitches $= \frac{l}{p}$ and time required $t = \frac{l}{v\cos\theta}$

Lorentz Force

When the moving charged particle is subjected simultaneously to both electric field $\vec{E}$ and magnetic field $\vec{B}$, the moving charged particle will experience electric force $\vec{F_e} = q\vec{E}$ and magnetic force $\vec{F_m} = q(\vec{v}\times\vec{B})$; so the net force on it will be $\boldsymbol{\vec{F} = q[\vec{E} + (\vec{v}\times\vec{B})]}$. Which is the famous 'Lorentz-force equation'.

Depending on the directions of $\vec{v}, E$ and $\vec{B}$ following situations are possible

(i) **When $\vec{v}, \vec{E}$ and $\vec{B}$ all the three are collinear :** In this situation the magnetic force on it will be zero and only electric force will act and so $\vec{a} = \frac{\vec{F}}{m} = \frac{q\vec{E}}{m}$

(ii) The particle will pass through the field following a straight-line path (parallel field) with change in its speed. So in this situation speed, velocity, momentum and kinetic energy all will change without change in direction of motion as shown

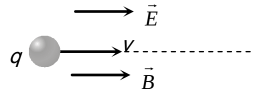


Fig. 21.31

(iii) **$\vec{v}, \vec{E}$ and $\vec{B}$ are mutually perpendicular :** In this situation if $\vec{E}$ and $\vec{B}$ are such that $\vec{F} = \vec{F_e} + \vec{F_m} = 0$ *i.e.*, $\vec{a} = (\vec{F}/m) = 0$

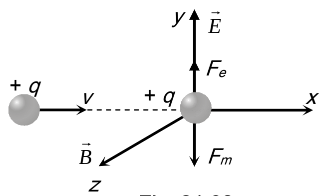


Fig. 21.32

as shown in figure, the particle will pass through the field with same velocity, without any deviation in path.

And in this situation, as $F_e = F_m$ *i.e.*, $qE = qvB \quad v = E/B$

This principle is used in 'velocity-selector' to get a charged beam having a specific velocity.

Cyclotron

Cyclotron is a device used to accelerated positively charged particles (like, α-particles, deutrons *etc.*) to acquire enough energy to carry out nuclear disintegration *etc.*

It is based on the fact that the electric field accelerates a charged particle and the magnetic field keeps it revolving in circular orbits of constant frequency.

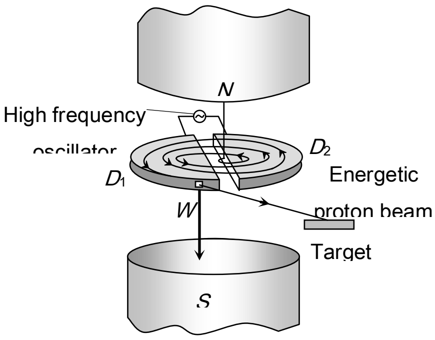


Fig. 21.33

It consists of two hollow *D*-shaped metallic chambers D_1 and D_2 called dees. The two dees are placed horizontally with a small gap separating them. The dees are connected to the source of high frequency electric field. The dees are enclosed in a metal box containing a gas at a low pressure of the order of 10^{-3} *mm* mercury. The whole apparatus is placed between the two poles of a strong electromagnet *NS* as shown in fig. The magnetic field acts perpendicular to the plane of the dees.

(1) **Cyclotron frequency :** Time taken by ion to describe a semicircular path is given by $t = \frac{\pi r}{v} = \frac{\pi m}{qB}$

If T = time period of oscillating electric field then $T = 2t = \frac{2\pi m}{qB}$ the cyclotron frequency $\nu = \frac{1}{T} = \frac{Bq}{2\pi m}$

(2) **Maximum energy of particle :** Maximum energy gained by the charged particle $E_{\max} = \left(\frac{q^2B^2}{2m}\right)r^2$

where r_0 = maximum radius of the circular path followed by the positive ion.

Hall Effect

The Phenomenon of producing a transverse emf in a current carrying conductor on applying a magnetic field perpendicular to the direction of the current is called Hall effect.

Hall effect helps us to know the nature and number of charge carriers in a conductor.

Consider a conductor having electrons as current carriers. The electrons move with drift velocity $\vec{v}$ opposite to the direction of flow of current

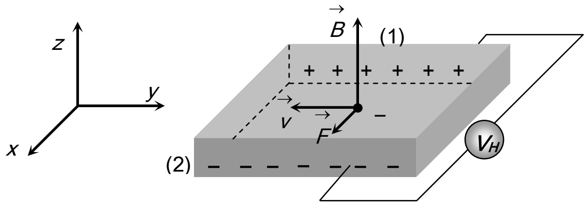


Fig. 21.34

Force acting on electron $F_m = -e(\vec{v} \times \vec{B})$. This force acts along *x*-axis and hence electrons will move towards face (2) and it becomes negatively charged.

Force On a Current Carrying Conductor In Magnetic Field

In case of current carrying conductor in a magnetic field force experienced by its small length element is $d\vec{F} = i\,d\vec{l} \times \vec{B}$; $i\,d\vec{l}$ = current element $d\vec{F} = i(d\vec{l} \times \vec{B})$

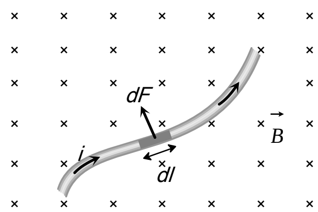


Fig. 21.35

Total magnetic force $\vec{F} = \int d\vec{F} = \int i(d\vec{l} \times \vec{B})$. If magnetic field is uniform *i.e.*, $\vec{B}$ = constant $\vec{F} = i[\int d\vec{l}] \times \vec{B} = i(\vec{L} \times \vec{B})$

$\int \vec{dl} = \vec{L}' =$ vector sum of all the length elements from initial to final point. Which is in accordance with the law of vector addition is equal to length vector $\vec{L}$ joining initial to final point.

(For a straight conductor $F = Bil\sin\theta$)

Direction of force : The direction of force is always perpendicular to the plane containing $i\vec{dl}$ and $\vec{B}$ and is same as that of cross-product of two vectors $(\vec{A} \times \vec{B})$ with $\vec{A} = i\vec{dl}$.

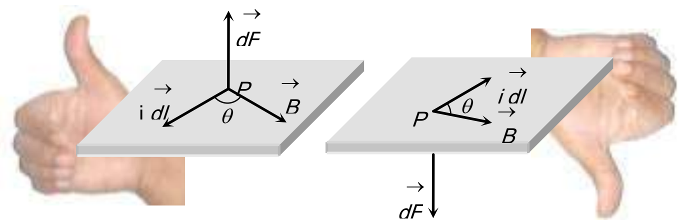


Fig. 21.36

The direction of force when current element $i\vec{dl}$ and $\vec{B}$ are perpendicular to each other can also be determined by applying either of the following rules

Fleming's left-hand rule : Stretch the fore-finger, central finger and thumb of left hand mutually perpendicular. Then if the fore-finger points in the direction of field $\vec{B}$ and the central in the direction of current *i*, the thumb will point in the direction of force.

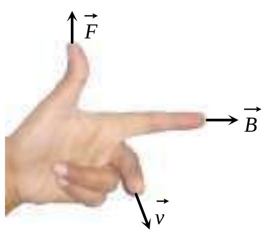


Fig. 21.37

Right-hand palm rule : Stretch the fingers and thumb of right hand at right angles to each other. Then if the fingers point in the direction of field $\vec{B}$ and thumb in the direction of current *i*, then normal to the palm will point in the direction of force

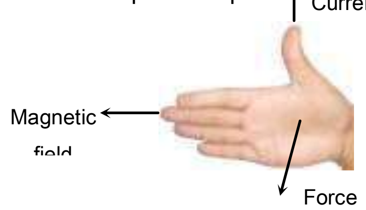


Fig. 21.38

Force Between Two Parallel Current Carrying Conductors

The force on a length *l* of each of two long, straight, parallel wires carrying currents i_1 and i_2 and separated by a distance *a* is

$$F = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a} \times l$$

Hence force per unit length

$$\frac{F}{l} = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a} \left(\frac{N}{m}\right) \text{ or } \frac{F}{l} = \frac{2i_1 i_2}{a} \left(\frac{dyne}{cm}\right)$$

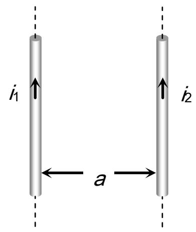


Fig. 21.39

Direction of force : If conductors carries current in same direction, then force between them will be attractive. If conductor carries current in opposite direction, then force between them will be repulsive.

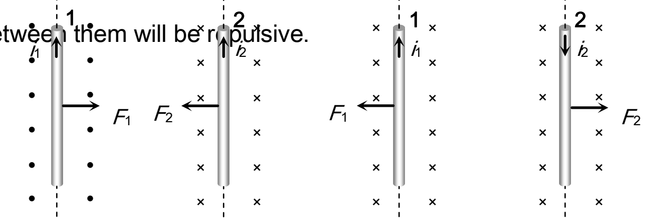


Fig. 21.40

Force Between Two Moving Charges

If two charges q_1 and q_2 are moving with velocities v_1 and v_2 respectively and at any instant the distance between them is r, then

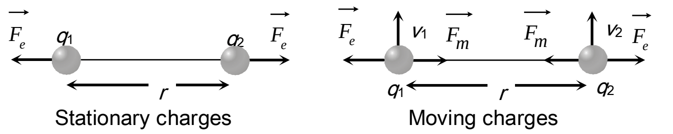


Fig. 21.41

Magnetic force between them is $F_m = \frac{\mu_0}{4\pi}.\frac{q_1 q_2 v_1 v_2}{r^2}$ .... (i)

and Electric force between them is $F_e = \frac{1}{4\pi\varepsilon_0}.\frac{q_1 q_2}{r^2}$ .... (ii)

From equation (i) and (ii) $\frac{F_m}{F_e} = \mu_0 \varepsilon_0 v^2$ but $\mu_0 \varepsilon_0 = \frac{1}{c^2}$;

where c is the velocity of light in vacuum. So $\frac{F_m}{F_e} = \left(\frac{v}{c}\right)^2$

As $v < c$ so $F_m < F_e$

Standard Cases For Force on Current Carrying Conductors

Case 1 : When an arbitrary current carrying loop placed in a magnetic field (⊥ to the plane of loop), each element of loop experiences a magnetic force due to which loop stretches and open into circular loop and tension developed in it's each part.

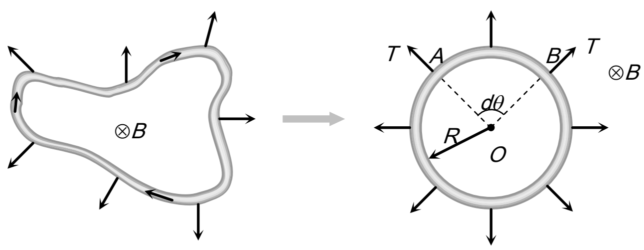


Fig. 21.42

Case 2 : **Equilibrium of a current carrying conductor :** When a finite length current carrying wire is kept parallel to another infinite length current carrying wire, it can suspend freely in air as shown below

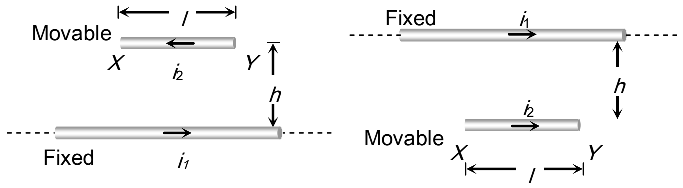


Fig. 21.43

In both the situations for equilibrium of XY it's downward weight = upward magnetic force *i.e.* $mg = \frac{\mu_0}{4\pi}.\frac{2 i_1 i_2}{h}.l$

Case 3 : **Current carrying spring :** If current is passed through a spring, then it will contract because current will flow through all the turns in the same direction.

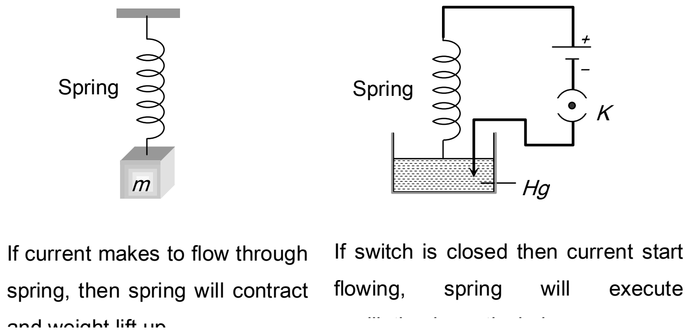


Fig. 21.44

Case 4 : **Tension less strings :** In the following figure the value and direction of current through the conductor XY so that strings becomes tensionless?

Strings becomes tensionless if weight of conductor XY balanced by magnetic force (F_m) .

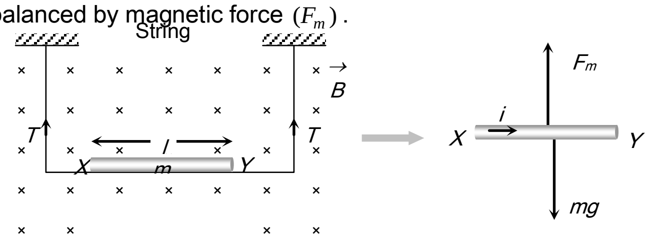


Fig. 21.45

Hence direction of current is from $X \to Y$ and in balanced condition $F_m = mg \Rightarrow Bil = mg \Rightarrow i = \frac{mg}{Bl}$

Case 5 : **Sliding of conducting rod on inclined rails :** When a conducting rod slides on conducting rails.

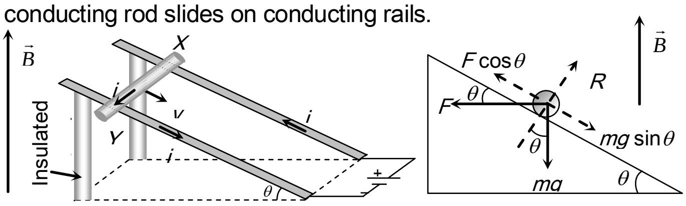


Fig. 21.46

In the following situation conducting rod (*X*, *Y*) slides at constant velocity if

$$F\cos\theta = mg\sin\theta \Rightarrow Bil\cos\theta = mg\sin\theta \Rightarrow B = \frac{mg}{il}\tan\theta$$

Current Loop as a Magnetic Dipole

A current carrying circular coil behaves as a bar magnet whose magnetic moment is $M = NiA$; *Where N* = Number of turns in the coil, i = Current through the coil and A = Area of the coil

Magnetic moment of a current carrying coil is a vector and it's direction is given by right hand thumb rule

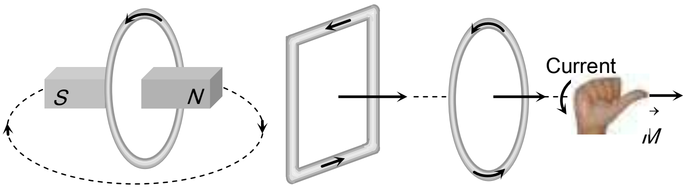


Fig. 21.47

(1) For a given perimeter circular shape have maximum area. Hence maximum magnetic moment.

(2) For a any loop or coil $\vec{B}$ at centre due to current in loop, and $\vec{M}$ are always parallel.

Fig. 21.48

Behaviour of Current Loop in a Magnetic Field

(1) **Torque :** Consider a rectangular current carrying coil *PQRS* having *N* turns and area *A*, placed in a uniform field $\vec{B}$, in such a way that the normal $(\hat{n})$ to the coil makes an angle θ with the direction of $\vec{B}$. the coil experiences a torque given by τ = *NBiA* sinθ. Vectorially $\vec{\tau} = \vec{M} \times \vec{B}$

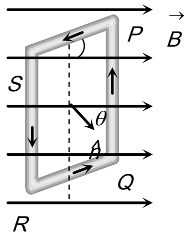


Fig. 21.49

(i) τ is zero when θ = 0, *i.e.*, when the plane of the coil is perpendicular to the field.

(ii) τ is maximum when $\theta = 90^o$, *i.e.*, the plane of the coil is parallel to the field $\tau_{\max} = NBiA$

(2) **Workdone :** If coil is rotated through an angle θ from it's equilibrium position then required work. $W = MB(1 - \cos\theta)$. It is maximum when θ = 180° $\Rightarrow W_{\max}$ = 2 *MB*

(3) **Potential energy :** $U = -MB\cos\theta \Rightarrow U = -\vec{M}.\vec{B}$

Moving Coil Galvanometer

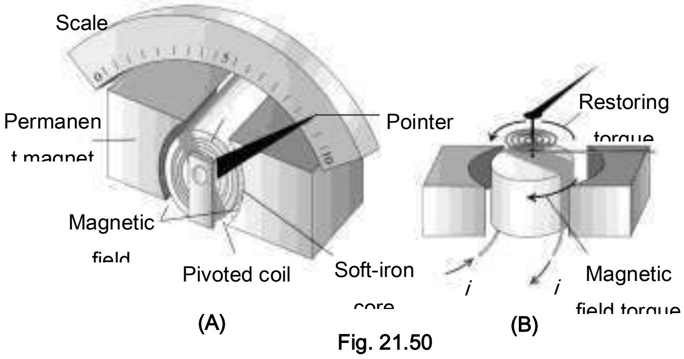


Fig. 21.50

In a moving coil galvanometer the coil is suspended between the pole pieces of a strong horse-shoe magnet. The pole pieces are made cylindrical and a soft iron cylindrical core is placed within the coil without touching it. This makes the field radial. In such a field the plane of the coil always remains parallel to the field. Therefore $\theta = 90^o$ and the deflecting torque always has the maximum value.

$\tau_{\text{def}} = NBiA$ ......(i)

Coil deflects, a restoring torque is set up in the suspension fibre. If α is the angle of twist, the restoring torque is

$\tau_{\text{rest}} = C\alpha$ .....(ii)

where C is the torsional constant of the fibre.

When the coil is in equilibrium $NBiA = C\alpha \Rightarrow i = K\alpha$,

where $K = \frac{C}{NBA}$ is the galvanometer constant. This linear relationship between i and α makes the moving coil galvanometer useful for current measurement and detection.

Current sensitivity (S_i) : The current sensitivity of a galvanometer is defined as the deflection produced in the galvanometer per unit current flowing through it.

$$S_i = \frac{\alpha}{i} = \frac{NBA}{C}$$

Voltage sensitivity (S_V) : Voltage sensitivity of a galvanometer is defined as the deflection produced in the galvanometer per unit voltage applied to it.

$$S_V = \frac{\alpha}{V} = \frac{\alpha}{iR} = \frac{S_i}{R} = \frac{NBA}{RC}$$

Tips & Tricks

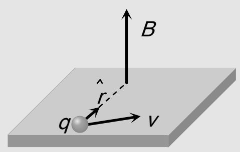
✍ The device whose working principle based on Halmholtz coils and in which uniform magnetic field is used called as "Halmholtz galvanometer".

✍ The value of magnetic field induction at a point, on the centre of separation of two linear parallel conductors carrying equal currents in the same direction is zero.

✍ If a current carrying circular loop (n = 1) is turned into a coil having n identical turns then magnetic field at the centre of the coil becomes n^2 times the previous field *i.e.* $B_{(n\ turn)} = n^2 B_{(single\ turn)}$

✍ When a current carrying coil is suspended freely in earth's magnetic field, it's plane stays in **East-West** direction.

✍ Magnetic field ($\vec{B}$) produced by a moving charge q is given by $\vec{B} = \frac{\mu_0}{4\pi}\frac{q(\vec{v} \times \vec{r})}{r^3} = \frac{\mu_0}{4\pi}\frac{q(\vec{v} \times \hat{r})}{r^2}$; where v = velocity of charge and $v << c$ (speed of light).



✍ If an electron is revolving in a circular path of radius r with speed v then magnetic field produced at the centre of circular path $B = \frac{\mu_0}{4\pi}.\frac{ev}{r^2} \Rightarrow r \propto \sqrt{\frac{v}{B}}$

✍ The line integral of magnetising field $(\vec{H})$ for any closed path called magnetomotive force (MMF). It's S.I. unit is amp.

✍ Ratio of dimension of e.m.f. to MMF is equal to the dimension of resistance.

✍ The positive ions are produced in the gap between the two dees by the ionisation of the gas. To produce proton, hydrogen gas is used; while for producing alpha-particles, helium gas is used.

✍ Cyclotron frequency is also known as magnetic resonance frequency.

✍ Cyclotron can not accelerate electrons because they have very small mass.

✍ The energy of a charged particle moving in a uniform magnetic field does not change because it experiences a force in a direction, perpendicular to it's direction of motion. Due to which the speed of charged particle remains unchanged and hence it's K.E. remains same.

✍ Magnetic force does no work when the charged particle is displaced while electric force does work in displacing the charged particle.

✍ Magnetic force is velocity dependent, while electric force is independent of the state of rest or motion of the charged particle.

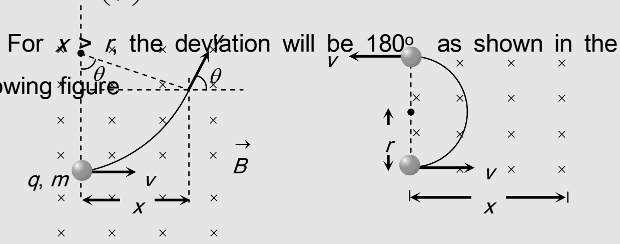
✍ If a particle enters a magnetic field normally to the magnetic field, then it starts moving in a circular orbit. The point at which it enters the magnetic field lies on the circumference. (Most of us confuse it with the centre of the orbit)

✍ Deviation of charged particle in magnetic field : If a charged particle (*q, m*) enters a uniform magnetic field $\vec{B}$ (extends upto a length x) at right angles with speed v as shown in figure. The speed of the particle in magnetic field does not change. But it gets deviated in the magnetic field.

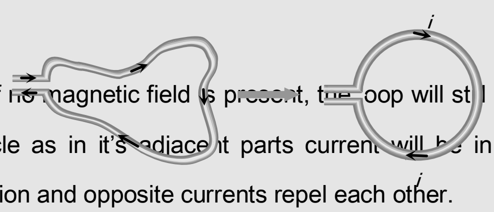
Deviation in terms of time t; $\theta = \omega t = \left(\frac{Bq}{m}\right)t$

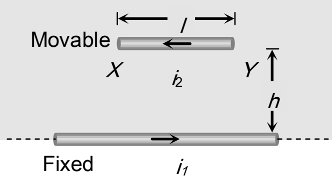
Deviation in terms of length of the magnetic field; $\theta = \sin^{-1}\left(\frac{x}{r}\right)$. This relation can be used only when $x \le r$.

For $x > r$, the deviation will be 180° as shown in the following figure



✍ If no magnetic field is present, the loop will still open into a circle as in it's adjacent parts current will be in opposite direction and opposite currents repel each other.



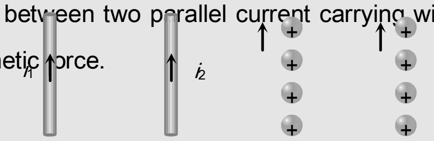


✍ In the following case if wire *XY* is slightly displaced from its equilibrium position, it executes SHM and it's time period is given by $T = 2\pi\sqrt{\frac{h}{g}}$.

✍ In the previous case if direction of current in movable wire is reversed then it's instantaneous acceleration produced is $2g$ ↓.

✍ Electric force is an absolute concept while magnetic force is a relative concept for an observer.

✍ The nature of force between two parallel charge beams decided by electric force, as it is dominator. The nature of force between two parallel current carrying wires decided by magnetic force.



$F_{net} = F_m$ only

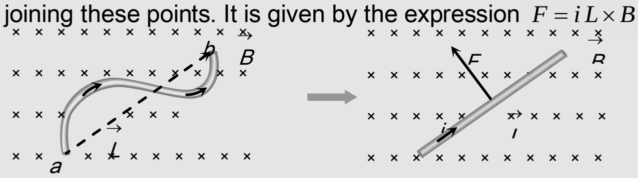
$F_e \rightarrow$ repulsion

$F_m \rightarrow$ attraction

$F_{net} \rightarrow$ repulsion (Due to

✍ If a straight current carrying wire is placed along the axis of a current carrying coil then it will not experience magnetic force because magnetic field produced by the coil is parallel to the wire.

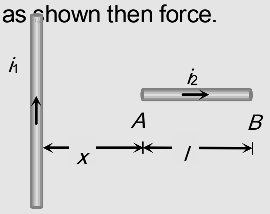
✍ The force acting on a curved wire joining points *a* and *b* as shown in the figure is the same as that on a straight wire joining these points. It is given by the expression $\vec{F} = i\vec{L} \times \vec{B}$



✍ If a current carrying conductor AB is placed transverse to a long current carrying conductor as shown then force.

Experienced by wire AB

$$F = \frac{\mu_0 i_1 i_2}{2\pi} \log_e \left(\frac{x+l}{x} \right)$$



Ordinary Thinking

Objective Questions

Biot-savart's Law and Ampere's Law

1. A length L of wire carries a steady current I. It is bent first to form a circular plane coil of one turn. The same length is now bent more sharply to give a double loop of smaller radius. The magnetic field at the centre caused by the same current is **[NCERT 1980; AIIMS 1980; MP PMT 1995, 99]**
   (a) A quarter of its first value
   (b) Unaltered
   (c) Four times of its first value
   (d) A half of its first value

2. A vertical straight conductor carries a current vertically upwards. A point P lies to the east of it at a small distance and another point Q lies to the west at the same distance. The magnetic field at P is **[MNR 1986; DPMT 2004]**
   (a) Greater than at Q
   (b) Same as at Q
   (c) Less than at Q
   (d) Greater or less than at Q depending upon the strength of the current

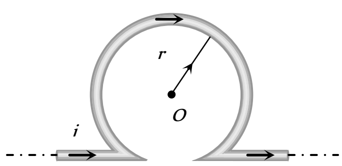
3. If a copper rod carries a direct current, the magnetic field associated with the current will be **[CPMT 1984]**
   (a) Only inside the rod
   (b) Only outside the rod
   (c) Both inside and outside the rod
   (d) Neither inside nor outside the rod

4. If a long hollow copper pipe carries a direct current, the magnetic field associated with the current will be [CBSE PMT 1999; AFMC 1999; CPMT 1984, 2000; Pb. PET 2000; JIPMER 2002]
(a) Only inside the pipe
(b) Only outside the pipe
(c) Neither inside nor outside the pipe
(d) Both inside and outside the pipe

5. The magnetic field $d\vec{B}$ due to a small current element $d\vec{l}$ at a distance $\vec{r}$ and element carrying current *i* is,
or
Vector form of Biot-savart's law is [CBSE PMT 1996; MP PET 2002; MP PMT 2000]
(a) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r}\right)$ (b) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r}\right)$
(c) $d\vec{B} = \frac{\mu_0}{4\pi} i^2 \left(\frac{d\vec{l} \times \vec{r}}{r^2}\right)$ (d) $d\vec{B} = \frac{\mu_0}{4\pi} i \left(\frac{d\vec{l} \times \vec{r}}{r^3}\right)$

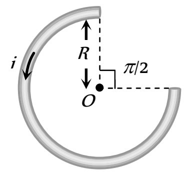
6. A charge *q coulomb* moves in a circle at *n* revolutions per second and the radius of the circle is *r metre*. Then magnetic field at the centre of the circle is
(a) $\frac{2\pi q}{nr} \times 10^{-7}$ *N/amp/metre* (b) $\frac{2\pi q}{r} \times 10^{-7}$ *N/amp/metre*
(c) $\frac{2\pi nq}{r} \times 10^{-7}$ *N/amp/metre* (d) $\frac{2\pi q}{r}$ *N/amp/metre*

7. An infinitely long straight conductor is bent into the shape as shown in the figure. It carries a current of *i ampere* and the radius of the circular loop is *r metre*. Then the magnetic induction at its centre will be [MP PMT 1999]



(a) $\frac{\mu_0}{4\pi} \frac{2i}{r}(\pi + 1)$
(b) $\frac{\mu_0}{4\pi} \frac{2i}{r}(\pi - 1)$
(c) Zero
(d) Infinite

8. A current *i ampere* flows in a circular arc of wire whose radius is *R*, which subtend an angle $3\pi/2$ radian at its centre. The magnetic induction *B* at the centre is



(a) $\frac{\mu_0 i}{R}$
(b) $\frac{\mu_0 i}{2R}$
(c) $\frac{2\mu_0 i}{R}$
(d) $\frac{3\mu_0 i}{8R}$

9. A current *i ampere* flows along the inner conductor of a coaxial cable and returns along the outer conductor of the cable, then the magnetic induction at any point outside the conductor at a distance *r metre* from the axis is
(a) ∞ (b) Zero
(c) $\frac{\mu_0}{4\pi} \frac{2i}{r}$ (d) $\frac{\mu_0}{4\pi} \frac{2\pi i}{r}$

10. A straight section *PQ* of a circuit lies along the *X*-axis from $x = -\frac{a}{2}$ to $x = \frac{a}{2}$ and carries a steady current *i*. The magnetic field due to the section *PQ* at a point $X = +a$ will be
(a) Proportional to *a* (b) Proportional to a^2
(c) Proportional to $1/a$ (d) Zero

11. A helium nucleus makes a full rotation in a circle of radius 0.8 *metre* in two seconds. The value of the magnetic field *B* at the centre of the circle will be [CPMT 1988; KCET 1998; UPSEAT 2001]
(a) $\frac{10^{-19}}{\mu_0}$ (b) $10^{-19} \mu_0$
(c) $2 \times 10^{-10} \mu_0$ (d) $\frac{2 \times 10^{-10}}{\mu_0}$

12. A solenoid of 1.5 *metre* length and 4.0 *cm* diameter posses 10 turn per *cm*. A current of 5 *ampere* is flowing through it. The magnetic induction at axis inside the solenoid is [CPMT 1990]
(a) $2\pi \times 10^{-3}$ *Tesla* (b) $2\pi \times 10^{-5}$ *Tesla*
(c) $4\pi \times 10^{-2}$ *Gauss* (d) $2\pi \times 10^{-5}$ *Gauss*

13. The magnetic induction at a point *P* which is distant 4 *cm* from a long current carrying wire is 10^{-8} *Tesla*. The field of induction at a distance 12 *cm* from the same current would be
(a) 3.33×10^{-9} *Tesla* (b) 1.11×10^{-4} *Tesla*
(c) 3×10^{-3} *Tesla* (d) 9×10^{-2} *Tesla*

14. The strength of the magnetic field at a point *r* near a long straight current carrying wire is *B*. The field at a distance $\frac{r}{2}$ will be
(a) $\frac{B}{2}$ (b) $\frac{B}{4}$
(c) $2B$ (d) $4B$

15. Field at the centre of a circular coil of radius *r*, through which a current *I* flows is [MP PMT 1993]
(a) Directly proportional to *r*
(b) Inversely proportional to *I*
(c) Directly proportional to *I*
(d) Directly proportional to I^2

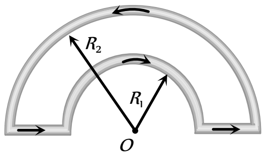
16. A current of 0.1 *A* circulates around a coil of 100 turns and having a radius equal to 5 *cm*. The magnetic field set up at the centre of the coil is
($\mu_0 = 4\pi \times 10^{-7}$ *weber / ampere – metre*) [MP PMT 1993]
(a) $4\pi \times 10^{-5}$ *tesla* (b) $8\pi \times 10^{-5}$ *tesla*
(c) 4×10^{-5} *tesla* (d) 2×10^{-5} *tesla*

17. The magnetic field B with in the solenoid having n turns per metre length and carrying a current of i *ampere* is given by [MP PET 1993]

(a) $\frac{\mu_0 ni}{e}$ (b) $\mu_0 ni$

(c) $4\pi\mu_0 ni$ (d) ni

18. The magnetic induction at the centre O in the figure shown is



(a) $\frac{\mu_0 i}{4}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

(b) $\frac{\mu_0 i}{4}\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$

(c) $\frac{\mu_0 i}{4}(R_1-R_2)$

(d) $\frac{\mu_0 i}{4}(R_1+R_2)$

19. Field inside a solenoid is [MP PMT 1993]

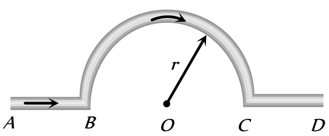
(a) Directly proportional to its length

(b) Directly proportional to current

(c) Inversely proportional to total number of turns

(d) Inversely proportional to current

20. In the figure, shown the magnetic induction at the centre of there arc due to the current in portion AB will be



(a) $\frac{\mu_0 i}{r}$

(b) $\frac{\mu_0 i}{2r}$

(c) $\frac{\mu_0 i}{4r}$

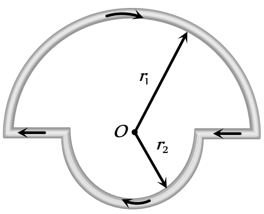
(d) Zero

21. In the above question, the magnetic induction at O due to the whole length of the conductor is [MP PMT/PET 1998; RPET 2002]

(a) $\frac{\mu_0 i}{r}$ (b) $\frac{\mu_0 i}{2r}$

(c) $\frac{\mu_0 i}{4r}$ (d) Zero

22. In the figure shown there are two semicircles of radii r_1 and r_2 in which a current i is flowing. The magnetic induction at the centre O will be



(a) $\frac{\mu_0 i}{r}(r_1+r_2)$

(b) $\frac{\mu_0 i}{4}(r_1-r_2)$

(c) $\frac{\mu_0 i}{4}\left(\frac{r_1+r_2}{r_1 r_2}\right)$

(d) $\frac{\mu_0 i}{4}\left(\frac{r_2-r_1}{r_1 r_2}\right)$

23. The magnetic moment of a current carrying loop is $2.1\times10^{-25}\ amp\times m^2$. The magnetic field at a point on its axis at a distance of $1\,\mathring{A}$ is [IIT 1988; KCET 2002]

(a) $4.2\times10^{-2}\ weber/m^2$ (b) $4.2\times10^{-3}\ weber/m^2$

(c) $4.2\times10^{-4}\ weber/m^2$ (d) $4.2\times10^{-5}\ weber/m^2$

24. Two straight horizontal parallel wires are carrying the same current in the same direction, d is the distance between the wires. You are provided with a small freely suspended magnetic needle. At which of the following positions will the orientation of the needle be independent of the magnitude of the current in the wires

(a) At a distance $d/2$ from any of the wires

(b) At a distance $d/2$ from any of the wires in the horizontal plane

(c) Anywhere on the circumference of a vertical circle of radius d and centre halfway between the wires

(d) At points halfway between the wires in the horizontal plane

25. A particle carrying a charge equal to 100 times the charge on an electron is rotating per second in a circular path of radius 0.8 *metre*. The value of the magnetic field produced at the centre will be (μ_0 = permeability for vacuum) [CPMT 1986; KCET 2001; BHU 2001]

(a) $\frac{10^{-7}}{\mu_0}$ (b) $10^{-17}\mu_0$

(c) $10^{-6}\mu_0$ (d) $10^{-7}\mu_0$

26. A circular coil of radius R carries an electric current. The magnetic field due to the coil at a point on the axis of the coil located at a distance r from the centre of the coil, such that $r >> R$, varies as [EAMCET 1987

(a) $\frac{1}{r}$ (b) $\frac{1}{r^{3/2}}$

(c) $\frac{1}{r^2}$ (d) $\frac{1}{r^3}$

27. In hydrogen atom, an electron is revolving in the orbit of radius $0.53\,\mathring{A}$ with 6.6×10^{15} *rotations/second*. Magnetic field produced at the centre of the orbit is [MP PET 2003]

(a) $0.125\,wb/m^2$ (b) $1.25\,wb/m^2$

(c) $12.5\,wb/m^2$ (d) $125\,wb/m^2$

28. The magnetic induction due to an infinitely long straight wire carrying a current i at a distance r from wire is given by [MP PET 1994]

(a) $|\mathbf{B}|=\left(\frac{\mu_0}{4\pi}\right)\frac{2i}{r}$ (b) $|\mathbf{B}|=\left(\frac{\mu_0}{4\pi}\right)\frac{r}{2i}$

(c) $|\mathbf{B}|=\left(\frac{4\pi}{\mu_0}\right)\frac{2i}{r}$ (d) $|\mathbf{B}|=\left(\frac{4\pi}{\mu_0}\right)\frac{r}{2i}$

29. Magnetic effect of current was discovered by [MP PET 1994]

(a) Faraday (b) Oersted

(c) Ampere (d) Bohr

30. Two concentric circular coils of ten turns each are situated in the same plane. Their radii are 20 and 40 *cm* and they carry respectively

0.2 and 0.3 *ampere* current in opposite direction. The magnetic field in $weber/m^2$ at the centre is

[MP PMT 1994]

(a) $\frac{35}{4}\mu_0$ (b) $\frac{\mu_0}{80}$

(c) $\frac{7}{80}\mu_0$ (d) $\frac{5}{4}\mu_0$

31. A long solenoid has a radius *a* and number of turns per unit length is *n*. If it carries a current *i*, then the magnetic field on its axis is directly proportional to [MP PMT 1994]

(a) *ani* (b) *ni*

(c) $\frac{ni}{a}$ (d) $n^2 i$

32. A cell is connected between two points of a uniformly thick circular conductor. The magnetic field at the centre of the loop will be

(a) Zero (b) $\frac{\mu_0}{2a}(i_1 - i_2)$

(c) $\frac{\mu_0}{2a}(i_1 + i_2)$ (d) $\frac{\mu_0}{a}(i_1 + i_2)$

(Here i_1 and i_2 are the currents flowing in the two parts of the circular conductor of radius '*a*' and μ_0 has the usual meaning)

33. A long solenoid is formed by winding 20 *turns/cm*. The current necessary to produce a magnetic field of 20 *millitesla* inside the solenoid will be approximately

$(\frac{\mu_0}{4\pi} = 10^{-7}\ tesla\text{–}metre/ampere)$ [MP PMT 1994]

(a) 8.0 *A* (b) 4.0 *A*

(c) 2.0 *A* (d) 1.0 *A*

34. A battery is connected between two points *A* and *B* on the circumference of a uniform conducting ring of radius *r* and resistance *R*. One of the arcs *AB* of the ring subtends an angle θ at the centre. The value of the magnetic induction at the centre due to the current in the ring is [IIT 1995]

(a) Proportional to $2(180° - \theta)$

(b) Inversely proportional to *r*

(c) Zero, only if $\theta = 180°$

(d) Zero for all values of θ

35. A current of 1 *ampere* is passed through a straight wire of length 2.0 *metres*. The magnetic field at a point in air at a distance of 3 *metres* from either end of wire and lying on the axis of wire will be

(a) $\frac{\mu_0}{2\pi}$ (b) $\frac{\mu_0}{4\pi}$

(c) $\frac{\mu_0}{8\pi}$ (d) Zero

36. A long copper tube of inner radius *R* carries a current *i*. The magnetic field *B* inside the tube is [MP PMT 1995]

(a) $\frac{\mu_0 i}{2\pi R}$ (b) $\frac{\mu_0 i}{4\pi R}$

(c) $\frac{\mu_0 i}{2R}$ (d) Zero

37. A straight wire of length (π^2) *metre* is carrying a current of 2*A* and the magnetic field due to it is measured at a point distant 1 *cm* from it. If the wire is to be bent into a circle and is to carry the same current as before, the ratio of the magnetic field at its centre to that obtained in the first case would be

(a) 50 : 1 (b) 1 : 50

(c) 100 : 1 (d) 1 : 100

38. The direction of magnetic lines of forces close to a straight conductor carrying current will be

[RPMT 2002; RPET 2003; MP PET 2003]

(a) Along the length of the conductor

(b) Radially outward

(c) Circular in a plane perpendicular to the conductor [MP PMT 1994]

(d) Helical

39. If the strength of the magnetic field produced 10*cm* away from a infinitely long straight conductor is $10^{-5}\ Weber/m^2$, the value of the current flowing in the conductor will be

[MP PET 1996]

(a) 5 *ampere* (b) 10 *ampere*

(c) 500 *ampere* (d) 1000 *ampere*

40. Due to 10 *ampere* of current flowing in a circular coil of 10 *cm* radius, the magnetic field produced at its centre is $3.14\times10^{-3}\ Weber/m^2$. The number of turns in the coil will be

(a) 5000 (b) 100

(c) 50 (d) 25

41. There are 50 turns of a wire in every *cm* length of a long solenoid. If 4 *ampere* current is flowing in the solenoid, the approximate value of magnetic field along its axis at an internal point and at one end will be respectively

[MP PET 1996]

(a) $12.6\times10^{-3}\ Weber/m^2, 6.3\times10^{-3}\ Weber/m^2$

(b) $12.6\times10^{-3}\ Weber/m^2, 25.1\times10^{-3}\ Weber/m^2$

(c) $25.1\times10^{-3}\ Weber/m^2, 12.6\times10^{-3}\ Weber/m^2$

(d) $25.1\times10^{-5}\ Weber/m^2, 12.6\times10^{-5}\ Weber/m^2$

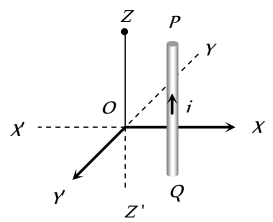
42. A solenoid is 1.0 *metre* long and it has 4250 turns. If a current of 5.0 *ampere* is flowing through it, what is the magnetic field at its centre $[\mu_0 = 4\pi\times10^{-7}\ weber/amp-m]$ [MP PET 1995]

[MP PMT 1996]

(a) $5.4\times10^{-2}\ weber/m^2$ (b) $2.7\times10^{-2}\ weber/m^2$

(c) $1.35\times10^{-2}\ weber/m^2$ (d) $0.675\times10^{-2}\ weber/m^2$

43. A vertical wire kept in *Z-X* plane carries a current from *Q* to *P* (see figure). The magnetic field due to current will have the direction at the origin *O* along



(a) *OX*

(b) *OX'*

(c) OY

(d) OY'

44. One metre length of wire carries a constant current. The wire is bent to form a circular loop. The magnetic field at the centre of this loop is *B*. The same is now bent to form a circular loop of smaller radius to have four turns in the loop. The magnetic field at the centre of this new loop is

(a) 4 B (b) 16 B

(c) $B/2$ (d) $B/4$

45. In a hydrogen atom, an electron moves in a circular orbit of radius $5.2\times10^{-11}\ m$ and produces a magnetic induction of 12.56 T at its nucleus. The current produced by the motion of the electron will be (Given $\mu_0 = 4\pi\times10^{-7}\ Wb/A-m$)

[MP PET 1997]

(a) 6.53×10^{-3} *ampere* (b) 13.25×10^{-10} *ampere*

(c) 9.6×10^{6} *ampere* (d) 1.04×10^{-3} *ampere*

46. An arc of a circle of radius *R* subtends an angle $\frac{\pi}{2}$ at the centre. It carries a current *i*. The magnetic field at the centre will be

(a) $\frac{\mu_0 i}{2R}$ (b) $\frac{\mu_0 i}{8R}$

(c) $\frac{\mu_0 i}{4R}$ (d) $\frac{2\mu_0 i}{5R}$

47. At a distance of 10 *cm* from a long straight wire carrying current, the magnetic field is 0.04 *T*. At the distance of 40 *cm*, the magnetic field will be [MP PMT 1997]

(a) 0.01 T (b) 0.02 T

(c) 0.08 T (d) 0.16 T

48. A uniform wire is bent in the form of a circle of radius *R*. A current *I* enters at *A* and leaves at *C* as shown in the figure :

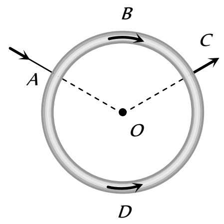
If the length *ABC* is half of the length *ADC*, the magnetic field at the centre *O* will be [MP PMT 1997]

(a) Zero

(b) $\frac{\mu_0 I}{2R}$

(c) $\frac{\mu_0 I}{4R}$

(d) $\frac{\mu_0 I}{6R}$



49. The magnetic induction at any point due to a long straight wire carrying a current is [MP PMT/PET 1998]

(a) Proportional to the distance from the wire

(b) Inversely proportional to the distance from wire

(c) Inversely proportional to the square of the distance from the wire

(d) Does not depend on distance

50. The expression for magnetic induction inside a solenoid of length *L* carrying a current *I* and having *N* number of turns is

(a) $\frac{\mu_0}{4\pi}\frac{N}{LI}$ (b) $\mu_0 NI$

(c) $\frac{\mu_0}{4\pi}NLI$ (d) $\mu_0\frac{N}{L}I$

51. In a current carrying long solenoid, the field produced does not depend upon [MP PET 1999]

(a) Number of turns per unit length

(b) Current flowing

(c) Radius of the solenoid

(d) All of the above three

52. The earth's magnetic induction at a certain point is $7\times10^{-5}\ Wb/m^2$. This is to be annulled by the magnetic induction at the centre of a circular conducting loop of radius 5 *cm*. The required current in the loop is

[MP PET 1999; MP PMT 2002]

(a) 0.56 A (b) 5.6 A

(c) 0.28 A (d) 2.8 A

53. Magnetic field due to 0.1 *A* current flowing through a circular coil of radius 0.1 *m* and 1000 turns at the centre of the coil is

(a) $2\times10^{-1}\ T$ (b) $4.31\times10^{-2}\ T$

(c) $6.28\times10^{-4}\ T$ (d) $9.81\times10^{-4}\ T$

54. Magnetic field intensity at the centre of coil of 50 turns, radius 0.5 *m* and carrying a current of 2 *A* is [MP PET 2003]

[CBSE PMT 1999; BHU 2002]

(a) $0.5\times10^{-5}\ T$ (b) $1.25\times10^{-4}\ T$

(c) $3\times10^{-5}\ T$ (d) $4\times10^{-5}\ T$

55. A circular coil '*A*' has a radius *R* and the current flowing through it is *I*. Another circular coil '*B*' has a radius 2*R* and if 2*I* is the current flowing through it, then the magnetic fields at the centre of the circular coil are in the ratio of (*i.e.* B_A to B_B)

(a) 4 : 1 (b) 2 : 1

(c) 3 : 1 (d) 1 : 1

56. The magnetic field at a distance *r* from a long wire carrying current *i* is 0.4 *Tesla*. The magnetic field at a distance 2*r* is

[CBSE PMT 1992; DPMT 2004]

(a) 0.2 *Tesla* (b) 0.8 *Tesla*

(c) 0.1 *Tesla* (d) 1.6 *Tesla*

57. A current *I* flows along the length of an infinitely long, straight and thin-walled pipe. Then [IIT-JEE 1993]

(a) The magnetic field at all points inside the pipe is the same but not zero

(b) The magnetic field at any point inside the pipe is zero

(c) The magnetic field is zero only on the axis of the pipe

(d) The magnetic field is different at different points inside the pipe

58. The magnetic field at the centre of current carrying coil is

[CPMT 1996; RPET 2002, 03]

(a) $\frac{\mu_0 ni}{2r}$ [MP PMT/PET 1998] (b) $\frac{\mu_0}{2\pi}\frac{ni}{r}$

(c) $\frac{\mu_0 ni}{4r}$ (d) $\mu_0 ni$

59. A straight wire of diameter 0.5 *mm* carrying a current of 1 *A* is replaced by another wire of 1 *mm* diameter carrying the same current. The strength of magnetic field far away is [CBSE PMT 1997, 99]

(a) Twice the earlier value
(b) Half of the earlier value
(c) Quarter of its earlier value
(d) Unchanged

60. A neutral point is obtained at the centre of a vertical circular coil carrying current. The angle between the plane of the coil and the magnetic meridian is [SCRA 1998]

(a) 0 (b) 45° (c) 60° (d) 90°

61. One *Tesla* is equal to [AFMC 1998]

(a) 10^7 *gauss* (b) 10^{-4} *gauss* (c) 10^4 *gauss* (d) 10^{-8} *gauss*

62. A current carrying wire in the neighborhood produces [AFMC 1999]

(a) No field
(b) Electric field only
(c) Magnetic field only
(d) Electric and magnetic fields

63. Tesla is the unit of [AIIMS 1999]

(a) Electric flux (b) Magnetic flux (c) Electric field (d) Magnetic field

64. The magnetic induction in air at a point 1*cm* away from a long wire that carries a current of 1*A*, will be [BHU 1999]

(a) $1\times10^{-5}T$ (b) $2\times10^{-5}T$ (c) $3\times10^{-5}T$ (d) $4\times10^{-5}T$

65. The magnetic field at the centre of coil of *n* turns, bent in the form of a square of side $2l$, carrying current *i*, is [AMU (Engg.) 1999]

(a) $\frac{\sqrt{2}\mu_0 ni}{\pi l}$ (b) $\frac{\sqrt{2}\mu_0 ni}{2\pi l}$ (c) $\frac{\sqrt{2}\mu_0 ni}{4\pi l}$ (d) $\frac{2\mu_0 ni}{\pi l}$

66. Which of the following gives the value of magnetic field according to, Biot-Savart's law' [BHU 2000]

(a) $\frac{i\Delta l\sin\theta}{r^2}$ (b) $\frac{\mu_0}{4\pi}\frac{i\Delta l\sin\theta}{r}$ (c) $\frac{\mu_0}{4\pi}\frac{i\Delta l\sin\theta}{r^2}$ (d) $\frac{\mu_0}{4\pi}i\Delta l\sin\theta$

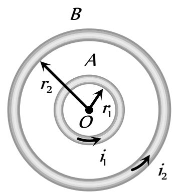
67. A toroid has number of turns per unit length *n*, current *i*, then the magnetic field is [RPET 2000]

(a) $\mu_0 ni$ (b) $\mu_0 n^2 i$ (c) $\mu_0 i/n$ (d) None of these

68. Magnetic field due to a ring having *n* turns at a distance *x* on its axis is proportional to (if *r* = radius of ring) [RPET 2000]

(a) $\frac{r}{(x^2+r^2)}$ (b) $\frac{r^2}{(x^2+r^2)^{3/2}}$ (c) $\frac{nr^2}{(x^2+r^2)^{3/2}}$ (d) $\frac{n^2r^2}{(x^2+r^2)^{3/2}}$

69. *A* and *B* are two concentric circular conductors of centre *O* and carrying currents i_1 and i_2 as shown in the adjacent figure. If ratio of their radii is 1 : 2 and ratio of the flux densities at *O* due to *A* and *B* is 1 : 3, then the value of i_1/i_2 is [KCET 2000]



(a) $\frac{1}{6}$ (b) $\frac{1}{4}$ (c) $\frac{1}{3}$ (d) $\frac{1}{2}$

70. A long straight wire carries an electric current of 2*A*. The magnetic induction at a perpendicular distance of 5*m* from the wire is

(a) $4\times10^{-8}T$ (b) $8\times10^{-8}T$ (c) $12\times10^{-8}T$ (d) $16\times10^{-8}T$

71. A straight wire carrying a current 10 *A* is bent into a semicircular arc of radius 5 *cm*. The magnitude of magnetic field at the center is

(a) $1.5\times10^{-5}T$ (b) $3.14\times10^{-5}T$ (c) $6.28\times10^{-5}T$ (d) $19.6\times10^{-5}T$

72. A long solenoid of length *L* has a mean diameter *D*. It has n layers of windings of *N* turns each. If it carries a current '*i*' the magnetic field at its centre will be [MP PMT 2000]

(a) Proportional to *D*
(b) Inversely proportional to *D*
(c) Independent of *D*
(d) Proportional to *L*

73. A circular loop of radius 0.0157*m* carries a current of 2.0 amp. The magnetic field at the centre of the loop is

$(\mu_0 = 4\pi\times10^{-7}\ weber/amp-m)$

(a) $1.57\times10^{-5}\ weber/m^2$ (b) $8.0\times10^{-5}\ weber/m^2$ (c) $2.5\times10^{-5}\ weber/m^2$ (d) $3.14\times10^{-5}\ weber/m^2$

74. A long solenoid has 200 turns per *cm* and carries a current of 2.5 *amps*. The magnetic field at its centre is $(\mu_0 = 4\pi\times10^{-7}\ weber/amp\text{-}m)$

(a) $3.14\times10^{-2} weber/m^2$
(b) $6.28\times10^{-2} weber/m^2$

(c) $9.42 \times 10^{-2} weber/m^2$

(d) $12.56 \times 10^{-2} weber/m^2$

75. Two concentric coplanar circular loops of radii r_1 and r_2 carry currents of respectively i_1 and i_2 in opposite directions (one clockwise and the other anticlockwise.) The magnetic induction at the centre of the loops is half that due to i_1 alone at the centre. If $r_2 = 2r_1$. the value of i_2/i_1 is

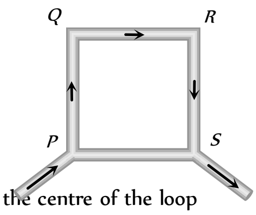
[MP PET 2000]

(a) 2 (b) 1/2

(c) 1/4 (d) 1

76. *PQRS* is a square loop made of uniform conducting wire the current enters the loop at *P* and leaves at *S*. Then the magnetic field will be

[KCET 2000]



(a) Maximum at the centre of the loop

(b) Zero at the centre of loop

(c) Zero at all points inside the loop

(d) Zero at all points outside of the loop

77. Magnetic fields at two points on the axis of a circular coil at a distance of 0.05m and 0.2m from the centre are in the ratio 8 : 1. The radius of the coil is

[KCET 2002]

(a) 1.0 m (b) 0.1 m

(c) 0.15 m (d) 0.2 m

78. An electric current passes through a long straight wire. At a distance 5 *cm* from the wire, The magnetic field is *B*. The field at 20 *cm* from the wire would be

[CPMT 2001; Pb PET 2002]

(a) $\frac{B}{6}$ (b) $\frac{B}{4}$

(c) $\frac{B}{3}$ (d) $\frac{B}{2}$

79. A closely wound flat circular coil of 25 turns of wire has diameter of 10 *cm* and carries a current of 4 *ampere*. Determine the flux density at the centre of a coil

[AIIMS 2001]

(a) $1.679 \times 10^{-5} tesla$ (b) $2.028 \times 10^{-4} tesla$

(c) $1.257 \times 10^{-3} tesla$ (d) $1.512 \times 10^{-6} tesla$

80. The dimension of the magnetic field intensity *B* is

[MP PET 2001]

(a) $MLT^{-2}A^{-1}$ (b) $MT^{-2}A^{-1}$

(c) ML^2TA^{-2} (d) $M^2LT^{-2}A^{-1}$

81. A current of 2 *amp*. flows in a long, straight wire of radius 2 *mm*. The intensity of magnetic field on the axis of the wire is

(a) $\left(\frac{\mu_o}{\pi}\right) \times 10^3$ *Tesla* (b) $\left(\frac{\mu_o}{2\pi}\right) \times 10^3$ *Tesla*

(c) $\left(\frac{2\mu_o}{\pi}\right) \times 10^3$ *Tesla* (d) Zero

82. The magnetic field at the centre of a circular coil of radius *r* carrying current *I* is B_1. The field at the centre of another coil of radius 2 *r* carrying same current *I* is B_2. The ratio $\frac{B_1}{B_2}$ is

(a) $\frac{1}{2}$ (b) 1

(c) 2 (d) 4

83. 1*A* current flows through an infinitely long straight wire. The magnetic field produced at a point 1 *metres* away from it is

[MP PMT 2001]

(a) 2×10^{-3} *Tesla* (b) $\frac{2}{10}$ *Tesla*

(c) 2×10^{-7} *Tesla* (d) $2\pi \times 10^{-6}$ Tesla

84. Two infinitely long parallel wires carry equal current in same direction. The magnetic field at a mid point in between the two wires is [MP PMT 2001]

(a) Twice the magnetic field produced due to each of the wires

(b) Half of the magnetic field produced due to each of the wires

(c) Square of the magnetic field produced due to each of the wires

(d) Zero

85. A wire in the form of a square of side '*a*' carries a current *i*. Then the magnetic induction at the centre of the square wire is (Magnetic permeability of free space = μ_o) [EAMCET 2001]

(a) $\frac{\mu_0 i}{2\pi a}$ (b) $\frac{\mu_0 i\sqrt{2}}{\pi a}$

(c) $\frac{2\sqrt{2}\mu_o i}{\pi a}$ (d) $\frac{\mu_0 i}{\sqrt{2}\pi a}$

86. What should be the current in a circular coil of radius 5*cm* to annul $B_H = 5 \times 10^{-5} T$ [DCE 2001]

(a) 0.4 *A* (b) 4 *A*

(c) 40 *A* (d) 1 *A*

87. A current of 0.1 *A* circulates around a coil of 100 turns and having a radius equal to 5*cm*. The magnetic field set up at the centre of the coil is ($\mu_o = 4\pi \times 10^{-7}$ *weber/amp-metre*)

[DPMT 2002]

(a) 2×10^{-5} *Tesla* (b) 4×10^{-5} *Tesla*

(c) $8\pi \times 10^{-5}$ *Tesla* (d) $4\pi \times 10^{-5}$ *Tesla*

88. An electron moving in a circular orbit of radius *r* makes *n* rotation per second. The magnetic field produced at the centre has a magnitude of

[KCET 2001; UPSEAT 2001, 02]

(a) $\frac{\mu_0 ne}{2r}$ (b) $\frac{\mu_0 n^2 e}{2r}$

(c) $\frac{\mu_0 ne}{2\pi r}$ (d) Zero

89. A long solenoid has n turns per meter and current I A is flowing through it. The magnetic field at the ends of the solenoid is

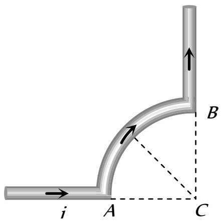
[MP PMT 2001; MP PET 2002]

(a) $\frac{\mu_0 nI}{2}$ (b) $\mu_0 nI$

(c) Zero (d) $2\mu_0 nI$

90. A wire carrying current i is shaped as shown. Section AB is a quarter circle of radius r. The magnetic field is directed

[KCET 2002]



(a) At an angle $\pi/4$ to the plane of the paper

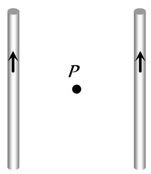
(b) Perpendicular to the plane of the paper and directed in to the paper

(c) Along the bisector of the angle ACB towards AB

(d) Along the bisector of the angle ACB away from AB

91. Two long straight wires are set parallel to each other. Each carries a current i in the same direction and the separation between them is $2r$. The intensity of the magnetic field midway between them is

[Kerala PET 2002; DCE 2002]



(a) $\mu_o i/r$

(b) $4\mu_o i/r$

(c) Zero

(d) $\mu_o i/4r$

92. A magnetic field can be produced by [AIEEE 2002]

(a) A moving charge (b) A changing electric field

(c) None of these (d) Both of these

93. Unit of magnetic permeability is [AFMC 2002]

(a) *Amp/metre* (b) *Amp*/m^2

(c) *Henry* (d) *Henry/metre*

94. A long straight wire carries a current of $\pi\, amp$. The magnetic field due to it will be $5\times10^{-5}\, weber/m^2$ at what distance from the wire $[\mu_o =$ permeability of air$]$

[MP PMT 2002]

(a) $10^4\mu_o$ *metre* (b) $\frac{10^4}{\mu_o}$ *metre*

(c) $10^6\mu_o$ *metre* (d) $\frac{10^6}{\mu_o}$ *metre*

95. When a certain length of wire is turned into one circular loop, the magnetic induction at the centre of coil due to some current flowing is B_1. If the same wire is turned into three loops to make a circular coil, the magnetic induction at the center of this coil for the same current will be

[MP PMT 2002]

(a) B_1 (b) $9B_1$

(c) $3B_1$ (d) $27B_1$

96. Gauss is unit of which quantity [MP PET 2002]

(a) H (b) B

(c) ϕ (d) 1

97. On connecting a battery to the two corners of a diagonal of a square conductor frame of side a the magnitude of the magnetic field at the centre will be [MP PET 2002]

(a) Zero (b) $\frac{\mu_o}{\pi a}$

(c) $\frac{2\mu_o}{\pi a}$ (d) $\frac{4\mu_o i}{\pi a}$

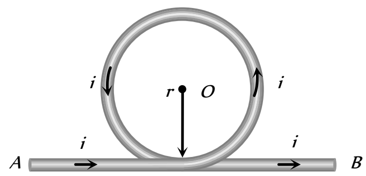
98. The ratio of the magnetic field at the centre of a current carrying coil of the radius a and at a distance 'a' from centre of the coil and perpendicular to the axis of coil is

[MP PET 2002]

(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$

(c) $\frac{1}{2\sqrt{2}}$ (d) $2\sqrt{2}$

99. A part of a long wire carrying a current i is bent into a circle of radius r as shown in figure. The net magnetic field at the centre O of the circular loop is [UPSEAT 2002]



(a) $\frac{\mu_o i}{4r}$

(b) $\frac{\mu_o i}{2r}$

(c) $\frac{\mu_o i}{2\pi r}(\pi+1)$

(d) $\frac{\mu_o i}{2\pi r}(\pi-1)$

100. The current in the windings on a toroid is 2.0A. There are 400 turns and the mean circumferential length is 40cm. If the inside magnetic field is 1.0T, the relative permeability is near to

(a) 100 (b) 200

(c) 300 (d) 400

101. "On flowing current in a conducting wire the magnetic field produces around it." It is a law of [RPET 2003]

(a) Lenz (b) Ampere

(c) Ohm (d) Maxwell

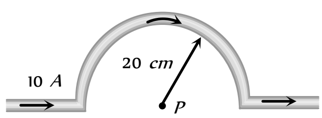
102. The magnetic field near a current carrying conductor is given by

(a) Coulomb's law (b) Lenz' law

(c) Biot-savart's law (d) Kirchoff's law

103. A current of 10A is passing through a long wire which has semicircular loop of the radius 20cm as shown in the figure. Magnetic field produced at the centre of the loop is

[Orissa JEE 2003]



(a) $10\pi\mu T$

(b) $5\pi\mu T$

(c) $4\pi\mu T$

(d) $2\pi\mu T$

104. A wire in the form of a circular loop of one turn carrying a current produces a magnetic field B at the centre. If the same wire is looped into a coil of two turns and carries the same current, the new value of magnetic induction at the centre is [CBSE 2002; KCET 2003]

(a) $5B$ (b) $3B$

(c) $2B$ (d) $4B$

105. A long solenoid carrying a current produces a magnetic field B along its axis. If the current is doubled and the number of turns per *cm* is halved, the new value of the magnetic field is

[CBSE PMT 2003]

(a) B (b) $2\ B$

(c) $4\ B$ (d) $B/2$

106. A long straight wire carrying current of $30A$ is placed in an external uniform magnetic field of induction $4 \times 10^{-4}\ T$. The magnetic field is acting parallel to the direction of current. The magnitude of the resultant magnetic induction in *tesla* at a point 2.0 cm away from the wire is [EAMCET 2003]

(a) 10^{-4} (b) 3×10^{-4}

(c) 5×10^{-4} (d) 6×10^{-4}

107. The earth's magnetic field at a given point is $0.5 \times 10^{-5}\ Wb\text{-}m^{-2}$. This field is to be annulled by magnetic induction at the center of a circular conducting loop of radius $5.0\ cm$. The current required to be flown in the loop is nearly [AIIMS 2003]

(a) $0.2\ A$ (b) $0.4A$

(c) $4A$ (d) $40A$

108. A coil having N turns carry a current I as shown in the figure. The magnetic field intensity at point P is

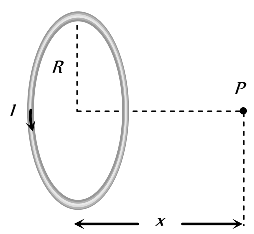
[BHU 2003; CPMT 2004]

(a) $\dfrac{\mu_0 NIR^2}{2(R^2+x^2)^{3/2}}$

(b) $\dfrac{\mu_0 NI}{2R}$

(c) $\dfrac{\mu_0 NIR^2}{(R+x)^2}$

(d) Zero



109. Two similar coils are kept mutually perpendicular such that their centres coincide. At the centre, find the ratio of the magnetic field due to one coil and the resultant magnetic field by both coils, if the same current is flown

[BHU 2003; CPMT 2004]

(a) $1:\sqrt{2}$ (b) $1:2$

(c) $2:1$ (d) $\sqrt{3}:1$

110. In the figure, what is the magnetic field at the point O

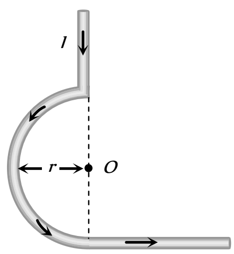
[MP PMT 2004]

(a) $\dfrac{\mu_0 I}{4\pi r}$

(b) $\dfrac{\mu_0 I}{4\pi r} + \dfrac{\mu_0 I}{2\pi r}$

(c) $\dfrac{\mu_0 I}{4r} + \dfrac{\mu_0 I}{4\pi r}$

(d) $\dfrac{\mu_0 I}{4r} - \dfrac{\mu_0 I}{4\pi r}$



111. The magnetic moment of a current (i) carrying circular coil of radius (r) and number of turns (n) varies as [AIIMS 2004]

(a) $1/r$ (b) $1/r$

(c) r (d) r

112. A current flows in a conductor from east to west. The direction of the magnetic field at a points above the conductor is .....

(a) Towards north (b) Towards south

(c) Towards east (d) Towards west

113. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B. It is then bent into a circular loop of n turns. The magnetic field at the centre of the coil will be [AIEEE 2004]

(a) nB (b) nB

(c) $2nB$ (d) $2nB$

114. The magnetic field due to a current carrying circular loop of radius 3 *cm* at a point on the axis at a distance of 4 *cm* from the centre is 54 μT. What will be its value at the centre of the loop

(a) 250 $\mu\ T$ (b) 150 $\mu\ T$

(c) 125 $\mu\ T$ (d) 75 $\mu\ T$

115. The magnetic induction at the centre of a current carrying circular of coil radius r, is [J & K CET 2004]

(a) Directly proportional to r

(b) Inversely proportional r

(c) Directly proportional to r

(d) Inversely proportional to r

116. The current is flowing in south direction along a power line. The direction of magnetic field above the power line (neglecting earth's field) is

[Pb. PMT 2004; Kerala PMT 2004]

(a) South (b) East

(c) North (d) West

117. Two wires of same length are shaped into a square and a circle. If they carry same current, ratio of the magnetic moment is

(a) $2:\pi$ (b) $\pi:2$

(c) $\pi:4$ (d) $4:\pi$

118. When the current flowing in a circular coil is doubled and the number of turns of the coil in it is halved, the magnetic field at its centre will become [DPMT 2003]

(a) Four times (b) Same

(c) Half (d) Double

119. An electron is revolving round a proton, producing a magnetic field of 16 *weber/m* in a circular orbit of radius 1Å. It's angular velocity will be [RPMT 2002]

(a) 10^{17} *rad/sec* (b) $1/2\pi \times 10^{12}$ *rad/sec*

(c) $2\ \pi \times 10^{12}$ *rad/sec* (d) $4\ \pi \times 10^{12}$ *rad/sec*

120. 20 *ampere* current is flowing in a long straight wire. The intensity of magnetic field at a distance 10 *cm* from the wire will be

(a) 4×10^{-5} *Wb/m* (b) 9×10^{-5} *Wb/m*

(c) 8×10^{-5} *Wb/m* (d) 6×10^{-5} *Wb/m*

121. The field due to a long straight wire carrying a current I is proportional to [MP PMT 1993]

(a) I (b) I^3

(c) $\sqrt{I}$ (d) $1/I$

122. Two concentric coils each of radius equal to $2\pi\ cm$ are placed at right angles to each other. 3 *ampere* and 4 *ampere* are the currents flowing in each coil respectively. The magnetic induction in

$Weber/m^2$ at the centre of the coils will be $(\mu_0 = 4\pi \times 10^{-7} Wb/A.m)$ [AIEEE 2005]

(a) 5×10^{-5} (b) 7×10^{-5}

(c) 12×10^{-5} (d) 10^{-5}

123. A wire carrying current I and other carrying $2I$ in the same direction produces a magnetic field B at the mid point. What will be the field when $2I$ wire is switched off [AFMC 2005]

(a) $B/2$ (b) $2B$

(c) B (d) $4B$

124. Two long parallel wires P and Q are both perpendicular to the plane of the paper with distance 5 m between them. If P and Q carry current of 2.5 *amp* and 5 *amp* respectively in the same direction, then the magnetic field at a point half way between the wires is

(a) $\frac{\sqrt{3}\mu_0}{2\pi}$ (b) $\frac{\mu_0}{\pi}$

(c) $\frac{3\mu_0}{2\pi}$ (d) $\frac{\mu_0}{2\pi}$

(e) $\frac{\sqrt{3}\mu_0}{\pi}$

125. The direction of magnetic lines of force produced by passing a direct current in a conductor is given by [J & K CET 2005]

(a) Lenz's law (b) Fleming's left hand rule

(c) Right hand palm rule (d) Maxwell's law

126. For the magnetic field to be maximum due to a small element of current carrying conductor at a point, the angle between the element and the line joining the element to the given point must be

(a) 0° (b) 90°

(c) 180° (d) 45°

Motion of Charged Particle In Magnetic Field

1. A proton moving with a constant velocity passes through a region of space without any change in its velocity. If $\vec{E}$ and $\vec{B}$ represent the electric and magnetic fields respectively, then this region of space may have

[IIT-JEE 1985; AMU 1995; AFMC 2001; Roorkee 2000; AMU (Med.) 2000]

(a) $E = 0, B = 0$ (b) $E = 0, B \neq 0$

(c) $E \neq 0, B = 0$ (d) $E \neq 0, B \neq 0$

2. A uniform electric field and a uniform magnetic field are produced, pointed in the same direction. An electron is projected with its velocity pointing in the same direction

[NCERT 1980; CBSE PMT 1993; JIPMER 1997; AIEEE 2005]

(a) The electron will turn to its right

(b) The electron will turn to its left

(c) The electron velocity will increase in magnitude

(d) The electron velocity will decrease in magnitude

3. Two particles X and Y having equal charges, after being accelerated through the same potential difference, enter a region of uniform magnetic field and describes circular path of radius R_1 and R_2 respectively. The ratio of mass of X to that of Y is[IIT-JEE 1988; CBSE PMT1995; M

(a) $\left(\frac{R_1}{R_2}\right)^{1/2}$ (b) $\frac{R_2}{R_1}$

(c) $\left(\frac{R_1}{R_2}\right)^2$ (d) $\frac{R_1}{R_2}$

4. A beam of ions with velocity $2 \times 10^5\ m/s$ enters normally into a uniform magnetic field of $4 \times 10^{-2}\ tesla$. If the specific charge of the ion is $5 \times 10^7\ C/kg$, then the radius of the circular path described will be [NCERT 1983; BVP 2003]

(a) 0.10 m [Kerala PMT 2005] (b) 0.16 m

(c) 0.20 m (d) 0.25 m

5. The radius of curvature of the path of the charged particle in a uniform magnetic field is directly proportional to

[MNR 1995; UPSEAT 1999, 2000]

(a) The charge on the particle

(b) The momentum of the particle

(c) The energy of the particle

(d) The intensity of the field

6. An electron has mass $9 \times 10^{-31}\ kg$ and charge $1.6 \times 10^{-19} C$ is moving with a velocity of $10^6\ m/s$, enters a region where magnetic field exists. If it describes a circle of radius 0.10 m, the intensity of magnetic field must be

[NCERT 1982; CPMT 1989; DCE 2005]

(a) $1.8 \times 10^{-4}\ T$ [J & K CET 2005] (b) $5.6 \times 10^{-5}\ T$

(c) $14.4 \times 10^{-5}\ T$ (d) $1.3 \times 10^{-6}\ T$

7. A proton (mass m and charge $+e$) and an $\alpha-$particle (mass $4m$ and charge $+2e$) are projected with the same kinetic energy at right angles to the uniform magnetic field. Which one of the following statements will be true [NCERT 1983]

(a) The $\alpha-$particle will be bent in a circular path with a small radius that for the proton

(b) The radius of the path of the $\alpha-$particle will be greater than that of the proton

(c) The $\alpha-$particle and the proton will be bent in a circular path with the same radius

(d) The $\alpha-$particle and the proton will go through the field in a straight line

8. A charged particle moving in a magnetic field experiences a resultant force [MP PMT 1994]

(a) In the direction of field

(b) In the direction opposite to that field

(c) In the direction perpendicular to both the field and its velocity

(d) None of the above

9. If the direction of the initial velocity of the charged particle is perpendicular to the magnetic field, then the orbit will be

or

The path executed by a charged particle whose motion is perpendicular to magnetic field is

[MP PMT 1993; CPMT 1996]

(a) A straight line (b) An ellipse

(c) A circle (d) A helix

10. If the direction of the initial velocity of the charged particle is neither along nor perpendicular to that of the magnetic field, then the orbit will be [MP PET 1993]

(a) A straight line (b) An ellipse
(c) A circle (d) A helix

11. Particles having positive charges occasionally come with high velocity from the sky towards the earth. On account of the magnetic field of earth, they would be deflected towards the

(a) North (b) South
(c) East (d) West

12. A 2 *MeV* proton is moving perpendicular to a uniform magnetic field of 2.5 *tesla*. The force on the proton is [CPMT 1989]

(a) $2.5\times10^{-10}\ N$ (b) $7.6\times10^{-11}\ N$
(c) $2.5\times10^{-11}\ N$ (d) $7.6\times10^{-12}\ N$

13. A charged particle moves with velocity v in a uniform magnetic field $\vec{B}$. The magnetic force experienced by the particle is

(a) Always zero
(b) Never zero
(c) Zero, if $\vec{B}$ and $\vec{v}$ are perpendicular
(d) Zero, if $\vec{B}$ and $\vec{v}$ are parallel

14. A proton is moving along *Z*-axis in a magnetic field. The magnetic field is along *X*-axis. The proton will experience a force along

(a) *X*-axis (b) *Y*-axis
(c) *Z*-axis (d) Negative *Z*-axis

15. A proton of mass *m* and charge +*e* is moving in a circular orbit in a magnetic field with energy 1 *MeV*. What should be the energy of $\alpha-$particle (mass = 4*m* and charge = + 2*e*), so that it can revolve in the path of same radius [BHU 1997]

(a) 1 *MeV* (b) 4 *MeV*
(c) 2 *MeV* (d) 0.5 *MeV*

16. An electron is moving with a speed of $10^8\ m/\sec$ perpendicular to a uniform magnetic field of intensity *B*. Suddenly intensity of the magnetic field is reduced to *B*/2. The radius of the path becomes from the original value of *r* [MP PET 1993]

(a) No change (b) Reduces to $r/2$
(c) Increases to 2*r* (d) Stops moving

17. A proton and an $\alpha-$particle enter a uniform magnetic field perpendicularly with the same speed. If proton takes 25 μ sec to make 5 revolutions, then the periodic time for the $\alpha-$particle would be [MP PET 1993]

(a) 50 μ sec (b) 25 μ sec
(c) 10 μ sec (d) 5 μ sec

18. A proton (mass $=1.67\times10^{-27}\ kg$ and charge $=1.6\times10^{-19}\ C$) enters perpendicular to a magnetic field of intensity 2 $weber/m^2$ with a velocity $3.4\times10^7\ m/\sec$. The acceleration of the proton should be [DPMT 1999]

(a) $6.5\times10^{15}\ m/\sec^2$ (b) $6.5\times10^{13}\ m/\sec^2$
(c) $6.5\times10^{11}\ m/\sec^2$ (d) $6.5\times10^{9}\ m/\sec^2$

19. An $\alpha-$particle travels in a circular path of radius 0.45 m in a magnetic field $B=1.2\,Wb/m^2$ with a speed of $2.6\times10^7\ m/\sec$. The period of revolution of the $\alpha-$particle is

(a) 1.1×10^{-5} sec (b) 1.1×10^{-6} sec
(c) 1.1×10^{-7} sec (d) 1.1×10^{-8} sec

20. A uniform magnetic field B is acting from south to north and is of magnitude 1.5 Wb/m^2. If a proton having mass $=1.7\times10^{-27}\ kg$ and charge $=1.6\times10^{-19}\ C$ moves in this field vertically downwards with energy 5 *MeV*, then the force acting on it will be [NCERT 1977]

(a) $7.4\times10^{12}\ N$ (b) $7.4\times10^{-12}\ N$
(c) $7.4\times10^{19}\ N$ (d) $7.4\times10^{-19}\ N$

21. A strong magnetic field is applied on a stationary electron, then [BIT 1989; MP P

(a) The electron moves in the direction of the field
(b) The electron moves in an opposite direction
(c) The electron remains stationary
(d) The electron starts spinning

22. A uniform magnetic field acts at right angles to the direction of motion of electrons. As a result, the electron moves in a circular path of radius 2 *cm*. If the speed of the electrons is doubled, then the radius of the circular path will be [CBSE PMT 1990] [CBSE PMT 1991]

(a) 2.0 *cm* (b) 0.5 *cm*
(c) 4.0 *cm* (d) 1.0 *cm*

23. A deutron of kinetic energy 50 *keV* is describing a circular orbit of radius 0.5 *metre* in a plane perpendicular to magnetic field $\vec{B}$. The kinetic energy of the proton that describes a circular orbit of radius 0.5 *metre* in the same plane with the same $\vec{B}$ is

(a) 25 *keV* (b) 50 *keV*
(c) 200 *keV* (d) 100 *keV*

24. If a proton is projected in a direction perpendicular to a uniform magnetic field with velocity *v* and an electron is projected along the lines of force, what will happen to proton and electron

(a) The electron will travel along a circle with constant speed and the proton will move along a straight line
(b) Proton will move in a circle with constant speed and there will be no effect on the motion of electron
(c) There will not be any effect on the motion of electron and proton
(d) The electron and proton both will follow the path of a parabola

25. An electron is travelling horizontally towards east. A magnetic field in vertically downward direction exerts a force on the electron along

(a) East (b) West
(c) North (d) South

26. Lorentz force can be calculated by using the formula [MP PET 1994, 2002, 03; CBSE PMT 2002]

(a) $\vec{F}=q(\vec{E}+\vec{v}\times\vec{B})$ (b) $\vec{F}=q(\vec{E}-\vec{v}\times\vec{B})$
(c) $\vec{F}=q(\vec{E}+\vec{v}\cdot\vec{B})$ (d) $\vec{F}=q(\vec{E}\times\vec{B}+\vec{v})$

27. A magnetic field [MP PET 1994; Pb PMT 2003]

(a) Always exerts a force on a charged particle
(b) Never exerts a force on a charged particle
(c) Exerts a force, if the charged particle is moving across the magnetic field lines
(d) Exerts a force, if the charged particle is moving along the magnetic field lines

28. A proton enters a magnetic field of flux density $1.5\, weber/m^2$ with a velocity of $2\times10^7\, m/\sec$ at an angle of $30°$ with the field. The force on the proton will be

[MP PET 1994 ; Pb. PMT 2004]

(a) $2.4\times10^{-12}\, N$ (b) $0.24\times10^{-12}\, N$

(c) $24\times10^{-12}\, N$ (d) $0.024\times10^{-12}\, N$

29. If a particle of charge $10^{-12}\, coulomb$ moving along the $\hat{x}-$direction with a velocity $10^5\, m/s$ experiences a force of $10^{-10}\, newton$ in $\hat{y}-$direction due to magnetic field, then the minimum magnetic field is [MP PMT 1994]

(a) $6.25\times10^3\, tesla$ in $\hat{z}-$direction

(b) $10^{-15}\, tesla$ in $\hat{z}-$direction

(c) $6.25\times10^{-3}\, tesla$ in $\hat{z}-$direction

(d) $10^{-3}\, tesla$ in $\hat{z}-$direction

30. If a proton, deutron and $\alpha-$particle on being accelerated by the same potential difference enters perpendicular to the magnetic field, then the ratio of their kinetic energies is

[MP PMT 2003; J & K CET 2005]

(a) 1 : 2 : 2 (b) 2 : 2 : 1

(c) 1 : 2 : 1 (d) 1 : 1 : 2

31. Which of the following statement is true

[Manipal MEE 1995]

(a) The presence of a large magnetic flux through a coil maintains a current in the coil if the circuit is continuous

(b) A coil of a metal wire kept stationary in a non-uniform magnetic field has an e.m.f. induced in it

(c) A charged particle enters a region of uniform magnetic field at an angle of $85°$ to the magnetic lines of force; the path of the particle is a circle

(d) There is no change in the energy of a charged particle moving in a magnetic field although a magnetic force is acting on it

32. An electron and a proton enter region of uniform magnetic field in a direction at right angles to the field with the same kinetic energy. They describe circular paths of radius r_e and r_p respectively. Then

(a) $r_e=r_p$

(b) $r_e<r_p$

(c) $r_e>r_p$

(d) r_e may be less than or greater than r_p depending on the direction of the magnetic field

33. A proton of mass $1.67\times10^{-27}\, kg$ and charge $1.6\times10^{-19}\, C$ is projected with a speed of $2\times10^6\, m/s$ at an angle of $60°$ to the $X-$axis. If a uniform magnetic field of 0.104 *Tesla* is applied along $Y-$axis, the path of proton is [IIT-JEE 1995]

(a) A circle of radius = 0.2 m and time period $\pi\times10^{-7}\, s$

(b) A circle of radius = 0.1 m and time period $2\pi\times10^{-7}\, s$

(c) A helix of radius = 0.1 m and time period $2\pi\times10^{-7}\, s$

(d) A helix of radius = 0.2 m and time period $4\pi\times10^{-7}\, s$

34. A proton and a deutron both having the same kinetic energy, enter perpendicularly into a uniform magnetic field B. For motion of proton and deutron on circular path of radius R_p and R_d respectively, the correct statement is

[MP PET 1995]

(a) $R_d=\sqrt{2}\, R_p$ (b) $R_d=R_p/\sqrt{2}$

(c) $R_d=R_p$ (d) $R_d=2R_p$

35. A proton (or charged particle) moving with velocity v is acted upon by electric field E and magnetic field B. The proton will move undeflected if

[MP PMT 1995, 2003; UPSEAT 2002; DPMT 2003]

(a) E is perpendicular to B

(b) E is parallel to v and perpendicular to B

(c) E, B and v are mutually perpendicular and $v=\frac{E}{B}$

(d) E and B both are parallel to v

36. A proton and an electron both moving with the same velocity v enter into a region of magnetic field directed perpendicular to the velocity of the particles. They will now move in circular orbits such that [MP PMT 1995]

(a) Their time periods will be same

(b) The time period for proton will be higher

(c) The time period for electron will be higher

(d) Their orbital radii will be same

37. A charge + Q is moving upwards vertically. It enters a magnetic field directed to the north. The force on the charge will be towards[MP PMT 1995; AM

(a) North (b) South

(c) East (d) West

38. An electron is moving on a circular path of radius r with speed v in a transverse magnetic field B. e/m for it will be

[MP PMT 2003]

(a) $\frac{v}{Br}$ [Manipal MEE 1995] (b) $\frac{B}{rv}$

(c) Bvr (d) $\frac{vr}{B}$

39. A beam of well collimated cathode rays travelling with a speed of $5\times10^6\, ms^{-1}$ enter a region of mutually perpendicular electric and magnetic fields and emerge undeviated from this region. If $|\boldsymbol{B}|=0.02\, T$, the magnitude of the electric field is

(a) $10^5\, Vm^{-1}$ (b) $2.5\times10^8\, Vm^{-1}$

(c) $1.25\times10^{10}\, Vm^{-1}$ (d) $2\times10^3\, Vm^{-1}$

40. An electron having charge $1.6\times10^{-19}\, C$ and mass $9\times10^{-31}\, kg$ is moving with $4\times10^6\, ms^{-1}$ speed in a magnetic field $2\times10^{-1}\, tesla$ in a circular orbit. The force acting on electron and the radius of the circular orbit will be

[MP PET 1996; JIPMER 2000; BVP 2003]

(a) $12.8\times10^{-13}\, N, 1.1\times10^{-4}\, m$

(b) $1.28\times10^{-14}\,N, 1.1\times10^{-3}m$

(c) $1.28\times10^{-13}\,N, 1.1\times10^{-3}m$

(d) $1.28\times10^{-13}\,N, 1.1\times10^{-4}m$

41. An electron enters a magnetic field whose direction is perpendicular to the velocity of the electron. Then [MP PMT 1996; CBSE PMT 2003]

(a) The speed of the electron will increase

(b) The speed of the electron will decrease

(c) The speed of the electron will remain the same

(d) The velocity of the electron will remain the same

42. An electron is moving in the north direction. It experiences a force in vertically upward direction. The magnetic field at the position of the electron is in the direction of [MP PET 2003]

(a) East (b) West

(c) North (d) South

43. A current carrying long solenoid is placed on the ground with its axis vertical. A proton is falling along the axis of the solenoid with a velocity *v*. When the proton enters into the solenoid, it will

(a) Be deflected from its path

(b) Be accelerated along the same path

(c) Be decelerated along the same path

(d) Move along the same path with no change in velocity

44. A charged particle of mass *m* and charge *q* describes circular motion of radius *r* in a uniform magnetic field of strength *B*. The frequency of revolution is [MP PET 1997; RPET 2001]

(a) $\frac{Bq}{2\pi m}$ (b) $\frac{Bq}{2\pi rm}$

(c) $\frac{2\pi m}{Bq}$ (d) $\frac{Bm}{2\pi q}$

45. An electron is accelerated by a potential difference of 12000 *volts*. It then enters a uniform magnetic field of $10^{-3}\,T$ applied perpendicular to the path of electron. Find the radius of path. Given mass of electron $=9\times10^{-31}\,kg$ and charge on electron $=1.6\times10^{-19}\,C$ [MP PET 1997]

(a) 36.7 *m* (b) 36.7 *cm*

(c) 3.67 *m* (d) 3.67 *cm*

46. The charge on a particle *Y* is double the charge on particle *X*. These two particles *X* and *Y* after being accelerated through the same potential difference enter a region of uniform magnetic field and describe circular paths of radii R_1 and R_2 respectively. The ratio of the mass of *X* to that of *Y* is [MP PET 1997]

(a) $\left(\frac{2R_1}{R_2}\right)^2$ (b) $\left(\frac{R_1}{2R_2}\right)^2$

(c) $\frac{R_1^2}{2R_2^2}$ (d) $\frac{2R_1}{R_2}$

47. A particle with 10^{-11} *coulomb* of charge and $10^{-7}\,kg$ mass is moving with a velocity of $10^8\,m/s$ along the *y*-axis. A uniform static magnetic field $B=0.5\,Tesla$ is acting along the *x*-direction. The force on the particle is [MP PMT 1997]

(a) $5\times10^{-11}\,N$ along $\hat{i}$ (b) $5\times10^{3}\,N$ along $\hat{k}$

(c) $5\times10^{-11}\,N$ along $-\hat{j}$ (d) $5\times10^{-4}\,N$ along $-\hat{k}$

48. A particle of charge *q* and mass *m* moving with a velocity *v* along the *x*-axis enters the region $x > 0$ with uniform magnetic field *B* along the $\hat{k}$ direction. The particle will penetrate in this region in the *x*-direction upto a distance *d* equal to

(a) Zero (b) $\frac{mv}{qB}$

(c) $\frac{2mv}{qB}$ (d) Infinity

49. A charged particle is moving with velocity *v* in a magnetic field of induction *B*. The force on the particle will be maximum when

(a) *v* and *B* are in the same direction

(b) *v* and *B* are in opposite directions

(c) *v* and *B* are perpendicular

(d) *v* and *B* are at an angle of $45°$

50. A charged particle enters a magnetic field *H* with its initial velocity making an angle of $45°$ with *H*. The path of the particle will be [MP PET 1999;

(a) A straight line (b) A circle

(c) An ellipse (d) A helix

51. An electron and a proton enter a magnetic field perpendicularly. Both have same kinetic energy. Which of the following is true

(a) Trajectory of electron is less curved

(b) Trajectory of proton is less curved

(c) Both trajectories are equally curved

(d) Both move on straight-line path

52. A charged particle moves in a uniform magnetic field. The velocity of the particle at some instant makes an acute angle with the magnetic field. The path of the particle will be [MP PMT 1999]

(a) A straight line

(b) A circle

(c) A helix with uniform pitch

(d) A helix with non-uniform pitch

53. An electron is moving along positive *x*-axis. To get it moving on an anticlockwise circular path in *x-y* plane, a magnetic filed is applied

(a) Along positive *y*-axis (b) Along positive *z*-axis

(c) Along negative *y*-axis (d) Along negative *z*-axis

54. A moving charge will gain energy due to the application of [CPMT 1999]

(a) Electric field (b) Magnetic field

(c) Both of these (d) None of these

55. A proton, a deuteron and an $\alpha-$ particle having the same kinetic energy are moving in circular trajectories in a constant magnetic field. If r_p, r_d and r_α denote respectively the radii of the trajectories of these particles, then

[IIT 1997 Re-Exam]

(a) $r_\alpha = r_p < r_d$ (b) $r_\alpha > r_d > r_p$

(c) $r_\alpha = r_d > r_p$ (d) $r_p = r_d = r_\alpha$

56. When a magnetic field is applied in a direction perpendicular to the direction of cathode rays, then their [EAMCET 1994; BHU 2005]

(a) Energy decreases

(b) Energy increases

(c) Momentum increases

(d) Momentum and energy remain unchanged

57. A charge moves in a circle perpendicular to a magnetic field. The time period of revolution is independent of [RPET 1997; AIEEE 2002]

(a) Magnetic field (b) Charge

(c) Mass of the particle (d) Velocity of the particle

58. A proton of energy 200 *MeV* enters the magnetic field of 5 *T*. If direction of field is from south to north and motion is upward, the force acting on it will be [RPET 1997]

(a) Zero (b) $1.6\times10^{-10}\,N$

(c) $3.2\times10^{-8}\,N$ (d) $1.6\times10^{-6}\,N$

59. An electron enters a region where magnetic (*B*) and electric (*E*) fields are mutually perpendicular to one another, then [CBSE PMT1993]

(a) It will always move in the direction of *B*

(b) It will always move in the direction of *E*

(c) It always possess circular motion

(d) It can go undeflected also

60. A charge moving with velocity *v* in *X*-direction is subjected to a field of magnetic induction in the negative *X*-direction. As a result, the charge will [CBSE PMT1993]

(a) Remain unaffected

(b) Start moving in a circular path *Y*-*Z* plane

(c) Retard along *X*-axis

(d) Move along a helical path around *X*-axis

61. An electron and a proton with equal momentum enter perpendicularly into a uniform magnetic field, then [BHU 1997; AIEEE 2002; MH CET (Med.) 2000]

(a) The path of proton shall be more curved than that of electron

(b) The path of proton shall be less curved than that of electron

(c) Both are equally curved

(d) Path of both will be straight line

62. A positively charged particle moving due east enters a region of uniform magnetic field directed vertically upwards. The particle will

(a) Get deflected vertically upwards

(b) Move in a circular orbit with its speed increased

(c) Move in a circular orbit with its speed unchanged

(d) Continue to move due east

63. A particle moving in a magnetic field increases its velocity, then its radius of the circle [BHU 1998]

(a) Decreases (b) Increases

(c) Remains the same (d) Becomes half

64. A particle is moving in a uniform magnetic field, then [BHU 1998]

(a) Its momentum changes but total energy remains the same

(b) Both momentum and total energy remain the same

(c) Both will change

(d) Total energy changes but momentum remains the same

65. If an electron is going in the direction of magnetic field $\vec{B}$ with the velocity of $\vec{v}$ then the force on electron is [RPMT 1999]

(a) Zero (b) $e(\vec{v}\cdot\vec{B})$

(c) $e(\vec{v}\times\vec{B})$ (d) None of these

66. One proton beam enters a magnetic field of $10^{-4}\,T$ normally, Specific charge = $10^{11}\,C/kg$. velocity = $10^{7}\,m/s$. What is the radius of the circle described by it [DCE 1999]

(a) 0.1 *m* (b) 1 *m*

(c) 10 *m* (d) None of these

67. In a cyclotron, the angular frequency of a charged particle is independent of [CPMT 1999]

(a) Mass (b) Speed

(c) Charge (d) Magnetic field

68. A charged particle is moving in a uniform magnetic field in a circular path. Radius of circular path is *R*. When energy of particle is doubled, then new radius will be [CPMT 1999; Pb. PET 2002]

(a) $R\sqrt{2}$ (b) $R\sqrt{3}$

(c) 2 *R* (d) 3 *R*

69. The radius of curvature of the path of a charged particle moving in a static uniform magnetic field is [Roorkee 1999]

(a) Directly proportional to the magnitude of the charge on the particle

(b) Directly proportional to the magnitude of the linear momentum of the particle

(c) Directly proportional to the kinetic energy of the particle

(d) Inversely proportional to the magnitude of the magnetic field

70. A proton moving with a velocity, $2.5\times10^{7}\,m/s$, enters a magnetic field of intensity 2.5 *T* making an angle 30^o with the magnetic field. The force on the proton is [AFMC 2000; CBSE PMT 2000]

(a) $3\times10^{-12}\,N$ (b) $5\times10^{-12}\,N$

(c) $6\times10^{-12}\,N$ (d) $9\times10^{-12}\,N$

71. Maximum kinetic energy of the positive ion in the cyclotron is [CBSE PMT 1997]

(a) $\frac{q^2Br_0}{2m}$ (b) $\frac{qB^2r_o}{2m}$

(c) $\frac{q^2B^2r_0^2}{2m}$ (d) $\frac{qBr_0}{2m^2}$

72. A charge *q* is moving in a magnetic field then the magnetic force does not depend upon [RPET 2000]

(a) Charge (b) Mass

(c) Velocity (d) Magnetic field

73. An electron is travelling in east direction and a magnetic field is applied in upward direction then electron will deflect in

(a) South (b) North

(c) West (d) East

74. A charge of $1C$ is moving in a magnetic field of $0.5\,Tesla$ with a velocity of $10\,m/sec$ Perpendicular to the field. Force experienced is

(a) $5\,N$ (b) $10\,N$

(c) $0.5\,N$ (d) $0\,N$

75. An electron of mass m and charge q is travelling with a speed v along a circular path of radius r at right angles to a uniform of magnetic field B. If speed of the electron is doubled and the magnetic field is halved, then resulting path would have a radius of [Kerala PMT 2004; KCET 2000, 05]

(a) $\frac{r}{4}$ (b) $\frac{r}{2}$

(c) $2r$ (d) $4r$

76. If an electron enters a magnetic field with its velocity pointing in the same direction as the magnetic field, then [MP PMT 2000]

(a) The electron will turn to its right

(b) The electron will turn to its left

(c) The velocity of the electron will increase

(d) The velocity of the electron will remain unchanged

77. A particle of mass m and charge q enters a magnetic field B perpendicularly with a velocity v, The radius of the circular path described by it will be [MP PMT 2000]

(a) Bq/mv (b) mq/Bv

(c) mB/qv (d) mv/Bq

78. An electron moving towards the east enters a magnetic field directed towards the north. The force on the electron will be directed

(a) Vertically upward (b) Vertically downward

(c) Towards the west (d) Towards the south

79. An electron (mass $= 9.0\times10^{-31}\,kg$ and charge $= 1.6\times10^{-19}$ *coulomb*) is moving in a circular orbit in a magnetic field of $1.0\times10^{-4}\,weber/m^2$. Its period of revolution is

(a) $3.5\times10^{-7}\,sec$ (b) $7.0\times10^{-7}\,sec$

(c) $1.05\times10^{-6}\,sec$ (d) $2.1\times10^{-6}\,sec$

80. An electron (charge q coulomb) enters a magnetic field of H $weber/m^2$ with a velocity of $v\,m/s$ in the same direction as that of the field the force on the electron is [MP PET 2000]

(a) Hqv Newton's in the direction of the magnetic field

(b) Hqv dynes in the direction of the magnetic field

(c) Hqv Newton's at right angles to the direction of the magnetic field

(d) Zero

81. A homogeneous electric field E and a uniform magnetic field $\vec{B}$ are pointing in the same direction. A proton is projected with its velocity parallel to $\vec{E}$. It will [Roorkee 2000]

(a) Go on moving in the same direction with increasing velocity

(b) Go on moving in the same direction with constant velocity

(c) Turn to its right

(d) Turn to its left

82. The radius of circular path of an electron when subjected to a perpendicular magnetic field is [Pb. PMT 1999; DCE 2000; MH CET (Med.) 2000]

(a) $\frac{mv}{Be}$ (b) $\frac{me}{Be}$

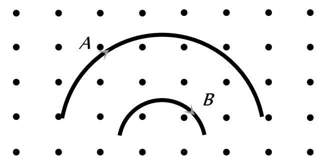
(c) $\frac{mE}{Be}$ [RPMT 2000] (d) $\frac{Be}{mv}$

83. Cyclotron is used to accelerate [AIIMS 2001; BCECE 2004]

(a) Electrons (b) Neutrons

(c) Positive ions (d) Negative ions

84. Two particles A and B of masses m_A and m_B respectively and having the same charge are moving in a plane. A uniform magnetic field exists perpendicular to this plane. The speeds of the particles are v_A and v_B respectively, and the trajectories are as shown in the figure. Then [IIT-JEE (Screening) 2001]



(a) $m_A v_A < m_B v_B$

(b) $m_A v_A > m_B v_B$

(c) $m_A < m_B$ and $v_A < v_B$

(d) $m_A = m_B$ and $v_A = v_B$

85. A proton and an alpha particle are separately projected in a region where a uniform magnetic field exists. Their initial velocities are perpendicular to direction of magnetic field. If both the particles move around magnetic field in circles of equal radii, the ratio of momentum of proton to alpha particle $\left(\frac{P_p}{P_\alpha}\right)$ is

(a) 1 (b) $\frac{1}{2}$

(c) 2 [MP PET 2000] (d) $\frac{1}{4}$

86. A particle of mass 0.6 g and having charge of 25 nC is moving horizontally with a uniform velocity $1.2\times10^4\,ms^{-1}$ in a uniform magnetic field, then the value of the magnetic induction is $(g = 10\,ms^{-2})$ [EAMCET 2001]

[MP PET 2000; Pb PET 2003]

(a) Zero (b) 10 T

(c) 20 T (d) 200 T

87. An α particle and a proton travel with same velocity in a magnetic field perpendicular to the direction of their velocities, find the ratio of the radii of their circular path [AIIMS 2004; DCE 2001, 03; Kerala PMT 2005]

(a) 4 : 1 (b) 1 : 4

(c) 2 : 1 (d) 1 : 2

88. Motion of a moving electron is not affected by [AMU (Engg.) 2001]

(a) An electric field applied in the direction of motion

(b) Magnetic field applied in the direction of motion

(c) Electric field applied perpendicular to the direction of motion

(d) Magnetic field applied perpendicular to the direction of motion

89. When a charged particle enters a uniform magnetic field its kinetic energy [MP PMT 2001; MP PET 2002]

(a) Remains constant (b) Increases

(c) Decreases (d) Becomes zero

90. If cathode rays are projected at right angles to a magnetic field, their trajectory is [JIPMER 2002]

(a) Ellipse (b) Circle

(c) Parabola (d) None of these

91. At a specific instant emission of radioactive compound is deflected in a magnetic field. The compound can emit

(i) Electrons (ii) Protons

(iii) He^{2+} (iv) Neutrons

The emission at the instant can be **[AIEEE 2002]**

(a) i, ii, iii (b) i, ii, iii, iv

(c) iv (d) ii, iii

92. Which particles will have minimum frequency of revolution when projected with the same velocity perpendicular to a magnetic field

(a) Li (b) Electron

(c) Proton (d) He^+

93. Mixed He^+ and O^{2+} ions (mass of $He^+ = 4\ amu$ and that of $O^{2+} = 16\ amu$) beam passes a region of constant perpendicular magnetic field. If kinetic energy of all the ions is same then

(a) He^+ ions will be deflected more than those of O^{2+}

(b) He^+ ions will be deflected less than those of O^{2+}

(c) All the ions will be deflected equally

(d) No ions will be deflected

94. An electron (mass = 9×10^{-31} *kg*. Charge = 1.6×10^{-19} *C*) whose kinetic energy is 7.2×10^{-18} *joule* is moving in a circular orbit in a magnetic field of 9×10^{-5} *weber/m*^{2}. The radius of the orbit is

(a) 1.25 *cm* (b) 2.5 *cm*

(c) 12.5 *cm* (d) 25.0 *cm*

95. An electron enters a region where electrostatic field is 20*N*/*C* and magnetic field is 5*T*. If electron passes undeflected through the region, then velocity of electron will be

[DPMT 2002]

(a) $0.25 ms^{-1}$ (b) $2 ms^{-1}$

(c) $4 ms^{-1}$ (d) $8 ms^{-1}$

96. A charged particle is released from rest in a region of steady uniform electric and magnetic fields which are parallel to each other the particle will move in a

[IIT-JEE 1999; DPMT 2000; UPSEAT 2003]

(a) Straight line (b) Circle

(c) Helix (d) Cycloid

97. A particle of mass *M* and charge *Q* moving with velocity $\vec{v}$ describes a circular path of radius *R* when subjected to a uniform transverse magnetic field of induction *B*. The work done by the field when the particle completes one full circle is

(a) $BQv\,2\pi R$ (b) $\left(\frac{Mv^2}{R}\right) 2\pi R$

(c) Zero (d) $BQ2\pi R$

98. A particle of charge -16×10^{-18} *coulomb* moving with velocity $10\ ms^{-1}$ along the *x*-axis enters a region where a magnetic field of induction *B* is along the *y*-axis, and an electric field of magnitude 10^4 *V*/*m* is along the negative *z*-axis. If the charged particle continues moving along the *x*-axis, the magnitude of *B* is

(a) $10^{-3} Wb/m^2$ (b) $10^3 Wb/m^2$

(c) $10^5 Wb/m^2$ (d) $10^{16} Wb/m^2$

99. Two ions having masses in the ratio 1 : 1 and charges 1 : 2 are projected into uniform magnetic field perpendicular to the field with speeds in the ratio 2 : 3. The ratio of the radii of circular paths along which the two particles move is

[EAMCET 2003]

(a) 4 : 3 (b) 2 : 3

(c) 3 : 1 (d) 1 : 4

100. An electron is travelling along the *x*-direction. It encounters a magnetic field in the *y*-direction. Its subsequent motion will be **[Orissa JEE 2002]**

(a) Straight line along the *x*-direction

(b) A circle in the *xz*-plane

(c) A circle in the *yz*-plane

(d) A circle in the *xy*-plane

101. An electron and a proton have equal kinetic energies. They enter in a magnetic field perpendicularly, Then **[Orissa JEE 2002]**

[UPSEAT 2003]

(a) Both will follow a circular path with same radius

(b) Both will follow a helical path

(c) Both will follow a parabolic path

(d) All the statements are false

102. Electrons move at right angles to a magnetic field of 1.5×10^{-2} *Tesla* with a speed of $6 \times 10^7\ m/s$. If the specific charge of the electron is 1.7×10^{11} *C*/*kg*. The radius of the circular path will be **[MP PMT 2002]** **[BHU 2003]**

(a) 2.9 *cm* (b) 3.9 *cm*

(c) 2.35 *cm* (d) 3 *cm*

103. The cyclotron frequency of an electron grating in a magnetic field of 1 *T* is approximately **[AIIMS 2004]**

(a) 28 *MHz* (b) 280 *MHz*

(c) 2.8 *GHz* (d) 28 *GHz*

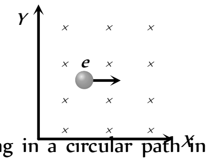
104. In the given figure, the electron enters into the magnetic field. It deflects in ...... direction **[Orissa PMT 2004]**

(a) + *ve X* direction

(b) – *ve X* direction

(c) + *ve Y* direction

(d) – *ve Y* direction



105. A proton of energy 8 *eV* is moving in a circular path in a uniform magnetic field. The energy of an alpha particle moving in the same magnetic field and along the same path will be

(a) 4 *eV* (b) 2 *eV*

(c) 8 *eV* (d) 6 *eV*

106. An electron, a proton, a deuteron and an alpha particle, each having the same speed are in a region of constant magnetic field perpendicular to the direction of the velocities of the particles. The radius of the circular orbits of these particles are respectively R_e, R_p, R_d and R_α. It follows that **[AIEEE 2003]**

(a) $R_e = R_p$ (b) $R_p = R_d$

(c) $R_d = R_\alpha$ (d) $R_p = R_\alpha$

107. An electron moving with a uniform velocity along the positive *x*-direction enters a magnetic field directed along the positive *y*-direction. The force on the electron is directed along **[AIEEE 2003]**

(a) Positive *y*-direction (b) Negative *y*-direction

(c) Positive z-direction (d) Negative z-direction

108. An electron is projected along the axis of a circular conductor carrying some current. Electron will experience force

(a) Along the axis

(b) Perpendicular to the axis

(c) At an angle of 4° with axis

(d) No force experienced

109. A very high magnetic field is applied to a stationary charge. Then the charge experiences [DCE 2004]

(a) A force in the direction of magnetic field

(b) A force perpendicular to the magnetic field

(c) A force in an arbitrary direction

(d) No force

110. A electron ($q = 1.6 \times 10^{-19}$ C) is moving at right angle to the uniform magnetic field 3.534×10^{-5} T. The time taken by the electron to complete a circular orbit is [MH CET 2004]

(a) 2 μs (b) 4 μs

(c) 3 μs (d) 1 μs

111. In case Hall effect for a strip having charge Q and area of cross-section A, the Lorentz force is [DCE 2004]

(a) Directly proportional to Q

(b) Inversely proportional to Q

(c) Inversely proportional to A

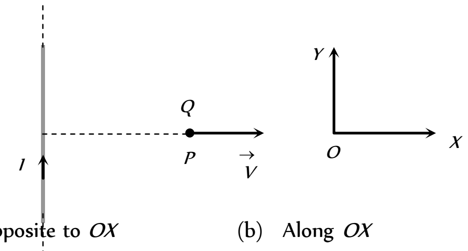
(d) Directly proportional to A

112. A charged particle of mass m and charge q travels on a circular path of radius r that is perpendicular to a magnetic field B. The time taken by the particle to complete one revolution is

(a) $\frac{2\pi qB}{m}$ (b) $\frac{2\pi m}{qB}$

(c) $\frac{2\pi mq}{B}$ (d) $\frac{2\pi q^2 B}{m}$

113. A very long straight wire carries a current I. At the instant when a charge $+Q$ at point P has velocity $\vec{V}$, as shown, the force on the charge is [CBSE PMT 2005]



(a) Opposite to OX (b) Along OX

(c) Opposite to OY (d) Along OY

114. The electron in the beam of a television tube move horizontally from south to north. The vertical component of the earth's magnetic field points down. The electron is deflected towards

(a) West (b) No deflection

(c) East (d) North to south

115. An electron moves in a circular orbit with a uniform speed v. It produces a magnetic field B at the centre of the circle. The radius of the circle is proportional to [CBSE PMT 2005]

(a) $\frac{B}{v}$ (b) $\frac{v}{R}$

(c) $\sqrt{\frac{v}{B}}$ (d) $\sqrt{\frac{B}{v}}$

116. An electric field of 1500 V/m and a magnetic field of 0.40 $weber/meter$ act on a moving electron. The minimum uniform speed along a straight line the electron could have is [DCE 2002]

(a) 1.6×10^{15} m/s (b) 6×10^{-16} m/s

(c) 3.75×10^{3} m/s (d) 3.75×10^{2} m/s

117. An electron (mass = 9.1×10^{-31} kg; charge = 1.6×10^{-19} C) experiences no deflection if subjected to an electric field of 3.2×10^{5} V/m, and a magnetic fields of 2.0×10^{-3} Wb/m. Both the fields are normal to the path of electron and to each other. If the electric field is removed, then the electron will revolve in an orbit of radius [BCECE 2005]

(a) 45 m (b) 4.5 m

(c) 0.45 m (d) 0.045 m

118. An electron, moving in a uniform magnetic field of induction of intensity $\vec{B}$, has its radius directly proportional to [DPMT 2005]

(a) Its charge (b) Magnetic field

(c) Speed (d) None of these

Force and Torque on a Current Carrying Conductor

1. Two free parallel wires carrying currents in opposite direction [CPMT 1977; MP PMT 1993; AFMC 2002; CPMT 2003]

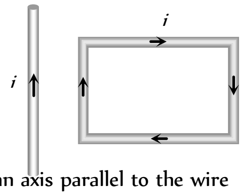
(a) Attract each other

(b) Repel each other

(c) Neither attract nor repel

(d) Get rotated to be perpendicular to each other

2. A rectangular loop carrying a current i is situated near a long straight wire such that the wire is parallel to the one of the sides of the loop and is in the plane of the loop. If a steady current I is established in wire as shown in figure, the loop will [AIEEE 2005] [IIT 1985; MP PET 1995; MP PMT 1995, 99; AIIMS 2003]



(a) Rotate about an axis parallel to the wire

(b) Move away from the wire or towards right

(c) Move towards the wire

(d) Remain stationary

3. A circular coil of radius 4 cm and of 20 turns carries a current of 3 $amperes$. It is placed in a magnetic field of intensity of 0.5 $weber/m^2$. The magnetic dipole moment of the coil is

(a) 0.15 $ampere - m^2$ (b) 0.3 $ampere - m^2$

(c) 0.45 $ampere - m^2$ [KCET 2005] (d) 0.6 $ampere - m^2$

4. A conducting circular loop of radius r carries a constant current i. It is placed in a uniform magnetic field $\vec{B}$, such that $\vec{B}$ is perpendicular to the plane of the loop. The magnetic force acting on the loop is [BIT 1992; MP PET 1994; IIT 1983; MP PMT 1999; AMU (Engg.) 2000]

(a) $ir\vec{B}$ (b) $2\pi ri\vec{B}$

(c) Zero (d) $\pi r i \vec{B}$

5. Two thin long parallel wires separated by a distance b are carrying a current i *amp* each. The magnitude of the force per unit length exerted by one wire on the other is

[CPMT 1991; IIT 1986; Bihar MEE 1995; RPMT 1997; MP PET 1996; MP PMT 1994, 96, 99; UPSEAT 2001, 03]

(a) $\frac{\mu_0 i^2}{b^2}$ (b) $\frac{\mu_0 i^2}{2\pi b}$

(c) $\frac{\mu_0 i}{2\pi b}$ (d) $\frac{\mu_0 i}{2\pi b^2}$

6. Through two parallel wires A and B, 10 and 2 *ampere* of currents are passed respectively in opposite direction. If the wire A is infinitely long and the length of the wire B is 2 *m*, the force on the conductor B, which is situated at 10 *cm* distance from A will be [CPMT 1988; MP PMT 1994]

(a) $8\times10^{-5}\,N$ (b) $4\times10^{-7}\,N$

(c) $4\times10^{-5}\,N$ (d) $4\pi\times10^{-7}\,N$

7. If two streams of protons move parallel to each other in the same direction, then they [MP PET 1999; AIIMS 2004]

(a) Do not exert any force on each other

(b) Repel each other

(c) Attract each other

(d) Get rotated to be perpendicular to each other

8. A straight wire carrying a current $i_1\,amp$ runs along the axis of a circular current $i_2\,amp$. Then the force of interaction between the two current carrying conductors is

(a) ∞ (b) Zero

(c) $\frac{\mu_0}{4\pi}\frac{2i_1i_2}{r}\,N/m$ (d) $\frac{2i_1i_2}{r}\,N/m$

9. Two parallel wires are carrying electric currents of equal magnitude and in the same direction. They exert

[CPMT 1990; MP PET/PMT 1988; Orissa JEE 2003; AFMC 2003]

(a) An attractive force on each other

(b) A repulsive force on each other

(c) No force on each other

(d) A rotational torque on each other

10. Two long and parallel wires are at a distance of 0.1 *m* and a current of 5 *A* is flowing in each of these wires. The force per unit length due to these wires will be [CPMT 1977]

(a) $5\times10^{-5}\,N/m$ (b) $5\times10^{-3}\,N/m$

(c) $2.5\times10^{-5}\,N/m$ (d) $2.5\times10^{-4}\,N/m$

11. Two straight parallel wires, both carrying 10 *ampere* in the same direction attract each other with a force of $1\times10^{-3}\,N$. If both currents are doubled, the force of attraction will be

[MP PET 1994]

(a) $1\times10^{-3}\,N$ (b) $2\times10^{-3}\,N$

(c) $4\times10^{-3}\,N$ (d) $0.25\times10^{-3}\,N$

12. A circular coil of radius 4 *cm* has 50 turns. In this coil a current of 2 *A* is flowing. It is placed in a magnetic field of 0.1 $weber/m^2$. The amount of work done in rotating it through $180°$ from its equilibrium position will be

[CPMT 1977]

(a) 0.1 *J* (b) 0.2 *J*

(c) 0.4 *J* (d) 0.8 *J*

13. 3 *A* of current is flowing in a linear conductor having a length of 40 *cm*. The conductor is placed in a magnetic field of strength 500 *gauss* and makes an angle of $30°$ with the direction of the field. It experiences a force of magnitude

[MP PET 1993]

(a) $3\times10^4\,newton$ (b) $3\times10^2\,newton$

(c) $3\times10^{-2}\,newton$ (d) $3\times10^{-4}\,newton$

14. The radius of a circular loop is r and a current i is flowing in it. The equivalent magnetic moment will be [CPMT 1990]

(a) ir (b) $2\pi ir$

(c) $i\pi r^2$ (d) $\frac{1}{r^2}$

15. A current carrying loop is placed in a uniform magnetic field. The torque acting on it does not depend upon

[CPMT 1985; RPMT 1997; Kerala PMT 2002]

(a) Shape of the loop (b) Area of the loop

(c) Value of the current (d) Magnetic field

16. To make the field radial in a moving coil galvanometer

[MP PET 1993]

(a) The number of turns in the coil is increased

(b) Magnet is taken in the form of horse-shoe

(c) Poles are cylindrically cut

(d) Coil is wounded on aluminium frame

17. The deflection in a moving coil galvanometer is

[MP PMT 1993]

(a) Directly proportional to the torsional constant

(b) Directly proportional to the number of turns in the coil

(c) Inversely proportional to the area of the coil

(d) Inversely proportional to the current flowing

18. A moving coil sensitive galvanometer gives at once much more deflection. To control its speed of deflection

[MP PET 1985]

(a) A high resistance is to be connected across its terminals

(b) A magnet should be placed near the coil

(c) A small copper wire should be connected across its terminals

(d) The body of galvanometer should be earthed

19. In a moving coil galvanometer, the deflection of the coil θ is related to the electrical current i by the relation

[MP PMT 1996, 2000, 03; RPMT 1997; CPMT 1975; MP PET 1999]

(a) $i\propto\tan\theta$ (b) $i\propto\theta$

(c) $i\propto\theta^2$ (d) $i\propto\sqrt{\theta}$

20. The unit of electric current "*ampere*" is the current which when flowing through each of two parallel wires spaced 1 *m* apart in vacuum and of infinite length will give rise to a force between them equal to

[BIT 1987; CBSE PMT1998; MP PET 1999; MP PMT 2002]

(a) $1\,N/m$ (b) $2\times10^{-7}\,N/m$

(c) $1\times10^{-2}\ N/m$ (d) $4\pi\times10^{-7}\ N/m$

21. A moving coil galvanometer has *N* number of turns in a coil of effective area *A*, it carries a current *I*. The magnetic field *B* is radial. The torque acting on the coil is [MP PMT 1994]

(a) NA^2B^2I (b) $NABI^2$

(c) N^2ABI (d) *NABI*

22. A small coil of *N* turns has an effective area *A* and carries a current *I*. It is suspended in a horizontal magnetic field $\vec{B}$ such that its plane is perpendicular to $\vec{B}$. The work done in rotating it by $180°$ about the vertical axis is [MP PMT 1994]

(a) *NAIB* (b) 2*NAIB*

(c) $2\pi NAIB$ (d) $4\pi NAIB$

23. A small coil of *N* turns has area *A* and a current I flows through it. The magnetic dipole moment of this coil will be [MP PMT 1994]

(a) NI/A (b) NI^2A

(c) N^2AI (d) *NIA*

24. A current of 10 *ampere* is flowing in a wire of length 1.5 *m*. A force of 15 *N* acts on it when it is placed in a uniform magnetic field of 2 *tesla*. The angle between the magnetic field and the direction of the current is [MP PMT 1994]

(a) $30°$ (b) $45°$

(c) $60°$ (d) $90°$

25. A rectangular loop carrying a current *i* is placed in a uniform magnetic field *B*. The area enclosed by the loop is *A*. If there are *n* turns in the loop, the torque acting on the loop is given by

(a) $ni\vec{A}\times\vec{B}$ (b) $ni\vec{A}\cdot\vec{B}$

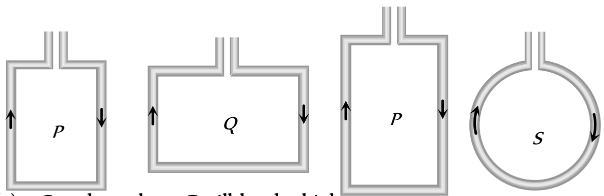
(c) $\frac{1}{n}(i\vec{A}\times\vec{B})$ (d) $\frac{1}{n}(i\vec{A}\cdot\vec{B})$

26. An electron moves with a constant speed *v* along a circle of radius *r*. Its magnetic moment will be (*e* is the electron's charge)

(a) *evr* (b) $\frac{1}{2}evr$

(c) πr^2ev (d) $2\pi rev$

27. Four wires each of length 2.0 *metres* are bent into four loops *P*, *Q*, *R* and *S* and then suspended into uniform magnetic field. Same current is passed in each loop. Which statement is correct



(a) Couple on loop *P* will be the highest

(b) Couple on loop *Q* will be the highest

(c) Couple on loop *R* will be the highest

(d) Couple on loop *S* will be the highest

28. A current carrying rectangular coil is placed in a uniform magnetic field. In which orientation, the coil will not tend to rotate

(a) The magnetic field is parallel to the plane of the coil

(b) The magnetic field is perpendicular to the plane of the coil

(c) The magnetic field is at 45° with the plane of the coil

(d) Always in any orientation

29. A current carrying circular loop is freely suspended by a long thread. The plane of the loop will point in the direction [MP PMT 1995]

(a) Wherever left free

(b) North-south

(c) East-west

(d) At $45°$ with the east-west direction

30. A current carrying loop is free to turn in a uniform magnetic field. The loop will then come into equilibrium when its plane is inclined at [CBSE PMT 1992; Haryana CEE 1996]

(a) $0°$ to the direction of the field

(b) $45°$ to the direction of the field

(c) $90°$ to the direction of the field

(d) $135°$ to the direction of the field

31. The expression for the torque acting on a coil having area of cross-section *A*, number of turns *n*, placed in a magnetic field of strength *B*, making an angle θ with the normal to the plane of the coil, when a current *i* is flowing in it, will be [MP PET 1996]

(a) $niAB\tan\theta$ (b) $niAB\cos\theta$

(c) $niAB\sin\theta$ (d) $niAB$

32. The pole pieces of the magnet used in a pivoted coil galvanometer are [MP PET 1996]

(a) Plane surfaces of a bar magnet

[MP PMT 1994]

(b) Plane surfaces of a horse-shoe magnet

(c) Cylindrical surfaces of a bar magnet

(d) Cylindrical surfaces of a horse-shoe magnet

33. The sensitiveness of a moving coil galvanometer can be increased by decreasing [MP PMT 1996]

(a) The number of turns in the coil [MP PMT 1994]

(b) The area of the coil

(c) The magnetic field

(d) The couple per unit twist of the suspension

34. A metallic loop is placed in a magnetic field. If a current is passed through it, then [UPSEAT 2003]

[MP PET 1995; DPMT 1999]

(a) The ring will feel a force of attraction

(b) The ring will feel a force of repulsion

(c) It will move to and fro about its centre of gravity

(d) None of these

35. Two parallel conductors *A* and *B* of equal lengths carry currents I and 10 I, respectively, in the same direction. Then [MP PET 2003]

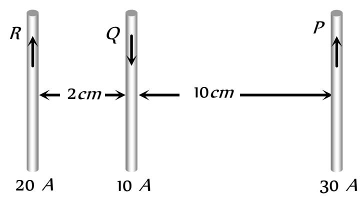
(a) *A* and *B* will repel each other with same force

(b) *A* and *B* will attract each other with same force

(c) A will attract *B*, but *B* will repel *A*

(d) *A* and *B* will attract each other with different forces

36. Three long, straight and parallel wires carrying currents are arranged as shown in figure. The force experienced by 10 *cm* length of wire *Q* is [MP PMT 1995] [MP PET 1997]



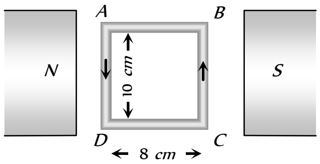
(a) $1.4\times10^{-4}N$ towards the right

(b) $1.4\times10^{-4}N$ towards the left

(c) $2.6\times10^{-4}N$ to the right

(d) $2.6\times10^{-4}N$ to the left

37. A 100 turns coil shown in figure carries a current of 2 *amp* in a magnetic field $B=0.2\,Wb/m^2$. The torque acting on the coil is



(a) 0.32 *Nm* tending to rotate the side *AD* out of the page

(b) 0.32 *Nm* tending to rotate the side *AD* into the page

(c) 0.0032 *Nm* tending to rotate the side *AD* out of the page

(d) 0.0032 *Nm* tending to rotate the side *AD* into the page

38. A current of 5 *ampere* is flowing in a wire of length 1.5 *metres*. A force of 7.5 *N* acts on it when it is placed in a uniform magnetic field of 2 *Tesla*. The angle between the magnetic field and the direction of the current is

[MP PET 1997; Pb. PET 2003]

(a) $30°$ (b) 45°

(c) 60° (d) 90°

39. A conductor in the form of a right angle *ABC* with *AB* = 3 *cm* and *BC* = 4 *cm* carries a current of 10 *A*. There is a uniform magnetic field of 5 *T* perpendicular to the plane of the conductor. The force on the conductor will be

[MP PMT 1997]

(a) 1.5 *N* (b) 2.0 *N*

(c) 2.5 *N* (d) 3.5 *N*

40. The coil of a galvanometer consists of 100 turns and effective area of 1 *square cm*. The restoring couple is $10^{-8}\,N-m/radian$. The magnetic field between the pole pieces is 5 *T*. The current sensitivity of this galvanometer will be

(a) $5\times10^4\,rad/\mu amp$ (b) $5\times10^{-6}\,per\,amp$

(c) $2\times10^{-7}\,per\,amp$ (d) $5\,rad/\mu amp$

41. A rectangular coil $20\,cm\times20\,cm$ has 100 turns and carries a current of 1 *A*. It is placed in a uniform magnetic field *B* =0.5 *T* with the direction of magnetic field parallel to the plane of the coil. The magnitude of the torque required to hold this coil in this position is [MP PMT 1997]

(a) Zero (b) 200 *N-m*

(c) 2 *N-m* (d) 10 *N-m*

42. If a current is passed in a spring, it

[MP PMT/PET 1998; AIEEE 2002]

(a) Gets compressed (b) Gets expanded

(c) Oscillates (d) Remains unchanged

43. A current carrying small loop behaves like a small magnet. If *A* be its area and *M* its magnetic moment, the current in the loop will be

[MP PMT/PET 1998; RPET 2001; MP PMT 2003]

(a) M/A (b) A/M

(c) *MA* (d) A^2M

44. In hydrogen atom, the electron is making $6.6\times10^{15}\,rev/\sec$ around the nucleus in an orbit of radius 0.528 Å. The magnetic moment $(A-m^2)$ will be

[MP PET 1999]

[MP PET 1997]

(a) 1×10^{-15} (b) 1×10^{-10}

(c) 1×10^{-23} (d) 1×10^{-27}

45. A triangular loop of side *l* carries a current *I*. It is placed in a magnetic field *B* such that the plane of the loop is in the direction of *B*. The torque on the loop is [MP PET 2003]

(a) Zero (b) *IBl*

(c) $\frac{\sqrt{3}}{2}Il^2B^2$ (d) $\frac{\sqrt{3}}{4}IBl^2$

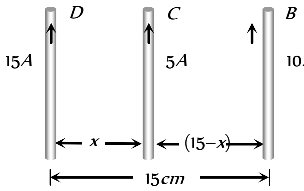
46. Three long, straight and parallel wires carrying currents are arranged as shown in the figure. The wire *C* which carries a current of 5.0 *amp* is so placed that it experiences no force. The distance of wire *C* from wire *D* is then [AMU 1995]

(a) 9 *cm*

(b) 7 *cm*

(c) 5 *cm*

(d) 3 *cm*



47. A vertical wire carrying a current in the upward direction is placed in horizontal magnetic field directed towards north. The wire will experience a force directed towards

[SCRA 1994]

(a) North (b) South

(c) East (d) West

48. A coil carrying electric current is placed in uniform magnetic field, then [CBSE PMT 1993]

(a) Torque is formed

[MP PMT 1997]

(b) E.M.F. is induced

(c) Both (a) and (b) are correct

(d) None of these

49. A circular loop carrying a current is replaced by an equivalent magnetic dipole. A point on the axis of the loop is

(a) An end-on position (b) A broad side-on position

(c) Both (a) and (b) (d) Neither (a) nor (b)

50. A power line lies along the east-west direction and carries a current of 10 *ampere*. The force per metre due to the earth's magnetic field of 10^{-4} *tesla* is [Roorkee 1992]

(a) $10^{-5}N$ (b) $10^{-4}N$

(c) $10^{-3}N$ (d) $10^{-2}N$

51. A straight wire of length 0.5 *metre* and carrying a current of 1.2 *ampere* placed in a uniform magnetic field of induction 2 *Tesla*. The magnetic field is perpendicular to the length of the wire. The force on the wire is

[CBSE PMT 1992; BHU 1998; DPMT 2001; RPET 2003]

(a) 2.4 N (b) 1.2 N

(c) 3.0 N (d) 2.0 N

52. Two parallel wires in free space are 10 cm apart and each carries a current of 10 A in the same direction. The force one wire exerts on the other per metre of length is

[CBSE PMT 1997; AFMC 1999]

(a) $2\times10^{-4}\,N$, attractive (b) $2\times10^{-4}\,N$, repulsive

(c) $2\times10^{-7}\,N$, attractive (d) $2\times10^{-7}\,N$, repulsive

53. The current sensitivity of a moving coil galvanometer can be increased by [Roorkee 1999]

(a) Increasing the magnetic field of the permanent magnet

(b) Increasing the area of the deflecting coil

(c) Increasing the number of turns in the coil

(d) Increasing the restoring couple of the coil

54. A circular coil of diameter 7cm has 24 turns of wire carrying current of 0.75A. The magnetic moment of the coil is

[AMU (Med.) 1999]

(a) $6.9\times10^{-2}\,amp-m^2$ (b) $2.3\times10^{-2}\,amp\text{-}m^2$

(c) $10^{-2}\,amp-m^2$ (d) $10^{-3}\,amp-m^2$

55. Two long parallel wires carrying equal current separated by 1m, exert a force of $2\times10^{-7}\,N/m$ on one another. The current flowing through them is [AMU (Engg.) 1999]

(a) 2.0 A (b) $2.0\times10^{-7}\,A$

(c) 1.0 A (d) $1.0\times10^{-7}\,A$

56. Two parallel beams of electrons moving in the same direction produce a mutual force [MP PET 1996; DCE 1999]

(a) Of attraction in plane of paper

(b) Of repulsion in plane of paper

(c) Upwards perpendicular to plane of paper

(d) Downwards perpendicular to plane of paper

57. A circular loop of area $0.01m^2$ carrying a current of 10 A, is held perpendicular to a magnetic field of intensity 0.1T. The torque acting on the loop is [Pb. PMT 2000]

(a) Zero (b) 0.01 N-m

(c) 0.001 N-m (d) 0.8 N-m

58. Magnetic dipole moment of a rectangular loop is

[RPET 2000]

(a) Inversely proportional to current in loop

(b) Inversely proportional to area of loop

(c) Parallel to plane of loop and proportional to area of loop

(d) Perpendicular to plane of loop and proportional to area of loop

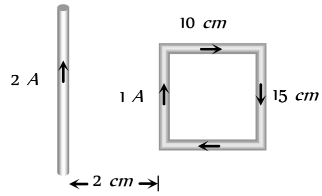
59. If m is magnetic moment and B is the magnetic field, then the torque is given by [DCE 2000]

(a) $\vec{m}.\vec{B}$ (b) $\dfrac{|\vec{m}|}{|\vec{B}|}$

(c) $\vec{m}\times\vec{B}$ (d) $|\vec{m}|.|\vec{B}|$

60. What is the net force on the square coil

[DCE 2000; RPMT 2000]



(a) $25\times10^{-7}\,N$ moving towards wire

(b) $25\times10^{-7}\,N$ moving away from wire

(c) $35\times10^{-7}\,N$ moving towards wire

(d) $35\times10^{-7}\,N$ moving away from wire

61. Two long parallel copper wires carry currents of 5A each in opposite directions. If the wires are separated by a distance of 0.5m, then the force between the two wires is

[EAMCET (Engg.) 2000]

(a) $10^{-5}\,N$, attractive (b) $10^{-5}\,N$, repulsive

(c) $2\times10^{-5}\,N$, attractive (d) $2\times10^{-5}\,N$, repulsive

62. In order to increase the sensitivity of a moving coil galvanometer, one should decrease [MP PMT 2000]

(a) The strength of its magnet

(b) The torsional constant of its suspension

(c) The number of turns in its coil

(d) The area of its coil

63. A circular loop has a radius of 5 cm and it is carrying a current of 0.1 amp. Its magnetic moment is [MP PMT 2000]

(a) $1.32\times10^{-4}\,amp-m^2$

(b) $2.62\times10^{-4}\,amp\text{-}m^2$

(c) $5.25\times10^{-4}\,amp\text{-}m^2$

(d) $7.85\times10^{-4}\,amp\text{-}m^2$

64. Due to the flow of current in a circular loop of radius R, the magnetic induction produced at the centre of the loop is B. The magnetic moment of the loop is

$(\mu_0 = \text{permeability constant})$ [MP PET 2000]

(a) $BR^3/2\pi\mu_0$ (b) $2\pi BR^3/\mu_0$

(c) $BR^2/2\pi\mu_0$ (d) $2\pi BR^2/\mu_0$

65. The magnetic moment of a circular coil carrying current is

[MP PET 2000]

(a) Directly proportional to the length of the wire in the coil

(b) Inversely proportional to the length of the wire in the coil

(c) Directly proportional to the square of the length of the wire in the coil

(d) Inversely proportional to the square of the length of the wire in the coil

66. A long wire A carries a current of 10 amp. Another long wire B, Which is parallel to A and separated by 0.1m from A, carries a current of 5 amp, in the opposite direction to that in A. what is the magnitude and nature of the force experienced per unit length of B

$(\mu_0 = 4\pi\times10^{-7}\,weber/amp\text{-}m)$ [MP PET 2000]

(a) Repulsive force of $10^{-4}\ N/m$

(b) Attractive force of $10^{-4}\ N/m$

(c) Repulsive force of $2\pi \times 10^{-5}\ N/m$

(d) Attractive force of $2\pi \times 10^{-5}\ N/m$

67. A stream of electrons is projected horizontally to the right. A straight conductor carrying a current is supported parallel to electron stream and above it. If the current in the conductor is from left to right then what will be the effect on electron stream

(a) The electron stream will be pulled upward

(b) The electron stream will be pulled downward

(c) The electron stream will be retarted

(d) The electron beam will be speeded up towards the right

68. The relation between voltage sensitivity (σ_V) and current sensitivity (σ_i) of a moving coil galvanometer is (Resistance of Galvanometer = G) **[CPMT 2001]**

(a) $\frac{\sigma_i}{G} = \sigma_V$ (b) $\frac{\sigma_V}{G} = \sigma_i$

(c) $\frac{G}{\sigma_V} = \sigma_i$ (d) $\frac{G}{\sigma_i} = \sigma_V$

69. What is shape of magnet in moving coil galvanometer to make the radial magnetic field **[RPET 2001]**

(a) Concave (b) Horse shoe magnet

(c) Convex (d) None of these

70. If a wire of length 1 *meter* placed in uniform magnetic field 1.5 *Tesla* at angle 30^o with magnetic field. The current in a wire 10 *amp.* Then force on a wire will be **[RPET 2001]**

(a) 7.5 N (b) 1.5 N

(c) 0.5 N (d) 2.5 N

71. A current i flows in a circular coil of radius r. If the coil is placed in a uniform magnetic field B with its plane parallel to the field, magnitude of the torque that acts on the coil is **[MP PET 2001]**

(a) Zero (b) $2\pi r i B$

(c) $\pi r^2 i B$ (d) $2\pi r^2 i B$

72. An arbitrary shaped closed coil is made of a wire of length L and a current I ampere is flowing in it. If the plane of the coil is perpendicular to magnetic field $\vec{B}$, the force on the coil is **[MP PMT 2001]**

(a) Zero (b) IBL

(c) $2IBL$ (d) $\frac{1}{2} IBL$

73. A circular coil having N turns is made from a wire of length L meter. If a current I ampere is passed through it and is placed in a magnetic field of B *Tesla*, the maximum torque on it is

(a) Directly proportional to N

(b) Inversely proportional to N

(c) Inversely proportional to N^2

(d) Independent of N

74. A small cylindrical soft iron piece is kept in a galvanometer so that

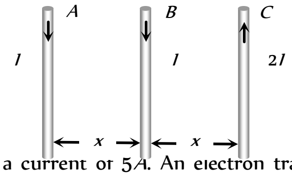
(a) A radial uniform magnetic field is produced

(b) A uniform magnetic field is produced

(c) There is a steady deflection of the coil

(d) All of these

75. *A, B* and *C* are parallel conductors of equal length carrying currents *I*, *I* and 2*I* respectively. Distance between *A* and *B* is *x*. Distance between *B* and *C* is also *x*. F_1 is the force exerted by *B* on *A* and F_2 is the force exerted by *B* on *A* choose the correct answer



(a) $F_1 = 2F_2$

(b) $F_2 = 2F_1$

(c) $F_1 = F_2$

(d) $F_1 = -F_2$

76. A straight conductor carries a current of 5*A*. An electron travelling with a speed of $5 \times 10^6\ ms^{-1}$ parallel to the wire at a distance of 0.1*m* from the conductor, experiences a force of **[Roorkee 2000]**

(a) $8 \times 10^{-20}\ N$ (b) $3.2 \times 10^{-19}\ N$

(c) $8 \times 10^{-18}\ N$ (d) $1.6 \times 10^{-19}\ N$

77. Two galvanometers *A* and *B* require 3*mA* and 5*mA* respectively to produce the same deflection of 10 divisions. Then

(a) *A* is more sensitive than *B*

(b) *B* is more sensitive than *A*

(c) *A* and *B* are equally sensitive

(d) Sensitiveness of *B* is 5/3 times that of *A*

78. Two long straight parallel conductors separated by a distance of 0.5*m* carry currents of 5*A* and 8*A* in the same direction. The force per unit length experienced by each other is

(a) $1.6 \times 10^{-5}\ N$ (attractive) (b) $1.6 \times 10^{-5}\ N$ (repulsive)

(c) $16 \times 10^{-5}\ N$ (attractive) (d) $16 \times 10^{-5}\ N$ (repulsive)

79. If the current is doubled, the deflection is also doubled in **[Orissa JEE 2002]**

(a) A tangent galvanometer

(b) A moving coil galvanometer

(c) Both (a) and (b)

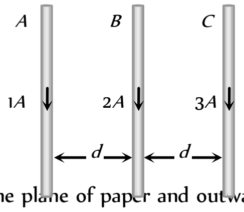
(d) None of these

80. Which is a vector quantity **[AFMC 2003]**

(a) Density (b) Magnetic flux

(c) Intensity of magnetic field (d) Magnetic potential

81. There long straight wires *A*, *B* and *C* are carrying current as shown figure. Then the resultant force on *B* is directed ..... **[KCET 2004]**



(a) Towards *A*

(b) Towards *C*

(c) Perpendicular to the plane of paper and outward

(d) Perpendicular to the plane of paper and inward

82. Two long conductors, separated by a distance d carry current I_1 and I_2 in the same direction. They exert a force F on each other. Now the current in one of them is increased to two times and its directions is reversed. The distance is also increased to 3d. The new value of the force between them is **[AIEEE 2004]** **[MP PMT 2001]**

(a) – 2F (b) F/3

(c) 2F/3 **[MP PMT 2001]** (d) – F/3

83. The resultant magnetic moment of neon atom will be **[J & K CET 2004]**

(a) Infinity (b) μ

(c) Zero (d) μ/2

84. A one metre long wire is lying at right angles to the magnetic field. A force of 1 *kg wt.* is acting on it in a magnetic field of 0.98 *Tesla*. The current flowing in it will be [J & K CET 2004]

(a) 100 *A* (b) 10 *A*

(c) 1 *A* (d) Zero

85. A beam of electrons and protons move parallel to each other in the same direction, then they [DCE 2004]

(a) Attract each other (b) Repel each other

(c) No relation (d) Neither attract nor repel

86. Two parallel wires of length 9 *m* each are separated by a distance 0.15 *m*. If they carry equal currents in the same direction and exerts a total force of 30×10^{-7} *N* on each other, then the value of current must be [MH CET 2003]

(a) 2.5 *amp* (b) 3.5 *amp*

(c) 1.5 *amp* (d) 0.5 *amp*

87. Current *i* is carried in a wire of length *L*. If the wire is turned into a circular coil, the maximum magnitude of torque in a given magnetic field *B* will be [Pb. PET 2004]

(a) $\frac{LiB^2}{2}$ (b) $\frac{Li^2B}{2}$

(c) $\frac{L^2iB}{4\pi}$ (d) $\frac{Li^2B}{4\pi}$

88. In ballistic galvanometer, the frame on which the coil is wound is non-metallic to [MH CET 2004]

(a) Avoid the production of induced e.m.f.

(b) Avoid the production of eddy currents

(c) Increase the production of eddy currents

(d) Increase the production of induced e.m.f.

89. Two thin, long, parallel wires, separated by a distance '*d*' carry a current of '*i*' *A* in the same direction. They will [AIEEE 2005]

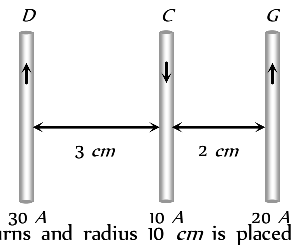
(a) Attract each other with a force of $\mu_0 i^2/(2\pi d^2)$

(b) Repel each other with a force of $\mu_0 i^2/(2\pi d^2)$

(c) Attract each other with a force of $\mu_0 i^2/(2\pi d)$

(d) Repel each other with a force of $\mu_0 i^2/(2\pi d)$

90. Three long, straight parallel wires carrying current, are arranged as shown in figure. The force experienced by a 25 *cm* length of wire *C* is [KCET 2005]



(a) 10^{-3} *N*

(b) 2.5×10^{-3} *N*

(c) Zero

(d) 1.5×10^{-3} *N*

91. A circular coil of 20 turns and radius 10 *cm* is placed in uniform magnetic field of 0.10 T normal to the plane of the coil. If the current in coil is 5 A, then the torque acting on the coil will be [J & K CET 2005]

(a) 31.4 *Nm* (b) 3.14 *Nm*

(c) 0.314 *Nm* (d) Zero

Critical Thinking

Objective Questions

1. A circular current carrying coil has a radius R. The distance from the centre of the coil on the axis where the magnetic induction will be $\frac{1}{8}th$ to its value at the centre of the coil, is

[MP PMT 1997]

(a) $\frac{R}{\sqrt{3}}$ (b) $R\sqrt{3}$

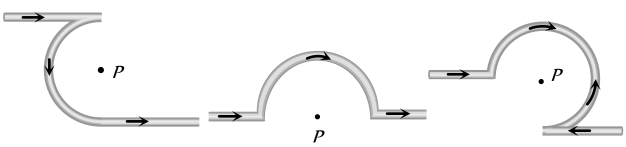
(c) $2\sqrt{3}\,R$ (d) $\frac{2}{\sqrt{3}}R$

2. The field normal to the plane of a wire of n turns and radius r which carries a current i is measured on the axis of the coil at a small distance h from the centre of the coil. This is smaller than the field at the centre by the fraction

(a) $\frac{3}{2}\frac{h^2}{r^2}$ (b) $\frac{2}{3}\frac{h^2}{r^2}$

(c) $\frac{3}{2}\frac{r^2}{h^2}$ (d) $\frac{2}{3}\frac{r^2}{h^2}$

3. The magnetic field at the centre of a circular coil of radius r is π times that due to a long straight wire at a distance r from it, for equal currents. Figure here shows three cases : in all cases the circular part has radius r and straight ones are infinitely long. For same current the B field at the centre P in cases 1, 2, 3 have the ratio [CPMT 1989]



(1) (2) (3)

(a) $\left(-\frac{\pi}{2}\right):\left(\frac{\pi}{2}\right):\left(\frac{3\pi}{4}-\frac{1}{2}\right)$

(b) $\left(-\frac{\pi}{2}+1\right):\left(\frac{\pi}{2}+1\right):\left(\frac{3\pi}{4}+\frac{1}{2}\right)$

(c) $-\frac{\pi}{2}:\frac{\pi}{2}:3\frac{\pi}{4}$

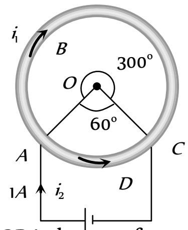
(d) $\left(-\frac{\pi}{2}-1\right):\left(\frac{\pi}{2}-\frac{1}{4}\right):\left(\frac{3\pi}{4}+\frac{1}{2}\right)$

4. Two straight long conductors AOB and COD are perpendicular to each other and carry currents i_1 and i_2. The magnitude of the magnetic induction at a point P at a distance a from the point O in a direction perpendicular to the plane $ACBD$ is

(a) $\frac{\mu_0}{2\pi a}(i_1+i_2)$ (b) $\frac{\mu_0}{2\pi a}(i_1-i_2)$

(c) $\frac{\mu_0}{2\pi a}(i_1^2+i_2^2)^{1/2}$ (d) $\frac{\mu_0}{2\pi a}\frac{i_1 i_2}{(i_1+i_2)}$

5. A cell is connected between the points A and C of a circular conductor $ABCD$ of centre O with angle $AOC=60^o$. If B_1 and B_2 are the magnitudes of the magnetic fields at O due to the currents in ABC and ADC respectively, the ratio $\frac{B_1}{B_2}$ is



(a) 0.2

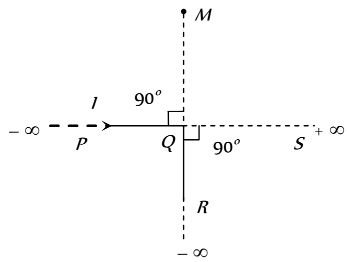
(b) 6

(c) 1

(d) 5

6. An infinitely long conductor PQR is bent to form a right angle as shown. A current I flows through PQR. The magnetic field due to this current at the point M is H. Now another infinitely long straight conductor QS is connected at Q so that the current is $I/2$ in QR as well as in QS. The current in PQ remaining unchanged. The magnetic field at M is now H_2. The ratio H_1/H_2 is given by

[IIT-JEE (Screening) 2000]



(a) $\frac{1}{2}$

(b) 1

(c) $\frac{2}{3}$

(d) 2

7. Two coaxial solenoids 1 and 2 of the same length are set so that one is inside the other. The number of turns per unit length are n_1 and n_2. The currents i_1 and i_2 are flowing in opposite directions. The magnetic field inside the inner coil is zero. This is possible when

(a) $i_1 \neq i_2$ and $n_1 = n_2$

(b) $i_1 = i_2$ and $n_1 \neq n_2$

(c) $i_1 = i_2$ and $n_1 = n_2$

(d) $i_1 n_1 = i_2 n_2$

8. A coil having N turns is wound tightly in the form of a spiral with inner and outer radii a and b respectively. When a current I passes through the coil, the magnetic field at the centre is

(a) $\frac{\mu_0 NI}{b}$ (b) $\frac{2\mu_0 NI}{a}$

(c) $\frac{\mu_0 NI}{2(b-a)}\ln\frac{b}{a}$ (d) $\frac{\mu_0 I^N}{2(b-a)}\ln\frac{b}{a}$

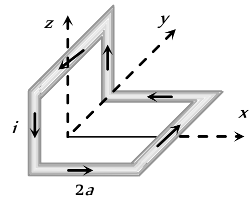
[MP PMT 1994]

9. A non-planar loop of conducting wire carrying a current I is placed as shown in the figure. Each of the straight sections of the loop is of length $2a$. The magnetic field due to this loop at the point P $(a,0,a)$ points in the direction

[IIT-JEE (Screening) 2001]

(a) $\frac{1}{\sqrt{2}}(-\hat{j}+\hat{k})$

(b) $\frac{1}{\sqrt{3}}(-\hat{j}+\hat{k}+\hat{i})$



(c) $\frac{1}{\sqrt{3}}(\hat{i}+\hat{j}+\hat{k})$

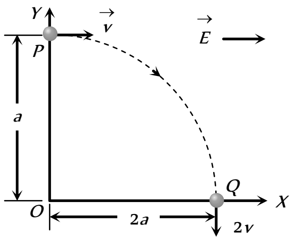
(d) $\frac{1}{\sqrt{2}}(\hat{i}+\hat{k})$

10. A long straight wire along the *z*-axis carries a current *I* in the negative *z* direction. The magnetic vector field $\vec{B}$ at a point having coordinates (*x, y*) in the *z* = 0 plane is [IIT-JEE (Screening) 2002]

(a) $\frac{\mu_o I(y\hat{i}-x\hat{j})}{2\pi(x^2+y^2)}$ (b) $\frac{\mu_o I(x\hat{i}+y\hat{j})}{2\pi(x^2+y^2)}$

(c) $\frac{\mu_o I(x\hat{j}-y\hat{i})}{2\pi(x^2+y^2)}$ (d) $\frac{\mu_o I(x\hat{i}-y\hat{j})}{2\pi(x^2+y^2)}$

11. A particle of charge +*q* and mass *m* moving under the influence of a uniform electric field $E\hat{i}$ and a uniform magnetic field $B\hat{k}$ follows trajectory from *P* to *Q* as shown in figure. The velocities at *P* and *Q* are $v\hat{i}$ and $-2v\hat{j}$ respectively. Which of the following statement(s) is/are correct [IIT 1991; BVP 2003]



(a) $E=\frac{3}{4}\frac{mv^2}{qa}$

(b) Rate of work done by electric field at *P* is $\frac{3}{4}\frac{mv^3}{a}$

(c) Rate of work done by electric field at *P* is zero

(d) Rate of work done by both the fields at *Q* is zero

12. H^+, He^+ and O^{++} ions having same kinetic energy pass through a region of space filled with uniform magnetic field *B* directed perpendicular to the velocity of ions. The masses of the ions H^+, He^+ and O^{++} are respectively in the ratio $1:4:16$. As a result

(a) H^+ ions will be deflected most

(b) O^{++} ions will be deflected least

(c) He^+ and O^{++} ions will suffer same deflection

(d) All ions will suffer the same deflection

13. An ionized gas contains both positive and negative ions. If it is subjected simultaneously to an electric field along the +*x* direction and a magnetic field along the +*z* direction, then [IIT-JEE (Screening) 2000]

(a) Positive ions deflect towards +*y* direction and negative ions towards –*y* direction

(b) All ions deflect towards +*y* direction

(c) All ions deflect towards –*y* direction

(d) Positive ions deflect towards –*y* direction and negative ions towards +*y* direction

14. An electron moves with speed 2×10^5 *m/s* along the positive *x*-direction in the presence of a magnetic induction $B=\hat{i}+4\hat{j}-3\hat{k}$ (in *Tesla*.) The magnitude of the force experienced by the electron in Newton's is (charge on the electron $=1.6\times10^{-19}C$) [EAMCET 2001]

(a) 1.18×10^{-13} (b) 1.28×10^{-13}

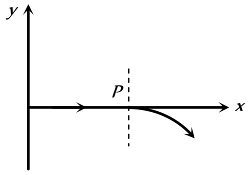
(c) 1.6×10^{-13} (d) 1.72×10^{-13}

15. A particle of mass *m* and charge *q* moves with a constant velocity *v* along the positive *x* direction. It enters a region containing a uniform magnetic field *B* directed along the negative *z* direction, extending from *x* = *a* to *x* = *b*. The minimum value of *v* required so that the particle can just enter the region $x>b$ is

(a) qbB/m (b) $q(b-a)B/m$

(c) qaB/m (d) $q(b+a)B/2m$

16. For a positively charged particle moving in a *x-y* plane initially along the *x*-axis, there is a sudden change in its path due to the presence of electric and/or magnetic fields beyond P. The curved path is shown in the *x-y* plane and is found to be non-circular. Which one of the following combinations is possible



(a) $\vec{E}=0; \vec{B}=b\hat{i}+c\hat{k}$ (b) $\vec{E}=a\hat{i}; \vec{B}=c\hat{k}+a\hat{i}$

(c) $\vec{E}=0; \vec{B}=c\hat{j}+b\hat{k}$ (d) $\vec{E}=a\hat{i}; \vec{B}=c\hat{k}+b\hat{j}$

17. A horizontal rod of mass 10 *gm* and length 10 *cm* is placed on a smooth plane inclined at an angle of $60°$ with the horizontal, with the length of the rod parallel to the edge of the inclined plane. A uniform magnetic field of induction *B* is applied vertically downwards. If the current through the rod is 1.73 *ampere*, then the value of *B* for which the rod remains stationary on the inclined plane is

(a) 1.73 *Tesla* (b) $\frac{1}{1.73}$ *Tesla*

(c) 1 *Tesla* (d) None of the above

18. Two long wires are hanging freely. They are joined first in parallel and then in series and then are connected with a battery. In both cases, which type of force acts between the two wires

(a) Attraction force when in parallel and repulsion force when in series

(b) Repulsion force when in parallel and attraction force when in series

(c) Repulsion force in both cases

(d) Attraction force in both cases

19. A wire of length *L metre* carrying a current of *I ampere* is bent in the form of a circle. Its magnitude of magnetic moment will be[MP PET 1995; M

(a) $\frac{IL}{4\pi}$ (b) $\frac{IL^2}{4\pi}$

(c) $\frac{I^2L^2}{4\pi}$ (d) $\frac{I^2L}{4\pi}$

20. A thin circular wire carrying a current I has a magnetic moment M. The shape of the wire is changed to a square and it carries the same current. It will have a magnetic moment [MP PET 2003; MP PMT 2004]

(a) M (b) $\frac{4}{\pi^2}M$

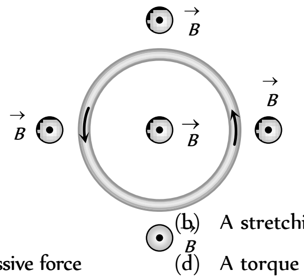
(c) $\frac{4}{\pi}M$ (d) $\frac{\pi}{4}M$

21. A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on

(a) ω and q (b) ω q and m

(c) q and m (d) ω and m

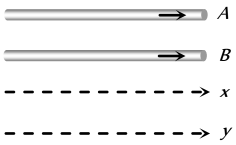
22. An elastic circular wire of length l carries a current I. It is placed in a uniform magnetic field $\vec{B}$ (Out of paper) such that its plane is perpendicular to the direction of $\vec{B}$. The wire will experience



(a) No force (b) A stretching force

(c) A compressive force (d) A torque

23. A and B are two conductors carrying a current i in the same direction. x and y are two electron beams moving in the same direction [Karnataka CET (Engg./Med.) 2002]



(a) There will be repulsion between A and B attraction between x and y
(b) There will be attraction between A and B, repulsion between x and y
(c) There will be repulsion between A and B and also x and y
(d) There will be attraction between A and B and also x and y

24. Wires 1 and 2 carrying currents i_1 and i_2 respectively are inclined at an angle θ to each other. What is the force on a small element dl of wire 2 at a distance of r from wire 1 (as shown in figure) due to the magnetic field of wire1

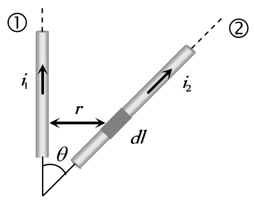
[AIEEE 2002]

(a) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \tan\theta$

(b) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \sin\theta$

(c) $\frac{\mu_0}{2\pi r} i_1 i_2 \, dl \cos\theta$

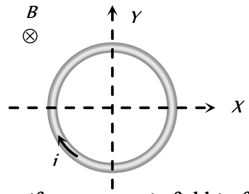
(d) $\frac{\mu_0}{4\pi r} i_1 i_2 \, dl \sin\theta$



25. A conducting loop carrying a current I is placed in a uniform magnetic field pointing into the plane of the paper as shown. The loop will have a tendency to

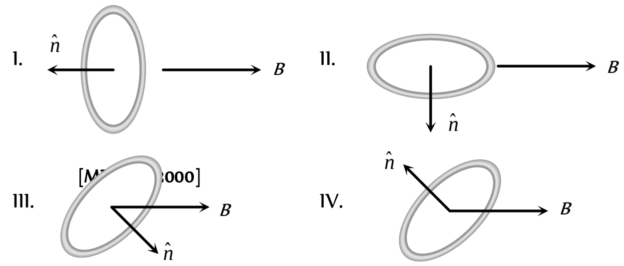
[IIT-JEE (Screening) 2003]

(a) Contract
(b) Expand
(c) Move towards $+ve$ x-axis
(d) Move towards $-ve$ x-axis



26. A current carrying loop is placed in a uniform magnetic field in four different orientations, I,II, III & IV arrange them in the decreasing order of potential Energy

[IIT-JEE (Screening) 2003]



(a) I > III > II > IV (b) I > II >III > IV

(c) I > IV > II > III (d) III > IV > I > II

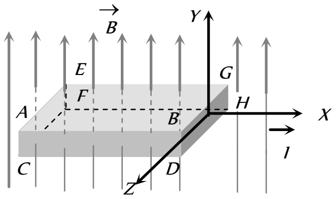
27. A metallic block carrying current I is subjected to a uniform magnetic induction $\vec{B}$ as shown in the figure. The moving charges experience a force $\vec{F}$ given by .... which results in the lowering of the potential of the face .... Assume the speed of the carriers to be v [IIT 1996]

(a) $eVB\hat{k}$, $ABCD$

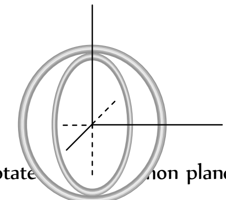
(b) $eVB\hat{k}$, $EFGH$

(c) $-eVB\hat{k}$, $ABCD$

(d) $-eVB\hat{k}$, $EFGH$



28. Two insulated rings, one of slightly smaller diameter than the other are suspended along their common diameter as shown. Initially the planes of the rings are mutually perpendicular. When a steady current is set up in each of them [IIT 1995]



(a) The two rings rotate [illegible] mon plane
(b) The inner ring oscillates about its initial position
(c) The inner ring stays stationary while the outer one moves into the plane of the inner ring
(d) The outer ring stays stationary while the inner one moves into the plane of the outer ring

29. Two particles each of mass m and charge q are attached to the two ends of a light rigid rod of length $2R$. The rod is rotated at constant angular speed about a perpendicular axis passing through its centre. The ratio of the magnitudes of the magnetic moment of the system and its angular momentum about the centre of the rod is [IIT 1998]

(a) $\frac{q}{2m}$ (b) $\frac{q}{m}$

(c) $\frac{2q}{m}$ (d) $\frac{q}{\pi m}$

30. Two very long, straight and parallel wires carry steady currents I and I respectively. The distance between the wires is d. At a certain instant of time, a point charge q is at a point equidistant from the two wires in the plane of the wires. Its instantaneous velocity v is perpendicular to this plane. The magnitude of the force due to the magnetic field acting on the charge at this instant is [IIT 1998]

(a) $\frac{\mu_0 Iqv}{2\pi d}$ (b) $\frac{\mu_0 Iqv}{\pi d}$

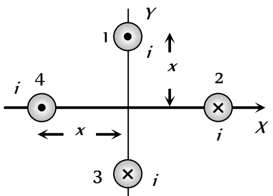
(c) $\frac{2\mu_0 Iqv}{\pi d}$ (d) 0

31. A ring of radius R, made of an insulating material carries a charge Q uniformly distributed on it. If the ring rotates about the axis passing through its centre and normal to plane of the ring with constant angular speed ω, then the magnitude of the magnetic moment of the ring is [MP PET 2001]

(a) $Q\omega R^2$ (b) $\frac{1}{2}Q\omega R^2$

(c) $Q\omega^2 R$ (d) $\frac{1}{2}Q\omega^2 R$

32. What will be the resultant magnetic field at origin due to four infinite length wires. If each wire produces magnetic field 'B' at origin



(a) 4 B (b) $\sqrt{2}\,B$

(c) $2\sqrt{2}\,B$ (d) Zero

33. The ratio of the magnetic field at the centre of a current carrying circular wire and the magnetic field at the centre of a square coil made from the same length of wire will be

(a) $\frac{\pi^2}{4\sqrt{2}}$ (b) $\frac{\pi^2}{8\sqrt{2}}$

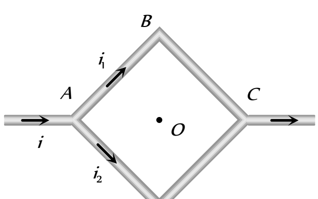
(c) $\frac{\pi}{2\sqrt{2}}$ (d) $\frac{\pi}{4\sqrt{2}}$

34. Two infinite length wires carries currents 8A and 6A respectively and placed along X and Y-axis. Magnetic field at a point $P(0,0,d)m$ will be

(a) $\frac{7\mu_0}{\pi d}$ (b) $\frac{10\mu_0}{\pi d}$

(c) $\frac{14\mu_0}{\pi d}$ (d) $\frac{5\mu_0}{\pi d}$

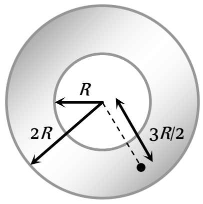
35. Figure shows a square loop $ABCD$ with edge length a. The resistance of the wire ABC is r and that of ADC is $2r$. The value of magnetic field at the centre of the loop assuming uniform wire is



(a) $\frac{\sqrt{2}\,\mu_0 i}{3\pi a}\odot$ (b) $\frac{\sqrt{2}\,\mu_0 i}{3\pi a}\otimes$

(c) $\frac{\sqrt{2}\,\mu_0 i}{\pi a}\odot$ (d) $\frac{\sqrt{2}\,\mu_0 i}{\pi a}\otimes$

36. Figure shows the cross-sectional view of the hollow cylindrical conductor with inner radius 'R' and outer radius '$2R$', cylinder carrying uniformly distributed current along it's axis. The magnetic induction at point 'P' at a distance $\frac{3R}{2}$ from the axis of the cylinder will be



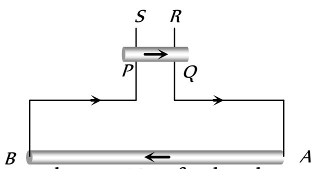
(a) Zero

(b) $\frac{5\mu_0 i}{72\pi R}$

(c) $\frac{7\mu_0 i}{18\pi R}$

(d) $\frac{5\mu_0 i}{36\pi R}$

37. A long wire AB is placed on a table. Another wire PQ of mass 1.0 g and length 50 cm is set to slide on two rails PS and QR. A current of 50A is passed through the wires. At what distance above AB, will the wire PQ be in equilibrium



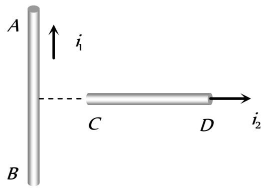
(a) 25 mm

(b) 50 mm

(c) 75 mm

(d) 100 mm

38. An infinitely long, straight conductor AB is fixed and a current is passed through it. Another movable straight wire CD of finite length and carrying current is held perpendicular to it and released. Neglect weight of the wire



(a) The rod CD will move upwards parallel to itself

(b) The rod CD will move downward parallel to itself

(c) The rod CD will move upward and turn clockwise at the same time

(d) The rod CD will move upward and turn anti –clockwise at the same time

39. A steady current i flows in a small square loop of wire of side L in a horizontal plane. The loop is now folded about its middle such that half of it lies in a vertical plane. Let $\vec{\mu_1}$ and $\vec{\mu_2}$ respectively denote the magnetic moments due to the current loop before and after folding. Then

[IIT-JEE 1993]

(a) $\overrightarrow{\mu_2} = 0$

(b) $\overrightarrow{\mu_1}$ and $\overrightarrow{\mu_2}$ are in the same direction

(c) $\frac{|\overrightarrow{\mu_1}|}{|\overrightarrow{\mu_2}|} = \sqrt{2}$

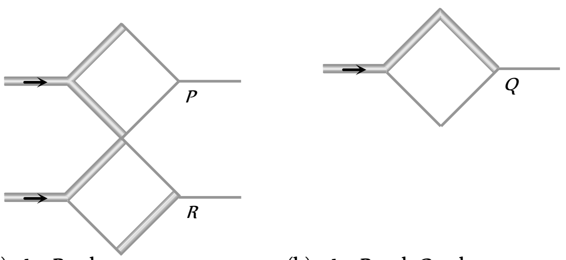
(d) $\frac{|\overrightarrow{\mu_1}|}{|\overrightarrow{\mu_2}|} = \left(\frac{1}{\sqrt{2}}\right)$

40. A current i is flowing in a straight conductor of length L. The magnetic induction at a point distant $\frac{L}{4}$ from its centre will be

(a) $\frac{4\mu_0 i}{\sqrt{5}\pi L}$ (b) $\frac{\mu_0 i}{2\pi L}$

(c) $\frac{\mu_0 i}{\sqrt{2}L}$ (d) Zero

41. Two thick wires and two thin wires, all of the same materials and same length form a square in the three different ways P, Q and R as shown in fig with current connection shown, the magnetic field at the centre of the square is zero in cases



(a) In P only (b) In P and Q only

(c) In Q and R only (d) P and R only

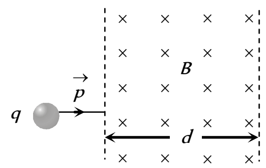
42. A particle with charge q, moving with a momentum p, enters a uniform magnetic field normally. The magnetic field has magnitude B and is confined to a region of width d, where $d < \frac{p}{Bq}$, The particle is deflected by an angle θ in crossing the field

(a) $\sin\theta = \frac{Bqd}{p}$

(b) $\sin\theta = \frac{p}{Bqd}$

(c) $\sin\theta = \frac{Bp}{qd}$

(d) $\sin\theta = \frac{pd}{Bq}$



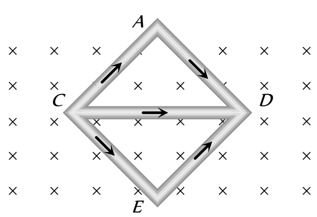
43. Same current i = 2A is flowing in a wire frame as shown in figure. The frame is a combination of two equilateral triangles ACD and CDE of side 1m. It is placed in uniform magnetic field B = 4T acting perpendicular to the plane of frame. The magnitude of magnetic force acting on the frame is

(a) 24 N

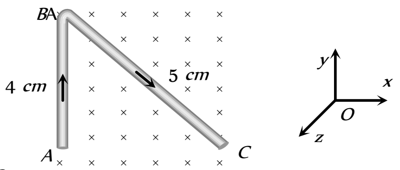
(b) Zero

(c) 16 N

(d) 8 N



44. A uniform conducting wire ABC has a mass of 10g. A current of 2A flows through it. The wire is kept in a uniform magnetic field $B = 2T$. The acceleration of the wire will be



(a) Zero

(b) $12\,ms^{-2}$ along y-axis

(c) $1.2\times10^{-3}ms^{-2}$ along y-axis

(d) $0.6\times10^{-3}ms^{-2}$ along y - axis

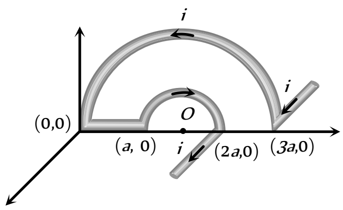
45. In the given figure net magnetic field at O will be

(a) $\frac{2\mu_0 i}{3\pi a}\sqrt{4-\pi^2}$

(b) $\frac{\mu_0 i}{3\pi a}\sqrt{4+\pi^2}$

(c) $\frac{2\mu_0 i}{3\pi a^2}\sqrt{4+\pi^2}$

(d) $\frac{2\mu_0 i}{3\pi a}\sqrt{(4-\pi^2)}$



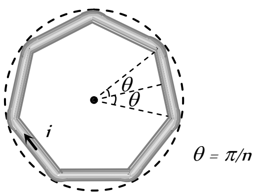
46. In the following figure a wire bent in the form of a regular polygon of n sides is inscribed in a circle of radius a. Net magnetic field at centre will be

(a) $\frac{\mu_0 i}{2\pi a}\tan\frac{\pi}{n}$

(b) $\frac{\mu_0 n i}{2\pi a}\tan\frac{\pi}{n}$

(c) $\frac{2}{\pi}\frac{ni}{a}\mu_0\tan\frac{\pi}{n}$

(d) $\frac{ni}{2a}\mu_0\tan\frac{\pi}{n}$



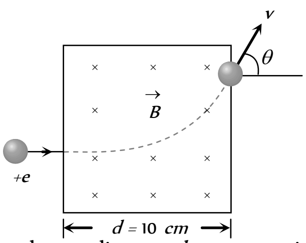
47. A proton accelerated by a potential difference $500\,KV$ moves though a transverse magnetic field of $0.51\,T$ as shown in figure. The angle θ through which the proton deviates from the initial direction of its motion is

(a) 15^o

(b) 30^o

(c) 45^o

(d) 60^o



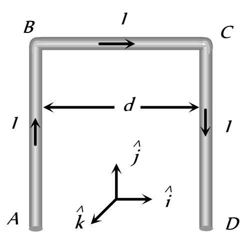
48. AB and CD are long straight conductor, distance d apart, carrying a current I. The magnetic field at the midpoint of BC is

(a) $\frac{-\mu_0 I}{2\pi d}\hat{k}$

(b) $\frac{-\mu_0 I}{\pi d}\hat{k}$

(c) $\frac{-\mu_0 I}{4\pi d}\hat{k}$

(d) $\frac{-\mu_0 I}{8\pi d}\hat{k}$



49. An electron is moving along the positive X-axis. You want to apply a magnetic field for a short time so that the electron may reverse its direction and move parallel to the negative X-axis. This can be done by applying the magnetic field along

(a) Y-axis (b) X-axis

(c) Y-axis only (d) None of these

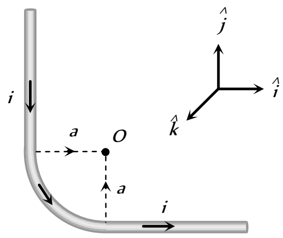
50. The unit vectors $\hat{i}, \hat{j}$ and $\hat{k}$ are as shown below. What will be the magnetic field at O in the following figure

(a) $\frac{\mu_0}{4\pi}\frac{i}{a}\left(2-\frac{\pi}{2}\right)\hat{j}$

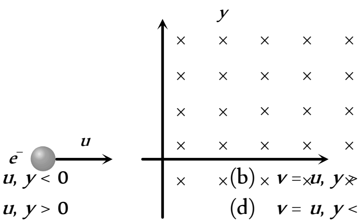
(b) $\frac{\mu_0}{4\pi}\frac{i}{a}\left(2+\frac{\pi}{2}\right)\hat{j}$

(c) $\frac{\mu_0}{4\pi}\frac{i}{a}\left(2+\frac{\pi}{2}\right)\hat{i}$

(d) $\frac{\mu_0}{4\pi}\frac{i}{a}\left(2+\frac{\pi}{2}\right)\hat{k}$



51. An electron moving with a speed u along the positive x-axis at $y = 0$ enters a region of uniform magnetic field $\vec{B} = -B_0\hat{k}$ which exists to the right of y-axis. The electron exits from the region after some time with the speed v at co-ordinate y, then [IIT-JEE (Screening 2004)]

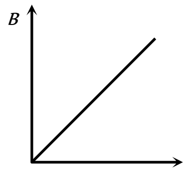


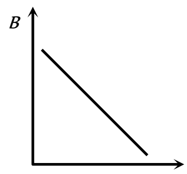
(a) $v > u, y < 0$ (b) $v = u, y > 0$

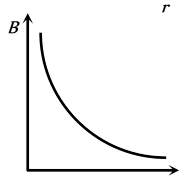
(c) $v > u, y > 0$ (d) $v = u, y < 0$

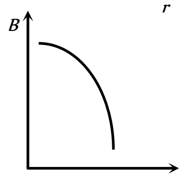
GQ Graphical Questions

1. Which of the following graphs shows the variation of magnetic induction B with distance r from a long wire carrying current [NCERT 1984; MNR 1998; MP PMT 1999]

(a) 

(b) 

(c) 

(d) 

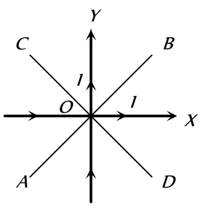
2. Two very thin metallic wires placed along X and Y-axis carry equal currents as shown here. AB and CD are lines at $45°$ with the axes with origin of axes at O. The magnetic field will be zero on the line [MP PMT 1995; CBSE PMT 1996]

(a) AB

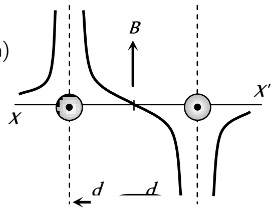
(b) CD

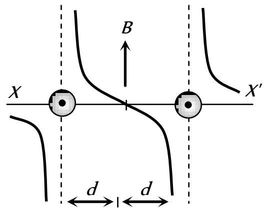
(c) Segment OB only of line AB

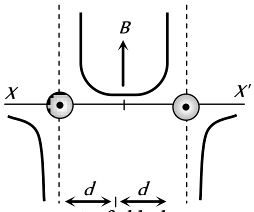
(d) Segment OC only of line CD

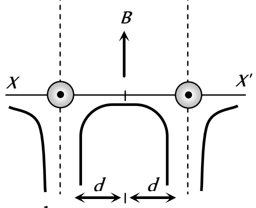


3. Two long parallel wires are at a distance $2d$ apart. They carry steady equal currents flowing out of the plane of the paper, as shown. The variation of the magnetic field B along the line XX' is given by

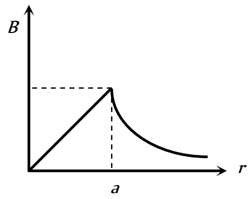
(a) 

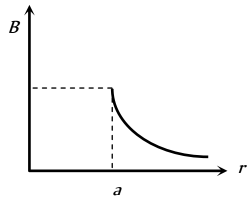
(b) 

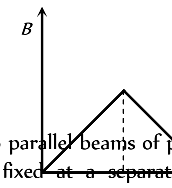
(c) 

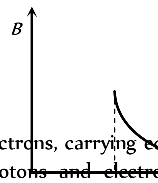
(d) 

4. The magnetic field due to a straight conduct ... rm cross section of radius a and carrying a steady current is represented by

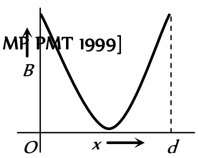
(a) 

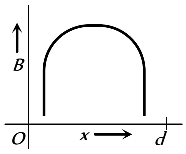
(b) 

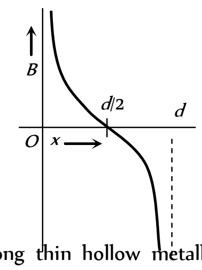
(c) 

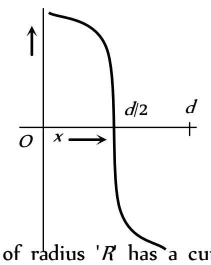
(d) 

5. Two parallel beams of protons and electrons, carrying equal currents are fixed at a separation d. The protons and electrons move in opposite directions. P is a point on a line joining the beams, at a distance x from any one beam. The magnetic field at P is B. If B is plotted against x, which of the following best represents the resulting curve

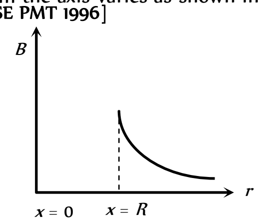
(a) 

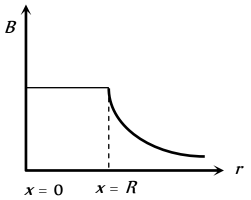
(b) 

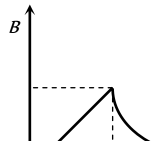
(c) 

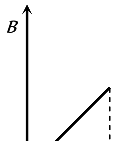
(d) 

6. A long thin hollow metallic cylinder of radius 'R' has a current i ampere. The magnetic induction 'B'-away from the axis at a distance r from the axis varies as shown in

(a) 

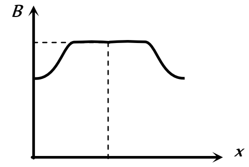
(b) 

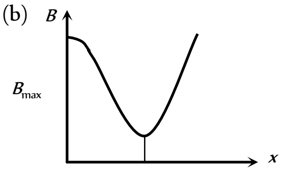


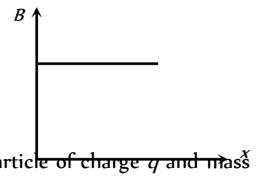


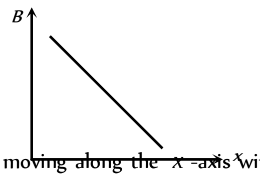
(c) (d)

7. The correct curve between the magnetic induction (B) along the axis of a long solenoid due to current flow i in it and distance x from one end is

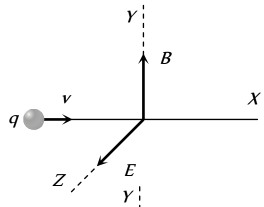
(a) 

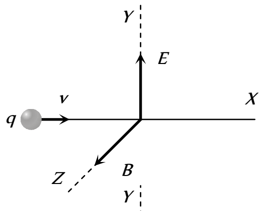
(b) 

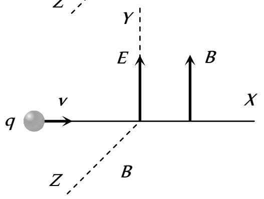
(c) 

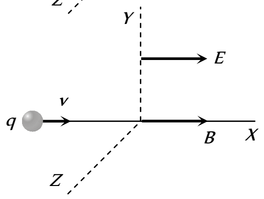
(d) 

8. A particle of charge q and mass m is moving along the x-axis with a velocity v and enters a region of electric field E and magnetic field B as shown in figure below for which figure the net force on the charge may be zero

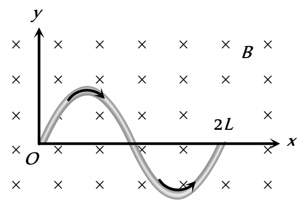
(a) 

(b) 

(c) 

(d) 

9. A wire carrying a current i is placed in a uniform magnetic field in the form of the curve $y = a\sin\left(\frac{\pi x}{L}\right) 0 \le x \le 2L.$ The force acting on the wire is



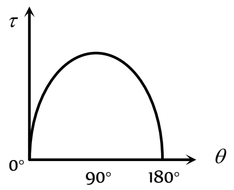
(a) $\frac{iBL}{\pi}$

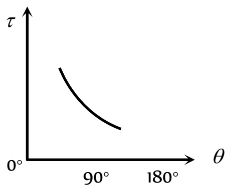
(b) $iBL\pi$

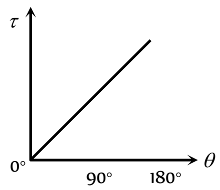
(c) $2iBL$

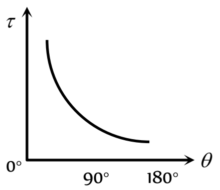
(d) Zero

10. The $(\tau - \theta)$ graph for a coil is

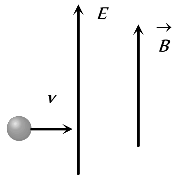
(a) 

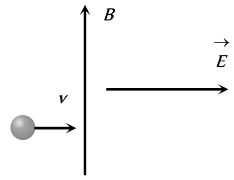
(b) 

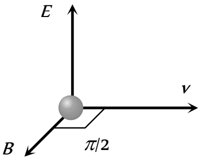
(c) 

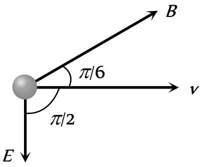
(d) 

11. A uniform magnetic field B and a uniform electric field E act in a common region. An electron is entering this region of space. The correct arrangement for it to escape undeviated is

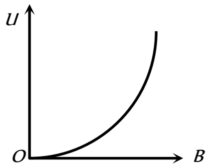
(a) 

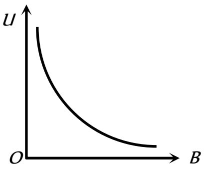
(b) 

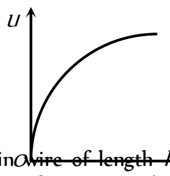
(c) 

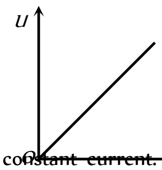
(d) 

12. If induction of magnetic field at a point is B and energy density is U then which of the following graphs is correct

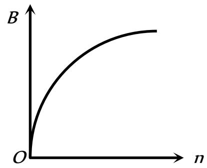
(a) 

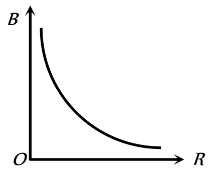
(b) 

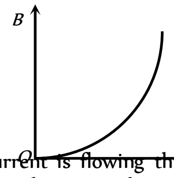
(c) 

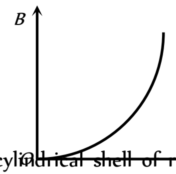
(d) 

13. A thin wire of length l is carrying a constant current. The wire is bent to form a circular coil. If radius of the coil, thus formed, is equal to R and number of turns in it is equal to n, then which of the following graphs represent (s) variation of magnetic field induction (B) at centre of the coil

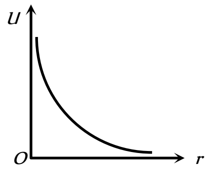
(a) 

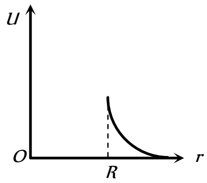
(b) 

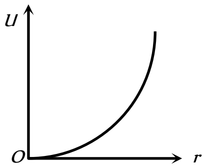
(c) 

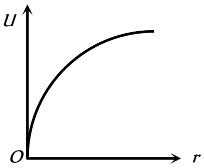
(d) 

14. A current is flowing through a thin cylindrical shell of radius R. If energy density in the medium, due to magnetic field, at a distance r from axis of the shell is equal to U then which of the following graphs is correct

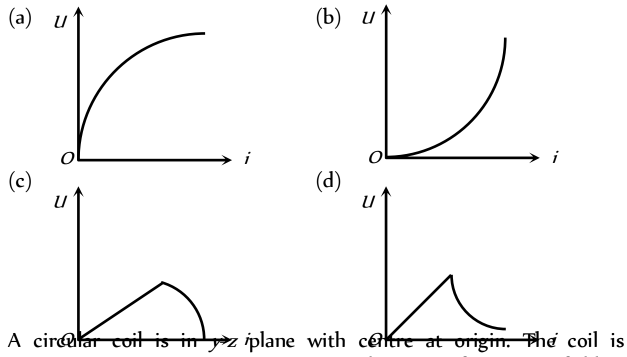
(a) 

(b) 

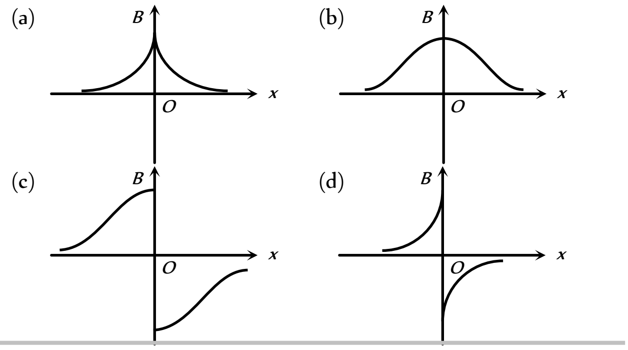
(c) 

(d) 

15. If current flowing through shell of previous objective is equal to i, then energy density at a point distance $2R$ from axis of the shell varies according to the graph



16. A circular coil is in y-z plane with centre at origin. The coil is carrying a constant current. Assuming direction of magnetic field at $x = -25\ cm$ to be positive direction of magnetic field, which of the following graphs shows variation of magnetic field along x-axis



Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Cyclotron does not accelerate electron.
   Reason : Mass of the electron is very small.
   [AIIMS 2000]

2. Assertion : Cyclotron is a device which is used to accelerate the positive ion.
   Reason : Cyclotron frequency depends upon the velocity. [AIIMS 1997]

3. Assertion : Magnetic field interacts with a moving charge and not with a stationary charge.
   Reason : A moving charge produces a magnetic field.

4. Assertion : If an electron is not deflected while passing through a certain region of space, then only possibility is that there is no magnetic region.
   Reason : Force is directly proportional to the magnetic field applied.

5. Assertion : Free electron always keep on moving in a conductor even then no magnetic force act on them in magnetic field unless a current is passed through it.
   Reason : The average velocity of free electron is zero.

6. Assertion : The ion cannot move with a speed beyond a certain limit in a cyclotron.
   Reason : As velocity increases time taken by ion increases.

7. Assertion : The coil is bound over the metallic frame in moving coil galvanometer.
   Reason : The metallic frame help in making steady deflection without any oscillation.

8. Assertion : A circular loop carrying current lies in XY plane with its center at origin having a magnetic flux in negative Z-axis.
   Reason : Magnetic flux direction is independent of the direction of current in the conductor.

9. Assertion : The energy of charged particle moving in a uniform magnetic field does not change.
   Reason : Work done by magnetic field on the charge is zero.

10. Assertion : If an electron, while coming vertically from outerspace, enter the earth's magnetic field, it is deflected towards west.
    Reason : Electron has negative charge.

11. Assertion : A direct current flows through a metallic rod, produced magnetic field only outside the rod.
    Reason : There is no flow of charge carriers inside the rod.

12. Assertion : An electron and proton enters a magnetic field with equal velocities, then, the force experienced by the proton will be more than electron.
    Reason : The mass of proton is 1837 times more than electron.

13. Assertion : Torque on the coil is the maximum, when coil is suspended in a radial magnetic field.
    Reason : The torque tends to rotate the coil on its own axis.

14. Assertion : A loosely round helix made of stiff wire is suspended vertically with the lower end just touching a dish of mercury. When a current is passed through the wire, the helical wire executes oscillatory motion with the lower end jumping out of and inside of mercury.
    Reason : When electric current is passed through helix, a magnetic field is produced both inside and outside the helix.

15. Assertion : The magnetic filed at the ends of a very long current carrying solenoid is half of that at the center.
    Reason : If the solenoid is sufficiently long, the field within it is uniform.

16. Assertion : If a charged particle is moving on a circular path in a perpendicular magnetic field, the momentum of the particle is not changing,.
    Reason : Velocity of the particle in not changing in the magnetic field.

17. Assertion : If a proton and an α-particle enter a uniform magnetic field perpendicularly, with the same speed, then the time period of revolution of the α-particle is double than that of proton.
    Reason : In a magnetic field, the time period of revolution of a charged particle is directly proportional to mass.

18. Assertion : If two long wires, hanging freely are connected to a battery in series, they come closer to each other.

Reason : Force of attraction acts between the two wires carrying current.

19. Assertion : A current I flows along the length of an infinitely long straight and thin walled pipe. Then the magnetic field at any point inside the pipe is zero.

Reason : $\oint \vec{B}.d\vec{l} = \mu_o I$

Answers

Biot-Savart's Law and Amperes Law

1	c	2	b	3	c	4	b	5	d
6	c	7	b	8	d	9	b	10	d
11	b	12	a	13	a	14	c	15	c
16	a	17	b	18	a	19	b	20	d
21	c	22	c	23	a	24	d	25	b
26	d	27	c	28	a	29	b	30	d
31	b	32	a	33	a	34	d	35	d
36	d	37	b	38	c	39	a	40	c
41	c	42	b	43	d	44	b	45	d
46	b	47	a	48	a	49	b	50	d
51	c	52	b	53	c	54	b	55	d
56	a	57	b	58	a	59	d	60	d
61	c	62	c	63	d	64	b	65	a
66	c	67	a	68	c	69	a	70	b
71	c	72	c	73	b	74	b	75	d
76	b	77	b	78	b	79	c	80	b
81	d	82	c	83	c	84	d	85	c
86	b	87	d	88	a	89	a	90	b
91	c	92	d	93	d	94	a	95	b
96	b	97	a	98	d	99	c	100	d
101	b	102	c	103	b	104	d	105	a
106	c	107	b	108	a	109	a	110	c
111	d	112	a	113	b	114	a	115	b
116	d	117	c	118	b	119	a	120	a
121	a	122	a	123	c	124	d	125	c
126	b								

Motion of Charged Particle In Magnetic Field

1	abd	2	d	3	c	4	a	5	b
6	b	7	c	8	c	9	c	10	d
11	c	12	d	13	d	14	b	15	a
16	c	17	c	18	a	19	c	20	b
21	c	22	c	23	d	24	b	25	d
26	a	27	c	28	a	29	d	30	d
31	d	32	b	33	c	34	a	35	c
36	b	37	d	38	a	39	a	40	d
41	c	42	a	43	d	44	a	45	b
46	c	47	d	48	b	49	c	50	d
51	b	52	c	53	b	54	a	55	a
56	d	57	d	58	b	59	d	60	a
61	c	62	c	63	b	64	a	65	a
66	b	67	b	68	a	69	bd	70	b
71	c	72	b	73	b	74	a	75	d
76	d	77	d	78	b	79	a	80	d
81	a	82	a	83	c	84	b	85	b
86	c	87	c	88	b	89	a	90	b
91	a	92	a	93	c	94	d	95	c
96	a	97	c	98	b	99	a	100	b
101	d	102	c	103	d	104	d	105	c
106	c	107	d	108	d	109	d	110	d
111	a	112	b	113	d	114	c	115	c
116	c	117	c	118	c				

Force and Torque on a Current Carrying Conductor

1	b	2	c	3	b	4	c	5	b
6	a	7	b	8	b	9	a	10	a
11	c	12	a	13	c	14	c	15	a
16	c	17	b	18	b	19	b	20	b
21	d	22	b	23	d	24	a	25	a
26	b	27	d	28	b	29	c	30	c
31	c	32	d	33	d	34	d	35	b
36	a	37	a	38	a	39	c	40	d
41	c	42	a	43	a	44	c	45	d
46	a	47	d	48	a	49	a	50	c
51	b	52	a	53	abc	54	a	55	c
56	b	57	a	58	d	59	c	60	a
61	b	62	b	63	d	64	b	65	c
66	a	67	b	68	a	69	a	70	a
71	c	72	a	73	a	74	d	75	d
76	c	77	a	78	a	79	b	80	c
81	b	82	c	83	c	84	b	85	a
86	d	87	c	88	b	89	c	90	c
91	d								

Critical Thinking Questions

1	b	2	a	3	a	4	c	5	c
6	c	7	cd	8	c	9	d	10	a
11	abd	12	ac	13	c	14	c	15	b
16	b	17	c	18	a	19	b	20	d
21	c	22	b	23	b	24	c	25	b
26	c	27	a	28	a	29	a	30	d
31	b	32	c	33	b	34	d	35	b
36	d	37	a	38	c	39	c	40	a
41	d	42	a	43	a	44	b	45	b
46	b	47	b	48	b	49	a	50	d
51	d								

Graphical Questions

1	c	2	a	3	b	4	a	5	c
6	a	7	a	8	b	9	c	10	a
11	c	12	a	13	bc	14	b	15	b
16	b								

Assertion and Reason

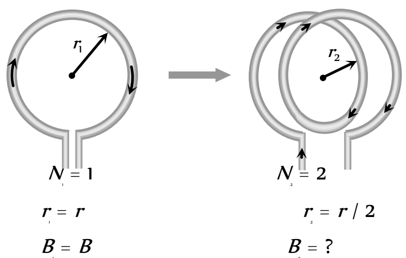
1	a	2	c	3	a	4	e	5	a
6	c	7	a	8	c	9	a	10	b
11	d	12	e	13	b	14	b	15	b
16	d	17	b	18	d	19	a		

Answers and Solutions

Biot-Savart's Law and Amperes Law

1. (c) Magnetic field at the centre of current carrying coil is given by $B = \frac{\mu_0}{4\pi}\cdot\frac{2\pi Ni}{r} \Rightarrow B \propto \frac{N}{r} \Rightarrow \frac{B_1}{B_2} = \frac{N_1}{N_2}\times\frac{r_2}{r_1}$.

The following figure shows that single turn coil changes to double turn coil.



$\Rightarrow \frac{B}{B_2} = \frac{1}{2}\times\frac{r/2}{r} = \frac{1}{4} \Rightarrow B_2 = 4B$

Short trick : For such type of problems remember $B_2 = n^2 B_1$

2. (b) If distance is same field will be same $\left(\because B = \frac{\mu_0}{4\pi}\cdot\frac{2i}{r}\right)$

3. (c) Magnetic field lies inside as well as outside the solid current carrying conductor.

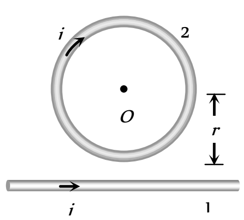
4. (b) Because for inside the pipe $i = 0$

$\therefore B = \frac{\mu_0 i}{2\pi r} = 0$

5. (d) $dB = \frac{\mu_0}{4\pi}\cdot\frac{idl\sin\theta}{r^2} \Rightarrow d\vec{B} = \frac{\mu_0}{4\pi}\cdot\frac{i(d\vec{l}\times\vec{r})}{r^3}$

6. (c) The magnetic field at the centre of the circle $= \frac{\mu_o}{4\pi}\times\frac{2\pi i}{r} = 10^{-7}\times\frac{2\pi(nq)}{r} = \frac{2\pi nq}{r}\times 10^{-7}\, N/A\text{-}m$

7. (b) The given shape is equivalent to the following diagram



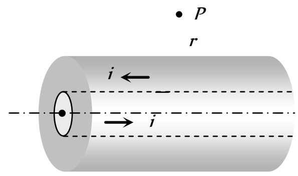
The field at O due to straight part of conductor is $B_1 = \frac{\mu_o}{4\pi}\cdot\frac{2i}{r}\odot$. The field at O due to circular coil is $B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2\pi i}{r}\otimes$. Both fields will act in the opposite direction, hence the total field at O.

i.e. $B = B_2 - B_1 = \left(\frac{\mu_o}{4\pi}\right)\times(\pi-1)\frac{2i}{r} = \frac{\mu_o}{4\pi}\cdot\frac{2i}{r}(\pi-1)$

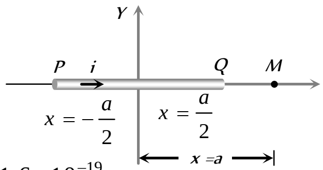
8. (d) $B = \frac{\mu_0}{4\pi}\frac{(2\pi-\theta)i}{R} = \frac{\mu_0}{4\pi}\frac{\left(2\pi-\frac{\pi}{2}\right)\times i}{R} = \frac{3\mu_0 i}{8R}$

9. (b) The respective figure is shown below

Magnetic field at P due to inner and outer conductors are equal and opposite. Hence net magnetic field at P will be zero.



10. (d) Magnetic field at a point on the axis of a current carrying wire is always zero.



11. (b) $i = \frac{q}{T} = \frac{2\times 1.6\times 10^{-19}}{2} = 1.6\times 10^{-19}\,A$

$\therefore B = \frac{\mu_o i}{2r} = \frac{\mu_o\times 1.6\times 10^{-19}}{2\times 0.8} = \mu_o\times 10^{-19}$

12. (a) $B = \mu_o ni = 4\pi\times 10^{-7}\times 5\times 1000 = 2\pi\times 10^{-3}$ *Tesla*

13. (a) $B = \frac{\mu_0}{4\pi}\cdot\frac{2i}{r} \Rightarrow \frac{B_1}{B_2} = \frac{r_2}{r_1} \Rightarrow \frac{10^{-8}}{B_2} = \frac{12}{4}$

$\Rightarrow B_2 = 3.33\times 10^{-9}$ *Tesla*

14. (c) $B \propto \frac{1}{r} \Rightarrow \frac{B_1}{B_2} = \frac{r_2}{r_1} \Rightarrow \frac{B}{B_2} = \frac{r/2}{r} \Rightarrow B_2 = 2B$

15. (c) Field at the centre of a circular coil of radius r is $B = \frac{\mu_o I}{2r}$

16. (a) $B = \frac{\mu_0 Ni}{2r} = \frac{4\pi\times 10^{-7}\times 100\times 0.1}{2\times 5\times 10^{-2}} = 4\pi\times 10^{-5}$ *Tesla*

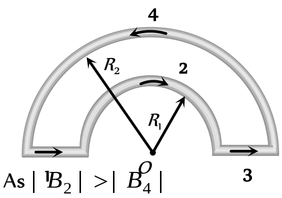
17. (b) Magnetic field inside the solenoid $B_{in} = \mu_0 ni$

18. (a) In the following figure, magnetic fields at O due to sections 1, 2, 3 and 4 are considered as B_1, B_2, B_3 and B_4 respectively.

$B_1 = B_3 = 0$

$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{\pi i}{R_1}\otimes$

$B_4 = \frac{\mu_0}{4\pi}\cdot\frac{\pi i}{R_2}\odot$



As $|B_2| > |B_4|$

So $B_{net}=B_2-B_4 \Rightarrow B_{net}=\frac{\mu_0 i}{4}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)\otimes$

19. (b) $B=\mu_o ni$

20. (d) The magnetic induction at O due to the current in portion AB will be zero because O lies on AB when extended.

21. (c) The induction due to AB and CD will be zero. Hence the whole induction will be due to the semicircular part BC.

$B=\frac{\mu_o i}{4r}$

22. (c) The magnetic induction due to both semicircular parts will be in the same direction perpendicular to the paper inwards.

$\therefore B=B_1+B_2=\frac{\mu_0 i}{4r_1}+\frac{\mu_0 i}{4r_2}=\frac{\mu_0 i}{4}\left(\frac{r_1+r_2}{r_1 r_2}\right)\otimes$

23. (a) Field at a point x from the centre of a current carrying loop on the axis is

$\mathrm{B}=\frac{\mu_0}{4\pi}\cdot\frac{2M}{x^3}=\frac{10^{-7}\times 2\times 2.1\times 10^{-25}}{(10^{-10})^3}$

$=4.2\times 10^{-32}\times 10^{30}=4.2\times 10^{-2}\,W/m^2$

24. (d) At these points, the resultant field $=0$

25. (b) $i=\frac{q}{t}=100\times e$

$B_{\text{centre}}=\frac{\mu_o}{4\pi}\cdot\frac{2\pi i}{r}=\frac{\mu_o}{4\pi}\cdot\frac{2\pi\times 100e}{r}$

$=\frac{\mu_o\times 200\times 1.6\times 10^{-19}}{4\times 0.8}=10^{-17}\mu_o$

26. (d) $B=\frac{\mu_o}{4\pi}\cdot\frac{2\pi NiR^2}{r^3}\Rightarrow B\propto\frac{1}{r^3}$

27. (c) $B=\frac{\mu_0}{4\pi}\cdot\frac{2\pi(q\nu)}{r}$

$=10^{-7}\times\frac{2\times 3.14\times(1.6\times 10^{-19}\times 6.6\times 10^{15})}{0.53\times 10^{-10}}=12.5\,Wb/m^2$

28. (a)

29. (b)

30. (d) Two coils carrying current in opposite direction, hence net magnetic field at centre will be difference of the two fields.

i.e. $B_{net}=\frac{\mu_0}{4\pi}\cdot 2\pi N\left[\frac{Ni_1}{r_1}-\frac{i_2}{r_2}\right]=\frac{10\mu_0}{2}\left[\frac{0.2}{0.2}-\frac{0.3}{0.4}\right]=\frac{5}{4}\mu_0$

31. (b) Because $B=\mu_0 ni\Rightarrow B\propto ni$.

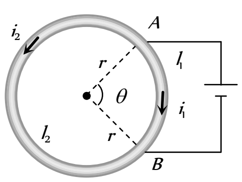
32. (a) See solution 34.

33. (a) $B=\mu_0 ni\Rightarrow i=\frac{B}{\mu_0 n}=\frac{20\times 10^{-3}}{4\pi\times 10^{-7}\times 20\times 100}$

$=7.9\,amp=8\,amp$

34. (d) Directions of currents in two parts are different, so directions of magnetic fields due to these currents are opposite. Also applying Ohm's law across AB

$i_1R_1=i_2R_2\Rightarrow i_1l_2=i_2l_2$



$\left(\because R=\rho\frac{l}{A}\right)$

Also $B_1=\frac{\mu_o}{4\pi}\times\frac{i_1l_1}{r^2}$ and $B_2=\frac{\mu_o}{4\pi}\times\frac{i_2l_2}{r^2}$ $\quad(\because l=r\theta)$

$\therefore\frac{B_2}{B_1}=\frac{i_1l_1}{i_2l_2}=1$

Hence, two field induction's are equal but of opposite direction. So, resultant magnetic induction at the centre is zero and is independent of θ.

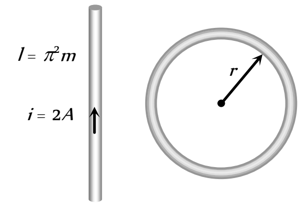
35. (d) The magnetic field at any point on the axis of wire be zero.

36. (d) Magnetic field inside the hollow conductor (tube) is zero.

37. (b) If a wire of length l is bent in the form of a circle of radius r then $2\pi r=l\Rightarrow$

$r=\frac{l}{2\pi}$

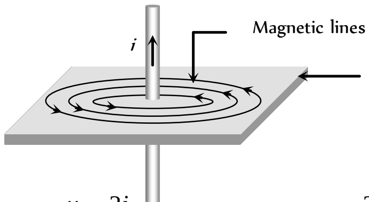
$r=\frac{l}{2\pi}=\frac{\pi^2}{2\pi}=\frac{\pi}{2}$



Magnetic field due to straight wire $B_1=\frac{\mu_0}{4\pi}\cdot\frac{2i}{r}=\frac{\mu_0}{4\pi}\times\frac{2\times 2}{1\times 10^{-2}}$ also magnetic field due to circular loop $B_2=\frac{\mu_0}{4\pi}\cdot\frac{2\pi i}{r}=\frac{\mu_0}{4\pi}\cdot\frac{2\pi\times 2}{\pi/2}\Rightarrow$

$\frac{B_2}{B_1}=\frac{1}{50}$

38. (c) See the following figure



39. (a) $B=\frac{\mu_0}{4\pi}\cdot\frac{2i}{r}\Rightarrow 10^{-5}=10^{-7}\times\frac{2i}{(10\times 10^{-2})}\Rightarrow i=5A$

40. (c) $B=\frac{\mu_0}{4\pi}\cdot\frac{2\pi Ni}{r}$

$\Rightarrow 3.14\times 10^{-3}=\frac{10^{-7}\times 2\times 3.14\times N\times 10}{(10\times 10^{-2})}\Rightarrow N=50$

41. (c) The magnetic field in the solenoid along its axis (i) At an internal point $=\mu_o ni$

$=4\pi\times 10^{-7}\times 5000\times 4=25.1\times 10^{-3}Wb/m^2$

(Here $n=50\,turns/cm=5000\,turns/m$)

(ii) At one end

$B_{end}=\frac{1}{2}B_{in}=\frac{\mu_0 ni}{2}=\frac{25.1\times 10^{-3}}{2}=12.6\times 10^{-3}Wb/m^2$

42. (b) Magnetic field at the centre of solenoid $(B)=\mu_0 ni$

Where n = Number of *turns* /*meter*

$\therefore B=4\pi\times 10^{-7}\times 4250\times 5=2.7\times 10^{-2}Wb/m^2$

43. (d) Use Right hand palm rule, or Maxwell's Cork screw rule or any other.

44. (b) $B' = n^2 B \Rightarrow B' = (4)^2 B = B' = 16B$

45. (d) $B = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r} \Rightarrow 12.56 = 10^{-7} \times \frac{2\pi \times i}{5.2 \times 10^{-11}}$

$\Rightarrow i = 1.04 \times 10^{-3}\ A$

46. (b) $B = \frac{\mu_0}{4\pi}\frac{\theta i}{r} = \frac{\mu_0}{4\pi} \times \frac{\pi}{2} \times \frac{i}{R} = \frac{\mu_0 i}{8R}$

47. (a) $B \propto \frac{1}{r} \Rightarrow \frac{B_1}{B_2} = \frac{r_2}{r_1} \Rightarrow \frac{0.04}{B_2} = \frac{40}{10} \Rightarrow B_2 = 0.01\,T$

48. (a) See solution 34.

49. (b) $B = \frac{\mu_0 i}{2\pi r}$ or $B \propto \frac{1}{r}$

50. (d) $B = \mu_0 ni = \mu_0 \frac{N}{L} i$

51. (c) Here $B = \mu_0 ni$

where n is number of turns per unit length $= \frac{N}{l}$

52. (b) $\frac{\mu_0}{4\pi} \times \frac{2\pi i}{r} = H \Rightarrow \frac{(10^{-7}) \times 2 \times 3.142 \times i}{0.05} = 7 \times 10^{-5}$

$\therefore i = \frac{7 \times 0.05 \times 10^{-5}}{2 \times 3.142 \times 10^{-7}} = \frac{35}{2 \times 3.142} = 5.6$ *amp*

53. (c) $B = \frac{\mu_0 Ni}{2r} = \frac{4\pi \times 10^{-7} \times 1000 \times 0.1}{2 \times 0.1} = 6.28 \times 10^{-4}\ T$

54. (b) $B = \frac{\mu_0 Ni}{2r} = \frac{4\pi \times 10^{-7} \times 50 \times 2}{2 \times 0.5} = 1.25 \times 10^{-4}\ T$

55. (d) $B \propto \frac{i}{r}$

56. (a) $B = \frac{\mu_0 i}{2\pi r}$ *i.e.* $B \propto \frac{1}{r}$ *i.e.* when r is doubled, B is halved.

57. (b) Applying Ampere's law $\oint B.dl = \mu_0 i$ to any closed path inside the pipe we find no current is enclosed. Hence $B = 0$.

58. (a) Magnetic field at the centre of current carrying coil is

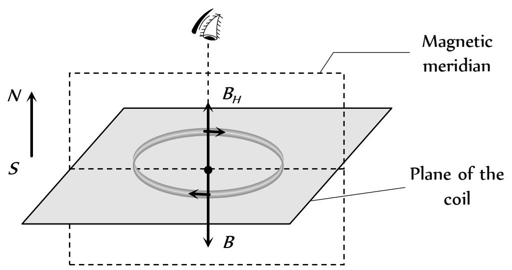
$B = \frac{\mu_0}{4\pi}\cdot\frac{2\pi ni}{r} = \frac{\mu_0 ni}{2r}$

59. (d) The magnetic field is given by $B = \frac{\mu_0}{4\pi}\frac{2i}{r}$.

It is independent of the radius of the wire.

60. (d) Magnetic meridian is a vertical *N-S* plane, the earth's magnetic field (B_H) lies in it. (For more details see magnetism).

To obtain neutral point at the centre of coil, magnetic field due to current (*B*) and B_H must cancel each other. Hence plane of the coil and magnetic meridian must be perpendicular to each other as shown



61. (c) 1 *Tesla* $= 10^4$ *Gauss*

62. (c)

63. (d)

64. (b) $B = \frac{\mu_0}{4\pi} \times \frac{2i}{r} = 10^{-7} \times \frac{2 \times 1}{10^{-2}} = 2 \times 10^{-5}$ *Tesla*

65. (a) Magnetic field due to one side of the square at centre O

$B_1 = \frac{\mu_0}{4\pi}.\frac{2i \sin 45^o}{a/2} \Rightarrow B_1 = \frac{\mu_0}{4\pi}.\frac{2\sqrt{2}\,i}{a}$

Hence magnetic field at centre due to all side

$B = 4B_1 = \frac{\mu_0(2\sqrt{2}i)}{\pi a}$

Magnetic field due to n turns

$B_{net} = nB = \frac{\mu_0 2\sqrt{2}ni}{\pi a} = \frac{\mu_0 2\sqrt{2}ni}{\pi(2l)} = \frac{\sqrt{2}\mu_0 ni}{\pi l}$ $(\because a = 2l)$

66. (c)

67. (a)

68. (c) Magnetic field on the axis of circular current

$B = \frac{\mu_0}{4\pi}\cdot\frac{2\pi nir^2}{(x^2 + r^2)^{3/2}} \Rightarrow B \propto \frac{nr^2}{(x^2 + r^2)^{3/2}}$

69. (a) $r_1 : r_2 = 1 : 2$ and $B_1 : B_2 = 1 : 3$ We know that

$B = \frac{\mu_0}{4\pi}.\frac{2\pi ni}{r} \Rightarrow \frac{i_1}{i_2} = \frac{B_1 r_1}{B_2 r_2} = \frac{1 \times 1}{3 \times 2} = \frac{1}{6}$

70. (b) $B = 10^{-7}\frac{2i}{r} = 10^{-7} \times \frac{2 \times 2}{5} = 8 \times 10^{-8}\ T$

71. (c) $B = \frac{\mu_0}{4\pi} \times \frac{\pi i}{r} \Rightarrow B = 10^{-7} \times \frac{\pi \times 10}{5 \times 10^{-2}} = 6.28 \times 10^{-5}\ T$

72. (c) Magnetic field due to solenoid is independent of diameter (Because $B = \mu_0 ni$).

73. (b) $B = \frac{\mu_0}{4\pi}\frac{2\pi i}{r} = 10^{-7} \times \frac{2\pi \times 2}{0.0157} = 8 \times 10^{-5}\,Wb/m^2$

74. (b) $B = \mu_0 ni = 4\pi \times 10^{-7} \times \frac{200}{10^{-2}} \times 2.5 = 6.28 \times 10^{-2}\,Wb/m^2$

75. (d) Magnetic field at centre due to smaller loop

$B_1 = \frac{\mu_0}{4\pi}.\frac{2\pi i_1}{r_1}$ ..... (i)

Due to Bigger loop $B_2 = \frac{\mu_0}{4\pi}.\frac{2\pi i_2}{r_2}$ So net magnetic field at centre

$B = B_1 - B_2 = \frac{\mu_0}{4\pi} \times 2\pi\left(\frac{i_1}{r_1} - \frac{i_2}{r_2}\right)$

According to question $B = \frac{1}{2} \times B_1$

$$\Rightarrow \frac{\mu_0}{4\pi}.2\pi\left(\frac{i_1}{r_1}-\frac{i_2}{r_2}\right)=\frac{1}{2}\times\frac{\mu_0}{4\pi}.\frac{2\pi i_1}{r_1}$$

$$\frac{i_1}{r_1}-\frac{i_2}{r_2}=\frac{i_1}{2r_1}\Rightarrow\frac{i_1}{2r_1}=\frac{i_2}{r_2}\Rightarrow\frac{i_1}{i_2}=1 \qquad \{r_2=2r_1\}$$

76. (b)

77. (b) $B=\frac{\mu_0}{4\pi}\times\frac{2\pi NiR^2}{(R^2+x^2)^{3/2}}\Rightarrow B\propto\frac{1}{(r^2+x^2)^{3/2}}$

$$\Rightarrow\frac{8}{1}=\frac{(R^2+x_2^2)^{3/2}}{(R^2+x_1^2)^{3/2}}\Rightarrow\left(\frac{8}{1}\right)^{2/3}=\frac{R^2+0.04}{R^2+0.0025}$$

$$\Rightarrow\frac{4}{1}=\frac{R^2+0.04}{R^2+0.0025}$$. On solving $R=0.1m$

78. (b) $B=10^{-7}\frac{2i}{r}\Rightarrow\frac{B}{B'}=\frac{20}{5}\Rightarrow B'=B/4$

79. (c) $B=10^{-7}\frac{2\pi ni}{r}=10^{-7}\times\frac{2\times\pi\times25\times4}{5\times10^{-2}}=1.257\times10^{-3}\,T$

80. (b) $F=Bil\Rightarrow[B]=\frac{[F]}{[i][l]}=\frac{MLT^{-2}}{AL}=MT^{-2}A^{-1}$

81. (d) Magnetic field on the axis of conductor is zero.

82. (c) $B\propto\frac{1}{r}\Rightarrow\frac{B_1}{B_2}=\frac{r_2}{r_1}=\frac{2r}{r}=2$

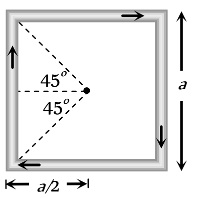
83. (c) $B=10^{-7}\times\frac{2i}{r}=10^{-7}\times\frac{2\times1}{1}=2\times10^{-7}\,T$

84. (d) At midpoint, magnetic fields due to both the wires are equal and opposite. So $B=0$.

85. (c) $B_0=4\times\frac{\mu_0}{4\pi}\times\frac{i}{(a/2)}(\sin45°+\sin45°)$

$$=4\times\frac{\mu_0}{4\pi}\times\frac{2i}{a}\times\frac{2}{\sqrt{2}}$$

$$=\frac{\mu_0 i2\sqrt{2}}{\pi a}$$



86. (b) $B=10^{-7}\frac{2\pi i}{r}$; according to question $B=B$

$$\Rightarrow5\times10^{-5}=10^{-7}\times\frac{2\times3.14\times i}{5\times10^{-2}}\Rightarrow i=4A$$

87. (d) $B=\frac{\mu_0}{4\pi}.\frac{2\pi Ni}{r}=\frac{10^{-7}\times2\pi\times100\times0.1}{5\times10^{-2}}=4\pi\times10^{-5}T$

88. (a) Corresponding current $i=en$

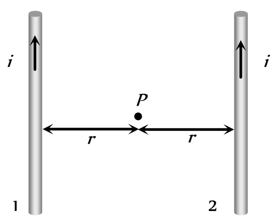
So $B=\frac{\mu_0}{4\pi}.\frac{2\pi(en)}{r}=\frac{\mu_0 ne}{2r}$

89. (a) B at ends of solenoid is $\frac{\mu_0}{2}ni$

90. (b) Use Right hand palm rule or Maxwell's Cork screw rule.

91. (c) At P

$$\Rightarrow B_{net}=B_1-B_2$$



Since $|B_1|=|B_2|$

So, $B=0$

92. (d) A moving charge and changing electric field both produces magnetic field.

93. (d)

94. (a) $B=\frac{\mu_0}{2\pi}\frac{i}{r}\Rightarrow5\times10^{-5}=\frac{\mu_0}{2\pi}\times\frac{\pi}{r}\Rightarrow r=10^4\mu_0\ metre$

95. (b) $B'=n^2B=(3)^2B=9B$

96. (b) B represents the magnetic field.

97. (a)

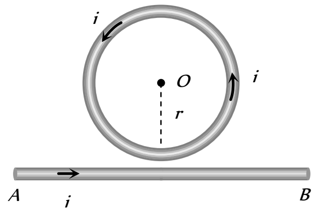
98. (d) $\frac{B_c}{B_a}=\left(1+\frac{x^2}{a^2}\right)^{3/2}=\left(1+\frac{a^2}{a^2}\right)^{3/2}=(1+1)^{3/2}=2\sqrt{2}$

99. (c) The given circuit can be considered as follows

$$B_{\text{loop}}=\frac{\mu_0 i}{2r}\odot$$

$$B_{\text{conductor}}=\frac{\mu_0 i}{2\pi r}\odot$$

$$B_{\text{net}}=\frac{\mu_0 i}{2\pi r}(\pi+1)\odot$$



100. (d) $B=\frac{\mu_0\mu_r Ni}{2\pi r}\Rightarrow1=\frac{4\pi\times10^{-7}\times\mu_r\times400\times2}{0.4}\Rightarrow\mu_r=400$

101. (b)

102. (c)

103. (b) $B=10^{-7}\times\frac{\pi\times i}{r}=10^{-7}\times\frac{\pi\times10}{20\times10^{-2}}=B=5\pi\mu T$

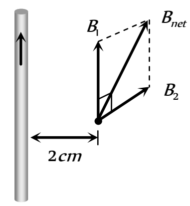
104. (d) $B'=n^2B=(2)^2B=4B$

105. (a) $B=\mu_0 ni\Rightarrow\frac{B}{B'}=\frac{n}{n'}\times\frac{i}{i'}=\frac{1}{(1/2)}\times\frac{1}{2}=1\Rightarrow B'=B$

106. (c) $B_1=4\times10^{-4}T$

$$B_2=10^{-7}\times\frac{2\times30}{2\times10^{-2}}=3\times10^{-4}T$$

$$\therefore\ B_{\text{net}}=\sqrt{B_1^2+B_2^2}=5\times10^{-4}T$$



107. (b) Magnetic field at the centre of circular loop

$$B=\frac{\mu_0}{4\pi}\frac{2\pi i}{r}\Rightarrow0.5\times10^{-5}=\frac{10^{-7}\times2\times3.14\times i}{5\times10^{-2}}$$

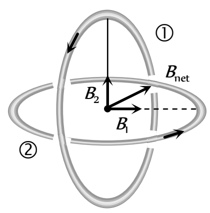
$i=0.4\ A$

108. (a)

109. (a) $B_1=B_2=B=\frac{\mu_0}{4\pi}\times\frac{2\pi i}{r}$

$$B_{net}=\sqrt{2}B$$

$$\Rightarrow\frac{B}{B_{net}}=\frac{1}{\sqrt{2}}$$



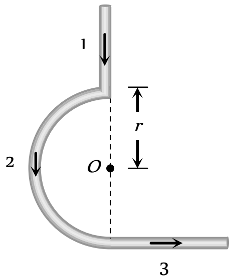
110. (c) Magnetic field due to different parts are

$B = 0$

$B_2 = \frac{\mu_0}{4\pi}.\frac{\pi i}{r} \odot$

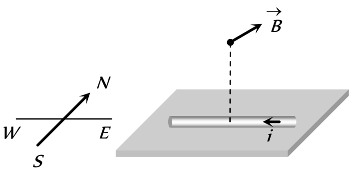
$B_3 = \frac{\mu_0}{4\pi}.\frac{i}{r} \odot$

$\therefore B_{net} = B_2 + B_3 = \frac{\mu_0 i}{4r} + \frac{\mu_0 i}{4\pi r}$



111. (d) $M = niA = ni(\pi r^2) \Rightarrow M \propto r^2$

112. (a)



113. (b) Magnetic field at the center of single turn loop $B = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r}$, magnetic field at the center of n-turn loop

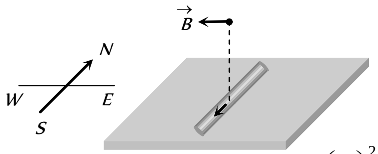
$B_n = \left(\frac{\mu_0}{4\pi}.\frac{2\pi i}{r/n}\right) \times n \Rightarrow B_n = n^2 B$

114. (a) $\frac{B_{center}}{B_{axis}} = \left(1 + \frac{x^2}{r^2}\right)^{3/2} \Rightarrow \frac{B_{center}}{54} = \left(1 + \left(\frac{4}{3}\right)^2\right)^{3/2} = \frac{125}{27}$

$B_{center} = 250\mu T$

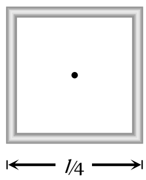
115. (b) $B = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r} \Rightarrow B \propto \frac{1}{r}$

116. (d)



117. (c) Suppose length of each wire *is l*. $A_{square} = \left(\frac{l}{4}\right)^2 = \frac{l^2}{16}$

$A_{cirde} = \pi r^2 = \pi\left(\frac{l}{2\pi}\right)^2 = \frac{l^2}{4\pi}$

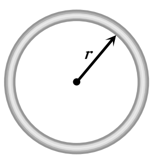


$\because$ Magnetic moment

$M = iA$

$\Rightarrow \frac{M_{square}}{M_{cirde}} = \frac{A_{square}}{A_{cirde}}$

$= \frac{l^2/16}{l^2/4\pi} = \frac{\pi}{4}$



118. (b) $B = \frac{\mu_0}{4\pi}.\frac{2\pi ni}{r} \Rightarrow B \propto ni$

119. (a) Magnetic field due to revolution of electron

$$B = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r} = \frac{\mu_0}{4\pi}.\frac{2\pi.\left(\frac{e\omega}{2\pi}\right)}{r} = 10^{-7} \times \frac{e\omega}{r}$$

$$\Rightarrow 16 = 10^{-7} \times \frac{1.6 \times 10^{-19}\omega}{1 \times 10^{-10}} \Rightarrow \omega = 10^{17} rad/\sec.$$

120. (a) $B = \frac{\mu_0}{4\pi}.\frac{2i}{r} = 10^{-7} \times \frac{2 \times 20}{10 \times 10^{-2}} = 4 \times 10^{-5} Wb/m^2$

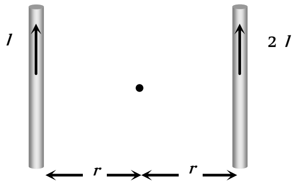
121. (a) $B = \frac{\mu_0}{4\pi}.\frac{2i}{r} \Rightarrow B \propto i$

122. (a) $B_{net} = \sqrt{B_1^2 + B_2^2} = \frac{\mu_0}{4\pi}.\frac{2\pi}{r}\sqrt{i_1^2 + i_2^2}$

$= 10^{-7} \times \frac{2\pi}{2\pi \times 10^{-2}}\sqrt{(3)^2 + (4)^2} = 5 \times 10^{-5}\ wb/m^2$

123. (c) When two parallel conductors carrying current I and $2I$ in same direction, then magnetic field at the midpoint is

$B = \frac{\mu_0 2I}{2\pi r} - \frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{2\pi r}$



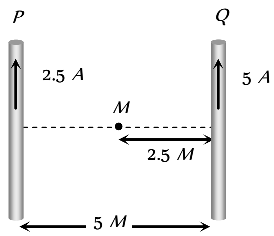
When current $2I$ is switched off then magnetic field due to conductor carrying current I is $B = \frac{\mu_0 I}{2\pi r}$.

124. (d) In the following figure magnetic field at mid point M is given by

$B_{net} = B_Q - B_P$

$= \frac{\mu_0}{4\pi}.\frac{2}{r}(i_Q - i_P)$

$= \frac{\mu_0}{4\pi} \times \frac{2}{2.5}(5 - 2.5) = \frac{\mu_0}{2\pi}$



125. (c)

126. (b) The magnetic field due to small element of conductor of length is given by $dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$

This value will be maximum when

$\sin\theta = 1 = \sin 90°$ or, $\theta = 90°$

Motion of Charged Particle in Magnetic Field

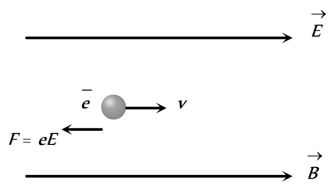
1. (a, b, d)

Here the proton has no acceleration so $E = B = 0$.

When $E = 0$ but $B \neq 0$, but parallel to the motion of proton, there will be no force acting.

When $E \neq 0$ and $B \neq 0$ and E, B and motion of proton (v) are mutually perpendicular, there may be no net force. Forces due to E and B cancel each other.

2. (d) Since electron is moving is parallel to the magnetic field, hence magnetic force on it $F_m = 0$.



The only force acting on the electron is electric force which reduces it's speed.

3. (c) $r = \dfrac{\sqrt{2mk}}{qB} = \dfrac{1}{B}\sqrt{\dfrac{2mV}{q}} \Rightarrow r \propto \sqrt{m} \Rightarrow \dfrac{m_1}{m_2} = \left(\dfrac{R_1}{R_2}\right)^2$

4. (a) $r = \dfrac{mv}{Bq} = \dfrac{v}{(q/m)B} = \dfrac{2\times10^5}{5\times10^7\times4\times10^{-2}} = 0.1m$

5. (b) $r = \dfrac{p}{qB} \Rightarrow r \propto p$

6. (b) $B = \dfrac{mv}{qr} = \dfrac{9\times10^{-31}\times10^6}{1.6\times10^{-19}\times0.1} = 5.6\times10^{-5}T$

7. (c) $r = \dfrac{\sqrt{2mK}}{qB}$ *i.e.* $r \propto \dfrac{\sqrt{m}}{q}$

Here kinetic energy K and B are same.

$\therefore \dfrac{r_p}{r_\alpha} = \dfrac{\sqrt{m_p}}{\sqrt{m_\alpha}}.\dfrac{q_\alpha}{q_p} = \dfrac{\sqrt{m_p}}{\sqrt{4m_p}}.\dfrac{2q_p}{q_p} = 1$

8. (c) $\vec{F} = q\vec{v}\times\vec{B}$

9. (c)

10. (d)

11. (c) East, (By $\vec{F} = q(\vec{v}\,v\times\vec{B})$) or by applying Fleming's left hand rule.

12. (d) $F = qvB = 1.6\times10^{-19}\times\left[\sqrt{\dfrac{2E}{m}}\right]2.5$

$= 4\times10^{-19}\sqrt{\dfrac{2\times2\times1.6\times10^{-19}\times10^6}{1.66\times10^{-27}}} = 7.6\times10^{-12}N$

13. (d) $\vec{F} = q(\vec{v}\times\vec{B})$; if $\vec{v}\,||\,\vec{B}$ then $\vec{F} = 0$

14. (b) This is according to the cross product $\vec{F} = q(\vec{v}\times\vec{B})$ otherwise can be evaluated by the left-hand rule of Fleming.

15. (a) $r = \dfrac{\sqrt{2mK}}{qB} \Rightarrow K \propto \dfrac{q^2}{m} \Rightarrow \dfrac{K_p}{K_\alpha} = \left(\dfrac{q_p}{q_\alpha}\right)^2 \times \dfrac{m_\alpha}{m_p}$

$\Rightarrow \dfrac{1}{K_\alpha} = \left(\dfrac{q_p}{2q_p}\right)^2 \times \dfrac{4m_p}{m_p} = 1 \Rightarrow K_\alpha = 1\,MeV$.

16. (c) $r \propto \dfrac{1}{B}$ *i.e.* $\dfrac{r_1}{r_2} = \dfrac{B_2}{B_1} \Rightarrow r_2 = \dfrac{B_1}{B_1/2}\times r = 2r$

17. (c) Time period of proton $T_p = \dfrac{25}{5} = 5\mu\,\text{sec}$

By using $T = \dfrac{2\pi m}{qB} \Rightarrow \dfrac{T_\alpha}{T_p} = \dfrac{m_\alpha}{m_p}\times\dfrac{q_p}{q_\alpha} = \dfrac{4m_p}{m_p}\times\dfrac{q_p}{2q_p}$

$\Rightarrow T_\alpha = 2T_p = 10\mu$ sec.

18. (a) $F = ma = qvB \Rightarrow a = \dfrac{qvB}{m} = \dfrac{1.6\times10^{-19}\times2\times3.4\times10^7}{1.67\times10^{-27}}$

$= 6.5\times10^{15}\,m/sec^2$

19. (c) $T = \dfrac{2\pi m}{qB} = \dfrac{2\pi r}{v} = \dfrac{2\times3.14\times0.45}{2.6\times10^7} = 1.08\times10^{-7}$ sec

20. (b) $F = qvB$ and $K = \dfrac{1}{2}mv^2 \Rightarrow F = qB\sqrt{\dfrac{2k}{m}}$

$= 1.6\times10^{-19}\times1.5\sqrt{\dfrac{2\times5\times10^6\times1.6\times10^{-19}}{1.7\times10^{-27}}}$

$= 7.344\times10^{-12}\,N$

21. (c) Magnetic force acts on a moving charge.

22. (c) $r = \dfrac{mv}{qB} \Rightarrow r \propto v, \Rightarrow r_2 = 2r_1 = 2\times2 = 4cm$

23. (d) $r = \dfrac{\sqrt{2mK}}{qB} \Rightarrow K \propto \dfrac{q^2}{m}$

$\Rightarrow \dfrac{K_p}{K_d} = \left(\dfrac{q_p}{q_d}\right)^2 \times \dfrac{m_d}{m_p} = \left(\dfrac{1}{1}\right)^2 \times \dfrac{2}{1} = \dfrac{2}{1}$

$\Rightarrow K_p = 2\times50 = 100\,keV$.

24. (b) Maximum force will act on proton so it will move on a circular path. Force on electron will be zero because it is moving parallel to the field.

25. (d) Fleming's left hand rule is used to the determine the direction of force.

26. (a) Lorentz force is given by

$\vec{F} = \vec{F_e} + \vec{F_m} = q\vec{E} + q(\vec{v}\times\vec{B}) = q[\vec{E} + (\vec{v}\times\vec{B})]$

27. (c) $\vec{F} = q\vec{v}\times\vec{B}$

28. (a) $F = qvB\sin\theta$

$= 1.6\times10^{-19}\times2\times10^7\times1.5\sin30^o$

$= 1.6\times10^{-19}\times2\times10^7\times1.5\times\dfrac{1}{2} = 2.4\times10^{-12}N$

29. (d) $F = qvB\sin\theta \Rightarrow B = \dfrac{F}{qv\sin\theta}$

$B_{\min} = \dfrac{F}{qv}$ (when $\theta = 90$)

$\therefore B_{\min} = \dfrac{F}{qv} = \dfrac{10^{-10}}{10^{-12}\times10^5} = 10^{-3}$ *Tesla* in $\hat{z}$ -direction.

30. (d) Kinetic energy in magnetic field remains constant and it is $K = qV \Rightarrow K \propto q$ (V = constant)

$\therefore K_p : K_d : K_\alpha = q_p : q_d : q_a = 1:1:2$

31. (d) When charged particle enters perpendicularly in a magnetic field, it moves on a circular path with a constant speed. Hence it's kinetic energy also remains constant.

32. (b) $r = \dfrac{\sqrt{2mK}}{qB}$ *i.e.* $r \propto \dfrac{\sqrt{m}}{q}$

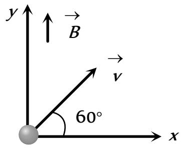
Here kinetic energy K and B are same.

$\therefore \dfrac{r_e}{r_p} = \sqrt{\dfrac{m_e}{m_p}}\times\dfrac{q_p}{q_e} \Rightarrow \dfrac{r_e}{r_p} = \sqrt{\dfrac{m_e}{m_p}}$ $(\because q_e = q_p)$

Since $m_e < m_p$, therefore $r_e < r_p$

33. (c) Path of the proton will be a helix of radius $r = \frac{mv\sin\theta}{qB}$

(where θ = Angle between $\vec{B}$ and $\vec{v}$)



$\Rightarrow r = \frac{1.67\times10^{-27}\times2\times10^{6}\times\sin30^{o}}{1.6\times10^{-19}\times0.104}$

$= 0.1m$

Time period $T = \frac{2\pi m}{qB} = \frac{2\pi\times1.67\times10^{-27}}{1.6\times10^{-19}\times0.104}$

$= 2\pi\times10^{-7}\, sec$

34. (a) $\frac{mv^2}{R} = qvB$. For proton $R_p = \frac{mv}{qB} = \frac{\sqrt{2m_pE}}{qB}$

and for deutron $R_d = \frac{\sqrt{2m_dE}}{qB}$

$\Rightarrow \frac{R_d}{R_p} = \sqrt{\frac{m_d}{m_p}} = \sqrt{2} \Rightarrow R_d = \sqrt{2}R_p$

35. (c) In this case $|\vec{F_e}| = |\vec{F_m}|$ and both forces are opposite to each other.

36. (b) We know that time period $T = \frac{2\pi m}{qB}$ *i.e.* $T \propto m$

(Since q and B are same)

∵ Mass of proton > Mass of electron

∴ Time period of proton > Time period of electron

37. (d) According to Fleming's right hand rule.

38. (a) $r = \frac{mv}{eB} \Rightarrow \frac{e}{m} = \frac{v}{rB}$

39. (a) Using $eE = evB \Rightarrow E = vB = 5\times10^{6}\times0.02 = 10^{5}\,Vm^{-1}$

40. (d) $F = evB = 1.6\times10^{-19}\times4\times10^{6}\times2\times10^{-1} = 1.28\times10^{-13}\,N$

Also $\frac{mv^2}{r} = evB \Rightarrow r = \frac{mv}{eB}$

$\Rightarrow r = \frac{9\times10^{-31}\times4\times10^{6}}{1.6\times10^{-19}\times2\times10^{-1}} = 1.1\times10^{-4}m$

41. (c) Force acts perpendicular to the velocity in a magnetic field, so speed of electron will remain same.

42. (a) By Fleming left hand rule.

43. (d) Direction of motion of proton is same as that of direction of magnetic field.

44. (a) Time period is given by $T = \frac{2\pi m}{qB}$

$\Rightarrow$ Frequency $\nu = \frac{1}{T} = \frac{qB}{2\pi m}$

45. (b) $r = \frac{\sqrt{2mK}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$

$= \frac{1}{10^{-3}}\sqrt{\frac{2\times9\times10^{-31}\times12000}{1.6\times10^{-19}}}$ =0.367 m = 36.7 cm

46. (c) $r = \frac{1}{B}\sqrt{\frac{2mV}{q}} \Rightarrow r \propto \sqrt{\frac{m}{q}} \Rightarrow \frac{r_x}{r_y} = \sqrt{\frac{m_x}{q_x}\times\frac{q_y}{m_y}}$

$\Rightarrow \frac{R_1}{R_2} = \sqrt{\frac{m_x}{m_y}\times\frac{2}{1}} \Rightarrow \frac{m_x}{m_y} = \frac{R_1^2}{2R_2^2}$

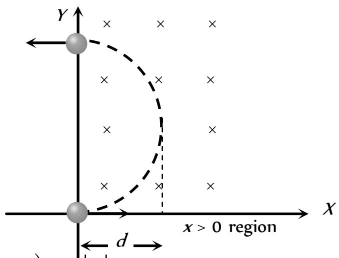
47. (d) $\vec{F} = q(\vec{v}\times\vec{B}) = 10^{-11}(10^{8}\hat{j}\times0.5\hat{i})$

$= 5\times10^{-4}(\hat{j}\times\hat{i}) = 5\times10^{-4}\,N(-\hat{k})$

48. (b) It is easy to understand the given problem, along with the following figure.

d = radius of path

$= \frac{mv}{qB}$



49. (c) Lorentz force $F = q(v\times B)$ or $|F| = qvB\sin\theta$

F will be maximum. when $\theta = 90^o$

50. (d) The component of velocity perpendicular to H will make the motion circular while that parallel to H will make it move along a straight line. The two together will make the motion helical.

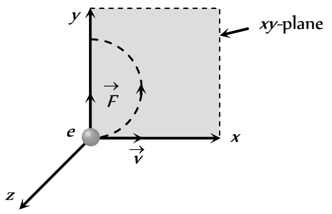
51. (b) We have $qvB = \frac{mv^2}{r}$ or $r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB}$

For same kinetic energy K, we have $r \propto \sqrt{m}$

Hence path of proton will have larger r and is therefore less curved.

52. (c) When particle enters at angle other than 0° or 90° or 180°, path followed is helix.

53. (b) To move the electron in xy plane, force on it must be acting in the y-direction initially. The direction of $\vec{F}$ is known, and the direction of v is known, hence by applying Fleming's left hand rule, the direction of magnetic field is also determined.



54. (a) A moving charge gains energy in electric field only because in magnetic field energy remains constant.

55. (a) Given that $K_p = K_d = K_\alpha = K$ (say)

We know that $m_p = m$, $m_d = 2m$ and $m_\alpha = 4m$ and $q_p = e$, $q_d = e$ and $q_\alpha = 2e$

Further $r=\frac{\sqrt{2mK}}{qB} \Rightarrow r_p=\frac{\sqrt{2mK}}{eB}$, $r_d=\frac{\sqrt{2(2m)K}}{eB}=\sqrt{2}r_p$

and $r_\alpha=\frac{\sqrt{2(4m)K}}{(2e)B}=r_p$. Hence $r_\alpha=r_p<r_d$

56. (d) Since force is perpendicular to direction of motion. energy and magnitude of momentum remains constant.

57. (d) $T=\frac{2\pi m}{qB} \Rightarrow T \; \alpha \; v^o$

58. (b) $F=qvB$ also Kinetic energy $K=\frac{1}{2}mv^2 \Rightarrow v=\sqrt{\frac{2K}{m}}$

$\therefore \; F=q\sqrt{\frac{2K}{m}}B$

$=1.6\times10^{-19}\sqrt{\frac{2\times200\times10^6\times1.6\times10^{-19}}{1.67\times10^{-27}}}\times5$

$=1.6\times10^{-10}\,N$

59. (d) The deflection produced by the electric field may be nullified by that produced by magnetic field.

60. (a) $\vec{F_m}=q(\vec{v}\times\vec{B})$

When the angle between $\vec{v}$ and $\vec{B}$ is 180°, $F_m = 0$

61. (c) $r=mv/qB$

Since both have same momentum, therefore the circular path of both will have the same radius.

62. (c) When particle enters perpendicularly in a magnetic field, it moves along a circular path with constant speed.

63. (b) For motion of a charged particle in a magnetic field, we have $r = mv/qB$ *i.e.* $r \propto v$

64. (a) The charged particle moving in a magnetic field does not gain energy. However, the direction of its velocity changes continuously. Hence momentum changes.

65. (a) $F=qvB\sin\theta=qvB\sin0=0$

66. (b) $r=\frac{mv}{qB}=\frac{10^7}{10^{11}\times10^{-4}}=1m \; (\because q/m=10^{11}\,C/kg)$

67. (b) $\omega=\frac{2\pi}{T}=\frac{qB}{m} \Rightarrow \omega \propto v^o \; \left(\because T=\frac{2\pi m}{qB}\right)$

68. (a) $r=\frac{\sqrt{2mK}}{qB} \Rightarrow r \propto \sqrt{K} \Rightarrow \frac{R}{R_2}=\sqrt{\frac{K}{2K}} \Rightarrow R_2=R\sqrt{2}$

69. (b, d) $r=\frac{mv}{qB}=\frac{P}{qB}$

70. (b) $F=qvB\sin\theta=1.6\times10^{-19}\times2.5\times2.5\times10^7\sin30^o$

$F=1.6\times10^{-19}\times6.25\times10^7\times\frac{1}{2}=5\times10^{-12}\,N$

71. (c) $K_{\max}=\frac{1}{2}mv^2$ and $r_0=\frac{mv}{qB} \Rightarrow v=\frac{qBr_0}{m}$

$\Rightarrow K_{\max}=\frac{1}{2}m\left(\frac{qBr_0}{m}\right)^2=\frac{q^2B^2r_0^2}{2m}$

72. (b) $F=qvB\sin\theta$; Independent of mass

73. (b) By Fleming left hand rule.

74. (a) $F=qBv=1\times0.5\times10=5N$

75. (d) $r=\frac{mv}{qB} \Rightarrow \frac{r_1}{r_2}=\frac{v_1}{v_2}\times\frac{B_2}{B_1} \Rightarrow \frac{r_1}{r_2}=\frac{1}{2}\times\frac{1}{2}=\frac{1}{4}$

$r_2=4r_1$

76. (d) Magnetic force on charge will be zero.

77. (d)

78. (b) Apply Fleming's left hand rule.

79. (a) $T=\frac{2\pi m}{qB}=\frac{2\times3.14\times9\times10^{-31}}{1.6\times10^{-19}\times1\times10^{-4}}=3.5\times10^{-7}$ *sec*

80. (d) $\vec{F}=q(\vec{v}\times\vec{B})=0$ as $\vec{v}$ and $\vec{B}$ are parallel.

81. (a) Here magnetic force is zero, but the velocity increases due to electric force.

82. (a)

83. (c)

84. (b) $r=\frac{mv}{qB} \Rightarrow r \propto mv$ (q and B are constant)

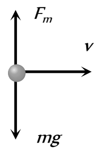
$\because r_A>r_B \Rightarrow m_Av_A>m_Bv_B$

85. (b) $r=\frac{p}{qB} \Rightarrow p \propto q$ ($\because$ r and B are constant)

$\frac{p_p}{p_\alpha}=\frac{q_p}{q_\alpha}=\frac{q_p}{(2q_p)}=\frac{1}{2}$

86. (c) Particle will move with uniform velocity when it's acceleration is zero.

i.e. $|F_m|=mg \Rightarrow mg=qvB$



$\Rightarrow B=\frac{mg}{qv}=\frac{0.6\times10^{-3}\times10}{25\times10^{-9}\times1.2\times10^4}=20\,T$

87. (c) $r=\frac{mv}{qB} \Rightarrow \frac{r_\alpha}{r_p}=\frac{m_\alpha}{m_p}\times\frac{q_p}{q_\alpha}=\frac{4}{1}\times\frac{1}{2}=\frac{2}{1}$

88. (b) When field is parallel to the direction of motion of charge, magnetic force on it is zero.

89. (a) Since $\vec{F}$ and $\vec{v}$ are perpendicular to each other work done by force is zero. Hence K.E. is constant.

90. (b)

91. (a) Charged particles deflects in magnetic field.

92. (a) $v=\frac{qB}{2\pi m} \Rightarrow v \propto \frac{q}{m}$

$\left(\frac{q}{m}\right)_{Li^+}$ is minimum so v_{Li^+} is minimum.

93. (c) $r=\frac{\sqrt{2mK}}{qB} \Rightarrow r \propto \frac{\sqrt{m}}{q} \Rightarrow \frac{r_{He^+}}{r_{O^{++}}}=\sqrt{\frac{m_{He^+}}{m_{O^{++}}}}\times\frac{q_{O^{++}}}{q_{He^+}}$

$= \sqrt{\frac{4}{16} \times \frac{2}{1}} = \frac{1}{1}$. Then will deflect equally.

94. (d) $r = \frac{\sqrt{2mE}}{qB} = \frac{\sqrt{2 \times 9 \times 10^{-31} \times 7.2 \times 10^{-18}}}{1.6 \times 10^{-19} \times 9 \times 10^{-5}}$

= 0.25 m = 25 cm

95. (c) $v = \frac{E}{B} = \frac{20}{5} = 4m/\sec$

96. (a) Because magnetic force on charge will be zero.

97. (c) $W = F.d\cos 90^o = 0$

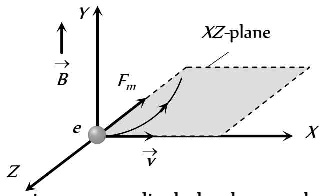
98. (b) Since particle is moving undeflected.

So $qE = qvB \Rightarrow B = E/v = \frac{10^4}{10} = 10^3 Wb/m^2$

99. (a) $r = \frac{mv}{qB} \Rightarrow \frac{r_1}{r_2} = \frac{m_1 v_1}{m_2 v_2} \times \frac{q_2}{q_1} = \frac{1 \times 2}{1 \times 3} \times \frac{2}{1} = \frac{4}{3}$

100. (b) $\vec{F} = -e(\vec{v} \times \vec{B}) \Rightarrow \vec{F} = -e[v\hat{i} \times B\hat{j}] = evB[-\hat{k}]$

i.e. Force on electron is acting towards negative *z*-axis. Hence particle will move on a circle in *xz*-plane.



101. (d) Particles entering perpendicularly, hence they will describe circular path. Since their masses are different so they will describe path of different radii.

102. (c) $r = \frac{mv}{qB} = \frac{6 \times 10^7}{1.7 \times 10^{11} \times 1.5 \times 10^{-2}} = 2.35\, cm$

103. (d) Cyclotron frequency $v = \frac{Bq}{2\pi m}$

$\Rightarrow v = \frac{1 \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 2.79 \times 10^{10} H_z$

$= 27.9 \times 10^9\, HZ \cong 28\, GHZ$

104. (d) By Fleming's left hand rule.

105. (c) $r = \frac{\sqrt{2mK}}{qB} \Rightarrow q \propto \sqrt{mK} \Rightarrow K \propto \frac{q^2}{m}$

$\Rightarrow \frac{K_\alpha}{K_p} = \left(\frac{q_\alpha}{q_p}\right)^2 \times \frac{m_p}{m_\alpha} \Rightarrow \frac{K_\alpha}{8} = \left(\frac{2q_p}{q_p}\right)^2 \times \frac{m_p}{4m_p} = 1$

$\Rightarrow K_\alpha = 8\, eV$

106. (c) By using $r = \frac{mv}{qB} = \frac{v}{\left(\frac{q}{m}\right)B} \Rightarrow r \propto \frac{1}{(q/m)}$

$\because \left(\frac{q}{m}\right)_{e^-} > \left(\frac{q}{m}\right)_{p^+} > \left\{\left(\frac{q}{m}\right)_d = \left(\frac{q}{m}\right)_\alpha\right\}$

$\therefore R_d = R_\alpha$

107. (d) By using Fleming's left hand rule.

108. (d) Along the axis of coil. $\vec{v}$ and $\vec{B}$ are parallel, so $F = 0$

109. (d) $F_m = qvB\sin\theta$, if $v = 0 \Rightarrow F_m = 0$

110. (d) $T = \frac{2\pi m}{qB} = \frac{2 \times 3.14 \times 9.1 \times 10^{-31}}{1.6 \times 10^{-19} \times 3.534 \times 10^{-5}}$

$= 1 \times 10^{-6} sec = 1\mu sec.$

111. (a)

112. (b)

113. (d) Magnetic field produced by wire at the location of charge is perpendicular to the paper inwards. Hence by applying Fleming's left hand rule, force is directed along *OY*.

114. (c) From Fleming's left hand rule the force on electron is towards the east means it is deflected towards east.

115. (c) Electric current corresponds to the revolution of electron is $i = \frac{ev}{2\pi r}$

Magnetic field due to circular current at the centre $B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi i}{r} = \frac{\mu_0}{4\pi} \cdot \frac{ev}{r^2} \Rightarrow r = \sqrt{\frac{\mu_0}{4\pi} \cdot \frac{ev}{B}} \Rightarrow r \propto \sqrt{\frac{v}{B}}$.

116. (c) When electron moves in both electric and magnetic field then $qE = qvB$.

$\therefore\ v = \frac{E}{B} = \frac{1500}{0.40} = 3750\ m/s = 3.75 \times 10^3 m/s$.

117. (c) For no deflection in mutually perpendicular electric and magnetic field $v = \frac{E}{B} = \frac{3.2 \times 10^5}{2 \times 10^{-3}} = 1.6 \times 10^8\ m/s$.

If electric field is removed then due to only magnetic field radius of the path described by electron $r = \frac{mv}{qB} = \frac{9.1 \times 10^{-31} \times 1.6 \times 10^8}{1.6 \times 10^{-19} \times 2 \times 10^{-3}} = 0.45\, m$

118. (c) $r = \frac{mv}{qB} \Rightarrow r \propto v$

Force and Torque on Current Carrying Conductor

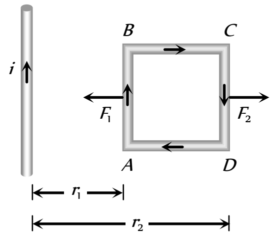
1. (b) Two wires, if carries current in opposite direction, they repel each other.

2. (c) $\because r_1 < r_2$

So $F_1 > F_2$

$\Rightarrow F_{net} = (F_1 - F_2)$

towards the wire.



3. (b) $M = NiA = 20 \times \frac{22}{7}(4 \times 10^{-2})^2 3 = 0.3\ A - m^2$

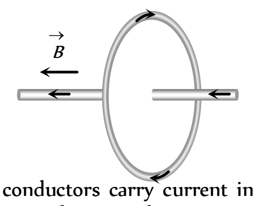
4. (c) Net force on a current carrying closed loop is always zero, if it is placed in an uniform magnetic field.

5. (b) Force per unit length $= \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{r} = \frac{\mu_0}{2\pi} \cdot \frac{i^2}{b}$

6. (a) $F = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a} \times l \Rightarrow F = 10^{-7} \times \frac{2 \times 10 \times 2}{(10 \times 10^{-2})} \times 2 = 8 \times 10^{-5} N$

7. (b) For charge particles, if they are moving freely in space, electrostatic force is dominant over magnetic force between them. Hence due to electric force they repel each other.

8. (b) As shown in the following figure straight wire is placed parallel to the magnetic field produced by circular current. Hence force on wire $F = 0$



9. (a) Two straight conductors carry current in same direction, then attractive force acts between them.

10. (a) $F = \frac{\mu_0}{4\pi} \frac{2 \times i_1 i_2}{a} = \frac{10^{-7} \times 2 \times 5 \times 5}{0.1} = 5 \times 10^{-5} N/m$

11. (c) $F = \frac{\mu_0}{4\pi} \frac{2i_1 i_2}{a} = 10^{-3} N$

When current in both the wires is doubled, then

$F' = \frac{\mu_0}{4\pi} \frac{2(2i_1 \times 2i_2)}{a} = 4 \times 10^{-3} N$

12. (a) The magnetic moment of current carrying loop

$M = niA = ni(\pi r^2)$

Hence the work done in rotating it through 180°

$W = MB(1 - \cos\theta) = 2MB = 2(ni\pi r^2)B$

$= 2 \times (50 \times 2 \times 3.14 \times 16 \times 10^{-4}) \times 0.1 = 0.1 J$

13. (c) $F = Bil \sin\theta$

$= 500 \times 10^{-4} \times 3 \times (40 \times 10^{-2}) \times \frac{1}{2} = 3 \times 10^{-2} N$

14. (c) $M = i\pi r^2$

15. (a) Because $\tau = NiAB \cos\theta$

16. (c)

17. (b) $\theta = \frac{NiAB}{C} \Rightarrow \theta \propto N$ (Number of turns)

18. (b) Magnet provides damping.

19. (b) $i = \frac{C\theta}{NAB} \Rightarrow i \propto \theta$

20. (b) Force per unit length on two parallel current carrying conductor is given by $\frac{F}{l} = 10^{-7} \times 2 \frac{i_1 i_2}{a}$

$\Rightarrow \frac{F}{l} = 10^{-7} \times 2 \times \frac{1 \times 1}{1} = 2 \times 10^{-7} N/m$

21. (d) $\tau = MB \sin\theta \Rightarrow \tau_{\max} = NiAB$, ($\theta = 90°$)

22. (b) $W = MB(\cos\theta_1 - \cos\theta_2)$

$= (NiA) B(\cos 0° - \cos 180°) = 2NAIB$

23. (d) Magnetic dipole moment of coil = NIA

24. (a) $F = Bil \sin\theta \Rightarrow \sin\theta = \frac{F}{Bil} = \frac{15}{2 \times 10 \times 1.5} = \frac{1}{2} \Rightarrow \theta = 30°$

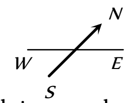
25. (a)

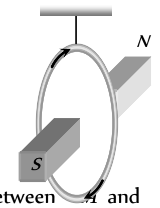
26. (b) $M = i(\pi r^2) = \frac{ev}{2\pi r} \times \pi r^2 \Rightarrow M = \frac{1}{2} evr$

27. (d) Couple of force on loop S will be maximum because for same perimeter the area of loop will be maximum and magnetic moment of loop $= i \times A$. So, it will also be maximum for loop S.

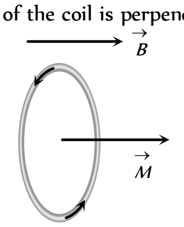
28. (b) According to the definition.

29. (c) Current carrying loop, behaves as a bar magnet. A freely suspended bar magnet stays in the $N - S$ direction.





30. (c) In equilibrium angle between $\vec{M}$ and $\vec{B}$ is zero. It is happened, when plane of the coil is perpendicular to $\vec{B}$



31. (c)

32. (d)

33. (d) Sensitivity $S = \frac{\theta}{i} = \frac{nBA}{C}$

34. (d)

35. (b) By Fleming left hand rule.

36. (a) Force on wire Q due to wire P is

$F_P = 10^{-7} \times \frac{2 \times 30 \times 10}{0.1} \times 0.1 = 6 \times 10^{-5} N$ (Towards left)

Force on wire Q due to wire R is

$F_R = 10^{-7} \times \frac{2 \times 20 \times 10}{0.02} \times 0.1 = 20 \times 10^{-5} N$ (Towards right)

Hence $F_{net} = F_R - F_P = 14 \times 10^{-5} N = 1.4 \times 10^{-4} N$

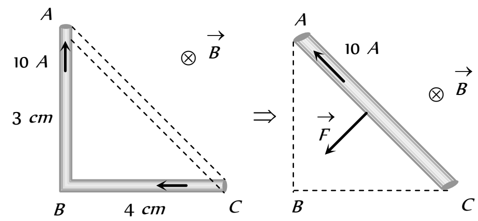
(Towards right)

37. (a) $\tau = NBiA = 100 \times 0.2 \times 2 \times (0.08 \times 0.1) = 0.32 N \times m$

Direction can be found by Fleming's left hand rule.

38. (a) $F = Bil \sin\theta \Rightarrow 7.5 = 2 \times 5 \times 1.5 \sin\theta \Rightarrow \theta = 30°$

39. (c) According to the question figure can be drawn as shown below.



Force on the conductor ABC = Force on the conductor AC

$= 5 \times 10 \times (5 \times 10^{-2}) = 2.5\ N$

40. (d) Current sensitivity $\frac{\theta}{i} = \frac{NBA}{C}$

$\Rightarrow \frac{\theta}{i} = \frac{100 \times 5 \times 10^{-4}}{10^{-8}} = 5\ rad/\mu\ Amp$

41. (c) $\tau = NBiA = 100 \times 0.5 \times 1 \times 400 \times 10^{-4} = 2\ N-m$

42. (a) When current is passed through a spring, it gets compressed.

43. (a) $M = iA \Rightarrow i = M/A$

44. (c) $i = 6.6 \times 10^{15} \times 1.6 \times 10^{-19} = 10.5 \times 10^{-4} amp$

$A = \pi R^2 = 3.142 \times (0.528)^2 \times 10^{-20} m^2$

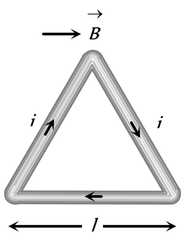
$\Rightarrow M = iA = 10.5 \times 10^{-4} \times 3.142 \times (0.528)^2 \times 10^{-20}$

$= 10 \times 10^{-24} units = 1 \times 10^{-23} units$

45. (d) Since $\theta = 90°$

Hence $\tau = NIAB = 1 \times I \times \left(\frac{\sqrt{3}}{4} l^2\right) B$

$= \frac{\sqrt{3}}{4} l^2 B$



46. (a) For no force on wire C, force on wire C due to wire D = force on wire C due to wire B

$\Rightarrow \frac{\mu_0}{4\pi} \times \frac{2 \times 15 \times 5}{x} \times l = \frac{\mu_0}{4\pi} \times \frac{2 \times 5 \times 10}{(15 - x)} \times l \Rightarrow x = 9cm.$

47. (d) By Fleming's left hand rule.

48. (a)

49. (a)

50. (c) Force on the wire = Bil

Force per unit length $= Bi = 10^{-4} \times 10 = 10^{-3}\ N$

51. (b) $F = Bil = 2 \times 1.2 \times 0.5 = 1.2N$

52. (a) $F = \frac{\mu_0}{4\pi} \frac{2i_1 i_2}{a} = 10^{-7} \times \frac{2 \times 10 \times 10}{0.1} = 2 \times 10^{-4}\ N$

Direction of current is same, so force is attractive.

53. (a,b,c) Sensitivity $\frac{\theta}{i} = \frac{NAB}{C}$

54. (a) $M = NiA = 24 \times 0.75 \times 3.14 \times (3.5 \times 10^{-2})^2$

$= 6.9 \times 10^{-2} A\text{-}m^2$

55. (c) $\frac{F}{l} = \frac{\mu_0}{4\pi} \times \frac{2i_1 i_2}{a} = \frac{\mu_0}{4\pi} \frac{2i^2}{a}$ $(\because i_1 = i_2 = i)$

$\Rightarrow 2 \times 10^{-7} = 10^{-7} \times \frac{2i^2}{1} \Rightarrow i = 1A$

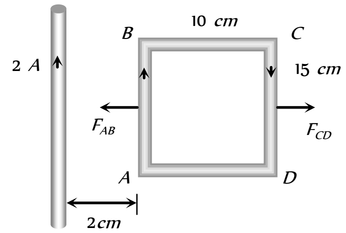
56. (b)

57. (a) $\tau = NiAB \sin\theta = 0$ $(\because \theta = 0^o)$

58. (d) $M = NiA$

59. (c)

60. (a) Force on side BC and AD are equal but opposite so their net will be zero.



But $F_{AB} = 10^{-7} \times \frac{2 \times 2 \times 1}{2 \times 10^{-2}} \times 15 \times 10^{-2} = 3 \times 10^{-6}\ N$

and $F_{CD} = 10^{-7} \times \frac{2 \times 2 \times 1}{(12 \times 10^{-2})} \times 15 \times 10^{-2} = 0.5 \times 10^{-6}\ N$

$\Rightarrow F_{net} = F_{AB} - F_{CD} = 2.5 \times 10^{-6}\ N$

$= 25 \times 10^{-7}\ N$, towards the wire.

61. (b) $F = 10^{-7} \frac{2i_1 i_2}{a} = 10^{-7} \times \frac{2 \times 5 \times 5}{0.5} = 10^{-5}\ N$ (repulsive)

62. (b) Sensitivity $= \frac{NAB}{C}$

63. (d) $M = iA = 0.1 \times \pi \times (0.05)^2$

$= (0.1) \times 3.14 \times 25 \times 10^{-4} = 7.85 \times 10^{-4} amp - m^2$

64. (b) $B = \frac{\mu_0 i}{2R} \Rightarrow i = \frac{B \times 2R}{\mu_0}$

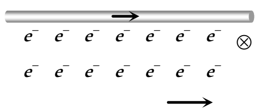
Now, $M = i \times A = i\pi R^2 = \frac{B \times 2R}{\mu_0} \times \pi R^2 = \frac{2\pi BR^3}{\mu_0}$

65. (c) $M = NiA \Rightarrow M \propto A \Rightarrow M \propto r^2$ $(\text{As}\, l = 2\pi r \Rightarrow l \propto r)$

$\Rightarrow M \propto l^2$

66. (a) $F = \frac{\mu_0}{4\pi} \frac{2i_1 i_2}{a} = 10^{-7} \times \frac{2 \times 10 \times 5}{0.1} = 10^{-4}\ N$ (Repulsive)

67. (b) According to Fleming's left hand rule, magnetic force on electrons will be downward.

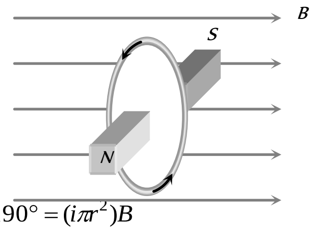


68. (a) $\sigma_i = \frac{\theta}{i} = \frac{\theta}{iG} \cdot G = \sigma_V G \Rightarrow \frac{\sigma_i}{G} = \sigma_V$

69. (a)

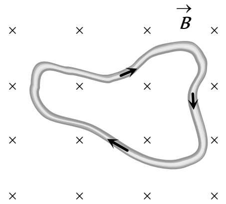
70. (a) $F = Bil \sin 30^o = 1.5 \times 10 \times 1 \times \frac{1}{2} = 7.5N$

71. (c) As shown in the following figure, the given situation is similar to a bar magnet placed in a uniform magnetic field perpendicularly. Hence torque on it



$\tau = MB\sin 90° = (i\pi r^2)B$

72. (a) As shown in figure, since $\vec{L} = 0$



Hence according to $\vec{F} = i(\vec{L} \times \vec{B}) \Rightarrow \vec{F} = 0$

73. (a) Because $\tau_{max} = BiNA \Rightarrow \tau \propto N$.

74. (d)

75. (d) $F = \frac{\mu_0}{4\pi}\frac{2i_1 i_2}{a}$

$F_1 = \frac{\mu_0}{4\pi} = \frac{2i^2}{x}$ (Attraction)

$F_2 = \frac{\mu_0}{4\pi} = \frac{2i \times 2i}{2x} = \frac{\mu_0}{4\pi}\frac{2i^2}{x}$ (Repulsion)

Thus $F_1 = -F_2$

76. (c) Magnetic field produced by wire is perpendicular to the motion of electron and it is given by

$B = \frac{\mu_0}{4\pi}\cdot\frac{2i}{a} = 10^{-7} \times \frac{2 \times 5}{0.1} = 10^{-5}\, Wb/m^2$

Hence force on electron

$F = qvB = (1.6 \times 10^{-19}) \times 5 \times 10^6 \times 10^{-5} = 8 \times 10^{-18}\, N$

77. (a) Sensitivity (S) = $\frac{\theta}{i} \Rightarrow \frac{S_A}{S_B} = \frac{i_B}{i_A} = \frac{5}{3} \Rightarrow S_A > S_B$

78. (a) $F = 10^{-7}\frac{2i_1 i_2}{a} = 10^{-7} \times \frac{2 \times 5 \times 8}{0.5} = 1.6 \times 10^{-5}$ (Attractive)

79. (b) In moving coil galvanometer $i \propto \theta$.

80. (c)

81. (b) $F \propto i_1 i_2$, so force on B due to C will be greater than that due A. Hence net force on B acts towards C.

82. (c) $F \propto \frac{i_1 i_2}{a}$; Since one of the current increase two times and distance increases three times, so force become $\frac{2}{3}$ times. Also due to the reversal of direction of current force becomes negative.

83. (c) Neon molecule is diatomic, so it's net magnetic moment is zero.

84. (b) $F = Bil \Rightarrow 1 \times 9.8 = 0.98 \times i \times 1 \Rightarrow i = 10A$

85. (a)

86. (d) $F = 10^{-7} \times \frac{2i^2}{a} \times l \Rightarrow 30 \times 10^{-7} = 10^{-7} \times \frac{2i^2}{0.15} \times 9$

$\Rightarrow i = 0.5A$

87. (c) $\tau_{max} = NiAB = 1 \times i \times (\pi r^2) \times B \quad \left(2\pi r = L, \Rightarrow r = \frac{L}{2\pi}\right)$

$\tau_{max} = \pi i\left(\frac{L}{2\pi}\right)^2 B = \frac{L^2 iB}{4\pi}$

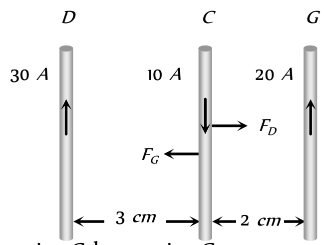
88. (b)

89. (c) $\left(\frac{F}{l}\right) = \frac{\mu_0}{4\pi}.\frac{2i_1 i_2}{a} \Rightarrow \left(\frac{F}{l}\right) = \frac{\mu_0}{4\pi}.\frac{2i^2}{d} = \frac{\mu_0 i^2}{2\pi d}$ (Attractive)

90. (c) Force on wire C due to wire D

$F_D = 10^{-7} \times \frac{2 \times 30 \times 10}{2 \times 10^{-2}} \times 25 \times 10^{-2} = 5 \times 10^{-4}\, N$

(towards right)



Force on wire C due to wire G

$F_G = 10^{-7} \times \frac{2 \times 20 \times 10}{2 \times 10^{-2}} \times 25 \times 10^{-2} = 5 \times 10^{-4}\, N$

(towards left)

$\Rightarrow$ Net force on wire C is $F_{net} = F_D - F_G = 0$

91. (d) Since $\theta = 0°$ so $\tau = 0$ ($\because \tau = NiAB\sin\theta$)

Critical Thinking Questions

1. (b) $\frac{B_{centre}}{B_{axis}} = \left(1 + \frac{x^2}{R^2}\right)^{3/2}$, also $B_{axis} = \frac{1}{8}B_{centre}$

$\Rightarrow \frac{8}{1} = \left(1 + \frac{x^2}{R^2}\right)^{3/2} \Rightarrow 2 = \left(1 + \frac{x^2}{R^2}\right)^{1/2}$

$\Rightarrow 4 = 1 + \frac{x^2}{R^2} \Rightarrow 3 = \frac{x^2}{R^2} \Rightarrow x^2 = 3R^2 \Rightarrow x = \sqrt{3}R$

2. (a) Field at the centre $B_1 = \frac{\mu_0}{4\pi} \times \frac{2\pi in}{r} = \frac{\mu_0}{2}.\frac{ni}{r}$

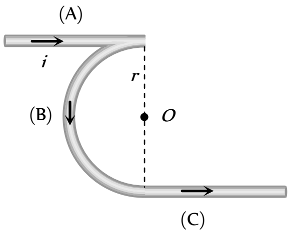
Field at a distance h from the centre

$B_2 = \frac{\mu_0}{4\pi}.\frac{2\pi nir^2}{(r^2 + h^2)^{3/2}} = \frac{\mu_0}{2}.\frac{nir^2}{r^3\left(1 + \frac{h^2}{r^2}\right)^{3/2}}$

$= B_1\left(1+\frac{h^2}{r^2}\right)^{-3/2} = B_1\left(1-\frac{3}{2}.\frac{h^2}{r^2}\right)$ (By binomial theorem)

Hence B_2 is less than B_1 by a fraction $= \frac{3}{2}\frac{h^2}{r^2}$

3. (a) ***Case* 1 :** $B_A = \frac{\mu_0}{4\pi}.\frac{i}{r}\otimes$



$B_B = \frac{\mu_0}{4\pi}.\frac{\pi i}{r}\odot$

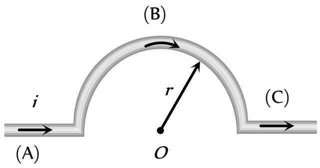
$B_C = \frac{\mu_0}{4\pi}.\frac{i}{r}\odot$

So net magnetic field at the centre of case 1

$B_1 = B_B - B_C - B_A \Rightarrow B_1 = \frac{\mu_0}{4\pi}.\frac{\pi i}{r}\odot$ ..... (i)

***Case* 2 :** As we discussed before magnetic field at the centre O in this case

$B_2 = \frac{\mu_0}{4\pi}.\frac{\pi i}{r}\otimes$ ..... (ii)

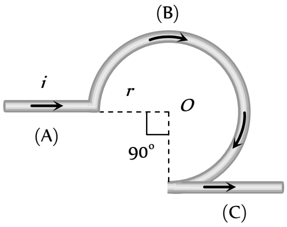


***Case 3* :** $B_A = 0$

$B_B = \frac{\mu_0}{4\pi}.\frac{(2\pi - \pi/2)i}{r}\otimes$

$B_C = \frac{\mu_0}{4\pi}.\frac{i}{r}\odot$

$= \frac{\mu_0}{4\pi}.\frac{3\pi i}{2r}\otimes$



So net magnetic field at the centre of case 3

$B_3 = \frac{\mu_0}{4\pi}.\frac{i}{r}\left(\frac{3\pi}{2}-1\right)\otimes$ ..... (iii)

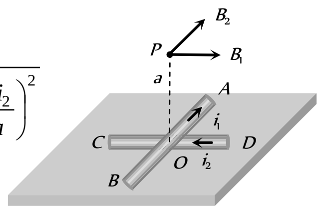
From equation (i), (ii) and (iii)

$B_1 : B_2 : B_3 = \pi\odot : \pi\otimes \left(\frac{3\pi}{2}-1\right)\otimes = -\frac{\pi}{2}:\frac{\pi}{2}:\left(\frac{3\pi}{4}-\frac{1}{2}\right)$

4. (c) At P: $B_{net} = \sqrt{B_1^2 + B_2^2}$

$= \sqrt{\left(\frac{\mu_0}{4\pi}\frac{2i_1}{a}\right)^2 + \left(\frac{\mu_0}{4\pi}\frac{2i_2}{a}\right)^2}$

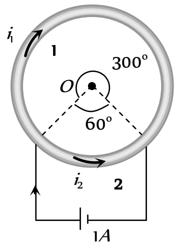
$= \frac{\mu_0}{2\pi a}(i_1^2 + i_2^2)^{1/2}$



5. (c) $B = \frac{\mu_0}{4\pi}\frac{\theta i}{r} \Rightarrow B \propto \theta i$ (but $\frac{i_1}{i_2} = \frac{l_2}{l_1} = \frac{\theta_2}{\theta_1}$)

$\Rightarrow \frac{B_1}{B_2} = \frac{\theta_1}{\theta_2}.\frac{i_1}{i_2}$

So, $\frac{B_1}{B_2} = \frac{\theta_1}{\theta_2}\times\frac{\theta_2}{\theta_1}$



$\Rightarrow B_1 = B_2$

6. (c) Magnetic field at any point lying on the current carrying straight conductor is zero.

Here H_1 = Magnetic field at M due to current in PQ.

H_2 = Magnetic field at M due to QR

+ magnetic field at M due to QS

+ magnetic field at M due to PQ

$= 0 + \frac{H_1}{2} + H_1 = \frac{3}{2}H_1 \Rightarrow \frac{H_1}{H_2} = \frac{2}{3}$

7. (c, d) $B_{net} = B_1 - B_2 \Rightarrow B_1 - B_2 = 0 \Rightarrow B_1 = B_2$

$\Rightarrow B \propto ni$. So $n_1 i_1 = n_2 i_2$ or $n_1 = n_2$ and $i_1 = i_2$

8. (c) Number of turns per unit width $= \frac{N}{b-a}$

Consider an elemental ring of radius x and with thickness dx

Number of turns in the ring $= dN = \frac{Ndx}{b-a}$

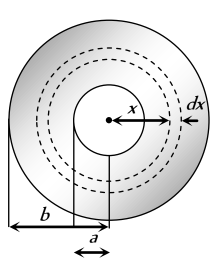
Magnetic field at the centre due to the ring element

$dB = \frac{\mu_0 (dN) i}{2x} = \frac{\mu_0 i}{2}.\frac{Ndx}{(b-a)}.\frac{1}{x}$

$\therefore$ Field at the centre

$= \int dB = \frac{\mu_0 Ni}{2(b-a)}\int_a^b \frac{dx}{x}$

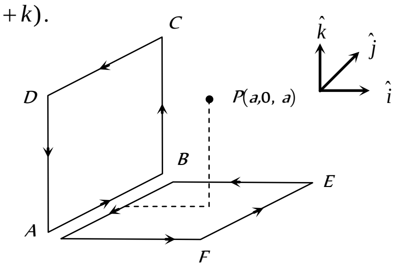
$= \frac{\mu_0 Ni}{2(b-a)}\ln\frac{b}{a}.$



9. (d) The magnetic field at $P(a, 0, a)$ due to the loop is equal to the vector sum of the magnetic fields produced by loops *ABCDA* and *AFEBA* as shown in the figure.

Magnetic field due to loop *ABCDA* will be along $\hat{i}$ and due to loop *AFEBA*, along $\hat{k}$. Magnitude of magnetic field due to both the loops will be equal.

Therefore, direction of resultant magnetic field at P will be $\frac{1}{\sqrt{2}}(\hat{i}+\hat{k})$.

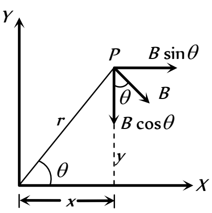


10. (a) Magnetic field at P is $\vec{B}$, perpendicular to OP in the direction shown in figure.

So, $\vec{B} = B\sin\theta\hat{i} - B\cos\theta\hat{j}$

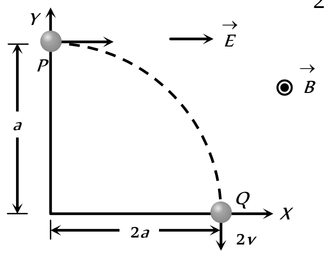
Here $B = \frac{\mu_0}{2\pi}\frac{I}{r}$

$\sin\theta = \frac{y}{r}$ and $\cos\theta = \frac{x}{r}$



$$\therefore\ \vec{B} = \frac{\mu_0 I}{2\pi}\cdot\frac{1}{r^2}(y\hat{i} - x\hat{j}) = \frac{\mu_0 I(y\hat{i} - x\hat{j})}{2\pi(x^2 + y^2)} \text{ (as } r^2 = x^2 + y^2\text{)}$$

11. (a, b, d) Kinetic energy of the particle at point $P = \frac{1}{2}mv^2$



K.E. of the particle at point $Q = \frac{1}{2}m(2v)^2$

Increase in K.E. $= \frac{3}{2}mv^2$

It comes from the work done by the electric force qE on the particle as it covers a distance $2a$ along the x-axis. Thus $\frac{3}{2}mv^2 = qE\times 2a \Rightarrow E = \frac{3}{4}\frac{mv^2}{qa}$. The rate of work done by the electric field at P $= F\times v = qE\times v = 3\frac{mv^3}{4a}$

At $Q, \vec{F_e} = q\vec{E}$ is along x-axis while velocity is along negative y-axis. Hence rate of work done by electric field $= \vec{F_e}.\vec{v} = 0$ $(\because \theta = 90^o)$ Similarly, according to equation $\vec{F_m} = q(\vec{v}\times\vec{B})$

Force $\vec{F_m}$ is also perpendicular to velocity vector $\boldsymbol{v}$.

Hence the rate of work done by the magnetic field = 0

12. (a, c) $r \propto \frac{\sqrt{m}}{q} \Rightarrow r_H : r_{He} : r_o = \frac{\sqrt{1}}{1} : \frac{\sqrt{4}}{1} : \frac{\sqrt{16}}{2} = 1:2:2$

Radius is smallest for H^+, so it is deflected most.

13. (c) As the electric field is switched on, positive ion will start to move along positive x-direction and negative ion along negative x-direction. Current associated with motion of both types of ions is along positive x-direction. According to Fleming's left hand rule force on both types of ions will be along negative y-direction.

14. (c) $\vec{v} = 2\times 10^5\hat{i}$ and $\vec{B} = (\hat{i} + 4\hat{j} - 3\hat{k})$

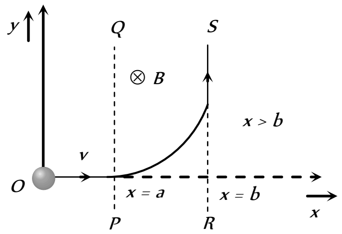
$$\vec{F} = q(\vec{v}\times\vec{B}) = -1.6\times 10^{-19}[2\times 10^5\hat{i}\times(\hat{i} + 4\hat{j} - 3\hat{k})]$$

$$= -1.6\times 10^{-19}\times 2\times 10^5[\hat{i}\times\hat{i} + 4(\hat{i}\times\hat{j}) - 3(\hat{i}\times\hat{k})]$$

$$= -3.2\times 10^{-14}[0 + 4\hat{k} + 3\hat{j}] = 3.2\times 10^{-14}(-4\hat{k} - 3\hat{k})$$

$$\Rightarrow |\vec{F}| = 3.2\times 10^{-14}\times 5 = 1.6\times 10^{-13}\,N.$$

15. (b) In the figure, the z-axis points out of the paper, and the magnetic field is directed into the paper, existing in the region between PQ and RS. The particle moves in a circular path of radius r in the magnetic field. It can just enter the region $x > b$ for $r \geq (b - a)$



Now, $r = \frac{mv}{qB} \geq (b - a)$

or $v \geq \frac{q(b-a)B}{m} \Rightarrow v_{\min} = \frac{q(b-a)B}{m}$

16. (b) Electric field can deviate the path of the particle in the shown direction only when it is along negative y-direction. In the given options $\vec{E}$ is either zero or along x-direction. Hence it is the magnetic field which is really responsible for its curved path. Options (a) and (c) can't be accepted as the path will be helix in that case (when the velocity vector makes an angle other than 0°, 180° or 90° with the magnetic field, path is a helix) option (d) is wrong because in that case component of net force on the particle also comes in k direction which is not acceptable as the particle is moving in x-y plane. Only in option (b) the particle can move in x-y plane.

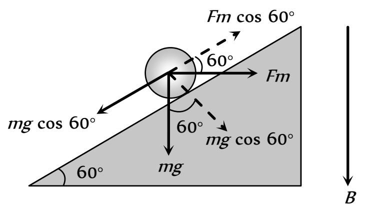
In option (d) : $\vec{F}_{net} = q\vec{E} + q(\vec{v}\times\vec{B})$

Initial velocity is along x-direction. So let $\vec{v} = v\hat{i}$

$$\therefore\ \vec{F}_{net} = qa\hat{i} + q[(v\hat{i})\times(c\hat{k} + b\hat{j}] = qa\hat{i} - qvc\hat{j} + qvb\hat{k}$$

In option (b) $\vec{F}_{net} = q(a\hat{i}) + q[(v\hat{i})\times(c\hat{k} + a\hat{i}) = qa\hat{i} - qvc\hat{j}$

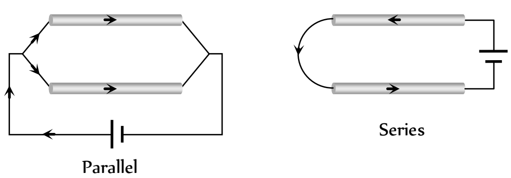
17. (c) The given situation can be drawn as follows



$$F = ilB \Rightarrow mg\sin 60^o = ilB\cos 60^o$$

$$\Rightarrow B = \frac{0.01\times 10\times\sqrt{3}}{0.1\times 1.73} = 1\,T$$

18. (a) When connected in parallel the current will be in the same direction and when connected in series the current will be in the opposite direction.



19. (b) If the radius of circle is r, then $2\pi r = L \Rightarrow r = \frac{L}{2\pi}$

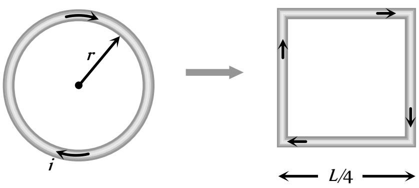
Area $= \pi r^2 = \dfrac{\pi L^2}{4\pi^2} = \dfrac{L^2}{4\pi}$

Magnetic moment $= IA = \dfrac{IL^2}{4\pi}$

20. (d) Initially for circular coil $L = 2\pi r$ and $M = i\times\pi r^2$

$= i\times\pi\left(\dfrac{L}{2\pi}\right)^2 = \dfrac{iL^2}{4\pi}$ ..... (i)

Finally for square coil $M' = i\times\left(\dfrac{L}{4}\right)^2 = \dfrac{iL^2}{16}$ ..... (ii)



Solving equation (i) and (ii) $M' = \dfrac{\pi M}{4}$

21. (c) The effective current $i = \dfrac{q\omega}{2\pi}$ and $A = \pi r^2$.

Magnetic moment $M = iA = \dfrac{1}{2}q\omega r^2$

Angular moment $L = I\omega = mr^2\omega \Rightarrow \dfrac{M}{L} = \dfrac{q}{2m}$

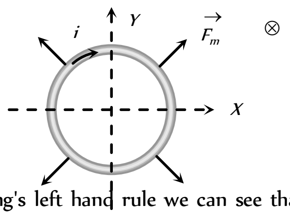
22. (b) On applying Fleming's left hand rule.

23. (b) Current carrying conductors will attract each other, while electron beams will repel each other.

24. (c) Length of the component dl which is parallel to wire (1) is $dl\cos\theta$, so force on it.

$F = \dfrac{\mu_0}{4\pi}.\dfrac{2i_1i_2}{r}(dl\cos\theta) = \dfrac{\mu_0 i_1 i_2 dl\cos\theta}{2\pi r}$

25. (b) Net force on a current carrying loop in uniform magnetic field is zero. Hence the loop can't translate. So, options (c) and (d) are wrong.



From Fleming's left hand rule we can see that if magnetic field is perpendicular to paper inwards and current in the loop is clockwise (as shown) the magnetic force $\vec{F_m}$ on each element of the loop is radially outwards, or the loops will have a tendency to expand.

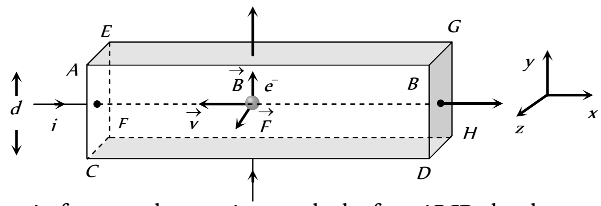
26. (c) $U = -MB\cos\theta$; where $\theta =$ Angle between normal to the plane of the coil and direction of magnetic field.

27. (a) As the block is of metal, the charge carriers are electrons, so for current along positive x-axis, the electrons are moving along negative x-axis, *i.e.* $\vec{v} = -v\hat{i}$

and as the magnetic field is along the y-axis, *i.e.* $\vec{B} = B\hat{j}$

so $\vec{F} = q(\vec{v}\times\vec{B})$ for this case yield $\vec{F} = (-e)[-v\hat{i}\times B\hat{j})]$

i.e., $\vec{F} = evB\hat{k}$ [As $\hat{i}\times\hat{j} = \hat{k}$]



As force on electrons is towards the face *ABCD,* the electrons will accumulate on it an hence it will acquire lower potential.

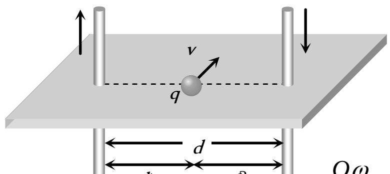
28. (a)

29. (a) $i = \dfrac{2q\omega}{2\pi} = \dfrac{q\omega}{\pi}$; $\therefore M = iA = \dfrac{q\omega}{\pi}\pi R^2 = q\omega R^2$

$L = 2R.mv = 2R.mR\omega = 2mR^2\omega$ $(\because v = R\omega)$

$\Rightarrow \dfrac{M}{L} = \dfrac{q}{2m}$

30. (d) According to gives information following figure can be drawn, which shows that direction of magnetic field is along the direction of motion of charge so net force on it is zero.

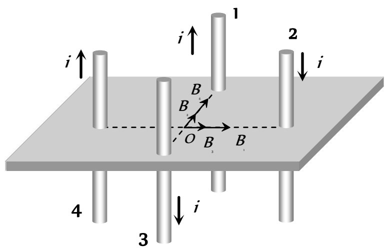


31. (b) $M = iA = i\times\pi R^2$ also $i = \dfrac{Q\omega}{2\pi} \Rightarrow M = \dfrac{1}{2}$

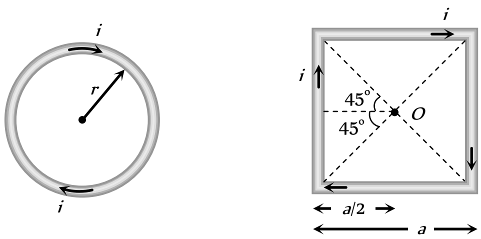
32. (c) Direction of magnetic field (B, B, B and B) at origin due to wires 1, 2, 3 and 4 are shown in the following figure.

$B_1 = B_2 = B_3 = B_4 = \dfrac{\mu_0}{4\pi}.\dfrac{2i}{x} = B$. So net magnetic field at origin O

$B_{net} = \sqrt{(B_1+B_3)^2+(B_2+B_4)^2} = \sqrt{(2B)^2+(2B)^2} = 2\sqrt{2}B$



33. (b) Circular coil Square coil



Length $L = 2\pi r$ Length $L = 4a$

Magnetic field at the centre of circular coil

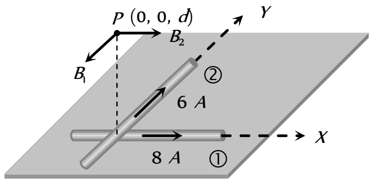
$$B_{circular} = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r} = \frac{\mu_0}{4\pi}.\frac{4\pi^2 i}{L}$$

Magnetic field at the centre of square coil

$$B_{square} = \frac{\mu_0}{4\pi}.\frac{8\sqrt{2}\,i}{a} = \frac{\mu_0}{4\pi}.\frac{32\sqrt{2}\,i}{L}$$

Hence $\frac{B_{circular}}{B_{square}} = \frac{\pi^2}{8\sqrt{2}}$

34. (d) Magnetic field at P due to wire 1, $B_1 = \frac{\mu_0}{4\pi}.\frac{2(8)}{d}$



and due to wire 2, $B_2 = \frac{\mu_0}{4\pi}.\frac{2(6)}{d}$

$$\Rightarrow B_{net} = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{\mu_0}{4\pi}.\frac{16}{d}\right)^2 + \left(\frac{\mu_0}{4\pi}.\frac{12}{d}\right)^2}$$

$$= \frac{\mu_0}{4\pi} \times \frac{2}{d} \times 10 = \frac{5\mu_0}{\pi d}$$

35. (b) According to question resistance of wire ADC is twice that of wire ABC. Hence current flows through ADC is half that of ABC *i.e.* $\frac{i_2}{i_1} = \frac{1}{2}$. Also $i_1 + i_2 = i \Rightarrow i_1 = \frac{2i}{3}$ and $i_2 = \frac{i}{3}$

Magnetic field at centre O due to wire AB and BC (part 1 and 2) $B_1 = B_2 = \frac{\mu_0}{4\pi}.\frac{2i_1 \sin 45^o}{a/2} \otimes = \frac{\mu_0}{4\pi}.\frac{2\sqrt{2}\,i_1}{a} \otimes$

and magnetic field at centre O due to wires AD and DC (*i.e.* part 3 and 4) $B_3 = B_4 = \frac{\mu_0}{4\pi}\frac{2\sqrt{2}\,i_2}{a} \odot$

Also $i_1 = 2i_2$. So $(B_1 = B_2) > (B_3 = B_4)$

Hence net magnetic field at centre O

$$B_{net} = (B_1 + B_2) - (B_3 + B_4)$$

$$= 2 \times \frac{\mu_0}{4\pi}.\frac{2\sqrt{2} \times \left(\frac{2}{3}i\right)}{a} - \frac{\mu_0}{4\pi}.\frac{2\sqrt{2}\left(\frac{i}{3}\right) \times 2}{a}$$

$$= \frac{\mu_0}{4\pi}.\frac{4\sqrt{2}\,i}{3a}(2-1)\otimes = \frac{\sqrt{2}\,\mu_0 i}{3\pi a}\otimes$$

36. (d) By using $B = \frac{\mu_0 i}{2\pi r}\left(\frac{r^2 - a^2}{b^2 - a^2}\right)$ here $r = \frac{3R}{2}$, $a = R$, $b = 2R$

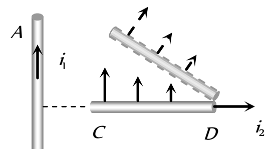
$$\Rightarrow B = \frac{\mu_0 i}{2\pi\left(\frac{3R}{2}\right)} \times \left\{\frac{\left(\frac{3R}{2}\right)^2 - R^2}{(2R^2) - R^2}\right\} = \frac{5.\mu_o i}{36\pi R}.$$

37. (a) Suppose in equilibrium wire PQ lies at a distance r above the wire AB

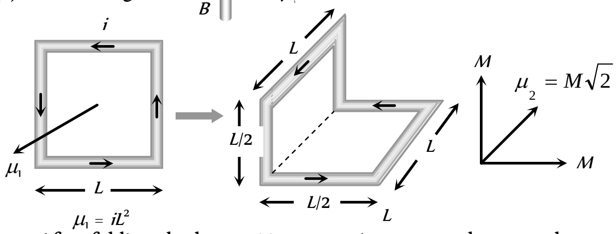
Hence in equilibrium $mg = Bil \Rightarrow mg = \frac{\mu_0}{4\pi}\left(\frac{2i}{r}\right) \times il$

$$\Rightarrow 10^{-3} \times 10 = 10^{-7} \times \frac{2 \times (50)^2}{r} \times 0.5 \Rightarrow r = 25\,mm$$

38. (c) Since the force on the rod CD is non-uniform it will experience force and torque. From the left hand side it can be seen that the force will be upward and torque is clockwise.



39. (c) Initial magnetic moment = $\mu_1 = iL^2$



After folding the loop, M = magnetic moment due to each part

$$= i\left(\frac{L}{2}\right) \times L = \frac{iL^2}{2} = \frac{\mu_1}{2}$$

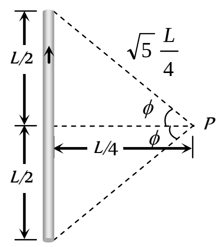
$$\Rightarrow \mu_2 = M\sqrt{2} = \frac{\mu_1}{2} \times \sqrt{2} = \frac{\mu_1}{\sqrt{2}}$$

40. (a) By using $B = \frac{\mu_0}{4\pi}.\frac{i}{a}(\sin\phi_1 + \sin\phi_2)$

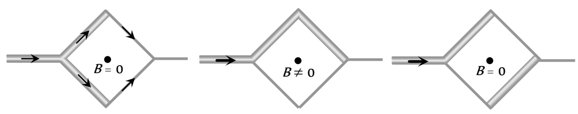
$$\Rightarrow B = \frac{\mu_0}{4\pi}.\frac{i}{(L/4)}(2\sin\phi)$$

Also $\sin\phi = \frac{L/2}{\sqrt{5}L/4} = \frac{2}{\sqrt{5}}$

$$\Rightarrow B = \frac{4\mu_0 i}{\sqrt{5}\pi L}$$



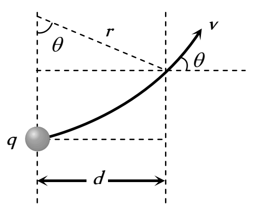
41. (d) In P and R loops, currents are divided in same proportion because the branches have equal resistance. Hence magnetic field produced at centre due to each segment is of equal magnitude but of opposite direction, so net field is zero.



42. (a) From figure it is clear that

$\sin\theta = \frac{d}{r}$ also $r = \frac{p}{qB}$

$$\therefore \sin\theta = \frac{Bqd}{p}$$

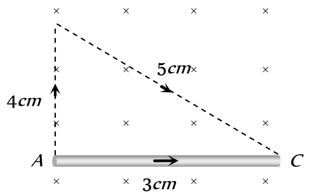


43. (a) $\vec{F}_{CAD} = \vec{F}_{CD} = \vec{F}_{CED}$

$\therefore$ Net force on frame $= 3\vec{F}_{CD} = (3)(2)(1)(4)$ ($F = ilB$)

$= 24\ N$

44. (b) The given curved wire can be treated as a straight wire as shown

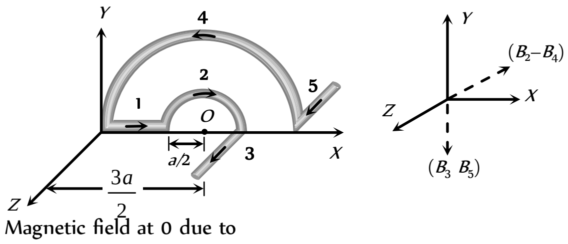


Force acting on the wire *AC*, $F = Bil = 2\times 2\times 3\times 10^{-2}$

$= 12\times 10^{-2} N$ along *y*-axis.

So acceleration of wire $= \frac{F}{m} = \frac{12\times 10^{-2}}{10\times 10^{-3}} = 12\,m/s^2$

45. (b)



Magnetic field at O due to

Part (1) : $B_1 = 0$

Part (2): $B_2 = \frac{\mu_0}{4\pi}.\frac{\pi i}{(a/2)} \otimes$ (along –*Z*-axis)

Part (3): $B_3 = \frac{\mu_0}{4\pi}.\frac{i}{(a/2)}(\downarrow)$ (along – *Y*-axis)

Part (4): $B_4 = \frac{\mu_0}{4\pi}.\frac{\pi i}{(3a/2)} \odot$ (along +*Z*-axis)

Part (5): $B_5 = \frac{\mu_0}{4\pi}.\frac{i}{(3a/2)}(\downarrow)$ (along – *Y*-axis)

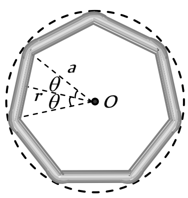
$$B_2 - B_4 = \frac{\mu_0}{4\pi}.\frac{\pi i}{a}\left(2 - \frac{2}{3}\right) = \frac{\mu_0 i}{3a} \otimes \text{ (along – Z-axis)}$$

$$B_3 + B_5 = \frac{\mu_0}{4\pi}.\frac{1}{a}\left(2 + \frac{2}{3}\right) = \frac{8\mu_0 i}{12\pi a}(\downarrow) \text{ (along – Y-axis)}$$

Hence net magnetic field

$$B_{net} = \sqrt{(B_2 - B_4)^2 + (B_3 + B_5)^2} = \frac{\mu_0 i}{3\pi a}\sqrt{\pi^2 + 4}$$

46. (b) Magnetic field at the centre due to one side



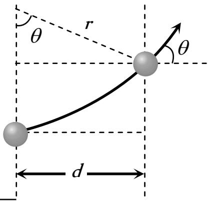
$B_1 = \frac{\mu_0}{4\pi}.\frac{2i\sin\theta}{r}$ where $r = a\cos\theta$

So $B_1 = \frac{\mu_0}{4\pi}.\frac{2i\sin\theta}{a\cos\theta} = \frac{\mu_0 i}{2\pi a}\tan\theta$

Hence net magnetic field

$$B_{net} = n\times\frac{\mu_0 i}{2\pi a}\tan\frac{\pi}{n}.$$

47. (b) According to following figure $\sin\theta = \frac{d}{r}$



also $r = \frac{\sqrt{2mk}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}}$

$\therefore \sin\theta = Bd\sqrt{\frac{q}{2mV}}$

$= 0.51\times 0.1\sqrt{\frac{1.6\times 10^{-19}}{2\times 1.67\times 10^{-27}\times 500\times 10^3}}$

$= \frac{1}{2} \Rightarrow \theta = 30^o$

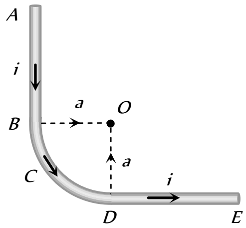
48. (b) The field at the midpoint of *BC* due to *AB* is $\left(-\frac{\mu_0}{4\pi}.\frac{i}{d/2}\hat{k}\right)$ and the same is due to *CD*. Therefore the total field is $\left[-\left(\frac{\mu_0 i}{\pi d}\right)\hat{k}\right]$

49. (a) The electron reverses it's direction. It can be done by covering semi-circular path in *x-z* or *x-y* plane.

50. (d) The field at O due to *AB* is $\frac{\mu_0}{4\pi}.\frac{i}{a}\hat{k}$ and that due to *DE* is also $\frac{\mu_0}{4\pi}.\frac{i}{a}\hat{k}$.

However the field due to *BCD* is $\frac{\mu_0}{4\pi}.\frac{i}{a}\left(\frac{\pi}{2}\right)\hat{k}$.

Thus the total field at *O* is $\frac{\mu_0}{4\pi}.\frac{i}{a}\left(2 + \frac{\pi}{2}\right)\hat{k}$



51. (d) The energy of a charged particle moving in magnetic field remains constant because the magnetic field does not do any work. Therefore kinetic energy is constant *i.e.* $u = v$.

The force on electron will act along negative *y*-axis initially. The electron will undergo circular motion in clockwise direction and emerge out the field. So $y < 0$.

Graphical Questions

1. (c) $|\vec{B}| = \frac{\mu_0}{4\pi}.\frac{2\pi i}{r} \Rightarrow |\vec{B}| \propto \frac{1}{r}$

2. (a) Every point on line *AB* will be equidistant from *X* and *Y*-axis. So magnetic field at every point on line *AB* due to wire 1 along *X*-axis is equal in magnitude but opposite in direction to the magnetic field due to wire along *Y*-axis. Hence B_{net} on $AB = 0$

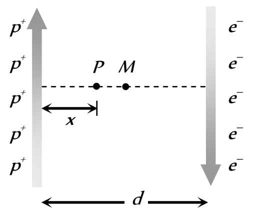
3. (b) If the current flows out of the paper, the magnetic field at points to the right of the wire will be upwards and to the left will be downward. Now magnetic field at *C*, is zero. The field in the region BX' will be upwards $(+ve)$ because all points lying in this region are to the right of both the wires. Similarly, magnetic field in the region *AX* will be downwards $(-\ ve)$. The field in the region *AC* will be upwards $(+ve)$ because points are closer to *A* compared to *B*. Similarly magnetic field in region *BC* will be downward $(-ve)$. Graph *(b)* satisfies all these conditions.

4. (a) Magnetic field inside the conductor $B_{in} \propto r$ and magnetic field outside the conductor $B_{out} \propto \frac{1}{r}$

(where *r* is the distance of observation point from axis)

5. (c) The magnetic field at points to the right of the proton beam acts perpendicular to the paper inwards (×). The magnetic field at points to the left of the electron beam acts perpendicular to the paper outwards (·).

Magnetic field at mid point *M* is zero.



Magnetic field at the points closer to proton beam acts perpendicular to the paper inwards (*i.e.* (×)) and at the points closer to electron beam it acts outwards *i.e.* (·). In the given options graph *(c)* satisfies all the conditions.

6. (a) Magnetic field inside the hollow metallic cylinder $B_{in} = 0$, and magnetic field outside it $B_{out} \propto \frac{1}{r}$

7. (a) Magnetic field in the middle of the solenoid's is maximum, magnetic field at the and $B_{end} = \frac{1}{2}B_{centre}$.

8. (b) The charge will not experience any force if $|\overrightarrow{F_e}| = |\overrightarrow{F_m}|$. This condition is satisfied in option (b) only.

9. (c) The given portion of the curved wire may be treated as a straight wire of length $2L$ which experiences a magnetic force $F_m = Bi(2L)$

10. (a) $\tau = NBiA\sin\theta$ so the graph between τ and θ is a sinusoidal graph.

11. (c) For undeviated motion $|\overrightarrow{F_e}| = |\overrightarrow{F_m}|$, which happened when $\vec{v}, \vec{E}$ and $\vec{B}$ are mutually perpendicular to each other.

12. (a) If at a place, magnetic induction is *B*, then energy density will be equal to $U = \frac{B^2}{2\mu_0}$. It means, graph between *U* and *B* will be a parabola passing through origin and symmetric about *U*-axis.

13. (b, c) Since length of the wire is equal to *l*, therefore, $2\pi Rn = l$ or $n = \frac{l}{2\pi R}$.

Magnetic induction at centre of a circular coil is given by

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi ni}{R} = \frac{\mu_0 l i}{4\pi R^2} \Rightarrow B \propto \frac{1}{R^2}$$

It means, when $R \to 0, B \to \infty$ and $R \to \infty, B \to 0$,

Hence (b) is correct and (d) is wrong.

Substituting $R = \frac{l}{2\pi n}$ in $B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi ni}{R}$

$B \propto n^2$. It means graph between *B* and *n* will be a parabola having increasing slope and passing through origin. Hence (c) is correct and (a) is wrong.

14. (b) When a current flows through cylindrical shell, then according to Ampere circuital law, magnetic induction inside it will be equal to zero. Hence energy density at $r < R$ is equal to zero.

Therefore, (a), (c) and (d) are wrong.

When $r > R$, $B = \frac{\mu_0 i}{2\pi r}$.

Since $U = \frac{B^2}{2\mu_0}$, therefore, outside the shell, $U = \frac{\mu_0 i^2}{8\pi^2 r^2}$. It means, just outside the shell, $U = \frac{\mu_0 i^2}{8\pi^2 R^2}$ and when $r \to \infty, U \to 0$.

Hence (b) is correct.

15. (b) Energy density in previous objective, at $r = 2R$, will be equal to $U = \frac{\mu_0 i^2}{32\pi^2 R^2}$ or $U \propto i^2$. It means, graph-between *U* and *i* will be a parabola, passing through origin, symmetric about *U*-axis and having increasing slope. Hence (b) is correct.

16. (b) Direction of magnetic field at every point on axis of a current carrying coil remains same though magnitude varies. Hence magnetic induction for whole the *x*-axis will remain positive.

Therefore, (c) and (d) are wrong.

Magnitude of magnetic field will very with *x* according to law,

$$B = \frac{\mu_0 NIR^2}{2(R^2 + x^2)^{3/2}}.$$

Hence, at $x = 0, B = \frac{\mu_0 NI}{2R}$ and when $x \to \infty, B \to 0$.

Slope of the graph will be $\frac{dB}{dx} = -\frac{3\mu_0 NIR^2.x}{2(R^2+x^2)^{5/2}}$.

It means, at $x = 0$, slope is equal to zero or tangent to the graph at $x = 0$, must be parallel to x-axis.

Hence (b) is correct and (a) is wrong.

Assertion and Reason

1. (a) Cyclotron is suitable for accelerating heavy particles like protons, α-particles *etc*, and not for electrons because of low mass. Because electrons acquire very high velocities very near to velocity of light and appreciable variation in their mass, occurs.

2. (c) Cyclotron is utilised to accelerate the positive ion. And cyclotron frequency is given by $\nu = \frac{Be}{2\pi m}$. It means cyclotron frequency doesn't depends upon velocity. Therefore, assertion is true and reason false.

3. (a) A moving charge experiences a force in magnetic field. It is because of interaction of two magnetic fields, one which is produced due to the motion of charge and other in which charge is moving.

4. (e) In this case we can not be sure about the absence of the magnetic field because if the electron moving parallel to the direction of magnetic field, the angle between velocity and applied magnetic field is zero ($F = 0$). Then also electron passes without deflection. Also $F = evB\sin\theta \Rightarrow F \propto B$.

5. (a) In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecules in a gas. Their average velocity is zero. *i.e.* they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

6. (c) Time taken is independent of velocity and radius of path. However, maximum velocity will be given by $v_{max} = \frac{qBR}{m}$ where R is radius of Dee's.

7. (a) Due to metallic frame the deflection is only due to current in a coil and magnetic field, not due to vibration in the strings. If string start oscillating, presence of metallic frame in the field make these oscillations damped.

8. (c) The direction of magnetic field due to current carrying conductor can be found by applying right hand thumb rule or right hand palm rule. When electric current is passed through a circular conductor, the magnetic field lines near the center of the conductor are almost straight lines. Magnetic flux direction is determined only by the direction of current.

9. (a) The force on a charged particle moving in a uniform magnetic field always acts in direction perpendicular to the direction of motion of the charge. As work done by magnetic field on the charge is zero, [$W = FS\cos\theta$], so the energy of the charged particle does not change.

10. (b) We know that the direction of the earth's magnetic field is toward north and the velocity of electron is vertically downward. Applying Fleming's left hand rule, the direction of force is towards west. Therefore, an electron coming from outer space will be deflected toward west.

11. (d) In the case of metallic rod, the charge carriers flow through whole of the cross section. Therefore, the magnetic field exists both inside as well as outside. However magnetic field inside the rod will go on decreasing as we go towards the axis.

12. (e) The force experienced by a charge particle in a magnetic field is given by, $\vec{F} = q(\vec{v} \times \vec{B})$

which is independent of mass. As q, v and B are same for both the electron and proton, hence both will experience same force.

13. (b) The torque on the coil in a magnetic field is given by $\tau = nIBA\cos\theta$

For radial field, the coil is set with its plane parallel to the direction of the magnetic field B, then $\theta = 0°$ and $\cos\theta = 1 \Rightarrow$ Torque $= nIBA\,(1) = nIBA$ (maximum).

14. (b) The winding of helix carry currents in the same direction therefore they experience an attractive force pulling the lower end out of mercury. As a result of this, the circuit breaks, current becomes zero and hence the force of attraction vanishes. Therefore helix comes back to its final position, completing the circuit again. In this way, the process is repeated and helix executes oscillatory motion.

15. (b) For a solenoid $B_{end} = \frac{1}{2}(B_{in})$. Also for a long solenoid, magnetic field is uniform within it but this reason is not explaining the assertion.

16. (d) When a charged particle is moving on a circular path in a magnetic field, the magnitude of velocity does not change but direction of velocity is changing every moment. Hence velocity is changing, so momentum $(m\vec{v})$ is also changing.

17. (b) Time period, $T = \frac{2\pi m}{Bq}$ as $\left(\frac{m}{q}\right)_\alpha = 2\left(\frac{m}{q}\right)_p \Rightarrow T_\alpha = 2T_p$

Also $T \propto m$, but then $T_\alpha = 4T_p$ which is not the case.

18. (d) When two long parallel wires, are connected to a battery in series. They carry currents in opposite directions, hence they repel each other.

19. (a) Here, both Assertion and Reason are correct and reason is the correct explanation of assertion.

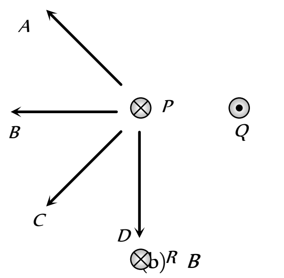
Magnetic Effect of Current — SET Self Evaluation Test - 21

1. In the hydrogen atom, the electron is making 6.6×10^{15} $r.p.s.$ If the radius of the orbit is 0.53×10^{-10} $metre$, then magnetic field produced at the centre of the orbit is
(a) 140 *Tesla* (b) 12.5 *Tesla*
(c) 1.4 *Tesla* (d) 0.14 *Tesla*

2. A coil carrying a heavy current and having large number of turns mounted in a *N-S* vertical plane and a current flows in clockwise direction. A small magnetic needle at its cente will have its north pole in
(a) East-north direction (b) West-north direction
(c) East-south direction (d) West-south direction

3. A charged particle is projected in a plane perpendicular to a uniform magnetic field. The area bounded by the path described by the particle is proportional to
(a) The velocity (b) The momentum
(c) The kinetic energy (d) None of these

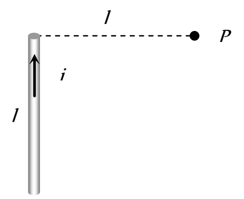
4. In figure shows three long straight wires *P, Q* and *R* carrying currents normal to the plane of the paper. All three currents have the same magnitude. Which arrow best shows the direction of the resultant force on the wire *P*



(a) *A* (b) *B*
(c) *C* (d) *D*

5. A moving coil galvanometer has 48 turns and area of coil is $4\times10^{-2}m^2$. If the magnetic field is 0.2 *T*, then to increase the current sensitivity by 25% without changing area (A) and field (B) the number of turns should become
(a) 24 (b) 36
(c) 60 (d) 54

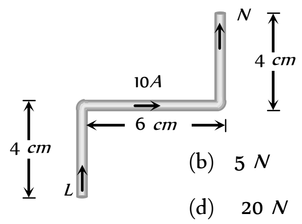
6. Figure shows a straight wire of length *l* current *i*. The magnitude of magnetic field produced by the current at point *P* is



(a) $\frac{\sqrt{2}\mu_0 i}{\pi l}$
(b) $\frac{\mu_0 i}{4\pi l}$
(c) $\frac{\sqrt{2}\mu_0 i}{8\pi l}$
(d) $\frac{\mu_0 i}{2\sqrt{2}\pi l}$

7. A winding wire which is used to frame a solenoid can bear a maximum 10 *A* current. If length of solenoid is 80*cm* and it's cross sectional radius is 3 *cm* then required length of winding wire is $(B=0.2\,T)$
(a) $1.2\times10^2\,m$ (b) $4.8\times10^2\,m$
(c) $2.4\times10^3\,m$ (d) $6\times10^3\,m$

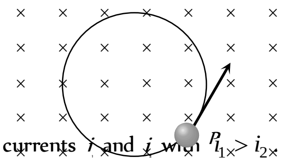
8. A current carrying wire *LN* is bent in the from shown below. If wire carries a current of 10 *A* and it is placed in a magnetic field of 5 *T* which acts perpendicular to the paper outwards then it will experience a force



(a) Zero (b) 5 *N*
(c) 30 *N* (d) 20 *N*

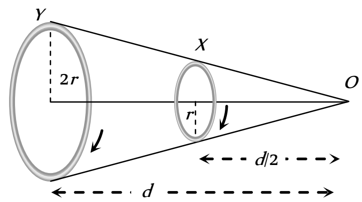
9. A wire of length *L* is bent in the form of a circular coil and current *i* is passed through it. If this coil is placed in a magnetic field then the torque acting on the coil will be maximum when the number of turns is
(a) As large as possible (b) Any number
(c) 2 (d) 1

10. A particle having a charge of $10.0\mu C$ and mass $1\mu g$ moves in a circle of radius 10 cm under the influence of a magnetic field of induction $0.1T$. When the particle is at a point P, a uniform electric field is switched on so that the particle starts moving along the tangent with a uniform velocity. The electric field is
(a) 0.1 *V/m*
(b) 1.0 *V/m*
(c) 10.0 *V/m*
(d) 100 *V/m*



11. Two parallel long wires carry currents i_1 and i_2 with $i_1 > i_2$. When the currents are in the same direction, the magnetic field midway between the wires is 10 μT. When the direction of i_2 is reversed, it becomes 40 μT. the ratio i_1/i_2 is
(a) 3 : 4 (b) 11 : 7
(c) 7 : 11 (d) 5 : 3

12. Two circular coils *X* and *Y*, having equal number of turns, carry equal currents in the same sense and subtend same solid angle at point *O*. If the smaller coil, *X* is midway between *O* and *Y*, then if we represent the magnetic induction due to bigger coil *Y* at *O* as B_Y and that due to smaller coil *X* at *O* as B_X, then
(a) $\frac{B_Y}{B_X}=1$
(b) $\frac{B_Y}{B_X}=2$
(c) $\frac{B_Y}{B_X}=\frac{1}{2}$



(d) $\frac{B_Y}{B_X} = \frac{1}{4}$

13. A fixed horizontal wire carries a current of 200 *A*. Another wire having a mass per unit length $10^{-2} kg/m$ is placed below the first wire at a distance of 2 *cm* and parallel to it. How much current must be passed through the second wire if it floats in air without any support? What should be the direction of current in it

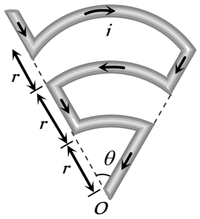
(a) 25A (direction of current is same to first wire)

(b) 25A (direction of current is opposite to first wire)

(c) 49 A (direction of current is same to first wire)

(d) 49 A (direction of current is opposite to first wire)

14. Find magnetic field at *O*



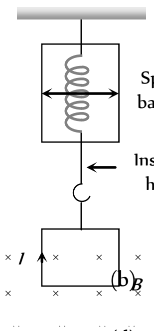
(a) $\frac{5\mu_0 i\theta}{24\pi r}$

(b) $\frac{\mu_0 i\theta}{24\pi r}$

(c) $\frac{11\mu_0 i\theta}{24\pi r}$

(d) Zero

15. A square loop of side a hangs from an insulating hanger of spring balance. The magnetic field of strength *B* occurs only at the lower edge. It carries a current *I*. Find the change in the reading of the spring balance if the direction of current is reversed



(a) *IaB*

(b) 2 *IaB*

(c) $\frac{IaB}{2}$

(d) $\frac{3}{2} IaB$

16. A charge of $2.0\,\mu C$ moves with a speed of $3.0 \times 10^6 ms^{-1}$ along + *ve X*-axis A magnetic field of strength $\vec{B} = -0.2\,\hat{k}$ *Tesla* exists in space. What is the magnetic force $(\vec{F}_m)$ on the charge

(a) $F_m = 1.2\,N$ along + $ve\ x-$ direction

(b) $F_m = 1.2\,N$ along – $ve\ x-$ direction

(c) $F_m = 1.2\,N$ along + $ve\ y-$ direction

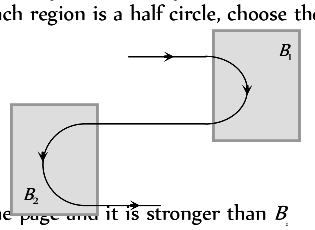
(d) $F_m = 1.2\,N$ along – $ve\ y-$ direction

17. Five very long, straight wires are bound together to form a small cable. Currents carried by the wires are $I_1 = 20A$, $I_2 = -6A$, $I_3 = 12A, I_4 = -7A, I_5 = 18A$. The magnetic induction at a distance of 10 *cm* from the cable is

(a) 34 μT (b) 74 mT

(c) 34 mT (d) 74 μT

18. Following figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitudes B_1 and B_2. It's path in each region is a half circle, choose the correct option



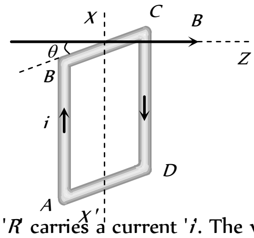
(a) B_1 is into the page and it is stronger than B_2

(b) B_1 is in to the page and it is weaker than B_2

(c) B_1 is out of the page and it is weaker than B_2

(d) B_1 is out of the page and it is stronger than B_2

19. The square loop *ABCD*, carrying a current *i*, is placed in uniform magnetic field *B*, as shown. The loop can rotate about the axis *XX'*. The plane of the loop makes and angle θ (θ < 90°) with the direction of *B*. Through what angle will the loop rotate by itself before the torque on it becomes zero



(a) θ

(b) 90°– θ

(c) 90° + θ

(d) 180°– θ

20. A cylindrical conductor of radius '*R*' carries a current '*i*'. The value of magnetic field at a point which is *R*/4 distance inside from the surface is 10 *T*. Find the value of magnetic field at point which is 4*R* distance outside from the surface

(a) $\frac{4}{3}T$ (b) $\frac{8}{3}T$

(c) $\frac{40}{3}T$ (d) $\frac{80}{3}T$

21. Three long straight wires are connected parallel to each other across a battery of negligible internal resistance. The ratio of their resistances are 3 : 4 : 5. What is the ratio of distances of middle wire from the others if the net force experienced by it is zero

(a) 4 : 3 (b) 3 : 1

(c) 5 : 3 (d) 2 : 3

Answers and Solutions

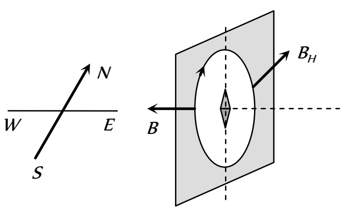
(SET -21)

1. (b) $i = qv$

$$B = \frac{\mu_0 i}{2r} = \frac{\mu_0 q v}{2r} = \frac{4\pi \times 10^{-7} \times 1.6 \times 10^{-19} \times 6.6 \times 10^{15}}{2 \times 0.53 \times 10^{-10}}$$

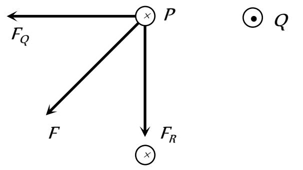
$$= \frac{2\pi \times 1.6 \times 6.6}{5.3} = 12.518 \ \textit{Tesla}$$

2. (b)



3. (c) $r = \frac{\sqrt{2mK}}{qB}$ and $A = \pi r^2 \Rightarrow A = \frac{\pi(2mK)}{q^2B^2} \Rightarrow A \propto K.$

4. (c) The forces F_Q and F_R are the forces applies by wires Q and R respectively on the wire P as shown in figure. Their resultant force F is best shown by C.

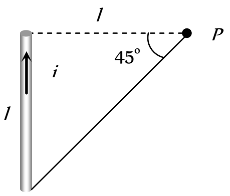


5. (c) As we know

Current sensitivity $S_i = \frac{NBA}{C}$

$\Rightarrow S_i \propto N \Rightarrow \frac{(S_i)_1}{(S_i)_2} = \frac{N_1}{N_2} \Rightarrow \frac{100}{125} = \frac{48}{N_2} \Rightarrow N_2 = 60.$

6. (c) The given situation can be redrawn as follow.



As we know the general formula for finding the magnetic field due to a finite length wire

$$B = \frac{\mu_0}{4\pi}.\frac{i}{r}(\sin\phi_1 + \sin\phi_2)$$

Here $\phi_1 = 0^o, \phi = 45^o$

$$\therefore B = \frac{\mu_0}{4\pi}.\frac{i}{r}(\sin 0^o + \sin 45^o) = \frac{\mu_0}{4\pi}.\frac{i}{\sqrt{2}l} \Rightarrow B = \frac{\sqrt{2}\mu_0 i}{8\pi l}$$

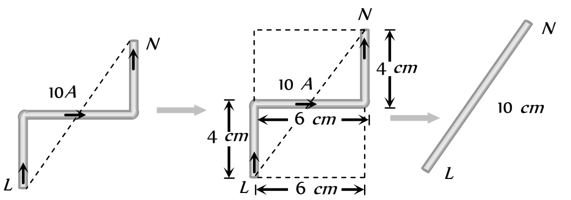
7. (c) $B = \frac{\mu_0 Ni}{l}$ where N = Total number of turns, l = length of the solenoid

$$\Rightarrow 0.2 = \frac{4\pi \times 10^{-7} \times N \times 10}{0.8} \Rightarrow N = \frac{4 \times 10^4}{\pi}$$

Since N turns are made from the winding wire so length of the wire $(L) = 2\pi r \times N$ [$2\pi r$ = length of each turns]

$$\Rightarrow L = 2\pi \times 3 \times 10^{-2} \times \frac{4 \times 10^4}{\pi} = 2.4 \times 10^3 m$$

8. (b) The given wire can be replaced by a straight wire as shown below



Hence force experienced by the wire

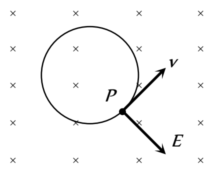
$F = Bil = 5 \times 10 \times 0.1 = 5N$

9. (d) $\tau_{max} = MB$ or $\tau_{max} = ni\pi r^2 B$. Let number of turns in length l is n so $l = n(2\pi r)$ or $\alpha = \frac{l}{2\pi n}$

$$\Rightarrow \tau_{max} = \frac{ni\pi Bl^2}{4\pi^2 n^2} = \frac{l^2 iB}{4\pi n_{min}} \Rightarrow \tau_{max} \propto \frac{1}{n_{min}} \Rightarrow n_{min} = 1$$

10. (c) When the particle moves along a circle in the magnetic field B, the magnetic force is radially inward. If an electric field of proper magnitude is switched on which is directed radially outwards, the particle may experience no force. It will then move along a straight line with uniform velocity. This will be the case when $qE = qvB \Rightarrow E = vB$

also $r = \frac{mv}{qB} \Rightarrow v = \frac{qBr}{m}$

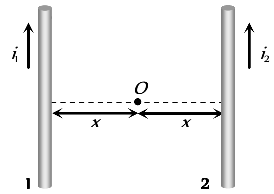


So $E = \frac{qB^2 r}{m}$

$$= \frac{(10 \times 10^{-6}) \times (0.1)^2 \times 10 \times 10^{-2}}{1 \times 10^{-3} \times 10^{-6}} = 10\ V/m$$

11. (d) Initially when wires carry currents in the same direction as shown.

Magnetic field at mid point O due to wires 1 and 2 are respectively



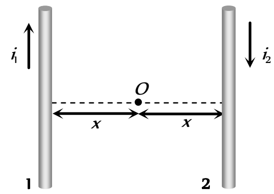
$B_1 = \frac{\mu_0}{4\pi}.\frac{2i_1}{x} \otimes$

and $B_2 = \frac{\mu_0}{4\pi}.\frac{2i_2}{x} \odot$

Hence net magnetic field at O $B_{net} = \frac{\mu_0}{4\pi} \times \frac{2}{x} \times (i_1 - i_2)$

$\Rightarrow 10 \times 10^{-6} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 - i_2)$ ..... (i)

If the direction of i_2 is reversed then



$B_1 = \frac{\mu_0}{4\pi}.\frac{2i_1}{x} \otimes$

and $B_2 = \frac{\mu_0}{4\pi}.\frac{2i_2}{x} \otimes$

So $B_{net} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 + i_2)$

$\Rightarrow 40 \times 10^{-6} = \frac{\mu_0}{4\pi}.\frac{2}{x}(i_1 + i_2)$ ..... (ii)

Dividing equation (ii) by (i) $\frac{i_1 + i_2}{i_1 - i_2} = \frac{4}{1} \Rightarrow \frac{i_1}{i_2} = \frac{5}{3}$

12. (c) Magnetic field at O due to bigger coil Y, is

$$B_Y = \frac{\mu_0}{4\pi}.\frac{2\pi i(2r)^2}{\{d^2 + (2r)^2\}^{3/2}} = \frac{\mu_0}{4\pi}.\frac{8\pi i r^2}{(d^2 + 4r^2)^{3/2}}$$

Magnetic field at O due to smaller coil X is

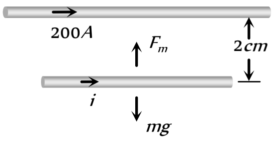
$$B_X = \frac{\mu_0}{4\pi}.\frac{2\pi i r^2}{\left\{\left(\frac{d}{2}\right)^2 + r^2\right\}^{3/2}} = \frac{\mu_0}{4\pi}.\frac{16\pi i r^2}{(d^2 + 4r^2)^{3/2}}$$

$\Rightarrow \frac{B_Y}{B_X} = \frac{1}{2}$

13. (c) For floating the second wire

$$\left|\begin{matrix}\text{Down ward weight} \\ \text{of second wire}\end{matrix}\right| = \left|\begin{matrix}\text{Magnetic force} \\ \text{on it}\end{matrix}\right|$$

$\Rightarrow mg = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a} \times l$



$\Rightarrow \left(\frac{m}{l}\right) g = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{a}$

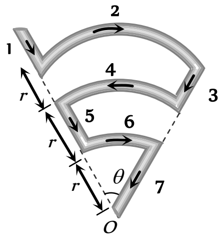
$\Rightarrow 10^{-2} \times 9.8 = 10^{-7} \times \frac{2 \times 200 \times i}{2 \times 10^{-2}} \Rightarrow i = 49A$

(Direction of current is same to first wire)

14. (a) $B_1 = B_3 = B_5 = 0$

$B_2 = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{3r} \otimes, \; B_4 = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{2r} \odot$

and $B_6 = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{r} \otimes$



$\therefore$ Net magnetic field at O,

$B_{net} = B_2 - B_4 + B_6 = \frac{\mu_0}{4\pi} \cdot \frac{\theta i}{r}\left(\frac{1}{3} - \frac{1}{2} + 1\right) = \frac{5\mu_0 \theta i}{24\pi r}$

***

15. (b) Initially $F_1 = mg + IaB$ (down wards)

when the direction of current is reversed

$F_2 = mg - IaB$ (down wards) $\Rightarrow \Delta F = 2IaB$

16. (c) By using $\vec{F}_m = q(\vec{v} \times \vec{B})$

$\Rightarrow \vec{F}_m = 2 \times 10^{-6}\{3 \times 10^6 \hat{i} \times (-0.2)\hat{k}\} = -1.2(\hat{i} \times \hat{k}) = +1.2\hat{j}$

i.e., 1.2 N in positive y direction.

17. (d) $i_{net} = 20 - 6 + 12 - 7 + 18 = 37A$ so $B = \frac{\mu_0}{4\pi} \cdot \frac{2i}{a}$

$= 10^{-7} \times \frac{2 \times 37}{10 \times 10^{-2}} = 74 \times 10^{-6} T = 74 \mu T$

18. (a) Direction of field can be find using Fleming left hand rule and $r \propto \frac{1}{B}$.

19. (c) In the position shown, AB is outside and CD is inside the plane of the paper. The Ampere force on AB acts into the paper. The torque on the loop will be clockwise, as seen from above. The loop must rotate through an angle $(90^o + \theta)$ before the plane of the loop becomes normal to the direction of the direction of B and the torque becomes zero.

20. (b) Magnetic field inside the cylindrical conductor

$B_{in} = \frac{\mu_0}{4\pi} \cdot \frac{2ir}{R^2}$ (R=Radius of cylinder, r = distance of observation point from axis of cylinder)

Magnetic field out side the cylinder at a distance r' from it's axis $B_{out} = \frac{\mu_0}{4\pi} \cdot \frac{2i}{r'}$

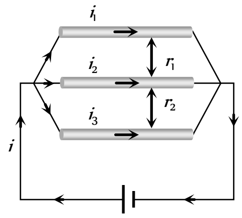
$\Rightarrow \frac{B_{in}}{B_{out}} = \frac{rr'}{R^2} \Rightarrow \frac{10}{B_{out}} = \frac{\left(R - \frac{R}{4}\right)(R + 4R)}{R^2} \Rightarrow B_{out} = \frac{8}{3} T$

21. (c) The wires are in parallel and ratio of their resistances are 3 : 4 : 5, Hence currents in wires are in the ratio $\frac{1}{3} : \frac{1}{4} : \frac{1}{5}$

$i_1 = \frac{k}{3}$

$i_2 = \frac{k}{4}$

$i_3 = \frac{k}{5}$



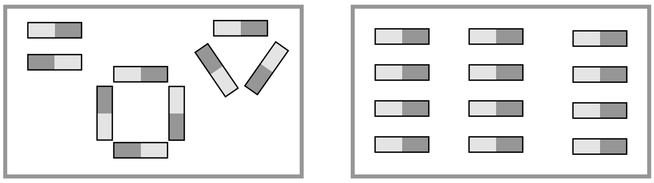
Force between top and middle wire $F_1 = \frac{\mu_0}{4\pi} \cdot \frac{2i_1 i_2}{r_1}$

$= \frac{\mu_0}{4\pi} \times \frac{2\left(\frac{1}{3}\right)\left(\frac{1}{4}\right)k^2}{r_1}$. Force between bottom and middle wire $F_2 = \frac{\mu_0}{4\pi} \frac{\left(\frac{1}{4}\right)\left(\frac{1}{5}\right)k^2}{r_2}$. As the forces are equal and opposite so $F_1 = F_2 \Rightarrow \frac{r_1}{r_2} = \frac{5}{3}$.

Chapter 22
Magnetism

The molecular theory of magnetism was given by Weber and modified later by Ewing. According to this theory.

Every molecule of a substance is a complete magnet in itself. However, in an **magnetic** substance the molecular magnets are randomly oriented to give net zero magnetic moment. On magnetising, the molecular magnets are realigned in a specific direction leading to a net magnetic moment.

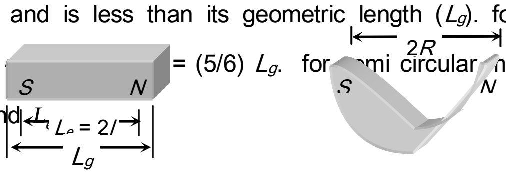


(A) Unmagnetised **(B)** Magnetised

Fig. 22.1

Bar Magnet

A bar magnet consist of two equal and opposite magnetic pole separated by a small distance. Poles are not exactly at the ends. The shortest distance between two poles is called effective length (L_e) and is less than its geometric length (L_g). for bar magnet L_e = (5/6) L_g. for semi circular magnet $L_g = \pi R$ and $L_e = 2R$



(A) Bar magnet **(B)** Semicircular magnet

Fig. 22.2

(1) **Directive properties** : When a magnet suspended freely it stays in the earth's *N-S* direction (in magnetic meridian).

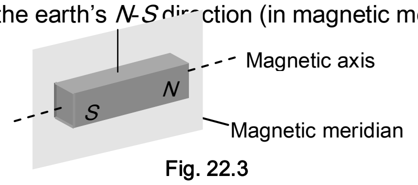


Fig. 22.3

(2) **Monopole concept** : If a magnet is Broken into number of pieces, each piece becomes a magnet. This in turn implies that monopoles do not exist. (*i.e.*, ultimate individual unit of magnetism in any magnet is called dipole).

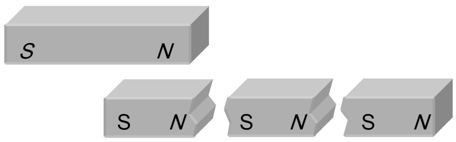


Fig. 22.4

(3) For two rods as shown, if both the rods attract in figure (A) and doesn't attract in figure (B) then, *Q* is a magnetic and *P* is simple iron rod. Repulsion is sure test of magnetism.

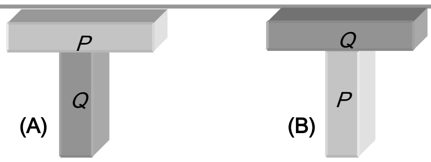


Fig. 22.5

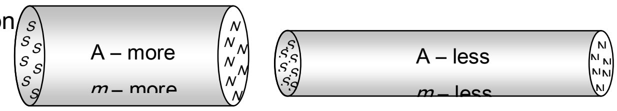
(4) **Pole strength (m) :** The strength of a magnetic pole to attract magnetic materials towards itself is known as pole strength.

(i) It is a scalar quantity.

(ii) Pole strength of N and S pole of a magnet is conventionally represented by $+m$ and $-m$ respectively.

(iii) It's SI unit is *amp* × *m* or *N*/*Tesla* and dimensions are [LA].

(iv) Pole strength of the magnet depends on the nature of material of magnet and area of cross section. It doesn't depends upon



(A) (B)

Fig. 22.6

(5) **Magnetic moment or magnetic dipole moment ($\vec{M}$) :** It represents the strength of magnet. Mathematically it is defined as the product of the strength of either pole and effective length. *i.e.* $\vec{M} = m(2\vec{l})$

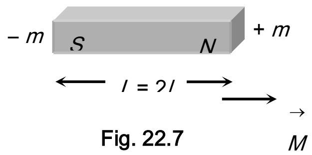


Fig. 22.7

(i) It is a vector quantity directed from south to north.

(ii) It's S.I. unit *amp*×*m*^{2} or *N*-*m* / *Tesla* and dimensions [AL^2]

(6) **Cutting of a rectangular bar magnet :** Suppose we have a rectangular bar magnet having length, breadth and mass are L, b and w respectively if it is cut in n equal parts along the length as well as perpendicular to the length simultaneously as shown in the figure then

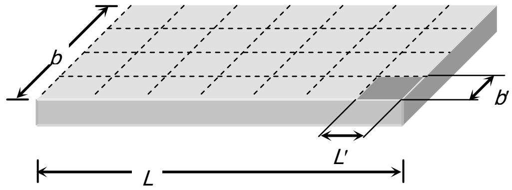


Fig. 22.8

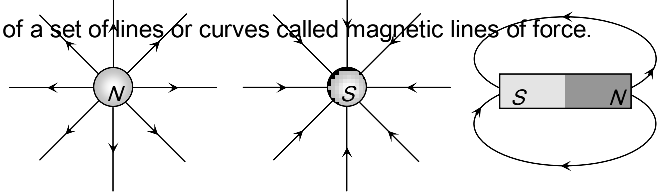
Length of each part $L' = \frac{L}{\sqrt{n}}$, breadth of each part $b' = \frac{b}{\sqrt{n}}$, Mass of each part $w' = \frac{w}{n}$, pole strength of each part $m' = \frac{m}{\sqrt{n}}$, Magnetic moment of each part $M' = m'L' = \frac{m}{\sqrt{n}} \times \frac{L}{\sqrt{n}} = \frac{M}{n}$

If initially moment of inertia of bar magnet about the axes passing from centre and perpendicular to it's length is $I = w\left(\frac{L^2+b^2}{12}\right)$ then moment of inertia of each part $I' = \frac{I}{n^2}$

(7) **Cutting of a thin bar magnet :** For thin magnet $b = 0$ so $L' = \frac{L}{n}$, $w' = \frac{w}{n}$, $m' = \frac{m}{n}$, $I' = \frac{I}{n^3}$

Various Terms Related to Magnetism

(1) **Magnetic field and magnetic lines of force :** Space around a magnetic pole or magnet or current carrying wire within which it's effect can be experienced is defined as magnetic field. Magnetic field can be represented with the help of a set of lines or curves called magnetic lines of force.



(A) Isolated north pole (B) Isolated south pole (C) Magnetic dipole

Fig. 22.9

(2) **Magnetic flux (ϕ) and flux density (B)**

(i) The number of magnetic lines of force passing normally through a surface is defined as magnetic flux (ϕ). It's S.I. unit is *weber* (*wb*) and CGS unit is *Maxwell*.

Remeber 1 *wb* = 10^8 *Maxwell*.

(ii) When a piece of a magnetic substance is placed in an external magnetic field the substance becomes magnetised. The number of magnetic lines of induction inside a magnetised substance crossing unit area normal to their direction is called magnetic induction or magnetic flux density ($\vec{B}$). It is a vector quantity.

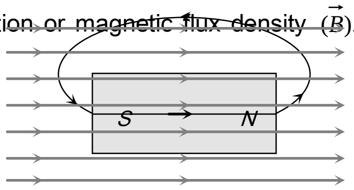


Fig. 22.10

It's SI unit is *Tesla* which is equal to $\frac{wb}{m^2}=\frac{N}{amp\times m}=\frac{J}{amp\times m^2}=\frac{volt\times\sec}{m^2}$

and CGS unit is *Gauss*. Remember 1 *Tesla* = 10^4 *Gauss*.

(3) **Magnetic permeability :** It is the degree or extent to which magnetic lines of force can enter a substance and is denoted by μ. Or characteristic of a medium which allows magnetic flux to pass through it is called it's permeability. *e.g.* permeability of soft iron is 1000 times greater than that of air.

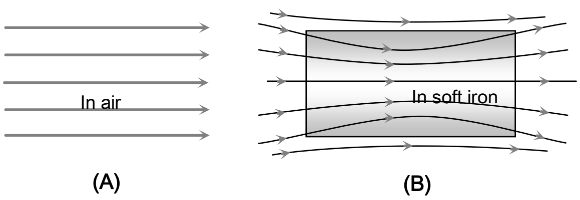


Fig. 22.11

Also μ = $\mu_0\ \mu_r$; where μ_0 = absolute permeability of air or free space = $4\pi\times10^{-7}\ tesla\times m/amp.$

and μ_r = Relative permeability of the medium = $\frac{B}{B_0}=\frac{\text{flux density in material}}{\text{flux density in vacuum}}$.

(4) **Intensity of magnetising field ($\vec{H}$) (magnetising field) :** It is the degree or extent to which a magnetic field can magnetise a substance. Also $H=\frac{B}{\mu}$.

It's SI unit is

$A/m.=\frac{N}{m^2\times Tesla}=\frac{N}{wb}=\frac{J}{m^3\times Tesla}=\frac{J}{m\times wb}$ It's CGS unit is *Oersted*. Also 1 *Oersted* = 80 *A*/*m*

(5) **Intensity of magnetisation (*I*) :** It is the degree to which a substance is magnetised when placed in a magnetic field.

It can also be defined as the pole strength per unit cross sectional area of the substance or the induced dipole moment per unit volume.

Hence *I* = $\frac{m}{A}=\frac{M}{V}$. It is a vector quantity, it's S.I. unit is *Amp*/*m*.

(6) **Magnetic susceptibility (χ_m) :** It is the property of the substance which shows how easily a substance can be magnetised. It can also be defined as the ratio of intensity of magnetisation (*I*) in a substance to the magnetic intensity (*H*) applied to the substance, *i.e.* $\chi_m=\frac{I}{H}$. It is a scalar quantity with no units and dimensions.

(7) **Relation between permeability and susceptibility :** Total magnetic flux density *B* in a material is the sum of magnetic flux density in vacuum B_0 produced by magnetising force and magnetic flux density due to magnetisation of material B_m. *i.e.* $B=B_0+B_m \Rightarrow B=\mu_0H+\mu_0I=\mu_0(H+I)=\mu_0H(1+\chi_m)$. Also $\mu_r=(1+\chi_m)$

Force and Field

(1) **Coulombs law in magnetism** : The force between two magnetic poles of strength m_1 and m_2 lying at a distance r is

given by $F = k.\frac{m_1 m_2}{r^2}$. In S.I. units $k = \frac{\mu_0}{4\pi} = 10^{-7} wb / Amp \times m$, In CGS units $k = 1$

(2) **Magnetic field**

(i) Magnetic field due to an imaginary magnetic pole (Pole strength *m*) : Is given by $B = \frac{F}{m_0}$ also $B = \frac{\mu_0}{4\pi}.\frac{m}{d^2}$

(ii) Magnetic field due to a bar magnet : At a distance *r* from the centre of magnet

(a) On axial position

$B_a = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}$; If *l* << *r* then $B_a = \frac{\mu_0}{4\pi}\frac{2M}{r^3}$

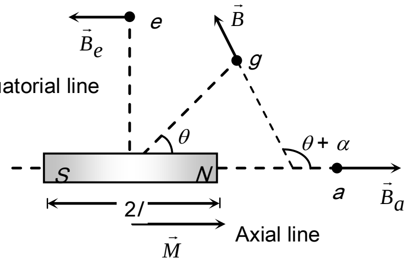


Fig. 22.12

(b) On equatorial position : $B_e = \frac{\mu_0}{4\pi}\frac{M}{(r^2 + l^2)^{3/2}}$; If *l* << *r* ; then $B_e = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

(c) General position : In general position for a short bar magnet $B_g = \frac{\mu_0}{4\pi}\frac{M}{r^3}\sqrt{(3\cos^2\theta + 1)}$

(3) **Bar magnet in magnetic field** : When a bar magnet is left free in an uniform magnetic field, if align it self in the directional field.

(i) Torque : $\tau = MB\sin\theta \Rightarrow \vec{\tau} = \vec{M} \times \vec{B}$

(ii) Work : $W = MB(1 - \cos\theta)$

(iii) Potential energy : $U = -MB\cos\theta = -\vec{M}.\vec{B}$; (θ = Angle made by the dipole with the field)

(4) **Gauss's law in magnetism** : Net magnetic flux through any closed surface is always zero *i.e.* $\oint \vec{B}.\vec{ds} = 0$

Earth's Magnetic Field (Terrestrial Magnetism)

As per the most established theory it is due to the rotation of the earth where by the various charged ions present in the molten state in the core of the earth rotate and constitute a current.

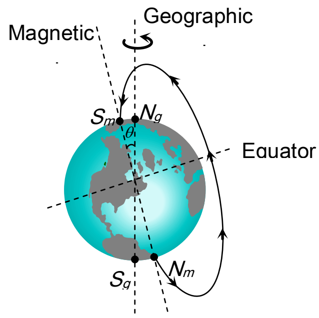


Fig. 22.13

(1) The magnetic field of earth is similar to one which would be obtained if a huge magnet is assumed to be buried deep inside the earth at it's centre.

(2) The axis of rotation of earth is called geographic axis and the points where it cuts the surface of earth are called geographical poles (N_g, S_g). The circle on the earth's surface perpendicular to the geographical axis is called equator.

(3) A vertical plane passing through the geographical axis is called geographical meridian.

(4) The axis of the huge magnet assumed to be lying inside the earth is called magnetic axis of the earth. The points where the magnetic axis cuts the surface of earth are called magnetic poles. The circle on the earth's surface perpendicular to the magnetic axis is called magnetic equator.

(5) Magnetic axis and Geographical axis don't coincide but they make an angle of 17.5° with each other.

(6) Magnetic equator divides the earth into two hemispheres. The hemisphere containing south polarity of

earth's magnetism is called northern hemisphere while the other, the southern hemisphere.

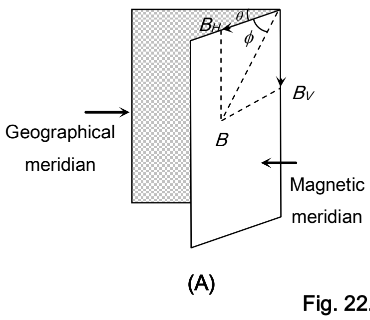
(7) The magnetic field of earth is not constant but changes irregularly from place to place on the surface of the earth and even at a given place it varies with time too.

(8) Direction of earth's magnetic field is from *S* (geographical south) to *N* (geographical north).

Elements of Earth's Magnetic Field

The magnitude and direction of the magnetic field of the earth at a place are completely given by certain. quantities known as magnetic elements.

(1) **Magnetic Declination (θ) :** It is the angle between geographic and the magnetic meridian planes.



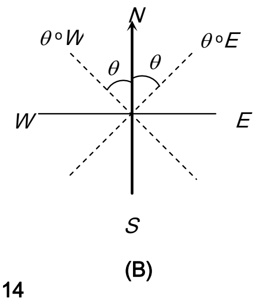


Fig. 22.14

Declination at a place is expressed at $\theta^o E$ or $\theta^o W$ depending upon whether the north pole of the compass needle lies to the east or to the west of the geographical axis.

(2) **Angle of inclination or Dip (ϕ) :** It is the angle between the direction of intensity of total magnetic field of earth and a horizontal line in the magnetic meridian.

(3) **Horizontal component of earth's magnetic field (B_H) :** Earth's magnetic field is horizontal only at the magnetic equator. At any other place, the total intensity can be resolved into horizontal component (B_H) and vertical component (B_V).

Also $B_H = B\cos\phi$ ...... (i) and $B_V = B\sin\phi$ ...... (ii)

By squaring and adding equation (i) and (ii)

$$B = \sqrt{B_{H^2} + B_{V^2}}$$

Dividing equation (ii) by equation (i) $\tan\phi = \frac{B_V}{B_H}$

Magnetic Maps and Neutral Points

(1) **Magnetic maps :** Magnetic maps (*i.e.* Declination, dip and horizontal component) over the earth vary in magnitude from place to place. It is found that many places have the same value of magnetic elements. The lines are drawn joining all place on the earth having same value of a magnetic element. These lines form magnetic map.

(i) Isogonic lines: These are the lines on the magnetic map joining the places of equal declination.

(ii) Agonic line: The line which passes through places having zero declination is called agonic line.

(iii) Isoclinic lines : These are the lines joining the points of equal dip or inclination.

(iv) Aclinic line : The line joining places of zero dip is called aclinic line (or magnetic equator)

(v) Isodynamic lines : The lines joining the points or places having the same value of horizontal component of earth's magnetic field are called isodynamic lines.

(2) **Neutral points :** A neutral point is a point at which the resultant magnetic field is zero. In general the neutral point is obtained when horizontal component of earth's field is balanced by the field produced by the magnet.

Tangent Law

When a small magnet is suspended in two uniform magnetic fields B and B_H which are at right angles to each other, the magnet comes to rest at an angle θ with respect to B_H .

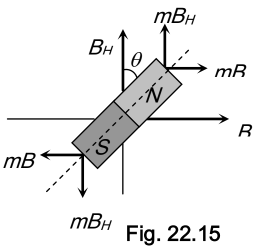


Fig. 22.15

In equilibrium

$$MB_H \sin\theta = MB\sin(90^o - \theta)$$

$\Rightarrow B = B_H \tan\theta.$ This is called tangent law.

Tangent Galvanometer

It consists of three circular coils of insulated copper wire wound on a vertical circular frame made of nonmagnetic material as ebonite or wood. A small magnetic compass needle is pivoted at the centre of the vertical circular frame. When the coil of the tangent galvanometer is kept in magnetic meridian and current passes through any of the coil then the needle at the centre gets deflected and comes to an equilibrium position under the action of two perpendicular field : one due to horizontal component of earth and the other due to field (*B*) set up by the coil due to current.

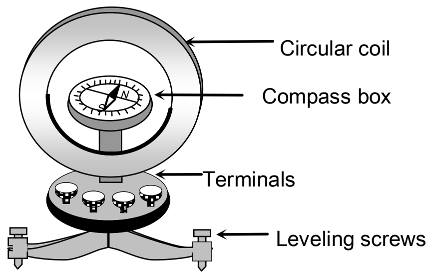


Fig. 22.16

In equilibrium $\boldsymbol{B} = \boldsymbol{B_H} \tan\theta$ where $B = \frac{\mu_0 ni}{2r}$; *n* = number of turns, *r* = radius of coil, *i* = the current to be measured, θ = angle made by needle from the direction of B_H in equilibrium.

Hence $\frac{\mu_0 Ni}{2r} = B_H \tan\theta \Rightarrow i = k \tan\theta$ where $k = \frac{2rB_H}{\mu_0 N}$ is called reduction factor.

Deflection Magnetometer

It's working is based on the principle of tangent law. It consists of a small compass needle, pivoted at the centre of a circular box. The box is kept in a wooden frame having two meter scale fitted on it's two arms. Reading of a scale at any point directly gives the distance of that point from the centre of compass needle.

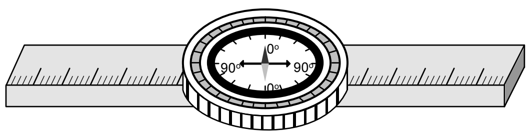


Fig. 22.17

(1) **Tan *A* position :** In this position the magnetometer is set perpendicular to magnetic meridian. So that, magnetic field due to magnet, is in axial position and perpendicular to earth's field. Hence $B_H \tan\theta = \frac{\mu_0}{4\pi} \cdot \frac{2Mr}{(r^2 - l^2)^2}$ or $B_H \tan\theta = \frac{\mu_0}{4\pi} \cdot \frac{2M}{r^3}$

(2) **Tan *B* position :** The arms of magnetometer are set in magnetic meridian, so that the magnetic field due to magnet is at it's equatorial position. Hence $B_H \tan\theta = \frac{\mu_0}{4\pi} \cdot \frac{M}{(r^2 + l^2)^{3/2}}$ or $B_H \tan\theta = \frac{\mu_0}{4\pi} \cdot \frac{M}{r^3}$

(3) **Comparison of magnetic moments :** According to deflection method $\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2}$

According to null deflection method $\frac{M_1}{M_2} = \left(\frac{d_1}{d_2}\right)^3$

Vibration Magnetometer

Vibration magnetometer is used for comparison of magnetic moments and magnetic fields. This device works on the principle, that whenever a freely suspended magnet in a uniform magnetic field, is disturbed from it's equilibrium position, it starts vibrating about the mean position.

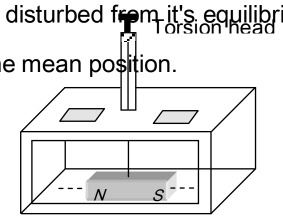


Fig. 22.18

Time period of oscillation of experimental bar magnet (magnetic moment *M*) in earth's magnetic field (B_H) is given by the formula. $T = 2\pi\sqrt{\frac{I}{MB_H}}$; where, $I =$ moment of inertia of short bar magnet $= \frac{wL^2}{12}$ (*w* = mass of bar magnet)

(1) **Determination of magnetic moment of a magnet :** The experimental (given) magnet is put into vibration magnetometer and it's time period *T* is determined. Now $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow M = \frac{4\pi^2 I}{B_H . T^2}$

(2) **Comparison of horizontal components of earth's magnetic field at two places**

$T = 2\pi\sqrt{\dfrac{I}{MB_H}}$; since I and M of the magnet are constant,

So $T^2 \propto \dfrac{1}{B_H} \Rightarrow \dfrac{(B_H)_1}{(B_H)_2} = \dfrac{T_2^2}{T_1^2}$

(3) **Comparison of magnetic moment of two magnets of same size and mass**

$T = 2\pi\sqrt{\dfrac{I}{M.B_H}}$; Here I and B_H are constants.

So $M \propto \dfrac{1}{T^2} \Rightarrow \dfrac{M_1}{M_2} = \dfrac{T_2^2}{T_1^2}$

(4) **Comparison of magnetic moments by sum and difference method**

Sum position

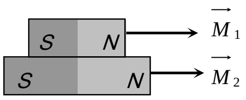


Fig. 22.19

Net magnetic moment $M_s = M_1 + M_2$

Net moment of inertia $I_s = I_1 + I_2$

Time period of oscillation of this pair in earth's magnetic field (B_H)

$$T_s = 2\pi\sqrt{\frac{I_s}{M_s B_H}} = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 + M_2)B_H}} \quad ....(i)$$

Frequency $\nu_s = \dfrac{1}{2\pi}\sqrt{\dfrac{(M_1 + M_2)B_H}{I_s}}$

Difference position

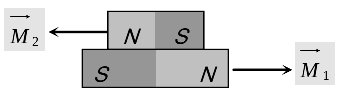


Fig. 22.20

Net magnetic moment

$M_d = M_1 + M_2$

Net moment of inertia $I_d = I_1 + I_2$

and $T_d = 2\pi\sqrt{\dfrac{I_d}{M_d B_H}} = 2\pi\sqrt{\dfrac{I_1 + I_2}{(M_1 - M_2)B_H}}$ ....(ii)

and $\nu_d = \dfrac{1}{2\pi}\sqrt{\dfrac{(M_1 + M_2)B_H}{(I_1 + I_2)}}$. From equation (i) and (ii) we get

$$\frac{T_s}{T_d} = \sqrt{\frac{M_1 - M_2}{M_1 + M_2}} \Rightarrow \frac{M_1}{M_2} = \frac{T_d^2 + T_s^2}{T_d^2 - T_s^2} = \frac{\nu_s^2 + \nu_d^2}{\nu_s^2 - \nu_d^2}$$

(5) **To find the ratio of magnetic field :** Suppose it is required to find the ratio $\dfrac{B}{B_H}$ where B is the field created by magnet and B_H is the horizontal component of earth's magnetic field.

To determine $\dfrac{B}{B_H}$ a primary (main) magnet is made to first oscillate in earth's magnetic field (B_H) alone and it's time period of oscillation (T) is noted.

$T = 2\pi\sqrt{\dfrac{I}{M\,B_H}}$

and frequency $\nu = \dfrac{1}{2\pi}\sqrt{\dfrac{M\,B_H}{I}}$

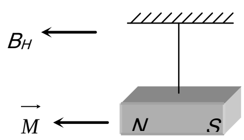


Fig. 22.21

Now a secondary magnet placed near the primary magnet so primary magnet oscillate in a new field with is the resultant of B and B_H and now time period, is noted again.

$T' = 2\pi\sqrt{\dfrac{I}{M(B + B_H)}}$

or $\nu' = \dfrac{1}{2\pi}\sqrt{\dfrac{M(B + B_H)}{I}}$

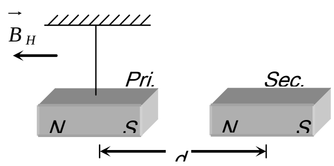


Fig. 22.22

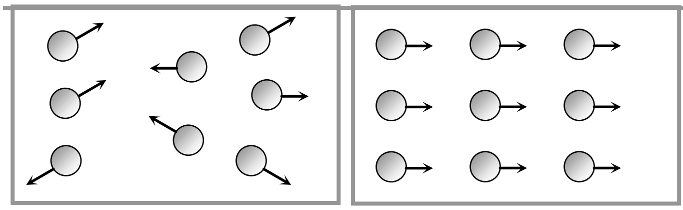
$\Rightarrow \dfrac{B}{B_H} = \left(\dfrac{\nu'}{\nu}\right)^2 - 1$

Magnetic Materials

On the basis of mutual interactions or behaviour of various materials in an external magnetic field, the materials are divided in three main categories.

(1) **Diamagnetic materials :** Diamagnetism is the intrinsic property of every material and it is generated due to mutual interaction between the applied magnetic field and orbital motion of electrons.

(2) **Paramagnetic materials :** In these substances the inner orbits of atoms are incomplete. The electron spins are uncoupled, consequently on applying a magnetic field the magnetic moment generated due to spin motion align in the direction of magnetic field and induces magnetic moment in its direction due to which the material gets feebly magnetised. In these materials the electron number is odd.



(A) When no field is applied

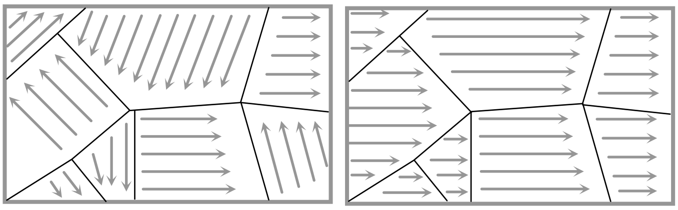
(B) On application of field $(\vec{B})$

Fig. 22.23

(3) **Ferromagnetic materials :** In some materials, the permanent atomic magnetic moments have strong tendency to align themselves even without any external field.

These materials are called ferromagnetic materials.

In every unmagnetised ferromagnetic material, the atoms form domains inside the material. Different domains, however, have different directions of magnetic moment and hence the materials remain unmagnetised. On applying an external magnetic field, these domains rotate and align in the direction of magnetic field.



(A) Unmagnetised

(B) Magnetised

Fig. 22.24

(4) **Curie Law :** The magnetic susceptibility of paramagnetic substances is inversely proportional to its absolute temperature *i.e.* $\chi \propto \frac{1}{T} \Rightarrow \chi \propto \frac{C}{T}$; where C = Curie constant, T = absolute temperature.

On increasing temperature, the magnetic susceptibility of paramagnetic materials decreases and vice versa.

The magnetic susceptibility of ferromagnetic substances does not change according to Curie law.

(5) **Curie temperature (T_c) :** The temperature above which a ferromagnetic material behaves like a paramagnetic material is defined as Curie temperature (T_c).

or

The minimum temperature at which a ferromagnetic substance is converted into paramagnetic substance is defined as Curie temperature. For various ferromagnetic materials its values are different, *e.g.* for *Ni*, $T_{C_{Ni}} = 358^o C$ for *Fe*, $T_{C_{Fe}} = 770^o C$

for *CO*, $T_{C_{CO}} = 1120^o C$

At this temperature the ferromagnetism of the substances suddenly vanishes.

(6) **Curie-weiss law :** At temperatures above Curie temperature the magnetic susceptibility of ferromagnetic materials is inversely proportional to ($T - T_c$)

i.e. $\chi \propto \frac{1}{T - T_c}$

$\Rightarrow \chi = \frac{C}{(T - T_c)}$

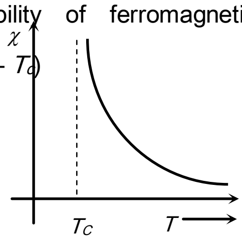


Fig. 22.25

Here T_c = Curie temperature

χ-T curve is shown (for Curie-Weiss Law)

Hysteresis Curve

For ferromagnetic materials, by removing external magnetic field *i.e.* H = 0. The magnetic moment of some domains remain aligned in the applied direction of previous magnetising field which results into a residual magnetism.

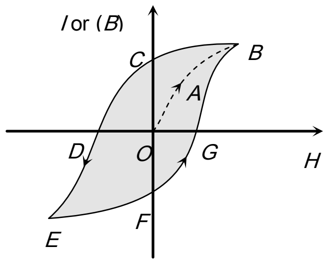


Fig. 22.26

The lack of retracibility as shown in figure is called hysteresis and the curve is known as hysteresis loop.

(1) **Retentivity :** When H is reduced, I reduces but is not zero when H = 0. The remainder value OC of magnetisation when H = 0 is called the residual magnetism or retentivity.

The property by virtue of which the magnetism (I) remains in a material even on the removal of magnetising field is called Retentivity or Residual magnetism.

(2) **Corecivity or corecive force** : When magnetic field H is reversed, the magnetisation decreases and for a particular value of H, denoted by H_c, it becomes zero *i.e.*, $H_c = OD$ when $I = 0$. This value of H is called the corecivity.

Magnetic hard substance (steel) $\rightarrow$ High corecvity

Magnetic soft substance (soft iron) $\rightarrow$ Low corecivity

(3) When field H is further increased in reverse direction, the intensity of magnetisation attains saturation value in reverse direction (*i.e.* point E)

(4) When H is decreased to zero and changed direction in steps, we get the part $EFGB$.

Thus complete cycle of magnetisation and demagnetisation is represented by $BCDEFGB$. This curve is known as hysteresis curve

Table 22.1 : Comparison between soft iron and steel

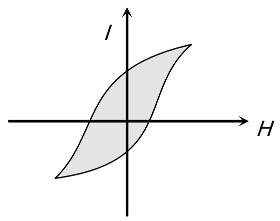
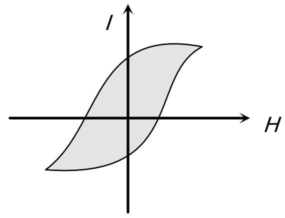
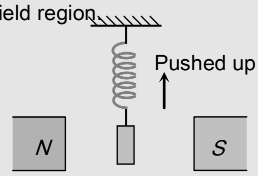
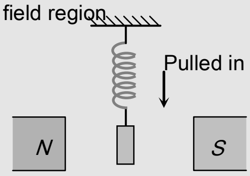
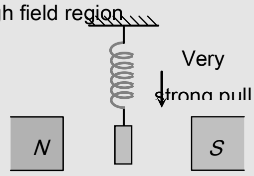
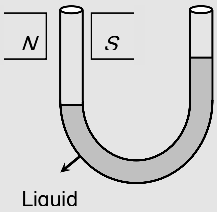
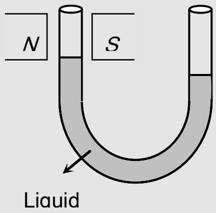
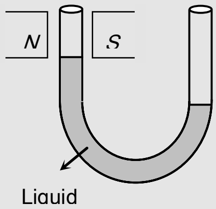
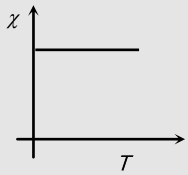
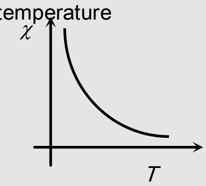
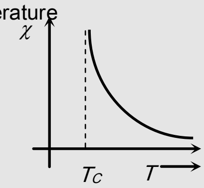
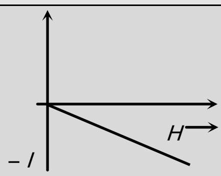
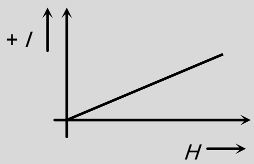
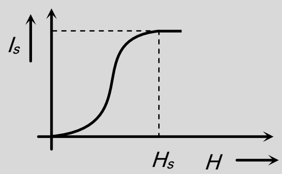
Soft iron	Steel
	
The area of hysteresis loop is less (low energy loss)	The area of hysteresis loop is large (high energy loss)
Less relativity and corecive force	More retentivity and corecive force
Magnetic permeability is high	Magnetic permeability is less
I and χ both are high	I and χ both are low
It magnetised and demagnetised easily	Magnetisation and demagnetisation is not easy
Used in dynamo, transformer, electromagnet tape recorder and tapes *etc.*	Used for making permanent magnet.

Table 22.2 : Comparative study of magnetic materials

Property	Diamagnetic substances	Paramagnetic substances	Ferromagnetic substances
Cause of magnetism	Orbital motion of electrons	Spin motion of electrons	Formation of domains
Explanation of magnetism	On the basis of orbital motion of electrons	On the basis of spin and orbital motion of electrons	On the basis of domains formed
Behaviour In a non-uniform magnetic field	These are repelled in an external magnetic field *i.e.* have a tendency to move from high to low field region 	These are feebly attracted in an external magnetic field *i.e.*, have a tendency to move from low to high field region 	These are strongly attracted in an external magnetic field *i.e.* they easily move from low to high field region 

State of magnetisation	These are weekly magnetised in a direction opposite to that of applied magnetic field	These get weekly magnetised in the direction of applied magnetic field	These get strongly magnetised in the direction of applied magnetic field
When the material in the form of liquid is filled in the *U*-tube and placed between pole pieces.	Liquid level in that limb gets depressed 	Liquid level in that limb rises up 	Liquid level in that limb rises up very much 
On placing the gaseous materials between pole pieces	The gas expands at right angles to the magnetic field.	The gas expands in the direction of magnetic field.	The gas rapidly expands in the direction of magnetic field
The value of magnetic induction B	$B < B_0$ (where B_0 is the magnetic induction in vacuum)	$B > B_0$	$B >> B_0$
Magnetic susceptibility χ	Low and negative $\|\chi\| \approx 1$	Low but positive $\chi \approx 1$	Positive and high $\chi \approx 10^2$
Dependence of χ on temperature	Does not depend on temperature (except *Bi* at low temperature) 	On cooling, these get converted to ferromagnetic materials at Curie temperature 	These get converted into paramagnetic materials at Curie temperature 
Relative permeability (μ_r)	$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$ $\mu_r = 10^2$
Intensity of magnetisation (I)	I is in a direction opposite to that of H and its value is very low	I is in the direction of H but value is low	I is in the direction of H and value is very high.
I-H curves			

Magnetic moment (*M*)	Very low (≈ 0)	Very low	Very high
Examples	*Cu*, *Ag*, *Au*, *Zn*, *Bi*, *Sb*, *NaCl*, H_2O air and diamond *etc.*	*Al*, *Mn*, *Pt*, *Na*, $CuCl_2$, O_2 and crown glass	*Fe*, *Co*, *Ni*, *Cd*, Fe_3O_4 *etc.*

Tips & Tricks

✍ Bohr magneton $\mu_B = \frac{eh}{4\pi m} = 9.27\times10^{-24}\ A/m^2$. It serves as natural unit of magnetic moment. Bohr magneton can be defined as the orbital magnetic moment of an electron circulating in inner most orbit.

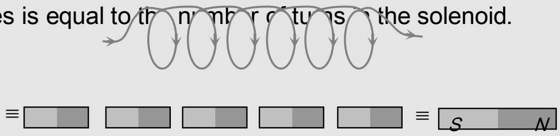
✍ Magnetic moment of straight current carrying wire is zero.

✍ Magnetic moment of toroid is zero

✍ Atoms which have paired electron have the magnetic moment zero.

✍ Magnetostriction : The length of an iron bar changes when it is magnetised, when an iron bar magnetised it's length increases due to alignment of spins parallel to the field. This increase is in the direction of magnetisation. This effect is known as magnetostriction.

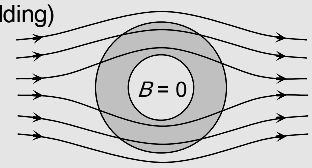
✍ A current carrying solenoid can be treated as the arrangement of small magnetic dipoles placed in line with each other as shown. The number of such small magnetic dipoles is equal to the number of turns in the solenoid.



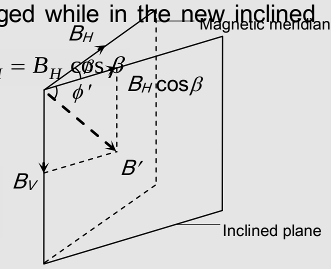
✍ When a magnetic dipole of moment *M* moves from unstable equilibrium to stable equilibrium position in a magnetic field B, the kinetic energy will decrease by 2 *MB*.

✍ Intensity of magnetisation (*I*) is produced in materials due to spin motion of electrons.

✍ For protecting a sensitive equipment from the external magnetic field it should be placed inside an iron cane. (magnetic shielding)



✍ **Apparent dip :** In a vertical plane inclined at an angle β to the magnetic meridian, vertical component of earth's magnetic field remains unchanged while in the new inclined plane horizontal component $B'_H = B_H \cos\beta$



ϕ' = apparent angle of dip

and $\tan\phi' = \frac{B_V}{B'_H} = \frac{B_V}{B_H\cos\beta}$

$\Rightarrow \tan\phi' = \frac{\tan\phi}{\cos\beta}$

✍ If at any place the angle of dip is θ and magnetic latitude is λ then tan θ = 2tanλ

✍ At the poles and equator of earth the values of total intensity are 0.66 and 0.33 *Oersted respectively.*

✍ Remember time period of oscillation in difference position is greater than that in sum position $T_d > T_s$.

✍ If a rectangular bar magnet is cut in n equal parts then time period of each part will be $\frac{1}{\sqrt{n}}$ times that of complete magnet (i.e. $T' = \frac{T}{\sqrt{n}}$) while for short magnet $T' = \frac{T}{n}$. If nothing is said then bar magnet is treated as short magnet.

✍ Suppose a magnetic needle is vibrating in earth's magnetic field. With temperature rise *M* decreases hence time period (*T*) increases but at 770°*C* (Curie temperature) it stops vibrating.

✍ An iron cored coil and a bulb are connected in series with an ac generator. If an iron rod is introduced inside a coil, then the intensity of bulb will decrease, because some energy lost in magnetising the rod.

✍ Hysteresis energy loss = Area bound by the hysteresis loop = *VAnt Joule*; Where , *V* = Volume of ferromagnetic sample, *A* = Area of *B* – *H* loop *P*, *n* = Frequency of alternating magnetic field and *t* = Time

Ordinary Thinking

Objective Questions

Magnet and it's Properties

1. An iron rod of length *L* and magnetic moment *M* is bent in the form of a semicircle. Now its magnetic moment will be

[CPMT 1984; MP Board 1986; NCERT 1975; MP PET/PMT 1988; EAMCET (Med.) 1995; Manipal MEE 1995;RPMT 1996; BHU 1995; MP PET 2002]

(a) M (b) $\frac{2M}{\pi}$

(c) $\frac{M}{\pi}$ (d) $M\pi$

2. Unit of magnetic flux density (or magnetic induction) is

[DPMT 1988;CPMT 1984, 78, 90; MP PMT 1992; MH CET 2004]

(a) *Tesla* (b) *Weber/metre*^{2}

(c) *Newton/ampere-metre* (d) All of the above

3. Magnetic intensity for an axial point due to a short bar magnet of magnetic moment *M* is given by

[MP PET 1984; CPMT 1974; Pb. PMT 1999]

(a) $\frac{\mu_0}{4\pi}\times\frac{M}{d^3}$ (b) $\frac{\mu_0}{4\pi}\times\frac{M}{d^2}$

(c) $\frac{\mu_0}{2\pi}\times\frac{M}{d^3}$ (d) $\frac{\mu_0}{2\pi}\times\frac{M}{d^2}$

4. A magnet is placed in iron powder and then taken out, then maximum iron powder is at

(a) Some away from north pole

(b) Some away from south pole

(c) The middle of the magnet

(d) The end of the magnet

5. A magnet of magnetic moment *M* and pole strength *m* is divided in two equal parts, then magnetic moment of each part will be **[MP Board 1985; MP PET 1984, 2000; NCERT 1974; AFMC 1996; MP PMT 2002; MH CET (Med.) 2001; CPMT 1983, 84; KCET 1994, 2001]**

(a) M (b) $M/2$

(c) $M/4$ (d) $2M$

6. Points *A* and *B* are situated along the extended axis of 2 *cm* long bar magnet at a distance *x* and 2*x cm* respectively. From the pole nearer to the points, the ratio of the magnetic field at A and B will be **[EAMCET 1984; CPMT 1986]**

(a) 4 : 1 exactly (b) 4 : 1 approx.

(c) 8 : 1 exactly (d) 8 : 1 approx.

7. If a magnet of pole strength *m* is divided into four parts such that the length and width of each part is half that of initial one, then the pole strength of each part will be

(a) $m/4$ (b) $m/2$

(c) $m/8$ (d) $4m$

8. The distance of two points on the axis of a magnet from its centre is 10 *cm* and 20 *cm* respectively. The ratio of magnetic intensity at these points is 12.5 : 1. The length of the magnet will be

(a) 5 *cm* (b) 25 *cm*

(c) 10 *cm* (d) 20 *cm*

9. Ratio of magnetic intensities for an axial point and a point on broad side-on position at equal distance *d* from the centre of magnet will be **or** The magnetic field at a

distance *d* from a short bar magnet in longitudinal and transverse positions are in the ratio **[CPMT 1978, 82; KCET 1998]**

(a) 1 : 1 (b) 2 : 3

(c) 2 : 1 (d) 3 : 2

10. The magnetism of magnet is due to [JIPMER 1997]

(a) The spin motion of electron
(b) Earth
(c) Pressure of big magnet inside the earth
(d) Cosmic rays

11. The pole strength of a bar magnet is 48 *ampere-metre* and the distance between its poles is 25 *cm*. The moment of the couple by which it can be placed at an angle of 30° with the uniform magnetic intensity of flux density 0.15 *Newton /ampere-metre* will be

(a) 12 *Newton × metre* (b) 18 *Newton × metre*
(c) 0.9 *Newton × metre* (d) None of the above

12. The magnetic field at a point x on the axis of a small bar magnet is equal to the field at a point y on the equator of the same magnet. The ratio of the distances of x and y from the centre of the magnet is [MP PMT 1990]

(a) 2^{-3} (b) $2^{-1/3}$
(c) 2^3 (d) $2^{1/3}$

13. A magnet of magnetic moment 20 C.G.S. units is freely suspended in a uniform magnetic field of intensity 0.3 C.G.S. units. The amount of work done in deflecting it by an angle of 30° in C.G.S. units is [MP PET 1991]

(a) 6 (b) $3\sqrt{3}$
(c) $3(2-\sqrt{3})$ (d) 3

14. A bar magnet having centre O has a length of 4 *cm*. Point P_1 is in the broad side-on and P_2 is in the end side-on position with OP_1 = OP_2 = 10 *metres*. The ratio of magnetic intensities H at P_1 and P_2 is [MP PET 1990]

(a) $H_1 : H_2 = 16 : 100$ (b) $H_1 : H_2 = 1 : 2$
(c) $H_1 : H_2 = 2 : 1$ (d) $H_1 : H_2 = 100 : 16$

15. The magnetic field due to a short magnet at a point on its axis at distance X *cm* from the middle point of the magnet is 200 *Gauss*. The magnetic field at a point on the neutral axis at a distance X *cm* from the middle of the magnet is

[CPMT 1971, 88; MP PET 1985]

(a) 100 *Gauss* (b) 400 *Gauss*
(c) 50 *Gauss* (d) 200 *Gauss*

16. Which of the following, the most suitable material for making permanent magnet is

(a) Steel (b) Soft iron
(c) Copper (d) Nickel

17. In the case of bar magnet, lines of magnetic induction

[CPMT 1975; CBSE PMT 1990]

(a) Start from the north pole and end at the south pole
(b) Run continuously through the bar and outside
(c) Emerge in circular paths from the middle of the bar
(d) Are produced only at the north pole like rays of light from a bulb

18. A sensitive magnetic instrument can be shielded very effectively from outside magnetic fields by placing it inside a box of [CPMT 1974]

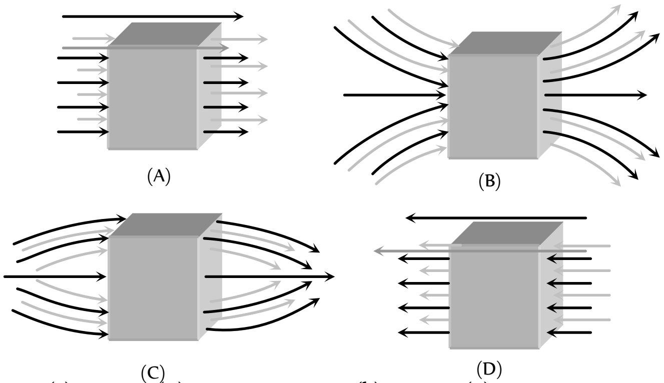
(a) Teak wood
(b) Plastic material
(c) Soft iron of high permeability
(d) A metal of high conductivity

19. The field due to a magnet at a distance R from the centre of the magnet is proportional to [MP PET 1996]

(a) R^2 (b) R^3
(c) $1/R^2$ (d) $1/R^3$

20. A uniform magnetic field, parallel to the plane of the paper existed in space initially directed from left to right. When a bar of soft iron is placed in the field parallel to it, the lines of force passing through it will be represented by

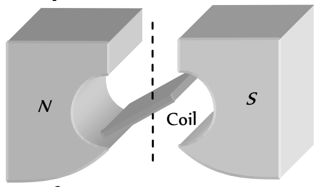
[CPMT 1986, 88]



(a) Figure (A) (b) Figure (B)
(c) Figure (C) (d) Figure (D)

21. The figure below shows the north and south poles of a permanent magnet in which n turn coil of area of cross-section A is resting, such that for a current i passed through the coil, the plane of the coil makes an angle θ with respect to the direction of magnetic field B. If the plane of the magnetic field and the coil are horizontal and vertical respectively, the torque on the coil will be

[CPMT 1986, 88; DPMT 2002]



(a) $\tau = niAB\cos\theta$
(b) $\tau = niAB\sin\theta$
(c) $\tau = niAB$
(d) None of the above, since the magnetic field is radial

22. Points A and B are situated perpendicular to the axis of a 2*cm* long bar magnet at large distances X and $3X$ from its centre on opposite sides. The ratio of the magnetic fields at A and B will be approximately equal to [CPMT 1988]

(a) 1 : 9 (b) 2 : 9
(c) 27 : 1 (d) 9 : 1

23. Two short magnets with their axes horizontal and perpendicular to the magnetic meridian are placed with their centres 40 *cm* east and 50 *cm* west of magnetic needle. If the needle remains undeflected, the ratio of their magnetic moments $M_1 : M_2$ is [MP PET 1990]

(a) 4 : 5 (b) 16 : 25
(c) 64 : 125 (d) $2:\sqrt{5}$

24. If a bar magnet of magnetic moment M is freely suspended in a uniform magnetic field of strength B, the work done in rotating the magnet through an angle θ is

[AFMC 1997; MNR 1998; RPET 1999; MP PMT 1989, 96, 99; MP PET 1984, 89, 2000; UPSEAT 1999, 2000, 05]

(a) $MB(1-\sin\theta)$ (b) $MB\sin\theta$
(c) $MB\cos\theta$ (d) $MB(1-\cos\theta)$

25. Two small bar magnets are placed in a line with like poles facing each other at a certain distance *d* apart. If the length of each magnet is negligible as compared to *d*, the force between them will be inversely proportional to

[CPMT 1971; NCERT 1971; MP PMT 1992]

(a) d (b) d^2

(c) $\frac{1}{d^2}$ (d) d^4

26. A magnet of magnetic moment *M* is situated with its axis along the direction of a magnetic field of strength B. The work done in rotating it by an angle of 180° will be

[MP PMT 1985; MP PET 1997]

(a) $-MB$ (b) $+MB$

(c) 0 (d) $+2MB$

27. A long magnet is cut in two parts in such a way that the ratio of their lengths is 2 : 1. The ratio of pole strengths of both the section is [CPMT 1986]

(a) Equal (b) In the ratio of 2 : 1

(c) In the ratio of 1 : 2 (d) In the ratio of 4 : 1

28. A bar magnet of length 10 *cm* and having the pole strength equal to 10^{-3} *weber* is kept in a magnetic field having magnetic induction (*B*) equal to $4\pi \times 10^{-3}$ *Tesla*. It makes an angle of 30° with the direction of magnetic induction. The value of the torque acting on the magnet is

[MP PMT 1993]

(a) $2\pi \times 10^{-7}\ N \times m$ (b) $2\pi \times 10^{-5}\ N \times m$

(c) $0.5 N \times m$ (d) $0.5 \times 10^2\ N \times m$

($\mu_0 = 4\pi \times 10^{-7}\ weber / amp \times m$)

29. Magnetic field intensity is defined as [MP PET 1993]

(a) Magnetic moment per unit volume

(b) Magnetic induction force acting on a unit magnetic pole

(c) Number of lines of force crossing per unit area

(d) Number of lines of force crossing per unit volume

30. If the magnetic flux is expressed in *weber*, then magnetic induction can be expressed in

[CPMT 1974, 77, 83, 86, 87; MP PET 1989]

(a) *Weber/m* (b) *Weber/m*

(c) *Weber-m* (d) *Weber-m*

31. A magnetic needle is kept in a non-uniform magnetic field. It experiences [MP PMT 1987; IIT 1982; Kerala PET 2002; AMU 1999; AIEEE 2005]

(a) A force and a torque

(b) A force but not a torque

(c) A torque but not a force

(d) Neither a torque nor a force

32. The magnetic induction in air at a distance *d* from an isolated point pole of strength *m* unit will be [MNR 1987; CPMT 1991; MP PET 1995; AMU 1999; J & K CET 2005]

(a) $\frac{m}{d}$ (b) $\frac{m}{d^2}$

(c) md (d) md^2

33. A magnetic needle lying parallel to a magnetic field requires *W* units of work to turn it through 60°. The torque required to maintain the needle in this position will be

[AIEEE 2003; UPSEAT 2000; BHU 2004; Pb PET 2004]

(a) $\sqrt{3}\,W$ (b) W

(c) $\frac{\sqrt{3}}{2}W$ (d) $2W$

34. A long magnetic needle of length $2L$, magnetic moment *M* and pole strength *m* units is broken into two pieces at the middle. The magnetic moment and pole strength of each piece will be

(a) $\frac{M}{2}, \frac{m}{2}$ (b) $M, \frac{m}{2}$

(c) $\frac{M}{2}, m$ (d) M, m

35. Two identical thin bar magnets each of length *l* and pole strength *m* are placed at right angle to each other with north pole of one touching south pole of the other. Magnetic moment of the system is

(a) *ml* (b) 2*ml*

(c) $\sqrt{2}ml$ (d) $\frac{1}{2}ml$

36. Magnetic induction is a [AFMC 1986]

(a) Scalar quantity (b) Vector quantity

(c) Both (a) and (b) (d) None of the above

37. What happens to the force between magnetic poles when their pole strength and the distance between them are both doubled[CPMT 1978, 80, 84, 8

(a) Force increases to two times the previous value

(b) No change

(c) Force decreases to half the previous value

(d) Force increases to four times the previous value

38. Force between two unit pole strength placed at a distance of one metre is [CPMT 1987]

(a) 1 *N* (b) $\frac{10^{-7}}{4\pi}N$

(c) $10^{-7}\ N$ (d) $4\pi \times 10^{-7} N$

39. A small bar magnet of moment *M* is placed in a uniform field *H*. If magnet makes an angle of 30° with field, the torque acting on the magnet is [CPMT 1989]

(a) *MH* (b) $\frac{MH}{2}$

(c) $\frac{MH}{3}$ (d) $\frac{MH}{4}$

40. If a hole is made at the centre of a bar magnet, then its magnetic moment will

(a) Increase (b) Decrease

(c) Not change (d) None of these

41. The small magnets each of magnetic moment 10 *A-m* are placed end-on position 0.1*m* apart from their centres. The force acting between them is [MNR 1994]

(a) $0.6 \times 10^7\ N$ (b) $0.06 \times 10^7\ N$

(c) $0.6N$ (d) $0.06N$

42. Magnetic lines of force [MP PET 1994]

(a) Always intersect

(b) Are always closed

(c) Tend to crowd far away from the poles of magnet

(d) Do not pass through vacuum

43. Rate of change of torque τ with deflection θ is maximum for a magnet suspended freely in a uniform magnetic field of induction *B*, when [MP PET 1994]

(a) $\theta = 0°$ (b) $\theta = 45°$

(c) $\theta = 60°$ (d) $\theta = 90°$

44. A magnet of magnetic moment *M* is rotated through 360° in a magnetic field *H*, the work done will be [KCET 1998; MP PMT 1994; Roorkee 2000]

(a) *MH* (b) 2*MH*

(c) $2\pi MH$ (d) Zero

45. The direction of line of magnetic field of bar magnet is [AFMC 1995]

(a) From south pole to north pole

(b) From north pole to south pole

(c) Across the bar magnet

(d) From south pole to north pole inside the magnet and from north pole to south pole outside the magnet

46. The work done in turning a magnet of magnetic moment '*M* by an angle of 90° from the meridian is '*n*' times the corresponding work done to turn it through an angle of 60°, where '*n*' is given by[CBSE PMT 1995; MP PET 2003]

(a) 1/2 (b) 2

(c) 1/4 (d) 1

47. Force between two identical bar magnets whose centres are *r metre* apart is 4.8 *N*, when their axes are in the same line. If separation is increased to 2*r*, the force between them is reduced to

(a) 2.4*N* (b) 1.2*N*

(c) 0.6*N* (d) 0.3*N*

48. A bar magnet of magnetic moment 10^4 *J/T* is free to rotate in a horizontal plane. The work done in rotating the magnet slowly from a direction parallel to a horizontal magnetic field of 4×10^{-5} *T* to a direction 60° from the field will be [MP PET 1995]

(a) 0.2 *J* (b) 2.0 *J*

(c) 4.18 *J* (d) 2×10^{2} *J*

49. Magnetic lines of force due to a bar magnet do not intersect because

(a) A point always has a single net magnetic field

(b) The lines have similar charges and so repel each other

(c) The lines always diverge from a single point

(d) The lines need magnetic lenses to be made to intersect

50. The unit of magnetic moment is [MP PET 1996; AMU 2000; MP PMT 1995, 2002]

(a) *Wb/m* (b) $Wb.m^2$

(c) *A.m* (d) $A.m^2$

51. The dipole moment of a short bar magnet is 1.25 *A-m*. The magnetic field on its axis at a distance of 0.5 *metre* from the centre of the magnet is

(a) $1.0\times10^{-4}\ Newton / amp - meter$

(b) $4\times10^{-2}\ Newton / amp - metre$

(c) $2\times10^{-6}\ Newton / amp - metre$

(d) $6.64\times10^{-8}\ Newton / amp - metre$

52. A permanent magnet [MP PET 1996]

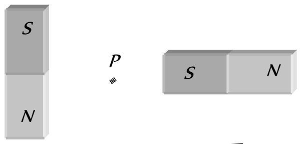
(a) Attracts all substances

(b) Attracts only magnetic substances

(c) Attracts magnetic substances and repels all non-magnetic substances

(d) Attracts non-magnetic substances and repels magnetic substances

53. Two equal bar magnets are kept as shown in the figure. The direction of resultant magnetic field, indicated by arrow head at the point *P* is (approximately)



(a) $\longrightarrow$ (b) $\nearrow$

(c) $\searrow$ (d) $\uparrow$

54. The S.I. unit of magnetic permeability is [MP PET 1997]

(a) Am^{-1}

(b) Am

(c) $Henry\,m^{-1}$

(d) No unit, it is a dimensionless number

55. A short bar magnet placed with its axis at 30° with a uniform external magnetic field of 0.16 *Tesla* experiences a torque of [AIIMS 1995] magnitude 0.032 *Joule*. The magnetic moment of the bar magnet will be [MP PMT 1997; UPSEAT 2004]

(a) 0.23 *Joule/Tesla* (b) 0.40 *Joule/Tesla*

(c) 0.80*Joule/Tesla* (d) Zero

56. The magnetic field to a small magnetic dipole of magnetic moment *M*, at distance *r* from the centre on the equatorial line is given by (in M.K.S. system) [MP PMT/PET 1998]

(a) $\frac{\mu_0}{4\pi}\times\frac{M}{r^2}$ (b) $\frac{\mu_0}{4\pi}\times\frac{M}{r^3}$

[MP PMT 1995]

(c) $\frac{\mu_0}{4\pi}\times\frac{2M}{r^2}$ (d) $\frac{\mu_0}{4\pi}\times\frac{2M}{r^3}$

57. The incorrect statement regarding the lines of force of the magnetic field *B* is [MP PET 1999]

(a) Magnetic intensity is a measure of lines of force passing through unit area held normal to it

(b) Magnetic lines of force form a close curve

(c) Inside a magnet, its magnetic lines of force move from north pole of a magnet towards its south pole

(d) Due to a magnet magnetic lines of force never cut each other

58. A straight wire carrying current *i* is turned into a circular loop. If the magnitude of magnetic moment associated with it in M.K.S. unit is *M*, the length of wire will be [MP PET 1999]

(a) $4\pi iM$ (b) $\sqrt{\frac{4\pi M}{i}}$

(c) $\sqrt{\frac{4\pi i}{M}}$ (d) $\frac{M\pi}{4i}$

59. A bar magnet of magnetic moment $\vec{M}$ is placed in a magnetic field of induction $\vec{B}$. The torque exerted on it is

[EAMCET (Engg.) 1995; CBSE PMT 1999; BHU 2003; CPMT 2004; MP PMT 2001, 05]

(a) $\vec{M}.\vec{B}$ (b) $-\vec{M}.\vec{B}$

(c) $\vec{M}\times\vec{B}$ (d) $\vec{B}\times\vec{M}$

60. For protecting a sensitive equipment from the external magnetic field, it should be

[KCET 1993; CBSE PMT 1998]

(a) Placed inside an aluminium cane
(b) Placed inside an iron cane
(c) Wrapped with insulation around it when passing current through it
(d) Surrounded with fine copper sheet

61. If a piece of metal was thought to be magnet, which one of the following observations would offer conclusive evidence

[KCET 1994]

(a) It attracts a known magnet
(b) It repels a known magnet
(c) Neither (a) nor (b)
(d) It attracts a steel screw driver

62. The magnet can be completely demagnetized by

[KCET 1994]

(a) Breaking the magnet into small pieces
(b) Heating it slightly
(c) Droping it into ice cold water
(d) A reverse field of appropriate strength

63. A current loop placed in a magnetic field behaves like a

[AFMC 1994]

(a) Magnetic dipole (b) Magnetic substance
(c) Magnetic pole (d) All are true

64. A magnet when placed perpendicular to a uniform field of strength $10^{-4}\,Wb/m^2$ experiences a maximum couple of moment $4\times10^{-5}\,N/m.$. What is its magnetic moment

[Bihar MEE 1995]

(a) $0.4A\times m^2$ (b) $0.2A\times m^2$
(c) $0.16A\times m^2$ (d) $0.04A\times m^2$
(e) $0.06A\times m^2$

65. *Weber/m* is equal to [CPMT 1985; AFMC 1997]

(a) *Volt* (b) *Henry*
(c) *Tesla* (d) All of these

66. Two magnets, each of magnetic moment '*M* are placed so as to form a cross at right angles to each other. The magnetic moment of the system will be

[AFMC 1999; Pb PET 2001]

(a) 2 *M* (b) $\sqrt{2}\,M$
(c) 0.5 *M* (d) *M*

67. Two like magnetic poles of strength 10 and 40 SI units are separated by a distance 30 *cm*. The intensity of magnetic field is zero on the line joining them [JIPMER 1999]

(a) At a point 10 *cm* from the stronger pole
(b) At a point 20 *cm* from the stronger pole
(c) At the mid-point
(d) At infinity

68. If a magnet of length 10 *cm* and pole strength 40 *A-m* is placed at an angle of 45° in an uniform induction field of intensity 2×10^{-4} *T*, the couple acting on it is

[Pb. PMT 1999; MH CET (Med.) 1999]

(a) 0.5656×10^{-4} *N-m* (b) 0.5656×10^{-3} *N-m*
(c) 0.656×10^{-4} *N-m* (d) 0.656×10^{-5} *N-m*

69. The intensity of magnetic field is *H* and moment of magnet is *M*. The maximum potential energy is

[Pb. PMT 1999; MH CET (Med.) 1999]

(a) *MH* (b) 2 *MH*
(c) 3 *MH* (d) 4 *MH*

70. A bar magnet of magnetic moment 200 *A-m* is suspended in a magnetic field of intensity 0.25 *N/A-m*. The couple required to deflect it through 30° is

[AFMC 1999; Pb. PET 2000]

(a) 50 *N-m* (b) 25 *N-m*
(c) 20 *N-m* (d) 15 *N-m*

71. Two similar bar magnets *P* and *Q*, each of magnetic moment *M*, are taken, If *P* is cut along its axial line and *Q* is cut along its equatorial line, all the four pieces obtained have [EAMCET (Engg.) 2000]

(a) Equal pole strength (b) Magnetic moment $\frac{M}{4}$

(c) Magnetic moment $\frac{M}{2}$ (d) Magnetic moment *M*

72. A magnet of magnetic moment $50\,\hat{i}\,A\text{-}m^2$ is placed along the *x*-axis in a magnetic field $\vec{B}=(0.5\,\hat{i}+3.0\,\hat{j})T$. The torque acting on the magnet is

[MP PMT 2000]

(a) $175\ \hat{k}\ N\text{-}m$ (b) $150\ \hat{k}\ N\text{-}m$

(c) $75\ \hat{k}\ N\text{-}m$ (d) $25\sqrt{37}\,\hat{k}\ N\text{-}m$

73. A bar magnet is held perpendicular to a uniform magnetic field. If the couple acting on the magnet is to be halved by rotating it, then the angle by which it is to be rotated is

[CBSE PMT 2000]

(a) 30° (b) 45°
(c) 60° (d) 90°

74. There is no couple acting when two bar magnets are placed coaxially separated by a distance because

[EAMCET (Engg.) 2000]

(a) There are no forces on the poles
(b) The forces are parallel and their lines of action do not coincide
(c) The forces are perpendicular to each other
(d) The forces act along the same line

75. A bar magnet of magnetic moment 3.0 *A-m* is placed in a uniform magnetic induction field of 2×10^{-5} *T*. If each pole of the

magnet experiences a force of 6×10^{-4} *N*, the length of the magnet is [EAMCET (Med.) 2000]

(a) 0.5 *m* (b) 0.3 *m*

(c) 0.2 *m* (d) 0.1 *m*

76. A bar magnet when placed at an angle of 30° to the direction of magnetic field induction of 5×10^{-2} *T*, experiences a moment of couple 25×10^{-6} *N-m*. If the length of the magnet is 5 *cm* its pole strength is

[EAMCET (Med.) 2000]

(a) 2×10^{-2} *A-m* (b) 5×10^{-2} *A-m*

(c) 2 *A-m* (d) 5 *A-m*

77. Two lines of force due to a bar magnet [MP PMT 2002]

(a) Intersect at the neutral point

(b) Intersect near the poles of the magnet

(c) Intersect on the equatorial axis of the magnet

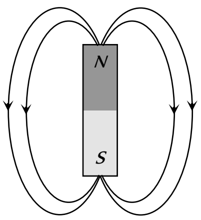
(d) Do not intersect at all

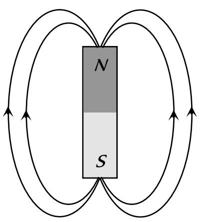
78. The ultimate individual unit of magnetism in any magnet is called [MP PET 2002; J & K CET 2004]

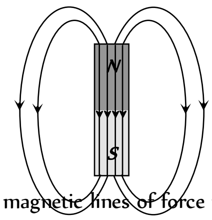
(a) North pole (b) South pole

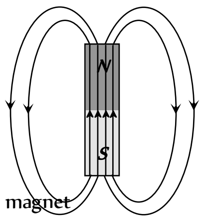
(c) Dipole (d) Quadrupole

79. The magnetic field lines due to a bar magnet are correctly shown in [IIT-JEE (Screening) 2002]

(a) 

(b) 

(c) 

(d) 

80. The magnetic lines of force inside a bar magnet

[AIEEE 2003]

(a) Are from south-pole to north-pole of the magnet

(b) Are from north-pole to south-pole of the magnet

(c) Do not exist

(d) Depend upon the area of cross-section of the bar magnet

81. If a magnet is hanged with its magnetic axis then it stops in

[AFMC 2003]

(a) Magnetic meridian (b) Geometric meridian

(c) Angle of dip (d) None of these

82. The work done in rotating a magnet of magnetic moment 2 *A-m* in a magnetic field of 5×10^{-3} *T* from the direction along the magnetic field to opposite direction to the magnetic field, is

(a) Zero (b) 2×10^{-2} *J*

(c) 10^{-2} *J* (d) 10 *J*

83. The torque on a bar magnet due to the earth's magnetic field is maximum when the axis of the magnet is

[MP PMT 2004]

(a) Perpendicular to the field of the earth

(b) Parallel to the vertical component of the earth's field

(c) At an angle of 33° with respect to the *N-S* direction

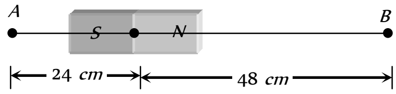
(d) Along the North-South (*N-S*) direction

84. Magnetic dipole moment is a [AFMC 2004]

(a) Scalar quantity (b) Vector quantity

(c) Constant quantity (d) None of these

85. A bar magnet of length 3 *cm* has points *A* and *B* along its axis at distances of 24 *cm* and 48 *cm* on the opposite sides. Ratio of magnetic fields at these points will be [DPMT 2004]



(a) 8 (b) $1/2\sqrt{2}$

(c) 3 (d) 4

86. A magnet of magnetic moment $2\,J\,T^{-1}$ is aligned in the direction of magnetic field of 0.1 T. What is the net work done to bring the magnet normal to the magnetic field

[DCE 2004]

(a) 0.1 *J* (b) 0.2 *J*

(c) 1 *J* (d) 2 *J*

87. The magnetic moment of a magnet of length 10 *cm* and pole strength 4.0 *Am* will be [DPMT 2003]

(a) $0.4\ Am^2$ (b) $1.6\ Am^2$

(c) $20\ Am^2$ (d) $8.0\ Am^2$

88. The effective length of a magnet is 31.4 *cm* and its pole strength is 0.5 *Am*. The magnetic moment, if it is bent in the form of a semicircle will be [DPMT 2003]

(a) $0.1\ Am^2$ (b) $0.01\ Am^2$

(c) $0.2\ Am^2$ (d) $1.2\ Am^2$

89. The magnetic potential at a point on the axial line of a bar magnet of dipole moment *M* is *V*. What is the magnetic potential due to a bar magnet of dipole moment $\frac{M}{4}$ at the same point

(a) $4\,V$ (b) $2\,V$

(c) $\frac{V}{2}$ (d) $\frac{V}{4}$

90. A small bar magnet has a magnetic moment 1.2 *A-m*. The magnetic field at a distance 0.1 *m* on its axis will be : ($\mu_0 = 4\pi \times 10^{-7}$ *T-m/A*) [MP PET 2003]

(a) 1.2×10^{-4} *T* (b) 2.4×10^{-4} *T*

(c) 2.4×10^{4} *T* (d) 1.2×10^{4} *T*

91. Two identical short bar magnets, each having magnetic moment of 10 *Am*, are arranged such that their axial lines are perpendicular to each other and their centres be along the same straight line in a horizontal plane. If the distance between their centres is 0.2 *m*, the resultant magnetic induction at a point midway between them is

$(\mu_0 = 4\pi \times 10^{-7}\, Hm^{-1})$ [EAMCET 2005]

(a) $\sqrt{2} \times 10^{-7}$ *Tesla* (b) $\sqrt{5} \times 10^{-7}$ *Tesla*

(c) $\sqrt{2} \times 10^{-3}$ *Tesla* (d) $\sqrt{5} \times 10^{-3}$ *Tesla*

92. A magnet of length 0.1 *m* and pole strength $10^{-4}\, A.m.$ is kept in a magnetic field of $30\, Wb/m^2$ at an angle 30°. The couple acting on it is .... $\times 10^{-4}\, Nm.$ [MP PET 2005]

(a) 7.5 (b) 3.0

(c) 1.5 (d) 6.0

Earth Magnetism

1. A very small magnet is placed in the magnetic meridian with its south pole pointing north. The null point is obtained 20 *cm* away from the centre of the magnet. If the earth's magnetic field (horizontal component) at this point be 0.3 *gauss*, the magnetic moment of the magnet is

[CPMT 1987; MNR 1978]

(a) $8.0 \times 10^2\, e.m.u.$ (b) $1.2 \times 10^3\, e.m.u.$

(c) $2.4 \times 10^3\, e.m.u.$ (d) $3.6 \times 10^3\, e.m.u.$

2. Intensity of magnetic field due to earth at a point inside a hollow steel box is [MP PET 1995]

(a) Less than outside (b) More than outside

(c) Same (d) Zero

3. Earth's magnetic field always has a horizontal component except at or Horizontal component of earth's magnetic field remains zero at

(a) Equator (b) Magnetic poles

(c) A latitude of 60° (d) An altitude of 60°

4. A dip needle in a plane perpendicular to magnetic meridian will remain [NCERT 1975; MP PMT 1984; MP PET 1995]

(a) Vertical

(b) Horizontal

(c) In any direction

(d) At an angle of dip to the horizontal

5. At magnetic poles of earth, angle of dip is

[CPMT 1977, 91; NCERT 1981; MP PET 1997; Pb PET 2002]

(a) Zero (b) 45°

(c) 90° (d) 180°

6. The correct relation is

[CPMT 1986; MP PET 1981; AFMC 1996]

(a) $\boldsymbol{B} = \dfrac{B_V}{B_H}$ (b) $\boldsymbol{B} = B_V \times B_H$

(c) $|\boldsymbol{B}| = \sqrt{B_H^2 + B_V^2}$ (d) $\boldsymbol{B} = B_H + B_V$

(Where B_H = Horizontal component of earth's magnetic field; B_V = Vertical component of earth's magnetic field and B = Total intensity of earth's magnetic field)

7. At a certain place, the horizontal component of earth's magnetic field is $\sqrt{3}$ times the vertical component. The angle of dip at that place is [MP PMT 1984, 85; AFMC 2000]

(a) 60° (b) 45°

(c) 90° (d) 30°

8. The vertical component of earth's magnetic field is zero at or The earth's magnetic field always has a vertical component except at the

[NCERT 1980, 88; CPMT 1983; MP PMT 1996]

(a) Magnetic poles (b) Geographical poles

(c) Every place (d) Magnetic equator

9. The angle between the magnetic meridian and geographical meridian is called

[MNR 1990; UPSEAT 1999, 2000; MP PMT 2000]

(a) Angle of dip (b) Angle of declination

(c) Magnetic moment (d) Power of magnetic field

10. The lines of forces due to earth's horizontal component of magnetic field are

[CPMT 1985; MP PMT 1980; AIIMS 1998]

(a) Parallel straight lines (b) Concentric circles

(c) Elliptical (d) Parabolic

11. At a place, if the earth's horizontal and vertical components of magnetic fields are equal, then the angle of dip will be

[SCRA 1994; DCE 2001; MP PMT 2002]

(a) 30° (b) 90°

(c) 45° (d) 0°

[CPMT 1971, 81, 83]

12. If the angles of dip at two places are 30° and 45° respectively, then the ratio of horizontal components of earth's magnetic field at the two places will be [MP PET 1989]

(a) $\sqrt{3} : \sqrt{2}$ (b) $1 : \sqrt{2}$

(c) $1 : \sqrt{3}$ (d) $1 : 2$

13. At a place the earth's horizontal component of magnetic field is $0.36 \times 10^{-4}\, weber/m^2$. If the angle of dip at that place is 60°, then the vertical component of earth's field at that place in *weber/m* will be approximately [MP PMT 1985]

(a) 0.12×10^{-4} (b) 0.24×10^{-4}

(c) 0.40×10^{-4} (d) 0.62×10^{-4}

14. The angle of dip at a place is 40.6° and the intensity of the vertical component of the earth's magnetic field $V = 6 \times 10^{-5}$ *Tesla*. The total intensity of the earth's magnetic field (*I*) at this place is

(a) $7 \times 10^{-5}\, tesla$ (b) $6 \times 10^{-5}\, tesla$

(c) $5 \times 10^{-5}\, tesla$ (d) $9.2 \times 10^{-5}\, tesla$

15. The angle of dip is the angle [CPMT 1978]

(a) Between the vertical component of earth's magnetic field and magnetic meridian

(b) Between the vertical component of earth's magnetic field and geographical meridian

(c) Between the earth's magnetic field direction and horizontal direction

(d) Between the magnetic meridian and the geographical meridian

16. At a certain place the angle of dip is 30° and the horizontal component of earth's magnetic field is 0.50 *Oersted*. The earth's total magnetic field is [CPMT 1990]

(a) $\sqrt{3}$ (b) 1

(c) $\frac{1}{\sqrt{3}}$ (d) $\frac{1}{2}$

17. The angle of dip at the magnetic equator is

[MP PET 1984; MP PMT 1987; CBSE PMT 1989, 90; MP Board 1980; CPMT 1977, 87, 90; Manipal MEE 1995]

(a) 0° (b) 45°

(c) 30° (d) 90°

18. The line on the earth's surface joining the points where the field is horizontal is

[MNR 1985; UPSEAT 1999; Pb PET 2004]

(a) Magnetic meridian (b) Magnetic axis

(c) Magnetic line (d) Magnetic equator

(e) Isogonic line

19. The angle between the earth's magnetic and the earth's geographical axes is [MNR 1979]

(a) Zero (b) 17°

(c) 23° (d) None of these

20. The lines joining the places of the same horizontal intensity are known as [MNR 1984]

(a) Isogonic lines (b) Aclinic lines

(c) Isoclinic lines (d) Agonic lines

(e) Isodynamic lines

21. Ratio between total intensity of magnetic field at equator to poles is

(a) 1 : 1 (b) 1 : 2

(c) 2 : 1 (d) 1 : 4

22. A line passing through places having zero value of magnetic dip is called [CPMT 1987]

(a) Isoclinic line (b) Agonic line

(c) Isogonic line (d) Aclinic line

23. At a place, the horizontal and vertical intensities of earth's magnetic field is 0.30 *Gauss* and 0.173 *Gauss* respectively. The angle of dip at this place is [MP PMT 1986]

(a) 30° (b) 90°

(c) 60° (d) 45°

24. The angle of dip at a place is 60°. At this place the total intensity of earth's magnetic field is 0.64 units. The horizontal intensity of earth's magnetic field at this place is

[MP PET 1984]

(a) 1.28 units (b) 0.64 units

(c) 0.16 units (d) 0.32 units

25. The magnetic compass is not useful for navigation near the magnetic poles because [BIT Ranchi 1982]

(a) The magnetic field near the poles is zero

(b) The magnetic field near the poles is almost vertical

(c) At low temperature, the compass needle looses its magnetic properties

(d) Neither of the above

26. The angle of dip at a place on the earth gives

[MP PET 1994]

(a) The horizontal component of the earth's magnetic field

(b) The location of the geographic meridian

(c) The vertical component of the earth's field

(d) The direction of the earth's magnetic field

27. At the magnetic north pole of the earth, the value of horizontal component of earth's magnetic field and angle of dip are, respectively [MP PMT 1994]

(a) Zero, maximum (b) Maximum, minimum

(c) Maximum, maximum (d) Minimum, minimum

28. At a place, the magnitudes of the horizontal component and total intensity of the magnetic field of the earth are 0.3 and 0.6 *Oersted* respectively. The value of the angle of dip at this place will be

(a) 60° (b) 45°

(c) 30° (d) 0°

29. A dip circle is at right angle to the magnetic meridian. What will be the apparent dip [AFMC 1995]

(a) 0° (b) 30°

(c) 60° (d) 90°

30. A bar magnet is placed north-south with its north pole due north. The points of zero magnetic field will be in which direction from the centre of the magnet

[MNR 1995; MP PMT 1995; UPSEAT 2000]

(a) North and south

(b) East and west

(c) North-east and south-west

(d) North-west and south-east [IIT 1979; CPMT 1986]

31. In two separate experiments the neutral points due to two small magnets are at a distance of r and $2r$ in broad side-on position. The ratio of their magnetic moments will be

(a) 4 : 1 (b) 1 : 2

(c) 2 : 1 (d) 1 : 8

32. The magnetic field due to the earth is closely equivalent to that due to [BIT Ranchi 1982]

(a) A large magnet of length equal to the diameter of the earth

(b) A magnetic dipole placed at the centre of the earth

(c) A large coil carrying current

(d) Neither of the above

33. The earth's magnetic field at a certain place has a horizontal component 0.3 *Gauss* and the total strength 0.5 *Gauss*. The angle of dip is [MP PMT 1995]

(a) $\tan^{-1}\frac{3}{4}$ (b) $\sin^{-1}\frac{3}{4}$

(c) $\tan^{-1}\frac{4}{3}$ (d) $\sin^{-1}\frac{3}{5}$

34. The value of the horizontal component of the earth's magnetic field and angle of dip are $1.8\times10^{-5}\,Weber/m^2$ and 30° respectively at some place. The total intensity of earth's magnetic field at that place will be [MP PET 1996]

(a) $2.08\times10^{-5}\,Weber/m^2$ (b) $3.67\times10^{-5}\,Weber/m^2$

(c) $3.18 \times 10^{-5} Weber/m^2$ (d) $5.0 \times 10^{-5} Weber/m^2$

35. When the *N*-pole of a bar magnet points towards the south and *S*-pole towards the north, the null points are at the [MP PMT 1996]

(a) Magnetic axis

(b) Magnetic centre

(c) Perpendicular divider of magnetic axis

(d) *N* and *S* poles

36. Lines which represent places of constant angle of dip are called

(a) Isobaric lines (b) Isogonic lines

(c) Isoclinic lines (d) Isodynamic lines

37. The vertical component of the earth's magnetic field is zero at a place where the angle of dip is [MP PMT/PET 1998]

(a) 0° (b) 45°

(c) 60° (d) 90°

38. At a certain place, the horizontal component B_0 and the vertical component V_0 of the earth's magnetic field are equal in magnitude. The total intensity at the place will be [MP PMT 1999, 2003]

(a) B_0 (b) B_0^2

(c) $2B_0$ (d) $\sqrt{2}B_0$

39. A compass needle will show which one of the following directions at the earth's magnetic pole [KCET 1993, 94]

(a) Vertical (b) No particular direction

(c) Bent at 45° to the vertical (d) Horizontal

40. The north pole of the earth's magnet is near the geographical

(a) South (b) East

(c) West (d) North

41. The magnetic field of earth is due to [JIPMER 1997]

(a) Motion and distribution of some material in and outside the earth

(b) Interaction of cosmic rays with the current of earth

(c) A magnetic dipole buried at the centre of the earth

(d) Induction effect of the sun

42. A short magnet of moment 6.75 *Am* produces a neutral point on its axis. If horizontal component of earth's magnetic field is $5 \times 10^{-5} Wb/m^2$, then the distance of the neutral point should be

(a) 10 *cm* (b) 20 *cm*

(c) 30 *cm* (d) 40 *cm*

43. Due to the earth's magnetic field, charged cosmic ray particles

(a) Require greater kinetic energy to reach the equator than the poles

(b) Require less kinetic energy to reach the equator than the poles

(c) Can never reach the equator

(d) Can never reach the poles

44. Two bar magnets with magnetic moments 2 *M* and *M* are fastened together at right angles to each other at their centres to form a crossed system, which can rotate freely about a vertical axis through the centre. The crossed system sets in earth's magnetic field with magnet having magnetic moment 2*M* making and angle θ with the magnetic meridian such that [AFMC 1999]

(a) $\theta = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (b) $\theta = \tan^{-1}\left(\sqrt{3}\right)$

(c) $\theta = \tan^{-1}\left(\frac{1}{2}\right)$ (d) $\theta = \tan^{-1}\left(\frac{3}{4}\right)$

45. Angle of dip is 90° at [AIIMS 1999]

(a) Poles (b) Equator

(c) Both (a) and (b) (d) None of these

46. At a certain place the horizontal component of the earth's magnetic field is *B* and the angle of dip is 45°. The total intensity of the field at that place will be [MP PET 2000; Pb PET 2003]

(a) *B* (b) $\sqrt{2}\,B_0$

(c) 2 *B* (d) B_0^2

47. The value of angle of dip is zero at the magnetic equator because on it [MP PET 2001]

(a) *V* and *H* are equal

(b) The value of *V* and *H* is zero

(c) The value of *V* is zero

(d) The value of *H* is zero

48. Which of the following relation is correct in magnetism [KCET (Engg./Med.) 2001]

(a) $I^2 = V^2 + H^2$ (b) $I = V + H$

(c) $V = I^2 + H^2$ (d) $V^2 = I + H$

49. The direction of the null points is on the equatorial line of a bar magnet, when the north pole of the magnet is pointing [KCET 1994] [AFMC 1999; Pb. PMT 2000; CPMT 2001; MH CET 2003]

(a) North (b) South

(c) East (d) West

50. Magnetic meridian is a [Orissa JEE 2002]

(a) Point (b) Horizontal plane

(c) Vertical plane (d) Line along *N-S*

51. The angle of dip at a certain place is 30°. If the horizontal component of the earth's magnetic field is *H*, the intensity of the total magnetic field is [SCRA 1994] [UPSEAT 1993, 2000; MP PMT 2002]

(a) $\frac{H}{2}$ [CBSE PMT 1997] (b) $\frac{2H}{\sqrt{3}}$

(c) $H\sqrt{2}$ (d) $H\sqrt{3}$

52. The horizontal component of the earth's magnetic field is 0.22 *Gauss* and total magnetic field is 0.4 *Gauss*. The angle of dip. is

(a) $\tan^{-1}(1)$ (b) $\tan^{-1}(\infty)$

(c) $\tan^{-1}(1.518)$ (d) $\tan^{-1}(\pi)$

53. A bar magnet is situated on a table along east-west direction in the magnetic field of earth. The number of neutral points, where the magnetic field is zero, are [MP PMT 2004]

(a) 2 (b) 0

(c) 1 (d) 4

54. At which place, earth's magnetism become horizontal [AFMC 2004]

(a) Magnetic pole (b) Geographical pole

(c) Magnetic meridian (d) Magnetic equator

55. Isogonic lines on magnetic map will have [AFMC 2004]

(a) Zero angle of dip

(b) Zero angle of declination

(c) Same angle of declination

(d) Same angle of dip

56. A current carrying coil is placed with its axis perpendicular to *N-S* direction. Let horizontal component of earth's magnetic field be H_0 and magnetic field inside the loop is *H*. If a magnet is suspended inside the loop, it makes angle θ with *H*. Then θ =

(a) $\tan^{-1}\left(\frac{H_0}{H}\right)$ (b) $\tan^{-1}\left(\frac{H}{H_0}\right)$

(c) $\text{cosec}^{-1}\left(\frac{H}{H_0}\right)$ (d) $\cot^{-1}\left(\frac{H_0}{H}\right)$

57. Let *V* and *H* be the vertical and horizontal components of earth's magnetic field at any point on earth. Near the north pole

(a) $V >> H$ (b) $V << H$

(c) $V = H$ (d) $V = H = 0$

58. At the magnetic poles of the earth, a compass needle will be [DCE 2003]

(a) Vertical

(b) Bent slightly

(c) Horizontal

(d) Inclined at 45° to the horizontal

59. If magnetic lines of force are drawn by keeping magnet vertical, then number of neutral points will be [MP PMT 1985; CPMT 1985]

(a) One (b) Two

(c) Four (d) Five

Magnetic Equipments

1. Time period of a freely suspended magnet does not depend upon [NCERT 1980; CPMT 1986; MP PET 1997]

(a) Length of the magnet

(b) Pole strength of the magnet

(c) Horizontal component of earth's magnetic field

(d) Length of the suspension thread

2. Magnetic moments of two bar magnets may be compared with the help of [MP PET/PMT 1988]

(a) Deflection magnetometer

(b) Vibration magnetometer

(c) Both of the above

(d) None of the above

3. The time period of oscillation of a freely suspended bar magnet with usual notations is given by [CPMT 1973, 76, 87; MP PET 1994, 96]

(a) $T = 2\pi\sqrt{\frac{I}{MB_H}}$ (b) $T = 2\pi\sqrt{\frac{MB_H}{I}}$

(c) $T = \sqrt{\frac{I}{MB_H}}$ (d) $T = 2\pi\sqrt{\frac{B_H}{MI}}$

4. In sum and difference method in vibration magnetometer, the time period is more if [MP PMT 1989; MP PET/PMT 1988]

(a) Similar poles of both magnets are on same sides

(b) Opposite poles of both magnets are on same sides

(c) Both magnets are perpendicular to each other

(d) Nothing can be said

[Orissa PMT 2004]

5. At a certain place a magnet makes 30 oscillations per minute. At another place where the magnetic field is double, its time period will be [MP PMT 1989; MP PET/PMT 1988]

(a) 4 *sec* (b) 2 *sec*

(c) $\frac{1}{2}$ sec (d) $\sqrt{2}$ sec

[UPSEAT 2004]

6. Vibration magnetometer is used for comparing [MP PET/PMT 1988]

(a) Magnetic fields (b) Earth's field

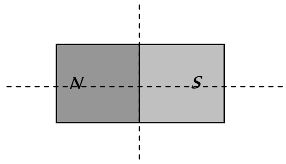
(c) Magnetic moments (d) All of the above

7. Two magnets of same size and mass make respectively 10 and 15 *oscillations per minute* at certain place. The ratio of their magnetic moments is [Bihar PET 1984; MP PET/PMT 1988; MP PET 1992]

(a) 4 : 9 (b) 9 : 4

(c) 2 : 3 (d) 3 : 2

8. Time period for a magnet is *T*. If it is divided in four equal parts along its axis and perpendicular to its axis as shown then time period for each part will be



(a) $4T$ (b) $T/4$

(c) $T/2$ (d) T

9. Keeping dissimilar poles of two magnets of equal pole strength and length same side, their time period will be [DPMT 2001]

(a) Zero (b) One second

(c) Infinity (d) Any value

10. Time period in vibration magnetometer will be infinity at

(a) Magnetic equator (b) Magnetic poles

(c) Equator (d) At all places

11. Twists of suspension fibre should be removed in vibration magnetometer so that

(a) Time period be less

(b) Time period be more

(c) Magnet may vibrate freely

(d) Cannot be said with certainty

12. The period of oscillation of a magnet in vibration magnetometer is 2 sec. The period of oscillation of a magnet whose magnetic moment is four times that of the first magnet is[CPMT 1975, 77, 79, 89, 90; MP PMT 1986]

(a) 1 *sec* (b) 4 *sec*

(c) 8 *sec* (d) 0.5 *sec*

13. Moment of inertia of a magnetic needle is 40 *gm-cm* has time period 3 *seconds* in earth's horizontal field = 3.6×10^{-5} *weber/m*. Its magnetic moment will be

(a) $0.5\, A \times m^2$ (b) $5\, A \times m^2$

(c) $0.250\, A \times m^2$ (d) $5 \times 10^2\, A \times m^2$

14. Vibration magnetometer before use, should be set

(a) In magnetic meridian

(b) In geographical meridian

(c) Perpendicular to magnetic meridian

(d) In any position

15. If a brass bar is placed on a vibrating magnet, then its time period

(a) Decreases

(b) Increases

(c) Remains unchanged

(d) First increases then decreases

16. A magnetic needle is made to vibrate in uniform field *H*, then its time period is *T*. If it vibrates in the field of intensity 4*H*, its time period will be

[MP Board 1988; MP PMT 1992; MH CET (Med.) 1999]

(a) $2T$ (b) $T/2$

(c) $2/T$ (d) T

17. Two bar magnets of the same mass, length and breadth but magnetic moments *M* and 2*M* respectively, when placed in same position, time period is 3 *sec*. What will be the time period when they are placed in different position

[NCERT 1977; DPMT 1999]

(a) $\sqrt{3}$ sec (b) $3\sqrt{3}$ sec

(c) 3 sec (d) 6 sec

18. To compare magnetic moments of two magnets by vibration magnetometer, 'sum and difference method' is better because

(a) Determination of moment of inertia is not needed which minimises the errors

(b) Less observations are required

(c) Comparatively less calculations

(d) All the above

19. A magnet is suspended in such a way that it oscillates in the horizontal plane. It makes 20 *oscillations per minute* at a place where dip angle is 30° and 15 *oscillations per minute* at a place where dip angle is 60°. The ratio of total earth's magnetic field at the two places is

[MP PMT 1991; BHU 1997]

(a) $3\sqrt{3}:8$ (b) $16:9\sqrt{3}$

(c) $4:9$ (d) $2\sqrt{3}:9$

20. The time period of oscillation of a magnet in a vibration magnetometer is 1.5 *seconds*. The time period of oscillation of another magnet similar in size, shape and mass but having one-fourth magnetic moment than that of first magnet, oscillating at same place will be

[MP PMT 1991; MP PMT 2002]

(a) 0.75 *sec* (b) 1.5 *sec*

(c) 3 *sec* (d) 6 *sec*

21. A bar magnet *A* of magnetic moment M_A is found to oscillate at a frequency twice that of magnet *B* of magnetic moment M_B when placed in a vibrating *magneto-meter*. We may say that

(a) $M_A = 2M_B$ (b) $M_A = 8M_B$

(c) $M_A = 4M_B$ (d) $M_B = 8M_A$

22. Two magnets *A* and *B* are identical in mass, length and breadth but have different magnetic moments. In a vibration magnetometer, if the time period of *B* is twice the time period of *A*. The ratio of the magnetic moments M_A / M_B of the magnets will be [MP PET 1990; MP PMT 19

(a) $1/2$ (b) 2

(c) 4 (d) $1/4$

23. A magnet of magnetic moment *M* oscillating freely in earth's horizontal magnetic field makes *n* oscillations per minute. If the magnetic moment is quadrupled and the earth's field is doubled, the number of oscillations made per minute would be

(a) $\frac{n}{2\sqrt{2}}$ (b) $\frac{n}{\sqrt{2}}$

(c) $2\sqrt{2}n$ (d) $\sqrt{2}n$

24. A magnetic needle suspended horizontally by an unspun silk fibre, oscillates in the horizontal plane because of the restoring force originating mainly from [CPMT 1980, 89]

(a) The torsion of the silk fibre

(b) The force of gravity

(c) The horizontal component of earth's magnetic field

(d) All the above factors

25. At two places *A* and *B* using vibration magnetometer, a magnet vibrates in a horizontal plane and its respective periodic time are 2 *sec* and 3 *sec* and at these places the earth's horizontal components are H_A and H_B respectively. Then the ratio between H_A and H_B will be

[MP PMT 1985, 89]

(a) 9 : 4 (b) 3 : 2

(c) 4 : 9 (d) 2 : 3

26. The time period of a bar magnet suspended horizontally in the earth's magnetic field and allowed to oscillate

[MP PET 1992]

(a) Is directly proportional to the square root of its mass

(b) Is directly proportional to its pole strength

(c) Is inversely proportional to its magnetic moment

(d) Decreases if the length increases but pole strength remains same

27. Magnets *A* and *B* are geometrically similar but the magnetic moment of *A* is twice that of *B*. If T_1 and T_2 be the time periods of the oscillation when their like poles and unlike poles are kept together respectively, then $\frac{T_1}{T_2}$ will be

[SCRA 1998]

(a) $\frac{1}{3}$ (b) $\frac{1}{2}$

(c) $\frac{1}{\sqrt{3}}$ (d) $\sqrt{3}$

28. A small bar magnet *A* oscillates in a horizontal plane with a period *T* at a place where the angle of dip is 60°. When the same needle is made to oscillate in a vertical plane coinciding with the magnetic meridian, its period will be

[MP PMT 1992]

(a) $\frac{T}{\sqrt{2}}$ (b) T

(c) $\sqrt{2}T$ (d) $2T$

29. Vibration magnetometer works on the principle of **[MP PET 1993]**

(a) Torque acting on the bar magnet
(b) Force acting on the bar magnet
(c) Both the force and the torque acting on the bar magnet
(d) None of these

30. Tangent galvanometer is used to measure **[MP PET 1993]**

(a) Steady currents
(b) Current impulses
(c) Magnetic moments of bar magnets
(d) Earth's magnetic field

31. A tangent galvanometer has a coil with 50 turns and radius equal to 4 *cm*. A current of 0.1 *A* is passing through it. The plane of the coil is set parallel to the earth's magnetic meridian. If the value of the earth's horizontal component of the magnetic field is 7×10^{-5} *tesla* and $\mu_0 = 4\pi\times10^{-7}\,weber/amp\times m$, then the deflection in the galvanometer needle will be **[MP PMT 1993]**

(a) 45° (b) 48.2°
(c) 50.7° (d) 52.7°

32. A bar magnet has a magnetic moment equal to $5\times10^{-5}\,weber\times m$. It is suspended in a magnetic field which has a magnetic induction (*B*) equal to $8\pi\times10^{-4}\,tesla$ The magnet vibrates with a period of vibration equal to 15 *sec*. The moment of inertia of the magnet is **[MP PMT 1993; CBSE PMT 2001]**

(a) $22.5 kg\times m^2$ (b) $11.25\times kg\times m^2$

(c) $5.62\times kg\times m^2$ (d) $7.16\times10^{-7}kg-m^2$

33. The time period of a freely suspended magnet is 4 *seconds*. If it is broken in length into two equal parts and one part is suspended in the same way, then its time period will be **[NCERT 1984; CPMT 1991; MP PMT 1994; MH CET 2004]**

(a) 4 *sec* (b) 2 *sec*

(c) 0.5 *sec* (d) 0.25 *sec*

34. Which of the following statement is true about magnetic moments of atoms of different elements **[CPMT 1977]**

(a) All have a magnetic moment
(b) None has a magnetic moment
(c) All acquire a magnetic moment under external magnetic field and in same direction as the field
(d) None of the above statements are accurate

35. The number of turns and radius of cross-section of the coil of a tangent galvanometer are doubled. The reduction factor *K* will be **[NCERT 1983; MP PMT 2002]**

(a) *K* (b) 2*K*

(c) 4*K* (d) *K*/4

36. A magnetic needle suspended by a silk thread is vibrating in the earth's magnetic field. If the temperature of the needle is increased by 500°*C*, then **[MNR 1994]**

(a) The time period decreases
(b) The time period remains unchanged
(c) The time period increases
(d) The needle stops vibrating

37. The sensitivity of a tangent galvanometer is increased if **[AFMC 1995]**

(a) Number of turn decreases (b) Number of turn increases

(c) Field increases (d) None of the above

38. Two tangent galvanometers having coils of the same radius are connected in series. A current flowing in them produces deflections of 60° and 45° respectively. The ratio of the number of turns in the coils is **[MP PET 1995; MP PMT 1999]**

(a) 4/3 (b) $(\sqrt{3}+1)/1$

(c) $(\sqrt{3}+1)/(\sqrt{3}-1)$ (d) $\sqrt{3}/1$

39. Using a bar magnet *P*, a vibration magnetometer has time period 2*seconds*. When a bar *Q* (identical to *P* in mass and size) is placed on top of *P*, the time period is unchanged. Which of the following statements is true **[MP PMT 1995]**

(a) *Q* is of non-magnetic material
(b) *Q* is a bar magnet identical to *P*, and its north pole placed on top of *P*s north pole
(c) *Q* is of unmagnetized ferromagnetic material
(d) Nothing can be said about *Q*s properties

40. The strength of the magnetic field in which the magnet of a vibration magnetometer is oscillating is increased 4 times its original value. The frequency of oscillation would then become

(a) Twice its original value
(b) Four times its original value
(c) Half its original value
(d) One-fourth its original value

41. A certain amount of current when flowing in a properly set tangent galvanometer, produces a deflection of 45°. If the current be reduced by a factor of $\sqrt{3}$, the deflection would **[MP PMT 1996; DPMT 2005]**

(a) Decrease by 30° (b) Decrease by 15°

(c) Increase by 15° (d) Increase by 30°

42. Two normal uniform magnetic field contain a magnetic needle making an angle 60° with *F*. Then the ratio of $\frac{F}{H}$ is **[CPMT 1987; DPMT 2001]**

(a) 1 : 2 (b) 2 : 1

(c) $\sqrt{3}:1$ (d) $1:\sqrt{3}$

43. A short magnetic needle is pivoted in a uniform magnetic field of strength 1 *T*. When another magnetic field of strength $\sqrt{3}\,T$ is applied to the needle in a perpendicular direction, the needle deflects through an angle θ, where θ is **[KCET 1999]**

(a) 30° (b) 45°

(c) 90° (d) 60°

44. Two magnets are held together in a vibration magnetometer and are allowed to oscillate in the earth's magnetic field with like poles together, 12 oscillations per minute are made but for unlike poles together only 4 oscillations per minute are executed. The ratio of their magnetic moments is

[MP PMT 1996; CPMT 2002]

(a) 3 : 1 (b) 1 : 3

(c) 3 : 5 (d) 5 : 4

45. To measure which of the following, is a tangent galvanometer used [MP PET 1997; CBSE PMT 2001]

(a) Charge (b) Angle

(c) Current (d) Magnetic intensity

46. When $\sqrt{3}$ *ampere* current is passed in a tangent galvanometer, there is a deflection of 30° in it. The deflection obtained when 3 *amperes* current is passed, is

[MP PMT 1997]

(a) 30° (b) 45°

(c) 60° (d) 75°

47. The period of oscillations of a magnetic needle in a magnetic field is 1.0 *sec*. If the length of the needle is halved by cutting it, the time period will be [MP PMT/PET 1998]

(a) 1.0 *sec* (b) 0.5 *sec*

(c) 0.25 *sec* (d) 2.0 *sec*

48. The time period of a freely suspended magnet is 2 *sec*. If it is broken in length into two equal parts and one part is suspended in the same way, then its time period will be

[MP PMT 1999]

(a) 4 *sec* (b) 2 *sec*

(c) $\sqrt{2}$ sec (d) 1 *sec*

49. The bob of a simple pendulum is replaced by a magnet. The oscillations are set along the length of the magnet. A copper coil is added so that one pole of the magnet passes in and out of the coil. The coil is short-circuited. Then which one of the following happens

[KCET 1994]

(a) Period decreases

(b) Period does not change

(c) Oscillations are damped

(d) Amplitude increases

50. The period of oscillation of a vibration magnetometer depends on which of the following factors [KCET 1994]

(a) *I* and *M* only (b) *M* and *H* only

(c) *I* and *H* only (d) *I*, M and *H* only

where *I* is the moment of inertia of the magnet about the axis of suspension, *M* is the magnetic moment of the magnet and *H* is the external magnetic field

51. The time period of oscillation of a bar magnet suspended horizontally along the magnetic meridian is T_0. If this magnet is replaced by another magnet of the same size and pole strength but with double the mass, the new time period will be

(a) $\frac{T_0}{2}$ (b) $\frac{T_0}{\sqrt{2}}$

(c) $\sqrt{2}T_0$ (d) $2T_0$

52. Two short magnets having magnetic moments in the ratio 27 : 8, when placed on opposite sides of a deflection magnetometer, produce no deflection. If the distance of the weaker magnet is 0.12 *m* from the centre of deflection magnetometer, the distance of the stronger magnet from the centre is

(a) 0.06 *m* (b) 0.08 *m*

(c) 0.12 *m* (d) 0.18 *m*

53. The magnet of a vibration magnetometer is heated so as to reduce its magnetic moment by 19%. By doing this the periodic time of the magnetometer will [MP PMT 2000, 01]

(a) Increase by 19% (b) Decrease by 19%

(c) Increase by 11% (d) Decrease by 21%

54. A magnet makes 40 oscillations per minute at a place having magnetic field intensity of 0.1×10^{-5} *T*. At another place, it takes 2.5 *sec* to complete one vibration. The value of earth's horizontal field at that place is

[AIIMS 2000; CPMT 2000; Pb PET 2002]

(a) 0.25×10^{-6} *T* (b) 0.36×10^{-6} *T*

(c) 0.66×10^{-8} *T* (d) 1.2×10^{-6} *T*

55. A tangent galvanometer has a coil of 25 turns and radius of 15 *cm*. The horizontal component of the earth's magnetic field is 3×10^{-5} *T*. The current required to produce a deflection of 45° in it, is

[MP PMT 2000]

(a) 0.29 *A* (b) 1.2 *A*

(c) 3.6×10^{-5} *A* (d) 0.14 *A*

56. The time period of a vibration magnetometer is T_0. Its magnet is replaced by another magnet whose moment of inertia is 3 times and magnetic moment is 1/3 of the initial magnet. The time period now will be [MP PMT 2000]

(a) $3T_0$ (b) T_0

(c) $T_0/\sqrt{3}$ (d) $T_0/3$

57. The error in measuring the current with a tangent galvanometer is minimum when the deflection is about

[MP PET 2001]

(a) 0° (b) 30°

(c) 45° (d) 60°

58. Before using the tangent galvanometer, its coil is set in

[MP PMT 2001; CPMT 2005]

(a) Magnetic meridian (or vertically north south)

(b) Perpendicular to magnetic meridian

(c) At angle of 45° to magnetic meridian

(d) It does not require any setting

59. The time period of a thin bar magnet in earth's magnetic field is *T*. If the magnet is cut into two equal parts perpendicular to its length, the time period of each part in the same field will be

(a) $\frac{T}{2}$ (b) *T*

(c) $\sqrt{2}\,T$ (d) 2*T*

60. A magnet freely suspended in a vibration magnetometer makes 10 oscillations per minute at a place *A* and 20 oscillations per minute at a place *B*. If the horizontal component of earth's magnetic field at *A* is $36 \times 10^{-6}\,T$, then its value at *B* is [SCRA 1994; JIPMER 2001, 02]

(a) 36×10^{-6} *T* (b) 72×10^{-6} *T*

(c) 144×10^{-6} *T* (d) 288×10^{-6} *T*

61. When 2 *amperes* current is passed through a tangent galvanometer, it gives a deflection of 30°. For 60° deflection, the current must be [EAMCET (Med.) 2000]

(a) 1 *amp* (b) $2\sqrt{3}$ *amp*

(c) 4 *amp* (d) 6 *amp*

62. Which of the following statement is not the true

[KCET (Engg./Med.) 2001]

(a) While taking reading of tangent galvanometer, the plane of the coil must be set at right angles to the earth's magnetic meridian

(b) A short magnet is used in a tangent galvanometer since a long magnet would be heavy and may not easily move

(c) Measurements with the tangent galvanometer will be more accurate when the deflection is around 45°

(d) A tangent galvanometer can not be used in the polar region

63. The period of oscillations of a magnet is 2 *sec*. When it is remagnetised so that the pole strength is 4 times its period will be

(a) 4 *sec* (b) 2 *sec*

(c) 1 *sec* (d) 1/2 *sec*

64. When two magnetic moments are compared using equal distance method the deflections produced are 45° and 30°. If the length of magnets are in the ratio 1 : 2, the ratio of their pole strengths is

(a) 3 : 1 (b) 3 : 2

(c) $\sqrt{3}:1$ (d) $2\sqrt{3}:1$

65. The magnetic needle of a tangent galvanometer is deflected at an angle 30° due to a magnet. The horizontal component of earth's magnetic field 0.34×10^{-4} *T* is along the plane of the coil. The magnetic intensity is

[AIIMS 2000, 2002; BHU 2000; AFMC 2000; KCET (Engg./Med.) 1999]

(a) 1.96×10^{-4} *T* (b) 1.96×10^{-5} *T*

(c) 1.96×10^{4} *T* (d) 1.96×10^{5} *T*

66. In a tangent galvanometer a current of 0.1 *A* produces a deflection of 30°. The current required to produce a deflection of 60° is

(a) 0.2 A (b) 0.3 A

(c) 0.4 A (c) 0.5 A

67. A bar magnet is oscillating in the Earth's magnetic field with a period *T*. What happens to its period and motion if its mass is quadrupled **[CBSE PMT 2003]**

(a) Motion remains S.H.M. with time period = $2T$

(b) Motion remains S.H.M. with time period = $4T$

(c) Motion remains S.H.M. and period remains nearly constant

(d) Motion remains S.H.M. with time period $=\dfrac{T}{2}$

68. A thin rectangular magnet suspended freely has a period of oscillation equal to *T*. Now it is broken into two equal halves (each having half of the original length) and one piece is made to oscillate freely in the same field. If its period of oscillation is T', then ratio $\dfrac{T'}{T}$ is **[AIEEE 2003]**

(a) $\dfrac{1}{4}$ (b) $\dfrac{1}{2\sqrt{2}}$

(c) $\dfrac{1}{2}$ (c) 2

69. A bar magnet is oscillating in the earth's magnetic field with time period *T*. If its mass is increased four times then its time period will be **[J & K CET 2004]**

(a) 4 *T* (b) 2 *T*

(c) *T* (d) *T*/2

70. The length of a magnet is large compared to its width and breadth. The time period of its oscillation in a vibration magnetometer is 2 *s*. The magnet is cut along its length into three equal parts and three parts are then placed on each other with their like poles together. The time period of this combination will be

(a) 2 *s* (b) 2/3 *s*

(c) $2\sqrt{3}\ s$ (d) $2/\sqrt{3}\ s$

[Kerala PMT 2002]

71. A magnet oscillating in a horizontal plane has a time period of 2 *second* at a place where the angle of dip is 30° and 3 *seconds* at another place where the angle of dip is 60°. The ratio of resultant magnetic fields at the two places is

[Pb. PET 2001]

(a) $\dfrac{4\sqrt{3}}{7}$ (b) $\dfrac{4}{9\sqrt{3}}$

[JIPMER 2002]

(c) $\dfrac{9}{4\sqrt{3}}$ (d) $\dfrac{9}{\sqrt{3}}$

72. Two identical bar magnets are placed on above the other such that they are mutually perpendicular and bisect each other. The time period of this combination in a horizontal magnetic field is *T*. The time period of each magnet in the same field is

(a) $\sqrt{2}\,T$ (b) $2^{\frac{1}{4}}T$

(c) $2^{-\frac{1}{4}}T$ (d) $2^{-\frac{1}{2}}T$

[MP PET 2003]

73. The radius of the coil of a Tangent galvanometer. which has 10 turns is 0.1*m*. The current required to produce a deflection of 60° $(B_H=4\times10^{-5}T)$ is **[MP PET 2005]**

(a) 3 *A* (b) 1.1 *A*

(c) 2.1 *A* (d) 1.5 *A*

Magnetic Materials

1. Magnets cannot be made from which of the following substances

(a) Iron (b) Nickel

(c) Copper (d) All of the above

2. The magnetic moment of atomic neon is

[NCERT 1984]

(a) Zero (b) $\mu B/2$

(c) μB (d) $3\mu B/2$

3. Which of the following is most suitable for the core of electromagnets **[AIIMS 1980; NCERT 1980; AFMC 1988; CBSE PMT 1990]**

(a) Soft iron (b) Steel

(c) Copper-nickel alloy (d) Air

4. Demagnetisation of magnets can be done by

[DPMT 1984; CBSE PMT 1988]

(a) Rough handling

(b) Heating

(c) Magnetising in the opposite direction

(d) All the above

5. A ferromagnetic material is heated above its curie temperature. Which one is a correct statement [MP PET 1995]
   (a) Ferromagnetic domains are perfectly arranged
   (b) Ferromagnetic domains becomes random
   (c) Ferromagnetic domains are not influenced
   (d) Ferromagnetic material changes itself into diamagnetic material

6. If a diamagnetic substance is brought near north or south pole of a bar magnet, it is [EAMCET (Engg.) 1995; CBSE PMT 1999; AFMC 2003]
   (a) Attracted by the poles
   (b) Repelled by the poles
   (c) Repelled by the north pole and attracted by the south pole
   (d) Attracted by the north pole and repelled by the south pole

7. The material of permanent magnet has [KCET 1994, 2003; AFMC 2004]
   (a) High retentivity, low coercivity
   (b) Low retentivity, high coercivity
   (c) Low retentivity, low coercivity
   (d) High retentivity, high coercivity

8. The permanent magnet is made from which one of the following substances [Bihar MEE 1995]
   (a) Diamagnetic (b) Paramagnetic
   (c) Ferromagnetic (d) Electromagnetic

9. Temperature above which a ferromagnetic substance becomes paramagnetic is called [SCRA 1994; J & K CET 2004]
   (a) Critical temperature (b) Boyle's temperature
   (c) Debye's temperature (d) Curie temperature

10. When a magnetic substance is heated, then it [AIIMS 1999]
   (a) Becomes a strong magnet
   (b) Losses its magnetism
   (c) Does not effect the magnetism
   (d) Either (a) or (c)

11. The only property possessed by ferromagnetic substance is [KCET 1999]
   (a) Hysteresis
   (b) Susceptibility
   (c) Directional property
   (d) Attracting magnetic substances

12. Substances in which the magnetic moment of a single atom is not zero, is known as [AFMC 1999]
   (a) Diamagnetism (b) Ferromagnetism
   (c) Paramagnetism (d) Ferrimagnetism

13. Diamagnetic substances are [AFMC 1999]
   (a) Feebly attracted by magnets
   (b) Strongly attracted by magnets
   (c) Feebly repelled by magnets
   (d) Strongly repelled by magnets

14. The magnetic susceptibility is [RPMT 1999]
   (a) $\chi = \frac{I}{H}$ (b) $\chi = \frac{B}{H}$
   (c) $\chi = \frac{M}{V}$ (d) $\chi = \frac{M}{H}$

15. Which of the following statements are true about the magnetic susceptibility χ_m of paramagnetic substance [Roorkee 1999]
   (a) Value of χ_m is inversely proportional to the absolute temperature of the sample
   (b) χ_m is positive at all temperature
   (c) χ_m is negative at all temperature
   (d) χ_m does not depend on the temperature of the sample

16. Relative permeability of iron is 5500, then its magnetic susceptibility will be [KCET 2000; Kerala PMT 2004]
   (a) 5500×10^{7} (b) 5500×10^{-7}
   (c) 5501 (d) 5499

17. An example of a diamagnetic substance is [KCET 2000]
   (a) Aluminium (b) Copper
   (c) Iron (d) Nickel

18. The use of study of hysteresis curve for a given material is to estimate the [KCET (Engg./Med.) 2000]
   (a) Voltage loss (b) Hysteresis loss
   (c) Current loss (d) All of these

19. Magnetic permeability is maximum for [AIIMS 2000; MH CET 2003; DPMT 2003]
   (a) Diamagnetic substance (b) Paramagnetic substance
   (c) Ferromagnetic substance (d) All of these

20. If a diamagnetic solution is poured into a *U*-tube and one arm of this *U*-tube placed between the poles of a strong magnet with the meniscus in a line with the field, then the level of the solution will
   (a) Rise (b) Fall
   (c) Oscillate slowly (d) Remain as such

21. The relative permeability is represented by μ_r and the susceptibility is denoted by χ for a magnetic substance. Then for a paramagnetic substance [KCET (Engg./Med.) 2001]
   (a) $\mu_r < 1, \chi < 0$ (b) $\mu_r < 1, \chi > 0$
   (c) $\mu_r > 1, \chi < 0$ (d) $\mu_r > 1, \chi > 0$

22. Which of the following is true [BHU 2001]
   (a) Diamagnetism is temperature dependent
   (b) Paramagnetism is temperature dependent
   (c) Paramagnetism is temperature independent
   (d) None of these

23. The magnetic susceptibility does not depend upon the temperature in [CBSE PMT 2001]
   (a) Ferrite substances (b) Ferromagnetic substances
   (c) Diamagnetic substances (d) Paramagnetic substances

24. Identify the paramagnetic substance [KCET 2001]
   (a) Iron (b) Aluminium
   (c) Nickel (d) Hydrogen

25. If a magnetic substance is kept in a magnetic field, then which of the following is thrown out [DCE 1999, 2001]

(a) Paramagnetic (b) Ferromagnetic
(c) Diamagnetic (d) Antiferromagnetic

26. If the angular momentum of an electron is $\vec{J}$ then the magnitude of the magnetic moment will be [MP PET 2002]

(a) $\frac{eJ}{m}$ (b) $\frac{eJ}{2m}$
(c) $eJ\,2m$ (d) $\frac{2m}{eJ}$

27. The magnetic susceptibility is negative for [AIEEE 2002]

(a) Paramagnetic materials
(b) Diamagnetic materials
(c) Ferromagnetic materials
(d) Paramagnetic and ferromagnetic materials

28. The universal property of all substances is [CPMT 2002]

(a) Diamagnetism (b) Ferromagnetism
(c) Paramagnetism (d) All of these

29. Which of the following statements is incorrect about hysteresis

(a) This effect is common to all ferromagnetic substances
(b) The hysteresis loop area is proportional to the thermal energy developed per unit volume of the material
(c) The hysteresis loop area is independent of the thermal energy developed per unit volume of the material
(d) The shape of the hysteresis loop is characteristic of the material

30. Curies law can be written as

[MH CET 2002; CBSE PMT 2003]

(a) $\chi \propto (T - T_c)$ (b) $\chi \propto \frac{1}{T - T_c}$
(c) $\chi \propto \frac{1}{T}$ (d) $\chi \propto T$

31. A superconductor exhibits perfect [KCET 2002]

(a) Ferrimagnetism (b) Ferromagnetism
(c) Paramagnetism (d) Diamagnetism

32. A small rod of bismuth is suspended freely between the poles of a strong electromagnet. It is found to arrange itself at right angles to the magnetic field. This observation establishes that bismuth is

(a) Diamagnetic (b) Paramagnetic
(c) Ferri-magnetic (d) Antiferro-magnetic

33. A diamagnetic material in a magnetic field moves

[Pb. PMT 1999; AIIMS 2000; MH CET 2000; CBSE PMT 2003]

(a) From weaker to the stronger parts of the field
(b) Perpendicular to the field
(c) From stronger to the weaker parts of the field
(d) In none of the above directions

34. Curie temperature is the temperature above which

[DCE 2002; AIEEE 2003]

(a) A paramagnetic material becomes ferromagnetic
(b) A ferromagnetic material becomes paramagnetic
(c) A paramagnetic material becomes diamagnetic
(d) A ferromagnetic material becomes diamagnetic

35. A frog can be deviated in a magnetic field produced by a current in a vertical solenoid placed below the frog. This is possible because the body of the frog behaves as

[AIIMS 2003]

(a) Paramagnetic (b) Diamagnetic
(c) Ferromagnetic (d) Antiferromagnetic

36. Which one of the following is a non-magnetic substance

[MP PET 2004]

(a) Iron (b) Nickel
(c) Cobalt (d) Brass

37. Liquid oxygen remains suspended between two pole faces of a magnet because it is [AIIMS 2004]

(a) Diamagnetic (b) Paramagnetic
(c) Ferromagnetic (d) Antiferromagnetic

38. Curie-Weiss law is obeyed by iron at a temperature ......

[KCET 2004]

(a) Below Curie temperature (b) Above Curie temperature
(c) At Curie temperature only (d) At all temperatures

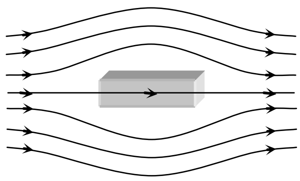
39. The materials suitable for making electromagnets should have

[UPSEAT 2002]

(a) High retentivity and high coercivity
(b) Low retentivity and low coercivity
(c) High retentivity and low coercivity
(d) Low retentivity and high coercivity

40. The given figure represents a material which is

[Orissa PMT 2004]



(a) Paramagnetic (b) Diamagnetic
(c) Ferromagnetic (d) None of these

41. For an isotropic medium B, μ, H and M are related as (where B, μ_0, H and M have their usual meaning in the context of magnetic material [Pb. PMT 2004]

[Kerala 2002]

(a) $(B - M) = \mu_0 H$ (b) $M = \mu_0(H + M)$
(c) $H = \mu_0(H + M)$ (d) $B = \mu_0(H + M)$

42. The magnetic susceptibility of any paramagnetic material changes with absolute temperature T as

[UPSEAT 2004; DCE 2005]

(a) Directly proportional to T
(b) Remains constant
(c) Inversely proportional to T
(d) Exponentially decaying with T

43. When a piece of a ferromagnetic substance is put in a uniform magnetic field, the flux density inside it is four times the flux density away from the piece. The magnetic permeability of the material is

(a) 1 (b) 2
(c) 3 (d) 4

44. Which of the following is diamagnetism [DCE 2002]

(a) Aluminium (b) Quartz

(c) Nickel (d) Bismuth

45. If a ferromagnetic material is inserted in a current carrying solenoid, the magnetic field of solenoid **[DCE 2004]**

(a) Largely increases (b) Slightly increases

(c) Largely decreases (d) Slightly decreases

46. In the hysteresis cycle, the value of H needed to make the intensity of magnetisation zero is called **[DCE 2004]**

(a) Retentivity (b) Coercive force

(c) Lorentz force (d) None of the above

47. If the magnetic dipole moment of an atom of diamagnetic material, paramagnetic material and ferromagnetic material denoted by μ_d, μ_p, μ_f respectively then **[CBSE PMT 2005]**

(a) $\mu_d \neq 0$ and $\mu_f \neq 0$ (b) $\mu_p = 0$ and $\mu_f \neq 0$

(c) $\mu_d = 0$ and $\mu_p \neq 0$ (d) $\mu_d \neq 0$ and $\mu_p = 0$

48. Among the following properties describing diamagnetism identify the property that is wrongly stated **[KCET 2005]**

(a) Diamagnetic material do not have permanent magnetic moment

(b) Diamagnetism is explained in terms of electromagnetic induction

(c) Diamagnetic materials have a small positive susceptibility

(d) The magnetic moment of individual electrons neutralize each other

49. Susceptibility of ferromagnetic substance is **[Orissa JEE 2005]**

(a) > 1 (b) < 1

(c) 0 (d) 1

50. When a ferromagnetic material is heated to temperature above its Curie temperature, the material **[UPSEAT 2005]**

(a) Is permanently magnetized

(b) Remains ferromagnetic

(c) Behaves like a diamagnetic material

(d) Behaves like a paramagnetic material

CT Critical Thinking

Objective Questions

1. Two identical magnetic dipoles of magnetic moments 1.0 A-m each, placed at a separation of $2m$ with their axis perpendicular to each other. The resultant magnetic field at a point midway between the dipoles is **[Roorkee 1995]**

(a) $5 \times 10^{-7} T$ (b) $\sqrt{5} \times 10^{-7} T$

(c) $10^{-7} T$ (d) None of these

2. Two short magnets placed along the same axis with their like poles facing each other repel each other with a force which varies inversely as

(a) Square of the distance

(b) Cube of the distance

(c) Distance

(d) Fourth power of the distance

3. Two identical short bar magnets, each having magnetic moment M, are placed a distance of $2d$ apart with axes perpendicular to each other in a horizontal plane. The magnetic induction at a point midway between them is **[IIT-JEE (Screening) 2000]**

(a) $\frac{\mu_0}{4\pi}(\sqrt{2})\frac{M}{d^3}$ (b) $\frac{\mu_0}{4\pi}(\sqrt{3})\frac{M}{d^3}$

(c) $\left(\frac{2\mu_0}{\pi}\right)\frac{M}{d^3}$ (d) $\frac{\mu_0}{4\pi}(\sqrt{5})\frac{M}{d^3}$

4. If a magnet is suspended at an angle 30° to the magnetic meridian, it makes an angle of 45° with the horizontal. The real dip is

(a) $\tan^{-1}(\sqrt{3}/2)$ (b) $\tan^{-1}(\sqrt{3})$

(c) $\tan^{-1}(\sqrt{3/2})$ (d) $\tan^{-1}(2/\sqrt{3})$

5. A short bar magnet with its north pole facing north forms a neutral point at P in the horizontal plane. If the magnet is rotated by 90° in the horizontal plane, the net magnetic induction at P is (Horizontal component of earth's magnetic field = B_H)

(a) 0 (b) $2B_H$

(c) $\frac{\sqrt{5}}{2}B_H$ (d) $\sqrt{5}B_H$

6. The true value of angle of dip at a place is 60°, the apparent dip in a plane inclined at an angle of 30° with magnetic meridian is

(a) $\tan^{-1}\frac{1}{2}$ (b) $\tan^{-1}(2)$

(c) $\tan^{-1}\left(\frac{2}{3}\right)$ (d) None of these

7. A vibration magnetometer consists of two identical bar magnets placed one over the other such that they are perpendicular and bisect each other. The time period of oscillation in a horizontal magnetic field is $2^{5/4}$ *seconds*. One of the magnets is removed and if the other magnet oscillates in the same field, then the time period in seconds is

(a) $2^{1/4}$ (b) $2^{1/2}$

(c) 2 (d) $2^{3/4}$

8. In a vibration magnetometer, the time period of a bar magnet oscillating in horizontal component of earth's magnetic field is 2 *sec*. When a magnet is brought near and parallel to it, the time period reduces to 1 *sec*. The ratio H/F of the horizontal component H and the field F due to magnet will be **[MP PMT 1990; Pb PET 2000]**

(a) 3 (b) $1/3$

(c) $\sqrt{3}$ (d) $1/\sqrt{3}$

9. A cylindrical rod magnet has a length of 5 cm and a diameter of 1 cm. It has a uniform magnetisation of 5.30 × 10^3 Amp/m. What its magnetic dipole moment

(a) $1 \times 10^{-2} J/T$ (b) $2.08 \times 10^{-2} J/T$

(c) $3.08 \times 10^{-2} J/T$ (d) $1.52 \times 10^{-2} J/T$

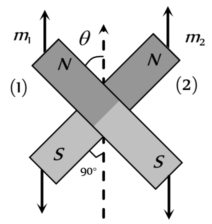
10. Two magnets of equal mass are joined at right angles to each other as shown the magnet 1 has a magnetic moment 3 times that of magnet 2. This arrangement is pivoted so that it is free to rotate in the horizontal plane. In equilibrium what angle will the magnet 1 subtend with the magnetic meridian

(a) $\tan^{-1}\left(\frac{1}{2}\right)$

(b) $\tan^{-1}\left(\frac{1}{3}\right)$

(c) $\tan^{-1}(1)$

(d) 0°



11. The dipole moment of each molecule of a paramagnetic gas is 1.5×10^{-23} *amp* × m^2. The temperature of gas is 27°*C* and the number of molecules per unit volume in it is 2×10^{26} m^{-3}. The maximum possible intensity of magnetisation in the gas will be

(a) 3×10^{3} *amp/m* (b) 4×10^{-3} *amp/m*

(c) 5×10^{5} *amp/m* (d) 6×10^{-4} *amp/m*

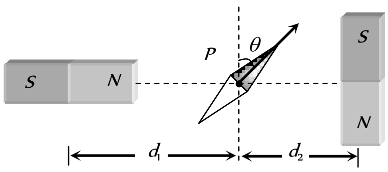
12. Two magnets *A* and *B* are identical and these are arranged as shown in the figure. Their length is negligible in comparison to the separation between them. A magnetic needle is placed between the magnets at point *P* which gets deflected through an angle θ under the influence of magnets. The ratio of distance d_1 and d_2 will be

(a) $(2\tan\theta)^{1/3}$

(b) $(2\tan\theta)^{-1/3}$

(c) $(2\cot\theta)^{1/3}$

(d) $(2\cot\theta)^{-1/3}$



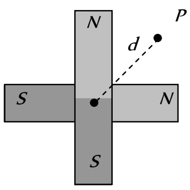
13. Two short magnets of equal dipole moments *M* are fastened perpendicularly at their centre (figure). The magnitude of the magnetic field at a distance *d* from the centre on the bisector of the right angle is

(a) $\frac{\mu_0}{4\pi}\frac{M}{d^3}$

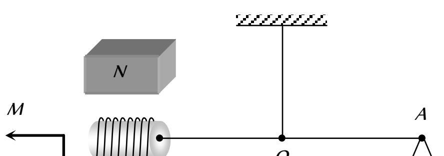
(b) $\frac{\mu_0}{4\pi}\frac{M\sqrt{2}}{d^3}$

(c) $\frac{\mu_0}{4\pi}\frac{2\sqrt{2}M}{d^3}$

(d) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$



14. A small coil C with *N* = 200 turns is mounted on one end of a balance beam and introduced between the poles of an electromagnet as shown in figure. The cross sectional area of coil is A= 1.0 *cm*, length of arm OA of the balance beam is $l = 30\,cm$. When there is no current in the coil the balance is in equilibrium. On passing a current *I* = 22 mA through the coil the equilibrium is restored by putting the additional counter weight of mass $\Delta m = 60\,mg$ on the balance pan. Find the magnetic induction at the spot where coil is located.



(a) 0.4 *T* (b) 0.3 *T*

(c) 0.2 *T* (d) 0.1 *T*

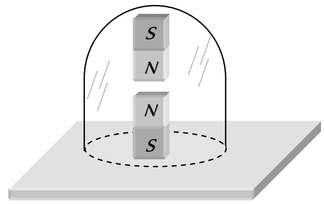
15. Two identical bar magnets with a length 10 *cm* and weight 50 *gm-weight* are arranged freely with their like poles facing in a inverted vertical glass tube. The upper magnet hangs in the air above the lower one so that the distance between the nearest pole of the magnet is 3*mm*. Pole strength of the poles of each magnet will be

(a) 6.64 *amp* × *m*

(b) 2 *amp* × *m*

(c) 10.25 *amp* × *m*

(d) None of these



16. If ϕ_1 and ϕ_2 be the angles of dip observed in two vertical planes at right angles to each other and ϕ be the true angle of dip, then

(a) $\cos^2\phi = \cos^2\phi_1 + \cos^2\phi_2$

(b) $\sec^2\phi = \sec^2\phi_1 + \sec^2\phi_2$

(c) $\tan^2\phi = \tan^2\phi_1 + \tan^2\phi_2$

(d) $\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$

17. Each atom of an iron bar $(5\,cm \times 1\,cm \times 1\,cm)$ has a magnetic moment $1.8 \times 10^{-23}\ Am^2$. Knowing that the density of iron is $7.78 \times 10^3\ kg^{-3}m$, atomic weight is 56 and Avogadro's number is 6.02×10^{23} the magnetic moment of bar in the state of magnetic saturation will be

(a) $4.75\ Am^2$ (b) $5.74\ Am^2$

(c) $7.54\ Am^2$ (d) $75.4\ Am^2$

18. An iron rod of volume $10^{-4}\,m^3$ and relative permeability 1000 is placed inside a long solenoid wound with 5 *turns/cm*. If a current of 0.5 *A* is passed through the solenoid, then the magnetic moment of the rod is

(a) $10\ Am^2$ (b) $15\ Am^2$

(c) $20\ Am^2$ (d) $25\ Am^2$

19. A bar magnet has coercivity $4 \times 10^3\ Am^{-1}$. It is desired to demagnetise it by inserting it inside a solenoid 12 *cm* long and having 60 turns. The current that should be sent through the solenoid is

(a) 2 *A* (b) 4 *A*

(c) 6 *A* (d) 8 *A*

20. A magnet is suspended in the magnetic meridian with an untwisted wire. The upper end of wire is rotated through 180° to deflect the magnet by 30° from magnetic meridian. When this magnet is replaced by another magnet, the upper end of wire is rotated through 270° to deflect the magnet 30° from magnetic meridian. The ratio of magnetic moments of magnets is

(a) 1 : 5 (b) 1 : 8

(c) 5 : 8 (d) 8 : 5

21. A dip needle vibrates in the vertical plane perpendicular to the magnetic meridian. The time period of vibration is found to be 2 *seconds*. The same needle is then allowed to vibrate in the horizontal plane and the time period is again found to be 2 *seconds*. Then the angle of dip is

(a) 0° (b) 30°

(c) 45° (d) 90°

22. The unit for molar susceptibility is

(a) m^3 (b) $kg\text{-}m^3$

(c) $kg^{-1}\ m^3$ (d) No units

23. A short magnet oscillates with a time period 0.1 *s* at a place where horizontal magnetic field is $24\mu T$. A downward current of 18 *A* is established in a vertical wire 20 *cm* east of the magnet. The new time period of oscillator

(a) 0.1 *s* (b) 0.089 *s*

(c) 0.076 *s* (d) 0.057 *s*

24. A dip needle lies initially in the magnetic meridian when it shows an angle of dip θ at a place. The dip circle is rotated through an angle *x* in the horizontal plane and then it shows an angle of dip θ'. Then $\dfrac{\tan\theta'}{\tan\theta}$ is

(a) $\dfrac{1}{\cos x}$ (b) $\dfrac{1}{\sin x}$

(c) $\dfrac{1}{\tan x}$ (d) $\cos x$

25. A dip circle is adjusted so that its needle moves freely in the magnetic meridian. In this position, the angle of dip is 40°. Now the dip circle is rotated so that the plane in which the needle moves makes an angle of 30° with the magnetic meridian. In this position the needle will dip by an angle

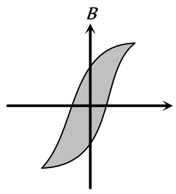
[DCE 2005]

(a) 40° (b) 30°

(c) More than 40° (d) Less than 40°

GQ Graphical Questions

1. For substances hysteresis (*B* - *H*) curves are given as shown in figure. For making temporary magnet which of the following is best.

(a)


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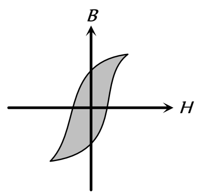

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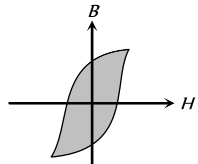
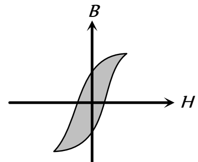
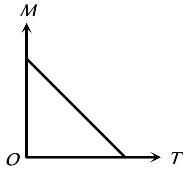


(d)


2. A curve between magnetic moment and temperature of magnet is

(a)


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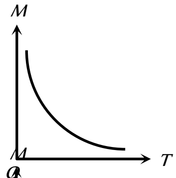

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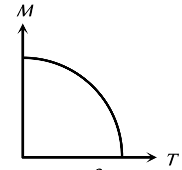
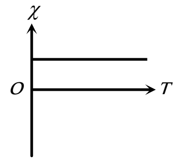
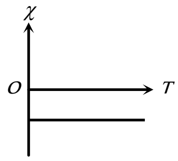
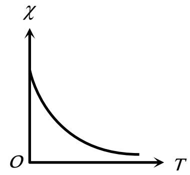


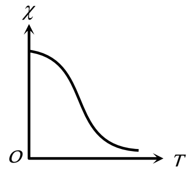
(d)


3. The variation of magnetic susceptibility (χ) with temperature for a diamagnetic substance is best represented by

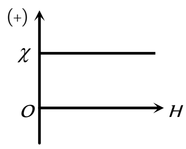
(a)


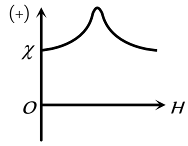
(b)


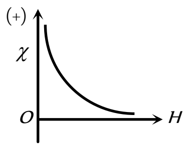
(c)


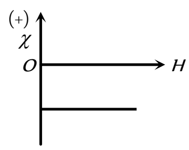
(d)


4. The variation of magnetic susceptibility (χ) with magnetising field for a paramagnetic substance is

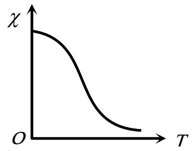
(a)


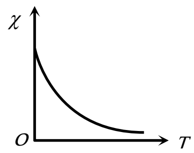
(b)


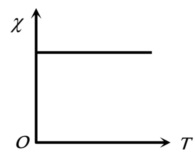
(c)


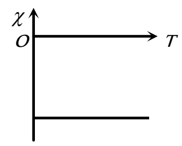
(d)


5. The variation of magnetic susceptibility (χ) with absolute temperature *T* for a ferromagnetic material is

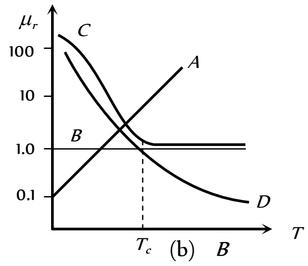
(a)


(b)


(c)


(d)


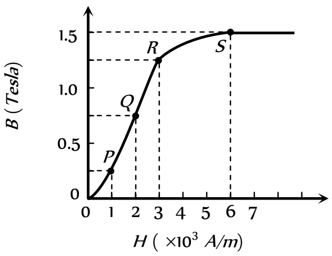
6. The relative permeability (μ_r) of a ferromagnetic substance varies with temperature *(T)* according to the curve



(a) *A* (b) *B*

(c) *C* (d) *D*

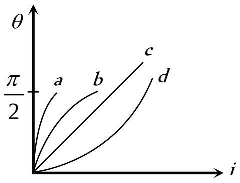
7. The basic magnetization curve for a ferromagnetic material is shown in figure. Then, the value of relative permeability is highest for the point



(a) *P* (b) *Q*

(c) *R* (d) *S*

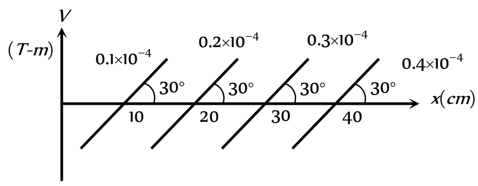
8. Which curve may best represent the current deflection in a tangent galvanometer



(a) *A* (b) *B*

(c) *C* (d) *D*

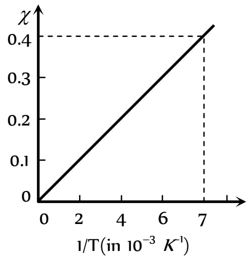
9. Some equipotential surfaces of the magnetic scalar potential are shown in the figure. Magnetic field at a point in the region is



(a) $10^{-4}T$ (b) $2\times10^{-4}T$

(c) $0.5\times10^{-4}T$ (d) None of these

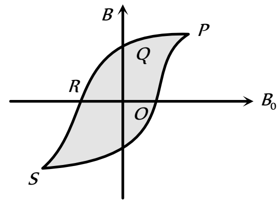
10. The $\chi - 1/T$ graph for an alloy of paramagnetic nature is shown in Fig. The curie constant is, then



(a) 57 *K* (b) $2.8\times10^{-3}K$

(c) 570 *K* (d) $17.5\times10^{-3}K$

11. The figure illustrate how *B*, the flux density inside a sample of unmagnetised ferromagnetic material varies with B_0, the magnetic flux density in which the sample is kept. For the sample to be suitable for making a permanent magnet **[AMU 2001]**



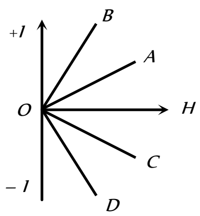
(a) *OQ* should be large, *OR* should be small

(b) *OQ* and *OR* should both be large

(c) *OQ* should be small and *OR* should be large

(d) *OQ* and *OR* should both be small

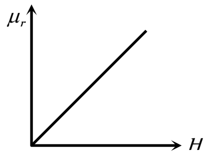
12. The variation of the intensity of magnetisation *(I)* with respect to the magnetising field *(H)* in a diamagnetic substance is described by the graph **[KCET 2002]**

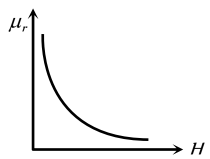


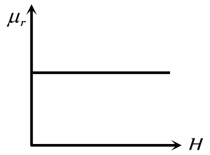
(a) *OD* (b) *OC*

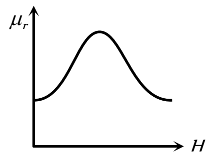
(c) *OB* (d) *OA*

13. For ferromagnetic material, the relative permeability (μ_r), versus magnetic intensity *(H)* has the following shape

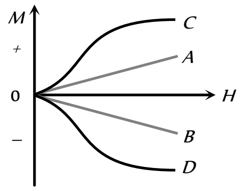
(a) 

(b) 

(c) 

(d) 

14. The most appropriate magnetization *M* versus magnetising field *H* curve for a paramagnetic substance is



(a) A (b) B

(c) C (d) D

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : We cannot think of magnetic field configuration with three poles.
Reason : A bar magnet does exert a torque on itself due to its own field. [AIIMS 2002]

2. Assertion : The poles of magnet cannot be separated by breaking into two pieces.
Reason : The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.[SCRA 1994]

3. Assertion : Basic difference between an electric line and magnetic line of force is that former is discontinuous and the latter is continuous or endless.
Reason : No electric lines of forces exist inside a charged body but magnetic lines do exist inside a magnet.

4. Assertion : Magnetic moment of an atom is due to both, the orbital motion and spin motion of every electron.
Reason : A charged particle produces a magnetic field.

5. Assertion : When radius of circular loop carrying current is doubled, its magnetic moment becomes four times.
Reason : Magnetic moment depends on area of the loop.

6. Assertion : The earth's magnetic field is due to iron present in its core.
Reason : At a high temperature magnet losses its magnetic property or magnetism.

7. Assertion : A compass needle when placed on the magnetic north pole of the earth rotates in vertical direction.
Reason : The earth has only horizontal component of its magnetic field at the north poles.

8. Assertion : The tangent galvanometer can be made more sensitive by increasing the number of turns of its coil.
Reason : Current through galvanometer is proportional to the number of turns of coil.

9. Assertion : The ferromagnetic substance do not obey Curie's law.
Reason : At Curie point a ferromagnetic substance start behaving as a paramagnetic substance.

10. Assertion : The properties of paramagnetic and ferromagnetic substance are not effected by heating.
Reason : As temperature rises, the alignment of molecular magnets gradually decreases.

11. Assertion : Soft iron is used as transformer core.
Reason : Soft iron has narrow hysteresis loop.

12. Assertion : Magnetism is relativistic.
Reason : When we move along with the charge so that there is no motion relative to us, we find no magnetic field associated with the charge.

13. Assertion : The earth's magnetic field does not affect the working of a moving coil galvanometer.
Reason : Earth's magnetic field is very weak.

14. Assertion : A paramagnetic sample display greater magnetisation (for the same magnetising field) when cooled.
Reason : The magnetisation does not depend on temperature.

15. Assertion : Electromagnets are made of soft iron.
Reason : Coercivity of soft iron is small.

16. Assertion : To protect any instrument from external magnetic field, it is put inside an iron body.
Reason : Iron is a magnetic substance.

17. Assertion : When a magnet is brought near iron nails, only translatory force act on it.
Reason : The field due to a magnet is generally uniform.

18. Assertion : When a magnetic dipole is placed in a non uniform magnetic field, only a torque acts on the dipole.
Reason : Force would also acts on dipole if magnetic field were uniform.

19. Assertion : Reduction factor (K) of a tangent galvanometer helps in reducing deflection to current.
Reason : Reduction factor increases with increase of current.

20. Assertion : The susceptibility of diamagnetic materials does not depend upon temperature.
Reason : Every atom of a diamagnetic material is not a complete magnet in itself.

21. Assertion : The permeability of a ferromagnetic material is independent of the magnetic field.
Reason : Permeability of a material is a constant quantity.

22. Assertion : For a perfectly diamagnetic substance permeability is always one.
Reason : The ability of a material of permit the passage of magnetic lines of force through it is called magnetic permeability.

23. Assertion : Gauss theorem is not applicable in magnetism.
Reason : Mono magnetic pole does not exist.

24. Assertion : Magnetic moment of helium atom is zero.
Reason : All the electron are paired in helium atom orbitals.

25. Assertion : For making permanent magnets, steel is preferred over soft iron.
Reason : As retentivity of steel is smaller.

Answers

Magnet and It's Properties

1	b	2	d	3	c	4	d	5	b
6	d	7	b	8	c	9	c	10	a
11	c	12	d	13	c	14	b	15	a
16	a	17	b	18	c	19	d	20	b
21	a	22	c	23	c	24	d	25	d
26	d	27	a	28	a	29	b	30	a
31	a	32	b	33	a	34	c	35	c
36	b	37	b	38	c	39	b	40	c
41	c	42	b	43	a	44	d	45	d
46	b	47	d	48	a	49	a	50	d
51	c	52	b	53	b	54	c	55	b
56	b	57	c	58	b	59	c	60	b
61	b	62	d	63	a	64	a	65	c
66	b	67	b	68	b	69	a	70	b
71	c	72	b	73	c	74	d	75	d
76	a	77	d	78	c	79	d	80	a
81	a	82	b	83	a	84	b	85	a
86	b	87	a	88	a	89	d	90	b
91	d	92	c						

Earth Magnetism

1	b	2	d	3	b	4	a	5	c
6	c	7	d	8	d	9	b	10	a
11	c	12	a	13	d	14	d	15	c
16	c	17	a	18	d	19	b	20	e
21	b	22	d	23	a	24	d	25	b
26	d	27	a	28	a	29	d	30	b
31	d	32	a	33	c	34	a	35	a
36	c	37	a	38	d	39	a	40	a
41	a	42	c	43	c	44	c	45	a
46	b	47	c	48	a	49	a	50	c
51	b	52	c	53	b	54	d	55	c
56	a	57	a	58	b	59	a		

Magnetic Equipments

1	d	2	c	3	a	4	b	5	d
6	d	7	a	8	c	9	c	10	b
11	c	12	a	13	a	14	a	15	b
16	b	17	b	18	d	19	b	20	c
21	c	22	c	23	c	24	c	25	a
26	a	27	c	28	a	29	a	30	a
31	b	32	d	33	b	34	d	35	a
36	c	37	b	38	d	39	b	40	a
41	b	42	d	43	d	44	d	45	c
46	b	47	b	48	d	49	c	50	d
51	c	52	d	53	c	54	b	55	a
56	a	57	c	58	a	59	a	60	c
61	d	62	a	63	c	64	d	65	b
66	b	67	a	68	c	69	b	70	b
71	c	72	c	73	b				

Magnetic Materials

1	c	2	a	3	a	4	d	5	b
6	b	7	d	8	c	9	d	10	b
11	a	12	c	13	c	14	a	15	ab
16	d	17	b	18	b	19	c	20	b
21	d	22	b	23	c	24	b	25	c
26	b	27	b	28	a	29	c	30	c
31	d	32	a	33	c	34	b	35	b
36	d	37	b	38	b	39	c	40	b
41	d	42	c	43	d	44	d	45	a
46	b	47	c	48	c	49	a	50	d

Critical Thinking Questions

1	b	2	d	3	d	4	a	5	d
6	b	7	c	8	b	9	b	10	b
11	a	12	c	13	c	14	a	15	a
16	d	17	c	18	d	19	d	20	c
21	c	22	a	23	c	24	a	25	c

Graphical Questions

1	d	2	c	3	b	4	a	5	a
6	c	7	b	8	b	9	b	10	a
11	b	12	b	13	d	14	a		

Assertion and Reason

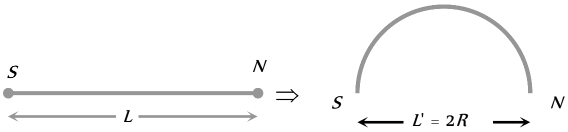
1	d	2	b	3	a	4	c	5	b
6	e	7	d	8	b	9	b	10	e
11	a	12	a	13	a	14	c	15	a
16	a	17	d	18	d	19	c	20	c
21	d	22	e	23	a	24	a	25	b

AS Answers and Solutions

Magnet and it's Properties

1. (b) On bending a rod it's pole strength remains unchanged where as its magnetic moment changes.

New magnetic moment $M' = m(2R) = m\left(\frac{2L}{\pi}\right) = \frac{2M}{\pi}$



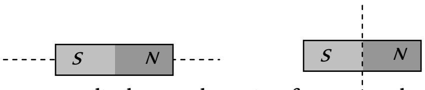
2. (d)

3. (c) $B_a = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = \frac{\mu_0}{2\pi}\frac{M}{d^3}$

4. (d)

5. (b) If cut along the axis of magnet of length l, then new pole strength $m' = \frac{m}{2}$ and new length $l' = l$

$\therefore$ New magnetic moment $M' = \frac{m}{2} \times l = \frac{ml}{2} = \frac{M}{2}$



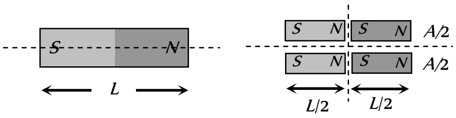
If cut perpendicular to the axis of magnet, then new pole strength $m' = m$ and new length, $l' = l/2$

$\therefore$ New magnetic moment $M' = m \times \frac{l}{2} = \frac{ml}{2} = \frac{M}{2}$

6. (d) For a magnet $B = \frac{\mu_0}{4\pi} \cdot \frac{2M}{x^3}$ (Nearly)

$\Rightarrow \frac{B_1}{B_2} = \left(\frac{x_1}{x_2}\right)^3 = \left(\frac{x}{2x}\right)^3 = \frac{1}{8}$ (Approx.)

7. (b) For each part $m' = \frac{m}{2}$



8. (c) $\frac{B_1}{B_2} = \frac{d_1}{d_2}\left(\frac{d_2^2 - l^2}{d_1^2 - l^2}\right)^2 \Rightarrow \frac{12.5}{1} = \frac{10}{20}\left(\frac{400 - l^2}{100 - l^2}\right)^2$

$\Rightarrow l = 5\ cm$

Hence length of magnet $= 2l = 10\ cm$

9. (c) $B_1 = \frac{2M}{d^3} . B_2 = \frac{M}{d^3}$; $\therefore \frac{B_1}{B_2} = 2:1$

10. (a)

11. (c) $\tau = MB\sin\theta = 48 \times 25 \times 10^{-2} \times 0.15 \times \frac{1}{2} = 0.9\ N \times m$

12. (d) $B_1 = \frac{2M}{x^3}$ *and* $B_2 = \frac{M}{y^3}$

As $B_1 = B_2$

Hence $\frac{2M}{x^3} = \frac{M}{y^3}$ or $\frac{x^3}{y^3} = 2$ or $\frac{x}{y} = 2^{1/3}$

13. (c) Work done $W = MB_H(1 - \cos\theta)$

$= 20 \times 0.3(1 - \cos 30°) = 6\left(1 - \frac{\sqrt{3}}{2}\right) = 3(2 - \sqrt{3})$

14. (b) Magnetic intensity on end side-on position is twice than broad side on position.

15. (a) Along the axis of magnet $B_a = \frac{2M}{X^3} = 200\ guass$

$\Rightarrow B_a = \frac{M}{X^3} = 100\ guass$

16. (a)

17. (b)

18. (c)

19. (d) Provided length of magnet is <<the distance.

20. (b) Permeability of soft iron is maximum, so maximum lines of force tries to pass through the soft iron.

21. (a) Plane of coil is having angle θ with the magnetic field.

$\therefore \tau = MB\sin(90 - \theta)$ or $\tau = niAB\cos\theta$ [As $M = niA$]

22. (c) $B \propto \frac{1}{x^3} \Rightarrow \frac{B_1}{B_2} = \left(\frac{x_2}{x_1}\right)^3 = \left(\frac{3x}{x}\right)^3 = \frac{27}{1}$

23. (c) For null deflection $\frac{M_1}{M_2} = \left(\frac{d_1}{d_2}\right)^3 = \left(\frac{40}{50}\right)^3 = \frac{64}{125}$

24. (d)

25. (d) $F = \frac{\mu_0}{4\pi}\left(\frac{6MM'}{d^4}\right)$ in end-on position.

26. (d) Work done $MB(\cos\theta_1 - \cos\theta_2)$

$\theta_1 = 0^o$ and $\theta_2 = 180^o$

$\Rightarrow W = MB(\cos 0 - \cos 180) = 2MB$

27. (a) Pole strength doesn't depend upon the length.

28. (a) Torque $\tau = MB_H\sin\theta$

$= 0.1 \times 10^{-3} \times 4\pi \times 10^{-3} \times \sin 30^o = 10^{-7} \times 4\pi \times \frac{1}{2}$

$= 2\pi \times 10^{-7}\ N \times m$

29. (b) Number of lines of force passing through per unit area normally is intensity of magnetic field, hence option (c) is incorrect. The correct option is (b).

30. (a) Flux $= B \times A$; $\therefore B = \frac{Flux}{A} = Weber/m^2$

31. (a)

32. (b) $B = \frac{m}{d^2}$ in C.G.S. system.

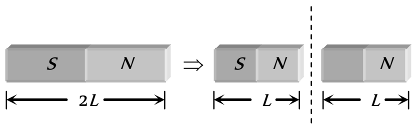
33. (a) $W = MB(\cos\theta_1 - \cos\theta_2) = MB(\cos 0^o - \cos 60^o)$

$= MB\left(1 - \frac{1}{2}\right) = \frac{MB}{2}$

and $\tau = MB\sin\theta = MB\sin 60^o = MB\frac{\sqrt{3}}{2}$

$\therefore \tau = \left(\frac{MB}{2}\right)\sqrt{3} \Rightarrow \tau = \sqrt{3}\ W$

34. (c)

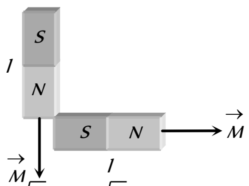


Pole strength of each part $= m$

Magnetic moment of each part

$= M' = m'L' = mL = \frac{M}{2}$

35. (c)



$M_{net} = \sqrt{2}M = \sqrt{2}ml.$

36. (b)

37. (b) $F \propto \frac{m_1 m_2}{r^2}$

38. (c) $F = 10^{-7} \times \frac{m^2}{r^2} = \frac{10^{-7}(1)^2}{(1)^2} = 10^{-7}\,N$

39. (b) $\tau = MH\sin\theta = MH\sin 30^o = \frac{MH}{2}$

40. (c)

41. (c) $F = \frac{\mu_0}{4\pi}\left(\frac{6MM'}{d^4}\right)$ in end-on position between two small magnets.

$\therefore F = 10^{-7}\left(\frac{6\times 10\times 10}{(0.1)^4}\right) = 0.6\,N$

42. (b)

43. (a) $\tau = MB_H\sin\theta$ or $\frac{d\tau}{d\theta} = MB_H\cos\theta$

This will be maximum. when $\theta = 0^o$.

44. (d) $W = MB(\cos\theta_1 - \cos\theta_2)$; $\theta_1 = 0^o$ and $\theta_2 = 360^o \Rightarrow W = 0$

45. (d)

46. (b) $W_1 = MB(\cos 0^o - \cos 90^o) = MB(1-0) = MB$

$W_2 = MB(\cos 0^o - \cos 60^o) = MB\left(1 - \frac{1}{2}\right) = \frac{MB}{2}$

$\therefore W_1 = 2W_2 \Rightarrow n = 2$

47. (d) In magnetic dipole, force $\propto \frac{1}{r^4}$

Hence new force $= \frac{4.8}{2^4} = \frac{4.8}{16} = 0.3\,N$

48. (a) Magnetic moment of bar $M = 10^4\,J/T$

$B = 4\times 10^{-5}\,T$

Hence work done $W = \vec{M}.\vec{B}$

$= 10^4 \times 4\times 10^{-5} \times \cos 60^o = 0.2\,J$

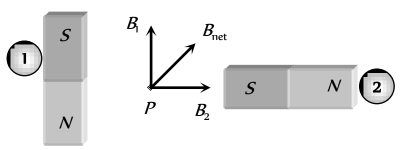
49. (a)

50. (d)

51. (c) $B = \frac{\mu_0}{4\pi}\frac{2M}{d^3} = 10^{-7}\times\frac{2\times 1.25}{(0.5)^3} = 2\times 10^{-6}\,N/A-m$

52. (b)

53. (b)



54. (c)

55. (b) $\tau = MB_H\sin\theta \Rightarrow 0.032 = M\times 0.16\times\sin 30^o$

$\Rightarrow M = 0.4\,J/tesla$

56. (b) $B_{equatorial} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

57. (c) Inside a magnet, magnetic lines of force move form south pole to north pole.

58. (b) Magnetic moment of circular loop carrying current

$M = IA = I(\pi R^2) = I\pi\left(\frac{L}{2\pi}\right)^2 = \frac{IL^2}{4\pi} \Rightarrow L = \sqrt{\frac{4\pi M}{I}}$

59. (c)

60. (b) Concept of magnetic screening.

61. (b) Repulsion is the sure test of magnetism.

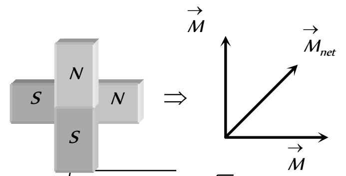
62. (d)

63. (a)

64. (a) $C_{max} = MB \Rightarrow 4\times 10^{-5} = M\times 10^{-4} \Rightarrow M = 0.4\,A\times m^2$

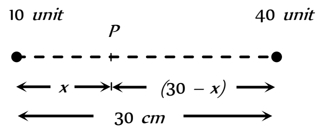
65. (c) Magnetic flux $\phi = BA \Rightarrow B = \frac{\phi}{A} = \frac{Weber}{m^2} = Tesla$

66. (b)



$\Rightarrow M_{net} = \sqrt{M^2 + M^2} = \sqrt{2}M$

67. (b) Suppose magnetic field is zero at point *P*. Which lies at a distance *x* from 10 unit pole. Hence at *P*



$\frac{\mu_0}{4\pi}\cdot\frac{10}{x^2} = \frac{\mu_0}{4\pi}\cdot\frac{40}{(30-x)^2} \Rightarrow x = 10cm$

So from stronger pole distance is 20 *cm*.

68. (b) $\tau = MB\sin\theta = (mL)B\sin\theta$

$= (40\times 10\times 10^{-2})\times 2\times 10^{-4}\times\sin 45°$

$= 0.565\times 10^{-3}\,N-m$

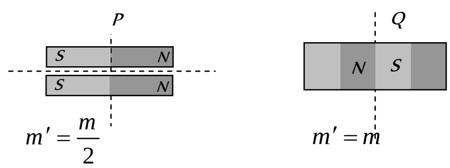
69. (a) Potential energy $U = -MB\cos\theta$

$\Rightarrow U_{max} = MH(\text{at}\,\theta = 180^o)$

70. (b) $\tau = MB\sin\theta$

$\tau = 200\times 0.25\times\sin 30° = 25\,N\times m.$

71. (c) If pole strength, magnetic moment and length of each part are m', M' and L' respectively then



$m' = \frac{m}{2}$ $\qquad$ $m' = m$

$L' = L$ $\qquad$ $L' = \frac{L}{2}$

$\Rightarrow M' = \frac{M}{2}$ $\qquad$ $\Rightarrow M' = \frac{M}{2}$

72. (b) $\vec{\tau} = \vec{M}\times\vec{B} \Rightarrow \vec{\tau} = 50\hat{i}\times(0.5\hat{i} + 3\hat{j})$

$= 150(\hat{i}\times\hat{j}) = 150\hat{k}\,N\times m.$

73. (c) $\tau = MB\sin\theta \Rightarrow \tau \propto \sin\theta$

$$\Rightarrow \frac{\tau_1}{\tau_2} = \frac{\sin\theta_1}{\sin\theta_2} \Rightarrow \frac{\tau}{\tau/2} = \frac{\sin 90}{\sin\theta_2}$$

$$\Rightarrow \sin\theta_2 = \frac{1}{2} \Rightarrow \theta_2 = 30^o$$

$\Rightarrow$ angle of rotation $= 0Å - 30 = 60°$

74. (d)

75. (d) $F = mB \Rightarrow F = \frac{M}{L} \times B$

$$\Rightarrow 6 \times 10^{-4} = \frac{3}{L} \times 2 \times 10^{-5} \Rightarrow L = 0.1\, m.$$

76. (a) $\tau = MB\sin\theta \Rightarrow \tau = (mL)B\sin\theta$

$$\Rightarrow 25 \times 10^{-6} = (m \times 5 \times 10^{-2}) \times 5 \times 10^{-2} \times \sin 30$$

$$\Rightarrow m = 2 \times 10^{-2}\, A - m.$$

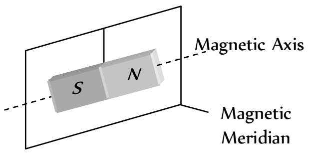
77. (d)

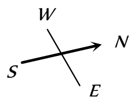
78. (c) Monopole do not exists.

79. (d)

80. (a)

81. (a)





82. (b) $W = MB(1 - \cos\theta)$; where $\theta = 180^o$

$$\Rightarrow W = 2MB \Rightarrow W = 2 \times 2 \times 5 \times 10^{-3} = 2 \times 10^{-2}\, J$$

83. (a) Torque on a bar magnet in earths magnetic field (B) is $\tau = MB_H \sin\theta$. τ will be maximum if sin θ = maximum *i.e.* θ = 90°. Hence axis of the magnet is perpendicular to the field of earth.

84. (b)

85. (a) Both points A and B lying on the axis of the magnet and on axial position

$$B \propto \frac{1}{d^3} \Rightarrow \frac{B_A}{B_B} = \left(\frac{d_B}{d_A}\right)^3 = \left(\frac{48}{24}\right)^3 = \frac{8}{1}$$

86. (b) $W = MB(1 - \cos\theta) = 2 \times 0.1 \times (1 - \cos 90^o) = 0.2 J$

87. (a) $M = mL = 4 \times 10 \times 10^{-2} = 0.4 A \times m^2$

88. (a) Similar to solution (1)

New magnetic moment

$$M' = \frac{2M}{\pi} = \frac{2mL}{\pi} = \frac{2 \times 0.5 \times 31.4 \times 10^{-2}}{3.14} = 0.1\, amp \times m^2$$

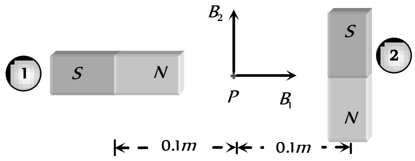
89. (d) Magnetic potential at a distance d from the bar magnet on it's axial line is given by

$$V = \frac{\mu_0}{4\pi} \cdot \frac{M}{d^2} \Rightarrow V \propto M \Rightarrow \frac{V_1}{V_2} = \frac{M_1}{M_2}$$

$$\Rightarrow \frac{V}{V_2} = \frac{M}{M/4} \Rightarrow V_2 = \frac{V}{4}$$

90. (b) $B = \frac{\mu_0}{4\pi} \cdot \frac{2M}{d^3} \Rightarrow B = 10^{-7} \times \frac{2 \times 1.2}{(0.1)^3} = 2.4 \times 10^{-4}\, T$

91. (d)



From figure $B_{net} = \sqrt{B_a^{\,2} + B_e^{\,2}}$

$$= \sqrt{\left(\frac{\mu_0}{4\pi} \cdot \frac{2M}{d^3}\right)^2 + \left(\frac{\mu_0}{4\pi} \cdot \frac{M}{d^3}\right)^2}$$

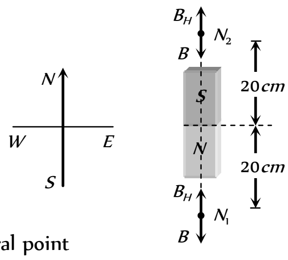
$$= \sqrt{5} \cdot \frac{\mu_0}{4\pi} \cdot \frac{M}{d^3} = \sqrt{5} \times 10^{-7} \times \frac{10}{(0.1)^3} = \sqrt{5} \times 10^{-3}\ \textit{Tesla.}$$

92. (c) $\tau = MB\sin\theta = m \times (2l) \times B\sin\theta$

$$= 10^{-4} \times 0.1 \times 30 \sin 30° = 1.5 \times 10^{-4}\, Nm$$

Earth Magnetism

1. (b)



At neutral point

$$|B| = |B_H| \Rightarrow \frac{2M}{(20)^3} = 0.3 \Rightarrow M = 1.2 \times 10^3\ emu.$$

2. (d) No magnetic lines of force passes through the steel box.

3. (b) At magnetic poles, the angle of dip is 90°. Hence the horizontal component $B_H = B\cos\theta = 0.$

4. (a)

5. (c)

6. (c)

7. (d) $B_H = \sqrt{3}\, B_V$, also $\tan\theta = \frac{B_V}{B_H} = \frac{1}{\sqrt{3}} \Rightarrow \theta = 30^o$

8. (d) At magnetic equator, the angle of dip is 0°. Hence the vertical component $V = I\sin\phi = 0.$

9. (b)

10. (a)

11. (c) $B_V = H_H \tan\phi$; If $B_V = B_H$, then $\tan\phi = 1$ or $\phi = 45^o$

12. (a) The horizontal components are $(B_H)_1 = B\cos\phi_1$ and $(B_H)_2 = B\cos\phi_2$

$$\therefore \frac{(B_H)_1}{(B_H)_2} = \frac{\cos\phi_1}{\cos\phi_2} = \frac{\cos 30^o}{\cos 45^o} = \frac{\sqrt{3}}{2} \times \sqrt{2} = \frac{\sqrt{3}}{\sqrt{2}}$$

13. (d) From the relation $B_H = B\cos\phi$ and $B_V = B\sin\phi$

$\frac{B_V}{B_H} = \tan\phi$ or $B_V = B_H \tan\phi$

$= 0.36 \times 10^{-4} \times \tan 60^o = 0.623 \times 10^{-4}\ Wb/m^2$

14. (d) From the relation $B_V = I\sin\phi$

$I = \frac{V}{\sin\phi} = \frac{6\times10^{-5}}{\sin 40.6^o} = \frac{6\times10^{-5}}{0.65} = 9.2\times10^{-5}$ *tesla*

15. (c)

16. (c) $B_H = B\cos\phi; \therefore B = \frac{B_H}{\cos\phi} = \frac{0.5}{\cos 30^o} = \frac{0.5}{\sqrt{3}/2} = \frac{1}{\sqrt{3}}$

17. (a)

18. (d)

19. (b)

20. (e)

21. (b)

22. (d)

23. (a) $\tan\phi = \frac{B_V}{B_H} = \frac{0.173}{0.30} = \frac{1.73}{3.0} = \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} \Rightarrow \phi = 30^o$

24. (d) $B_H = B\cos\phi = 0.64\times\cos 60^o = 0.64\times\frac{1}{2} = 0.32$ units

25. (b)

26. (d)

27. (a)

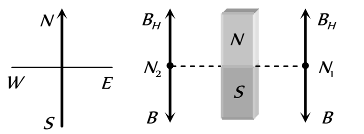
28. (a) $B_H = 0.3\ Oersted,\ I = 0.6\ Oersted$

We have $B_H = I\cos\phi \Rightarrow \cos\phi = \frac{B_H}{I} = \frac{0.3}{0.6} = \frac{1}{2}$

$\therefore \phi = 60^o$

29. (d)

30. (b)



31. (d) At broad side-on position $B = \frac{M}{d^3}$

$\therefore \frac{M_1}{d_1^3} = \frac{M_2}{d_2^3}$ or $\frac{M_1}{r^3} = \frac{M_2}{8r^3}$ or $\frac{M_1}{M_2} = \frac{r^3}{8r^3} = \frac{1}{8}$

32. (a)

33. (c) $B^2 = B_V^2 + B_H^2 \Rightarrow B_V = \sqrt{B^2 - B_H^2} = \sqrt{(0.5)^2 - (0.3)^2} = 0.4$

Now $\tan\phi = \frac{B_V}{B_H} = \frac{0.4}{0.3} = \frac{4}{3} \Rightarrow \phi = \tan^{-1}\left(\frac{4}{3}\right)$.

34. (a) Horizontal component $B_H = B\cos\phi$

Total intensity of earth magnetic field $B = \frac{B_H}{\cos\phi}$

$= \frac{1.8\times10^5}{\cos 30^o} = \frac{1.8\times10^{-5}}{\sqrt{3}/2} = 2.08\times10^{-5}\ Wb/m^2$

35. (a)

36. (c)

37. (a) The vertical component of earth's magnetic field is zero at equator where angle of dip is also zero.

38. (d) $B_0 = V_0$ also total intensity $B = \sqrt{B_0^2 + V_0^2} \Rightarrow B = \sqrt{2}B_0$

39. (a) At poles magnetic field is perpendicular to the surface of earth.

40. (a)

41. (a)

42. (c) At neutral point

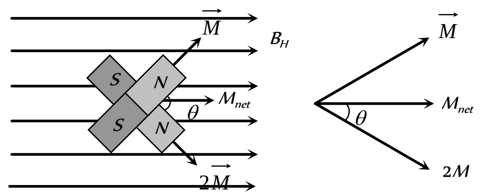
$\left|\text{Magnetic field due to magnet}\right| = \left|\text{Magnetic field due to earth}\right|$

$\frac{\mu_0}{4\pi}\cdot\frac{2M}{d^3} = 5\times10^{-5} \Rightarrow 10^{-7}\times\frac{2\times6.75}{d^3} = 5\times10^{-5}$

$\Rightarrow d = 0.3\ m = 30\ cm$

43. (c) As they enter the magnetic field of the earth, they are deflected away from the equator.

44. (c)



$\Rightarrow \tan\theta = \frac{M}{2M} = \frac{1}{2} \Rightarrow \theta = \tan^{-1} = \frac{1}{2}$

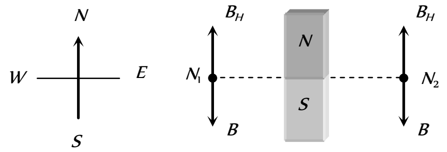
45. (a)

46. (b) $B_H = B\sin\phi \Rightarrow B = \frac{B_H}{\sin\phi} \Rightarrow B = \frac{B_o}{\sin 45^o} = \sqrt{2}B_0$

47. (c)

48. (a)

49. (a)



N_1 and N_2 are two null points. And

B_H = Horizontal component of earth's magnetic field

B = Magnetic field due to bar magnet.

50. (c)

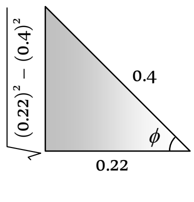
51. (b) $B_H = B\cos\phi \Rightarrow B = \frac{B_H}{\cos\phi} \Rightarrow B = \frac{B_H}{\cos 30^o} = \frac{2B_H}{\sqrt{3}}$

52. (c) By using $B_H = B\cos\phi$

$\Rightarrow \cos\phi = \frac{B_H}{B} = \frac{0.22}{0.4}$

$\Rightarrow \tan\phi = \frac{\sqrt{(0.4)^2 - (0.22)^2}}{0.22}$

$\Rightarrow \phi = \tan^{-1}(1.518)$



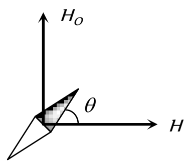
53. (b)

54. (d) At equator angle of dip is zero.

55. (c)

56. (a) In given case H and H_0 are perpendicular to each other.

From figure $\tan\theta = \frac{H_0}{H}$



$\Rightarrow \theta = \tan^{-1}\left(\frac{H_0}{H}\right)$

57. (a)
58. (b)
59. (a)

Magnetic Equipments

1. (d)
2. (c)
3. (a)

4. (b) In sum position : $T_S = 2\pi\sqrt{\frac{I_s}{(M_1+M_2)B_H}}$

In difference position : $T_d = 2\pi\sqrt{\frac{I_d}{(M_1-M_2)B_H}}$

It is clear that $T_d > T_s$

5. (d) $T = 2\pi\sqrt{\frac{I}{MB_H}}; \therefore \frac{T_1}{T_2} = \sqrt{\frac{(B_H)_2}{(B_H)_1}} \Rightarrow T_2 = T_1\sqrt{\frac{(B_H)_1}{(B_H)_2}}$

Here n=30 *oscillation / min* $= \frac{1}{2}$ *oscillation/sec*

$\therefore T_1 = \frac{1}{n_1} = 2\sec$

$\therefore T_2 = 2\sqrt{\frac{B_H}{2B_H}} = 2\times\frac{1}{\sqrt{2}} = \sqrt{2}\sec$

6. (d)

7. (a) $T = 2\pi\sqrt{\frac{1}{MB_H}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$

$\Rightarrow \frac{M_1}{M_2} = \frac{T_2^2}{T_1^2} = \frac{(60/15)^2}{(60/10)^2} = \frac{4}{9}$

8. (c) When magnet of length l is cut into four equal parts. then $m' = \frac{m}{2}$ and $l' = \frac{l}{2}$; $\therefore M' = \frac{m}{2}\times\frac{l}{2} = \frac{ml}{4} = \frac{M}{4}$

New moment of inertia $I' = \frac{wl^2}{12} = \frac{\frac{w}{4}.\left(\frac{1}{2}\right)^2}{12} = \frac{1}{16}.\frac{wl^2}{12}$

Here w is the mass of magnet.

$\therefore I' = \frac{1}{16}I$; Time period of each part $T' = 2\pi\sqrt{\frac{I'}{M'B_H}}$

$= 2\pi\sqrt{\frac{I/16}{(M/4)B_H}} = 2\pi\sqrt{\frac{I}{4MB_H}} = \frac{T}{2}$

9. (c) $T = 2\pi\sqrt{\frac{I_1+I_2}{(M_1-M_2)B_H}}$

Here $M_1 = M_2 = M, \therefore T = \infty$

10. (b) Time period in vibration magnetometer

$T = 2\pi\sqrt{\frac{I}{MB_H}}$, At poles $B_H = 0$ *so* $T = \infty$

11. (c)

12. (a) $\frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{4M}{M}} = 2 \Rightarrow \frac{2}{T_2} = 2 \Rightarrow T_2 = 1\sec$

13. (a) $T = 2\pi\sqrt{\frac{I}{MB_H}}$

$I = 40gm - cm^2 = 400\times10^{-8}kg - m^2$

$\therefore 3 = 2\pi\sqrt{\frac{400\times10^{-8}}{36\times10^{-6}\times M}}$

$\Rightarrow \frac{1}{M} = \frac{9}{4\pi^2}\times\frac{36}{4} \Rightarrow M = 0.5\ A\times m^2$

14. (a)

15. (b) Because moment of inertia increases i.e. $T \propto \sqrt{I}$

16. (b) $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{(B_H)_2}{(B_H)_1}}$

$\Rightarrow T_2 = T\sqrt{\frac{(BH)_1}{(BH)_2}} = \frac{T}{2}$ $\left(\because (B_H)_2 = 4(B_H)_1\right)$

17. (b) In sum position $T \propto \frac{1}{\sqrt{M_1+M_2}}$ and in difference position $T \propto \frac{1}{\sqrt{M_1-M_2}}$

$\Rightarrow \frac{3^2}{T^2} = \frac{2M-M}{2M+M} \Rightarrow T^2 = 9\times3\sec^2$

$\therefore T = 3\sqrt{3}\sec$

18. (d)

19. (b) Given $\nu_1 = \frac{20}{60} = \frac{1}{3}\sec^{-1}$ and $\nu_2 = \frac{15}{60} = \frac{1}{4}\sec^{-1}$

Now $\nu = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}} = \frac{1}{2\pi}\sqrt{\frac{MB\cos\phi}{I}}$ $(\because B_H = B\cos\phi)$

$\therefore \frac{\nu_1}{\nu_2} = \sqrt{\frac{B_1\cos\phi_1}{B_2\cos\phi_2}} \Rightarrow \frac{B_1}{B_2} = \left(\frac{\nu_1}{\nu_2}\right)^2\left(\frac{\cos\phi_2}{\cos\phi_1}\right)^2$

$\Rightarrow \frac{B_1}{B_2} = \left(\frac{1/3}{1/4}\right)^2\frac{\cos60^\circ}{\cos30^\circ} = \frac{16}{9}\times\frac{1/2}{\sqrt{3}/2} = \frac{16}{9\sqrt{3}}$.

20. (c) $T \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}} \Rightarrow \frac{1.5}{T_2} = \sqrt{\frac{M_1/4}{M_1}} = \frac{1}{2}$

$\Rightarrow T_2 = 3\sec$

21. (c) $\nu = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}} \Rightarrow \nu \propto \sqrt{M}$

$\Rightarrow \frac{\nu_A}{\nu_B} = \sqrt{\frac{M_A}{M_B}} \Rightarrow \frac{2}{1} = \sqrt{\frac{M_A}{M_B}} \Rightarrow M_A = 4M_B$

22. (c) $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow T \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{M_A}{M_B} = \left(\frac{T_B}{T_A}\right)^2 = \frac{4}{1}$

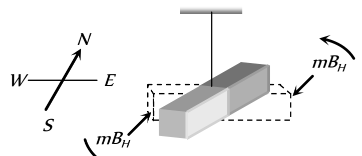
23. (c) No. of oscillation per minute $= \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}}$

$\Rightarrow n \propto \sqrt{MB_H};\ M \to 4\ times$

$B_H \to 2\ times$

So $\nu \to \sqrt{8}\ times\ i.e.\ \nu' = \sqrt{8}\nu = 2\sqrt{2}n$

24. (c)



25. (a) $T = 2\pi\sqrt{\frac{I}{MH}} \Rightarrow T \propto \frac{1}{\sqrt{H}} \Rightarrow \frac{T_A}{T_B} = \sqrt{\frac{H_B}{H_A}}$

$\Rightarrow \frac{H_A}{H_B} = \left(\frac{T_B}{T_A}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$.

26. (a) $T = 2\pi\sqrt{\frac{I}{MB_H}}$ and $I = \frac{w(l^2+b^2)}{12}$; $\therefore T \propto \sqrt{w}$

(w = Mass of the magnet)

27. (c) $T_{Sum} = 2\pi\sqrt{\frac{(I_1+I_2)}{(M_1+M_2)B_H}}$

$T_{diff} = 2\pi\sqrt{\frac{I_1+I_2}{(M_1-M_2)B_H}}$

$\Rightarrow \frac{T_s}{T_d} = \frac{T_1}{T_2} = \sqrt{\frac{M_1-M_2}{M_1+M_2}} = \sqrt{\frac{2M-M}{2M+M}} = \frac{1}{\sqrt{3}}$

28. (a) $T = 2\pi\sqrt{\frac{I}{MB}} \Rightarrow \frac{T}{T'} = \sqrt{\frac{B'}{B}} = \sqrt{\frac{B}{B_H}}$

$\Rightarrow \frac{T}{T'} = \sqrt{\frac{1}{\cos\phi}} = \sqrt{\frac{1}{\cos 60^o}} = \sqrt{2} \Rightarrow T' = \frac{T}{\sqrt{2}}$

29. (a)

30. (a)

31. (b) For tangent galvanometer $I = \frac{2rB}{\mu_0 n}\tan\theta$

$\therefore \tan\theta = \frac{I\mu_0 n}{2rB} = \frac{0.1\times 4\pi\times 10^{-7}\times 50}{0.04\times 7\times 10^{-5}\times 2} = 1.12$

or $\theta = \tan^{-1}(1.12) = 48.2^o$

32. (d) Time period of a magnet $T = 2\pi\sqrt{\frac{I}{MB}}$

or $I = \frac{T^2 MB}{4\pi^2} = \frac{225\times 5\times 10^{-5}\times 8\pi\times 10^{-4}}{4\pi^2}$

$\therefore I = 7.16\times 10^{-7}\,kg - m^2$

33. (b) $T = 2\pi\sqrt{\frac{I}{MB_H}} = 4\sec$

When magnet is cut into two equal halves, then New magnetic moment $M' = \frac{M}{2}$

New moment of inertia $I' = \frac{(w/2)(l/2)^2}{12} = \frac{1}{8}\cdot\frac{wl^2}{12}$

Where w is the initial mass of the magnet

But $I = \frac{wl^2}{12}$; $\therefore I' = \frac{I}{8}$

$\therefore$ New time period $T' = 2\pi\sqrt{\frac{I'}{M'B_H}}$

$= 2\pi\sqrt{\frac{I/8}{(M/2)B_H}} = \frac{1}{2}2\pi\sqrt{\frac{I}{M_H}} = \frac{1}{2}\times T = \frac{1}{2}\times 4 = 2\sec$

34. (d)

35. (a) $K = \frac{2RB_H}{\mu_0 N}$ (R = radius, N= number of turns)

36. (c) $T \propto \frac{1}{\sqrt{M}}$. Since magnetic moment decreases with increase in temperature hence time period T increases.

37. (b) Sensitivity $S = \frac{\theta}{i} = \frac{\theta}{K\tan\theta}$ where $K = \frac{2RB_H}{\mu_0 N}$

For increasing sensitivity K should be decreased and hence number of turns should be increased.

38. (d) In the first galvanometer

$i_1 = K_1\tan\theta_1 = K_1\tan 60^o = K_1\sqrt{3}$

In the second galvanometer

$i_2 = K_2\tan\theta_2 = K_2\tan 45^o = K_2$

In series $i_1 = i_2 \Rightarrow K_1\sqrt{3} = K_2 \Rightarrow \frac{K_1}{K_2} = \frac{1}{\sqrt{3}}$

But $K \propto \frac{1}{n} \Rightarrow \frac{K_1}{K_2} = \frac{n_2}{n_1}$ $\therefore \frac{n_1}{n_2} = \frac{\sqrt{3}}{1}$.

39. (b) $T = 2\pi\sqrt{\frac{I}{MB_H}}$. If Q is an identical bar magnet then time period of system will be $T' = 2\pi\sqrt{\frac{2I}{(2M)B_H}} = T$

40. (a) Frequency $\nu \propto \sqrt{B_H}$

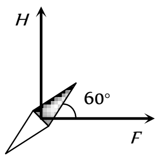
41. (b) In tangent galvanometer, $I \propto \tan\theta$

$$\therefore \frac{I_1}{I_2} = \frac{\tan\theta_1}{\tan\theta_2} \Rightarrow \frac{I_1}{I_1/\sqrt{3}} = \frac{\tan 45^0}{\tan\theta_2}$$

$$\Rightarrow \sqrt{3}\tan\theta_2 = 1 \Rightarrow \tan\theta_2 = \frac{1}{\sqrt{3}} \Rightarrow \theta_2 = 30^o$$

So deflection will decrease by $45^\circ - 30^\circ = 15^\circ$.

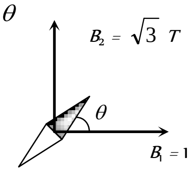
42. (d) From figure at equilibrium



$$\tan 60° = \frac{H}{F}$$

$$\Rightarrow \sqrt{3} = \frac{H}{F} \Rightarrow \frac{F}{H} = \frac{1}{\sqrt{3}}$$

43. (d) In balance condition $B_2 = B_1 \tan\theta$



$$\Rightarrow \tan\theta = \frac{\sqrt{3}}{1}$$

$$\Rightarrow \theta = 60^o$$

44. (d) In the sum and difference method of vibration magnetometer

$$\frac{M_1}{M_2} = \frac{T_2^2 + T_1^2}{T_2^2 - T_1^2}$$

Here $T_1 = \frac{1}{n_1} = \frac{60}{12} = 5\,\text{sec}$. $T_2 = \frac{1}{n_2} = \frac{60}{4} = 15\,\text{sec}$

$$\therefore \frac{M_1}{M_2} = \frac{15^2 + 5^2}{15^2 - 5^2} = \frac{225+25}{225-25} = \frac{5}{4}$$

45. (c)

46. (b) $i \propto \tan\theta \Rightarrow \frac{i_1}{i_2} = \frac{\tan\theta_1}{\tan\theta_2} \Rightarrow \frac{\sqrt{3}}{3} = \frac{\tan 30^o}{\tan\theta_2} \Rightarrow \theta = 45^o$

47. (b) $T = 2\pi\sqrt{\frac{I}{MB}} = 2\pi\sqrt{\frac{wl^2/12}{\text{Pole strength} \times 2l \times B}}$

$$\therefore T \propto \sqrt{Wl}$$

$$\therefore \frac{T_2}{T_1} = \sqrt{\frac{w_2}{w_1} \times \frac{l_2}{l_1}} = \sqrt{\frac{w_1/2}{w_1} \times \frac{l_1/2}{l_1}} = \frac{1}{2}$$

$$\Rightarrow T_2 = \frac{T_1}{2} = 0.5\ sec$$

48. (d) $T' = \frac{T}{n} \Rightarrow T' = \frac{2}{2} = 1 sec$

49. (c) It is due to the magnetic field produced by coil.

50. (d)

51. (c) $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow T \propto \sqrt{I} \propto \sqrt{w} \Rightarrow T' = \sqrt{2}\ T_0$

52. (d) $\frac{M_1}{M_2} = \left(\frac{d_1}{d_2}\right)^3 \Rightarrow \frac{27}{8} = \left(\frac{d_1}{0.12}\right)^3$

$$\Rightarrow \frac{3}{2} = \frac{d_1}{0.12} \Rightarrow 0.18\ m$$

53. (c) $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow T \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$

If $M_1 = 100$ than M_2 $(100 - 19) = 81$

So $\frac{T_1}{T_2} = \sqrt{\frac{81}{100}} = \frac{9}{10} \Rightarrow T_2 = \frac{10}{9}T_1 = 1.11\,T_1$

$\Rightarrow$ Time period increases by 11%

54. (b) $T = 2\pi\sqrt{\frac{I}{M \times B_H}} \Rightarrow T \propto \frac{1}{\sqrt{B_H}}$

$$\Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{(B_H)_2}{(B_H)_1}} \Rightarrow \frac{60/40}{2.5} = \sqrt{\frac{(B_H)_2}{0.1\times10^{-5}}}$$

$$\Rightarrow (B_H)_2 = 0.36\times10^{-6}\,T$$

55. (a) $i = \frac{2rB_H}{\mu_0 N}\tan\theta$

$$\Rightarrow i = \frac{2\times15\times10^{-2}\times3\times10^{-5}}{4\pi\times10^{-7}\times25}\times\tan 45^o \Rightarrow i = 0.29\ A$$

56. (a) $T = 2\pi\sqrt{\frac{I}{MB_H}}$; $I \to 3$ times and $M \to \frac{1}{3}$ times

So $T \to 3$ times *i.e.* $T' = 3T_0$

57. (c) In case of tangent galvanometer as

$$i = k\tan\phi$$

Differentiating both side *w.r.t.* ϕ

$$\frac{di}{d\phi} = k\sec^2\phi \Rightarrow di = k\sec^2 d\phi$$

$$\Rightarrow \frac{di}{i} = \frac{d\phi}{\sin\phi\cos\phi} = \frac{2d\phi}{\sin2\phi}$$

Hence the error in the measurement will be least when

$$\sin2\phi = \text{max} = 1 \Rightarrow 2\phi = 90^o \Rightarrow \phi = 45^o$$

58. (a)

59. (a) $T' = \frac{T}{n}$

60. (c) $\frac{T_A}{T_B} = \sqrt{\frac{(B_H)_B}{(B_H)_A}} \Rightarrow \frac{60/10}{60/20} = \sqrt{\frac{(B_H)_B}{36\times10^{-6}}}$

$$\Rightarrow (B_H)_B = 144\times10^{-6}\,T$$

61. (d) $i \propto \tan\phi \Rightarrow \frac{i_1}{i_2} = \frac{\tan\phi_1}{\tan\phi_2}$

$$\Rightarrow \frac{2}{i_2} = \frac{\tan 30}{\tan 60} \Rightarrow i_2 = 6\ amp$$

62. (a) In tangent galvanometer experiment. The plane of the coil firstly set in the magnetic meridian.

63. (c) $T \propto \frac{1}{\sqrt{M}} \Rightarrow T \propto \frac{1}{\sqrt{m}}$; If $m \to 4$ times.

$T \to \frac{1}{2}$ times i.e. $T' = \frac{T}{2} = \frac{2}{2} = 1\,\text{sec}$

64. (d) $\frac{M_1}{M_2} = \frac{\tan\theta_1}{\tan\theta_2} \Rightarrow \frac{m_1 L_1}{m_2 L_2} = \frac{\tan\theta_1}{\tan\theta_2}$

$\Rightarrow \frac{m_1}{m_2} = \frac{2}{1} \times \frac{\tan 45°}{\tan 30°} = \frac{2\sqrt{3}}{1}$

65. (b) $B = B_H \tan\theta = 0.34 \times 10^{-4} \tan 30° = 1.96 \times 10^{-5} T$

66. (b) $i \propto \tan\phi \Rightarrow \frac{i_1}{i_2} = \frac{\tan\phi_1}{\tan\phi_2}$

$\Rightarrow \frac{0.1}{i_2} = \frac{\tan 30°}{\tan 60°} = \frac{1}{3} \Rightarrow i_2 = 0.3A$

67. (a) As $T \propto \sqrt{I}$; where I = moment of inertia

$= \frac{wL^2}{12} \Rightarrow T \propto \sqrt{w}$ (w = Mass of magnet. If w $\to$ quadrupled, then $T \to$ doubled *i.e.* $T' = 2T$

68. (c) Oscillation of *n* part of magnet $T' = \frac{T}{n}$

$\Rightarrow \frac{T'}{T} = \frac{1}{n}$; here *n* = 2 so $\frac{T'}{T} = \frac{1}{2}$.

69. (b) $T = 2\pi\sqrt{\frac{I}{M B_H}}$; where $I = \frac{w(L^2 + b^2)}{12}$

(w =Mass of magnet)

$\Rightarrow T \propto \sqrt{w}$, If w $\to$ four times then $T \to$ Two times

70. (b) Initially, the time period of the magnet

$T = 2 = 2\pi\sqrt{\frac{I}{MB}}$ ..... (i)

For each part, it's moment of inertia $= \frac{I}{27}$ and magnetic moment $= \frac{M}{3}$

$\therefore$ Moment of inertia of system $I_s = \frac{I}{27} \times 3 = \frac{I}{9}$

Magnetic moment of system $M_s = \frac{M}{3} \times 3 = M$

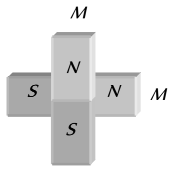
Time period of system

$T_s = 2\pi\sqrt{\frac{I_s}{M_s B}} = \frac{1}{3} \times 2\pi\sqrt{\frac{I}{MB}} = \frac{T}{3} = \frac{2}{3}\,\text{sec}$

71. (c) $T \propto \frac{1}{\sqrt{B_H}} = \frac{1}{\sqrt{B\cos\phi}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{B_2\cos\phi_2}{B_1\cos\phi_1}}$

$\Rightarrow \frac{B_1}{B_2} = \frac{T_2^2}{T_1^2} \times \frac{\cos\phi_2}{\cos\phi_1} = \left(\frac{3}{2}\right)^2 \times \frac{\cos 60°}{\cos 30°} \Rightarrow \frac{B_1}{B_2} = \frac{9}{4\sqrt{3}}$

72. (c) Time period of combination



$T = 2\pi\sqrt{\frac{2I}{\sqrt{2}\,M.H}}$ .....(i)

and time period of each magnet

$T' = 2\pi\sqrt{\frac{I}{MH}}$ ......(ii)

from (i) and (ii) we get

$T' = \frac{T}{2^{1/4}} = 2^{-1/4}T$

73. (b) $B = B_H \tan\theta \Rightarrow \frac{\mu_0 ni}{2r} = B_H \tan\theta$

$\Rightarrow i = \frac{2r.\,B_H \tan\theta}{\mu_0 n} = \frac{2 \times 0.1 \times 4 \times 10^{-5}}{10 \times 4\pi \times 10^{-7}} = 1.1A$

Magnetic Materials

1. (c)

2. (a) Neon atom is diamagnetic, hence it's net magnetic moment is zero.

3. (a) Soft iron is highly ferromagnetic.

4. (d)

5. (b) On heating, different domains have net magnetisation in them which are randomly distributes. Thus the net magnetisastion of the substance due to various domains decreases to minimum.

6. (b) Repelled due to induction of similar poles.

7. (d) From the characteristic of *B-H* curve.

8. (c)

9. (d)

10. (b)

11. (a)

12. (c) The property of paramagnetism is found in these substances whose atoms have an excess of electrons spinning in the same direction. Hence atoms of paramagnetic substances have a net non-zero magnetic moment of their own.

13. (c)

14. (a)

15. (a, b)

16. (d) $\chi_m = (\mu_r - 1) \Rightarrow \chi_m = (5500 - 1) = 5499$

17. (b)

18. (b)

19. (c)

20. (b) Because, diamagnetic substance, moves from stronger magnetic field to weaker field.

21. (d)

22. (b) With rise in temperature their magnetic susceptibility decreases *i.e.* $\chi_m \propto \frac{1}{T}$

23. (c)

24. (b)

25. (c) Diamagnetic substances are repelled by magnetic field.

26. (b) As we know for circulating electron magnetic moment

$M = \frac{1}{2}evr$ ...... (i)

and angular momentum $J = mvr$ ...... (ii)

From equation (i) and (ii) $M = \frac{eJ}{2m}$

27. (b)

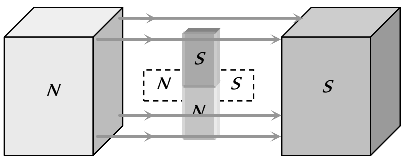
28. (a)

29. (c) The energy lost per unit volume of a substance in a complete cycle of magnetisation is equal to the area of the hysteresis loop.

30. (c)

31. (d)

32. (a) A diamagnetic rod set itself perpendicular to the field if free to rotate between the poles of a magnet as in this situation the field is strongest near the poles.



33. (c)

34. (b)

35. (b) Diamagnetic substances are repelled by the magnetic field.

36. (d)

37. (b)

38. (b)

39. (c)

40. (b)

41. (d) Net magnetic induction $B = B_0 + B_m = \mu_0 H + \mu_0 M$

42. (c)

43. (d) $\mu_r = \frac{B}{B_0} = 4$

44. (d)

45. (a)

46. (b)

47. (c)

48. (c) Susceptibility of diamagnetic substance is negative and it does not change with temperature.

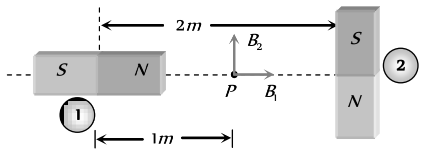
49. (a)

50. (d) When a ferromagnetic material in heated above its curie temperature then it behaves like paramagnetic material.

Critical Thinking Questions

1. (b) With respect to 1st magnet, *P* lies in end side-on position

$\therefore B_1 = \frac{\mu_0}{4\pi}\left(\frac{2M}{d^3}\right)$ (RHS)



With respect to 2nd magnet. *P* lies in broad side on position.

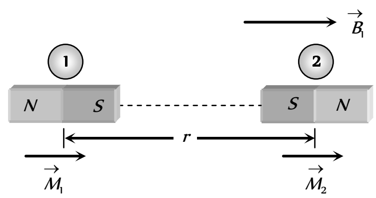
$\therefore B_2 = \frac{\mu_0}{4\pi}\left(\frac{M}{d^3}\right)$ (Upward)

$B_1 = 10^{-7} \times \frac{2\times 1}{1} = 2\times 10^{-7}\,T,\ B_2 = \frac{B_1}{2} = 10^{-7}\,T$

As B_1 and B_2 are mutually perpendicular, hence the resultant magnetic field

$B_R = \sqrt{B_1^2 + B_2^2} = \sqrt{(2\times 10^{-7})^2 + (10^{-7})^2} = \sqrt{5}\times 10^{-7}\,T$

2. (d)



Both the magnets are placed in the field of one another, hence potential energy of dipole (2) is

$U_2 = -M_2 B_1 \cos 0 = -M_2 B_1 = M_2 \times \frac{\mu_0}{4\pi}.\frac{2M_1}{r^3}$

By using $F = -\frac{dU}{dr}$, Force on magnet (2) is

$F_2 = -\frac{dU_2}{dr} = -\frac{d}{dr}\left(\frac{\mu_0}{4\pi}.\frac{2M_1M_2}{r^3}\right) = -\frac{\mu_0}{4\pi}.6\frac{M_1M_2}{r^4}$

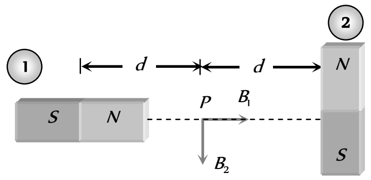
It can be proved $|F_1| = |F_2| = F = \frac{\mu_0}{4\pi}.\frac{6M_1M_2}{r^4}$

$\Rightarrow F \propto \frac{1}{r^4}$

3. (d) At point *P* net magnetic field $B_{net} = \sqrt{B_1^2 + B_2^2}$

where $B_1 = \frac{\mu_0}{4\pi}.\frac{2M}{d^3}$ and $B_2 = \frac{\mu_0}{4\pi}.\frac{M}{d^3}$

$\Rightarrow B_{net} = \frac{\mu_0}{4\pi}.\frac{\sqrt{5}M}{d^3}$



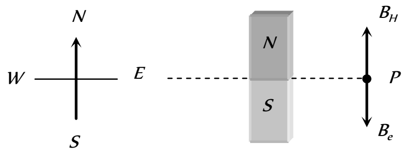
4. (a) Let the real dip be ϕ, then $\tan\phi = \frac{B_V}{B_H}$

For apparent dip,

$$\tan\phi' = \frac{B_V}{B_H\cos\beta} = \frac{B_V}{B_H\cos 30^o} = \frac{2B_V}{\sqrt{3}B_H}$$

or $\tan 45^o = \frac{2}{\sqrt{3}}.\tan\phi$ or $\phi = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

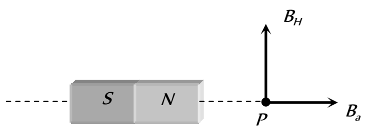
5. (d) Initially



Neutral point obtained on equatorial line and at neutral point $|B_H| = |B_e|$

where B_H = Horizontal component of earth's magnetic field, B_e = Magnetic field due to bar magnet on it's equatorial line

Finally



Point P comes on axial line of the magnet and at P, net magnetic field $B = \sqrt{B_a^2 + B_H^2}$

$$= \sqrt{(2B_e)^2 + (B_H)^2} = \sqrt{(2B_H)^2 + B_H^2} = \sqrt{5}\ B_H$$

6. (b) $\tan\phi' = \frac{\tan\phi}{\cos\beta}$; where ϕ' =Apparent angle of dip,

ϕ = True angle of dip, β =Angle made by vertical plane with magnetic meridian.

$$\Rightarrow \tan\phi' = \frac{\tan 60^o}{\cos 30^o} = 2 \Rightarrow \phi' = \tan^{-1}(2)$$

7. (c) Initially magnetic moment of system

$M_1 = \sqrt{M^2 + M^2} = 2M$ and moment of inertia

$I_1 = I + I = 2I.$

Finally when one of the magnet is removed then

$M_2 = M$ and $I_2 = I$

So $T = 2\pi\sqrt{\frac{I}{M\ B_H}}$

$$\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2} \times \frac{M_2}{M_1}} = \sqrt{\frac{2I}{I} \times \frac{M}{\sqrt{2}M}} \Rightarrow T_2 = \frac{2^{5/4}}{2^{1/4}} = 2\ \text{sec}.$$

8. (b) $T \propto \frac{1}{\sqrt{H}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{H_2}{H_1}} \Rightarrow \frac{2}{1} = \sqrt{\frac{H+F}{H}} \Rightarrow F = 3H$

or $\frac{H}{F} = \frac{1}{3}$

9. (b) Relation for dipole moment is, $M = I \times V$. Volume of the cylinder $V = \pi r^2 l$, Where r is the radius and l is the length of the cylinder, then dipole moment,

$$M = I\pi r^2 l = (5.30 \times 10^3) \times \frac{22}{7} \times (0.5 \times 10^{-2})^2 (5 \times 10^{-2})$$

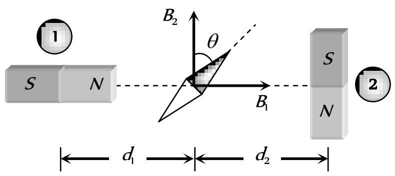
$$= 2.08 \times 10^{-2}\ J/T$$

10. (b) For equilibrium of the system torques on M_1 and M_2 due to B_H must counter balance each other *i.e.* $M_1 \times B_H = M_2 \times B_H$. If θ is the angle between M_1 and B_H will be $(90-\theta)$; so $M_1 B_H \sin\theta = M_2 B_H \sin(90-\theta)$

$$\Rightarrow \tan\theta = \frac{M_2}{M_1} = \frac{M}{3M} = \frac{1}{3} \Rightarrow \theta = \tan^{-1}\left(\frac{1}{3}\right)$$

11. (a) $I = \frac{M}{V} = \frac{\mu N}{V} = \frac{1.5 \times 10^{-23} \times 2 \times 10^{26}}{1} = 3 \times 10^3\ Amp/m$

12. (c) In equilibrium $B_1 = B_2\tan\theta$

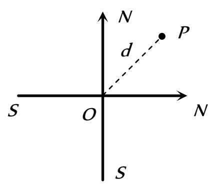


$$\Rightarrow \frac{\mu_0}{4\pi}.\frac{2M}{d_1^3} = \frac{\mu_0}{4\pi}.\frac{M}{d_2^3}\tan\theta$$

$$\Rightarrow \frac{d_1}{d_2} = (2\cot\theta)^{1/3}$$

13. (c) Resultant magnetic moment of the two magnets is

$$M_{net} = \sqrt{M^2 + M^2} = \sqrt{2}M$$



Imagine a short magnet lying along OP with magnetic moment equal to $M\sqrt{2}$. Thus point P lies on the axial line of the magnet.

$\therefore$ Magnitude of magnetic field at P is given by

$$B = \frac{\mu_0}{4\pi}.\frac{2\sqrt{2}M}{d^3}$$

14. (a) On passing current through the coil, it acts as a magnetic dipole. Torque acting on magnetic dipole is counter balanced by the moment of additional weight about position O. Torque acting on a magnetic dipole

$$\tau = MB\sin\theta = (NiA)B\sin 90^o = NiAB.$$

Again $\tau = Force \times Lever\ arm = \Delta mg \times l$

$\Rightarrow NiAB = \Delta mgl$

$\Rightarrow B = \frac{\Delta mgl}{NiA} = \frac{60\times10^{-3}\times9.8\times30\times10^{-2}}{200\times22\times10^{-3}\times1\times10^{-4}} = 0.4\ T$

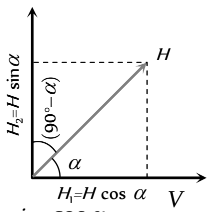
15. (a) The weight of upper magnet should be balanced by the repulsion between the two magnet

$\therefore \frac{\mu}{4\pi}.\frac{m^2}{r^2} = 50gm - wt$

$\Rightarrow 10^{-7}\times\frac{m^2}{(9\times10^{-6})} = 50\times10^{-3}\times9.8$

$\Rightarrow m = 6.64 amp\times m$

16. (d) Let α be the angle which one of the planes make with the magnetic meridian the other plane makes an angle $(90^o - \alpha)$ with it. The components of H in these planes will be $H\cos\alpha$ and $H\sin\alpha$ respectively. If ϕ_1 and ϕ_2 are the apparent dips in these two planes, then



$\tan\phi_1 = \frac{V}{H\cos\alpha}$ *i.e.* $\cos\alpha = \frac{V}{H\tan\phi_1}$ ..... (i)

$\tan\phi_2 = \frac{V}{H\sin\alpha}$ *i.e.* $\sin\alpha = \frac{V}{H\tan\phi_2}$ ..... (ii)

Squaring and adding (i) and (ii), we get

$\cos^2\alpha + \sin^2\alpha = \left(\frac{V}{H}\right)^2\left(\frac{1}{\tan^2\phi_1} + \frac{1}{\tan^2\phi_2}\right)$

i.e. $1 = \frac{V^2}{H^2}\left(\cot^2\phi_1 + \cot^2\phi_2\right)$

or $\frac{H^2}{V^2} = \cot^2\phi_1 + \cot^2\phi_2$ *i.e.* $\cot^2\phi = \cot^2\phi_1 + \cot^2\phi_2$

This is the required result.

17. (c) The number of atoms per unit volume in a specimen,

$n = \frac{\rho N_A}{A}$

For iron, $\rho = 7.8\times10^{-3} kgm^{-3}$,

$N_A = 6.02\times10^{26} / kgmol$, A=56

$\Rightarrow n = \frac{7.8\times10^3\times6.02\times10^{26}}{56} = 8.38\times10^{28} m^{-3}$

Total number of atoms in the bar is

$N_0 = nV = 8.38\times10^{28}\times(5\times10^{-2}\times1\times10^{-2}\times1\times10^{-2})$

$N_0 = 4.19\times10^{23}$

The saturated magnetic moment of bar

$= 4.19\times10^{23}\times1.8\times10^{-23} = 7.54\ Am^2$

18. (d) We have, $B = \mu_0 H + \mu_0 I$

or $I = \frac{B - \mu_0 H}{\mu_0}$ or $I = \frac{\mu H - \mu_0 H}{\mu_0} = \left(\frac{\mu}{\mu_0} - 1\right)H$

$I = (\mu_r - 1)H$

For a solenoid of n-turns per unit length and current i

$H = ni$

$\therefore I = (\mu_r - 1)ni = (1000-1)\times500\times0.5$

$I = 2.5\times10^5\ Am^{-1}$

$\therefore$ Magnetic moment $M=IV$

$M = 2.5\times10^5\times10^{-4} = 25\ Am$

19. (d) The bar magnet coercivity $4\times10^3 Am^{-1}$ *i.e.*, it requires a magnetic intensity $H = 4\times10^3 Am^{-1}$ to get demagnetised. Let i be the current carried by solenoid having n number of turns per metre length, then by definition $H = ni$. Here $H = 4\times10^3$ *Amp turn metre*

$n = \frac{N}{l} = \frac{60}{0.12} = 500$ *turn metre*

$\Rightarrow i = \frac{H}{n} = \frac{4\times10^3}{500} = 8.0\ A$

20. (c) Let M and $M_{,}$ be the magnetic moments of magnets and H the horizontal component of earth's field.

We have $\tau = MH\sin\theta$. If ϕ is the twist of wire, then $\tau = C\phi$, C being restoring couple per unit twist of wire

$\Rightarrow C\phi = MH\sin\theta$

Here $\phi_1 = (180^o - 30^o) = 150^o = 150\times\frac{\pi}{180}$ *rad*

$\phi_2 = (270^o - 30^o) = 240^o = 240\times\frac{\pi}{180}$ *rad*

So, $C\phi_1 = M_1 H\sin\theta$ (For deflection $\theta = 30^o$ of I magnet)

$C\phi_2 = M_2 H\sin\theta$ (For deflection $\theta = 30^o$ of II magnet)

Dividing $\frac{\phi_1}{\phi_2} = \frac{M_1}{M_2}$

$\Rightarrow \frac{M_1}{M_2} = \frac{\phi_1}{\phi_2} = \frac{150\times\left(\frac{\pi}{180}\right)}{240\times\left(\frac{\pi}{180}\right)} = \frac{15}{24} = \frac{5}{8}$

$\Rightarrow M_1 : M_2 = 5:8$

21. (c) In vertical plane perpendicular to magnetic meridian.

$T = 2\pi\sqrt{\frac{I}{MB_V}}$ ..... (i)

In horizontal plane $T = 2\pi\sqrt{\dfrac{I}{MB_H}}$ ..... (ii)

Equation (i) and (ii) gives $B_V = B_H$

Hence by using $\tan\phi = \dfrac{B_V}{B_H} \Rightarrow \tan\phi = 1 \Rightarrow \phi = 45^o$

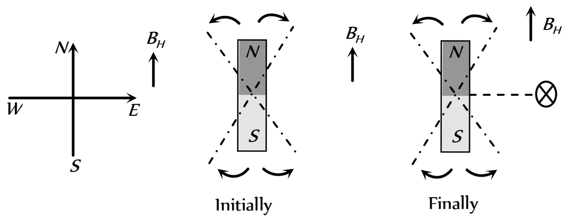
22. (a) Molar susceptiblity

$$= \frac{\text{Volume susceptiblity}}{\text{Density of material}} \times \text{molecular weight}$$

$$= \frac{I/H}{\rho} \times M = \frac{I/H}{M/V} \times M$$

So it's unit is m.

23. (c)



Initially $T = 2\pi\sqrt{\dfrac{I}{mB_H}}$, Finally $T' = 2\pi\sqrt{\dfrac{I}{m(B+B_H)}}$

Where B = Magnetic field due to down ward conductor

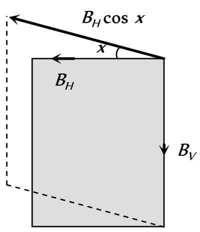
$$= \frac{\mu_0}{4\pi}.\frac{2i}{a} = 18\mu T$$

$$\therefore \frac{T'}{T} = \sqrt{\frac{B_H}{B+B_H}} \Rightarrow \frac{T'}{0.1} = \frac{24}{18+24} \Rightarrow T' = 0.076\,s.$$

24. (a) In first case $\tan\theta = \dfrac{B_V}{B_H}$ ..... (i)

Second case $\tan\theta' = \dfrac{B_V}{B_H\cos x}$ ..... (ii)

From equation (i) and (ii), $\dfrac{\tan\theta'}{\tan\theta} = \dfrac{1}{\cos x}$



25. (c) $\tan\theta = \dfrac{B_V}{B_H}$ ... (i)

If apparent dip is θ' then

$$\tan\theta' = \frac{B'_V}{B'_H} = \frac{B_V}{B_H\cos 30^\circ} = \frac{B_V}{B_H \times \frac{\sqrt{3}}{2}}$$

$$\Rightarrow \tan\theta' = \left(\frac{2}{\sqrt{3}}\right)\tan\theta \Rightarrow \tan\theta' > \tan\theta \Rightarrow \theta' > \theta$$

Graphical Questions

1. (d) For a temporary magnet the hysteresis loop should be long and narrow.

2. (c) Magnetism of a magnet falls with rise of temperature and becomes practically zero above curie temperature.

3. (b) For a diamagnetic substance χ is small, negative and independent of temperature.

4. (a) Susceptibility of a paramagnetic substance is independent of magnetising field.

5. (a) Susceptibility of a ferromagnetic substance falls with rise of temperature $\left(\chi = \dfrac{c}{T - T_c}\right)$ and the substance becomes paramagnetic above curie temperature, so magnetic susceptibility becomes very small above curie temperature.

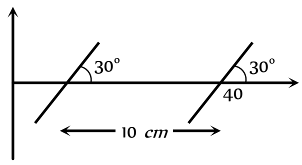
6. (c)

7. (b) $B = \mu_0\mu_r H \Rightarrow \mu_r \propto \dfrac{B}{H}$ = slope of *B- H* curve

According to the given graph, slope of the graph is highest point *Q*.

8. (b) $i \propto \tan\theta$

9. (b) $|B| = \dfrac{\Delta V}{\Delta x} = \dfrac{0.1 \times 10^{-4}}{0.1\sin 30^o} = 2 \times 10^{-4}T$



10. (a) $X = C \times \dfrac{1}{T} = \dfrac{0.4}{7 \times 10^{-3}} = 57K$

11. (b) In the given figure *OQ* refers to retentivity while *OR* refers to corecivity, for permanents both retentivity and corecivity should be high.

12. (b) Intensity of magnetisation of diamagnetic substance is very small and negative.

13. (d) $\mu_r = 1 + \dfrac{I}{H}$; as we know *I* dependent on *H*, initially value of $\dfrac{I}{H}$ is smaller so value of μ increases with *H* but slowly but with further increases of *H* value of $\dfrac{I}{H}$ also increases *i.e.* μ increases speedily. When material fully magnetised *I* becomes constant then with the increase of *H* $\left(\dfrac{I}{H}\text{ decreases}\right)$ μ decreases. This is confirm with the option (d).

14. (a) For paramagnetic substance magnetization *M* proportional to magnetising field *H*, and *M* is positive.

Assertion and Reason

1. (d) It is quite clear that magnetic poles always exists in pairs. Since, one can imagine magnetic field configuration with three poles. When north poles or south poles of two magnets are glued together. They provide a three pole field configuration. It is also known that a bar magnet does not exert a torque on itself due to own its field.

2. (b) As we know every atom of a magnet acts as a dipole, So poles cannot be separated. When magnet is broken into two equal pieces, magnetic moment of each part will be half of the original magnet.

3. (a) In case of the electric field of an electric dipole, the electric lines of force originate from positive charge and end at negative charge. Since isolated magnetic lines are closed continuous loops extending through out the body of the magnet.

4. (c) In an atom, electrons revolve around the nucleus and as such the circular orbits of electrons may be considered as the small current loops. In addition to orbital motion, an electron has got spin motion also. So the total magnetic moment of electron is the vector sum of its magnetic moments due to orbital and spin motion. Charge particles at rest do not produce electric field.

5. (b) Magnetic dipole moment of the current loop

= Ampere turns × Area of the coil

Initially magnetic moment $M = i\pi r$, new magnetic moment $M' = i\pi(2r)^2 = 4i(\pi r^2) = 4M.$

So magnetic moment becomes four times when radius is doubled.

6. (e) The temperature inside the earth is so high that it is impossible for iron core to behave as magnet and act as a source of magnetic field. The magnetic field of earth is considered to be due to circulating electric current in the iron (In molten state) and other conducting materials inside the earth.

7. (d) The earth has only vertical component of its magnetic field at the magnetic poles. Since compass needle is only free to rotate in horizontal plane. At north pole the vertical component of earth's field will exert torque on the magnetic needle so as to align it along its direction. As the compass needle can not rotate in vertical plane, it will rest horizontally, when placed on the magnetic pole of the earth.

8. (b) In tangent galvanometer the current through the coil is given by $I = \frac{2r}{n\mu_0}.B_H \tan\theta \Rightarrow \tan\theta \propto n/r$

i.e. by reducing its radius or by increasing number of turns of coil we can increase the sensitivity of tangent galvanometer.

9. (b) The susceptibility of ferromagnetic substance decreases with the rise of temperature in a complicated manner. After Curies point the susceptibility of ferromagnetic substance varies inversely with its absolute temperature. Ferromagnetic substance obey's Curies law only above its Curie point.

10. (e) The properties of substance is due to alignment of molecules in it. When these substance are heated, molecules acquire some kinetic energy. Some of molecules may get back to the closed chain arrangement (produce zero resultant). So they lose their magnetic property or magnetism. Therefor the properties of both ferromagnetic and paramagnetic are effected by heating.

11. (a) The core of a transformer undergoes cycles of magnetisation again and again. During each cycle of magnetisation, energy numerically equal to the area of the hysteresis loop is spent per unit volume of the core. Therefore, for high efficiency of transformer, the energy loss will be lesser if the hystersis loop is of lesser area, i.e. narrow. That's why the soft iron is used as core, which has narrow hysteresis loop (or area of $B-H$ curve is very small). Also soft iron (ferromegnetic substance) has high permeability, high retentivity, low coercivity and low hystersis loss.

12. (a) A magnetic field is produced by the motion of electric charge. Since motion is relative, the magnetic field is also relative.

13. (a) In a moving coil galvanometer, the coil is suspended in a very strong uniform magnetic field created by two magnetic pole pieces. The earth's magnetic field is quite weak as compared to that field, therefore, it does not effect the working of magnetic field.

14. (c) A paramagnetic sample display greater magnetisation when cooled, this is because at lower temperature, the tendency to disrupt the alignment of dipoles (due to magnetising field) decreases on account of reduced random thermal motion.

15. (a) Electromagnets are magnets, which can be turned on and off by switching the current on and off. As the material in electromagnets is subjected to cyclic change (magnification and demagentisation), the hysteresis loss of the material must be small. The material should attain high value of I and B with low value of magnetising field intensity H. As soft iron has small coercivity, so it is a best choice for this purpose.

16. (a) Since iron is ferromagnetic in nature, therefore, lines of force due to external magnetic field prefer to pass through iron.

17. (d) In general, the field due to a magnet is non-uniform. Therefore, it exerts both, a net force and a torque on the nails which will translate and also rotate the nails before striking to north pole of magnet with their induced south poles and vice-versa.

18. (d) In a non-uniform magnetic field, both a torque and a net force acts on the dipole. If magnetic field were uniform, net force on dipole would be zero.

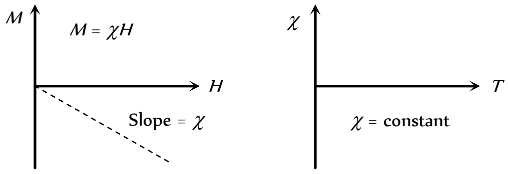
19. (c) The reduction factor of tangent galvanometer is

$$K = \frac{B_H}{G} = B_H \times \frac{2r}{n\mu_0}$$

Thus reduction factor of a tangent galvanometer depends upon the geometry of its coil. It increases with increase of radius and decreases with increase in number of turn of the coil of the galvanometer.

20. (c) Diamagnetism is non-cooperative behaviour of orbiting electrons when exposed to an applied magnetic field. Diamagnetic substance are composed of atom which have no net magnetic moment (*i.e.*, all the orbital shells are filled and there are no unpaired electrons). When exposed to a field, a negative magnetization is produced and thus the susceptibility is negative.

Behaviour of diamagnetic material is that the susceptibility is temperature independent.



21. (d) The permeability of a ferromagnetic material is not independent of magnetic field, $\vec{B} = K_m \vec{B}_0$.

B_0 is applied field. The total magnetic field $\vec{B}$ inside a ferromagnet may be 10^3 or 10^4 times the applied field B_0. The permeability K_m of a ferromagnetic material is not constant, neither the field $\vec{B}$ nor the magnetization $\vec{M}$ increases linearly with $\vec{B}$. Even at small value of B_0. From the hysteresis curve, magnetic permeability is greater for lower field.

22. (e) For a perfectly diamagnetic substance,

$B = \mu_0(H + I) = 0 \qquad \therefore I = -H.$

Therefore, $\chi_m = \dfrac{I}{H} = -1$

Therefore relative permeability

$\mu_r = 1 + \chi_m = 1 - 1 = 0. \quad \therefore \mu = \mu_0 \mu_r =$ zero.

i.e. for a perfectly diamagnetic material permeability is zero.

23. (a)

24. (a) Helium atom has paired electrons so their electron spin are opposite to each other and hence it's net magnetic moment is zero.

25. (b) Steel is preferred over soft iron for making permanent magnets, because coercivity of steel is larger.

Magnetism

Self Evaluation Test - 22

1. A compass needle whose magnetic moment is 60 *amp* × *m* pointing geographical north at a certain place, where the horizontal component of earth's magnetic field is 40 μ *Wb/m*, experiences a torque $1.2 \times 10^{-3}\ N \times m$. What is the declination at this place

(a) 30° (b) 45°

(c) 60° (d) 25°

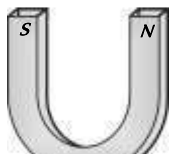
2. The distance between the poles of a horse shoe magnet is 0.1 *m* and its pole strength is 0.01 *amp-m*. The induction of magnetic field at a point midway between the poles will be

(a) $2 \times 10^{-5}\ T$

(b) $4 \times 10^{-6}\ T$

(c) $8 \times 10^{-7}\ T$

(d) Zero



3. Due to a small magnet intensity at a distance *x* in the end on position is 9 Gauss. What will be the intensity at a distance $\frac{x}{2}$ on broad side on position

(a) 9 *Gauss* (b) 4 *Gauss*

(c) 36 *Gauss* (d) 4.5 *Gauss*

4. The magnetic moment produced in a substance of $1 gm$ is $6 \times 10^{-7}\ ampere-metre^2$. If its density is $5\ gm/cm^3$, then the intensity of magnetisation in *A/m* will be

(a) 8.3×10^6 (b) 3.0

(c) 1.2×10^{-7} (d) 3×10^{-6}

5. The needle of a deflection galvanometer shows a deflection of 60° due to a short bar magnet at a certain distance in $\tan A$ position. If the distance is doubled, the deflection is

(a) $\sin^{-1}\left(\frac{\sqrt{3}}{8}\right)$ (b) $\cos^{-1}\left(\frac{\sqrt{3}}{8}\right)$

(c) $\tan^{-1}\left(\frac{\sqrt{3}}{8}\right)$ (d) $\cot^{-1}\left(\frac{\sqrt{3}}{8}\right)$

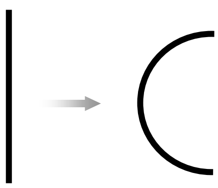
6. The area of hysteresis loop of a material is equivalent to 250 *joule*. When 10 *kg* material is magnetised by an alternating field of 50 *Hz* then energy lost in one *hour* will be if the density of material is $7.5\ gm/cm^3$

(a) $6 \times 10^4\ J$ (b) $6 \times 10^4\ erg$

(c) $3 \times 10^2\ J$ (d) $3 \times 10^2\ erg$

7. A magnetised wire of moment *M* is bent into an arc of a circle subtending an angle of 60° at the centre; then the new magnetic moment is

(a) $(2M/\pi)$



(b) (M/π)

(c) $(3\sqrt{3}M/\pi)$

(d) $(3M/\pi)$ **[EAMCET (Engg.) 1996]**

8. A tangent galvanometer shows a deflection 45° when 10 *mA* current pass through it. If the horizontal component of the earth's field is $3.6 \times 10^{-5}\ T$ and radius of the coil is 10 *cm*. The number of turns in the coil is

(a) 5700 turns (b) 57 turns

(c) 570 turns (d) 5.7 turns

9. A magnet is parallel to a uniform magnetic field. If it is rotated by 60°, the work done is 0.8 *J*. How much work is done in moving it 30° further

(a) 0.8×10^7 *ergs* (b) 0.4 *J*

(c) 8 *J* (d) 0.8 *ergs*

10. Susceptibility of *Mg* at 300 *K* is 1.2×10^{-5}. The temperature at which susceptibility will be 1.8×10^{-5} is **[Roorkee 1999]**

(a) 450 *K* (b) 200 *K*

(c) 375 *K* (d) None of these

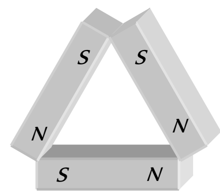
11. Three identical bar magnets each of magnetic moment *M* are placed in the form of an equilateral triangle as shown. The net magnetic moment of the system is

(a) Zero

(b) 2 *M*

(c) $M\sqrt{3}$

(d) $\frac{3M}{2}$



12. A magnetic needle is placed on a cork floating in a still lake in the northern hemisphere. Does the needle together with the cork move towards the north of the lake

(a) Yes

(b) No

(c) May be or may not be move

(d) Nothing can be said

13. The magnet of vibration magnetometer is heated so as to reduce its magnetic moment by 36%. By doing this the periodic time of the magnetometer will

(a) Increases by 36% (b) Increases by 25%

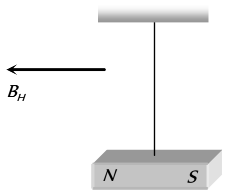
(c) Decreases by 25% (d) Decreases by 64%

14. The ratio of magnetic moments of two bar magnet is 13 : 5. These magnets are held together in a vibration magnetometer are allowed to oscillate in earth's magnetic field with like poles together 15 oscillation per minute are made. What will be the frequency of oscillation of system if unlike poles are together

(a) 10 *oscillations/min* (b) 15 *oscillations/min*

(c) 12 *oscillations/min* (d) $\frac{75}{13}$ *oscillations/min*

15. A magnet is suspended horizontally in the earth's magnetic field. When it is displaced and then released it oscillates in a horizontal plane with a period *T*. If a place of wood of the same moment of inertia (about the axis of rotation) as the magnet is attached to the magnet what would the new period of oscillation of the system become



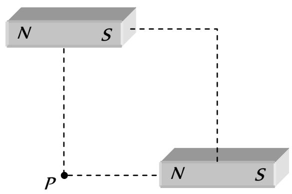
(a) $\frac{T}{3}$

(b) $\frac{T}{2}$

(c) $\frac{T}{\sqrt{2}}$

(d) $T\sqrt{2}$

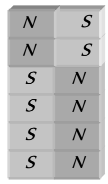
16. Two short magnets of magnetic moment 1000 Am^2 are placed as shown at the corn ers of a square of side 10 *cm*. The net magnetic induction at *P* is



(a) 0.1 *T* (b) 0.2 *T*

(c) 0.3 *T* (d) 0.4 *T*

17. The length of *a* magnet is large compared to it's width and breadth. The time period of its oscillation in a vibration magnetometer is *T*. The magnet is cut along it's length into six parts and these parts are then placed together as shown in the figure. The time period of this combination will be



(a) *T*

(b) $\frac{T}{\sqrt{3}}$

(c) $\frac{T}{2\sqrt{3}}$

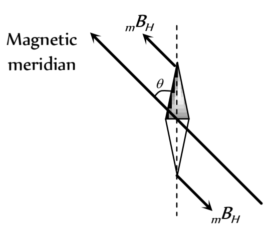
(d) Zero

Answers and Solutions

(SET -22)

1. (a) As the compass needle is free to rotate in a horizontal plane and points along the magnetic meridian,

so when it is pointing along the geographic meridian, it will experience a torque due



to the horizontal component of earth's magnetic field *i.e.* $\tau = MB_H \sin\theta$

where θ = angle between geographical

and magnetic meridians called angle of declination

So, $\sin\theta = \frac{1.2\times10^{-3}}{60\times40\times10^{-6}} = \frac{1}{2} \Rightarrow \theta = 30^o$

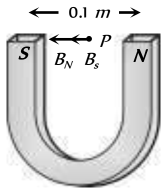
2. (c) Net magnetic field at mid point P, $B = B_N + B_S$

where B_N = magnetic field due to N- pole

B_S = magnetic field due to S- pole

$B_N = B_S = \frac{\mu_0}{4\pi}\frac{m}{r^2}$

$= 10^{-7}\times\frac{0.01}{\left(\frac{0.1}{2}\right)^2} = 4\times10^{-7}\,T$



$\therefore B_{net} = 8\times10^{-7}\,T.$

3. (c) In C.G.S. $B_{axial} = 9 = \frac{2M}{x^3}$ .....(i)

$B_{\text{equaterial}} = \frac{M}{\left(\frac{x}{2}\right)^3} = \frac{8M}{x^3}$ .....(ii)

From equation (i) and (ii) $B_{\text{equaterial}} = 36$ *Gauss.*

4. (b) $I = \frac{M}{V} = \frac{M}{\text{mass/density}}$,

given mass = $1gm$ = $10^{-3}\,kg$,

and density $= 5gm/cm^3 = \frac{5\times10^{-3}\,kg}{(10^{-2})^3\,m^3} = 5\times10^3\,kg/m^3$

Hence $I = \frac{6\times10^{-7}\times5\times10^3}{10^{-3}} = 3$

5. (c) For short bar magnet in tan A-position

$\frac{\mu_0}{4\pi}\frac{2M}{d^3} = H\tan\theta$ .....(i)

When distance is doubled, then new deflection θ' is given by

$\frac{\mu_0}{4\pi}\frac{2M}{(2d)^3} = H\tan\theta'$ .....(ii)

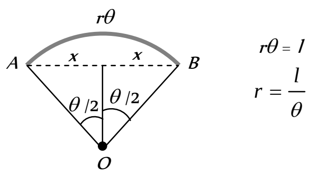
$\therefore \frac{\tan\theta'}{\tan\theta} = \frac{1}{8} \Rightarrow \tan\theta' = \frac{\tan\theta}{8} = \frac{\tan 60^\circ}{8} = \frac{\sqrt{3}}{8}$

$\Rightarrow \theta' = \tan^{-1}\left(\frac{\sqrt{3}}{8}\right)$

6. (a) $E = nAVt = nA\frac{m}{d}t = \frac{50\times250\times10\times3600}{7.5\times10^3} = 6\times10^4\,J$

7. (d) From figure

$\sin\frac{\theta}{2} = \frac{x}{r}$



$\Rightarrow x = r\sin\frac{\theta}{2}$

Hence new magnetic moment $M' = m(2x) = m.2r\sin\frac{\theta}{2}$

$= m.\frac{2l}{\theta}\sin\frac{\theta}{2} = \frac{2ml\sin\theta/2}{\theta} = \frac{2M\sin(\pi/6)}{\pi/3} = \frac{3M}{\pi}$

8. (c) $K = \frac{2rB_H}{\mu_0 n}$

or $n = \frac{2rB_H}{\mu_0 K} = \frac{2\times0.1\times3.6\times10^{-5}}{4\pi\times10^{-7}\times10\times10^{-3}} = \frac{1.8\times10^3}{3.14} = 570$

9. (a) $W = MB(\cos\theta_1 - \cos\theta_2)$

When the magnet is rotated from 0° to 60°, then work done is 0.8 J

$0.8 = MB(\cos0^\circ - \cos60^\circ) = \frac{MB}{2}$

$\Rightarrow MB = 1.6\,N-m$

In order to rotate the magnet through an angle of 30°, *i.e.*, from 60° to 90°, the work done is

$W' = MB(\cos60^\circ - \cos90^\circ) = MB\left(\frac{1}{2} - 0\right)$

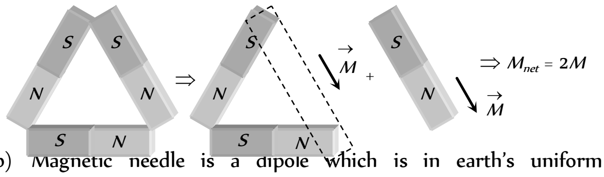
$= \frac{MB}{2} = \frac{1.6}{2} = 0.8\,J = 0.8\times10^7\,ergs$

10. (b) $\chi \propto \frac{1}{T}$

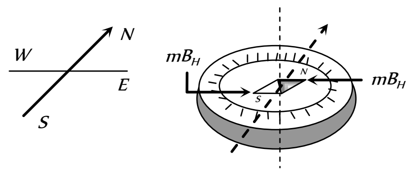
$\therefore \chi_1 T_1 = \chi_2 T_2$

Hence $T_2 = \frac{1.2\times10^{-5}\times300}{1.8\times10^{-5}} = 200\,K$

11. (b) The resultant magnetic moment can be calculated as follows.



12. (b) Magnetic needle is a dipole which is in earth's uniform magnetic field and as a dipole in a uniform field does not experience any net force but may experience a couple as shown in figure, so the needle together with the cork will not translate *i.e.* move towards the north of the lake, but will rotate and set itself parallel to the field with it's north pole pointing north.



13. (b) $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow T \propto \frac{1}{\sqrt{M}} \Rightarrow \frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}}$

If $M_1 = 100$ then $M_2 = (100-36) = 64$

So $\frac{T_1}{T_2} = \sqrt{\frac{64}{100}} = \frac{8}{10} \Rightarrow T_2 = \frac{10}{8}T_1 = 1.25\,T_1$

So % increase in time period = 25%

14. (a) $\frac{M_1}{M_2} = \frac{\nu_s^2 + \nu_d^2}{\nu_s^2 - \nu_d^2} \Rightarrow \frac{13}{5} = \frac{(15)^2 + \nu_d^2}{(15)^2 - \nu_d^2}$

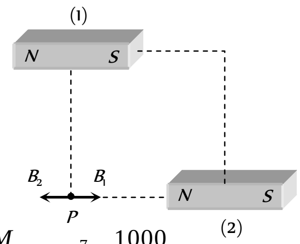
$\Rightarrow \nu_d = 10$ *oscillations/min*

***

15. (d) Due to wood moment of inertia of the system becomes twice but there is no change in magnetic moment of the system.

Hence by using $T = 2\pi\sqrt{\frac{I}{MB_H}} \Rightarrow T \propto \sqrt{I} \Rightarrow T' = \sqrt{2}\,T$

16. (a) Point P lies on equatorial line of magnet (1) and axial line of magnet (2) as shown



$B_1 = \frac{\mu_0}{4\pi}\cdot\frac{M}{d^3} = 10^{-7}\times\frac{1000}{(0.1)^3} = 0.1\,T$

$B_2 = \frac{\mu_0}{4\pi}\cdot\frac{2M}{d^3} = 10^{-7}\times\frac{2\times 1000}{(0.1)^3} = 0.2\,T$

$\therefore\ B_{net} = B_2 - B_1 = 0.1\,T$

17. (c) $T = 2\pi\sqrt{\frac{I}{MH}}$; MI of each part $= \frac{I}{6^3}$

and magnetic moment of each part $= \frac{M}{6}$

so net *MI* of system $= \frac{I}{6^3}\times 6 = \frac{I}{6^2}$

and net magnetic moment $= \frac{4M}{6} - \frac{2M}{6} = \frac{M}{3}$

$\therefore$ time period of the system

$T' = 2\pi\sqrt{\frac{I/36}{(M/3)H}} = \frac{1}{2\sqrt{3}}2\pi\sqrt{\frac{I}{MH}} = \frac{T}{2\sqrt{3}}$

Chapter
23

Electromagnetic Induction

Magnetic Flux

(1) The total number of magnetic lines of force passing normally through an area placed in a magnetic field is equal to the magnetic flux linked with that area.

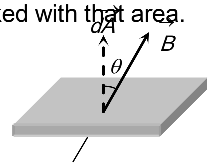


Fig. 23.1

(2) Net flux through the surface $\phi = \oint \vec{B} \cdot d\vec{A} = BA\cos\theta$

(θ is the angle between area vector and magnetic field vector)

If $\theta = 0^o$ then $\phi = BA$, If $\theta = 90^o$ then $\phi = 0$

(3) **Unit and Dimension :** Magnetic flux is a scalar quantity. It's S.I. unit is *weber* (*wb*), CGS unit is *Maxwell* or *Gauss* × *cm*^{2}; ($1 wb = 10^8$ *Maxwell*).

(4) Other units : *Tesla* × *m*^{2} $= \frac{N \times m}{Amp} = \frac{Joule}{Amp} = \frac{Volt \times \text{Coulomb}}{Amp}$

$= Volt \times sec$ = *Ohm* × *Coulomb* = *Henry* × *Amp*. It's dimensional formula [ϕ] = [$ML^2T^{-2}A^{-1}$]

Faraday's Laws of Electromagnetic Induction

(1) **First law :** Whenever the number of magnetic lines of force (magnetic flux) passing through a circuit changes an emf is produced in the circuit called induced emf. The induced emf persists only as long as there is change or cutting of flux.

(2) **Second law :** The induced emf is given by rate of change of magnetic flux linked with the circuit *i.e.* $e = -\frac{d\phi}{dt}$. For *N* turns $e = -\frac{N\,d\phi}{dt}$; Negative sign indicates that induced emf (*e*) opposes the change of flux.

(3) **Other formulae :** $\phi = BA\cos\theta$; Hence ϕ will change if either, *B*, *A* or θ will change

So $e = -N\frac{d\phi}{dt} = -\frac{N(\phi_2 - \phi_1)}{\Delta t} = -\frac{NA(B_2 - B_1)\cos\theta}{\Delta t}$

$= -\frac{NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$

Table 23.1 : Induced *i*, *q* and *P*

Induced current (*i*)	Induced charge (*q*)	Induced power (*P*)
$i = \frac{e}{R} = -\frac{N}{R}\cdot\frac{d\phi}{dt}$	$dq = i\,dt = -\frac{N}{R}\cdot d\phi$ Induced charge is time independent.	$P = \frac{e^2}{R} = \frac{N^2}{R}\left(\frac{d\phi}{dt}\right)^2$ It depends on time and resistance

Lenz's Law

This law gives the direction of induced emf/induced current. According to this law, the direction of induced emf or current in a circuit is such as to oppose the cause that produces it. This law is based upon law of conservation of energy.

(1) When *N*-pole of a bar magnet moves towards the coil, the flux associated with loop increases and an emf is induced in it. Since the circuit of loop is closed, induced current also flows in it.

(2) Cause of this induced current, is approach of north pole and therefore to oppose the cause, *i.e.*, to repel the approaching north pole, the induced current in loop is in such a direction so that the front face of loop behaves as north pole. Therefore induced current as seen by observer *O* is in anticlockwise direction. (figure)

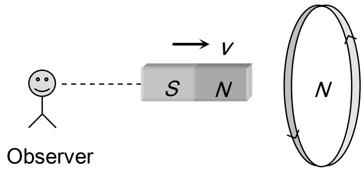
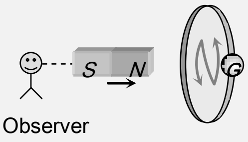
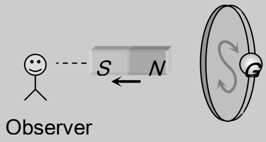
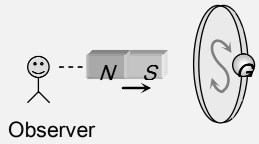
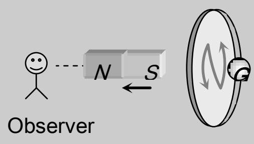


Fig. 23.2

Table 23.2 : The various positions of relative motion between the magnet and the coil

Position of magnet	 Observer	 Observer	 Observer	 Observer
Direction of induced current	Anticlockwise direction	Clockwise direction	Clockwise direction	Anticlockwise direction
Behaviour of face of the coil	As a north pole	As a south pole	As a south pole	As a north pole
Type of magnetic force opposed	Repulsive force	Attractive force	Repulsive force	Attractive force
Magnetic field linked with the coil and it's progress as viewed from left	Cross (×), Increases	Cross (×), Decreases	Dots (·) Increases	Dots (·) Decreases

(3) If the loop is free to move the cause of induced emf in the coil can also be termed as relative motion. Therefore to oppose the cause, the relative motion between the approaching magnet and the loop should be opposed. For this, the loop will itself start moving in the direction of motion of the magnet.

(4) It is important to remember that whenever cause of induced emf is relative motion, the new motion is always in the direction of motion of the cause.

Induced Electric Field

It is non-conservative and non-electrostatic in nature. Its field lines are concentric circular closed curves.

A time varying magnetic field $\frac{dB}{dt}$ always produced induced electric field in all space surrounding it.

Induced electric field (E_{in}) is directly proportional to induced emf so $e = \oint \vec{E}_{in} \cdot d\vec{l}$ .....(i)

From Faraday's second laws $e = -\frac{d\phi}{dt}$ .....(ii)

From (i) and (ii) $e = \oint \vec{E}_{in} . d\vec{l} = -\frac{d\phi}{dt}$ This is known as integral form of Faraday's laws of EMI.

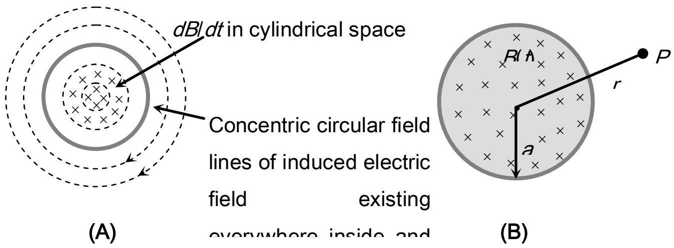


Fig. 23.3

A uniform but time varying magnetic field $B(t)$ exists in a circular region of radius 'a' and is directed into the plane of the paper as shown, the magnitude of the induced electric field (E_{in}) at point P lies at a distance r from the centre of the circular region is calculated as follows.

So $\oint \vec{E}_{in} d\vec{l} = e = \frac{d\phi}{dt} = A\frac{dB}{dt}$ *i.e.* $E(2\pi r) = \pi a^2 \frac{dB}{dt}$

where $r \geq a$ or $E = \frac{a^2}{2r}\frac{dB}{dt}$; $\boldsymbol{E_{in} \propto \frac{1}{r}}$

Dynamic (Motional) EMI Due to Translatory Motion

(1) Consider a conducting rod of length l moving with a uniform velocity $\vec{v}$ perpendicular to a uniform magnetic field $\vec{B}$, directed into the plane of the paper. Let the rod be moving to the right as shown in figure. The conducting electrons also move to the right as they are trapped within the rod.

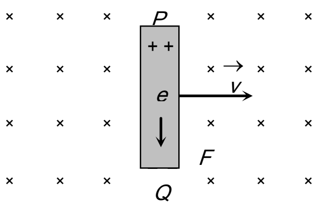
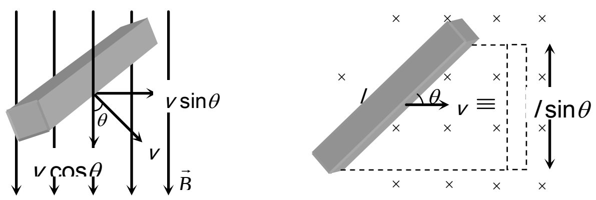


Fig. 23.4

Conducting electrons experiences a magnetic force $F_m = evB$. So they move from P to Q within the rod. The end P of the rod becomes positively charged while end Q becomes negatively charged, hence an electric field is set up within the rod which opposes the further downward movement of electrons *i.e.* an equilibrium is reached and in equilibrium $F_e = F_m$ *i.e.* $eE = evB$ or $E = vB \Rightarrow$ Induced emf $\boldsymbol{e = El = Bvl}$ $[E = \frac{V}{l}]$

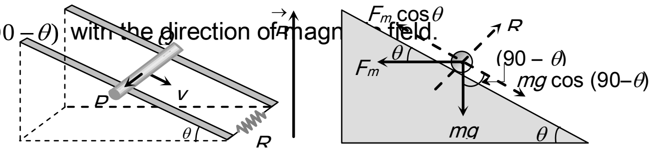
(2) If rod is moving by making an angle θ with the direction of magnetic field or length. Induced emf $e = Bvl\sin\theta$



(A) (B)

Fig. 23.5

(3) **Motion of conducting rod on an inclined plane :** When conductor start sliding from the top of an inclined plane as shown, it moves perpendicular to it's length but at an angle $(90 - \theta)$ with the direction of magnetic field.



(A) (B)

Fig. 23.6

Hence induced emf across the ends of conductor $e = Bv\sin(90-\theta)l = Bvl\cos\theta$

So induced current $i = \frac{Bvl\cos\theta}{R}$ (Directed from Q to P).

The forces acting on the bar are shown in following figure. The rod will move down with constant velocity only if

$$F_m\cos\theta = mg\cos(90-\theta) = mg\sin\theta \Rightarrow Bil\cos\theta = mg\sin\theta$$

$$B\left(\frac{Bv_T l\cos\theta}{R}\right)l\cos\theta = mg\sin\theta \Rightarrow v_T = \frac{mgR\sin\theta}{B^2l^2\cos^2\theta}$$

Motional Emi in Loop by Generated Area

If conducting rod moves on two parallel conducting rails as shown in following figure then phenomenon of induced emf can also be understand by the concept of generated area (The area swept of conductor in magnetic field, during it's motion)

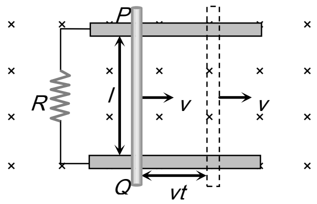


Fig. 23.7

As shown in figure in time t distance travelled by conductor = vt

Area generated $A = lvt$. Flux linked with this area $\phi = BA = Blvt$. Hence induced emf $|e| = \frac{d\phi}{dt} = Bvl$

(1) **Induced current :** $i = \frac{e}{R} = \frac{Bvl}{R}$

(2) **Magnetic force :** Conductor *PQ* experiences a magnetic force in opposite direction of it's motion and $F_m = Bil = B\left(\frac{Bvl}{R}\right)l = \frac{B^2vl^2}{R}$

(3) **Power dissipated in moving the conductor :** For uniform motion of rod *PQ*, the rate of doing mechanical work by external agent or mech. Power delivered by external source is given as

$$P_{mech} = P_{ext} = \frac{dW}{dt} = F_{ext}.v = \frac{B^2vl^2}{R} \times v = \frac{B^2v^2l^2}{R}$$

(4) **Electrical power :** Also electrical power dissipated in resistance or rate of heat dissipation across resistance is given as

$$P_{thermal} = \frac{H}{t} = i^2R = \left(\frac{Bvl}{R}\right)^2.R \; ; \quad P_{thermal} = \frac{B^2v^2l^2}{R}$$

(It is clear that $P_{mech.}$ = $P_{thermal}$ which is consistent with the principle of conservation of energy.)

(5) **Motion of conductor rod in a vertical plane :** If conducting rod released from rest (at *t* = 0) as shown in figure then with rise in it's speed (*v*), induces emf (*e*), induced current (*i*), magnetic force (F_m) increases but it's weight remains constant.

Rod will achieve a constant maximum (terminal) velocity v_T if $F_m = mg$

So $\frac{B^2v_T^2l^2}{R} = mg$

$\Rightarrow \quad v_T = \frac{mgR}{B^2l^2}$

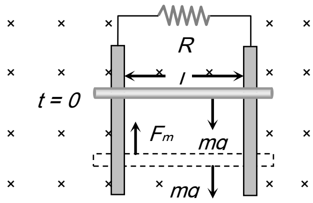


Fig. 23.8

Special cases

Motion of train and aeroplane in earth's magnetic field

(A) Fig. 23.9 (B)

Induced emf across the axle of the wheels of the train and it is across the tips of the wing of the aeroplane is given by *e* = $B_v lv$ where *l* = length of the axle or distance between the tips of the wings of plane, B_v = vertical component of earth's magnetic field and *v* = speed of train or plane.

Motional EMI Due to Rotational Motion

(1) **Conducting rod :** A conducting rod of length *l* whose one end is fixed, is rotated about the axis passing through it's fixed end and perpendicular to it's length with constant angular velocity ω. Magnetic field (*B*) is perpendicular to the plane of the paper.

emf induces across the ends of the rod

where ν = frequency (revolution per sec) and *T* = Time period.

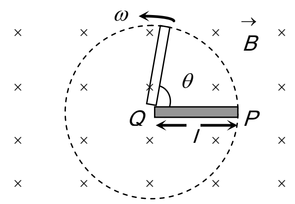


Fig. 23.10

(2) **Cycle wheel** : A conducting wheel each spoke of length *l* is rotating with angular velocity ω in a given magnetic field as shown below in fig.

Due to flux cutting each metal spoke becomes identical cell of emf *e* (say), all such identical cells connected in parallel fashion $e_{net} = e$ (emf of single cell). Let *N* be the number of spokes hence $e_{net} = \frac{1}{2}Bwl^2; \omega = 2\pi\nu$

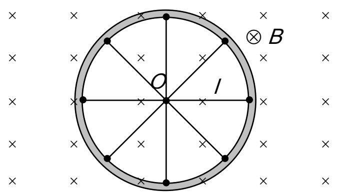


Fig. 23.11

Here $e_{net} \propto N^o$ *i.e.* total emf does not depends on number of spokes '*N*.

(3) **Faraday copper disc generator :** A metal disc can be assumed to made of uncountable radial conductors when metal disc rotates in transverse magnetic field these radial conductors cuts away magnetic field lines and because of this flux cutting all becomes identical cells each of emf 'e' where $e = \frac{1}{2}B\omega r^2$,

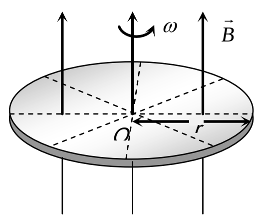


Fig. 23.12

(4) **Semicircular conducting loop** : If a semi-circular conducting loop (*ACD*) of radius '*r*' with centre at *O*, the plane of loop being in the plane of paper. The loop is now made to rotate with a constant angular velocity ω, about an axis passing through *O* and perpendicular to the plane of paper. The effective resistance of the loop is *R*.

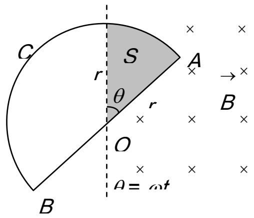


Fig. 23.13

In time *t* the area swept by the loop in the field *i.e.* region II

$A = \frac{1}{2} r(r\theta) = \frac{1}{2} r^2 \omega t$; $\frac{dA}{dt} = \frac{r^2 \omega}{2}$

Flux link with the rotating loop at time t $\phi = BA$

Hence induced emf in the loop in magnitude $|e| = \frac{d\phi}{dt} = B\frac{dA}{dt} = \frac{B\omega r^2}{2}$ and induced current $i = \frac{|e|}{R} = \frac{B\omega r^2}{2R}$

Periodic EMI

Suppose a rectangular coil having *N* turns placed initially in a magnetic field such that magnetic field is perpendicular to it's plane as shown.

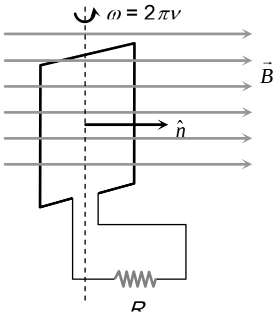


Fig. 23.14

ω – Angular speed

ν – Frequency of rotation of coil

R – Resistance of coil

For uniform rotational motion with ω, the flux linked with coil at any time t

$\phi = NBA \cos\theta = NBA \cos\omega t$

$\phi = \phi_0 \cos\omega t$ where ϕ_0 = *NBA* = maximum flux

(1) **Induced emf in coil :** Induced emf also changes in periodic manner that's why this phenomenon called periodic EMI

$e = -\frac{d\phi}{dt} = NBA\omega \sin\omega t \Rightarrow e = e_0 \sin\omega t$ where e_0 = emf amplitude or max. emf $= NBA\omega = \phi_0 \omega$

(2) **Induced current :** At any time *t*, $i = \frac{e}{R} = \frac{e_0}{R} \sin\omega t = i_0 \sin\omega t$ where i_0 = current amplitude or max. current $i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R} = \frac{\phi_0 \omega}{R}$

Inductance

(1) Inductance is that property of electrical circuits which opposes any change in the current in the circuit.

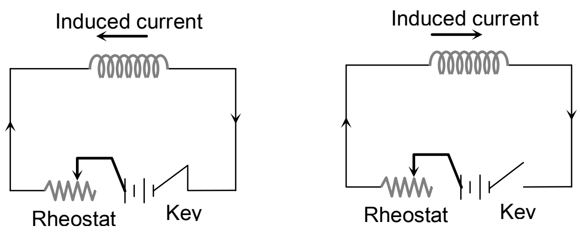
(2) Inductance is inherent property of electrical circuits. It will always be found in an electrical circuit whether we want it or not.

(3) A straight wire carrying current with no iron part in the circuit will have lesser value of inductance.

(4) Inductance is analogous to inertia in mechanics, because inductance of an electrical circuit opposes any change of current in the circuit.

Self Induction

Whenever the electric current passing through a coil or circuit changes, the magnetic flux linked with it will also change. As a result of this, in accordance with Faraday's laws of electromagnetic induction, an emf is induced in the coil or the circuit which opposes the change that causes it. This phenomenon is called 'self induction' and the emf induced is called back emf, current so produced in the coil is called induced current.



(A) Main current **(B)** Main current decreasing

Fig. 23.15

(1) **Coefficient of self-induction :** Number of flux linkages with the coil is proportional to the current *i*. *i.e.* $N\phi \propto i$ or $N\phi = Li$ (*N* is the number of turns in coil and $N\phi$ – total flux linkage). Hence $\boldsymbol{L = \frac{N\phi}{i}}$ = coefficient of self-induction.

(2) If i = 1*amp*, N = 1 then, $L = \phi$ *i.e.* the coefficient of self induction of a coil is equal to the flux linked with the coil when the current in it is 1 *amp*.

(3) By Faraday's second law induced emf $e = -N\dfrac{d\phi}{dt}$. Which gives $\boldsymbol{e = -L\dfrac{di}{dt}}$; If $\dfrac{di}{dt} = 1\, amp/sec$ then $|e| = L$.

Hence coefficient of self induction is equal to the emf induced in the coil when the rate of change of current in the coil is unity.

(4) **Units and dimensional formula of 'L' :** It's S.I. unit

$$\frac{weber}{Amp} = \frac{Tesla \times m^2}{Amp} = \frac{N \times m}{Amp^2} = \frac{Joule}{Amp^2} = \frac{Coulomb \times volt}{Amp^2}$$

$= \dfrac{volt \times \sec}{amp} = ohm \times \sec$. But practical unit is henry (H). It's dimensional formula $[L] = [ML^2T^{-2}A^{-2}]$

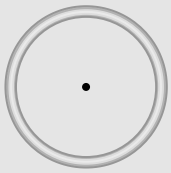
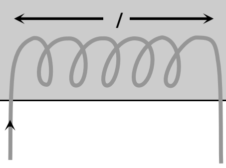
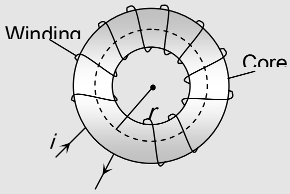
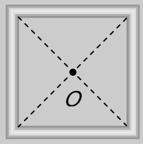
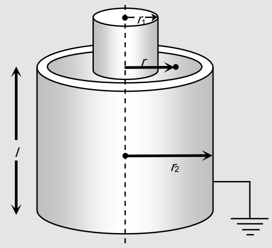
(5) **Dependence of self inductance (L) :** 'L' does not depend upon current flowing or change in current flowing but it depends upon number of turns (N), Area of cross section (A) and permeability of medium (μ).

'L' does not play any role till there is a constant current flowing in the circuit. 'L' comes in to the picture only when there is a change in current.

(6) **Magnetic potential energy of inductor :** In building a steady current in the circuit, the source emf has to do work against of self inductance of coil and whatever energy consumed for this work stored in magnetic field of coil this energy called as magnetic potential energy (U) of coil

$U = \int_0^i Li\,di = \dfrac{1}{2}Li^2$; Also $U = \dfrac{1}{2}(Li)i = \dfrac{N\phi i}{2}$

(7) **The various formulae for L**

Condition	Figure
Circular coil $L = \dfrac{\mu_0 \pi N^2 r}{2}$	
Solenoid $L = \dfrac{\mu_0\mu_r N^2 A}{l} = \dfrac{\mu N^2 A}{l} (\mu = \mu_0\mu_r)$	
Toroid $L = \dfrac{\mu_0 N^2 r}{2}$	
Square coil $L = \dfrac{2\sqrt{2}\mu_0 N^2 a}{\pi}$	
Coaxial cylinders $L = \dfrac{\mu_0}{2\pi r}\log_e\dfrac{r_2}{r_1}$ $\dfrac{2.303}{2\pi r}\mu_0 \log_{10}\dfrac{r_2}{r_1}$	

Mutual Induction

Whenever the current passing through a coil or circuit changes, the magnetic flux linked with a neighbouring coil or circuit will also change. Hence an emf will be induced in the neighbouring coil or circuit. This phenomenon is called 'mutual induction'.

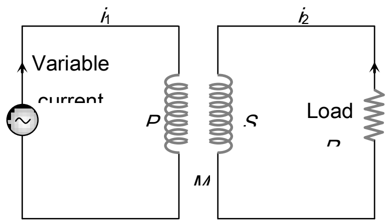


Fig. 23.16

(1) **Coefficient of mutual induction :** Total flux linked with the secondary due to current in the primary is $N_2\phi_2$ and $N_2\phi_2 \propto i_1 \Rightarrow N_2\phi_2 = Mi_1$ where N_1 - Number of turns in primary; N_2 - Number of turns in secondary; ϕ_2 - Flux linked with each turn of secondary; i_1 - Current flowing through primary; M-Coefficient of mutual induction or mutual inductance.

(2) According to Faraday's second law emf induces in secondary $e_2 = -N_2\dfrac{d\phi_2}{dt}$; $e_2 = -M\dfrac{di_1}{dt}$

(3) If $\dfrac{di_1}{dt} = \dfrac{1Amp}{sec}$ then $|e_2| = M$. Hence coefficient of mutual induction is equal to the emf induced in the secondary coil when rate of change of current in primary coil is unity.

(4) **Units and dimensional formula of M :** Similar to self-inductance (L)

(5) **Dependence of mutual inductance**

(i) Number of turns (N_1, N_2) of both coils

(ii) Coefficient of self inductances (L_1, L_2) of both the coils

(iii) Area of cross-section of coils

(iv) Magnetic permeability of medium between the coils (μ_r) or nature of material on which two coils are wound

(v) Distance between two coils (As d increases so M decreases)

(vi) Orientation between primary and secondary coil (for 90° orientation no flux relation $M = 0$)

(vii) Coupling factor 'K' between primary and secondary coil

(6) **Relation between M, L_1 and L_2 :** For two magnetically coupled coils $M = k\sqrt{L_1L_2}$; where k – coefficient of coupling or coupling factor which is defined as

$$k = \frac{\text{Magnetic flux linked in secondary}}{\text{Magnetic flux linked in primary}}; \quad 0 \le k \le 1$$

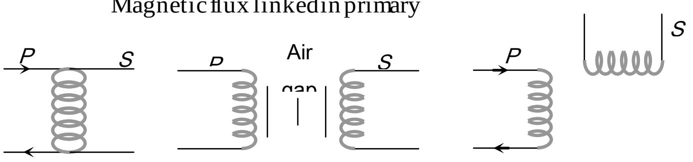
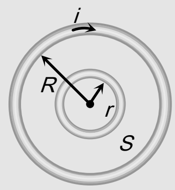
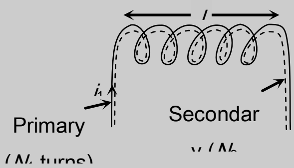
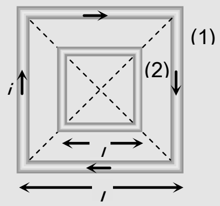


Fig. 23.17

(A) $k = 1$ (B) $0 < k < 1$ (C) $k = 0$

(7) **The various formulae for M :**

Condition	Figure
Two concentric coplaner circular coils $M = \dfrac{\pi\mu_0 N_1 N_2 r^2}{2R}$	
Two Solenoids $M = \dfrac{\mu_0 N_1 N_2 A}{l}$	
Two concentric coplaner square coils $M = \dfrac{\mu_0 2\sqrt{2}\, N_1 N_2 l^2}{\pi L}$	

Combination of Inductance

(1) **Series :** If two coils of self-inductances L_1 and L_2 having mutual inductance are in series and are far from each other, so that the mutual induction between them is negligible, then net self inductance $L_S = L_1 + L_2$

When they are situated close to each other, then net inductance $L_S = L_1 + L_2 \pm 2M$

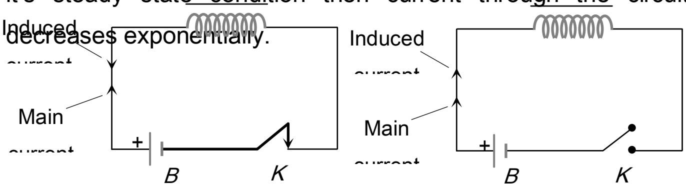
(2) **Parallel :** If two coils of self-inductances L_1 and L_2 having mutual inductance are connected in parallel and are far from each other, then net inductance L is $\dfrac{1}{L_P} = \dfrac{1}{L_1} + \dfrac{1}{L_2} \Rightarrow$ $L_P = \dfrac{L_1L_2}{L_1 + L_2}$

When they are situated close to each other, then

$$L_P = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$$

Growth and Decay of Current In *LR*- Circuit

If a circuit containing a pure inductor *L* and a resistor *R* in series with a battery and a key then on closing the circuit current through the circuit rises exponentially and reaches up to a certain maximum value (steady state). If circuit is opened from it's steady state condition then current through the circuit decreases exponentially.



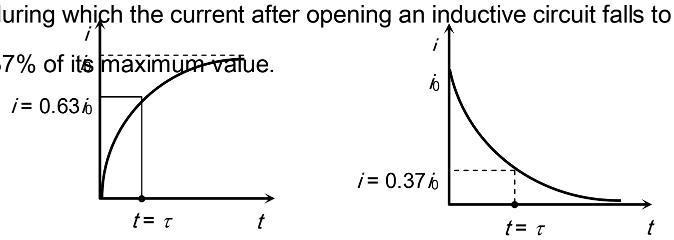
(A) Growth of current **(B)** Decay of current

Fig. 23.18

(1) The value of current at any instant of time *t* after closing the circuit (*i.e.* during the rising of current) is given by $i = i_0\left[1 - e^{-\frac{R}{L}t}\right]$; where $i_0 = i_{max} = \frac{E}{R}$ = steady state current.

(2) The value of current at any instant of time *t* after opening from the steady state condition (*i.e.* during the decaying of current) is given by $i = i_0 e^{-\frac{R}{L}t}$

(3) **Time constant (τ) :** It is given as $\tau = \frac{L}{R}$; It's unit is *second*. In other words the time interval, during which the current in an inductive circuit rises to 63% of its maximum value at make, is defined as time constant or it is the time interval, during which the current after opening an inductive circuit falls to 37% of its maximum value.



(A) (B)

Fig. 23.19

LC- Oscillation

When a charged capacitor *C* having an initial charge q_0 is discharged through an inductance *L*, the charge and current in the circuit start oscillating simple harmonically. If the resistance of the circuit is zero, no energy is dissipated as heat. We also assume an idealized situation in which energy is not radiated away from the circuit. The total energy associated with the circuit is constant.

Frequency of oscillation is given by

$$\omega = \frac{1}{\sqrt{LC}} \frac{rad}{sec}$$

or $\nu = \frac{1}{2\pi\sqrt{LC}} Hz$

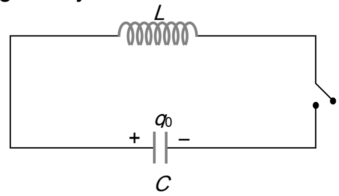


Fig. 23.20

Eddy Current

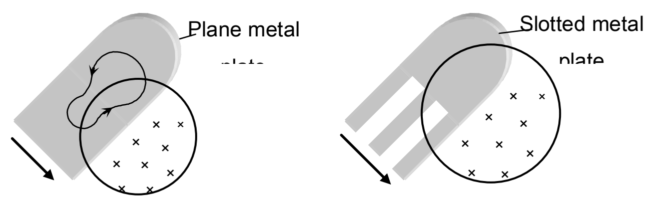
When a changing magnetic flux is applied to a bulk piece of conducting material then circulating currents called eddy currents are induced in the material. Because the resistance of the bulk conductor is usually low, eddy currents often have large magnitudes and heat up the conductor.

(1) These are circulating currents like eddies in water.

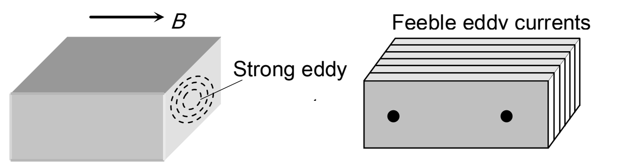
(2) Experimental concept given by Focault hence also named as "Focault current".

(3) The production of eddy currents in a metallic block leads to the loss of electric energy in the form of heat.

(4) By Lamination, slotting processes the resistance path for circulation of eddy current increases, resulting in to weakening them and also reducing losses causes by them



(A) Strong eddies produced **(B)** Feeble eddies Gradual damping



(C) Solid metallic core (D) Laminated core

(5) **Application of eddy currents :** Though most of the times eddy currents are undesirable but they find some useful applications as enumerated below

(i) **Dead-beat galvanometer :** A dead beat galvanometer means one whose pointer comes to rest in the final equilibrium position immediately without any oscillation about the equilibrium position when a current is passed in its coil.

This is achieved by winding the coil on a metallic frame the large eddy currents induced in the frame provide electromagnetic damping.

(ii) **Electric-brakes :** When the train is running its wheel is moving in air and when the train is to be stopped by electric breaks the wheel is made to move in a field created by electromagnet. Eddy currents induced in the wheels due to the changing flux oppose the cause and stop the train.

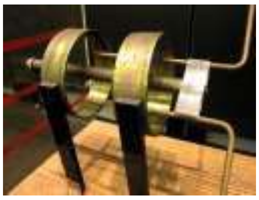
(iii) **Induction furnace :** Joule's heat causes the melting of a metal piece placed in a rapidly changing magnetic field.

(iv) **Speedometer :** In the speedometer of an automobile, a magnet is geared to the main shaft of the vehicle and it rotates according to the speed of the vehicle. The magnet is mounted in an aluminium cylinder with the help of hair springs. When the magnet rotates, it produces eddy currents in the drum and drags it through an angle, which indicates the speed of the vehicle on a calibrated scale.

(v) **Energy meter :** In energy meters, the armature coil carries a metallic aluminium disc which rotates between the poles of a pair of permanent horse shoe magnets. As the armature rotates, the current induced in the disc tends to oppose the motion of the armature coil. Due to this braking effect, deflection is proportional to the energy consumed.

dc Motor

It is an electrical machine which converts electrical energy into mechanical energy.



(1) **Principle :** It is based on the fact that a current carrying coil placed in the magnetic field experiences a torque. This torque rotates the coil.

(2) **Construction :** It consists of the following components figure.

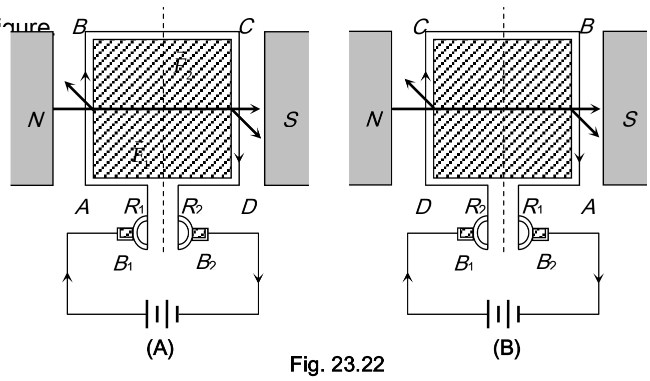


Fig. 23.22

ABCD = Armature coil, S_1, S_2 = split ring comutators

B_1, B_2 = Carbon brushes, *N*, *S* = Strong magnetic poles

(3) **Working :** Force on any arm of the coil is given by $\vec{F} = i(\vec{l} \times \vec{B})$ in fig., force on *AB* will be perpendicular to plane of the paper and pointing inwards. Force on *CD* will be equal and opposite. So coil rotates in clockwise sense when viewed from top in fig. The current in *AB* reverses due to commutation keeping the force on *AB* and *CD* in such a direction that the coil continues to rotate in the same direction.

(4) **Back emf in motor :** Due to the rotation of armature coil in magnetic field a back emf is induced in the circuit. Which is given by $e = E - iR$.

Back emf directly depends upon the angular velocity ω of armature and magnetic field *B*. But for constant magnetic field *B*, value of back emf *e* is given by $e \propto \omega$ or $e = k\omega$ ($e = NBA\omega \sin\omega t$)

(5) **Current in the motor :** $i = \frac{E-e}{R} = \frac{E-k\omega}{R}$; When motor is just switched on *i.e.* $\omega = 0$ so $e = 0$ hence $i = \frac{E}{R} = \text{maximum}$ and at full speed, ω is maximum so back emf *e* is maximum and *i* is minimum. Thus, maximum current is drawn when the motor is just switched on which decreases when motor attains the speed.

(6) **Motor starter :** At the time of start a large current flows through the motor which may burn out it. Hence a starter is used for starting a dc motor safely. Its function is to introduce a suitable resistance in the circuit at the time of starting of the motor. This resistance decreases gradually and reduces to zero when the motor runs at full sped.

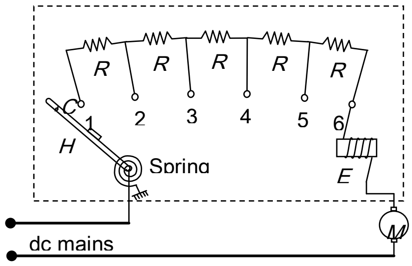


Fig. 23.23

The value of starting resistance is maximum at time $t = 0$ and its value is controlled by spring and electromagnetic system and is made to zero when the motor attains its safe speed.

(7) **Mechanical power and Efficiency of dc motor :**

Efficiency $\eta = \frac{P_{mechanical}}{P_{supplied}} = \frac{P_{out}}{P_{in}} = \frac{e}{E} = \frac{\text{Back e.m.f.}}{\text{Supply voltage}}$

(8) **Uses of dc motors :** They are used in electric locomotives, electric ears, rolling mills, electric cranes, electric lifts, dc drills, fans and blowers, centrifugal pumps and air compressors, *etc.*

ac Generator/Alternator/Dynamo

An electrical machine used to convert mechanical energy into electrical energy is known as ac generator/alternator.

(1) **Principle :** It works on the principle of electromagnetic induction *i.e.*, when a coil is rotated in uniform magnetic field, an induced emf is produced in it.

(2) **Construction :** The main components of ac generator are

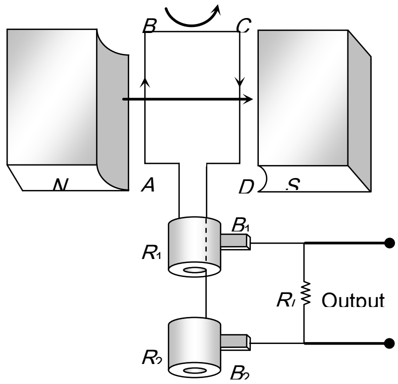


Fig. 23.24

(i) **Armature :** Armature coil (*ABCD*) consists of large number of turns of insulated copper wire wound over a soft iron core.

(ii) **Strong field magnet :** A strong permanent magnet or an electromagnet whose poles (*N* and *S*) are cylindrical in shape in a field magnet. The armature coil rotates between the pole pieces of the field magnet. The uniform magnetic field provided by the field magnet is perpendicular to the axis of rotation of the coil.

(iii) **Slip rings :** The two ends of the armature coil are connected to two brass slip rings R_1 and R_2. These rings rotate along with the armature coil.

(iv) **Brushes :** Two carbon brushes (B_1 and B_2), are pressed against the slip rings. The brushes are fixed while slip rings rotate along with the armature. These brushes are connected to the load through which the output is obtained.

(3) **Working :** When the armature coil *ABCD* rotates in the magnetic field provided by the strong field magnet, it cuts the magnetic lines of force. Thus the magnetic flux linked with the coil changes and hence induced emf is set up in the coil. The direction of the induced emf or the current in the coil is determined by the Fleming's right hand rule.

The current flows out through the brush B_1 in one direction of half of the revolution and through the brush B_2 in the next half revolution in the reverse direction. This process is repeated. Therefore, emf produced is of alternating nature.

$e = -\frac{Nd\phi}{dt} = NBA\omega \sin\omega t = e_0 \sin\omega t$ where $e_0 = NBA\omega$

$i = \frac{e}{R} = \frac{e_0}{R}\sin\omega t = i_0 \sin\omega t$ $R \rightarrow$ Resistance of the circuit

dc Generator

If the current produced by the generator is direct current, then the generator is called dc generator.

dc generator consists of (i) Armature (coil) (ii) Magnet (iii) Commutator (iv) Brushes

In dc generator commutator is used in place of slip rings. The commutator rotates along with the coil so that in every cycle when direction of '*e*' reverses, the commutator also reverses or makes contact with the other brush so that in the external load the current remains in the some direction giving dc

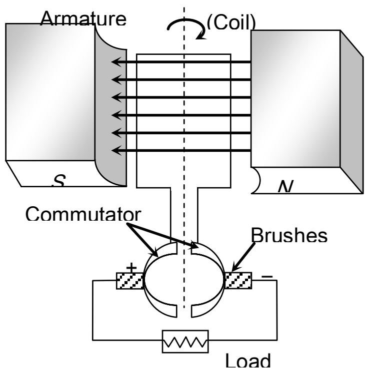


Fig. 23.25

Transformer

It is a device which raises or lowers the voltage in ac circuits through mutual induction.

It consists of two coils wound on the same core. The alternating current passing through the primary creates a continuously changing flux through the core. This changing flux induces an alternating emf in the secondary.

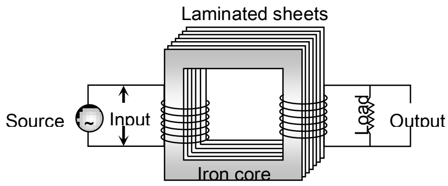


Fig. 23.26

(1) Transformer works on ac only and never on dc.

(2) It can increase or decrease either voltage or current but not both simultaneously.

(3) Transformer does not change the frequency of input ac.

(4) There is no electrical connection between the winding but they are linked magnetically.

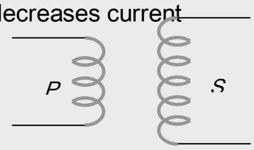
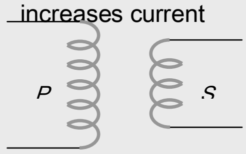
(5) Effective resistance between primary and secondary winding is infinite.

(6) The flux per turn of each coil must be same *i.e.* $\phi_S = \phi_P$; $-\frac{d\phi_S}{dt} = -\frac{d\phi_P}{dt}$.

(7) If N_P = number of turns in primary, N_S = number of turns in secondary, V_P = applied (input) voltage to primary, V_S = Voltage across secondary (load voltage or output), e_P = induced emf in primary ; e_S = induced emf in secondary, ϕ = flux linked with primary as well as secondary, i_P = current in primary; i_S = current in secondary (or load current)

As in an ideal transformer there is no loss of power *i.e.* $P_{out} = P_{in}$ so $V_S i_S = V_P i_P$ and $V_P \approx e_P$, $V_S \approx e_S$. Hence $\frac{e_S}{e_P} = \frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{i_P}{i_S} = k$; k = Transformation ratio (or turn ratio)

Table 23.3 : Types of transformer

Step up transformer	Step down transformer
It increases voltage and decreases current 	It decreases voltage and increases current 

$V_S > V_P$	$V_S < V_P$
$N_S > N_P$	$N_S < N_P$
$E_S > E_P$	$E_S < E_P$
$i_S < i_P$	$i_S > i_P$
$R_S > R_P$	$R_S < R_P$
$t_S > t_P$	$t_S > t_P$
$k > 1$	$k < 1$

(8) **Efficiency of transformer (η) :** Efficiency is defined as the ratio of output power and input power

i.e. $\eta\% = \frac{P_{out}}{P_{in}} \times 100 = \frac{V_S i_S}{V_P i_P} \times 100$

For an ideal transformer $P_{out} = P_{in}$ so $\eta = 100\%$ (But efficiency of practical transformer lies between 70% – 90%)

For practical transformer $P_{in} = P_{out} + P_{losses}$

so $\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_{out}}{(P_{out} + P_L)} \times 100 = \frac{(P_{in} - P_L)}{P_{in}} \times 100$

(9) **Losses in transformer :** In transformers some power is always lost due to, heating effect, flux leakage eddy currents, hysteresis and humming.

(i) ***Cu* loss (i^2R) :** When current flows through the transformer windings some power is wasted in the form of heat $(H = i^2 Rt)$. To minimize this loss windings are made of thick *Cu* wires (To reduce resistance)

(ii) **Eddy current loss :** Some electrical power is wasted in the form of heat due to eddy currents, induced in core, to minimize this loss transformers core are laminated and silicon is added to the core material as it increases the resistivity. The material of the core is then called silicon-iron (steel).

(iii) **Hystersis loss :** The alternating current flowing through the coils magnetises and demagnetises the iron core again and again. Therefore, during each cycle of magnetisation, some energy is lost due to hysteresis. However, the loss of energy can be minimised by selecting the material of core, which has a narrow hysterisis loop. Therefore core of transformer is made of soft iron. Now a days it is made of "Permalloy" (*Fe*-22%, *Ni*-78%).

(iv) **Magnetic flux leakage :** Magnetic flux produced in the primary winding is not completely linked with secondary because few magnetic lines of force complete their path in air only. To minimize this loss secondary winding is kept inside the primary winding.

(v) **Humming losses :** Due to the passage of alternating current, the core of the transformer starts vibrating and produces humming sound. Thus, some part (may be very small) of the electrical energy is wasted in the form of humming sounds produced by the vibrating core of the transformer.

(10) **Uses of transformer :** A transformer is used in almost all ac operations *e.g.*

(i) In voltage regulators for TV, refrigerator, computer, air conditioner etc.

(ii) In the induction furnaces.

(iii) Step down transformer is used for welding purposes.

(iv) In the transmission of ac over long distance.

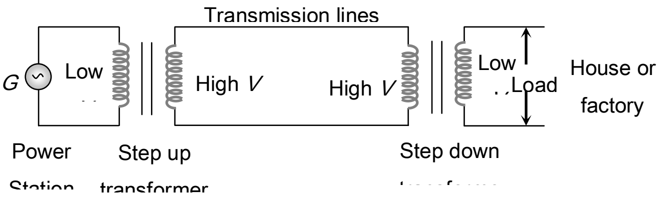


Fig. 23.27

(v) Step down and step up transformers are used in electrical power distribution.

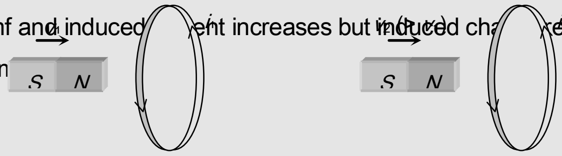
(vi) Audio frequency transformers are used in radiography, television, radio, telephone *etc.*

(vii) Radio frequency transformers are used in radio communication.

(viii) Transformers are also used in impedance matching.

Tips & Tricks

✍ If a bar magnet moves towards a fixed conducting coil, then due to the flux changes an emf, current and charge induces in the coil. If speed of magnet increases then induced emf and induced current increases but induced charge remains same.



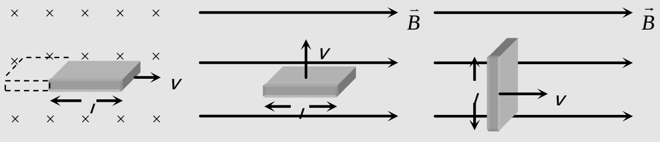
Induced parameter : e_1, i_1, q_1 $\quad$ e_2 (> e_1), i_2(> i_1), q_2 (= q_1)

✍ Can ever electric lines of force be closed curve ? Yes, when produced by a changing magnetic field.

✍ No flux cutting ⟶ No EMI

✍ Vector form of motional emf : $e = (\vec{v} \times \vec{B}).\vec{l}$

✍ In motional emf $\vec{B}, \vec{v}$ and $\vec{l}$ are three vectors. If any two vector are parallel – No flux cutting.



$\vec{v} \,||\, \vec{l}$ so $e = 0$ $\quad$ $\vec{B} \,||\, \vec{l}$ so $e = 0$ $\quad$ $\vec{v} \,||\, \vec{B}$ so $e = 0$

✍ A piece of metal and a piece of non-metal are dropped from the same height near the surface of the earth. The non-metallic piece will reach the ground first because there will be no induced current in it.

✍ If an aeroplane is landing down or taking off and its wings are in the east-west direction, then the potential difference or emf will be induced across the wings. If an aeroplane is landing down or taking off and its wings are in the north-south direction, then no potential difference or emf will be induced.

✍ When a conducting rod moving horizontally on equator of earth no emf induces because there is no vertical component of earth's magnetic field. But at poles B_V is maximum so maximum flux cutting hence emf induces.

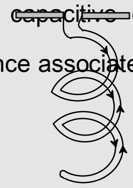
✍ When a conducting rod falling freely in earth's magnetic field such that it's length lies along East - West direction then induced emf continuously increases w.r.t. time and induced current flows from West - East.

✍ 1 *henry* = 10^9 *emu* of inductance or 10^9 *ab-henry*.

✍ Inductance at the ends of a solenoid is half of it's the inductance at the centre. $\left(L_{end} = \frac{1}{2} L_{centre}\right)$.

✍ A thin long wire made up of material of high resistivity behaves predominantly as a resistance. But it has some amount of inductance as well as capacitance in it. It is thus difficult to obtain pure resistor. Similarly it is difficult to obtain pure capacitor as well as pure inductor.

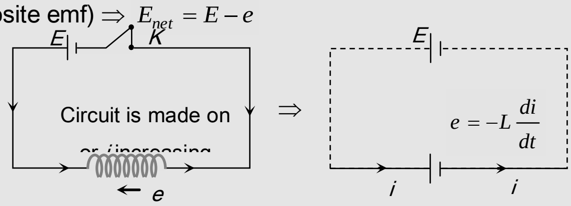
✍ Due to inherent presence of self inductance in all electrical circuits, a resistive circuit with no capacitive or inductive element in it, also has some inductance associated with it.



The effect of self-inductance can be eliminated as in the coils of a resistance box by doubling back the coil on itself.

✍ It is not possible to have mutual inductance without self inductance but it may or may not be possible self inductance without mutual inductance.

✍ If main current through a coil increases (i↑) so $\frac{di}{dt}$ will be positive (+*ve*), hence induced emf *e* will be negative (*i.e.* opposite emf) ⇒ $E_{net} = E - e$

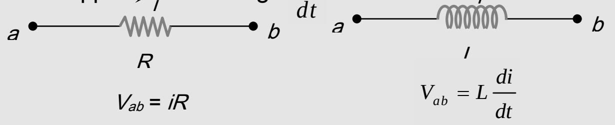


✍ Sometimes at sudden opening of key, because of high inductance of circuit a high momentarily induced emf produced and a sparking occurs at key position. To avoid sparking a capacitor is connected across the key.

✍ Sometimes at sudden opening of key, because of high inductance of circuit a high momentarily induced emf produced and a sparking occurs at key position. To avoid sparking a capacitor is connected across the key.

✍ One can have resistance with or without inductance but one can't have inductance without having resistance.

✍ The circuit behaviour of an inductor is quite different from that of a resistor. while a resistor opposes the current *i,* an inductor opposes the change $\frac{di}{dt}$ in the circuit.



✍ In *RL*-circuit with dc source the time taken by the current to reach half of the maximum value is called half life time and it is given by $T = 0.693\ \frac{L}{R}$.

✍ dc motor is a highly versatile energy conversion device. It can meet the demand of loads requiring high starting torque, high accelerating and decelerating torque.

✍ When a source of emf is connected across the two ends of the primary winding alone or across the two ends of secondary winding alone, ohm's law can be applied. But in the transformer as a whole, ohm's law should not be applied because primary winding and secondary winding are not connected electrically.

✍ Even when secondary circuit of the transformer is open it also draws some current called no load primary current for supplying no load *Cu* and iron loses.

✍ Transformer has highest possible efficiency out of all the electrical machines.

Ordinary Thinking

Objective Questions

Faraday's and Lenz's Law

1. In electromagnetic induction, the induced e.m.f. in a coil is independent of [CPMT 1984]
   (a) Change in the flux (b) Time
   (c) Resistance of the circuit (d) None of the above

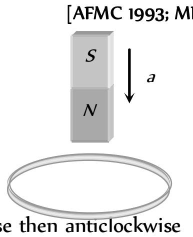
2. Lenz's law is consequence of the law of conservation of [JIPMER 1997; CPMT 1990; RPMT 1997; MP PET 1999; MP PMT 2000, 03; RPET 2003; AFMC 2004]
   (a) Charge (b) Momentum
   (c) Mass (d) Energy

3. In electromagnetic induction, the induced charge in a coil is independent of
   (a) Change in the flux (b) Time
   (c) Resistance in the circuit (d) None of the above

4. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in time Δt, Then the total quantity of electric charge Q, which passing during this time through any point of the circuit is given by [Haryana CEE 1996; CBSE PMT 2004]
   (a) $Q = \frac{\Delta\phi}{\Delta t}$ (b) $Q = \frac{\Delta\phi}{\Delta t} \times R$
   (c) $Q = -\frac{\Delta\phi}{\Delta t} + R$ (d) $Q = \frac{\Delta\phi}{R}$

5. A cylindrical bar magnet is kept along the axis of a circular coil. If the magnet is rotated about its axis, then [CPMT 1983; BCECE 2004]
   (a) A current will be induced in a coil
   (b) No current will be induced in a coil
   (c) Only an e.m.f. will be induced in the coil
   (d) An e.m.f. and a current both will be induced in the coil

6. A metallic ring is attached with the wall of a room. When the north pole of a magnet is brought near to it, the induced current in the ring will be [AFMC 1993; MP PMT/PET 1998; Pb PET 2003]



   (a) First clockwise then anticlockwise
   (b) In clockwise direction
   (c) In anticlockwise direction
   (d) First anticlockwise then clockwise

7. A coil having an area A_0 is placed in a magnetic field which changes from B_0 to $4B_0$ in a time interval *t*. The e.m.f. induced in the coil will be [MP PET 1990]
   (a) $\frac{3A_0B_0}{t}$ (b) $\frac{4A_0B_0}{t}$
   (c) $\frac{3B_0}{A_0 t}$ (d) $\frac{4B_0}{A_0 t}$

8. The magnetic flux linked with a coil is given by an equation ϕ (in *webers*) = $8t^2 + 3t + 5$. The induced e.m.f. in the coil at the fourth second will be [MP PET 1990]
   (a) 16 *units* (b) 39 *units*
   (c) 67 *units* (d) 145 *units*

9. The current flowing in two coaxial coils in the same direction. On increasing the distance between the two, the electric current will
   (a) Increase
   (b) Decrease
   (c) Remain unchanged
   (d) The information is incomplete

10. A copper ring is held horizontally and a bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet while it is passing through the ring is [CBSE PMT 1996; MP PET 1990, 99; CPMT 1991, 99; JIPMER 1997; CPMT 2003; MP PET/PMT 2001; KCET 2001; Kerala (Engg.) 2001]
    (a) Equal to that due to gravity
    (b) Less than that due to gravity
    (c) More than that due to gravity
    (d) Depends on the diameter of the ring and the length of the magnet

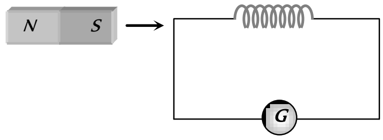
11. A square coil $10^{-2} m^2$ area is placed perpendicular to a uniform magnetic field of intensity $10^3 Wb/m^2$. The magnetic flux through the coil is [MP PMT 1990, 2001]
    (a) 10 *weber* (b) 10^{-5} *weber*
    (c) 10^5 *weber* (d) 100 *weber*

12. A magnet is brought towards a coil (i) speedly (ii) slowly then the induced e.m.f./induced charge will be respectively [RPMT 1997; MP PMT 2003]
    (a) More in first case / More in first case
    (b) More in first case/Equal in both case
    (c) Less in first case/More in second case
    (d) Less in first case/Equal in both case

13. The direction of induced e.m.f. during electromagnetic induction is given by [MP PET 1994, 96]
    (a) Faraday's law (b) Lenz's law
    (c) Maxwell's law (d) Ampere's law

14. In a coil of area $10\ cm^2$ and 10 turns with a magnetic field directed perpendicular to the plane and is changing at the rate of 10^8 *gauss/second*. The resistance of the coil is 20 *ohm*. The current in the coil will be [CPMT 1976]
    (a) 5 *amp* (b) 0.5 *amp*
    (c) 0.05 *amp* (d) 5×10^8 *amp*

15. As shown in the figure, a magnet is moved with a fast speed towards a coil at rest. Due to this induced electromotive force, induced current and induced charge in the coil is E, I and Q respectively. If the speed of the magnet is doubled, the incorrect statement is [MP PET 1995]



(a) E increases (b) I increases

(c) Q remains same (d) Q increases

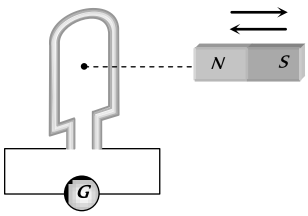
16. A coil having 500 square loops each of side 10 *cm* is placed normal to a magnetic flux which increases at the rate of 1.0 *tesla/second*. The induced e.m.f. in volts is

[CPMT 1989, 90; DCE 2002]

(a) 0.1 (b) 0.5

(c) 1 (d) 5

17. When a magnet is pushed in and out of a circular coil C connected to a very sensitive galvanometer G as shown in the adjoining diagram with a frequency ν, then



(a) Constant deflection is observed in the galvanometer

(b) Visible small oscillations will be observed in the galvanometer if ν is about 50 *Hz*

(c) Oscillations in the deflection will be observed clearly if $\nu = 1$ or 2 *Hz*

(d) No variation in the deflection will be seen if $\nu = 1$ or 2 *Hz*

18. A coil of area $100 cm^2$ has 500 turns. Magnetic field of $0.1\ weber/metre^2$ is perpendicular to the coil. The field is reduced to zero in 0.1 *second*. The induced e.m.f. in the coil is

(a) 1 *V* (b) 5 *V*

(c) 50 *V* (d) Zero

19. A 50 turns circular coil has a radius of $3\ cm$, it is kept in a magnetic field acting normal to the area of the coil. The magnetic field B increased from 0.10 *tesla* to 0.35 *tesla* in 2 *milliseconds*. The average induced e.m.f. in the coil is

[MP PET 1994]

(a) $1.77\ volts$ (b) $17.7\ volts$

(c) $177\ volts$ (d) $0.177\ volts$

20. A coil having an area $2m^2$ is placed in a magnetic field which changes from $1Wb/m^2$ to $4Wb/m^2$ in a interval of 2 *second*. The e.m.f. induced in the coil will be

[DPMT 1999; MP PET 2002]

(a) 4 *V* (b) 3 *V*

(c) 1.5 *V* (d) 2 *V*

21. A coil has 2000 turns and area of $70 cm^2$. The magnetic field perpendicular to the plane of the coil is $0.3 Wb/m^2$ and takes 0.1*sec* to rotate through 180^o. The value of the induced e.m.f. will be

[MP PET 1993; Similar to AIIMS 1997]

(a) $8.4V$ (b) $84V$

(c) $42V$ (d) $4.2V$

22. Two different loops are concentric and lie in the same plane. The current in the outer loop is clockwise and increasing with time. The induced current in the inner loop then, is

[MP PET 1993]

(a) Clockwise

(b) Zero

(c) Counter clockwise

(d) In a direction that depends on the ratio of the loop radii

23. According to Faraday's law of electromagnetic induction

[MP PET 1994]

(a) The direction of induced current is such that it opposes the cause producing it

(b) The magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of magnetic flux

(c) The direction of induced e.m.f. is such that it opposes the cause producing it

(d) None of the above

24. The unit of magnetic flux is

[MP PMT 1994; MP PET 1995; AFMC 1998]

(a) $Weber/m^2$ (b) *Weber*

(c) *Henry* (d) *Ampere/m*

25. The north pole of a long horizontal bar magnet is being brought closer to a vertical conducting plane along the perpendicular direction. The direction of the induced current in the conducting plane will be [MP PMT 1994]

(a) Horizontal (b) Vertical

(c) Clockwise (d) Anticlockwise

26. The magnetic field in a coil of 100 turns and 40 *square cm* area is increased from 1 *Tesla* to 6 *Tesla* in 2 *second*. The magnetic field is perpendicular to the coil. The e.m.f. generated in it is [MP PMT 1991; MH CET (Med.) 1999]

(a) $10^4\ V$ (b) 1.2 *V*

(c) 1.0 *V* (d) $10^{-2}\ V$

27. The dimensions of magnetic flux are

[MP PMT 1994; CBSE PMT 1999]

(a) $MLT^{-2}A^{-2}$ (b) $ML^2T^{-2}A^{-2}$

(c) $ML^2T^{-1}A^{-2}$ (d) $ML^2T^{-2}A^{-1}$

28. Lenz's law gives [MP PMT 1994]

(a) The magnitude of the induced e.m.f.

(b) The direction of the induced current

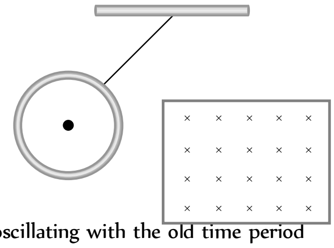
(c) Both the magnitude and direction of the induced current

(d) The magnitude of the induced current

29. The north pole of a bar magnet is moved swiftly downward towards a closed coil and then second time it is raised upwards slowly. The magnitude and direction of the induced currents in the two cases will be of [MP PET 1996]

	First case	*Second case*
(a)	Low value clockwise	Higher value anticlockwise
(b)	Low value clockwise	Equal value anticlockwise
(c)	Higher value clockwise	Low value clockwise
(d)	Higher value anticlockwise	Low value clockwise

30. A metallic ring connected to a rod oscillates freely like a pendulum. If now a magnetic field is applied in horizontal direction so that the pendulum now swings through the field, the pendulum will



(a) Keep oscillating with the old time period

(b) Keep oscillating with a smaller time period

(c) Keep oscillating with a larger time period

(d) Come to rest very soon

31. A circular coil of 500 turns of wire has an enclosed area of $0.1 m^2$ per turn. It is kept perpendicular to a magnetic field of induction 0.2 *T* and rotated by 180° about a diameter perpendicular to the field in 0.1 *sec*. How much charge will pass when the coil is connected to a galvanometer with a combined resistance of 50 *ohms*

(a) 0.2 *C* (b) 0.4 *C*

(c) 2 *C* (d) 4 *C*

32. A coil of 100 *turns* and area 5 *square centimetre* is placed in a magnetic field B = 0.2 *T*. The normal to the plane of the coil makes an angle of 60° with the direction of the magnetic field. The magnetic flux linked with the coil is

[MP PMT 1997]

(a) $5 \times 10^{-3} Wb$ (b) $5 \times 10^{-5} Wb$

(c) $10^{-2} Wb$ (d) $10^{-4} Wb$

33. In a circuit with a coil of resistance 2 *ohms*, the magnetic flux changes from 2.0 *Wb* to 10.0 *Wb* in 0.2 second. The charge that flows in the coil during this time is

[MP PMT 1997]

(a) 5.0 *coulomb* (b) 4.0 *coulomb*

(c) 1.0 *coulomb* (d) 0.8 *coulomb*

34. The direction of induced current is such that it opposes the very cause that has produced it. This is the law of

[MP PMT/PET 1998]

(a) Lenz (b) Faraday

(c) Kirchhoff (d) Fleming

35. To induce an e.m.f. in a coil, the linking magnetic flux

[KCET 1994]

(a) Must decrease

(b) Can either increase or decrease

(c) Must remain constant

(d) Must increase

36. A solenoid is 1.5 *m* long and its inner diameter is 4.0 *cm*. It has three layers of windings of 1000 turns each and carries a current of 2.0 *amperes*. The magnetic flux for a cross-section of the solenoid is nearly [AMU 1995]

(a) 2.5×10^{-7} *weber* (b) 6.31×10^{-6} *weber*

(c) 5.2×10^{-5} *weber* (d) 4.1×10^{-5} *weber*

37. A coil of 40 Ω resistance has 100 turns and radius 6 *mm* is connected to ammeter of resistance of 160 *ohms*. Coil is placed perpendicular to the magnetic field. When coil is taken out of the field, 32 μ C charge flows through it. The intensity of magnetic field will be [RPET 1997]

(a) 6.55 *T* (b) 5.66 *T*

(c) 0.655 *T* (d) 0.566 *T*

38. Faraday's laws are consequence of conservation of

[CBSE PMT 1993; BHU 2002]

(a) Energy

(b) Energy and magnetic field

(c) Charge

(d) Magnetic field

39. A magnetic field of 2×10^{-2} *T* acts at right angles to a coil of area 100 *cm* with 50 turns. The average emf induced in the coil is 0.1 *V*, when it is removed from the field in time *t*. The value of *t* is[CBSE PMT 1992; CI

(a) 0.1 *sec* (b) 0.01 *sec*

(c) 1 *sec* (d) 20 *sec*

40. The total charge induced in a conducting loop when it is moved in magnetic field depends on
[MP PET 1997]

[CBSE PMT 1992; ISM Dhanbad 1994]

(a) The rate of change of magnetic flux

(b) Initial magnetic flux only

(c) The total change in magnetic flux

(d) Final magnetic flux only

41. A rectangular coil of 20 turns and area of cross- section 25 *sq* cm has a resistance of 100 *ohm*. If a magnetic field which is perpendicular to the plane of the coil changes at the rate of 1000 *Tesla* per second, the current in the coil is

[CBSE PMT 1992;
Very Similar to MHCET 2002; DPMT 2004]

(a) 1.0 *ampere* (b) 50 *ampere*

(c) 0.5 *ampere* (d) 5.0 *ampere*

42. The north pole of a magnet is brought near a metallic ring. The direction of the induced current in the ring will be

[AIIMS 1999]

(a) Clockwise (b) Anticlockwise

(c) Towards north (d) Towards south

43. Lenz's law applies to [DCE 1999]

(a) Electrostatics

(b) Lenses

(c) Electro-magnetic induction

(d) Cinema slides

44. If a coil of metal wire is kept stationary in a non-uniform magnetic field, then [BHU 2000]

(a) An e.m.f. is induced in the coil

(b) A current is induced in the coil

(c) Neither e.m.f. nor current is induced

(d) Both e.m.f. and current is induced

45. The magnetic flux linked with a coil, in *webers*, is given by the equations $\phi = 3t^2 + 4t + 9$. Then the magnitude of induced e.m.f. at t = 2 *second* will be

[KCET 2000; CPMT 2003; MP PET 2005]

(a) 2 *volt* (b) 4 *volt*
(c) 8 *volt* (d) 16 *volt*

46. A coil has an area of 0.05 *m* and it has 800 turns. It is placed perpendicularly in a magnetic field of strength $4 \times 10^{-5}\ Wb/m^2$, it is rotated through 90^o in 0.1 *sec*. The average e.m.f. induced in the coil is **[CPMT 2001]**

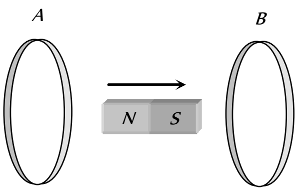
(a) 0.056 *V* (b) 0.046 *V*
(c) 0.026 *V* (d) 0.016 *V*

47. A moving conductor coil in a magnetic field produces an induced e.m.f. This is in accordance with

[AFMC 1993; MH CET 2001, 03]

(a) Amperes law (b) Coulomb law
(c) Lenz's law (d) Faraday's law

48. In the diagram shown if a bar magnet is moved along the common axis of two single turn coils *A* and *B* in the direction of arrow



(a) Current is induced only in *A* & not in *B*
(b) Induced currents in *A* & *B* are in the same direction
(c) Current is induced only in *B* and not in *A*
(d) Induced currents in *A* & *B* are in opposite directions

49. Magnetic flux ϕ (in *weber*) linked with a closed circuit of resistance 10 *ohm* varies with time *t* (in seconds) as

$$\phi = 5t^2 - 4t + 1$$

The induced electromotive force in the circuit at t = 0.2 *sec.* is

(a) 0.4 *volts* (b) – 0.4 *volts*
(c) – 2.0 *volts* (d) 2.0 *volts*

50. The formula for induced e.m.f. in a coil due to change in magnetic flux through the coil is (here *A* = area of the coil, *B* = magnetic field) **[MP PET 2002]**

(a) $e = -A.\dfrac{dB}{dt}$ (b) $e = -B.\dfrac{dA}{dt}$

(c) $e = -\dfrac{d}{dt}(A.B)$ (d) $e = -\dfrac{d}{dt}(A \times B)$

51. Lenz's law is expressed by the following formula (here *e* = induced e.m.f., ϕ = magnetic flux in one turn and *N* = number of turns)

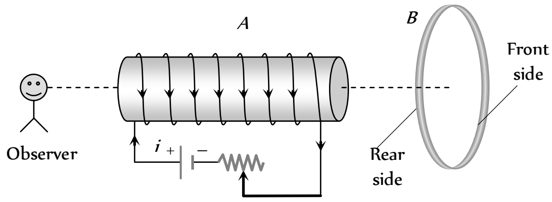
(a) $e = -\phi\dfrac{dN}{dt}$ (b) $e = -N\dfrac{d\phi}{dt}$

(c) $e = -\dfrac{d}{dt}\left(\dfrac{\phi}{N}\right)$ (d) $e = N\dfrac{d\phi}{dt}$

52. A magnet is dropped down an infinitely long vertical copper tube

(a) The magnet moves with continuously increasing velocity and ultimately acquires a constant terminal velocity
(b) The magnet moves with continuously decreasing velocity and ultimately comes to rest
(c) The magnet moves with continuously increasing velocity but constant acceleration
(d) The magnet moves with continuously increasing velocity and acceleration

53. An aluminium ring *B* faces an electromagnet *A*. The current *I* through *A* can be altered **[Kerala PET 2002]**



(a) Whether *I* increases or decreases, *B* will not experience any force
(b) If *I* decreases, *A* will repel *B* **[Kerala (Engg.) 2001]**
(c) If *I* increases, *A* will attract *B*
(d) If *I* increases, *A* will repel *B*

54. The magnetic flux linked with a coil at any instant '*t*' is given by ϕ = 5*t* – 100*t* + 300, the e.m.f. induced in the coil at *t* = 2 *second* is

(a) – 40 *V* (b) 40 *V*
(c) 140 *V* (d) 300 *V*

55. A coil has 1,000 turns and 500 *cm* as its area. The plane of the coil is placed at right angles to a magnetic induction field of $2 \times 10^{-5}\ Wb/m^2$. The coil is rotated through 180^o in 0.2 *seconds*. The average e.m.f. induced in the coil, in *milli-volts*, is

(a) 5 (b) 10
(c) 15 (d) 20

56. When a bar magnet falls through a long hollow metal cylinder fixed with its axis vertical, the final acceleration of the magnet is **[MP PMT 2001]**

(a) Equal to zero
(b) Less than *g*
(c) Equal to *g*
(d) Equal to *g* in to beginning and then more than *g*

57. The magnetic flux linked with a vector area $\vec{A}$ in a uniform magnetic field $\vec{B}$ is **[MP PET 2003]**

(a) $\vec{B} \times \vec{A}$ (b) AB

(c) $\vec{B}.\vec{A}$ **[MP PET 2002]** (d) $\dfrac{B}{A}$

58. The magnetic flux linked with a circuit of resistance 100 *ohm* increases from 10 to 60 *webers*. The amount of induced charge that flows in the circuit is (in *coulomb*)

[MP PET 2003]

(a) 0.5 (b) 5

(c) 50 (d) 100

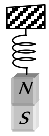
59. A magnet *NS* is suspended from a spring and while it oscillates, the magnet moves in and out of the coil *C*. The coil is connected to a galvanometer *G*. Then as the magnet oscillates,

(a) *G* shows deflection to the left and right with constant amplitude

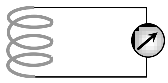
(b) *G* shows deflection on one side

(c) *G* shows no deflection.

(d) *G* shows deflection to the left and right but the amplitude steadily decreases.



60. A coil having n turns and resistance $R\,\Omega$ is connected with a galvanometer of resistance $4R\Omega$. This combination is moved in time t *seconds* from a magnetic field W_1 *weber* to W_2 *weber*. The induced current in the circuit is



(a) $-\dfrac{W_2 - W_1}{5\,Rnt}$ (b) $-\dfrac{n(W_2 - W_1)}{5\,Rt}$

(c) $-\dfrac{(W_2 - W_1)}{Rnt}$ (d) $-\dfrac{n(W_2 - W_1)}{Rt}$

61. If a copper ring is moved quickly towards south pole of a powerful stationary bar magnet, then [Pb. PMT 2004]

(a) Current flows through the copper ring

(b) Voltage in the magnet increase

(c) Current flows in the magnet

(d) Copper ring will get magnetised

62. The magnetic flux linked with coil, in weber is given by the equation, $\phi = 5t^2 + 3t + 16$. The induced emf in the coil in the fourth second is [Pb. PMT 2004]

(a) 10 *V* (b) 30 *V*

(c) 45 *V* (d) 90 *V*

63. The coil of area 0.1 m^2 has 500 turns. After placing the coil in a magnetic field of strength $4\times10^{-4}\,Wb/m^2$, if rotated through 90° in 0.1 s, the average emf induced in the coil is

[Pb. PET 2002]

(a) 0.012 *V* (b) 0.05 *V*

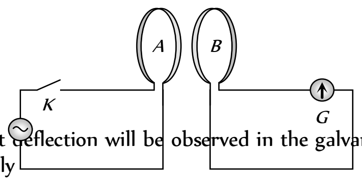
(c) 0.1 *V* (d) 0.2 *V*

64. Magnetic flux in a circuit containing a coil of resistance 2Ω changes from 2.0 *Wb* to 10 *Wb* in 0.2 *sec*. The charge passed through the coil in this time is [DPMT 2003]

(a) 0.8 *C* (b) 1.0 *C*

(c) 5.0 *C* (d) 4.0 *C*

65. The diagram below shows two coils *A* and *B* placed parallel to each other at a very small distance. Coil *A* is connected to an ac supply. *G* is a very sensitive galvanometer. When the key is closed



(a) Constant deflection will be observed in the galvanometer for 50 *Hz* supply

(b) Visible small variations will be observed in the galvanometer for 50 *Hz* input

(c) Oscillations in the galvanometer may be observed when the input ac voltage has a frequency of 1 to 2 *Hz*

(d) No variation will be observed in the galvanometer even when the input ac voltage is 1 or 2 *Hz*

66. An infinitely long cylinder is kept parallel to an uniform magnetic field B directed along positive *z* axis. The direction of induced current as seen from the *z* axis will be

[IIT-JEE (Screening) 2005]

(a) Clockwise of the +*ve z* axis

(b) Anticlockwise of the +*ve z* axis

(c) Zero

(d) Along the magnetic field

67. In a magnetic field of 0.05 *T*, area of a coil changes from $101\,cm^2$ to $100\,cm^2$ without changing the resistance which is 2Ω. The amount of charge that flow during this period is [KCET 2004]

[Orissa PMT 2005]

(a) 2.5×10^{-6} *coulomb* (b) 2×10^{-6} *coulomb*

(c) 10^{-6} *coulomb* (d) 8×10^{-6} *coulomb*

68. If a coil of 40 turns and area 4.0 cm^2 is suddenly removed from a magnetic field, it is observed that a charge of $2.0\times10^{-4}\,C$ flows into the coil. If the resistance of the coil is 80Ω, the magnetic flux density in Wb/m^2 is [AIEEE 2004] [MP PET 2005]

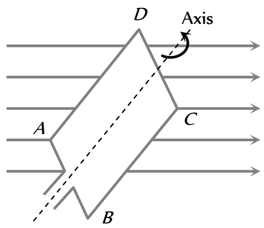
(a) 0.5 (b) 1.0

(c) 1.5 (d) 2.0

Motional EMI

1. A rectangular coil ABCD is rotated anticlockwise with a uniform angular velocity about the axis shown in diagram below. The axis of rotation of the coil as well as the magnetic field *B* are horizontal. The induced e.m.f. in the coil would be maximum when

[Haryana CEE 1996; MP PMT 1992, 94, 99]



(a) The plane of the coil is horizontal

(b) The plane of the coil makes an angle of 45° with the magnetic field

(c) The plane of the coil is at right angles to the magnetic field

(d) The plane of the coil makes an angle of 30° with the magnetic field

[CPMT 1986]

2. A 10 *metre* wire kept in east-west falling with velocity 5 *m/sec* perpendicular to the field $0.3\times10^{-4}\,Wb/m^2$. The induced e.m.f. across the terminal will be [MP PET 2000]

(a) 0.15 *V* (b) 1.5 *mV*

(c) 1.5 *V* (d) 15.0 *V*

3. An electric potential difference will be induced between the ends of the conductor shown in the diagram, when the conductor moves in the direction

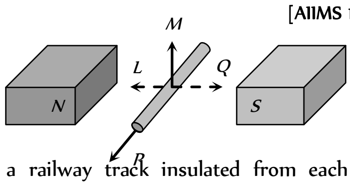
[AIIMS 1982; DPMT 2001]

(a) *P*

(b) *Q*

(c) *L*

(d) *M*



4. Two rails of a railway track insulated from each other and the ground are connected to a milli voltmeter. What is the reading of voltmeter, when a train travels with a speed of 180 *km/hr* along the track. Given that the vertical component of earth's magnetic field is $0.2 \times 10^{-4}\, weber/m^2$ and the rails are separated by 1 *metre*

[IIT 1981; KCET 2001]

(a) 10^{-2} *volt* (b) 10^{-4} *volt*

(c) 10^{-3} *volt* (d) 1 *volt*

5. A conductor of 3 *m* in length is moving perpendicularly to magnetic field of 10^{-3} *tesla* with the speed of $10^2\, m/s$, then the e.m.f. produced across the ends of conductor will be

(a) 0.03 *volt* (b) 0.3 *volt*

(c) 3×10^{-3} *volt* (d) 3 *volt*

6. When a wire loop is rotated in a magnetic field, the direction of induced e.m.f. changes once in each

[MP PMT 1991, 04]

(a) $\frac{1}{4}$ revolution (b) $\frac{1}{2}$ revolution

(c) 1 revolution (d) 2 revolution

7. An aeroplane in which the distance between the tips of wings is 50 *m* is flying horizontally with a speed of 360 *km/hr* over a place where the vertical components of earth magnetic field is $2.0 \times 10^{-4}\, weber/m^2$. The potential difference between the tips of wings would be

[CPMT 1990; MP PET 1991]

(a) 0.1 *V* (b) 1.0 *V*

(c) 0.2 *V* (d) 0.01 *V*

8. A copper disc of radius 0.1 *m* is rotated about its centre with 10 revolutions per second in a uniform magnetic field of 0.1 *Tesla* with its plane perpendicular to the field. The e.m.f. induced across the radius of disc is [MH CET (Med) 2001]

(a) $\frac{\pi}{10} V$ (b) $\frac{2\pi}{10} V$

(c) $\pi \times 10^{-2} V$ (d) $2\pi \times 10^{-2} V$

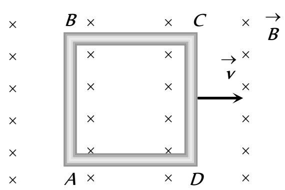
9. A metal conductor of length 1*m* rotates vertically about one of its ends at angular velocity 5 *radians per second*. If the horizontal component of earth's magnetic field is $0.2 \times 10^{-4} T$, then the e.m.f. developed between the two ends of the conductor is[MP PMT 1992; AIEEE 2004]

(a) 5 mV (b) $5 \times 10^{-4} V$

(c) 50 mV (d) 50 μV

10. A conducting square loop of side *L* and resistance *R* moves in its plane with a uniform velocity *v* perpendicular to one of its sides. A magnetic induction *B* constant in time and space, pointing perpendicular and into the plane of the loop exists everywhere. The current induced in the loop is

[IIT 1989; MP PET 1997; MP PMT 1996, 99; MP PMT 2002]



(a) $\frac{Blv}{R}$ clockwise

(b) $\frac{Blv}{R}$ anticlockwise

(c) $\frac{2Blv}{R}$ anticlockwise

(d) Zero

11. A player with 3 *m* long iron rod runs towards east with a speed of 30 *km/hr*. Horizontal component of earth's magnetic field is $4 \times 10^{-5}\, Wb/m^2$. If he is running with rod in horizontal and vertical positions, then the potential difference induced between the two ends of the rod in two cases will be

(a) Zero in vertical position and $1 \times 10^{-3} V$ in horizontal position

(b) $1 \times 10^{-3} V$ in vertical position and zero is horizontal position

(c) Zero in both cases

(d) $1 \times 10^{-3} V$ in both cases

12. A coil of area 80 *square cm* and 50 turns is rotating with 2000 *revolutions per minute* about an axis perpendicular to a magnetic field of 0.05 *Tesla*. The maximum value of the e.m.f. developed in it is [MP PET 1996] [MP PMT 1994]

(a) 200π *volt* (b) $\frac{10\pi}{3}$ *volt*

(c) $\frac{4\pi}{3}$ *volt* (d) $\frac{2}{3}$ *volt*

13. A conducting rod of length *l* is falling with a velocity *v* perpendicular to a uniform horizontal magnetic field *B*. The potential difference between its two ends will be

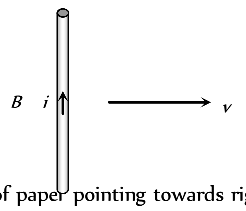
[MP PMT 1994]

(a) 2*Blv* (b) *Blv*

(c) $\frac{1}{2} Blv$ (d) $B^2 l^2 v^2$

14. A conducting wire is moving towards right in a magnetic field *B*. The direction of induced current in the wire is shown in the figure. The direction of magnetic field will be

[MP PET 1995]



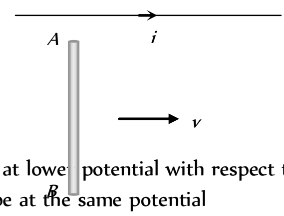
(a) In the plane of paper pointing towards right

(b) In the plane of paper pointing towards left

(c) Perpendicular to the plane of paper and down-wards

(d) Perpendicular to the plane of paper and upwards

15. The current carrying wire and the rod *AB* are in the same plane. The rod moves parallel to the wire with a velocity *v*. Which one of the following statements is true about induced emf in the rod



(a) End *A* will be at lower potential with respect to *B*

(b) *A* and *B* will be at the same potential

(c) There will be no induced e.m.f. in the rod

(d) Potential at *A* will be higher than that at *B*

16. A long horizontal metallic rod with length along the east-west direction is falling under gravity. The potential difference between its two ends will [MP PMT 1997]

(a) Be zero (b) Be constant

(c) Increase with time (d) Decrease with time

17. A two metre wire is moving with a velocity of 1 m/*sec* perpendicular to a magnetic field of 0.5 *weber*/*m*. The e.m.f. induced in it will be

[MP PMT/PET 1998; Pb PET 2003]

(a) 0.5 *volt* (b) 0.1 *volt*

(c) 1 *volt* (d) 2 *volt*

18. A metal rod moves at a constant velocity in a direction perpendicular to its length. A constant uniform magnetic field exists in space in a direction perpendicular to the rod as well as its velocity. Select the correct statement(s) from the following

(a) The entire rod is at the same electric potential

(b) There is an electric field in the rod

(c) The electric potential is highest at the centre of the rod and decreases towards its ends

(d) The electric potential is lowest at the centre of the rod and increases towards its ends

19. A conducting wire is dropped along east-west direction, then [RPMT 1997]

(a) No emf is induced

(b) No induced current flows

(c) Induced current flows from west to east

(d) Induced current flows from east to west

20. The magnetic induction in the region between the pole faces of an electromagnet is 0.7 *weber/m*. The induced e.m.f. in a straight conductor 10 *cm* long, perpendicular to *B* and moving perpendicular both to magnetic induction and its own length with a velocity 2 *m/sec* is [AMU (Med.) 1999]

(a) 0.08 *V* (b) 0.14 *V*

(c) 0.35 *V* (d) 0.07 *V*

21. A straight conductor of length 0.4 *m* is moved with a speed of 7 *m/s* perpendicular to the magnetic field of intensity of 0.9 *Wb/m*. The induced e.m.f. across the conductor will be [MH CET (Med.) 1999]

(a) 7.25 *V* (b) 3.75 *V*

(c) 1.25 *V* (d) 2.52 *V*

22. A coil of *N* turns and mean cross-sectional area *A* is rotating with uniform angular velocity ω about an axis at right angle to uniform magnetic field *B*. The induced e.m.f. *E* in the coil will be

(a) $NBA \sin\omega t$ (b) $NB\,\omega \sin\omega t$

(c) $NB/A \sin\omega t$ (d) $NBA\,\omega \sin\omega t$

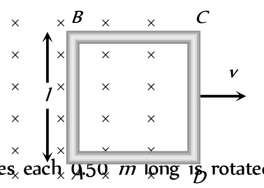
23. A conducting square loop of side *l* and resistance *R* moves in its plane with a uniform velocity *v* perpendicular to one of its sides. A magnetic induction *B* constant in time and space, pointing perpendicular and into the plane at the loop exists everywhere with half the loop outside the field, as shown in figure. The induced e.m.f. is [AIEEE 2002]

(a) Zero

(b) *RvB*

(c) *VBl/R*

(d) *VBl*



24. A wheel with ten metallic spokes each 0.50 *m* long is rotated with a speed of 120 *rev/min* in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.4 Gauss, the induced e.m.f. between the axle and the rim of the wheel is equal to

(a) $1.256 \times 10^{-3}\ V$ (b) $6.28 \times 10^{-4}\ V$

(c) $1.256 \times 10^{-4}\ V$ (d) $6.28 \times 10^{-5}\ V$

25. A metal rod of length 2 *m* is rotating with an angular velocity of 100 *rad/sec* in a plane perpendicular to a uniform magnetic field of 0.3 *T*. The potential difference between the ends of the rod is

(a) 30 *V* (b) 40 *V*

(c) 60 *V* (d) 600 *V*

26. The wing span of an aeroplane is 20 *metre*. It is flying in a field, where the vertical component of magnetic field of earth is 5 × 10 *tesla*, with velocity 360 *km/h*. The potential difference produced between the blades will be [CPMT 2003]

(a) 0.10 *V* (b) 0.15 *V*

(c) 0.20 *V* (d) 0.30 *V*

27. A horizontal straight conductor kept in north-south direction falls under gravity, then [MP PMT 2003]

(a) A current will be induced from South to North

(b) A current will be induced from North to South

(c) No induce e.m.f. along the length of conductor

(d) An induced e.m.f. is generated along the length of conductor

28. A rectangular coil of 300 turns has an average area of average area of $25\,cm \times 10\,cm$. The coil rotates with a speed of 50 *cps* in a uniform magnetic field of strength $4 \times 10^{-2}\,T$ about an axis perpendicular of the field. The peak value of the induced e.m.f. is (in volt) [KCET 2004]

(a) 3000π (b) 300π

(c) 30π (d) 3π

29. A rod of length 20 *cm* is rotating with angular speed of 100 rps in a magnetic field of strength 0.5 *T* about it's one end. What is the potential difference between two ends of the rod [Orissa PMT 2004]

(a) 2.28 *V* (b) 4.28 *V*

(c) 6.28 *V* (d) 2.5 *V*

30. A circular metal plate of radius *R* is rotating with a uniform angular velocity ω with its plane perpendicular to a uniform magnetic field *B*. Then the emf developed between the centre and the rim of the plate is [UPSEAT 2004]

(a) $\pi\omega BR^2$ (b) ωBR^2

(c) $\pi\omega BR^2/2$ [MP PMT 2002] (d) $\omega BR^2/2$

31. A circular coil of mean radius of 7 *cm* and having 4000 turns is rotated at the rate of 1800 revolutions per minute in the earth's magnetic field (*B* = 0.5 gauss), the maximum e.m.f. induced in coil will be [Pb. PMT 2003]

(a) 1.158 *V* (b) 0.58 *V*

(c) 0.29 *V* (d) 5.8 *V*

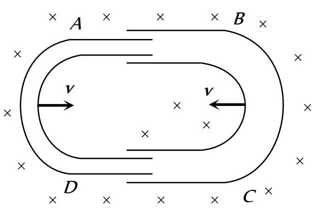
32. One conducting *U* tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field *B* is perpendicular to the plane of the figure. If each tube moves towards the other at a constant sped *v* then the emf induced in the circuit in terms of *B, l* and *v* where *l* is the width of each tube, will be [AIEEE 2005]

(a) Zero

(b) $2\,Blv$

(c) Blv [AMU (Med.) 2002]

(d) $-Blv$



33. The magnitude of the earth's magnetic field at a place is B_0 and the angle of dip is δ. A horizontal conductor of length *l* lying along the magnetic north-south moves eastwards with a velocity *v*. The emf induced across the conductor is [MP PET 2003] [Kerala PET 2005]

(a) Zero (b) $B_0 l v \sin\delta$

(c) $B_0 l v$ (d) $B_0 l v \cos\delta$

Static EMI

1. The back e.m.f. induced in a coil, when current changes from 1 ampere to zero in one *milli-second*, is 4 *volts*, the self inductance of the coil is [MP PET/PMT 1988]

(a) 1 *H* (b) 4 *H*

(c) 10^{-3} *H* (d) 4×10^{-3} *H*

2. An e.m.f. of 5 *volt* is produced by a self inductance, when the current changes at a steady rate from 3 *A* to 2 *A* in 1 millisecond. The value of self inductance is

[CPMT 1982; MP PMT 1991; CBSE PMT 1993; AFMC 2002]

(a) Zero (b) 5 *H*

(c) 5000 *H* (d) 5 *mH*

3. A 50 *mH* coil carries a current of 2 *ampere*. The energy stored in joules is [MP PET/PMT 1988; MP PET 2005]

(a) 1 (b) 0.1

(c) 0.05 (d) 0.5

4. The current passing through a choke coil of 5 henry is decreasing at the rate of 2 *ampere/sec*. The e.m.f. developing across the coil is

[CPMT 1982; MP PMT 1990; AIIMS 1997; MP PET 1999]

(a) 10 *V* (b) – 10 *V*

(c) 2.5 *V* (d) – 2.5 *V*

5. Average energy stored in a pure inductance *L* when a current *i* flows through it, is [MP PET/PMT 1988]

(a) Li^2 (b) $2Li^2$

(c) $\frac{Li^2}{4}$ (d) $\frac{Li^2}{2}$

6. A solenoid has 2000 turns wound over a length of 0.30 *metre*. The area of its cross-section is $1.2\times10^{-3}m^2$. Around its central section, a coil of 300 turns is wound. If an initial current of 2 A in the solenoid is reversed in 0.25 *sec*, then the e.m.f. induced in the coil is

[NCERT 1982; MP PMT 2003]

(a) $6\times10^{-4}V$ (b) $4.8\times10^{-3}V$

(c) $6\times10^{-2}V$ (d) 48 *mV*

7. A coil is wound as a transformer of rectangular cross-section. If all the linear dimensions of the transformer are increased by a factor 2 and the number of turns per unit length of the coil remain the same, the self inductance increased by a factor of

(a) 16 (b) 12

(c) 8 (d) 4

8. Two coils of self inductance L_1 and L_2 are placed closer to each other so that total flux in one coil is completely linked with other. If M is mutual inductance between them, then

[DCE 2002]

(a) $M = L_1L_2$ (b) $M = L_1/L_2$

(c) $M=\sqrt{L_1L_2}$ (d) $M=(L_1L_2)^2$

9. The equivalent quantity of mass in electricity is

(a) Charge (b) Potential

(c) Inductance (d) Current

10. The momentum in mechanics is expressed as $m\times v$. The analogous expression in electricity is [MP PMT 2003]

(a) $I\times Q$ (b) $I\times V$

(c) $L\times I$ (d) $L\times Q$

11. In what form is the energy stored in an inductor or

A coil of inductance *L* is carrying a steady current *i*. What is the nature of its stored energy [CBSE PMT 1990, 92;

MP PMT 1996, 2000, 02; Kerala PMT 2002]

(a) Magnetic

(b) Electrical

(c) Both magnetic and electrical

(d) Heat

12. The coefficient of self inductance of a solenoid is 0.18 *mH*. If a crode of soft iron of relative permeability 900 is inserted, then the coefficient of self inductance will become nearly

(a) 5.4 *mH* (b) 162 *mH*

(c) 0.006 *mH* (d) 0.0002 *mH*

13. In a transformer, the coefficient of mutual inductance between the primary and the secondary coil is 0.2 *henry*. When the current changes by 5 *ampere/second* in the primary, the induced e.m.f. in the secondary will be

[MP PMT 1989]

(a) 5 *V* (b) 1 *V*

(c) 25 *V* (d) 10 *V*

14. When the current in a coil changes from 8 *ampere* to 2 *ampere* in 3×10^{-2} *second*, the e.m.f. induced in the coil is $2\ volt$. The self inductance of the coil (in *millihenry*) is

[MNR 1991; UP SEAT 2000; Pb PET 2004]

(a) 1 (b) 5

(c) 20 (d) 10

15. The mutual inductance between two coils is 1.25 *henry*. If the current in the primary changes at the rate of 80 *ampere/second*, then the induced e.m.f. in the secondary is

[MP PET 1990]

(a) 12.5 *V* (b) 64.0 *V*

(c) 0.016 *V* (d) 100.0 *V*

16. A coil of wire of a certain radius has 600 turns and a self inductance of 108 *mH*. The self inductance of a 2nd similar coil of 500 turns will be [MP PMT 1990]

(a) 74 *mH* (b) 75 *mH*

(c) 76 *mH* (d) 77 *mH*

[AIIMS 1980]

17. When the number of turns in a coil is doubled without any change in the length of the coil, its self inductance becomes

[MP PMT 1986; CBSE PMT 1992; Pb PET 2000]

(a) Four times (b) Doubled

(c) Halved (d) Unchanged

18. The average e.m.f. induced in a coil in which the current changes from 2 *ampere* to 4 *ampere* in 0.05 *second* is 8 *volt*. What is the self inductance of the coil ?

[NCERT 1984; CPMT 1997; MP PMT 1999, 2003;

UPSEAT 2000; RPMT 2000; Pb. PMT 2002; RPET 2003;

DPMT 2005]

(a) 0.1 *H* (b) 0.2 *H*

(c) 0.4 *H* (d) 0.8 *H*

19. If a current of 3.0 *amperes* flowing in the primary coil is reduced to zero in 0.001 *second*, then the induced e.m.f. in the secondary coil is 15000 *volts*. The mutual inductance between the two coils is

(a) 0.5 *henry* (b) 5 *henry*

(c) 1.5 *henry* (d) 10 *henry*

20. An e.m.f. of 12 *volts* is induced in a given coil when the current in it changes at the rate of 48 *amperes per minute*. The self inductance of the coil is [MP PMT 2000]

(a) 0.25 *henry* (b) 15 *henry*
(c) 1.5 *henry* (d) 9.6 *henry*

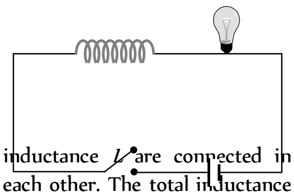
21. A closely wound coil of 100 turns and area of cross-section $1\ cm^2$ has a coefficient of self-induction 1 *mH*. The magnetic induction in the centre of the core of the coil when a current of $2A$ flows in it, will be [MP PET 1992]

(a) $0.022\ Wbm^{-2}$ (b) $0.4\ Wb\,m^{-2}$
(c) $0.8\ Wb\,m^{-2}$ (d) $1\ Wb\,m^{-2}$

22. Two circuits have coefficient of mutual induction of 0.09 *henry*. Average e.m.f. induced in the secondary by a change of current from 0 to 20 *ampere* in 0.006 *second* in the primary will be

(a) 120 *V* (b) 80 *V*
(c) 200 *V* (d) 300 *V*

23. In the following circuit, the bulb will become suddenly bright if



(a) Contact is made or broken
(b) Contact is made
(c) Contact is broken
(d) Won't become bright at all

24. Two pure inductors each of self inductance *L* are connected in parallel but are well separated from each other. The total inductance is

[MP PET 1991; Pb. PMT 1999; BHU 1998, 05]

(a) $2L$ (b) L
(c) $\frac{L}{2}$ (d) $\frac{L}{4}$

25. A coil and a bulb are connected in series with a dc source, a soft iron core is then inserted in the coil. Then

[MP PMT 1990; RPET 2001]

(a) Intensity of the bulb remains the same
(b) Intensity of the bulb decreases
(c) Intensity of the bulb increases
(d) The bulb ceases to glow

26. Self induction of a solenoid is [MP PMT 1993]

(a) Directly proportional to current flowing through the coil
(b) Directly proportional to its length
(c) Directly proportional to area of cross-section
(d) Inversely proportional to area of cross-section

27. Mutual inductance of two coils can be increased by

[MP PET 1994]

(a) Decreasing the number of turns in the coils
(b) Increasing the number of turns in the coils
(c) Winding the coils on wooden core
(d) None of the above

28. The self inductance of a coil is 5 *henry*, a current of 1 *amp* change to 2 *amp* within 5 *second* through the coil. The value of induced e.m.f. will be [MP PET 1994;

Similar MP PET/PMT 1998; CBSE PMT 1990]

(a) 10 *volt* (b) 0.10 *volt*
(c) 1.0 *volt* (d) 100 *volt*

29. The unit of inductance is [MP PMT 1994, 95;

MP PET 1997; MP PMT/PET 1998; RPET 2001]

(a) *Volt/ampere* (b) *Joule/ampere*
(c) *Volt-sec/ampere* (d) *Volt-ampere/sec*

30. The current flowing in a coil of self inductance 0.4 *mH* is increased by 250 *mA* in 0.1 *sec*. The e.m.f. induced will be

[MP PMT 1994]

(a) + 1 *V* (b) – 1 *V*
(c) + 1 *mV* (d) – 1 *mV*

31. 5 *cm* long solenoid having 10 *ohm* resistance and 5 *mH* inductance is joined to a 10 *volt* battery. At steady state the current through the solenoid in *ampere* will be

[MP PET 1995]

(a) 5 (b) 1
(c) 2 (d) Zero

32. When current in a coil changes to 2 *ampere* from 8 *ampere* in [MP PET 1992] $3\times10^{-3}\ second$, the e.m.f. induced in the coil is 2 *volt*. The self inductance of the coil in *millihenry* is

[MP PET 1995]

[CBSE PMT 1989]

(a) 1 (b) 5
(c) 20 (d) 10

33. An ideal coil of 10 *henry* is joined in series with a resistance of 5 *ohm* and a battery of 5 *volt*. 2 second after joining, the current flowing in *ampere* in the circuit will be

[MP PET 1995]

(a) e^{-1} (b) $(1-e^{-1})$
(c) $(1-e)$ (d) e

34. The number of turns of primary and secondary coils of a transformer are 5 and 10 respectively and the mutual inductance of the transformer is 25 *henry*. Now the number of turns in the primary and secondary of the transformer are made 10 and 5 respectively. The mutual inductance of the transformer in *henry* will be [MP PET 1995]

(a) 6.25 (b) 12.5
(c) 25 (d) 50

35. The inductance of a coil is $60\ \mu H$. A current in this coil increases from 1.0 *A* to 1.5 *A* in 0.1 *second*. The magnitude of the induced e.m.f. is [MP PMT 1995]

(a) $60\times10^{-6}\ V$ (b) $300\times10^{-4}\ V$
(c) $30\times10^{-4}\ V$ (d) $3\times10^{-4}\ V$

36. A circular coil of radius 5 *cm* has 500 turns of a wire. The approximate value of the coefficient of self induction of the coil will be [MP PET 1996; Pb PET 2000]

(a) 25 *millihenry* (b) 25×10^{-3} *millihenry*
(c) 50×10^{-3} *millihenry* (d) 50×10^{-3} *henry*

37. An e.m.f. of 100 *millivolts* is induced in a coil when the current in another nearby coil becomes 10 *ampere* from zero in 0.1 *second*. The coefficient of mutual induction between the two coils will be

[MP PET 1996; Kerala PMT 2004]

(a) 1 *millihenry* (b) 10 *millihenry*
(c) 100 *millihenry* (d) 1000 *millihenry*

38. In a coil of self inductance 0.5 *henry*, the current varies at a constant rate from zero to 10 *amperes* in 2 *seconds*. The e.m.f. generated in the coil is [MP PMT 1996]

(a) 10 *volts* (b) 5 *volts*
(c) 2.5 *volts* (d) 1.25 *volts*

39. A coil of self inductance 50 *henry* is joined to the terminals of a battery of e.m.f. 2 *volts* through a resistance of 10 *ohm* and a steady current is flowing through the circuit. If the battery is now disconnected, the time in which the current will decay to 1/*e* of its steady value is [MP PMT 1996]

(a) 500 *seconds* (b) 50 *seconds*

(c) 5 *seconds* (d) 0.5 *seconds*

40. The self inductance of a solenoid of length *L*, area of cross-section *A* and having *N* turns is [MP PET 1997; MP PET 2003]

(a) $\frac{\mu_0 N^2 A}{L}$ (b) $\frac{\mu_0 NA}{L}$

(c) $\mu_0 N^2 LA$ (d) $\mu_0 NAL$

41. The self inductance of a coil is *L*. Keeping the length and area same, the number of turns in the coil is increased to four times. The self inductance of the coil will now be [MP PMT 1997]

(a) $\frac{1}{4}L$ (b) *L*

(c) 4 *L* (d) 16 *L*

42. The mutual inductance between a primary and secondary circuits is 0.5 *H*. The resistances of the primary and the secondary circuits are 20 *ohms* and 5 *ohms* respectively. To generate a current of 0.4 *A* in the secondary, current in the primary must be changed at the rate of [MP PMT 1997]

(a) 4.0 *A/s* (b) 16.0 *A/s*

(c) 1.6 *A/s* (d) 8.0 *A/s*

43. The energy stored in a 50 *mH* inductor carrying a current of 4 *A* will be [MP PET 1999]

(a) 0.4 *J* (b) 4.0 *J*

(c) 0.8 *J* (d) 0.04 *J*

44. The average e.m.f. induced in a coil in which a current changes from 0 to 2 *A* in 0.05 *s* is 8 *V*. The self inductance of the coil is

(a) 0.1 *H* (b) 0.2 *H*

(c) 0.4 *H* (d) 0.8 *H*

45. If the current is halved in a coil, then the energy stored is how much times the previous value [CPMT 1999]

(a) $\frac{1}{2}$ (b) $\frac{1}{4}$

(c) 2 (d) 4

46. The SI unit of inductance, the henry, can be written as [IIT JEE 1998]

(a) *Weber/ampere* (b) *Volt-second/ampere*

(c) *Joule/(ampere)* (d) *Ohm-second*

47. A varying current in a coil changes from 10 *amp* to zero in 0.5 *sec*. If average EMF is induced in the coil is 220 *volts*, the self inductance of coil is [EAMCET 1994; MH CET (Med.) 1999]

(a) 5 *H* (b) 10 *H*

(c) 11 *H* (d) 12 *H*

48. Which of the following is wrong statement [AMU 1995]

(a) An emf can be induced between the ends of a straight conductor by moving it through a uniform magnetic field

(b) The self induced emf produced by changing current in a coil always tends to decrease the current

(c) Inserting an iron core in a coil increases its coefficient of self induction

(d) According to Lenz's law, the direction of the induced current is such that it opposes the flux change that causes it

49. A coil has an inductance of 2.5 *H* and a resistance of 0.5 *r*. If the coil is suddenly connected across a 6.0 *volt* battery, then the time required for the current to rise 0.63 of its final value is

(a) 3.5 *sec* (b) 4.0 *sec*

(c) 4.5 *sec* (d) 5.0 *sec*

50. When the number of turns and the length of the solenoid are doubled keeping the area of cross-section same, the inductance [CBSE PMT 1993

(a) Remains the same (b) Is halved

(c) Is doubled (d) Becomes four times

51. A 100 *mH* coil carries a current of 1 *ampere*. Energy stored in its magnetic field is [CBSE PMT 1992; KCET 1998]

(a) 0.5 *J* (b) 1 *J*

(c) 0.05 *J* (d) 0.1 *J*

52. The mutual inductance of an induction coil is $5H$. In the primary coil, the current reduces from $5A$ to zero in $10^{-3}s$. What is the induced emf in the secondary coil [RPET 1996]

(a) $2500V$ (b) 25000 *V*

(c) 2510 *V* (d) Zero

53. The self inductance of a straight conductor is [KCET 1998]

(a) Zero (b) Very large

(c) Infinity (d) Very small

54. What is the coefficient of mutual inductance when the magnetic flux changes by $2\times10^{-2}Wb$ and change in current is 0.01*A*[BHU 1998; AIIMS 2002]

(a) 2 *henry* (b) 3 *henry*

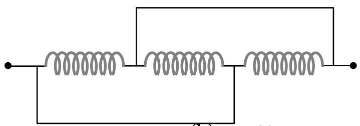
(c) $\frac{1}{2}$ *henry* (d) Zero

55. The current in a coil changes from 4 *ampere* to zero in 0.1 *s*. If the average e.m.f. induced is 100 *volt*, what is the self inductance of the coil [CPMT 1999] [MNR 1998]

(a) 2.5 *H* (b) 25 *H*

(c) 400 *H* (d) 40 *H*

56. Pure inductance of 3.0 *H* is connected as shown below. The equivalent inductance of the circuit is [MNR 1998; AIEEE 2002]



(a) 1 *H* (b) 2 *H*

(c) 3 *H* (d) 9 *H*

57. A varying current at the rate of 3 *A/s* in a coil generates an e.m.f. of 8 *mV* in a nearby coil. The mutual inductance of the two coils is

(a) 2.66 *mH* (b) $2.66\times10^{-3}\,mH$

(c) 2.66 *H* (d) 0.266 *H*

58. If a current of 10 *A* flows in one second through a coil, and the induced e.m.f. is 10 *V*, then the self-inductance of the coil is [CPMT 2000; Pb. PM

(a) $\frac{2}{5}H$ (b) $\frac{4}{5}H$

(c) $\frac{5}{4}H$ (d) 1 *H*

59. The inductance of a closed-packed coil of 400 turns is 8 *mH*. A current of 5 *mA* is passed through it. The magnetic flux through each turn of the coil is [Roorkee 2000]

(a) $\frac{1}{4\pi}\mu_0 Wb$ (b) $\frac{1}{2\pi}\mu Wb$

(c) $\frac{1}{3\pi}\mu_0 Wb$ [AMU 1995] (d) $0.4\,\mu_0 Wb$

60. When the current through a solenoid increases at a constant rate, the induced current [UPSEAT 2000]

(a) Is constant and is in the direction of the inducing current

(b) Is a constant and is opposite to the direction of the inducing current

(c) Increases with time and is in the direction of the inducing current

(d) Increases with time and opposite to the direction of the inducing current

61. If in a coil rate of change of area is 5 *m/milli second* and current become 1 *amp* from 2 *amp* in 2×10^{-3} *sec*. If magnitude of field is 1 *tesla* then self inductance of the coil is [RPET 2000]

(a) 2 *H* (b) 5 *H*

(c) 20 *H* (d) 10 *H*

62. The inductance of a solenoid 0.5 *m* long of cross-sectional area 20 *cm* and with 500 turns is [AMU (Med.) 2000]

(a) 12.5 *mH* (b) 1.25 *mH*

(c) 15.0 *mH* (d) 0.12 *mH*

63. The equivalent inductance of two inductances is 2.4 *henry* when connected in parallel and 10 *henry* when connected in series. The difference between the two inductances is [MP PMT 2000]

(a) 2 *henry* (b) 3 *henry*

(c) 4 *henry* (d) 5 *henry*

64. An e.m.f. of 12 *volt* is produced in a coil when the current in it changes at the rate of 45 *amp/minute*. The inductance of the coil is

(a) 0.25 *henry* (b) 1.5 *henry*

(c) 9.6 *henry* (d) 16.0 *henry*

65. An average induced e.m.f. of 1*V* appears in a coil when the current in it is changed from 10*A* in one direction to 10 *A* in opposite direction in 0.5 *sec*. Self-inductance of the coil is [CPMT 2001]

(a) 25 *mH* (b) 50 *mH*

(c) 75 *mH* (d) 100 *mH*

66. A coil of resistance 10 Ω and an inductance 5*H* is connected to a 100 *volt* battery. Then energy stored in the coil is [Pb. PMT 2001; CPMT 2002]

(a) 125 *erg* (b) 125 *J*

(c) 250 *erg* (d) 250 *J*

67. If a change in current of 0.01 *A* in one coil produces a change in magnetic flux of $1.2\times10^{-2}Wb$ in the other coil, then the mutual inductance of the two coils in henries is [EAMCET 2001]

(a) 0 (b) 0.5

(c) 1.2 (d) 3

68. Energy stored in a coil of self inductance 40*mH* carrying a steady current of 2 *A* is [Kerala (Engg.) 2001]

(a) 0.8 *J* (b) 8 *J*

(c) 0.08 *J* (d) 80 *J*

69. A solenoid of length *l metre* has self-inductance *L* henry. If number of turns are doubled, its self inductance [MP PMT 2001]

(a) Remains same (b) Becomes 2*L* henry

(c) Becomes 4*L henry* (d) Becomes $\frac{L}{\sqrt{2}}$ *henry*

70. Two coils *A* and *B* having turns 300 and 600 respectively are placed near each other, on passing a current of 3.0 *ampere* in *A*, the flux linked with *A* is 1.2×10^{-4} *weber* and with *B* it is 9.0×10^{-5} *weber*. The mutual inductance of the system is

(a) 2×10^{-5} *henry* (b) 3×10^{-5} *henry*

(c) 4×10^{-5} *henry* (d) 6×10^{-5} *henry*

71. In a circular conducting coil, when current increases from 2 *A* to 18 *A* in 0.05 *sec*., the induced e.m.f. is 20 *V*. The self inductance of the coil is [MP PET 2001]

(a) 62.5 *mH* (b) 6.25 *mH*

(c) 50 *mH* (d) None of these

72. Find out the e.m.f. produced when the current changes from 0 to 1 *A* in 10 *second*, given *L* = 10 *μH* [DCE 2001]

(a) 1 *V* (b) 1 *μV*

(c) 1 *mV* (d) 0.1 *V*

73. Which of the following is not the unit of self inductance [AMU (Med.) 2001]

(a) *Weber/Ampere* (b) *Ohm-Second*

(c) *Joule-Ampere* (d) *Joule Ampere*$^{-2}$

74. A coil of 100 turns carries a current of 5 *mA* and creates a magnetic flux of 10^{-5} *weber*. the inductance is [Orissa JEE 2002]

(a) 0.2 *mH* (b) 2.0 *mH*

(c) 0.02 *mH* [MP PET 2000] (d) None of these

75. In circular coil, when no. of turns is doubled and resistance becomes $\frac{1}{4}th$ of initial, then inductance becomes [AIEEE 2002]

(a) 4 *times* (b) 2 *times*

(c) 8 *times* (d) No change

76. The current in a coil of inductance 5 *H* decreases at the rate of 2 *A/s*. The induced e.m.f. is [MH CET 2002]

(a) 2 *V* (b) 5 *V*

(c) 10 *V* (d) – 10 *V*

77. The self-induced e.m.f. in a 0.1 *H* coil when the current in it is changing at the rate of 200 *ampere/second* is [DPMT 2002]

(a) 8×10^{-4} *V* (b) 8×10^{-5} *V*

(c) 20 *V* (d) 125 *V*

78. Two circuits have mutual inductance of 0.1 *H*. What average e.m.f. is induced in one circuit when the current in the other circuit changes from 0 to 20 *A* in 0.02 *s* [Kerala PET 2002]

(a) 240 *V* (b) 230 *V*

(c) 100 *V* (d) 300 *V*

79. An air core solenoid has 1000 turns and is one *metre* long. Its cross-sectional area is 10 *cm*. Its self inductance is [JIPMER 2002]

(a) 0.1256 *mH* (b) 12.56 *mH*

(c) 1.256 *mH* (d) 125.6 *mH*

80. The coefficient of mutual inductance of two coils is 6 *mH*. If the current flowing in one is 2 *ampere*, then the induced e.m.f. in the second coil will be [BVP 2003]

(a) 3 *mV* (b) 2 *mV*

(c) 3 *V* (d) Zero

81. An L-R circuit has a cell of e.m.f. E, which is switched on at time t = 0. The current in the circuit after a long time will be [MP PET 2003]

(a) Zero (b) $\frac{E}{R}$

(c) $\frac{E}{L}$ (d) $\frac{E}{\sqrt{L^2+R^2}}$

82. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon [AIEEE 2003]

(a) The currents in the two coils

(b) The rates at which currents are changing in the two coils

(c) Relative position and orientation of the two coils

(d) The materials of the wires of the coils

83. When the current change from + 2A to – 2A in 0.05 *second*, an e.m.f. of 8 V is induced in a coil. The coefficient of self-induction of the coil is [AIEEE 2003]

(a) 0.1 H (b) 0.2 H

(c) 0.4 H (d) 0.8 H

84. A coil resistance 20Ω and inductance 5H is connected with a 100 V battery. Energy stored in the coil will be [MP PMT 2003]

(a) 41.5 J (b) 62.50 J

(c) 125 J (d) 250 J

85. Why the current does not rise immediately in a circuit containing inductance [EAMCET 1994]

(a) Because of induced emf

(b) Because of high voltage drop

(c) Because of low power consumption

(d) Because of Joule heating

86. Two circular coils have their centres at the same point. The mutual inductance between them will be maximum when their axes

(a) Are parallel to each other

(b) Are at 60° to each other

(c) Are at 45° to each other

(d) Are perpendicular to each other

87. The current in a coil decreases from 1 A to 0.2 A. In 10*sec*. Calculate the coefficient of self inductance. If induced emf is 0.4 *volt*.

(a) 5 H (b) 3 H

(c) 4 H (d) 2 H

88. The current through choke coil increases form zero to 6A in 0.3 *seconds* and an induced e.m.f. of 30 V is produced. The inductance of the coil of choke is [MP PMT 2004]

(a) 5 H (b) 2.5 H

(c) 1.5 H (d) 2 H

89. The resistance and inductance of series circuit are 5Ω and 20H respectively. At the instant of closing the switch, the current is increasing at the rate 4A-*s*. The supply voltage is [MP PMT 2004]

(a) 20 V (b) 80 V

(c) 120 V (d) 100 V

90. A coil of N = 100 turns carries a current I = 5 A and creates a magnetic flux $\phi = 10^{-5} Tm^{-2}$ per turn. The value of its inductance L will be [UPSEAT 2004]

(a) 0.05 *mH* (b) 0.10 *mH*

(c) 0.15 *mH* (d) 0.20 *mH*

91. Two identical induction coils each of inductance L joined in series are placed very close to each other such that the winding direction of one is exactly opposite to that of the other, what is the net inductance [DCE 2003]

(a) L (b) 2L

(c) L/2 (d) Zero

92. If the current 30 A flowing in the primary coil is made zero in 0.1 *sec*. The emf induced in the secondary coil is 1.5 *volt*. The mutual inductance between the coil is [Pb PMT 2003]

(a) 0.05 H (b) 1.05 H

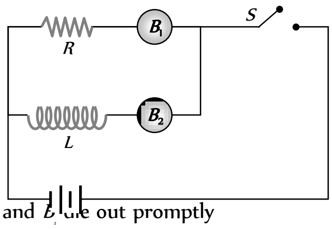
(c) 0.1 H (d) 0.2 H

93. Eddy currents are used in [AFMC 2004]

(a) Induction furnace (b) Electromagnetic brakes

(c) Speedometers (d) All of these

94. The adjoining figure shows two bulbs B and B resistor R and an inductor L. When the switch S is turned off [CPMT 1989]



(a) Both B and B die out promptly

(b) Both B and B die out with some delay

(c) B dies out promptly but B with some delay

(d) B dies out promptly but B with some delay

95. In L-R circuit, for the case of increasing current, the magnitude of current can be calculated by using the formula [MP PET 1994]

(a) $I = I_0 e^{-Rt/L}$ (b) $I = I_0(1-e^{-Rt/L})$

(c) $I = I_0(1-e^{Rt/L})$ (d) $I = I_0 e^{Rt/L}$

96. An ind[MP PMT 2004]a resistance R are first connected to a battery. After some time the battery is disconnected but L and R remain connected in a closed circuit. Then the current reduces to 37% of its initial value in [MP PMT 1994]

(a) *RL sec* (b) $\frac{R}{L}$ *sec*

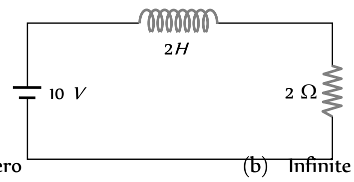
(c) $\frac{L}{R}$ *sec* [BCECE 2004] (d) $\frac{1}{LR}$ *sec*

97. In an LR-circuit, time constant is that time in which current grows from zero to the value (where I_0 is the steady state current) [MP PMT/PET 199

(a) $0.63\, I_0$ (b) $0.50\, I_0$

(c) $0.37\, I_0$ (d) I_0

98. In the figure magnetic energy stored in the coil is [RPET 2000]



(a) Zero (b) Infinite

(c) 25 *joules* (d) None of the above

99. A capacitor is fully charged with a battery. Then the battery is removed and coil is connected with the capacitor in parallel, current varies as [RPET 2000; DCE 2000]

(a) Increases monotonically (b) Decreases monotonically

(c) Zero (d) Oscillates indefinitely

100. A coil of inductance 40 *henry* is connected in 0series with a resistance of 8 *ohm* and the combination is joined to the terminals of a 2 *volt* battery. The time constant of the circuit is

(a) 40 *seconds* (b) 20 *seconds*

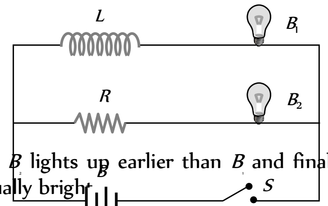
(c) 8 *seconds* (d) 5 *seconds*

101. A solenoid has an inductance of 60 *henrys* and a resistance of 30 *ohms*. If it is connected to a 100 volt battery, how long will it take for the current to reach $\frac{e-1}{e} \approx 63.2\%$ of its final value

(a) 1 *second* (b) 2 *seconds*

(c) *e seconds* (d) 2*e seconds*

102. An inductor, *L* a resistance *R* and two identical bulbs, B_1 and B_2 are connected to a battery through a switch *S* as shown in the figure. The resistance *R* is the same as that of the coil that makes *L*. Which of the following statements gives the correct description of the happenings when the switch *S* is closed



(a) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright

(b) B_1 light up earlier and finally both the bulbs acquire equal brightness

(c) B_2 lights up earlier and finally B_1 shines brighter than B_2

(d) B_1 and B_2 light up together with equal brightness all the time

103. The time constant of an *LR* circuit represents the time in which the current in the circuit [MP PMT 2002]

(a) Reaches a value equal to about 37% of its final value

(b) Reaches a value equal to about 63% of its final value

(c) Attains a constant value

(d) Attains 50% of the constant value

104. A *LC* circuit is in the state of resonance. If $C = 0.1 \mu F$ and $L = 0.25$ *henry*. Neglecting ohmic resistance of circuit what is the frequency of oscillations [BHU 2003; MP PMT 2005]

(a) 1007 *Hz* (b) 100 *Hz*

(c) 109 *Hz* (d) 500 *Hz*

105. An oscillator circuit consists of an inductance of 0.5 *mH* and a capacitor of 20 μF. The resonant frequency of the circuit is nearly

(a) 15.92 *Hz* (b) 159.2 *Hz*

(c) 1592 *Hz* (d) 15910 *Hz*

106. A coil of inductance 300 *mH* and resistance 2Ω is connected to a source of voltage $2V$. The current reaches half of its steady state value in [AIEEE 2005]

(a) 0.15 *s* (b) 0.3 *s*

(c) 0.05 *s* (d) 0.1 *s*

107. A coil having an inductance of 0.5 *H* carries a current which is uniformly varying from zero to 10 ampere in 2 second. The e.m.f. (in volts) generated in the coil is

[Kerala PET 2005]

(a) 10 (b) 5

(c) 2.5 (d) 1.25

108. The square root of the product of inductance and capacitance has the dimension of [KCET 2005]

(a) Length (b) Mass

(c) Time (d) No dimension

[MP PET 2000]

Application of EMI (Motor, Dynamo, Transformer...)

1. Which of the following does not depend upon the magnetic effect of some sort

(a) Moving coil galvanometer

(b) Hot wire ammeter [MP PET 2000]

(c) Dynamo

(d) Electric motor

2. Use of eddy currents is done in the following except

(a) Moving coil galvanometer

(b) Electric brakes

(c) Induction motor [AMU (Med.) 2002]

(d) Dynamo

3. Plane of eddy currents makes an angle with the plane of magnetic lines of force equal to

(a) 40^o (b) 0^o

(c) 90^o (d) 180^o

4. Which of the following is constructed on the principle of electromagnetic induction [MP PMT 2002]

(a) Galvanometer (b) Electric motor

(c) Generator (d) Voltmeter

5. A transformer is based on the principle of

[AIIMS 1998; AFMC 2005]

(a) Mutual inductance (b) Self inductance

(c) Ampere's law (d) Lenz's law

6. Which of the following is not an application of eddy currents

[CBSE PMT 1989]

(a) Induction furnace

(b) Galvanometer damping

(c) Speedometer of automobiles

(d) *X*-ray crystallography

7. The core of a transformer is laminated to reduce energy losses due to

[Kerala PET 2002] [CBSE PMT 1990; Karnataka CET (Med.) 2001]

(a) Eddy currents (b) Hysteresis

(c) Resistance in winding (d) None of these

8. The pointer of a dead-beat galvanometer gives a steady deflection because [MP PMT 1994]

(a) Eddy currents are produced in the conducting frame over which the coil is wound

(b) Its magnet is very strong

(c) Its pointer is very light

(d) Its frame is made of abonite

9. The device that does not work on the principle of mutual induction is [KCET 1994]

(a) Induction coil (b) Motor

(c) Tesla coil (d) Transformer

10. Eddy currents are produced when

[CBSE PMT 1993; AFMC 2002]

(a) A metal is kept in varying magnetic field

(b) A metal is kept in the steady magnetic field

(c) A circular coil is placed in a magnetic field

(d) Through a circular coil, current is passed

11. If rotational velocity of a dynamo armature is doubled, then induced e.m.f. will become [MP PMT 1991; AIIMS 2000]

(a) Half (b) Two times

(c) Four times (d) Unchanged

12. Dynamo is a device for converting

(a) Electrical energy into mechanical energy

(b) Mechanical energy into electrical energy

(c) Chemical energy into mechanical energy

(d) Mechanical energy into chemical energy

13. The working of dynamo is based on principle of [CPMT 1984]

(a) Electromagnetic induction

(b) Conversion of energy into electricity

(c) Magnetic effects of current

(d) Heating effects of current

14. Choke coil works on the principle of [MP PET/PMT 1988]

(a) Transient current (b) Self induction

(c) Mutual induction (d) Wattless current

15. When the speed of a dc motor increases the armature current [CPMT 1984, 85; MP PMT 2004]

(a) Increases

(b) Decreases

(c) Does not change

(d) Increases and decreases continuously

16. The output of a dynamo using a splitting commutator is

(a) dc

(b) ac

(c) Fluctuating dc

(d) Half-wave rectified voltage

17. Which of the following statement is incorrect

(a) Both ac and dc dynamo have a field magnet

(b) Both ac and dc dynamo have an armature

(c) Both ac and dc dynamo convert mechanical energy into electrical energy

(d) Both ac and dc dynamo have slip rings

18. The coil of dynamo is rotating in a magnetic field. The developed induced e.m.f. changes and the number of magnetic lines of force also changes. Which of the following condition is correct

(a) Lines of force minimum but induced e.m.f. is zero

(b) Lines of force maximum but induced e.m.f. is zero

(c) Lines of force maximum but induced e.m.f. is not zero

(d) Lines of force maximum but induced e.m.f. is also maximum

19. Dynamo core is laminated because [MP PET 1995]

(a) Magnetic field increases

(b) Magnetic saturation level in core increases

(c) Residual magnetism in core decreases

(d) Loss of energy in core due to eddy currents decreases

20. Armature current in dc motor will be maximum when [CPMT 1986, 88; MP PET 1995]

(a) Motor has acquired maximum speed

(b) Motor has acquired intermediate speed

(c) Motor has just started moving

(d) Motor is switched off

21. The armature of dc motor has $20\,\Omega$ resistance. It draws current of 1.5 ampere when run by 220 *volts* dc supply. The value of back e.m.f. induced in it will be [MP PMT 1999]

(a) 150 *V* (b) 170 *V*

(c) 180 *V* (d) 190 *V*

22. In an induction coil, the secondary e.m.f. is [KCET 1994]

(a) Zero during break of the circuit

(b) Very high during make of the circuit

(c) Zero during make of the circuit

(d) Very high during break of the circuit

23. The number of turns in the coil of an ac generator is 5000 and the area of the coil is $0.25\,m^2$. The coil is rotated at the rate of 100 *cycles/sec* in a magnetic field of $0.2\,W/m^2$. The peak value of the emf generated is nearly [AMU 1995]

(a) 786 *kV* (b) 440 *kV*

(c) 220 *kV* (d) 157.1 *kV*

24. In a dc motor, induced e.m.f. will be maximum [RPMT 1997]

(a) When motor takes maximum speed

(b) When motor starts rotating

(c) When speed of motor increases

(d) When motor is switched off

25. Work of electric motor is [RPMT 1997]

(a) To convert ac into dc

(b) To convert dc into ac

(c) Both (a) and (b)

(d) To convert ac into mechanical work

26. In an induction coil with resistance, the induced emf will be maximum when [RPMT 1996]

(a) The switch is put on due to high resistance

(b) The switch is put off due to high resistance

(c) The switch is put on due to low resistance

(d) The switch is put off due to low resistance

27. An electric motor operating on a 60 *V* dc supply draws a current of 10 *A*. If the efficiency of the motor is 50%, the resistance of its winding is [MP PET 1993] [AMU (Engg.) 2001]

(a) 3Ω (b) 6Ω

(c) 15Ω (d) 30Ω

28. A device which converts electrical energy into mechanical energy is

(a) Dynamo (b) generator

(c) Electric motor (d) Induction coil

29. An electric motor operates on a 50 *volt* supply and a current of 12*A*. If the efficiency of the motor is 30%, what is the resistance of the winding of the motor [Kerala PET 2002]

(a) 6Ω (b) 4Ω

(c) $2.9\,\Omega$ (d) 3.1Ω

30. A motor having an armature of resistance 2Ω is designed to operate at 220 *V* mains. At full speed, it develops a back e.m.f. of 210 *V*. When the motor is running at full speed, the current in the armature is [UPSEAT 2002]

(a) 5*A* (b) 105*A*

(c) 110*A* (d) 215*A*

31. Fan is based on [AFMC 2003]

(a) Electric Motor (b) Electric dynamo

(c) Both (d) None of these

32. A transformer is employed to [MP PET 1985; MP PMT 1993; RPET 1999]

(a) Obtain a suitable dc voltage

(b) Convert dc into ac

(c) Obtain a suitable ac voltage

(d) Convert ac into dc

33. What is increased in step-down transformer [MP PMT/PET 1998; CPMT 1999]

(a) Voltage (b) Current

(c) Power (d) Current density

34. The core of a transformer is laminated so that [CPMT 1985; MP PMT 1994, 2000, 02, 03; BHU 1999]

(a) Ratio of voltage in the primary and secondary may be increased

(b) Rusting of the core may be stopped

(c) Energy losses due to eddy currents may be reduced

(d) Change in flux is increased

35. In transformer, core is made of soft iron to reduce [AIIMS 1998; UPSEAT 2001; AFMC 2005]

(a) Hysteresis losses

(b) Eddy current losses

(c) Force opposing electric current

(d) None of the above

36. The transformation ratio in the step-up transformer is

(a) 1

(b) Greater than one

(c) Less than one

(d) The ratio greater or less than one depends on the other factors

37. In a transformer 220 ac voltage is increased to 2200 *volts*. If the number of turns in the secondary are 2000, then the number of turns in the primary will be [MP PET/PMT 1988]

(a) 200 (b) 100

(c) 50 (d) 20

38. The ratio of secondary to the primary turns in a transformer is 3 : 2. If the power output be *P*, then the input power neglecting all loses must be equal to [MP PMT 1984; KCET 2003]

(a) 5 *P* (b) 1.5 *P*

(c) *P* (d) $\frac{2}{5}P$

39. The primary winding of a transformer has 100 turns and its secondary winding has 200 turns. The primary is connected to an ac supply of 120 *V* and the current flowing in it is 10 A. The voltage and the current in the secondary are [MP PMT 1991; DPMT 2004]

(a) 240 *V*, 5 *A* (b) 240 *V*, 10 *A*

(c) 60 *V*, 20 *A* (d) 120 *V*, 20 *A*

40. A step-down transformer is connected to 2400 *volts* line and 80 amperes of current is found to flow in output load. The ratio of the turns in primary and secondary coil is 20 : 1. If transformer efficiency is 100%, then the current flowing in primary coil will be

(a) 1600 *A* (b) 20 *A*

(c) 4 *A* (d) 1.5 *A*

41. A loss free transformer has 500 turns on its primary winding and 2500 in secondary. The meters of the secondary indicate 200 *volts* at 8 *amperes* under these conditions. The voltage and current in the primary is [MP PMT 1996]

(a) 100 *V*, 16 *A* (b) 40 *V*, 40 *A*

(c) 160 *V*, 10 *A* (d) 80 *V*, 20 *A*

42. An ideal transformer has 100 turns in the primary and 250 turns in the secondary. The peak value of the ac is 28 *V*. The *r.m.s.* secondary voltage is nearest to [MP PMT 1992]

(a) 50 *V* (b) 70 *V*

(c) 100 *V* (d) 40 *V*

43. A transformer is employed to reduce 220 *V* to 11 *V*. The primary draws a current of 5 *A* and the secondary 90 *A*. The efficiency of the transformer is [MP PMT 1992, 2001, 04]

(a) 20% (b) 40%

(c) 70% (d) 90%

44. In a step-up transformer, the turn ratio is 1 : 2. A Leclanche cell (e.m.f. 1.5V) is connected across the primary. The voltage developed in the secondary would be [MP PET 1992, 99; AIIMS 2000; MP PMT 2000; RPET 2001]

(a) 3.0 *V* (b) 0.75 *V*

(c) 1.5 *V* (d) Zero

45. The alternating voltage induced in the secondary coil of a transformer is mainly due to [MP PET 1992; MP PMT 1996]

(a) A varying electric field

(b) A varying magnetic field

(c) The vibrations of the primary coil

(d) The iron core of the transformer

46. We can reduce eddy currents in the core of transformer [MP PET 1993]

(a) By increasing the number of turns in secondary coil

(b) By taking laminated core

(c) By making step-down transformer

(d) By using a weak ac at high potential

47. A 100% efficient transformer has 100 turns in the primary and 25 turns in its secondary coil. If the current in the secondary coil is 4 amp, then the current in the primary coil is

(a) 1 *amp* (b) 4 *amp*

(c) 8 *amp* (d) 16 *amp*

48. The efficiency of transformer is very high because [MP PET 1994]

(a) There is no moving part in a transformer

(b) It produces very high voltage

(c) It produces very low voltage

(d) None of the above

49. In a lossless transformer an alternating current of 2 *amp* is flowing in the primary coil. The number of turns in the primary and secondary coils are 100 and 20 respectively. The value of the current in the secondary coil is [MP PMT 1994]

(a) 0.08 *A* (b) 0.4 *A*

(c) 5 *A* (d) 10 *A*

50. A transformer connected to 220 *volt* line shows an output of 2 *A* at 11000 *volt*. The efficiency is 100%. The current drawn from the line is

(a) 100 *A* (b) 200 *A*

(c) 22 *A* (d) 11 *A*

51. The coils of a step down transformer have 500 and 5000 turns. In the primary coil an ac of 4 *ampere* at 2200 *volts* is sent. The value of the current and potential difference in the secondary coil will be

(a) 20 *A*, 220 *V* (b) 0.4 *A*, 22000 *V*

(c) 40 *A*, 220 *V* (d) 40 *A*, 22000 *V*

52. A power transformer is used to step up an alternating e.m.f. of 220 *V* to 11 *kV* to transmit 4.4 *kW* of power. If the primary coil has 1000 turns, what is the current rating of the secondary ? Assume 100% efficiency for the transformer [MP PET 1997]

(a) 4 *A* (b) 0.4 *A*

(c) 0.04 *A* (d) 0.2 *A*

53. A step up transformer connected to a 220 *V AC* line is to supply 22 *kV* for a neon sign in secondary circuit. In primary circuit a fuse wire is connected which is to blow when the current in the secondary circuit exceeds 10 *mA*. The turn ratio of the transformer is [MP PET 1997]

(a) 50 (b) 100

(c) 150 (d) 200

54. In a transformer the primary has 500 *turns* and secondary has 50 *turns*. 100 *volts* are applied to the primary coil, the voltage developed in the secondary will be [MP PMT 1997]

(a) 1 *V* (b) 10 *V*

(c) 1000 *V* (d) 10000 *V*

55. A transformer is used to [MP PET 1999]

(a) Change the alternating potential

(b) Change the alternating current

(c) To prevent the power loss in alternating current flow

(d) To increase the power of current source

56. A step-up transformer operates on a 230 *V* line and supplies a load of 2 *ampere*. The ratio of the primary and secondary windings is 1 : 25. The current in the primary is [CBSE PMT 1998]

(a) 15 *A* (b) 50 *A*

(c) 25 *A* (d) 12.5 *A*

57. The number of turns in the primary coil of a transformer is 200 and the number of turns in the secondary coil is 10. If 240 *volt AC* is applied to the primary, the output from the secondary will be [BHU 1997; JIPMER

(a) 48 *V* (b) 24 *V*

(c) 12 *V* (d) 6 *V*

58. The primary winding of transformer has 500 turns whereas its secondary has 5000 turns. The primary is connected to an ac supply of 20 *V*, 50 *Hz*. The secondary will have an output of [CBSE PMT 1997; AIIMS 19

(a) 200 *V*, 50 *Hz* (b) 2 *V*, 50 *Hz*

(c) 200 *V*, 500 *Hz* (d) 2 *V*, 5 *Hz*

59. A step-up transformer has transformation ratio of 3 : 2. What is the voltage in secondary if voltage in primary is 30 *V*

(a) 45 *V* (b) 15 *V*

(c) 90 *V* [MP PMT 1995] (d) 300 *V*

60. In a transformer, the number of turns in primary coil and secondary coil are 5 and 4 respectively. If 240 *V* is applied on the primary coil, then the ratio of current in primary and secondary coil is [AFMC 1998; CPMT 20

(a) 4 : 5 (b) 5 : 4

(c) 5 : 9 [MP PET 1996] (d) 9 : 5

61. A step-down transformer is connected to main supply 200 *V* to operate a 6 *V*, 30 *W* bulb. The current in primary is [AMU (Engg.) 1999]

(a) 3 *A* (b) 1.5 *A*

(c) 0.3 *A* (d) 0.15 *A*

62. The number of turns in primary and secondary coils of a transformer are 100 and 20 respectively. If an alternating potential of 200 *volt* is applied to the primary, the induced potential in secondary will be [RPET 1999]

(a) 10 *V* (b) 40 *V*

(c) 1000 *V* (d) 20,000 *V*

63. The ratio of secondary to primary turns is 9 : 4. If power input is *P*, what will be the ratio of power output (neglect all losses) to power input [DCE 1999]

(a) 4 : 9 (b) 9 : 4

(c) 5 : 4 (d) 1 : 1

64. Voltage in the secondary coil of a transformer does not depend upon. [BHU 2000]

(a) Voltage in the primary coil

(b) Ratio of number of turns in the two coils

(c) Frequency of the source

(d) Both (a) and (b)

65. A transformer has turn ratio 100/1. If secondary coil has 4 *amp* current then current in primary coil is [RPET 2000]

(a) 4 *A* (b) 0.04 *A*

(c) 0.4 *A* (d) 400 *A*

66. In a step-up transformer the turn ratio is 1:10. A resistance of 200 *ohm* connected across the secondary is drawing a current of 0.5 *A*. What is the primary voltage and current [MP PET 2000]

(a) 50 *V*, 1 *amp* (b) 10 *V*, 5 *amp*

(c) 25 *V*, 4 *amp* (d) 20 *V*, 2 *amp*

67. Large transformers, when used for some time, become hot and are cooled by circulating oil. The heating of transformer is due to

(a) Heating effect of current alone
(b) Hysteresis loss alone
(c) Both the hysteresis loss and heating effect of current
(d) None of the above

68. In a step-up transformer the voltage in the primary is 220 V and the current is 5A. The secondary voltage is found to be 22000 V. The current in the secondary (neglect losses) is [Kerala PMT 2002]

(a) 5 A (b) 50 A
(c) 500 A (d) 0.05 A

69. In a transformer, number of turns in the primary are 140 and that in the secondary are 280. If current in primary is 4A then that in the secondary is [AIEEE 2002]

(a) 4 A (b) 2 A
(c) 6 A (d) 10 A

70. A transformer has 100 turns in the primary coil and carries 8 A current. If input power is one kilowatt, the number of turns required in the secondary coil to have 500 V output will be [MP PET 2002]

(a) 100 (b) 200
(c) 400 (d) 300

71. An ideal transformer has 500 and 5000 turn in primary and secondary windings respectively. If the primary voltage is connected to a 6V battery then the secondary voltage is [Orissa JEE 2003]

(a) 0 (b) 60 V
(c) 0.6 V (d) 6.0 V

72. In a primary coil 5A current is flowing on 220 volts. In the secondary coil 2200 V voltage produces. Then ratio of number of turns in secondary coil and primary coil will be [RPET 2003]

(a) 1 : 10 (b) 10 : 1
(c) 1 : 1 (d) 11 : 1

73. A step up transformer has transformation ration 5 : 3. What is voltage in secondary if voltage in primary is 60 V [Pb. PET 2000]

(a) 20 V (b) 60 V
(c) 100 V (d) 180 V

74. In a step up transformer, 220 V is converted into 200 V. The number of turns in primary coil is 600. What is the number of turns in the secondary coil [DCE 2004]

(a) 60 (b) 600
(c) 6000 (d) 100

75. The output voltage of a transformer connected to 220 *volt* line is 1100 *volt* at 1 *amp* current. Its efficiency is 100%. The current coming from the line is [Pb. PET 2003]

(a) 20 A (b) 10 A
(c) 11 A (d) 22 A

76. Quantity that remains unchanged in a transformer is [MP PMT/PET 1998; AIIMS 1999; J & K CET 2005]

(a) Voltage (b) Current
(c) Frequency (d) None of the above

77. In a region of uniform magnetic induction $B = 10^{-2}\, tesla$, a circular coil of radius 30 *cm* and resistance π *ohm* is rotated about an axis which is perpendicular to the direction of B and which forms a diameter of the coil. If the coil rotates at 200 *rpm* the amplitude of the alternating current induced in the coil is [MP PET 2001]

(a) 4π *mA* (b) 30 *mA*
(c) 6 *mA* (d) 200 *mA*

78. In a transformer, the number of turns in primary and secondary are 500 and 2000 respectively. If current in primary is 48 A, the current in the secondary is [Orissa PMT 2004]

(a) 12 A (b) 24 A
(c) 48 A (d) 144 A

79. In an inductor of inductance L = 100 *mH*, a current of $I = 10A$ is flowing. The energy stored in the inductor is [Orissa PMT 2004]

(a) 5 J (b) 10 J
(c) 100 J (d) 1000 J

80. The turn ratio of a transformers is given as 2 : 3. If the current through the primary coil is 3 A, thus calculate the current through load resistance [BHU 2005]

(a) 1 A (b) 4.5 A
(c) 2 A (d) 1. 5 A

81. Core of transformer is made up of [AFMC 2005]

(a) Soft iron (b) Steel
(c) Iron (d) Alnico

82. The induction coil works on the principle of [KCET 2005]

(a) Self-induction (b) Mutual induction
(c) Ampere's rule (d) Fleming's right hand rule

83. A transformer with efficiency 80% works at 4 *kW* and 100 V. If the secondary voltage is 200 V, then the primary and secondary currents are respectively [Kerala PMT 2005]

(a) 40 A, 16 A (b) 16 A, 40 A
(c) 20 A, 40 A (d) 40 A, 20 A

84. In a step up transformer, if ratio of turns of primary to secondary is 1 : 10 and primary voltage is 230 V. If the load current is 2A, then the current in primary is [Orissa PMT 2005]

(a) 20 A (b) 10 A
(c) 2 A (d) 1 A

85. If a coil made of conducting wires is rotated between poles pieces of the permanent magnet. The motion will generate a current and this device is called [CPMT 2005]

(a) An electric motor (b) An electric generator
(c) An electromagnet (d) All of above

86. A step-down transformer is used on a 1000 V line to deliver 20 A at 120 V at the secondary coil. If the efficiency of the transformer is 80% the current drawn from the line is . [Kerala PET 2005]

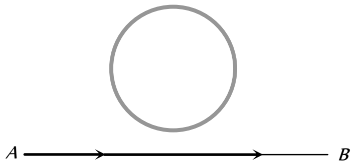
(a) 3 A (b) 30 A
(c) 0.3 A (d) 2.4 A

Critical Thinking

Objective Questions

1. An electron moves along the line *AB*, which lies in the same plane as a circular loop of conducting wires as shown in the diagram. What will be the direction of current induced if any, in the loop

[MP PET 1989; AIIMS 1982, 2001; KCET 2003; UPSEAT 2005]



(a) No current will be induced
(b) The current will be clockwise
(c) The current will be anticlockwise
(d) The current will change direction as the electron passes by

2. A copper rod of length *l* is rotated about one end perpendicular to the magnetic field *B* with constant angular velocity ω. The induced e.m.f. between the two ends is

[MP PMT 1992; Orissa JEE 2003]

(a) $\frac{1}{2}B\omega l^2$ (b) $\frac{3}{4}B\omega l^2$

(c) $B\omega l^2$ (d) $2B\omega l^2$

3. Two different coils have self-inductance $L_1 = 8\ mH$, $L_2 = 2mH$. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same rate. At a certain instant of time, the power given to the two coils is the same. At that time the current, the induced voltage and the energy stored in the first coil are i_1, V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are i_2, V_2 and W_2 respectively. Then [IIT JEE 1994]

(a) $\frac{i_1}{i_2} = \frac{1}{4}$ (b) $\frac{i_1}{i_2} = 4\ 8$

(c) $\frac{W_2}{W_1} = 4$ (d) $\frac{V_2}{V_1} = \frac{1}{4}$

4. An e.m.f. of 15 *volt* is applied in a circuit containing 5 *henry* inductance and 10 *ohm* resistance. The ratio of the currents at time $t = \infty$ and at $t = 1$ *second* is [MP PMT 1994]

(a) $\frac{e^{1/2}}{e^{1/2}-1}$ (b) $\frac{e^2}{e^2-1}$

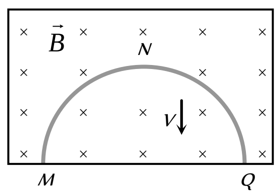
(c) $1-e^{-1}$ (d) e^{-1}

5. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coinciding. If $R_1 >> R_2$, the mutual inductance *M* between them will be directly proportional to [MP PMT 1994; MP PET 2001]

(a) R_1/R_2 (b) R_2/R_1

(c) R_1^2/R_2 (d) R_2^2/R_1

6. A thin semicircular conducting ring of radius *R* is falling with its plane vertical in a horizontal magnetic induction *B*. At the position *MNQ*, the speed of the ring is *V* and the potential difference developed across the ring is [IIT JEE 1996]



(a) Zero
(b) $Bv\pi R^2/2$ and *M* is at higher potential
(c) πRBV and *Q* is at higher potential
(d) $2RBV$ and *Q* is at higher potential

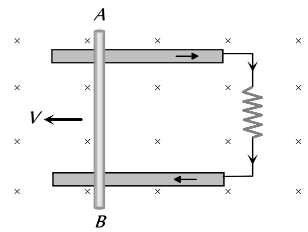
7. At a place the value of horizontal component of the earth's magnetic field *H* is $3\times10^{-5}\ Weber/m^2$. A metallic rod *AB* of length 2 *m* placed in east-west direction, having the end *A* towards east, falls vertically downward with a constant velocity of 50 *m/s*. Which end of the rod becomes positively charged and what is the value of induced potential difference between the two ends

(a) End *A*, $3\times10^{-3}\ mV$ (b) End *A*, 3 *mV*

(c) End *B*, $3\times10^{-3}\ mV$ (d) End *B*, 3 *mV*

8. Consider the situation shown in the figure. The wire *AB* is sliding on the fixed rails with a constant velocity. If the wire *AB* is replaced by semicircular wire, the magnitude of the induced current will

(a) Increase
(b) Remain the same
(c) Decrease
(d) Increase or decrease depending on whether the semicircle bulges towards the resistance or away from it



9. A circular loop of radius *R* carrying current *I* lies in *x-y* plane with its centre at origin. The total magnetic flux through *x-y* plane is [IIT-JEE 1999]

(a) Directly proportional to *I*
(b) Directly proportional to *R*
(c) Directly proportional to R^2
(d) Zero

10. Two identical circular loops of metal wire are lying on a table without touching each other. Loop-*A* carries a current which increases with time. In response, the loop-*B*

[IIT JEE 1999; UPSEAT 2003]

(a) Remains stationary
(b) Is attracted by the loop-*A*
(c) Is repelled by the loop-*A*
(d) Rotates about its CM, with CM fixed

(CM is the centre of mass)

11. Two coils have a mutual inductance 0.005 *H*. The current changes in the first coil according to equation $I = I_0 \sin\omega t$, where $I_0 = 10A$ and ω = 100 π *radian/sec*. The maximum value of e.m.f. in the second coil is

[CBSE PMT 1998; Pb. PMT 2000]

(a) 2π (b) 5π

(c) π (d) 4π

12. A small square loop of wire of side *l* is placed inside a large square loop of wire of side *L* (*L* > *l*). The loop are coplanar and their centre coincide. The mutual inductance of the system is proportional to

(a) l/L (b) l^2/L

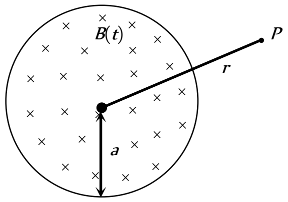
(c) L/l (d) L^2/l

13. A wire of length 1 *m* is moving at a speed of 2 *ms* perpendicular to its length and a homogeneous magnetic field of 0.5 *T*. The ends of the wire are joined to a circuit of resistance 6 Ω. The rate at which work is being done to keep the wire moving at constant speed is [Roorkee 1999]

(a) $\frac{1}{12}W$ (b) $\frac{1}{6}W$

(c) $\frac{1}{3}W$ (d) 1*W*

14. A uniform but time-varying magnetic field *B*(*t*) exists in a circular region of radius *a* and is directed into the plane of the paper, as shown. The magnitude of the induced electric field at point *P* at a distance *r* from the centre of the circular region



(a) Is zero

(b) Decreases as $\frac{1}{r}$

(c) Increases as *r*

(d) Decreases as $\frac{1}{r^2}$

15. A coil of wire having finite inductance and resistance has a conducting ring placed coaxially within it. The coil is connected to a battery at time *t* = 0, so that a time-dependent current $I_1(t)$ starts flowing through the coil. If $I_2(t)$ is the current induced in the ring. and $B(t)$ is the magnetic field at the axis of the coil due to $I_1(t)$, then as a function of time (*t* > 0), the product $I_2(t)\,B(t)$

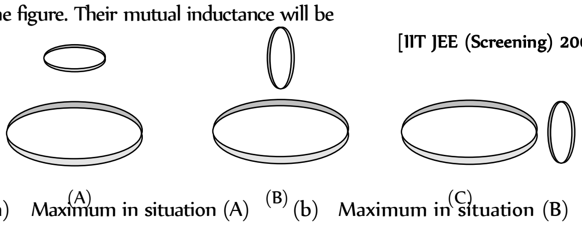
[IIT-JEE (Screening) 2000]

(a) Increases with time (b) Decreases with time

(c) Does not vary with time (d) Passes through a maximum

16. Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be

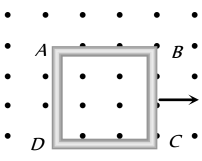
[IIT JEE (Screening) 2001]



(a) Maximum in situation (A) (b) Maximum in situation (B)

(c) Maximum in situation (C) (d) The same in all situations

17. A metallic square loop *ABCD* is moving in its own plane with velocity *v* in a uniform magnetic field perpendicular to its plane as shown in the figure. An electric field is induced



(a) In *AD*, but not in *BC*

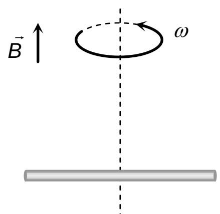
(b) In *BC*, but not in *AD*

(c) Neither in *AD* nor in *BC*

(d) In both *AD* and *BC*

18. A conducting rod of length 2*l* is rotating with constant angular speed *ω* about its perpendicular bisector. A uniform magnetic field $\vec{B}$ exists parallel to the axis of rotation. The e.m.f. induced between two ends of the rod is

[MP PET 2001]



(a) $B\omega l$

(b) $\frac{1}{2}B\omega l^2$

(c) $\frac{1}{8}B\omega l^2$

(d) Zero

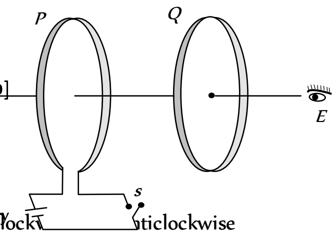
19. An inductor of 2 *henry* and a resistance of 10 *ohms* are connected in series with a battery of 5 *volts*. The initial rate of change of current is [MP PMT 2001]

(a) 0.5 *amp/sec* (b) 2.0 *amp/sec*

(c) 2.5 *amp/sec* (d) 0.25 *amp/sec*

20. As shown in the figure, *P* and *Q* are two coaxial conducting loops separated by some distance. When the switch *S* is closed, a clockwise current I_P flows in *P* (as seen by *E*) and an induced current I_{Q_1} flows in *Q*. The switch remains closed for a long time. When *S* is opened, a current I_{Q_2} flows in *Q*. Then the directions of I_{Q_1} and I_{Q_2} (as seen by *E*) are [IIT JEE (Screening) 2002]

[IIT-JEE (Screening) 2000]



(a) Respectively clockwise and anticlockwise

(b) Both clockwise

(c) Both anticlockwise

(d) Respectively anticlockwise and clockwise

21. A short-circuited coil is placed in a time-varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be

(a) Halved (b) The same

(c) Doubled (d) Quadrupled

22. A physicist works in a laboratory where the magnetic field is 2 *T*. She wears a necklace enclosing area 0.01 *m* in such a way that the plane of the necklace is normal to the field and is having a resistance *R* = 0.01 Ω. Because of power failure, the field decays to 1 *T* in time 10^{-3} *seconds*. Then what is the total heat produced in her necklace ? (*T* = *Tesla*)

[Orissa JEE 2002]

(a) 10 *J* (b) 20 *J*

(c) 30 *J* (d) 40 *J*

23. A coil of inductance 8.4 *mH* and resistance 6 Ω is connected to a 12 *V* battery. The current in the coil is 1.0 *A* at approximately the time

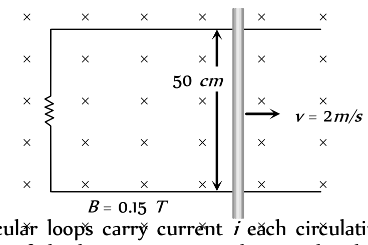
[IIT-JEE (Screening) 1999; UPSEAT 2003]

[IIT JEE (Screening) 2001]

(a) 500 *sec* (b) 20 *sec*

(c) 35 *milli sec* (d) 1 *milli sec*

24. As shown in the figure a metal rod makes contact and complete the circuit. The circuit is perpendicular to the magnetic field with $B = 0.15\,tesla$ If the resistance is $3\,\Omega$, force needed to move the rod as indicated with a constant speed of $2m/sec$ is



(a) $3.75\times10^{-3}\,N$

(b) $3.75\times10^{-2}\,N$

(c) $3.75\times10^{2}\,N$

(d) $3.75\times10^{-4}\,N$

25. Two identical coaxial circular loops carry current *i* each circulating in the clockwise direction. If the loops are approaching each other, then [MP PMT 1995, 96]

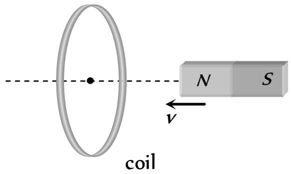
(a) Current in each loop increases

(b) Current in each loop remains the same

(c) Current in each loop decreases

(d) Current in one-loop increases and in the other it decreases

26. In the following figure, the magnet is moved towards the coil with a speed v and induced *emf* is e. If magnet and coil recede away from one another each moving with speed v, the induced *emf* in the coil will be



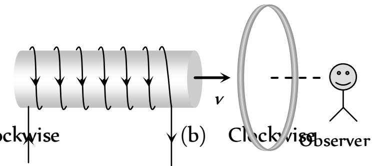
(a) e

(b) $2e$

(c) $e/2$

(d) $4e$

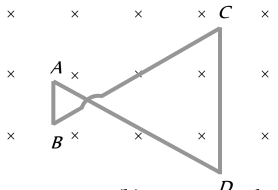
27. A current carrying solenoid is approaching a conducting loop as shown in the figure. The direction of induced current as observed by an observer on the other side of the loop will be



(a) Anticlockwise (b) Clockwise

(c) East (d) West

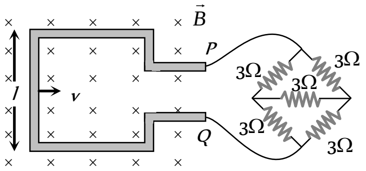
28. A conducting wire frame is placed in a magnetic field which is directed into the paper. The magnetic field is increasing at a constant rate. The directions of induced current in wires *AB* and *CD* are



(a) *B* to *A* and *D* to *C* (b) *A* to *B* and *C* to *D*

(c) *A* to *B* and *D* to *C* (d) *B* to *A* and *C* to *D*

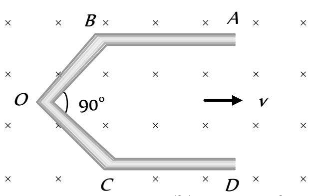
29. A square metallic wire loop of side 0.1 m and resistance of 1Ω is moved with a constant velocity in a magnetic field of 2 wb/m as shown in figure. The magnetic field is perpendicular to the plane of the loop, loop is connected to a network of resistances. What should be the velocity of loop so as to have a steady current of $1 mA$ in loop



(a) 1 cm/sec (b) 2 cm/sec

(c) 3 cm/sec (d) 4 cm/sec

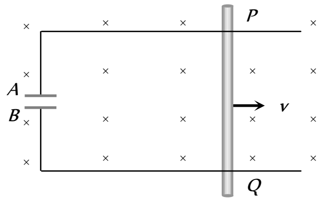
30. A conductor *ABOCD* moves along its bisector with a velocity of 1 m/s through a perpendicular magnetic field of 1 wb/m, as shown in fig. If all the four sides are of $1m$ length each, then the induced emf between points *A* and *D* is



(a) 0 (b) 1.41 *volt*

(c) 0.71 *volt* (d) None of the above

31. A conducting rod *PQ* of length L = 1.0 m is moving with a uniform speed v = 2 m/s in a uniform magnetic field $B = 4.0\,T$ directed into the paper. A capacitor of capacity C = 10 μF is connected as shown in figure. Then



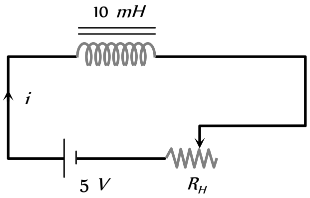
(a) $q_A = +80\ \mu C$ and $q_B = -80\ \mu C$

(b) $q_A = -80\ \mu C$ and $q_B = +80\ \mu C$

(c) $q_A = 0 = q_B$

(d) Charge stored in the capacitor increases exponentially with time

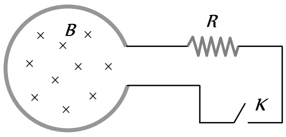
32. The resistance in the following circuit is increased at a particular instant. At this instant the value of resistance is 10Ω. The current in the circuit will be now



(a) i = 0.5 A (b) i > 0.5 A

(c) i < 0.5 A (d) i = 0

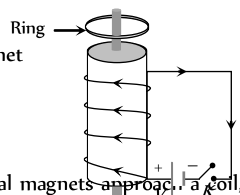
33. Shown in the figure is a circular loop of radius r and resistance R. A variable magnetic field of induction $B = B_0 e^{-t}$ is established inside the coil. If the key (K) is closed, the electrical power developed right after closing the switch is equal to



(a) $\dfrac{B_0^2 \pi r^2}{R}$ (b) $\dfrac{B_0 10 r^3}{R}$

(c) $\dfrac{B_0^2 \pi^2 r^4 R}{5}$ (d) $\dfrac{B_0^2 \pi^2 r^4}{R}$

34. A conducting ring is placed around the core of an electromagnet as shown in fig. When key K is pressed, the ring



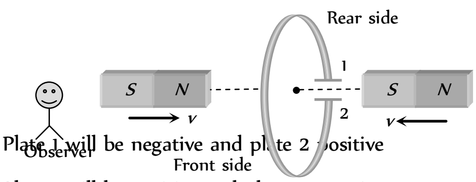
(a) Remain stationary

(b) Is attracted towards the electromagnet

(c) Jumps out of the core

(d) None of the above

35. The north and south poles of two identical magnets approach a coil, containing a condenser, with equal speeds from opposite sides. Then



(a) Plate 1 will be negative and plate 2 positive

(b) Plate 1 will be positive and plate 2 negative

(c) Both the plates will be positive

(d) Both the plates will be negative

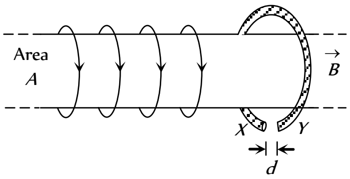
36. A highly conducting ring of radius R is perpendicular to and concentric with the axis of a long solenoid as shown in fig. The ring has a narrow gap of width d in its circumference. The solenoid has cross sectional area A and a uniform internal field of magnitude B_0. Now beginning at $t = 0$, the solenoid current is steadily increased to so that the field magnitude at any time t is given by $B(t) = B_0 + \alpha t$ where $\alpha > 0$. Assuming that no charge can flow across the gap, the end of ring which has excess of positive charge and the magnitude of induced e.m.f. in the ring are respectively

(a) X, $A\alpha$

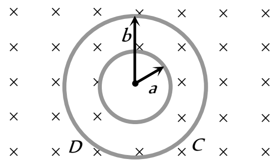
(b) X $\pi R\alpha$

(c) Y, $\pi A\alpha$

(d) Y, $\pi R\alpha$



37. Plane figures made of thin wires of resistance R = 50 *milli ohm/metre* are located in a uniform magnetic field perpendicular into the plane of the figures and which decrease at the rate dB/dt = 0.1 *m T/s*. Then currents in the inner and outer boundary are. (The inner radius a = 10 *cm* and outer radius b = 20 *cm*)



(a) 10· A (Clockwise), 2 × 10· A (Clockwise)

(b) 10· A (Anticlockwise), 2 × 10· A (Clockwise)

(c) 2 × 10· A (clockwise), 10· A (Anticlockwise)

(d) 2 × 10· A (Anticlockwise), 10· A (Anticlockwise)

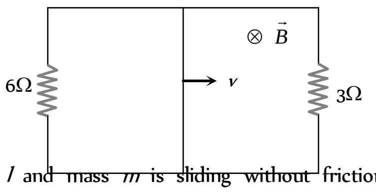
38. A rectangular loop with a sliding connector of length l = 1.0 m is situated in a uniform magnetic field B = 2T perpendicular to the plane of loop. Resistance of connector is r = 2Ω. Two resistance of 6Ω and 3Ω are connected as shown in figure. The external force required to keep the connector moving with a constant velocity v = 2m/s is

(a) 6 N

(b) 4 N

(c) 2 N

(d) 1 N



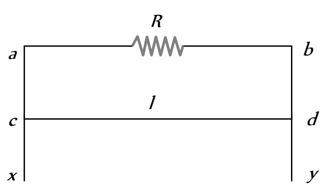
39. A wire cd of length l and mass m is sliding without friction on conducting rails ax and by as shown. The vertical rails are connected to each other with a resistance R between a and b. A uniform magnetic field B is applied perpendicular to the plane $abcd$ such that cd moves with a constant velocity of

(a) $\dfrac{mgR}{Bl}$

(b) $\dfrac{mgR}{B^2l^2}$

(c) $\dfrac{mgR}{B^3l^3}$

(d) $\dfrac{mgR}{B^2l}$



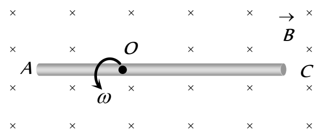
40. A conducting rod AC of length $4l$ is rotated about a point O in a uniform magnetic field $\vec{B}$ directed into the paper. $AO = l$ and $OC = 3l$. Then

(a) $V_A - V_O = \dfrac{B\omega l^2}{2}$

(b) $V_O - V_C = \dfrac{7}{2}B\omega l^2$

(c) $V_A - V_C = 4B\omega l^2$

(d) $V_C - V_O = \dfrac{9}{2}B\omega l^2$



41. How much length of a very thin wire is required to obtain a solenoid of length l_0 and inductance L

(a) $\sqrt{\dfrac{2\pi L l_0}{\mu_0}}$

(b) $\sqrt{\dfrac{4\pi L l_0}{\mu_0^2}}$

(c) $\sqrt{\dfrac{4\pi L l_0}{\mu_0}}$

(d) $\sqrt{\dfrac{8\pi L l_0}{\mu_0}}$

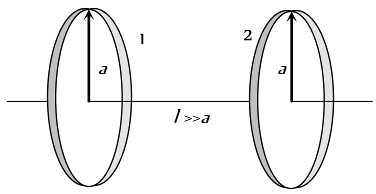
42. What is the mutual inductance of a two-loop system as shown with centre separation l

(a) $\dfrac{\mu_0 \pi a^4}{8l^3}$

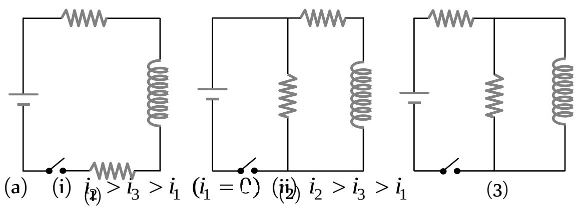
(b) $\dfrac{\mu_0 \pi a^4}{4l^3}$

(c) $\dfrac{\mu_0 \pi a^4}{6l^3}$

(d) $\dfrac{\mu_0 \pi a^4}{2l^3}$



43. The figure shows three circuits with identical batteries, inductors, and resistors. Rank the circuits according to the current through the battery (i) just after the switch is closed and (ii) a long time later, greatest first



(a) (i) $i_2 > i_3 > i_1$ $(i_1 = 0)$ (ii) $i_2 > i_3 > i_1$

(b) (i) $i_2 < i_3 < i_1$ $(i_1 \neq 0)$ (ii) $i_2 > i_3 > i_1$

(c) (i) $i_2 = i_3 = i_1$ $(i_1 = 0)$ (ii) $i_2 < i_3 < i_1$

(d) (i) $i_2 = i_3 > i_1$ $(i_1 \neq 0)$ (ii) $i_2 > i_3 > i_1$

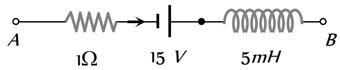
44. The network shown in the figure is a part of a complete circuit. If at a certain instant the current i is 5 A and is decreasing at the rate of $10^3\,A/s$ then $V_A - V_B$ is

(a) 5 V

(b) 10 V

(c) 15 V

(d) 20 V



45. A 50 *volt* potential difference is suddenly applied to a coil with $L = 5 \times 10^{-3}$ *henry* and $R = 180\,ohm$. The rate of increase of current after 0.001 *second* is [MP PET 1994]

(a) 27.3 *amp/sec*

(b) 27.8 *amp/sec*

(c) 2.73 *amp/sec*

(d) None of the above

46. The current in a LR circuit builds up to $\dfrac{3}{4}th$ of its steady state value in $4s$. The time constant of this circuit is

[Roorkee 2000]

(a) $\frac{1}{\ln 2}s$ (b) $\frac{2}{\ln 2}s$

(c) $\frac{3}{\ln 2}s$ (d) $\frac{4}{\ln 2}s$

47. A conducting ring of radius 1 *meter* is placed in an uniform magnetic field B of 0.01 *Telsa* oscillating with frequency 100 *Hz* with its plane at right angles to B. What will be the induced electric field [AIIMS 2005]

(a) $\pi\, volt/m$ (b) $2\, volt/m$

(c) $10\, volt/m$ (d) $62\, volt/m$

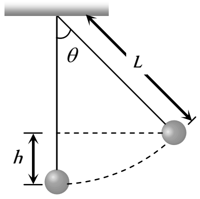
48. A simple pendulum with bob of mass m and conducting wire of length L swings under gravity through an angle 2θ. The earth's magnetic field component in the direction perpendicular to swing is B. Maximum potential difference induced across the pendulum is [MP PET 2005]

(a) $2BL\sin\left(\frac{\theta}{2}\right)(gL)^{1/2}$

(b) $BL\sin\left(\frac{\theta}{2}\right)(gL)$

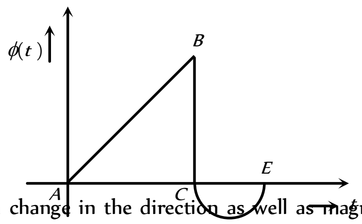
(c) $BL\sin\left(\frac{\theta}{2}\right)(gL)^{3/2}$

(d) $BL\sin\left(\frac{\theta}{2}\right)(gL)^{2}$



Graphical Questions

1. The graph Shows the variation in magnetic flux $\phi(t)$ with time through a coil. Which of the statements given below is not correct



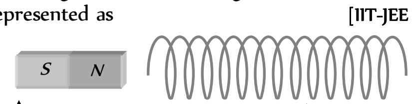
(a) There is a change in the direction as well as magnitude of the induced emf between B and D

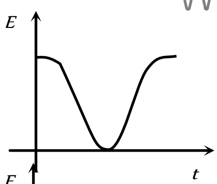
(b) The magnitude of the induced emf is maximum between B and C

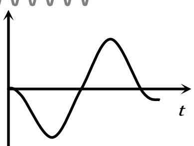
(b) There is a change in the direction as well as magnitude of induced emf between A and C

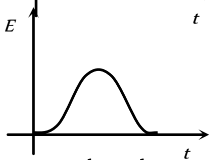
(d) The induced emf is zero at B

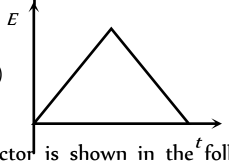
2. The variation of induced emf (E) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as [IIT-JEE (Screening) 2004]



(a)


(b)


(c)


(d)


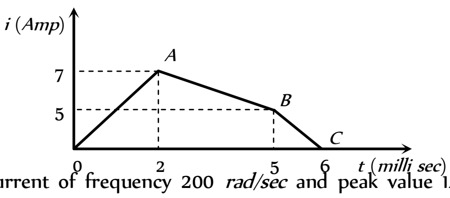
3. The current through a 4.6 H inductor is shown in the following graph. The induced emf during the time interval $t = 5$ *milli-sec* to 6 *milli-sec* will be

(a) 10^3 V

(b) -23×10^3 V

(c) 23×10^3 V

(d) Zero



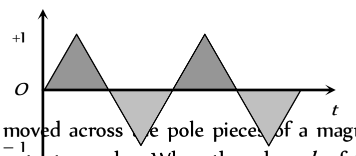
4. An alternating current of frequency 200 *rad/sec* and peak value 1A as shown in the figure, is applied to the primary of a transformer. If the coefficient of mutual induction between the primary and the secondary is 1.5 H, the voltage induced in the secondary will be

(a) 300 V

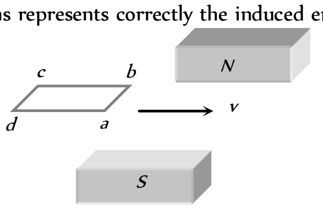
(b) 191 V

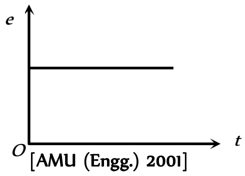
(c) 220 V

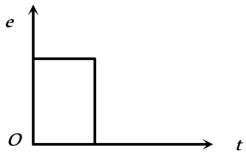
(d) 471 V



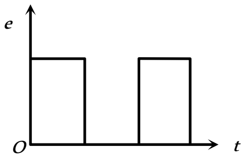
5. A horizontal loop $abcd$ is moved across the pole pieces of a magnet as shown in fig. with a constant speed v. When the edge ab of the loop enters the pole pieces at time $t = 0$ *sec.* Which one of the following graphs represents correctly the induced emf in the coil

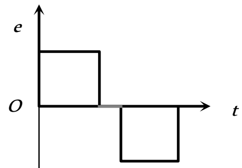


(a)


(b)


[AMU (Engg.) 2001]

(c)


(d)


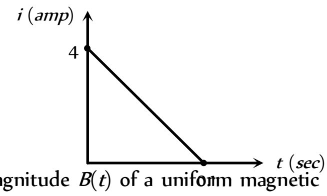
6. Some magnetic flux is changed from a coil of resistance 10 *ohm*. As a result an induced current is developed in it, which varies with time as shown in figure. The magnitude of change in flux through the coil in *webers* is

(a) 2

(b) 4

(c) 6

(d) None of these



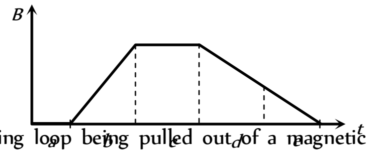
7. The graph gives the magnitude $B(t)$ of a uniform magnetic field that exists throughout a conducting loop, perpendicular to the plane of the loop. Rank the five regions of the graph according to the magnitude of the emf induced in the loop, greatest first

(a) $b > (d = e) < (a = c)$

(b) $b > (d = e) > (a = c)$

(c) $b < d < e < c < a$

(d) $b > (a = c) > (d = e)$



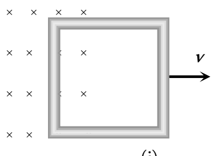
8. Figure (i) shows a conducting loop being pulled out of a magnetic field with a speed v. Which of the four plots shown in figure (ii) may represent the power delivered by the pulling agent as a function of the speed v

(a) a

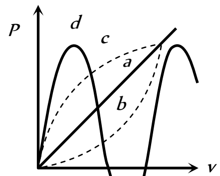
(b) b

(c) c

(d) d

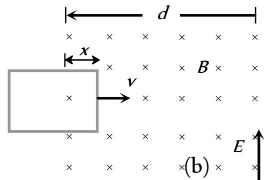


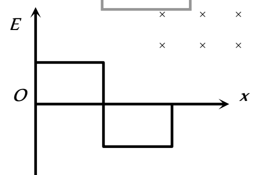
(i)

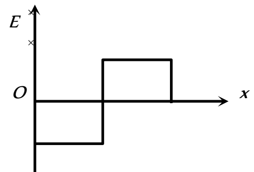


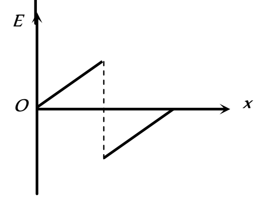
(ii)

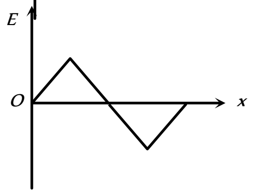
9. A rectangular loop is being pulled at a constant speed v, through a region of certain thickness d, in which a uniform magnetic field B is set up. The graph between position x of the right hand edge of the loop and the induced emf E will be



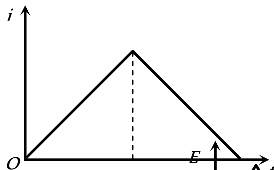
(a)


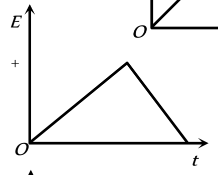
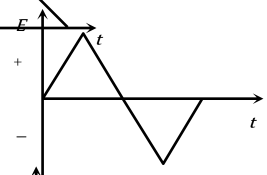
(b)


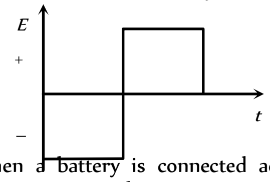
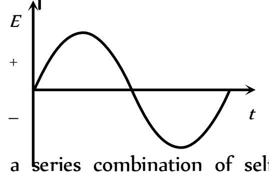
(c)


(d)


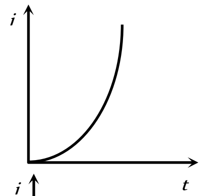
10. The current i in an inductance coil varies with time, t according to the graph shown in fig. Which one of the following plots shows the variation of voltage in the coil with time



(a)

(b)


(c)

(d)


11. When a battery is connected across a series combination of self inductance L and resistance R, the variation in the current i with time t is best represented by [MP PET 2004]

(a)

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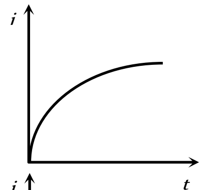
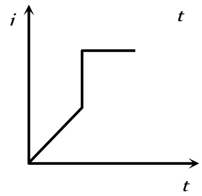
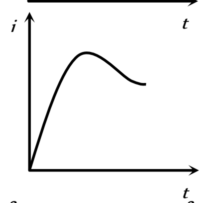


(c)

(d)


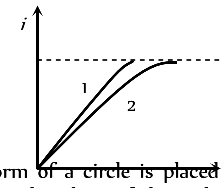
12. When a certain circuit consisting of a constant e.m.f. E an inductance L and a resistance R is closed, the current in, it increases with time according to curve 1. After one parameter (E, L or R) is changed, the increase in current follows curve 2 when the circuit is closed second time. Which parameter was changed and in what direction

(a) L is increased

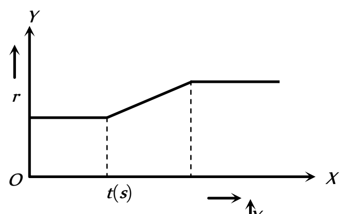
(b) L is decreased

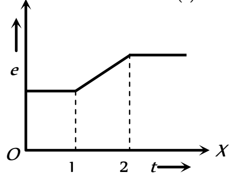
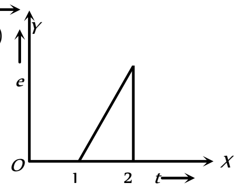
(c) R is increased

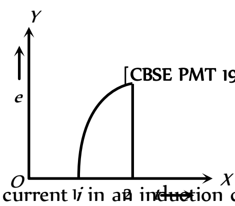
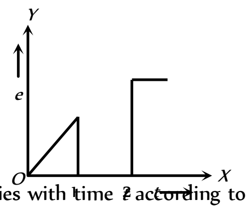
(d) R is decreased



13. A flexible wire bent in the form of a circle is placed in a uniform magnetic field perpendicular to the plane of the coil. The radius of the coil changes as shown in figure. The graph of induced emf in the coil is represented by

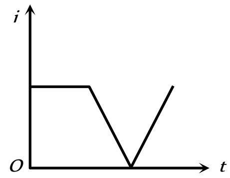


(a)

(b)


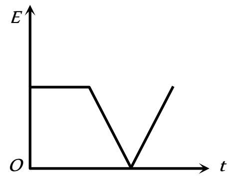
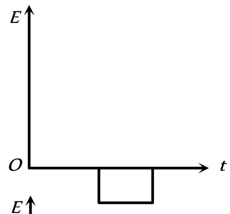
(c)

(d)


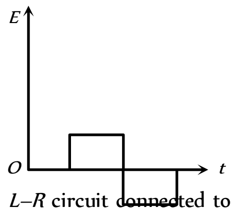
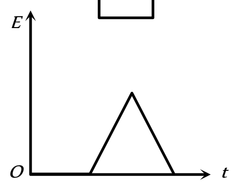
[CBSE PMT 1994]

14. The current i in an induction coil varies with time t according to the graph shown

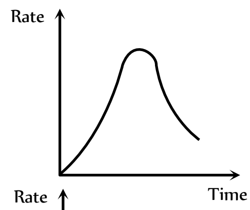
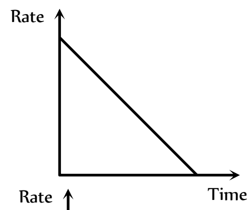


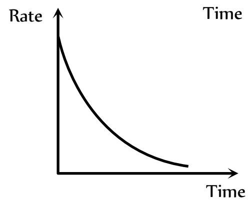
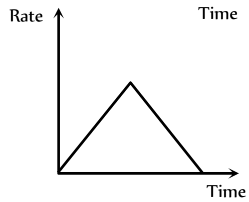
in figure. Which of the following graphs shows the induced emf (e) in the coil with time

(a)

(b)


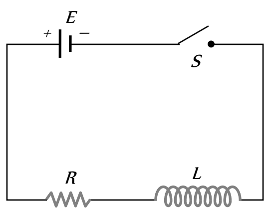
(c)

(d)


15. In an L–R circuit connected to a battery the rate at which energy is stored in the inductor is plotted against time during the growth of the current in the circuit. Which of the following best represents the resulting curve

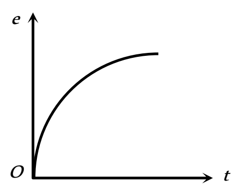
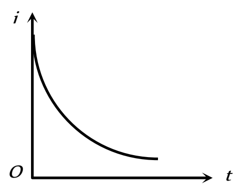
(a)

(b)


(c)

(d)


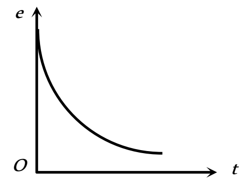
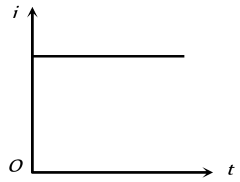
16. Switch S of the circuit shown in figure. is closed at t = 0. If e denotes the induced



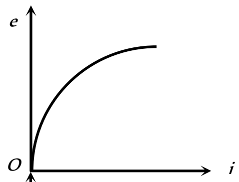
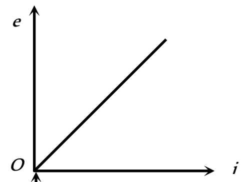
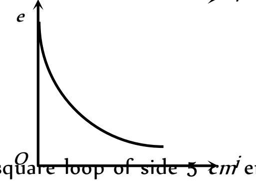
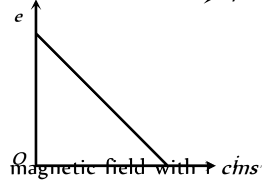
emf in L and i, the current flowing through the circuit at time t, which of the following graphs is correct

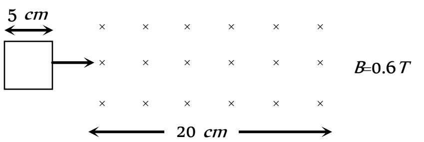
(a) (b) IV.

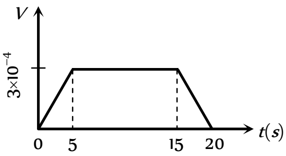
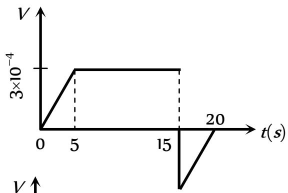
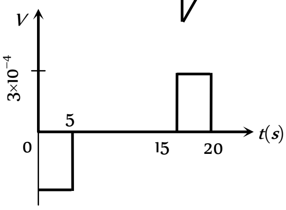
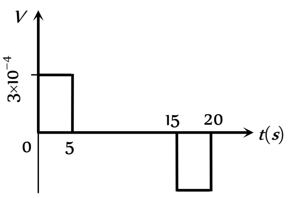
(c) 
(d) 

17. For previous objective, which of the following graphs is correct

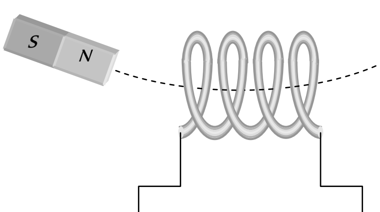
(a) 
(b) 
(c) 
(d) 

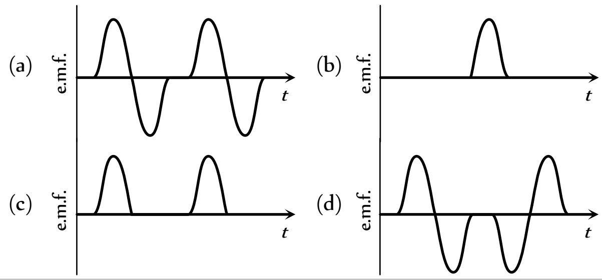
18. A square loop of side 5 *cm* enters a magnetic field with 1 *cm/s*. The front edge enters the magnetic field at $t = 0$ then which graph best depicts *emf*



(a) 
(b) 
(c) 
(d) 

19. A magnet is made to oscillate with a particular frequency, passing through a coil as shown in figure. The time variation of the magnitude of e.m.f. generated across the coil during one cycle is





Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Eddy currents is produced in any metallic conductor when magnetic flux is changed around it.
Reason : Electric potential determines the flow of charge. **[AIIMS 1995]**

2. Assertion : The quantity *L/R* possesses dimensions of time.
Reason : To reduce the rate of increases of current through a solenoid should increase the time constant (*L/R*). **[AIIMS 2002]**

3. Assertion : Faraday's laws are consequences of conservation of energy.
Reason : In a purely resistive ac circuit, the current lags behind the e.m.f. in phase. **[AIIMS 2002]**

4. Assertion : Only a change in magnetic flux will maintain an induced current the coil.
Reason : The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous. **[AIIMS 1999]**

5. Assertion : Magnetic flux can produce induced e.m.f.
Reason : Faraday established induced e.m.f. experimentally.

6. Assertion : The induced e.m.f. and current will be same in two identical loops of copper and aluminium, when rotated with same speed in the same magnetic field.
Reason : Induced e.m.f. is proportional to rate of change of magnetic field while induced current depends on resistance of wire.

7. Assertion : Inductance coil are made of copper.
Reason : Induced current is more in wire having less resistance.

8. Assertion : Self-inductance is called the inertia of electricity.
Reason : Self-inductance is the phenomenon, according to which an opposing induced e.m.f. is produced in a coil as a result of change in current or magnetic flux linked in the coil.

9. Assertion : When two coils are wound on each other, the mutual induction between the coils is maximum.
Reason : Mutual induction does not depend on the orientation of the coils. **[AIIMS 2005]**

10. Assertion : Acceleration of a magnet falling through a long solenoid decreases.
Reason : The induced current produced in a circuit always flow in such direction that it opposes the change or the cause the produced it.

11. Assertion : An aircraft flies along the meridian, the potential at the ends of its wings will be the same.
Reason : Whenever there is change in the magnetic flux e.m.f. induces.

12. Assertion : A spark occur between the poles of a switch when the switch is opened.
Reason : Current flowing in the conductor produces magnetic field.

13. Assertion : In the phenomenon of mutual induction, self induction of each of the coils persists.
Reason : Self induction arises when strength of current in same coil changes. In mutual induction, current is changing in both the individual coils.

14. Assertion : Lenz's law violates the principle of conservation of energy.
Reason : Induced e.m.f., opposes always the change in magnetic flux responsible for its production.

15. Assertion : The induced emf in a conducting loop of wire will be non zero when it rotates in a uniform magnetic field.
Reason : The emf is induced due to change in magnetic flux.

16. Assertion : An induced emf is generated when magnet is withdrawn from the solenoid.
Reason : The relative motion between magnet and solenoid induces emf.

17. Assertion : An artificial satellite with a metal surface is moving above the earth in a circular orbit. A current will be induced in satellite if the plane of the orbit is inclined to the plane of the equator.
Reason : The current will be induced only when the speed of satellite is more than 8 km/sec.

18. Assertion : A bar magnet is dropped into a long vertical copper tube. Even taking air resistance as negligible, the magnet attains a constant terminal velocity. If the tube is heated, the terminal velocity gets increased.
Reason : The terminal velocity depends on eddy current produced in bar magnet.

19. Assertion : A metal piece and a non-metal (stone) piece are dropped from the same height near earth's surface. Both will reach the earth's surface simultaneously.
Reason : There is no effect of earth's magnetic field on freely falling body.

20. Assertion : A transformer cannot work on dc supply.
Reason : dc changes neither in magnitude nor in direction.

21. Assertion : Soft iron is used as a core of transformer.
Reason : Area of hysteresis is loop for soft iron is small.

22. Assertion : An ac generator is based on the phenomenon of self-induction.
Reason : In single coil, we consider self-induction only.

23. Assertion : An electric motor will maximum efficient when back e.m.f. is equal to applied e.m.f.
Reason : Efficiency of electric motor is depends only on magnitude of back e.m.f..

24. Assertion : The back emf in a dc motor is maximum when the motor has just been switched on.
Reason : When motor is switched on it has maximum speed.

Answers

Faraday's and Lenz's Law

1	c	2	d	3	b	4	d	5	b
6	c	7	a	8	c	9	a	10	b
11	a	12	b	13	b	14	a	15	d
16	d	17	c	18	b	19	b	20	b
21	b	22	c	23	b	24	b	25	d
26	c	27	d	28	b	29	d	30	d
31	b	32	a	33	b	34	a	35	b
36	b	37	d	38	a	39	a	40	c
41	c	42	b	43	c	44	c	45	d
46	d	47	d	48	d	49	d	50	c
51	b	52	a	53	d	54	b	55	b
56	a	57	c	58	a	59	d	60	b
61	a	62	a	63	d	64	d	65	c
66	c	67	a	68	b				

Motional EMI

1	a	2	b	3	d	4	c	5	b
6	b	7	b	8	c	9	d	10	d
11	b	12	c	13	b	14	c	15	d
16	c	17	c	18	b	19	c	20	b
21	d	22	d	23	d	24	d	25	c
26	a	27	c	28	c	29	c	30	d
31	b	32	b	33	b				

Static EMI

1	d	2	d	3	b	4	a	5	d
6	d	7	c	8	c	9	c	10	c
11	a	12	b	13	b	14	d	15	d
16	b	17	a	18	b	19	b	20	b
21	a	22	d	23	c	24	c	25	b
26	c	27	b	28	c	29	c	30	d
31	b	32	a	33	b	34	c	35	d
36	a	37	a	38	c	39	c	40	a
41	d	42	a	43	a	44	b	45	b
46	abcd	47	c	48	b	49	d	50	c
51	c	52	b	53	a	54	a	55	a
56	a	57	a	58	d	59	a	60	b
61	d	62	b	63	a	64	d	65	a
66	d	67	c	68	c	69	c	70	b
71	a	72	b	73	c	74	b	75	a
76	c	77	c	78	c	79	c	80	d
81	b	82	c	83	a	84	b	85	a
86	a	87	a	88	c	89	b	90	d
91	d	92	a	93	d	94	c	95	b
96	c	97	a	98	c	99	d	100	d
101	b	102	c	103	b	104	a	105	c
106	d	107	c	108	c				

Application of EMI (Motor, Dynamo, Transformer ...)

1	b	2	d	3	c	4	c	5	a
6	d	7	a	8	a	9	c	10	a
11	b	12	b	13	a	14	b	15	b
16	c	17	d	18	b	19	d	20	c
21	d	22	d	23	d	24	a	25	d
26	b	27	a	28	c	29	c	30	a
31	a	32	c	33	b	34	c	35	a
36	b	37	a	38	c	39	a	40	c
41	b	42	a	43	d	44	d	45	b
46	b	47	a	48	a	49	d	50	a
51	c	52	b	53	b	54	b	55	a
56	b	57	c	58	a	59	a	60	a
61	d	62	b	63	d	64	c	65	b
66	b	67	c	68	d	69	b	70	c
71	a	72	b	73	c	74	c	75	b
76	c	77	c	78	a	79	a	80	c
81	a	82	b	83	a	84	a	85	b
86	a								

Critical Thinking Questions

1	d	2	a	3	acd	4	b	5	d
6	d	7	b	8	b	9	d	10	c
11	b	12	b	13	b	14	b	15	d
16	a	17	d	18	d	19	c	20	d
21	b	22	a	23	d	24	a	25	c
26	b	27	b	28	a	29	b	30	b
31	a	32	b	33	d	34	c	35	b
36	a	37	a	38	c	39	b	40	c
41	c	42	d	43	a	44	c	45	d
46	b	47	b	48	a				

Graphical Questions

1	d	2	a	3	c	4	b	5	d
6	a	7	b	8	b	9	b	10	c
11	b	12	a	13	b	14	c	15	a
16	c	17	d	18	c	19	a		

Assertion and Reason

1	b	2	b	3	c	4	c	5	e
6	e	7	a	8	b	9	c	10	a
11	a	12	b	13	a	14	e	15	a
16	a	17	c	18	b	19	d	20	a
21	a	22	e	23	d	24	d		

AS Answers and Solutions

Faraday's and Lenz's Law

1. (c) Because induced e.m.f. is given by $E = -N\frac{d\phi}{dt}$.

2. (d) The energy of the field increases with the magnitude of the field. Lenz's law infers that there is an opposite field created due to increase or decrease of magnetic flux around a conductor so as to hold the law of conservation of energy.

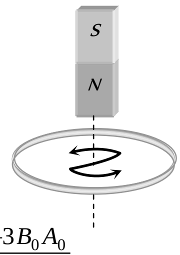
3. (b) We know that $e = \frac{d\phi}{dt}$

But $e = iR$ and $i = \frac{dq}{dt} \Rightarrow \frac{dq}{dt}R = \frac{d\phi}{dt} \Rightarrow dq = \frac{d\phi}{R}$

4. (d) Similar to Q.3

5. (b) Because there is no change in flux linked with coil

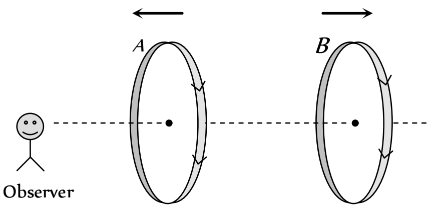
6. (c) As it is seen from the magnet side induced current will be anticlockwise.



7. (a) $e = -\frac{d\phi}{dt} = \frac{-3B_0A_0}{t}$

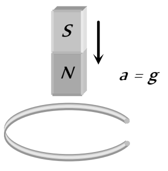
8. (c) $e = -\frac{d\phi}{dt} = -(16t + 3) = -67 units$

9. (a) Induced current in both the coils assist the main current so current through each coil increases.



10. (b) When the magnet is allowed to fall vertically along the axis of loop with its north pole towards the ring. The upper face of the ring will become north pole in an attempt to oppose the approaching north pole of the magnet. Therefore the acceleration in the magnet is less than *g.*

Note : If coil is broken at any point then induced *emf* will be generated in it but no induced current will flow. In this condition the coil will not oppose the motion of magnet and the magnet will fall freely with acceleration *g.* (*i.e. a = g*)



11. (a) $\phi = BA = 10\ weber$

12. (b) The magnitude of induced e.m.f. is directly proportional to the rate of change of magnetic flux. Induced charge doesn't depend upon time.

13. (b)

14. (a) $I = \frac{e}{R} = \frac{-N(d\phi/dt)}{R} = \frac{10\times10^8\times10^{-4}\times10^{-4}\times10}{20} = 5\ A$

15. (d) Induced charge doesn't depend upon the speed of magnet.

16. (d) $|e| = N\left(\frac{\Delta B}{\Delta t}\right).A\cos\theta = 500\times1\times(10\times10^{-2})^2\cos 0 = 5V.$

17. (c) When frequency is high, the galvanometer will not show deflection.

18. (b) $e = -\frac{N(B_2 - B_1)A\cos\theta}{\Delta t}$

$= -\frac{500\times(0-0.1)\times100\times10^{-4}\cos 0}{0.1} = 5V$

19. (b) $e = -\frac{N(B_2 - B_1)A\cos\theta}{\Delta t}$

$= -\frac{50(0.35-0.10)\times\pi(3\times10^{-2})^2\times\cos 0^o}{2\times10^{-3}} = 17.7\ V.$

20. (b) $|e| = A.\frac{\Delta B}{\Delta t} = 2\times\frac{(4-1)}{2} = 3\ V.$

21. (b) $e = -\frac{NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$

$= -2000\times0.3\times70\times10^{-4}\frac{(\cos 180 - \cos 0)}{0.1}$

$\Rightarrow e = 84\ V$

22. (c) The induced current will be in such a direction so that it opposes the change due to which it is produced.

23. (b)

24. (b)

25. (d) According to Lenz's law.

26. (c) $e = -N\left(\frac{\Delta B}{\Delta t}\right).A\cos\theta = -100\times\frac{(6-1)}{2}\times(40\times10^{-4})\cos 0$

$\Rightarrow |e| = 1\ V$

27. (d)

28. (b)

29. (d)

30. (d) Emf induces in ring and it will opposes the motion. Hence due to the resistance of the ring all energy dissipates.

31. (b) $\Delta Q = \frac{NBA}{R}(\cos\theta_1 - \cos\theta_2)$

$= \frac{500\times0.2\times0.1(\cos 0 - \cos 180)}{50} = 0.4\ C$

32. (a) $\phi = NBA\cos\theta = 100\times0.2\times5\times10^{-4}\cos 60^o$

$= 5\times10^{-3} Wb$

33. (b) $\Delta Q = \frac{\Delta\phi}{R} = \frac{(10-2)}{2} = 4C$

34. (a)

35. (b)

36. (b) $\phi = \mu_0 niA = 4\pi\times10^{-7}\times\frac{3000}{1.5}\times2\times\pi(2\times10^{-2})^2$

$= 6.31\times10^{-6}\,Wb$

37. (d) $q = -\frac{N}{R}(B_2 - B_1)A\cos\theta$

$32\times10^{-6} = -\frac{100}{(160+40)}(0-B)\times\pi\times(6\times10^{-3})^2\times\cos 0^o$

$\Rightarrow B = 0.565\ T$

38. (a) Faraday's laws involve conversion of mechanical energy into electric energy. This is in accordance with the law of conservation of energy.

39. (a) $e = -\frac{N(B_2 - B_1)A\cos\theta}{\Delta t}$

$\Rightarrow 0.1 = \frac{-50\times(0-2\times10^{-2})\times100\times10^{-4}\times\cos 0^o}{t}$

$\Rightarrow t = 0.1 sec$.

40. (c) $q = \frac{N}{R}d\phi\ \ \therefore q \propto d\phi$

41. (c) $i = \frac{|e|}{R} = \frac{N}{R}.\frac{\Delta B}{\Delta t}A\cos\theta = \frac{20}{100}\times1000\times(25\times10^{-4})\cos 0^o$

$\Rightarrow i = 0.5\ A$

42. (b) According to Lenz's law.

43. (c)

44. (c) E.m.f. or current induces, only when flux linked with the coil changes.

45. (d) $e = -\frac{d\phi}{dt} = -\frac{d}{dt}(3t^2 + 4t + 9) = -(6t+4)$

$e = -[6(2)+4] = -16 \Rightarrow |e| = 16\ volt$

46. (d) $e = -\frac{NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$

$= -\frac{800\times4\times10^{-5}\times0.05\,(\cos 90^o - \cos 0^o)}{0.1} = 0.016\ V$

47. (d)

48. (d)

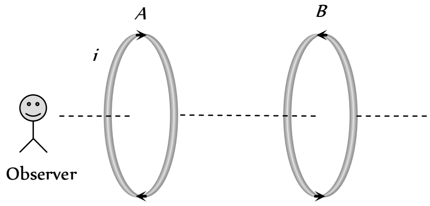
49. (d) $e = -\frac{d\phi}{dt} = -(10t-4) \Rightarrow (e)_{t=2} = -(10\times0.2-4) = 2\ volt$

50. (c)

51. (b)

52. (a) If bar magnet is falling vertically through the hollow region of long vertical copper tube then the magnetic flux linked with the copper tube (due to 'non-uniform' magnetic field of magnet) changes and eddy currents are generated in the body of the tube by Lenz's law the eddy currents opposes the falling of the magnet which therefore experience a retarding force. The retarding force increases with increasing velocity of the magnet and finally equals the weight of the magnet. The magnet then attains a constant final terminal velocity *i.e.* magnet ultimately falls with zero acceleration in the tube.

53. (d)



If current through A increases, crosses (X) linked with coil *B* increases, hence anticlockwise current induces in coil *B.* As shown in figure both the current produces repulsive effect.

54. (b) $e = -\frac{d\phi}{dt} = -\frac{d}{dt}(5t^3 - 100t + 300)$

$= -(15t^2 - 100)$ at $t = 2 sec$; $e = 40\ V$

55. (b) By using $e = -\frac{NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$

$e = -\frac{1000\times2\times10^{-5}\times500\times10^{-4}(\cos 180^o - \cos 0^o)}{0.2}$

$= 10^{-2} volt = 10 mV$

56. (a) Similar to Q. 52

57. (c)

58. (a) Induced charge $Q = -\frac{N}{R}(\phi_2 - \phi_1) = \frac{1}{100}(60-10) = 0.5C$

59. (d)

60. (b) $i = \frac{e}{R} = \frac{-N}{R}\frac{(\phi_2 - \phi_1)}{\Delta t} = \frac{-n(W_2 - W_1)}{5Rt}$

61. (a) Magnetic flux linked with the ring changes so current flows through it.

62. (a) $|e| = \frac{d\phi}{dt} = \frac{d}{dt}(5t^2 + 3t + 16) = (10t + 3)$

when $t = 3$ sec, $e_3 = (10\times3+3) = 33\ V$

when $t = 4$ sec, $e_4 = (10\times4+3) = 43\ V$

Hence emf induced in fourth second

$= e_4 - e_3 = 43 - 33 = 10\ V$

63. (d) $e = \frac{-NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$

$= -\frac{500\times4\times10^{-4}\times0.1(\cos 90 - \cos 0)}{0.1} = 0.2\ V$

64. (d) $q = \frac{N}{R}(\Delta\phi) = \frac{1}{2}\times(10-2) = 4C$

65. (c) At low frequency of 1 to 2 *Hz,* oscillations may be observed as our eyes will be able to detect it.

66. (c) Since the magnetic field is uniform therefore there will be no change in flux hence no current will be induced.

67. (a) $\phi = BA$

$\Rightarrow$ change in flux $d\phi = B.dA = 0.05\,(101-100)\,10^{-4}$

$= 5.10^{-6}$ Wb.

Now, charge $dQ = \frac{d\phi}{R} = \frac{5\times10^{-6}}{2} = 2.5\times10^{-6}\,C$.

68. (b) $\Delta Q = \frac{\Delta\phi}{R} = \frac{n\times BA}{R}$

$\Rightarrow B = \frac{\Delta Q.R}{nA} = \frac{2\times10^{-4}\times80}{40\times4\times10^{-4}} = 1\,Wb/m^2$

Motional EMI

1. (a) Emf = $e = e_0\sin\theta$; e will be maximum when θ is 90° *i.e.* plane of the coil will be horizontal.

2. (b) Induced e.m.f. $= Blv = 0.3\times10^{-4}\times10\times5$

$= 1.5\times10^{-3}\,V = 1.5\,mV$

3. (d) Conductor cuts the flux only when, if it moves in the direction of *M*.

4. (c) $e = B_v.vl = 0.2\times10^{-4}\times\left(\frac{180\times1000}{3600}\right)\times1 = 10^{-3}\,V$

5. (b) $e = Bvl = 3\times10^{-3}\times10^2 = 0.3\,volt$

6. (b) This is the case of periodic EMI

7. (b) $e = B_v.v.l = 2\times10^{-4}\times\left(\frac{360\times1000}{3600}\right)\times50 \Rightarrow e = 1\,V$

8. (c) $e = \frac{1}{2}B\omega r^2 = \frac{1}{2}\times0.1\times2\pi\times10\times(0.1)^2 = \pi\times10^{-2}\,V$

9. (d) $e = \frac{1}{2}B\omega r^2 = \frac{1}{2}\times0.2\times10^{-4}\times5\times(1)^2 = 50\,\mu V$

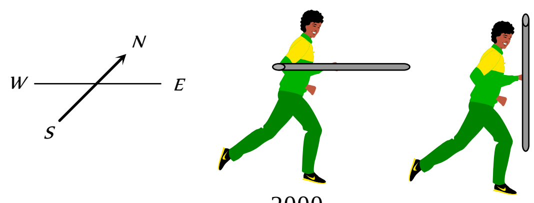
10. (d) No flux change is taking place because magnetic field exists everywhere and is constant in time and space.

11. (b) If player is running with rod in vertical position towards east, then rod cuts the magnetic field of earth perpendicularly (magnetic field of earth is south to north).

Hence Maximum emf induced is

$e = Bvl = 4\times10^{-5}\times\frac{30\times1000}{3600}\times3 = 1\times10^{-3}\,volt$

When he is running with rod in horizontal position, no field is cut by the rod, so $e = 0$.



12. (c) $e = NBA\omega;\ \omega = 2\pi f = 2\pi\times\frac{2000}{60}$

$\therefore e = 50\times0.05\times80\times10^{-4}\times2\pi\times\frac{2000}{60} = \frac{4\pi}{3}$

13. (b)

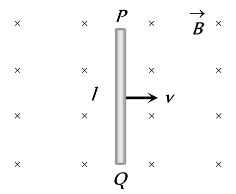
14. (c) According to Fleming right hand rule, the direction of *B* will be perpendicular to the plane of paper and act downward.

15. (d) By Fleming's right hand rule.

16. (c) $e = Bvl \Rightarrow e \propto v \propto gt$

17. (c) $e = Bvl = 0.5\times2\times1 = 1\,V$

18. (b) A motional emf $e = Bvl$ is induced in the rod, or we can say, a potential difference is induced between the two ends of the rod *AB*, with *P* at higher potential and *Q* at lower potential. Due to this potential difference, there is an electric field in the rod.



19. (c)

20. (b) $e = Bvl \Rightarrow e = 0.7\times2\times(10\times10^{-2}) = 0.14\,V$

21. (d) $e = Bvl \Rightarrow e = 0.9\times7\times0.4 = 2.52\,V$

22. (d)

23. (d)

24. (d) $e = Bl^2\pi\nu = 0.4\times10^{-4}\times(0.5)^2\times(3.14)\times\frac{120}{60}$

$= 6.28\times10^{-5}\,V$

25. (c) $e = \frac{1}{2}Bl^2\omega = \frac{1}{2}\times0.3\times(2)^2\times100 = 60V$

26. (a) $e = Bvl = 5\times10^{-5}\times\frac{360\times1000}{3600}\times20 = 0.1V$

27. (c)

28. (c) Peak value of $emf = e_0 = \omega NBA = 2\pi\nu NBA$

$= 2\pi\times50\times300\times4\times10^{-2}\times(25\times10^{-2}\times10\times10^{-2})$

$= 30\,\pi\,volt$

29. (c) $e = \frac{1}{2}Bl^2\omega = Bl^2\pi\nu$

$\Rightarrow e = 0.5(20\times10^{-2})^2\times3.14\times100 = 6.28\,V$

30. (d)

31. (b) $e_0 = \omega NBA = (2\pi\nu)NB(\pi r^2) = 2\times\pi^2\nu\,NBr^2$

$= 2\times(3.14)^2\times\frac{1800}{60}\times4000\times0.5\times10^{-4}\times(7\times10^{-2})^2$

$= 0.58\,V$

32. (b) Two emf's induces in the closed circuit each of value $Bl\,v$. These two emf's are additive. So $E_{net} = 2Bl\,v$.

33. (b) When a conductor lying along the magnetic north-south, moves eastwards it will cut vertical component of B_0. So induced *emf*

$e = vB_Vl = v(B_0\sin\delta\,l) = B_0lv\sin\delta$.

Static EMI

1. (d) $e = -L\frac{di}{dt}$ but $e = 4V$ and $\frac{di}{dt} = \frac{0-1}{10^{-3}} = -1/10^{-3}$

$\therefore \frac{-1}{10^{-3}}(-L) = 4 \Rightarrow L = 4\times 10^{-3}\, henry$

2. (d) $L = \frac{e}{di/dt} = \frac{5}{(3-2)/10^{-3}} = \frac{5}{1}\times 10^{-3} = 5 millihenry$

3. (b) Energy stored $E = \frac{1}{2}Li^2 = \frac{1}{2}\times 50\times 10^{-3}\times 4 = 0.1\ J$

4. (a) Given $\frac{di}{dt} = 2A/sec.,\ L = 5\ H\ \therefore e = L\frac{di}{dt} = 5\times 2 = 10\ V$

5. (d) As we know $e = -\frac{d\phi}{dt} = -L\frac{di}{dt}$

Work done against back e.m.f. e in time dt and current i is

$dW = -eidt = L\frac{di}{dt}idt = Li\,di \Rightarrow W = L\int_0^i i\,di = \frac{1}{2}Li^2$

6. (d) Induced emf $e = M\frac{di}{dt} = \frac{\mu_0 N_1 N_2 A}{l}.\frac{di}{dt}$

$= \frac{4\pi\times 10^{-7}\times 2000\times 300\times 1.2\times 10^{-3}}{0.30}\times\frac{|2-(-2)|}{0.25}$

$= 48.2\times 10^{-3}\ V = 48\ mV$

7. (c) Self inductance $L = \mu_0 N^2 A/l = \mu_0 n^2 lA$

Where n is the number of turns per unit length and N is the total number of turns and $N = nl$

In the given question n is same. A is increased 4 times and l is increased 2 times and hence L will be increased 8 times.

8. (c) $M = -\frac{e_2}{di_1/dt} = -\frac{e_1}{di_2/dt}$

Also $e_1 = -L_1\frac{di_1}{dt}.e_2 = -L_2\frac{di_2}{dt}$

$M^2 = \frac{e_1 e_2}{\left(\frac{di_1}{dt}\right)\left(\frac{di_2}{dt}\right)} = L_1 L_2 \Rightarrow M = \sqrt{L_1 L_2}$

9. (c) Inductance is inherent property of electrical circuits. It will always be found in an electrical circuit whether we want it or not. The circuit in which a large emf is induced when the current in the circuit changes is said to have greater inductance. A straight wire carrying current with no iron part in the circuit will have lesser value of inductance while if the circuit contains a circular coil having many number of turns, the induced emf to oppose the cause will be greater and the circuit is therefore said to have greater value of inductance.

10. (c) Magnetic flux $\phi = LI$

By analogy, since physical quantities mass *(m)* and linear velocity *(v)* are equivalent to electrical quantities inductance *(L)* and current *(I)* respectively. Thus magnetic flux $\phi = LI$ is equivalent to momentum $\mathbf{p} = m\times \mathbf{v}$.

11. (a) Energy stored $= \frac{1}{2}Li^2$, where Li is a magnetic flux.

12. (b) $L = \mu ni \Rightarrow \frac{L_2}{L_1} = \frac{\mu}{\mu_0}$ (n and i are same)

$\Rightarrow L_2 = \mu_r L_1 = 900\times 0.18 = 162\, mH$

13. (b) $e = M\frac{di}{dt} = 0.2\times 5 = 1\ V$

14. (d) $e = -L\frac{di}{dt} \Rightarrow 2 = -L\left(\frac{8-2}{3\times 10^{-2}}\right) \Rightarrow L = 0.01\ H = 10\ mH$

15. (d) $e = M\frac{di}{dt} = 1.25\times 80 = 100\ V$

16. (b) $\frac{L_B}{L_A} = \left(\frac{n_B}{n_A}\right)^2 \Rightarrow L_B = \left(\frac{500}{600}\right)^2\times 108 = 75\ mH$

17. (a) $L \propto N^2$ *i.e.* $\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2 \Rightarrow L_2 = L_1\left(\frac{N_2}{N_1}\right)^2 = 4L_1$

18. (b) $e = -L\frac{di}{dt} \Rightarrow 8 = L\frac{(4-2)}{0.05} \Rightarrow L = 0.2\ H$

19. (b) $e = M\frac{di}{dt} \Rightarrow M = \frac{15000}{3}\times 0.001 = 5\ H$

20. (b) $L = \frac{e}{di/dt} = \frac{12}{48/60} = 15\ H$

21. (a) $B = \frac{\mu_0 Ni}{2r} = \frac{4\pi\times 10^{-7}\times 100\times 2\times\sqrt{\pi}}{2\times 10^{-2}} = 0.022\ wb/m^2$

22. (d) $e = M\frac{di}{dt} = 0.09\times\frac{20}{0.006} = 300\ V$

23. (c)

24. (c) Inductors obey the laws of parallel and series combination of resistors.

25. (b) There will be self induction effect when soft iron core is inserted.

26. (c) $L = \mu_0 N^2 A/l$

27. (b)

28. (c) $e = -L\frac{di}{dt} \Rightarrow e = 5\times\frac{1}{5} = 1\ volt$

29. (c) $e = L\frac{di}{dt} \Rightarrow L = \frac{Volt-\sec}{Ampere}$

30. (d) $e = -L\frac{di}{dt} = -0.4\times 10^{-3}\times\frac{250\times 10^{-3}}{0.1} = -1\ mV$

31. (b) In steady state current passing through solenoid

$i = \frac{E}{R} = \frac{10}{10} = 1\ A$

32. (a) $e = L\frac{di}{dt} \Rightarrow 2 = L\times\frac{6}{3\times 10^{-3}} \Rightarrow L = 1\ mH$

33. (b) From $i = i_0[1 - e^{-Rt/L}]$, where $i_0 = \frac{5}{5} = 1\ amp$

$\therefore i = 1\left(1 - e^{\frac{-5\times 2}{10}}\right) = (1 - e^{-1})amp$

34. (c) $M = \frac{\mu_0 N_1 N_2 A}{l}$

35. (d) $e = L\frac{di}{dt} = 60\times 10^{-6}.\frac{(1.5-1.0)}{0.1} = 3\times 10^{-4}\,volt$

36. (a) $\phi = Li \Rightarrow NBA = Li$

Since magnetic field at the centre of circular coil carrying current is given by $B = \frac{\mu_0}{4\pi}.\frac{2\pi Ni}{r}$

$\therefore N.\frac{\mu_0}{4\pi}.\frac{2\pi Ni}{r}.\pi r^2 = Li \Rightarrow L = \frac{\mu_0 N^2 \pi r}{2}$

Hence self inductance of a coil

$= \frac{4\pi\times 10^{-7}\times 500\times 500\times \pi\times 0.05}{2} = 25\ mH$

37. (a) Induced $e.m.f.$ $e = M\frac{di}{dt} \Rightarrow 100\times 10^{-3} = M\left(\frac{10}{0.1}\right)$

$\therefore M = 10^{-3}H = 1\,mH$

38. (c) $\frac{\Delta i}{\Delta t} = \frac{10}{2} = 5\ A/\sec \Rightarrow e = L\frac{\Delta i}{\Delta t} = 0.5\times 5 = 2.5\ volts$

39. (c) Time in which the current will decay to $\frac{1}{e}$ of its steady value is $t = \tau = \frac{L}{R} = \frac{50}{10} = 5$ *seconds*

40. (a)

41. (d) $L \propto N^2$

42. (a) $e_2 = M\frac{di_1}{dt} \Rightarrow i_2 R_2 = M\frac{di_1}{dt} \Rightarrow 0.4\times 5 = 0.5\times\frac{di_1}{dt}$

$\Rightarrow \frac{di_1}{dt} = 4\ A/\sec.$

43. (a) $U = \frac{1}{2}Li^2 = \frac{1}{2}\times(50\times 10^{-3})\times(4)^2 = 400\times 10^{-3} = 0.4\,J$

44. (b) $e = -L\left(\frac{di}{dt}\right) \Rightarrow 8 = -L\times\left(-\frac{2}{0.05}\right) \Rightarrow L = 0.2H$

45. (b) $U = \frac{1}{2}Li^2$ i.e. $\frac{U_2}{U_1} = \left(\frac{i_2}{i_1}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4} \Rightarrow U_2 = \frac{1}{4}U_1$

46. (a, b, c, d)

47. (c) $|e| = L\frac{di}{dt} \Rightarrow 220 = L\times\frac{10}{0.5} \Rightarrow L = 11\ H$

48. (b)

49. (d) $t = \tau = \frac{L}{R} = \frac{2.5}{0.5} = 5$ sec

50. (c) $L = \mu_0\frac{N^2}{l}A$. When N and l are doubled. L is also doubled.

51. (c) Energy $= \frac{1}{2}LI^2 = \frac{1}{2}\times 100\times 10^{-3}\times 1^2 = 0.05J$

52. (b) $e = -M\frac{di}{dt} = -5\times\frac{(-5)}{10^{-3}} = 25000\ V$

53. (a) $L \propto n$ (Number of turns), For straight conductor $n = 0$, hence $L = 0$.

54. (a) $\Delta\phi = L\Delta I \Rightarrow L = \frac{\Delta\phi}{\Delta I} = \frac{2\times 10^{-2}}{0.01} = 2H$

55. (a) $e = L\frac{di}{dt} \Rightarrow 100 = L\times\frac{4}{0.1} \Rightarrow L = 2.5\ H$

56. (a) The inductances are in parallel $\Rightarrow L_{eq} = \frac{L}{3} = \frac{3}{3} = 1\ H$

57. (a) $|e| = M\frac{di}{dt} \Rightarrow 8\times 10^{-3} = M\times 3 \Rightarrow A_1 = 2.66mH$

58. (d) $|e| = L\frac{di}{dt} \Rightarrow 10 = L\times\frac{10}{1} \Rightarrow L = 1H$

59. (a) $N\phi = Li \Rightarrow \phi = \frac{Li}{N} = \frac{8\times 10^{-3}\times 5\times 10^{-3}}{400} = 10^{-7} = \frac{\mu_0}{4\pi}wb$

60. (b) According to Lenz's law.

61. (d) $N\phi = Li \Rightarrow \frac{Nd\phi}{dt} = \frac{Ldi}{dt} \Rightarrow NB\frac{dA}{dt} = \frac{Ldi}{dt}$

$\Rightarrow \frac{1\times 1\times 5}{10^{-3}} = L\times\left(\frac{2-1}{2\times 10^{-3}}\right) \Rightarrow L = 10H$

62. (b) $L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi\times 10^{-7}\times(500)^2\times 20\times 10^{-4}}{0.5} = 1.25mH$

63. (a) $L_S = L_1 + L_2 = 10H$ ..... (i)

$L_P = \frac{L_1 L_2}{L_1 + L_2} = 2.4H$ ..... (ii)

On solving (i) and (ii) $L_1 L_2 = 24$ ..... (iii)

Also $(L_1 - L_2)^2 = (L_1 + L_2)^2 - 4L_1 L_2$

$\Rightarrow (L_1 - L_2)^2 = (10)^2 - 4\times 24 = 4 \Rightarrow L_1 - L_2 = 2H$

64. (d) $e = L\frac{di}{dt} \Rightarrow 12 = L\times\frac{45}{60} \Rightarrow L = 16H$

65. (a) $|e| = L\frac{di}{dt} \Rightarrow 1 = \frac{L\times\{10-(-10)\}}{0.5} \Rightarrow L = 25mH$

66. (d) $U = \frac{1}{2}Li^2 \Rightarrow U = \frac{1}{2}\times 5\times\left(\frac{100}{10}\right)^2 = 250J$

67. (c) $\phi = Mi \Rightarrow M = \frac{1.2\times 10^{-2}}{0.01} = 1.2H$

68. (c) $U = \frac{1}{2}Li^2 \Rightarrow U = \frac{1}{2}\times 40\times 10^{-3}\times(2)^2 = 0.08J$

69. (c) $L \propto N^2$

70. (b) $N_2\phi_2 = Mi_1 \Rightarrow 9\times10^{-5} = M\times3 \Rightarrow M = 3\times10^{-5}H$

71. (a) $|e| = L\frac{di}{dt} \Rightarrow 20 = L\times\frac{(18-2)}{0.05} \Rightarrow L = 62.5\ mH$

72. (b) $|e| = L\frac{di}{dt} \Rightarrow |e| = 10\times10^{-6}\times\frac{1}{10} = 1\mu V$

73. (c)

74. (b) $\phi_T = Li \Rightarrow L = \frac{10^{-5}}{5\times10^{-3}} = 2mH$

75. (a) $L \propto N^2$

76. (c) $e = -L\frac{di}{dt}$, since current decreases so $\frac{di}{dt}$ is negative, hence $e = -5\times(-2) = +10V$

77. (c) $e = L\frac{di}{dt} \Rightarrow e = 0.1\times200 = 20V$

78. (c) $e = M\frac{di}{dt} \Rightarrow e = 0.1\times\frac{(20-0)}{0.02} = 100V$

79. (c) $L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi\times10^{-7}\times(1000)^2\times10\times10^{-4}}{1}$

$=1.256\ mH$

80. (d) In secondary e.m.f. induces only when current through primary changes.

81. (b)

82. (c)

83. (a) $e = L\frac{di}{dt} \Rightarrow 8 = L\times\frac{(2-(-2))}{0.05} \Rightarrow L = 0.1H$

84. (b) $U = \frac{1}{2}Li^2 = \frac{1}{2}L\left(\frac{E}{R}\right)^2 = \frac{1}{2}\times5\times\left(\frac{100}{20}\right)^2 = 62.50J$

85. (a)

86. (a)

87. (a) $e = -L\frac{di}{dt} \Rightarrow 0.4 = -\frac{L(0.2-1)}{10} \Rightarrow L = 5\ H$

88. (c) $|e| = L\frac{di}{dt} \Rightarrow 30 = L\times\frac{(6-0)}{0.3} \Rightarrow L = 1.5\ H$

89. (b) $i = i_0\left(1-e^{-\frac{Rt}{L}}\right) \Rightarrow \frac{di}{dt} = -i_0\left(-\frac{R}{L}\right)e^{-\frac{Rt}{L}} = \frac{i_0R}{L}.e^{-\frac{Rt}{L}}$

At $t = 0$; $\frac{di}{dt} = \frac{i_0R}{L} = \frac{E}{L} \Rightarrow 4 = \frac{E}{20} \Rightarrow E = 80\ V$

90. (d) $N\phi = Li \Rightarrow 100\times10^{-5} = L\times5 \Rightarrow L = 0.2\ mH.$

91. (d) When the two coils are joined in series such that the winding of one is opposite to the other, then the emf produced in first coil is 180° out of phase of the emf produced in second coil.

Thus, emf produced in first coil is negative and the emf produced in second coil is positive so, net inductance is

$L = L_1 + L_2 = L + L \Rightarrow L = -\frac{\phi}{i} + \frac{\phi}{i} = 0$

92. (a) $e = M\frac{di}{dt} \Rightarrow 1.5 = M\times\frac{30}{0.1} \Rightarrow M = 0.05\ H$

93. (d)

94. (c) Current in B_1 will promptly become zero while current in B_2 will slowly tend to zero.

95. (b)

96. (c) When battery disconnected current through the circuit start decreasing exponentially according to $i = i_0e^{-Rt/L}$

$\Rightarrow 0.37i_0 = i_0e^{-Rt/L} \Rightarrow 0.37 = \frac{1}{e} = e^{-Rt/L} \Rightarrow t = \frac{L}{R}$

97. (a) Current at any instant of time t after closing an L-R circuit is given by $I = I_0\left[1-e^{\frac{-R}{L}t}\right]$

Time constant $t = \frac{L}{R}$

$\therefore I = I_0\left[1-e^{\frac{-R}{L}\times\frac{L}{R}}\right] = I_0(1-e^{-1}) = I_0\left(1-\frac{1}{e}\right)$

$= I_0\left(1-\frac{1}{2.718}\right) = 0.63I_0 = 63\%$ of I_0

98. (c) $i = \frac{V}{R} = \frac{10}{2} = 5A$

$U = \frac{1}{2}Li^2 = \frac{1}{2}\times2\times25 = 25\ J$

99. (d)

100. (d) Time constant $= \frac{L}{R} = \frac{40}{8} = 5$ sec.

101. (b) $t = \tau = \frac{L}{R} = \frac{60}{30} = 2\,\text{sec}.$

102. (c)

103. (b)

104. (a) $\nu_0 = \frac{1}{2\pi\sqrt{(0.25)\times(0.1\times10^{-6})}} = \frac{10^4}{9.93} = 1007\,Hz$

105. (c) $\nu_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times3.14\sqrt{5\times10^{-4}\times20\times10^{-6}}}$

$\nu_0 = \frac{10^4}{6.28} = 1592\ Hz$

106. (d) $i = i_0\left(1-e^{\frac{-Rt}{L}}\right) \Rightarrow$ For $i = \frac{i_0}{2}$, $t = 0.693\frac{L}{R}$

$\Rightarrow t = 0.693\times\frac{300\times10^{-3}}{2} = 0.1\,sec$

107. (c) $|e| = L\left|\frac{di}{dt}\right| = 0.5 \times \frac{10}{2} = 2.5V$

108. (c) Time period of LC circuit oscillations

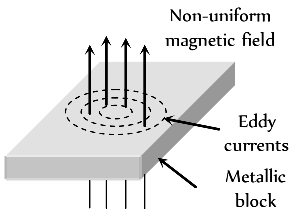
$T = 2\pi\sqrt{LC} \Rightarrow$ dimensions of $\sqrt{LC}$ is Time.

Application of EMI (Motor, Dynamo, Transformer...)

1. (b) Hot wire ammeter is not based on the phenomenon of electromagnetic induction.

2. (d)

3. (c) Direction of eddy currents is given by Lenz's rule.



4. (c) In a generator. e.m.f. is induced according as Lenz's rule.

5. (a)

6. (d)

7. (a) Circulation of eddy currents is prevented by use of laminated core.

8. (a)

9. (c)

10. (a)

11. (b) $e \propto \omega$

12. (b)

13. (a) Rotation of magnet in the dynamo creates the variable flux which in turn produces the induced current.

14. (b)

15. (b) With the increasing speed, ω increases. Thus current reduces due to increase in the back e.m.f.

Moreover $i = \frac{V - K\omega}{R}$. More ω will lead to the lesser current.

16. (c) Commutator converts ac into fluctuating dc.

17. (d) Only ac dynamo have slip rings.

18. (b) $e \propto \frac{d\phi}{dt}$; if $\phi \to$ maximum then $e \to$ minimum.

19. (d)

20. (c) Motor e.m.f. equation $E_b = V - I_a R_a$

At starting $E_b = 0$, so I_a will be maximum.

21. (d) $i = \frac{E-e}{R} \Rightarrow 1.5 = \frac{220 - e}{20} \Rightarrow e = 190\ V$

22. (d)

23. (d) $e_0 = \omega NBA = (2\pi\nu)\ NBA$

$= 2 \times 3.14 \times 1000 \times 5000 \times 0.2 \times 0.25 = 157\ kV$

24. (a) Back emf $\propto$ speed of motor.

25. (d)

26. (b)

27. (a) Efficiency $\eta = 50\%$ So $e = E/2$

and $i = \frac{E-e}{R} \Rightarrow i = \frac{E - E/2}{R} = \frac{E}{2R}$

$\Rightarrow R = \frac{E}{2i} = \frac{60}{2 \times 10} = 3\Omega$

28. (c)

29. (c) $\eta = \frac{e}{E} \times 100 \Rightarrow e = 0.3\ E$

Now, $i = \frac{E-e}{R} \Rightarrow 12 = \frac{50 - (0.3 \times 50)}{R} \Rightarrow R = 2.9\Omega$

30. (a) $i = \frac{E-e}{R} = \frac{220 - 210}{2} = \frac{10}{2} = 5A$

31. (a)

32. (c) A transformer is a device to convert alternating current at high voltage into low voltage and *vice-versa.*

33. (b) We know that for step down transformer

$V_p > V_s$ but $\frac{V_p}{V_s} = \frac{i_s}{i_p}$; $\therefore i_s > i_p$

Current in the secondary coil is greater than the primary.

34. (c)

35. (a)

36. (b) Transformation ratio $k = \frac{N_s}{N_p} = \frac{V_s}{V_p}$

For step-up transformers, $N_s > N_p$ *i.e.* $V_s > V_p$, hence $k > 1$.

37. (a) $\frac{V_p}{V_s} = \frac{N_p}{N_s} \Rightarrow N_p = \left(\frac{220}{2200}\right) 2000 = 200$

38. (c) Provided no power looses, being assumed.

39. (a) $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{200}{100} = \frac{V_s}{120} \Rightarrow V_s = 240\ V$

also $\frac{V_s}{V_p} = \frac{i_p}{i_s} \Rightarrow \frac{240}{120} = \frac{10}{i_s} \Rightarrow i_s = 5\ A$

40. (c) $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{1}{20} = \frac{V_s}{2400} \Rightarrow V_s = 120\ V$

For 100% efficiency $V_s i_s = V_p i_p$

$\Rightarrow 120 \times 80 = 2400\ i_p \Rightarrow i_p = 4\ A$

41. (b) $\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{500}{2500} = \frac{1}{5} \Rightarrow V_p = \frac{200}{5} = 40\ V$

Also $i_p V_p = i_s V_s \Rightarrow i_p = i_s \frac{V_s}{V_p} = 8 \times 5 = 40\ A$

42. (a) $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{250}{100} = \frac{V_s}{28/\sqrt{2}} \Rightarrow V_s = 50\ V$

43. (d) $\eta = \frac{V_s i_s}{V_p i_p} \times 100 = \frac{11 \times 90}{220 \times 5} \times 100 = 90\ \%$

44. (d) Transformer doesn't work on dc

45. (b)

46. (b)

47. (a) For 100% efficient transformer

$V_s i_s = V_p i_p \Rightarrow \frac{V_s}{V_p} = \frac{i_p}{i_s} = \frac{N_s}{N_p} \Rightarrow \frac{i_p}{4} = \frac{25}{100} \Rightarrow i_p = 1\ A$

48. (a)

49. (d) $\frac{N_s}{N_p} = \frac{i_p}{i_s} \Rightarrow i_s = i_p \times \frac{N_p}{N_s} = 2 \times \frac{100}{20} = 10\ A$

50. (a) $\frac{V_s}{V_p} = \frac{i_p}{i_s} \Rightarrow i_p = \frac{11000 \times 2}{220} = 100\ A$

51. (c) $\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{i_s}{i_p}$. The transformer is step-down type, so primary coil will have more turns. Hence

$\frac{5000}{500} = \frac{2200}{V_s} = \frac{i_s}{4} \Rightarrow V_s = 220\ V, i_s = 40\ amp$

52. (b) $i_s = \frac{P_s}{V_s} = \frac{4.4 \times 10^3}{11 \times 10^3} = 0.4\ A$

53. (b) $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{22000}{220} = 100$

54. (b)

55. (a)

56. (b) $\frac{N_s}{N_p} = \frac{i_p}{i_s}$ or $\frac{25}{1} = \frac{i_p}{2} \Rightarrow i_p = 50A$

57. (c) $\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow V_s = \frac{N_s}{N_p} \times V_p = \frac{10}{200} \times 240 = 12\ volts$

58. (a) $\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow \frac{V_s}{20} = \frac{5000}{500} \Rightarrow V_s = 200\ V$

Frequency remains unchanged.

59. (a) $\frac{V_s}{V_p} = \frac{N_s}{N_p} = k \Rightarrow \frac{V_s}{30} = \frac{3}{2} \Rightarrow V_s = 45\ V$

60. (a) $\frac{N_s}{N_p} = \frac{i_p}{i_s} \Rightarrow \frac{i_p}{i_s} = \frac{4}{5}$

61. (d) $V_p = 200\ V,\ V_s = 6V$

$P_{out} = V_s i_s \Rightarrow 30 = 6 \times i_s \Rightarrow i_s = 5\ A$

From $\frac{V_s}{V_p} = \frac{i_p}{i_s} \Rightarrow \frac{6}{200} = \frac{i_p}{5} \Rightarrow i_p = 0.15\ A$

62. (b) $\frac{E_p}{E_s} = \frac{N_p}{N_s} \Rightarrow \frac{200}{E_s} = \frac{100}{20} \Rightarrow E_s = 40\ V$

63. (d) Since all the losses are neglected.

So $P_{out} = P_{in}$

64. (c)

65. (b) $\frac{i_p}{i_s} = \frac{N_s}{N_p} \Rightarrow \frac{i_p}{4} = \frac{1}{100} \Rightarrow i_p = 0.04\ A$

66. (b) $N_p : N_s = 1:10$ and $V_s = 0.5 \times 200 = 100\ V$

$\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow \frac{100}{V_p} = \frac{10}{1} \Rightarrow V_p = 10\ V$

$\frac{i_p}{i_s} = \frac{N_s}{N_p} \Rightarrow \frac{i_p}{0.5} = \frac{10}{1}, i_p = 5\ amp$

67. (c)

68. (d) $\frac{V_p}{V_s} = \frac{i_s}{i_p} \Rightarrow \frac{220}{22000} = \frac{i_s}{5} \Rightarrow i_s = 0.05\ amp$

69. (b) $\frac{V_p}{V_s} = \frac{i_s}{i_p} \Rightarrow i_s = 4 \times \frac{140}{280} = 2A$

70. (c) $P_s = V_s i_s \Rightarrow 1000 = V_s \times 8 \Rightarrow V_s = \frac{1000}{8}$

$\frac{V_p}{V_s} = \frac{N_p}{N_s} \Rightarrow \frac{(1000/8)}{500} = \frac{100}{N_s} \Rightarrow N_s = 400$

71. (a) Transformer works on ac only.

72. (b) $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{2200}{220} = \frac{10}{1}$

73. (c) Transformation ratio $k = \frac{V_s}{V_p} \Rightarrow \frac{5}{3} = \frac{V_s}{60} \Rightarrow V_s = 100\ V$

74. (c) $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{N_s}{600} = \frac{2200}{220} \Rightarrow N_s = 6000$

75. (b) For 100% efficiency $V_s i_s = V_p i_p$

$\Rightarrow 1100 \times 2 = 220 \times i_p \Rightarrow i_p = 10A$

76. (c)

77. (c) Amplitude of the current $i_0 = \frac{e_0}{R} = \frac{\omega NBA}{R} = \frac{2\pi\nu NB(\pi r^2)}{R}$

$i_0 = \frac{2\pi \times 1 \times 10^{-2} \times \pi(0.3)^2}{\pi^2} = 6 \times 10^{-3} A = 6mA$

78. (a) $\frac{N_s}{N_p} = \frac{i_p}{i_s} \Rightarrow \frac{2000}{500} = \frac{48}{i_s} \Rightarrow i_s = 12A$

79. (a) $U = \frac{1}{2}Li^2 = \frac{1}{2} \times 100 \times 10^{-3} \times (10)^2 = 5J$

80. (c) As $\frac{I_P}{I_s} = \frac{n_p}{n_s}$; *i.e.* $\frac{3}{I_s} = \frac{3}{2} \Rightarrow I_s = 2A$.

81. (a)

82. (b)

83. (a) $\eta = \frac{\text{outputpower}}{\text{inputpower}} = \frac{E_s I_s}{E_p I_p} \Rightarrow \frac{80}{100} = \frac{200 \times I_s}{4 \times 10^3}$

$\Rightarrow I_S = \frac{80}{100} \times \frac{4 \times 1000}{200} = 16A$

Also, $E_p I_p = 4KW \Rightarrow I_p = \frac{4\times10^3}{100} = 40A$

84. (a) $\frac{N_P}{N_S} = \frac{I_S}{I_P} \Rightarrow I_P = \frac{N_S}{N_P} I_S = \frac{10}{1}\times 2 = 20\ A$.

85. (b)

86. (a) $\eta = \frac{\text{Output}}{\text{Input}} \Rightarrow \frac{80}{100} = \frac{20\times20}{1000\times i_l}$

$\Rightarrow i_l = \frac{20\times120\times100}{1000\times80} = 3A$.

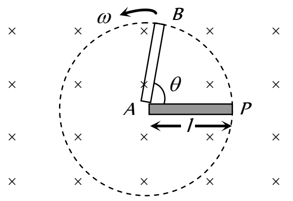
Critical Thinking Questions

1. (d) If electron is moving from left to right, the flux linked with the loop (which is into the page) will first increase and then decrease as the electron passes by. So the induced current in the loop will be first anticlockwise and will change direction as the electron passes by.

2. (a) If in time t the rod turns by an angle θ, the area generated by the rotation of rod will be

$= \frac{1}{2} l \times l\theta = \frac{1}{2} l^2\theta$

So the flux linked with the area generated by the rotation of rod



$$\phi = B\left(\frac{1}{2}l^2\theta\right)\cos 0 = \frac{1}{2}Bl^2\theta = \frac{1}{2}Bl^2\omega t$$

And so $e = \frac{d\phi}{dt} = \frac{d}{dt}\left(\frac{1}{2}Bl^2\omega t\right) = \frac{1}{2}Bl^2\omega$

3. (a, c, d) From Faraday's Law, the induced voltage $V \propto L$

rate of change of current is constant $\left(V = -L\frac{di}{dt}\right)$

$\therefore \frac{V_2}{V_1} = \frac{L_2}{L_1} = \frac{2}{8} = \frac{1}{4} \Rightarrow \frac{V_1}{V_2} = 4$

Power given to the two coils is same, *i.e.*,

$V_1 i_1 = V_2 i_2 \Rightarrow \frac{i_1}{i_2} = \frac{V_2}{V_1} = \frac{1}{4}$

Energy stored $W = \frac{1}{2}Li^2$

$\Rightarrow \frac{W_2}{W_1} = \left(\frac{L_2}{L_1}\right)\left(\frac{i_2}{i_1}\right)^2 = \left(\frac{1}{4}\right)(4)^2 = 4 \Rightarrow \frac{W_1}{W_2} = \frac{1}{4}$

4. (b) $i = i_0(1 - e^{-Rt/L})$

$i_0 = \frac{E}{R}$ (Steady current) when $t = \infty$

$i_\infty = \frac{E}{R}(1 - e^{-\infty}) = \frac{5}{10} = 1.5$

$i_1 = 1.5(1 - e^{-R/L}) = 1.5(1 - e^{-2}) \Rightarrow \frac{i_\infty}{i_1} = \frac{1}{1 - e^{-2}} = \frac{e^2}{e^2 - 1}$

5. (d) Mutual inductance between two coil in the same plane with their centers coinciding is given by

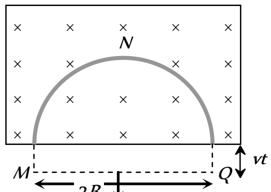
$M = \frac{\mu_0}{4\pi}\left(\frac{2\pi^2 R_2^2 N_1 N_2}{R_1}\right)$ *henry*.

6. (d) Rate of decrease of area of the semicircular ring

$-\frac{dA}{dt} = (2R)\ V$

According to Faraday's law of induction induced emf

$e = -\frac{d\phi}{dt} = -B\frac{dA}{dt} = -B(2RV)$



The induced current in the ring must generate magnetic field in the upward direction. Thus Q is at higher potential.

7. (b) Induced potential difference between two ends $= Blv = B_H lv$

$= 3\times10^{-5}\times2\times50 = 30\times10^{-3} volt = 3\,millivolt$

By Fleming's right hand rule, end A becomes positively charged.

8. (b) Effective length between A and B remains same.

9. (d) Circular loop behaves as a magnetic dipole whose one surface will be N-pole and another will be S-pole. Therefore magnetic lines a force emerges from N will meet at S. Hence total magnetic flux through x-y plane is zero.

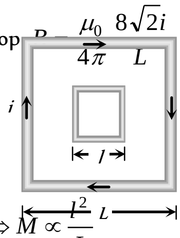
10. (c) If the current increases with time in loop A, then magnetic flux in B will increase. According to Lenz's law, loop $-B$ is repelled by loop $-A$.

11. (b) $e = M\frac{di}{dt} = 0.005\times\frac{d}{dt}(i_0 \sin\omega t) = 0.005\times i_0\omega\cos\omega t$

$\therefore e_{max} = 0.005\times10\times100\pi = 5\pi$

12. (b) Magnetic field produced due to large loop $B = \frac{\mu_0}{4\pi}\frac{8\sqrt{2}i}{L}$

Flux linked with smaller loop



$\phi = B(l^2) = \frac{\mu_0}{4\pi}\frac{8\sqrt{2}il^2}{L}$

$\therefore \phi = Mi \Rightarrow M = \frac{\phi}{i} = \frac{\mu_0}{4\pi}\cdot\frac{8\sqrt{2}l^2}{L} \Rightarrow M \propto \frac{l^2}{L}$

13. (b) Rate of work $= \frac{W}{t} = P = Fv$; also $F = Bil = B\left(\frac{Bvl}{R}\right)l$

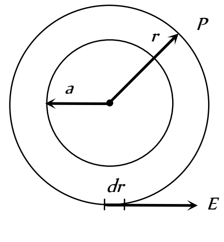
$\Rightarrow P = \frac{B^2v^2l^2}{R} = \frac{(0.5)^2\times(2)^2\times(1)^2}{6} = \frac{1}{6}W$

14. (b) Construct a concentric circle of radius r. The induced electric field (E) at any point on the circle is equal to that at P. For this circle

$\oint \vec{E}.d\vec{l} = \left|\frac{d\phi}{dt}\right| = A\left|\frac{dB}{dt}\right|$

or $E\times(2\pi r) = \pi a^2.\left|\frac{dB}{dt}\right|$

$\Rightarrow E = \frac{a^2}{2r}\left|\frac{dB}{dt}\right| \Rightarrow E \propto \frac{1}{r}$



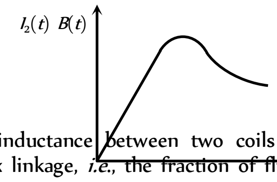
15. (d) Using k, k' etc, as different constants.

$I_1(t) = k_1[1 - e^{-t/\tau}]$, $B(t) = k_2 I_1(t)$

$I_2(t) = k_3 \dfrac{dB(t)}{dt} = k_4 e^{-t/\tau}$

$\therefore I_2(t)\, B(t) = k_5[1 - e^{-t/\tau}][e^{-t/\tau}]$

This quantity is zero for $t = 0$ and $t = \infty$ and positive for other value of *t*. It must, therefore, pass through a maximum.

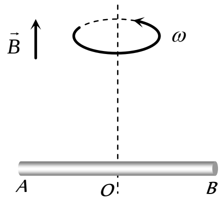


16. (a) The mutual inductance between two coils depends on their degree of flux linkage, *i.e.*, the fraction of flux linked with one coil which is also linked to the other coil. Here, the two coils in arrangement (a) are placed with their planes parallel. This will allow maximum flux linkage.

17. (d) Both *AD* and *BC* are straight conductors moving in a uniform magnetic field and emf will be induced in both. This will cause electric fields in both, but no net current flows in the circuit.

18. (d) Potential difference between

O and *A* is $V_0 - V_A = \dfrac{1}{2} Bl^2\omega$



O and *B* is $V_0 - V_B = \dfrac{1}{2} Bl^2\omega$

so $V_A - V_B = 0$

19. (c) $i = i_0\left(1 - e^{\frac{-Rt}{L}}\right) \Rightarrow \dfrac{di}{dt} = \dfrac{d}{dt} i_0 - \dfrac{d}{dt} i_0 e^{\frac{-Rt}{L}}$

$\Rightarrow \dfrac{di}{dt} = 0 - i_0\left(-\dfrac{R}{L}\right)e^{-\frac{Rt}{L}} = \dfrac{i_0 R}{L} e^{-\frac{Rt}{L}}$

Initially, $t = 0 \Rightarrow \dfrac{di}{dt} = \dfrac{i_0 \times R}{L} = \dfrac{E}{L} = \dfrac{5}{2} = 2.5\ amp/sec.$

20. (d) When switch *S* is closed magnetic field lines passing through *Q* increases in the direction from right to left. So, according to Lenz's law induced current in *Q i.e.* I_{Q_1} will flow in such a direction so that the magnetic field lines due to I_{Q_2} passes from left to right through *Q*. This is possible when I_{Q_1} flows in anticlockwise direction as seen by *E*. Opposite is the case when switch *S* is opened *i.e.* I_{Q_2} will be clockwise as seen by *E*.

21. (b) Power $P = \dfrac{e^2}{R}$; hence $e = -\left(\dfrac{d\phi}{dt}\right)$ where $\phi = NBA$

$\therefore e = -NA\left(\dfrac{dB}{dt}\right)$ Also $R \propto \dfrac{l}{r^2}$

Where *R* = resistance, *r* = radius, *l* = Length

$\therefore P \propto \dfrac{N^2 r^2}{l} \Rightarrow \dfrac{P_1}{P_2} = 1$

22. (a) $H = \dfrac{V^2 t}{R}$ *and* $V = \dfrac{N(B_2 - B_1)A\cos\theta}{t}$

$V = \dfrac{1 \times (1-2) \times 0.01 \times \cos 0^o}{10^{-3}} = 10\ V$

So, $H = \dfrac{(10)^2 \times 10^{-3}}{0.01} = 10\ J$

23. (d) Peak current in the circuits $i_0 = \dfrac{12}{6} = 2A$

Current decreases from 2*A* to 1*A i.e.,* becomes half in time $t = 0.693\dfrac{L}{R} = 0.693 \times \dfrac{8.4 \times 10^{-3}}{6} = 1 millisec.$

24. (a) Induced current in the circuit $i = \dfrac{Bvl}{R}$

Magnetic force acting on the wire $F_m = Bil = B\left(\dfrac{Bvl}{R}\right)l$

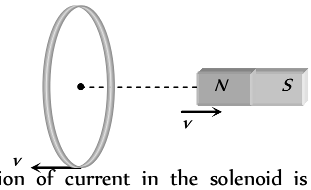
$\Rightarrow F_m = \dfrac{B^2 vl^2}{R}$ External force needed to move the rod with constant velocity

$(F_m) = \dfrac{B^2 vl^2}{R} = \dfrac{(0.15)^2 \times (2) \times (0.5)^2}{3} = 3.75 \times 10^{-3}\ N$

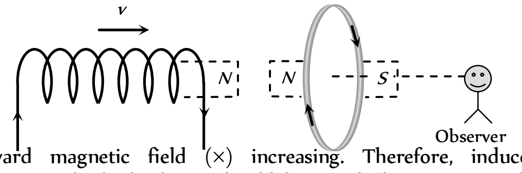
25. (c) According to Lenz's Law

26. (b) $\left(\dfrac{d\phi}{dt}\right)_{\text{In first case}} = e$

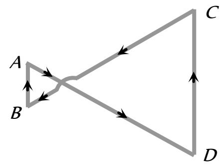
$\left(\dfrac{d\phi}{dt}\right)_{\text{relative velocity}\, 2v} = 2\left(\dfrac{d\phi}{dt}\right)_{\text{I case}} = 2e$



27. (b) The direction of current in the solenoid is anti-clockwise as seen by observer. On displacing it towards the loop a current in the loop will be induced in a direction so as to oppose the approach of solenoid. Therefore the direction of induced current as observed by the observer will be clockwise.



28. (a) Inward magnetic field (×) increasing. Therefore, induced current in both the loops should be anticlockwise. But as the area of loop on right side is more, induced *emf* in this will be more compared to the left side loop $\left(e = -\dfrac{d\phi}{dt} = -A.\dfrac{dB}{dt}\right)$. Therefore net current in the complete loop will be in a direction shown below. Hence only option (a) is correct.

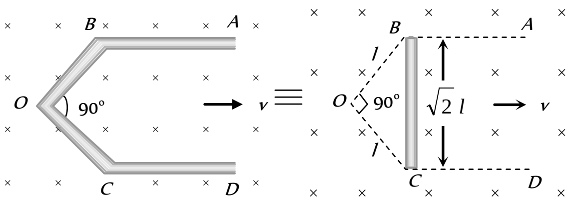


29. (b) Equivalent resistance of the given Wheatstone bridge circuit (balanced) is 3Ω so total resistance in circuit is $R = 3 + 1 = 4\Omega$. The emf induced in the loop $e = Bvl$.

So induced current $i = \dfrac{e}{R} = \dfrac{Bvl}{R}$

$\Rightarrow 10^{-3} = \dfrac{2 \times v \times (10 \times 10^{-2})}{4} \Rightarrow v = 2cm / sec.$

30. (b) There is no induced emf in the part AB and CD because they are moving along their length while emf induced between B and C *i.e.* between A and D can be calculated as follows

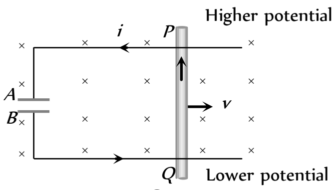


Induced emf between B and C = Induced emf between A and B

$= Bv(\sqrt{2}\,l) = 1 \times 1 \times 1 \times \sqrt{2} = 1.41 volt.$

31. (a) $Q = CV = C(Bvl) = 10 \times 10^{\cdot} \times 4 \times 2 \times 1 = 80\ \mu C$

According to Fleming's right hand rule induced current flows from Q to P. Hence P is at higher potential and Q is at lower potential. Therefore A is positively charged and B is negatively charged.



32. (b) If resistance is constant (10Ω) then steady current in the circuit $i = \dfrac{5}{10} = 0.5\ A$. But resistance is increasing it means current through the circuit start decreasing. Hence inductance comes in picture which induces a current in the circuit in the same direction of main current. So $i > 0.5\ A$.

33. (d) $P = \dfrac{e^2}{R}$; $e = -\dfrac{d}{dt}(BA) = A\dfrac{d}{dt}(B_o e^{-t}) = AB_o e^{-t}$

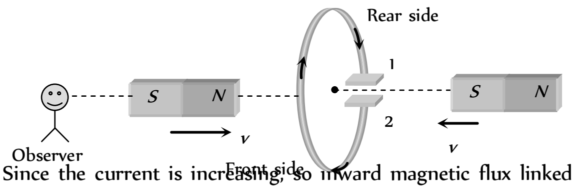
$\Rightarrow P = \dfrac{1}{R}(AB_o e^{-t})^2 = \dfrac{A^2 B_o^2 e^{-2t}}{R}$

At the time of starting $t = 0$ so $P = \dfrac{A^2 B_o^2}{R}$

$\Rightarrow P = \dfrac{(\pi r^2)^2 B_o^2}{R} = \dfrac{B_o^2 \pi^2 r^4}{R}$

34. (c) When key k is pressed, current through the electromagnet start increasing *i.e.* flux linked with ring increases which produces repulsion effect.

35. (b) By the movement of both the magnets, current will be anticlockwise, as seen from left side *i.e.* plate 1 will be positive and 2 will be negative.



36. (a) Since the current is increasing, so inward magnetic flux linked with the ring also increasing (as viewed from left side). Hence induced current in the ring is anticlockwise, so end x will be positive.

Induced emf $|e| = A\dfrac{dB}{dt} = A\dfrac{d}{dt}(B_o + \alpha t) \Rightarrow |e| = A\alpha$

37. (a) Current in the inner coil $i = \dfrac{e}{R} = \dfrac{A_1}{R_1}\dfrac{dB}{dt}$

length of the inner coil $= 2\pi a$

so it's resistance $R_1 = 50 \times 10^{-3} \times 2\pi\,(a)$

$\therefore i_1 = \dfrac{\pi a^2}{50 \times 10^{-3} \times 2\pi\,(a)} \times 0.1 \times 10^{-3} = 10^{-4}\,A$

According to lenz's law direction of i is clockwise.

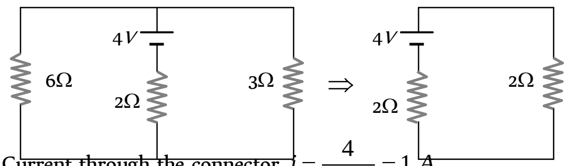
Induced current in outer coil $i_2 = \dfrac{e_2}{R_2} = \dfrac{A_2}{R_2}\dfrac{dB}{dt}$

$\Rightarrow i_2 = \dfrac{\pi b^2}{50 \times 10^{-3} \times (2\pi b)} \times 0.1 \times 10^{-3} = 2 \times 10^{-4}\,A\,(CW)$

38. (c) Motional emf $e = Bvl \Rightarrow e = 2 \times 2 \times 1 = 4\ V$

This acts as a cell of emf $E = 4\ V$ and internal resistance $r = 2\Omega$.

This simple circuit can be drawn as follows



Current through the connector $i = \dfrac{4}{2+2} = 1\ A$

$\therefore$ magnetic force on connector $F_m = Bil = 2 \times 1 \times 1 = 2\ N$

(Towards left)

39. (b) Due to magnetic field, wire will experience an upward force $F = Bil = B\left(\dfrac{Bvl}{R}\right)l \Rightarrow F = \dfrac{B^2 v l^2}{R}$

If wire slides down with constant velocity then

$F = mg \Rightarrow \dfrac{B^2 v l^2}{R} = mg \Rightarrow v = \dfrac{mgR}{B^2 l^2}$

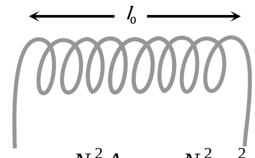
40. (c) By using $e = \dfrac{1}{2}Bl^2\omega$

For part AO; $e_{OA} = e_O - e_A = \dfrac{1}{2}Bl^2\omega$

For part OC; $e_{OC} = e_O - e_C = \dfrac{1}{2}B(3l)^2\omega$

$\therefore e_A - e_C = 4\,Bl^2\omega$

41. (c) Suppose solenoid has N turns, each of radius r and length of wire is l.



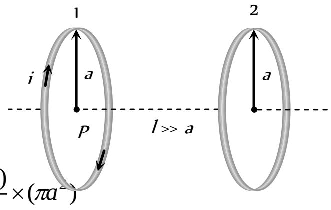
It's self inductance $L = \dfrac{\mu_0 N^2 A}{l_0} = \dfrac{\mu_0 N^2 \pi r^2}{l_0}$ .... (i)

Also length of the wire $l = N \times 2\pi r$

$\Rightarrow N^2 r^2 = \dfrac{l^2}{4\pi^2}$ .... (ii)

From equation (i) and (ii) $l=\sqrt{\dfrac{4\pi L l_o}{\mu_o}}$

42. (d) Magnetic field at the location of coil (2) produced due to coil (1)



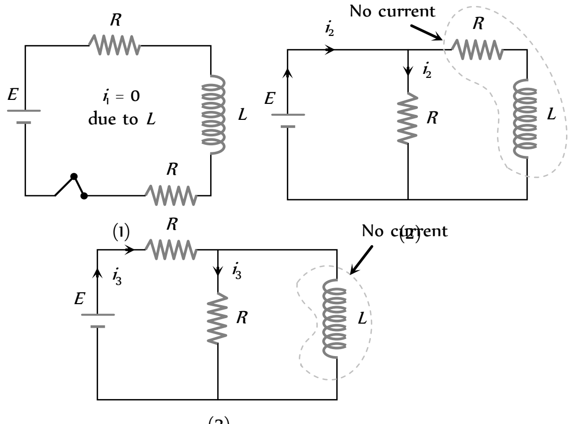
$B_1=\dfrac{\mu_o}{4\pi}\cdot\dfrac{2M}{l^3}$

Flux linked with coil (2)

$\phi_2=B_1A_2=\dfrac{\mu_o}{4\pi}\dfrac{2i\,(\pi a^2)}{l^3}\times(\pi a^2)$

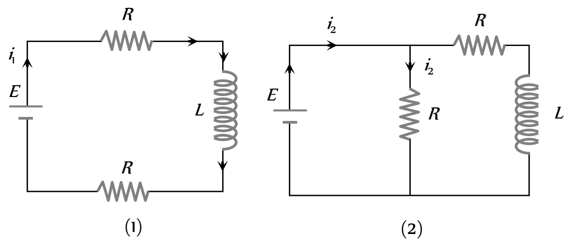
Also $\phi_2=Mi\Rightarrow M=\dfrac{\mu_o\pi a^4}{2l^3}$

43. (a) Just before closing the switch.

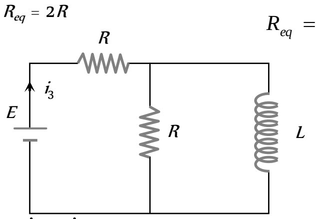


$i_1=0,\ i_2=\dfrac{E}{R},\ i_3=\dfrac{E}{2R}$ so $i_2>i_3>i_1$ $(i_1=0)$

After a long time closing the switch



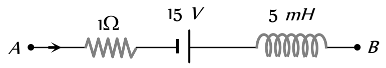
$R_{eq}=2R$ $\qquad R_{eq}=\dfrac{R}{2}$



Hence $i_2>i_3>i_1$ (3)

44. (c) By using Kirchoff's voltage law

$$V_A-iR+E-L\frac{di}{dt}=V_B\Rightarrow V_B-V_A=15\ volt.$$



45. (d) The rate of increase of current

$$=\frac{di}{dt}=\frac{d}{dt}i_0\left(1-e^{-Rt/L}\right)=\frac{d}{dt}i_0-\frac{d}{dt}i_0e^{-Rt/L}$$

$$=0-i_0e^{-Rt/L}\cdot\frac{d}{dt}\left(-\frac{Rt}{L}\right)=i_0\frac{R}{L}e^{-Rt/L}$$

$$=\frac{50}{180}\times\frac{180}{5\times10^{-3}}\times e^{-(180\times0.001)/(5\times10^{-3})}=10^4\times e^{-36}\,A/\sec$$

46. (b) We know that $i=i_o\left[1-e^{\frac{-Rt}{L}}\right]$ or $\dfrac{3}{4}i_o=i_o\left[1-e^{-t/\tau}\right]$

(where $\tau=\dfrac{L}{R}=$ time constant)

$\dfrac{3}{4}=1-e^{-t/\tau}$ or $e^{-t/\tau}=1-\dfrac{3}{4}=\dfrac{1}{4}$

$e^{t/\tau}=4$ or $\dfrac{t}{\tau}=\ln 4$

$\Rightarrow\tau=\dfrac{t}{\ln4}=\dfrac{4}{2\ln2}\Rightarrow\tau=\dfrac{2}{\ln2}\,sec.$

47. (b) In a constant magnetic field conducting ring oscillates with a frequency of 100 *Hz*.

i.e. $T=\dfrac{1}{100}$ s, in time $\dfrac{T}{2}$ flux links with coil changes from BA to zero. ⇒ Induced emf = $\dfrac{\text{change in flux}}{\text{time}}$

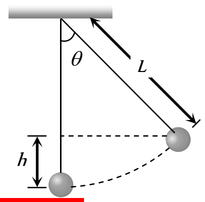
$$=\frac{BA}{T/2}=\frac{2BA}{T}=\frac{2B\times\pi r^2}{T}=\frac{2\times0.01\times\pi\times1^2}{1/100}=4\pi V$$

Induced electric field along the circle, using Maxwell equation

$$\oint E.dl=-\frac{d\phi}{dt}=A\frac{dB}{dt}=e$$

$$\Rightarrow E=\frac{1}{2\pi r}\times\left(\pi r^2\times\frac{dB}{dt}\right)=\frac{e}{2\pi r}=\frac{4\pi}{2\pi r}=2\,V/m$$

48. (a)



$\Rightarrow h=L(1-\cos\theta)$ ....(i)

Maximum velocity at equilibrium is given by

$\therefore\ v^2=2gh=2g\,L(1-\cos\theta)=2g\,L\left(2\sin^2\dfrac{\theta}{2}\right)$

$\Rightarrow v=2\sqrt{gL}\sin\dfrac{\theta}{2}$

Thus, max. potential difference

$$V_{\max}=BvL=B\times2\sqrt{gL}\sin\frac{\theta}{2}L=2BL\sin\frac{\theta}{2}(gL)^{1/2}.$$

Graphical Questions

1. (d) At B, flux is maximum, so from $|e| = \frac{d\phi}{dt}$ at B $|e| = 0$

2. (b) As the magnet moves towards the coil, the magnetic flux increases (nonlinearly). Also there is a change in polarity of induced emf when the magnet passes on to the other side of the coil.

3. (c) Rate of decay of current between t = 5 ms to 6 ms

$= \frac{di}{dt} = -(\text{Slope of the line} BC)$

$= -\left(\frac{5}{1\times 10^{-3}}\right) = -5\times 10^{3} A/s.$ Hence induced emf

$e = -L\frac{di}{dt} = -4.6\times(-5\times 10^{3}) = 23\times 10^{3} V.$

4. (b) $e = -M\frac{di}{dt} = -1.5\frac{(1-0)}{(T/4)} = -\frac{6}{T}$, $T = \frac{2\pi}{\omega} = \frac{2\pi}{200} = \frac{\pi}{100}$

$\Rightarrow |e| = \frac{600}{\pi} = 190.9\, V \simeq 191 V$

5. (d) When loop enters in field between the pole pieces, flux linked with the coil first increases (constantly) so a constant emf induces, when coil entered completely within the field, no flux change so $e = 0$.

When coil exit out, flux linked with the coil decreases, hence again emf induces, but in opposite direction.

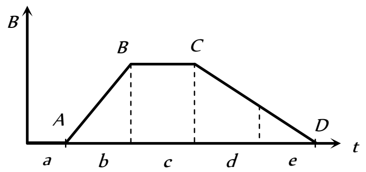
6. (a) $|dq| = \frac{d\phi}{R} = i\, dt$ = Area under $i - t$ graph

$\therefore d\phi =$ (Area under $i - t$ graph) R

$= \frac{1}{2}\times 4\times 0.1\times(10) = 2\, wb.$

7. (b) Induced emf $e = A\frac{dB}{dt}$

i.e. $e \propto \frac{dB}{dt}$ (= slope of $B - t$ graph)



In the given graph slope of AB > slope of CD, slope in the 'a' region = slope in the 'c' region = 0, slope in the 'd' region = slope in the 'e' region $\neq 0$. That's why $b > (d = e) > (a = c)$

8. (b) $P = Fv = Bil\times v = B\left(\frac{Bvl}{R}\right)l\times v = \frac{B^2v^2l^2}{R} \Rightarrow P \propto v^2$

9. (b) As x increases so $\frac{dB}{dt}$ increases *i.e.* induced emf (e) is negative.

When loop completely entered in the magnetic field, emf = 0

When it exit out x increases but $\frac{dB}{dt}$ decreases *i.e.* e is positive.

10. (c) According to $i - t$ graph, in the first half current is in-creasing uniformly so a constant negative emf induces in the circuit.

In the second half current is decreasing uniformly so a constant positive emf induces

Hence graph (c) is correct

11. (b) $i = i_0\left(1 - e^{-\frac{R}{L}t}\right)$

12. (a) $\frac{di}{dt}$ = slope of $i - t$ graph slope of graph (2) < slope of graph (1) so $\left(\frac{di}{dt}\right)_2 < \left(\frac{di}{dt}\right)_1$

Also $L \propto \frac{1}{(di/dt)} \Rightarrow L_2 > L_1$

13. (b) $\phi = BA = B\times\pi r^2$

$\therefore \phi \propto r^2 \Rightarrow \phi = kr^2$ (k = constant)

$\therefore e = \frac{d\phi}{dt} = k.2r\frac{dr}{dt}$

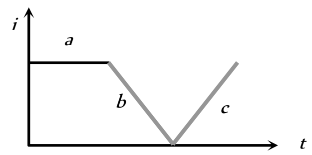
From 0 – 1, r is constant, $\therefore \frac{dr}{dt} = 0$ hence, e = 0

From 1 – 2, $r = \alpha t$, $\therefore \frac{dr}{dt} = \alpha$ hence $e \propto r \Rightarrow e \propto t$

From 2 – 3, again r is constant, $\therefore \frac{dr}{dt} = 0$ hence e = 0

14. (c) Emf induces during 'a' = 0

emf induced during 'b' is constant throughout emf induced during 'c' is constant throughout magnitude of emf induced during 'b' is equal to the magnitude of emf induced during 'c'. But the direction opposite.



15. (a) $U = \frac{1}{2}Li^2$

$\therefore$ Rate $= \frac{dU}{dt} = Li\left(\frac{di}{dt}\right)$

At $t = 0, i = 0$ $\therefore$ rate $= 0$

At $t = \infty, i = i_0$ but $\frac{di}{dt} = 0$, therefore rate = 0

16. (c) At the time t = 0, e is max and is equal to E, but current i is zero.

As the time passes, current through the circuit increases but induced emf decreases.

17. (d) If at any instant, current through the circuit is i then applying Kirchoffs voltage law, $iR+e=E \Rightarrow e=E-iR$. Therefore, graph between e and i will be a straight line having negative slope and having a positive intercept.

18. (c) When loop is entering in the field, magnetic flux (*i.e.* $\times$) linked with the loop increases so induced emf in it $e=Bvl=0.6\times10^{-2}\times5\times10^{-2}=3\times10^{-4}V$ (Negative) .

When loop completely entered in the field (after 5 *sec*) flux linked with the loop remains constant so $e = 0$.

After 15 *sec*, loop begins to exit out, linked magnetic flux decreases so induced emf $e=3\times10^{-4}V$ (Positive).

19. (a)

Assertion and Reason

1. (b) When a metallic conductor is moved in a magnetic field; magnetic flux is varied. It disturbs the free electrons of the metal and set up an induced emf in it. As there are no free ends of the metal *i.e.* it will be closed in itself so there will be induced current.

2. (b) The relation of induced emf is $e=\frac{Ldi}{dt}$ and current i is given by $i=\frac{e}{R}=\frac{1}{R}.\frac{L.di}{dt} \Rightarrow \frac{di}{dt}=i\frac{R}{L}=\frac{i}{L/R}$.

In order to decreases the rate of increase of current through solenoid. We have to increase the time constant $\frac{L}{R}$.

3. (c) According to Faraday's laws, the conversion of mechanical energy into electrical energy. This is in accordance with the law of conservation of energy. It is also clearly known that in pure resistance, the emf is in phase with the current.

4. (c) Presence of magnetic flux cannot produce current.

5. (e) E.M.F. induces, when there is change in magnetic flux. Faraday did experiment in which, there is relative motion between the coil and magnet, the flux linked with the coil changes and e.m.f. induces.

6. (e) Since both the loops are identical (same area and number of turns) and moving with a same speed in same magnetic field. Therefore same emf is induced in both the coils. But the induced current will be more in the copper loop as its resistance will be lesser as compared to that of the aluminium loop.

7. (a) The inductance coils made of copper will have very small ohmic resistance. Due to change in magnetic flux a large induced current will be produced in such an inductance, which will offer appreciable opposition to the flow of current.

8. (b) Self-inductance of a coil is its property virtue of which the coil opposes any change in the current flowing through it.

9. (c) The manner in which the two coils are oriented, determines the coefficient of coupling between them.

$M=K^2.L_1L_2$

When the two coils are wound on each other, the coefficient of coupling is maximum and hence mutual inductance between the coil is maximum.

10. (a) The induced current in the ring opposes the motion of falling magnet. Therefore, the acceleration of the falling magnet will be less than that due to gravity.

11. (e) As the aircraft flies, magnetic flux changes through its wings due to the vertical component of the earth's magnetic field. Due to this, induced emf is produced across the wings of the aircraft. Therefore, the wings of the aircraft will not be at the same potential.

12. (b) According to Lenz's law, induced emf are in a direction such as to attempt to maintain the original magnetic flux when a change occurs. When the switch is opened, the sudden drop in the magnetic field in the circuit induces an emf in a direction that attempts to keep the original current flowing. This can cause a spark as the current bridges the air gap between the poles of the switch. (The spark is more likely in circuits with large inductance).

13. (b) Mutual inductance is the phenomenon according to which an opposing e.m.f. produce flux in a coil as a result of change in current or magnetic flux linked with a neighboring coil. But when two coils are inductively coupled, in addition to induced e.m.f. produced due to mutual induction, also induced e.m.f. is produced in each of the two coils due to self-induction.

14. (e) Lenz's Law is based on conservation of energy and induced emf always opposes the cause of it *i.e.*, change in magnetic flux.

15. (a) As the coil rotates, the magnetic flux linked with the coil (being $\vec{B}\,.\,\vec{A}$) will change and emf will be induced in the loop.

16. (a)

17. (c) When the satellite moves in inclined plane with equatorial plane (including orbit around the poles), the value of magnetic field will change both in magnitude and direction. Due to this, the magnetic flux through the satellite will change and hence induced currents will be produced in the metal of the satellite. But no current will induced if satellite orbits in the equatorial plane because the magnetic flux does not change through the metal of the satellite in this plane.

18. (b) When the tube is heated its resistance gets increased due to which eddy currents produced in copper tube becomes weak. Hence opposing force also gets reduced and the terminal velocity of magnet gets increased.

19. (d) When a metal piece falls from a certain height then eddy currents are produced in it due to earth's magnetic field. Eddy current oppose the motion of piece. Hence metal piece falls with a smaller acceleration (as compared to g). But no eddy current are produced in non-metal piece, hence it drops with acceleration due to gravity. Therefore non-metal piece will reach the earth's surface earlier.

20. (a) Transformer works on *ac* only, *ac* changes in magnitude as well as in direction.

21. (a) Hysteresis loss in the core of transformer directly proportional to the hysteresis loop area of the core material. Since soft iron has narrow hysteresis loop area, that is why soft iron core is used in the transformer.

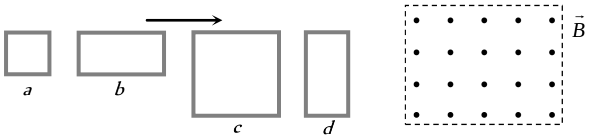
22. (e) *ac* generator is based on the principle of the electromagnetic induction. When a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an induced emf is produced across it.

23. (d) Efficiency of electric motor is maximum when the back emf set up in the armature is half the value of the applied battery *emf.*

24. (d) Backs *emf.* $e \propto \omega$. At start $\omega = 0$ so $e = 0$

Electromagnetic Induction — SET Self Evaluation Test - 23

1. The figure shows four wire loops, with edge lengths of either L or $2L$. All four loops will move through a region of uniform magnetic field $\vec{B}$ (directed out of the page) at the same constant velocity. Rank the four loops according to the maximum magnitude of the e.m.f. induced as they move through the field, greatest first



(a) $(e_c = e_d) < (e_a = e_b)$ (b) $(e_c = e_d) > (e_a = e_b)$

(c) $e_c > e_d > e_b > e_a$ (d) $e_c < e_d < e_b < e_a$

2. A circular coil and a bar magnet placed near by are made to move in the same direction. The coil covers a distance of 1 m in 0.5 sec and the magnet a distance of 2 m in 1 sec. The induced emf produced in the coil

(a) Zero

(b) 1 V

(c) 0.5 V

(d) Cannot be determined from the given information

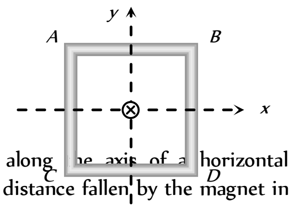
3. A square coil $ABCD$ lying in x-y plane with it's centre at origin. A long straight wire passing through origin carries a current $i = 2t$ in negative z-direction. The induced current in the coil is

(a) Clockwise

(b) Anticlockwise

(c) Alternating

(d) Zero



4. A short magnet is allowed to fall along the axis of a horizontal metallic ring. Starting from rest, the distance fallen by the magnet in one second may be

(a) 4 m (b) 5 m

(c) 6 m (d) 7 m

5. The horizontal component of the earth's magnetic field at a place is 3×10^{-4} T and the dip is $\tan^{-1}\left(\frac{4}{3}\right)$. A metal rod of length 0.25 m placed in the north-south position and is moved at a constant speed of 10 cm/s towards the east. The emf induced in the rod will be

(a) Zero (b) 1 μV

(c) 5 μV (d) 10 μV

6. A copper disc of radius 0.1 m rotates about its centre with 10 revolutions per second in a uniform magnetic field of 0.1 $Tesla$. The emf induced across the radius of the disc is

(a) $\frac{\pi}{10}V$ (b) $\frac{2\pi}{10}V$

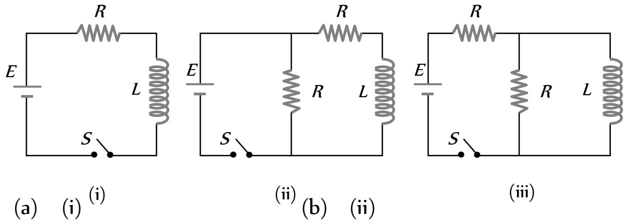
(c) 10 π mV (d) 20 π mV

7. A coil of Cu wire (radius-r, self inductance-L) is bent in two concentric turns each having radius $\frac{r}{2}$. The self inductance now

(a) $2L$ (b) L

(c) 4 L (d) $L/2$

8. In which of the following circuit is the current maximum just after the switch S is closed



(a) (i) (b) (ii)

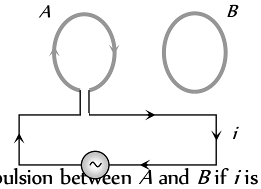
(c) (iii) (d) Both (ii) and (iii)

9. A small coil is introduced between the poles of an electromagnet so that its axis coincides with the magnetic field direction. The number of turns is n and the cross sectional area of the coil is A. When the coil turns through 180° about its diameter, the charge flowing through the coil is Q. The total resistance of the circuit is R. What is the magnitude of the magnetic induction

(a) $\frac{QR}{nA}$ (b) $\frac{2QR}{nA}$

(c) $\frac{Qn}{2RA}$ (d) $\frac{QR}{2nA}$

10. Two circular coils A and B are facing each other as shown in figure. The current i through A can be altered



(a) There will be repulsion between A and B if i is increased

(b) There will be attraction between A and B if i is increased

(c) There will be neither attraction nor repulsion when i is changed

(d) Attraction or repulsion between A and B depends on the direction of current. If does not depend whether the current is increased or decreased

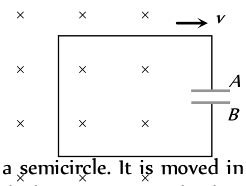
11. A conducting loop having a capacitor is moving outward from the magnetic field then which plate of the capacitor will be positive

(a) Plate – A

(b) Plate – B

(c) Plate – A and Plate – B both

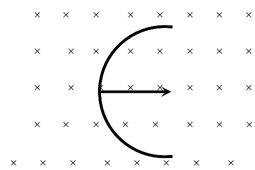
(d) None



12. A straight wire of length L is bent into a semicircle. It is moved in a uniform magnetic field with speed v with diameter perpendicular to the field. The induced emf between the ends of the wire is

(a) BLv

(b) $2BLv$



(c) $2\pi BLv$

(d) $\frac{2BvL}{\pi}$

13. If in a coil rate of change of area is $\frac{5\, metre^2}{millisecond}$ and current become 1 *amp* form 2 *amp* in 2×10^{-3} *sec*. If magnetic field is 1 *Tesla* then self inductance of the coil is

(a) 2 *H* (b) 5 *H*

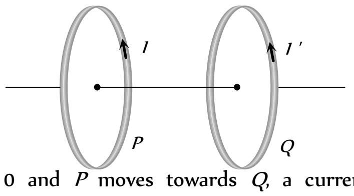
(c) 20 *H* (d) 10 *H*

14. In series with 20 *ohm* resistor a 5 *henry* inductor is placed. To the combination an e.m.f. of 5 *volt* is applied. What will be the rate of increase of current at $t = 0.25$ *sec*

(a) e (b) e^{-2}

(c) e^{-1} (d) None of these

15. Two coils P and Q are placed co-axially and carry current I and I' respectively



(a) If $I = 0$ and P moves towards Q, a current in the same direction as I is induced in Q

(b) If $I = 0$ and Q moves towards P, a current opposite in direction to that of I' is induced in P

(c) When $I \neq 0$ and $I' \neq 0$ are in the same direction, then two coil tend to move apart

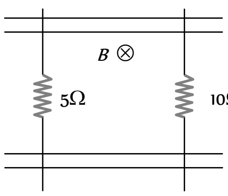
(d) None of these

16. The phase difference between the flux linkage and the induced e.m.f. in a rotating coil in a uniform magnetic field

(a) π (b) $\pi/2$

(c) $\pi/4$ (d) $\pi/6$

17. A pair of parallel conducting rails lie at right angle to a uniform magnetic field of 2.0 *T* as shown in the fig. Two resistors 10 Ω and 5 Ω are to slide without friction along the rail. The distance between the conducting rails is 0.1 *m*. Then



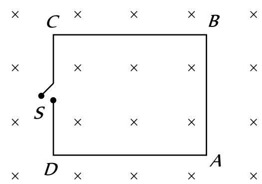
(a) Induced current $= \frac{1}{150} A$ directed clockwise if 10 Ω resistor is pulled to the right with speed 0.5 ms^{-1} and 5Ω resistor is held fixed

(b) Induced current $= \frac{1}{300} A$ directed anti-clockwise if 10 Ω resistor is pulled to the right with speed 0.5 ms^{-1} and 5Ω resistor is held fixed

(c) Induced current $= \frac{1}{300} A$ directed clockwise if 5 Ω resistor is pulled to the left at 0.5 ms^{-1} and 10 Ω resistor is held at rest

(d) Induced current $= \frac{1}{150} A$ directed anti-clockwise if 5 Ω resistor is pulled to the left at 0.5 ms^{-1} and 10 Ω resistor is held at rest

18. The magnetic field in the cylindrical region shown in figure increases at a constant rate of 20 *mT/sec*. Each side of the square loop *ABCD* has a length of 1 *cm* and resistance of 4Ω. Find the current in the wire *AB* if the switch *S* is closed



(a) $1.25 \times 10^{-7} A$, (anti-clockwise)

(b) $1.25 \times 10^{-7} A$ (clockwise)

(c) $2.5 \times 10^{-7} A$ (anti clockwise)

(d) $2.5 \times 10^{-7} A$ (clockwise)

19. An aircraft with a wing-span of 40 *m* flies with a speed of 1080 $km\, h^{-1}$ in the eastward direction at a constant altitude in the northern hemisphere, where the vertical component of earth's magnetic field is 1.75×10^{-5} *T*. Then the emf that develops between the tips of the wings is

(a) 0.5 *V* (b) 0.35 *V*

(c) 0.21 *V* (d) 2.1 *V*

20. A hundred turns of insulated copper wire are wrapped around an iron cylinder of area $1 \times 10^{-3}\, m^2$ and are connected to a resistor. The total resistance in the circuit is 10 *ohms*. If the longitudinal magnetic induction in the iron changes from 1 $weber\, m^{-2}$, in one direction to 1 $Weber\, m^{-2}$ in the opposite direction, how much charge flows through the circuit

(a) 2×10^{-2} *C* (b) 2×10^{-3} *C*

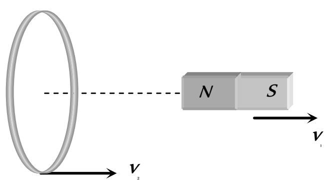
(c) 2×10^{-4} *C* (d) 2×10^{-5} *C*

Answers and Solutions

(SET -23)

1. (b) Emf induces across the length of the wire which cuts the magnetic field. (Length of c = Length d) > (Length of a = b). So $(e_c = e_d) > (e_a = e_b)$

2. (a) Speed of the magnet



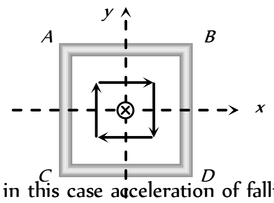
$v_1 = \frac{2}{1} = 2\, m/s$

Speed of the coil

$v_2 = \frac{1}{0.5} = 2\, m/s$

Relative speed between coil and magnet is zero, so there is no induced emf in the coil.

3. (d) Magnetic lines are tangential to the coil as shown in figure. Thus net magnetic flux passing through the coil is always zero or the induced current will be zero.



4. (a) We know that in this case acceleration of falling magnet will be lesser than *g*. If '*g*' would have been acceleration, then distance covered $= \frac{1}{2}gt^2 = 5m$.

Now the distance covered will be less than 5 *m*. hence only option (a) is correct.

5. (d) Rod is moving towards east, so induced emf across it's end will be $e = B_v vl = (B_H \tan\phi)vl$

$$\therefore e = 3\times10^{-4}\times\frac{4}{3}\times(10\times10^{-2})\times0.25 = 10^{-5}\,V = 10\,\mu V$$

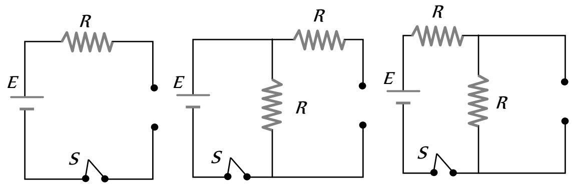
6. (c) The induced emf between centre and rim of the rotating disc is

$$E = \frac{1}{2}B\omega R^2 = \frac{1}{2}\times0.1\times2\pi\times10\times(0.1)^2 = 10\pi\times10^{-3}\,volt$$

7. (a) $\because\ L \propto N^2 r$; $\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2 \times \frac{r_1}{r_2}$

$$\Rightarrow \frac{L}{L_2} = \left(\frac{1}{2}\right)^2 \times \left(\frac{r}{r/2}\right) = \frac{1}{2};\quad L_2 = 2L$$

8. (b) At $t = 0$ current through *L* is zero so it acts as open circuit. The given figures can be redrawn as follow.



$i_1 = 0$ (i) $\quad i_2 = \frac{E}{R}$ (ii) $\quad i_3 = \frac{E}{2R}$ (iii)

Hence $i_2 > i_3 > i_1$.

***

9. (d) Induced charge $Q = -\frac{NBA}{R}(\cos\theta_2 - \cos\theta_1)$

$$= -\frac{NBA}{R}(\cos180^o - \cos0^o) \Rightarrow B = \frac{QR}{2NA}$$

10. (a) With rise in current in coil *A* flux through *B* increases. According to Lenz's law repulsion occurs between *A* and *B*.

11. (a) Crosses (×) linked with the loop are decreasing, so induced current in it is clockwise *i.e.* from $B \to A$. Hence electrons flow from plate *A* to *B* so plate *A* becomes positively charged.

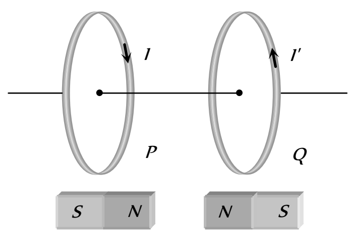
12. (d) Induced emf $e = Bvl \Rightarrow e = Bv(2R) = \frac{2BvL}{\pi}$

13. (d) $e = B.\frac{dA}{dt} = L\frac{di}{dt} \Rightarrow 1\times\frac{5}{10^{-3}} = L\times\frac{(2-1)}{2\times10^{-3}} \Rightarrow L = 10H$

14. (c) $i = i_0(1-e^{-Rt/L}) \Rightarrow \frac{di}{dt} = i_0\left(\frac{R}{L}\right)e^{-Rt/L} = \frac{E}{L}e^{-Rt/L}$

On putting values $\frac{di}{dt} = \frac{1}{e} = e^{-1}$.

15. (b)



16. (b) $\phi = BA\cos\theta$ where θ is the angle between area and field

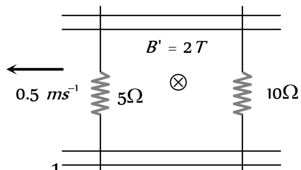
$$e = \frac{-d\phi}{dt} = -BA\sin\theta.\frac{d\theta}{dt} = BA\left(\frac{d\theta}{dt}\right)\cos(90+\theta)$$

Here phase difference = 90°.

17. (d) When 5Ω resistor is pulled left at 0.5 *m/sec* induced *emf*, in the said resistor $= e = vBl = 0.5\times2\times0.1 = 0.1\,V$

Resistor 10Ω is at rest so induced *emf* in it $(e = vBl)$ be zero.

Now net *emf*, in the circuit $= 0.1V$ and equivalent resistance of the circuit $R = 15\,\Omega$



Hence current $i = \frac{0.1}{15}amp = \frac{1}{150}amp$

And its direction will be anti-clockwise (according to Lenz's law)

18. (a) $i = \frac{e}{R} = \frac{A}{R}.\frac{dB}{dt} = \frac{(1\times10^{-2})^2}{16}\times20\times10^{-3} = 1.25\times10^{-7}A$

(Anti-clockwise).

19. (c) $L = 40\ m$, $v = 1080\,km\ h^{-1} = 300\,m\ sec^{-1}$ and $B = 1.75\times10^{-5}\ T \Rightarrow$

$$e = Blv = 1.75\times10^{-5}\times40\times300 = 0.21\,V$$

20. (a) $dQ = \frac{d\phi}{R} = \frac{nAdB}{R} = \frac{100\times1\times10^{-3}\times2}{10} = 2\times10^{-2}C$

Chapter

24

Alternating Current

Alternating Quantities (*i* or *V*)

(1) An alternating quantity (current *i* or voltage *V*) is one whose magnitude changes continuously with time between zero and a maximum value and whose direction reverses periodically.

(2) Some graphical representation for alternating quantities

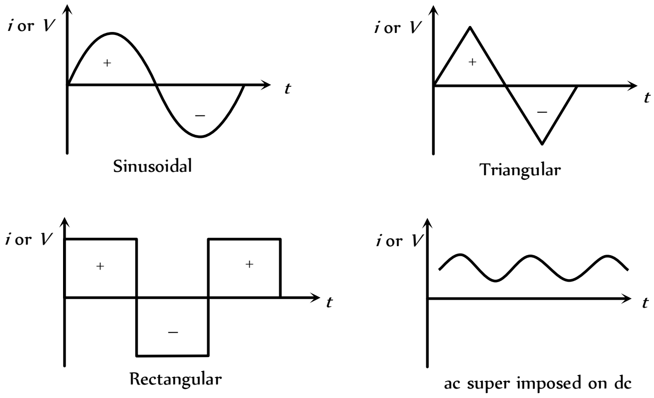


Fig. 24.1

(3) **Equation for *i* and *V* :** Alternating current or voltage varying as sine function can be written as

$$i = i_0 \sin\omega t = i_0 \sin 2\pi\nu t = i_0 \sin\frac{2\pi}{T}t$$

and $V = V_0 \sin\omega t = V_0 \sin 2\pi\nu t = V_0 \sin\frac{2\pi}{T}t$

where *i* and *V* are Instantaneous values of current and voltage,

i_0 and V_0 are peak values of current and voltage

ω = Angular frequency in *rad/sec*, ν = Frequency in *Hz* and *T* = time period

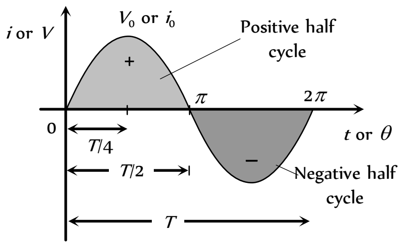


Fig. 24.2

(i) The time taken to complete one cycle of variations is called the periodic time or time period.

(ii) Alternating quantity is positive for half the cycle and negative for the rest half. Hence average value of alternating quantity (*i* or *V*) over a complete cycle is zero.

(iii) The value of alternating quantity is zero or maximum 2ν times every second. The direction also changes 2ν times every second.

(iv) Generally sinusoidal waveform is used as alternating current/voltage.

(v) At $t = \frac{T}{4}$ from the beginning, *i* or *V* reaches to their maximum value.

Important Values of Alternating Quantities

(1) **Peak value (i_0 or V_0) :** The maximum value of alternating quantity (i_0 or V_0) is defined as peak value or amplitude.

(2) **Mean square value ($\overline{V^2}$ or $\overline{i^2}$) :** The average of square of instantaneous values in one cycle is called mean square value. It is always positive for one complete cycle. *e.g.* $\overline{V^2} = \frac{1}{T}\int_0^T V^2 dt = \frac{V_0^2}{2}$ or $\overline{i^2} = \frac{i_0^2}{2}$

(3) **Root mean square (r.m.s.) value :** Root of mean of square of voltage or current in an *ac* circuit for one complete cycle is called *r.m.s.* value. It is denoted by V_{rms} or i_{rms}

$$i_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + ...}{n}} = \sqrt{\overline{i^2}} = \sqrt{\frac{\int_0^T i^2 dt}{\int_0^T dt}} = \frac{i_0}{\sqrt{2}} = 0.707\, i_0 = 70.7\%\, i_0$$

Similarly $V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707\, V_0 = 70.7\%$ of V_0

$$\left[\langle \sin^2(\omega t)\rangle = \langle \cos^2(\omega t)\rangle = \frac{1}{2}\right]$$

(i) The *r.m.s.* value of alternating current is also called virtual value or effective value.

(ii) In general when values of voltage or current for alternating circuits are given, these are *r.m.s.* value.

(iii) ac ammeter and voltmeter are always measure *r.m.s.* value. Values printed on *ac* circuits are *r.m.s.* values.

(iv) In our houses *ac* is supplied at 220 *V*, which is the *r.m.s.* value of voltage. It's peak value is $\sqrt{2} \times 200 = 311V$.

(v) *r.m.s.* value of *ac* is equal to that value of *dc*, which when passed through a resistance for a given time will produce the same amount of heat as produced by the alternating current when passed through the same resistance for same time.

(4) **Mean or Average value (i_{av} or V_{av}) :** The average value of alternating quantity for one complete cycle is zero.

The average value of *ac* over half cycle (t = 0 to $T/2$)

$$i_{av} = \frac{\int_0^{T/2} i\,dt}{\int_0^{T/2} dt} = \frac{2i_0}{\pi} = 0.637 i_0 = 63.7\% \text{ of } i_0$$

Similarly $V_{av} = \frac{2V_0}{\pi} = 0.637 V_0 = 63.7\%$ of V_0

(5) **Peak to peak value :** It is equal to the sum of the magnitudes of positive and negative peak values

$\therefore$ Peak to peak value = $V_0 + V_0 = 2V_0$

$$= 2\sqrt{2}\,V_{rms} = 2.828\,V_{rms}$$

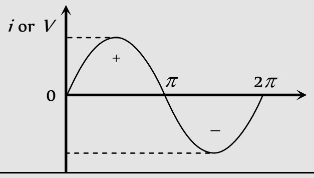
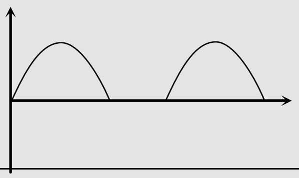
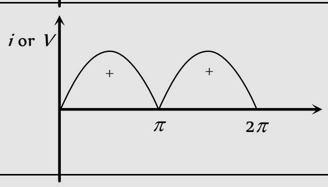
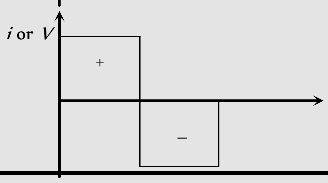
(6) **Form factor and peak factor :** The ratio of *r.m.s.* value of *ac* to it's average during half cycle is defined as form factor. The ratio of peak value and *r.m.s.* value is called peak factor

Phase

Physical quantity which represents both the instantaneous value and direction of alternating quantity at any instant is called it's phase. It's a dimensionless quantity and it's unit is radian.

If an alternating quantity is expressed as $X = X_0 \sin(\omega t \pm \phi_0)$ then the argument of $\sin(\omega t + \phi)$ is called it's phase. Where ωt = instantaneous phase (changes with time) and ϕ_0 = initial phase (constant *w.r.t.* time)

Table 24.1 : Some important values

Nature of wave form	Wave form	*r.m.s.* value	average value	Form factor $R_f = \frac{\text{r.m.s. value}}{\text{Average value}}$	Peak factor $R_p = \frac{\text{Peak value}}{\text{r.m.s. value}}$
Sinusoidal		$\frac{i_0}{\sqrt{2}}$	$\frac{2}{\pi} i_0$	$\frac{\pi}{2\sqrt{2}} = 1.11$	$\sqrt{2} = 1.41$
Half wave rectified		$\frac{i_0}{2}$	$\frac{i_0}{\pi}$	$\frac{\pi}{2} = 1.57$	2
Full wave rectified		$\frac{i_0}{\sqrt{2}}$	$\frac{2i_0}{\pi}$	$\frac{\pi}{2\sqrt{2}}$	$\sqrt{2}$
Square or Rectangular		i_0	i_0	1	1

(1) **Phase difference** (Phase constant) : The difference between the phases of currents and voltage is called phase difference. If alternating voltage and current are given by $V = V_0 \sin(\omega t + \phi_1)$ and $i = i_0 \sin(\omega t + \phi_2)$ then phase difference $\phi = \phi_1 - \phi_2$ (relative to current) or $\phi = \phi_2 - \phi_1$ (relative to voltage)

(2) **Time difference :** If phase difference between alternating current and voltage is ϕ then time difference between them is given as

$$\text{T.D.} = \frac{T}{2\pi} \times \phi$$

(3) **Phasor diagram :** A diagram representing alternating current and alternating voltage (of same frequency) as vectors (phasors) with the phase angle between them is called a phasor diagram.

While drawing phasor diagram for a pure element (*e.g.* *R*, *L* or *C*) either of the current or voltage can be plotted along *X*-axis.

But when phasor diagram for a combination of elements is drawn then quantity which remains constant for the combination must be plotted along *X*-axis so we observe that

(i) In series circuits current has to be plotted along *X*-axis.

(ii) In parallel circuits voltage has to be plotted along *X*-axis.

Measurement of Alternating Quantities

Alternating current shows heating effect only, hence meters used for measuring ac are based on heating effect and are called hot wire meters (Hot wire ammeter and hot wire voltmeter)

Table 24.2 : Measurement of ac and dc

ac measurement	*dc* measurement
(1) All ac meters read *r.m.s.* value.	(1) All dc meters read average value
(2) All ac meters are based on heating effect of current.	(2) All dc meters are based on magnetic effect of current
(3) Deflection in hot wire meters $\theta \propto i_{rms}^2$  (non-linear scale)	(3) Deflection in *dc* meters $\theta \propto i$  (Linear scale)

Impedance, Reactance, Admittance and Susceptance

(1) **Impedance (*Z*) :** The opposition offered by ac circuits to the flow of ac through it is defined it's impedance. It's unit is *ohm*(Ω).

(2) **Reactance (*X*) :** The opposition offered by inductor or capacitor or both to the flow of ac through it is defined as reactance. It is of following two type

(i) **Inductive reactance (*X*)** : Offered by inductive circuit $X_L = \omega L = 2\pi\nu L$ $\nu_{dc} = 0$ so for dc, $X_L = 0$.

Capacitive reactance (*X*) : Offered by capacitive circuit $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi\nu C}$ for dc $X_C = \infty$.

(3) **Admittance (*Y*) :** $Z = \dfrac{V_0}{i_0} = \dfrac{V_{rms}}{i_{rms}}$ Reciprocal of impedance is known as admittance $\left(Y = \dfrac{1}{Z}\right)$. It's unit is *mho*

(4) **Susceptance (*S*) :** the reciprocal of reactance is defined as susceptance $\left(S = \dfrac{1}{X}\right)$. It is of two type

(i) inductive susceptance $S_L = \dfrac{1}{X_L} = \dfrac{1}{2\pi\nu L}$ and

(ii) Capacitive susceptance, $S_C = \dfrac{1}{X_C} = \omega C = 2\pi\nu C$.

Power in ac Circuits

In dc circuits power is given by $P = Vi$. But in ac circuits, since there is some phase angle between voltage and current, therefore power is defined as the product of voltage and that component of the current which is in phase with the voltage.

Thus $\boldsymbol{P = V\,i\cos\phi}$; where *V* and *i* are *r.m.s.* value of voltage and current.

(1) **Instantaneous power :** Suppose in a circuit $V = V_0 \sin\omega t$ and $i = i_0 \sin(\omega t + \phi)$ then $P_{\text{instantaneous}} = Vi = V_0 i_0 \sin\omega t \sin(\omega t + \phi)$

(2) **Average power (True power) :** The average of instantaneous power in an ac circuit over a full cycle is called average power. It's unit is *watt i.e.*

$$P_{av} = V_{rms} i_{rms} \cos\phi = \frac{V_0}{\sqrt{2}} \cdot \frac{i_0}{\sqrt{2}} \cos\phi = \frac{1}{2} V_0 i_0 \cos\phi = i_{rms}^2 R = \frac{V_{rms}^2 R}{Z^2}$$

(3) **Apparent or virtual power :** The product of apparent voltage and apparent current in an electric circuit is called apparent power. This is always positive $P_{app} = V_{rms} i_{rms} = \dfrac{V_0 i_0}{2}$

Power Factor

(1) It may be defined as cosine of the angle of lag or lead (*i.e.* $\cos\phi$)

(2) It is also defined as the ratio of resistance and impedance (*i.e.* $\dfrac{R}{Z}$)

(3) The ratio $\dfrac{\text{True power}}{\text{Apparent power}} = \dfrac{W}{VA} = \dfrac{kW}{kVA} = \cos\phi$

Resistive Circuit (*R*-Circuit)

(1) Current : $i = i_0 \sin\omega t$

(2) Peak current : $i_0 = \dfrac{V_0}{R}$

(3) Phase difference between voltage and current : $\phi = 0$

(4) Power factor : $\cos\phi = 1$

(5) Power : $P = V_{rms} i_{rms} = \dfrac{V_0 i_0}{2}$

(6) Time difference : T.D. = 0

(7) Phasor diagram : Both are in same phase

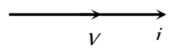
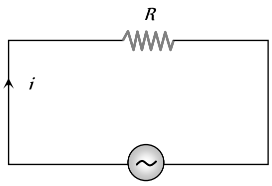


Fig. 24.4



$V = V_0 \sin\omega t$

Fig. 24.3

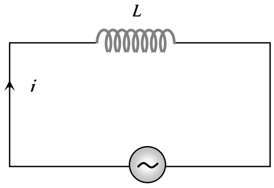
Inductive Circuit (*L*-Circuit)

(1) Current : $i = i_0 \sin\left(\omega t - \dfrac{\pi}{2}\right)$

(2) Peak current :

$$i_0 = \frac{V_0}{X_L} = \frac{V_0}{\omega_L} = \frac{V_0}{2\pi\nu L}$$

(3) Phase difference between



$V = V_0 \sin\omega t$

Fig. 24.5

voltage and current $\phi = 90^o$ (or $+\dfrac{\pi}{2}$)

(4) Power factor : $\cos\phi = 0$

(5) Power : $P = 0$

(6) Time difference : $\text{T.D.} = \dfrac{T}{4}$

(7) Phasor diagram : Voltage leads the current by $\dfrac{\pi}{2}$

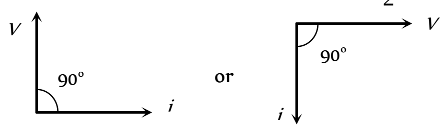
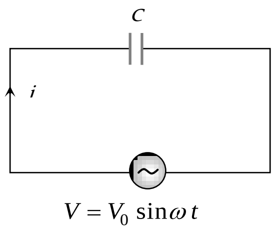


Fig. 24.6

Capacitive Circuit (*C*-Circuit)

(1) Current : $i = i_0 \sin\left(\omega t + \dfrac{\pi}{2}\right)$



$V = V_0 \sin\omega t$

Fig. 24.7

(2) Peak current :

$$i_0 = \frac{V_0}{X_C} = V_0\omega C = V_0(2\pi\nu C)$$

(3) Phase difference between voltage and current : $\phi = 90^o$ (or $-\dfrac{\pi}{2}$)

(4) Power factor : $\cos\phi = 0$

(5) Power : $P = 0$

(6) Time difference : $\text{TD} = \dfrac{T}{4}$

(7) Phasor diagram : Current leads the voltage by $\pi/2$

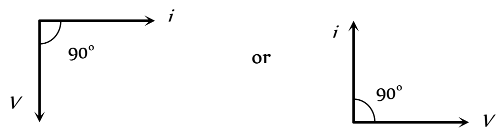
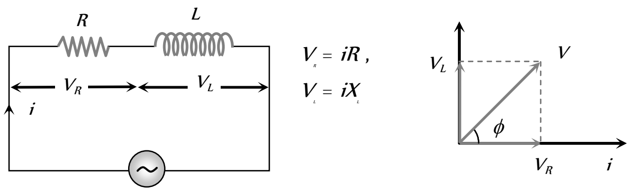


Fig. 24.8

Resistive, Inductive Circuit (*RL*-Circuit)



$V = V_0 \sin\omega t$

Fig. 24.9

(1) Applied voltage : $V = \sqrt{V_R^2 + V_L^2}$

(2) Impedance : $Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2} = \sqrt{R^2 + 4\pi^2\nu^2 L^2}$

(3) Current : $i = i_0 \sin(\omega t - \phi)$

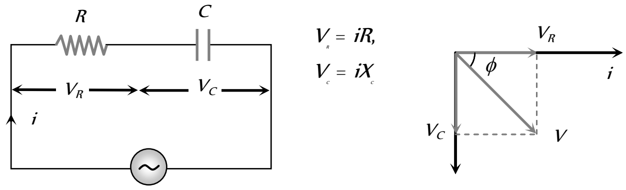
(4) Peak current $i_0 = \dfrac{V_0}{Z} = \dfrac{V_0}{\sqrt{R^2 + X_L^2}} = \dfrac{V_0}{\sqrt{R^2 + 4\pi^2\nu^2 L^2}}$

(5) Phase difference : $\phi = \tan^{-1}\dfrac{X_L}{R} = \tan^{-1}\dfrac{\omega L}{R}$

(6) Power factor : $\cos\phi = \dfrac{R}{\sqrt{R^2 + X_L^2}}$

(7) Leading quantity : Voltage

Resistive, Capacitive Circuit (*RC*-Circuit)



$V = V_0 \sin\omega t$

Fig. 24.10

(1) Applied voltage : $V = \sqrt{V_R^2 + V_C^2}$

(2) Impedance : $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}$

(3) Current : $i = i_0 \sin(\omega t + \phi)$

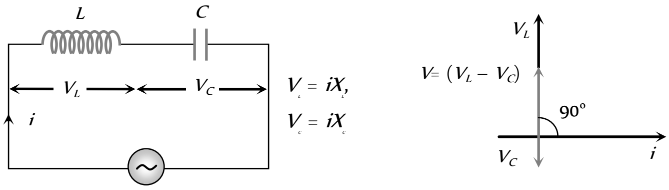
(4) Peak current : $i_0 = \dfrac{V_0}{Z} = \dfrac{V_0}{\sqrt{R^2 + X_C^2}} = \dfrac{V_0}{\sqrt{R^2 + \dfrac{1}{4\pi^2\nu^2 C^2}}}$

(5) Phase difference : $\phi = \tan^{-1}\dfrac{X_C}{R} = \tan^{-1}\dfrac{1}{\omega CR}$

(6) Power factor : $\cos\phi = \dfrac{R}{\sqrt{R^2 + X_C^2}}$

(7) Leading quantity : Current

Inductive, Capacitive Circuit (*LC*-Circuit)



$V = V_0 \sin\omega t$

Fig. 24.11

(1) Applied voltage : $V = V_L - V_C$

(2) Impedance : $Z = X_L - X_C = X$

(3) Current : $i = i_0 \sin\left(\omega t \pm \dfrac{\pi}{2}\right)$

(4) Peak current : $i_0 = \dfrac{V_0}{Z} = \dfrac{V_0}{X_L - X_C} = \dfrac{V_0}{\omega L - \dfrac{1}{\omega C}}$

(5) Phase difference : $\phi = 90^\circ$

(6) Power factor : $\cos\phi = 0$

(7) Leading quantity : Either voltage or current

Series *RLC*-Circuit

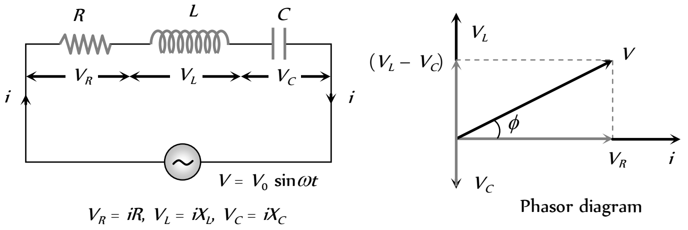


Fig. 24.12

(1) **Equation of current :** $i = i_0 \sin(\omega t \pm \phi)$; where $i_0 = \dfrac{V_0}{Z}$

(2) **Equation of voltage :** From phasor diagram

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

(3) **Impedance of the circuit :**

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

(4) **Phase difference :** From phasor diagram

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{\omega L - \dfrac{1}{\omega C}}{R} = \frac{2\pi\nu L - \dfrac{1}{2\pi\nu C}}{R}$$

(5) **If net reactance is inductive :** Circuit behaves as *LR* circuit

(6) **If net reactance is capacitive :** Circuit behave as *CR* circuit

(7) **If net reactance is zero :** Means $X = X_L - X_C = 0$

$\Rightarrow X_L = X_C$. This is the condition of resonance

(8) **At resonance** (series resonant circuit)

(i) $X_L = X_C \Rightarrow Z_{min} = R$ *i.e.* circuit behaves as resistive circuit

(ii) $V_L = V_C \Rightarrow V = V_R$ *i.e.* whole applied voltage appeared across the resistance

(iii) Phase difference : $\phi = 0° \Rightarrow$ p.f. = $\cos\phi = 1$

(iv) Power consumption $P = V_{rms} i_{rms} = \dfrac{1}{2} V_0 i_0$

(v) Current in the circuit is maximum and it is $i_0 = \dfrac{V_0}{R}$

(vi) These circuit are used for voltage amplification and as selector circuits in wireless telegraphy.

(9) **Resonant frequency** (Natural frequency)

At resonance $X_L = X_C \;\Rightarrow\; \omega_0 L = \dfrac{1}{\omega_0 C} \;\Rightarrow\; \omega_0 = \dfrac{1}{\sqrt{LC}} \dfrac{rad}{sec}$

$$\Rightarrow \nu_0 = \frac{1}{2\pi\sqrt{LC}} Hz \text{ (or } cps)$$

(Resonant frequency doesn't depend upon the resistance of the circuit)

(10) **Half power frequencies and band width :** The frequencies at which the power in the circuit is half of the maximum power (The power at resonance), are called half power frequencies.

(i) The current in the circuit at half power frequencies (HPF) is $\dfrac{1}{\sqrt{2}}$ or 0.707 or 70.7% of maximum current (current at resonance).

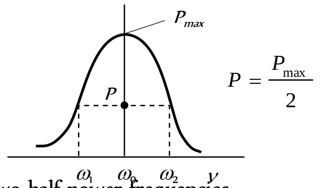


Fig. 24.13

(ii) There are two half power frequencies

(a) $\omega_1 \rightarrow$ called lower half power frequency. At this frequency the circuit is capacitive.

(b) $\omega_2 \rightarrow$ called upper half power frequency. It is greater than ω_0. At this frequency the circuit is inductive.

(iii) Band width $(\Delta\omega)$: The difference of half power frequencies ω_1 and ω_2 is called band width $(\Delta\omega)$ and $\Delta\omega = \omega_2 - \omega_1$. For series resonant circuit it can be proved $\Delta\omega = \left(\dfrac{R}{L}\right)$

(11) **Quality factor (*Q*-factor) of series resonant circuit**

(i) The characteristic of a series resonant circuit is determined by the quality factor (Q - factor) of the circuit.

(ii) It defines sharpness of i - ν curve at resonance when Q - factor is large, the sharpness of resonance curve is more and vice-versa.

(iii) Q - factor also defined as follows

$$Q\text{ - factor } = 2\pi \times \frac{\text{Max. energy stored}}{\text{Energy dissipation}}$$

$$= \frac{2\pi}{T} \times \frac{\text{Max. energy stored}}{\text{Mean power dissipated}} = \frac{\text{Resonant frequency}}{\text{Band width}} = \frac{\omega_0}{\Delta\omega}$$

(iv) Q - factor $= \dfrac{V_L}{V_R}$ or $\dfrac{V_C}{V_R} = \dfrac{\omega_0 L}{R}$ or $\dfrac{1}{\omega_0 CR}$

$$\Rightarrow Q\text{ - factor} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

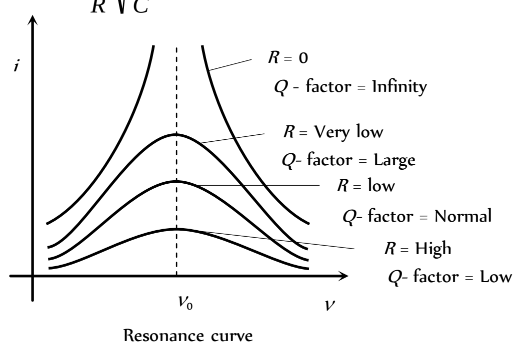


Fig. 24.14

Parallel *RLC* Circuits

$$i_R = \frac{V_0}{R} = V_0 G$$

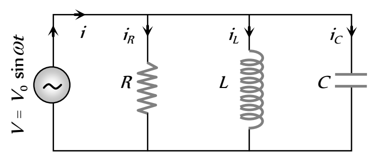


Fig. 24.15

$$i_L = \frac{V_0}{X_L} = V_0 S_L$$

$$i_C = \frac{V_0}{X_C} = V_0 S_C$$

(1) **Current and phase difference :** From phasor diagram current $i = \sqrt{i_R^2 + (i_C - i_L)^2}$ and phase difference $\phi = \tan^{-1}\frac{(i_C - i_L)}{i_R} = \tan^{-1}\frac{(S_C - S_L)}{G}$

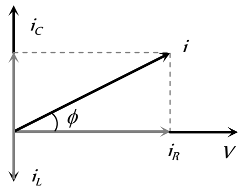


Fig. 24.16

(2) **Admittance (Y) of the circuit :** From equation of current

$$\frac{V_0}{Z} = \sqrt{\left(\frac{V_0}{R}\right)^2 + \left(\frac{V_0}{X_L} - \frac{V_0}{X_C}\right)^2}$$

$$\Rightarrow \frac{1}{Z} = Y = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2} = \sqrt{G^2 + (S_L - S_C)^2}$$

(3) **Resonance :** At resonance (i) $i_C = i_L \Rightarrow i_{\min} = i_R$

(ii) $\frac{V}{X_C} = \frac{V}{X_L} \Rightarrow S_C = S_L \Rightarrow \Sigma S = 0$

(iii) $Z_{\max} = \frac{V}{i_R} = R$

(iv) $\phi = 0 \Rightarrow$ p.f. $= \cos\phi = 1 =$ maximum

(v) Resonant frequency $\Rightarrow \nu = \frac{1}{2\pi\sqrt{LC}}$

(4) **Parallel LC circuits :** If inductor has resistance (R) and it is connected in parallel with capacitor as shown

(i) **At resonance**

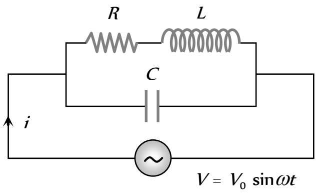


Fig. 24.17

(a) $Z_{\max} = \frac{1}{Y_{\min}} = \frac{L}{CR}$

(b) Current through the circuit is minimum and $i_{\min} = \frac{V_0 CR}{L}$

(c) $S_L = S_C \Rightarrow \frac{1}{X_L} = \frac{1}{X_C} \Rightarrow X = \infty$

(d) Resonant frequency $\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}\ \frac{rad}{sec}$ or

$\nu_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}\ Hz$ (Condition for parallel resonance is $R < \sqrt{\frac{L}{C}}$)

(e) Quality factor of the circuit $= \frac{1}{CR} \cdot \frac{1}{\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}}$. In the state of resonance the quality factor of the circuit is equivalent to the current amplification of the circuit.

(ii) **If inductance has no resistance :** If $R = 0$ then circuit becomes parallel LC circuit as shown

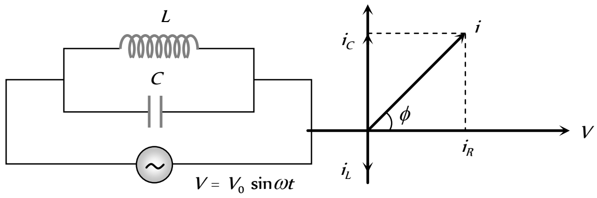


Fig. 24.18

Condition of resonance : $i_C = i_L \Rightarrow \frac{V}{X_C} = \frac{V}{X_L}$

$\Rightarrow X_C = X_L$. At resonance current i in the circuit is zero and impedance is infinite. Resonant frequency : $\nu_0 = \frac{1}{2\pi\sqrt{LC}}\ Hz$

Wattless Current

In an ac circuit $R = 0 \Rightarrow \cos\phi = 0$ so $P = 0$ *i.e.* in resistance less circuit the power consumed is zero. Such a circuit is called the wattless circuit and the current flowing is called the wattless current.

or

The component of current which does not contribute to the average power dissipation is called wattless current

(i) The average of wattless component over one cycle is zero

(ii) Amplitude of wattless current $= i\sin\phi$

and *r.m.s.* value of wattless current $= i_{rms}\sin\phi = \frac{i_0}{\sqrt{2}}\sin\phi$.

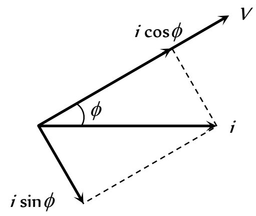


Fig. 24.19

It is quadrature (90) with voltage.

Choke Coil

Choke coil (or ballast) is a device having high inductance and negligible resistance. It is used to control current in ac circuits and is used in fluorescent tubes. The power loss in a circuit containing choke coil is least.

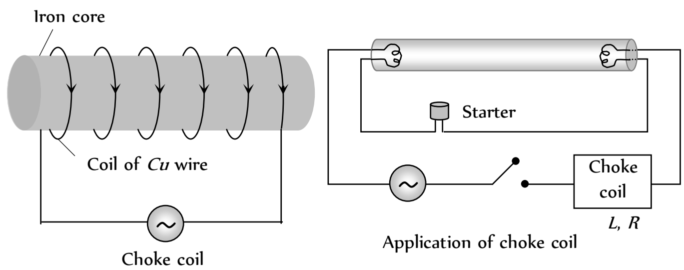


Fig. 24.20

(1) It consist of a Cu coil wound over a soft iron laminated core.

(2) Thick Cu wire is used to reduce the resistance (R) of the circuit.

(3) Soft iron is used to improve inductance (L) of the circuit.

(4) The inductive reactance or effective opposition of the choke coil is given by $X_L = \omega L = 2\pi\nu L$

(5) For an ideal choke coil $r = 0$, no electric energy is wasted *i.e.* average power $P = 0$.

(6) In actual practice choke coil is equivalent to a $R - L$ circuit.

(7) Choke coil for different frequencies are made by using different substances in their core.

For low frequency L should be large thus iron core choke coil is used. For high frequency ac circuit, L should be small, so air cored choke coil is used.

Tips & Tricks

☞ If ac is produced by a generator having a large number of poles then it's frequency

$$\nu = \frac{\text{Number of poles} \times \text{rotation per second}}{2} = \frac{P \times n}{2}$$

Where P is the number of poles; n is the rotational frequency of the coil.

✍ Alternating current in electric wires, bulbs etc. flows 50 times in one direction and 50 times in the opposite direction in 1 *second*. Since in one cycle the current becomes zero twice, hence a bulb lights up 100 times and is off 100 times in one second (50 cycles) but due to persistence of vision, it appears lighted continuously.

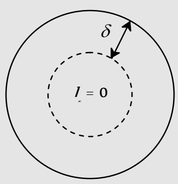
✍ ac is more dangerous than dc.

✍ The rate of change of ac is minimum at that instant when they are near their peak values.

✍ ac equipments such as electric motors, are more durable and convenient compared to dc equipments.

✍ **Skin Effect**

A direct current flows uniformly throughout the cross-section of the conductor. An alternating current, on the other hand, flows mainly along the surface of the conductor. This effect is known as skin effect. the reason is that when alternating current flows through a conductor, the flux changes in the inner part of the conductor are higher. Therefore the inductance of the inner part is higher than that of the outer part. Higher the frequency of alternating current, more is the skin effect.



The depth upto which ac current flows through a wire is called skin depth (δ).

Ordinary Thinking

Objective Questions

Alternating Current, Voltage and Power

1. The power is transmitted from a power house on high voltage ac because **[CPMT 1984, 85]**

(a) Electric current travels faster at higher *volts*

(b) It is more economical due to less power wastage

(c) It is difficult to generate power at low voltage

(d) Chances of stealing transmission lines are minimized

2. The potential difference V and the current i flowing through an instrument in an ac circuit of frequency f are given by $V = 5\cos\omega t$ *volts* and $I = 2\sin\omega t$ *amperes* (where $\omega = 2\pi f$). The power dissipated in the instrument is

[CPMT 1977, 80; MP PET 1999]

(a) Zero (b) 10 W

(c) 5 W (d) 2.5 W

3. In an ac circuit, V and I are given by

$V = 100\sin(100\,t)$ *volts*, $I = 100\sin\left(100t + \frac{\pi}{3}\right) mA$. The power dissipated in circuit is

[MP PET 1989; RPET 1999; MP PMT 1999, 2002]

(a) 10^4 *watt* (b) 10 *watt*

(c) 2.5 *watt* (d) 5 *watt*

4. Alternating current can not be measured by dc ammeter because

(a) ac cannot pass through dc ammeter

(b) Average value of complete cycle is zero

(c) ac is virtual

(d) ac changes its direction

5. The resistance of a coil for dc is in ohms. In ac, the resistance

(a) Will remain same (b) Will increase

(c) Will decrease (d) Will be zero

6. If instantaneous current is given by $i = 4\cos(\omega t + \phi)$ *amperes*, then the *r.m.s.* value of current is [RPET 2000]

(a) 4 amperes (b) $2\sqrt{2}$ amperes

(c) $4\sqrt{2}$ amperes (d) Zero amperes

7. In an ac circuit, peak value of voltage is 423 *volts*. Its effective voltage is [JIPMER 1997]

(a) 400 *volts* (b) 323 *volts*

(c) 300 *volts* (d) 340 *volts*

8. In an ac circuit $I = 100\sin 200\pi t$. The time required for the current to achieve its peak value will be [DPMT 2003]

(a) $\frac{1}{100}\,sec$ (b) $\frac{1}{200}\,sec$

(c) $\frac{1}{300}\,sec$ (d) $\frac{1}{400}\,sec$

9. The peak value of an Alternating current is 6 *amp*, then *r.m.s.* value of current will be

(a) 3 A (b) $3\sqrt{3}\,A$

(c) $3\sqrt{2}\,A$ (d) $2\sqrt{3}\,A$

10. A generator produces a voltage that is given by $V = 240\sin 120\,t$, where t is in seconds. The frequency and *r.m.s.* voltage are [MP PET 1993; MP PMT 1990]

(a) 60 *Hz* and 240 V (b) 19 *Hz* and 120 V

(c) 19 *Hz* and 170 V (d) 754 *Hz* and 70 V

11. If E_0 represents the peak value of the voltage in an ac circuit, the *r.m.s.* value of the voltage will be

[CPMT 1972; MP PMT 1996]

(a) $\frac{E_0}{\pi}$ (b) $\frac{E_0}{2}$

(c) $\frac{E_0}{\sqrt{\pi}}$ (d) $\frac{E_0}{\sqrt{2}}$

12. The peak value of 220 *volts* of ac mains is

[CPMT 1990; MP PMT 1999; MP PET 2000; RPET2001]

(a) 155.6 *volts* (b) 220.0 *volts*

(c) 311.0 *volts* (d) 440 *volts*

13. A sinusoidal ac current flows through a resistor of resistance R. If the peak current is I_p, then the power dissipated is

[MP PMT 1991]

(a) $I_p^2 R\cos\theta$ (b) $\frac{1}{2}I_p^2 R$

(c) $\frac{4}{\pi}I_p^2 R$ (d) $\frac{1}{\pi}I_p^2 R$

[AIEEE 2004]

14. A 40 Ω electric heater is connected to a 200 V, 50 Hz mains supply. The peak value of electric current flowing in the circuit is approximately [MP PET 1992]

(a) 2.5 A (b) 5.0 A

(c) 7 A (d) 10 A

15. The frequency of ac mains in India is

[CPMT 1987]

[NCERT 1974; MP PMT/PET 1988; RPMT 1997; RPET 2000]

(a) 30 *c/s* or *Hz* (b) 50 *c/s* or *Hz*

(c) 60 *c/s* or *Hz* (d) 120 *c/s* or *Hz*

16. The *r.m.s.* value of an ac of 50 *Hz* is 10 *amp*. The time taken by the alternating current in reaching from zero to maximum value and the peak value of current will be

[MP PET 1993; KCET 2003]

(a) 2×10^{-2} *sec* and 14.14 *amp*

(b) 1×10^{-2} *sec* and 7.07 *amp*

(c) 5×10^{-3} *sec* and 7.07 *amp*

(d) 5×10^{-3} *sec* and 14.14 *amp*

17. The root mean square value of the alternating current is equal to

(a) Twice the peak value

(b) Half the peak value

(c) $\frac{1}{\sqrt{2}}$ times the peak value

(d) Equal to the peak value

18. The peak value of an alternating e.m.f. E is given by $E = E_0\cos\omega t$ is 10 *volts* and its frequency is 50 *Hz*. At time $t = \frac{1}{600}\,sec$, the instantaneous e.m.f. is

[MP PMT 1990; MP PET 2004]

(a) 10 V (b) $5\sqrt{3}\,V$

(c) 5 V (d) 1 V

19. If a current I given by $I_0\sin\left(\omega t - \frac{\pi}{2}\right)$ flows in an ac circuit across which an ac potential of $E = E_0\sin\omega t$ has been applied, then the power consumption P in the circuit will be

[CPMT 1986; Roorkee 1992; SCRA 1996; MP PMT 1994; RPET 2001; MP PET 2001, 02]

(a) $P = \frac{E_0 I_0}{\sqrt{2}}$ (b) $P = \sqrt{2}E_0 I_0$

(c) $P = \frac{E_0 I_0}{2}$ (d) $P = 0$

20. In an ac circuit, the instantaneous values of e.m.f. and current are $e = 200 \sin 314\, t$ *volt* and $i = \sin\left(314t + \frac{\pi}{3}\right)$ *ampere*. The average power consumed in *watt* is [NCERT 1990; RPMT 1997]

(a) 200 (b) 100

(c) 50 (d) 25

21. An ac generator produced an output voltage $E = 170 \sin 377\, t\, volts$, where t is in seconds. The frequency of ac voltage is [MP PET 1994]

(a) 50 *Hz* (b) 110 *Hz*

(c) 60 *Hz* (d) 230 *Hz*

22. In general in an alternating current circuit [MP PMT 1994]

(a) The average value of current is zero

(b) The average value of square of the current is zero

(c) Average power dissipation is zero

(d) The phase difference between voltage and current is zero

23. An alternating current is given by the equation $i = i_1 \cos \omega t + i_2 \sin \omega t$. The *r.m.s.* current is given by [MP PMT 1994]

(a) $\frac{1}{\sqrt{2}}(i_1 + i_2)$ (b) $\frac{1}{\sqrt{2}}(i_i + i_2)^2$

(c) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$ (d) $\frac{1}{2}(i_1^2 + i_2^2)^{1/2}$

24. In an ac circuit, the current is given by $i = 5 \sin\left(100\, t - \frac{\pi}{2}\right)$ and the ac potential is $V = 200 \sin(100)\, volt$. Then the power consumption is [CBSE PMT 1995; MH CET 1999; CPMT 2002]

(a) 20 *watts* (b) 40 *watts*

(c) 1000 *watts* (d) 0 *watt*

25. An electric lamp is connected to 220 *V*, 50 *Hz* supply. Then the peak value of voltage is [AFMC 1996]

(a) 210 V (b) 211 *V*

(c) 311 V (d) 320 *V*

26. In a circuit, the value of the alternating current is measured by hot wire ammeter as 10 *ampere*. Its peak value will be [MP PET 1996; AMU (Med.) 1999; KCET (Engg./Med.) 2000; CPMT 2003]

(a) 10 *A* (b) 20 *A*

(c) 14.14 *A* (d) 7.07 *A*

27. The voltage of domestic ac is 220 *volt*. What does this represent

(a) Mean voltage

(b) Peak voltage

(c) Root mean voltage

(d) Root mean square voltage

28. The *r.m.s.* voltage of domestic electricity supply is 220 *volt*. Electrical appliances should be designed to withstand an instantaneous voltage of

(a) 220 *V* (b) 310 *V*

(c) 330 *V* (d) 440 *V*

29. The process by which ac is converted into dc is known as

(b) Purification (b) Amplification

(c) Rectification (d) Current amplification

30. In an ac circuit with voltage *V* and current *I*, the power dissipated is [CBSE PMT 1997]

(a) *VI*

(b) $\frac{1}{2} VI$

(c) $\frac{1}{\sqrt{2}} VI$

(d) Depends on the phase between *V* and *I*

31. For an ac circuit $V = 15 \sin \omega t$ and $I = 20 \cos \omega t$ the average power consumed in this circuit is [RPET 1999]

(a) 300 *Watt* (b) 150 *Watt*

(c) 75 *Watt* (d) zero

32. A bulb is connected first with dc and then ac of same voltage then it will shine brightly with [RPET 2000]

(a) AC

(b) DC

(c) Brightness will be in ratio 1/1.4

(d) Equally with both

33. An ac supply gives 30 *V r.m.s.* which passes through a 10 Ω resistance. The power dissipated in it is [AMU (Med.) 2001]

(a) $90\sqrt{2}\, W$ (b) $90\, W$

(c) $45\sqrt{2}\, W$ (d) $45\, W$

34. The frequency of an alternating voltage is 50 *cycles/sec* and its amplitude is 120 *V*. Then the *r.m.s.* value of voltage is [BHU 1999; MH CET (Med.) 2001; KCET (Med.) 2001; MH CET 2003]

(a) 101.3 *V* (b) 84.8 *V*

(c) 70.7 *V* (d) 56.5 *V*

35. A resistance of 20 *ohms* is connected to a source of an alternating potential $V = 220 \sin(100\pi t)$. The time taken by the current to change from its peak value to *r.m.s* value is [MP PET 2001]

(a) 0.2 *sec* (b) 0.25 *sec*

(c) 25×10^{-3} *sec* (d) 2.5×10^{-3} *sec*

36. Voltage and current in an ac circuit are given by $V = 5 \sin\left(100\pi t - \frac{\pi}{6}\right)$ and $I = 4 \sin\left(100\pi t + \frac{\pi}{6}\right)$ [Kerala PET 2001] [MP PMT 1996]

(a) Voltage leads the current by 30^o

(b) Current leads the voltage by 30^o

(c) Current leads the voltage by 60^o

(d) Voltage leads the current by 60^o

37. If an ac main supply is given to be 220 *V*. What would be the average e.m.f. during a positive half cycle [MH CET 2002]

(a) 198 *V* (b) 386 *V*

(c) 256 *V* (d) None of these

38. In an ac circuit, the *r.m.s.* value of current, I_{rms} is related to the peak current, I_0 by the relation [AFMC 2002]

(a) $I_{rms} = \frac{1}{\pi} I_0$ (b) $I_{rms} = \frac{1}{\sqrt{2}} I_0$

(c) $I_{rms} = \sqrt{2} I_0$ (d) $I_{rms} = \pi I_0$

39. An alternating voltage is represented as $E = 20\sin 300t$. The average value of voltage over one cycle will be

[MP PMT 2002]

(a) Zero (b) 10 *volt*

(c) $20\sqrt{2}$ *volt* (d) $\frac{20}{\sqrt{2}}$ *volt*

40. The ratio of peak value and *r.m.s* value of an alternating current is

(a) 1 (b) $\frac{1}{2}$

(c) $\sqrt{2}$ (d) $1/\sqrt{2}$

41. A 280 *ohm* electric bulb is connected to 200 *V* electric line. The peak value of current in the bulb will be

[MP PET 2002]

(a) About one ampere (b) Zero

(c) About two ampere (d) About four ampere

42. An ac source is rated at 220 *V*, 50 *Hz*. The time taken for voltage to change from its peak value to zero is

[Orissa JEE 2003]

(a) 50 *sec* (b) 0.02 *sec*

(c) 5 *sec* (d) 5×10^{-3} *sec*

43. If the value of potential in an ac, circuit is 10 *V*, then the peak value of potential is [CPMT 2003]

(a) $\frac{10}{\sqrt{2}}$ (b) $10\sqrt{2}$

(c) $20\sqrt{2}$ (d) $\frac{20}{\sqrt{2}}$

44. A lamp consumes only 50% of peak power in an a.c. circuit. What is the phase difference between the applied voltage and the circuit current [MP PMT 2004]

(a) $\frac{\pi}{6}$ (b) $\frac{\pi}{3}$

(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{2}$

45. If an alternating voltage is represented as

$E = 141\sin(628\,t)$, then the *rms* value of the voltage and the frequency are respectively [Kerala PET 2005]

(a) $141V, 628Hz$ (b) $100V, 50Hz$

(c) $100V, 100Hz$ (d) $141V,\ 100Hz$

46. The maximum value of a.c. voltage in a circuit is 707 *V*. Its *rms* value is [MP PET 2005]

(a) 70.7 *V* (b) 100 *V*

(c) 500 *V* (d) 707 *V*

ac Circuits

1. Choke coil works on the principle of [MP PET/PMT 1988]

(a) Transient current (b) Self induction

(c) Mutual induction (d) Wattless current

2. A choke coil has [RPET 1999; AIIMS 1999]

(a) High inductance and low resistance

(b) Low inductance and high resistance

(c) High inductance and high resistance

(d) Low inductance and low resistance

3. Choke coil is used to control [CPMT 1984]

(a) ac (b) dc

(c) Both ac and dc (d) Neither ac nor dc

4. Current in the circuit is wattless, if

(a) Inductance in the circuit is zero

(b) Resistance in the circuit is zero

[MP PMT 2002]

(c) Current is alternating

(d) Resistance and inductance both are zero

5. The phase angle between e.m.f. and current in *LCR* series ac circuit is [MP PMT/PET 1998]

(a) 0 to $\pi/2$ (b) $\pi/4$

(c) $\pi/2$ (d) π

6. A choke coil is preferred to a rheostat in ac circuit as

(a) It consumes almost zero power

(b) It increases current

(c) It increases power

(d) It increases voltage

7. An alternating e.m.f. is applied to purely capacitive circuit. The phase relation between e.m.f. and current flowing in the circuit is **or**

In a circuit containing capacitance only

[MP PET 1996; AIIMS 1997]

(a) e.m.f. is ahead of current by $\pi/2$

(b) Current is ahead of e.m.f. by $\pi/2$

(c) Current lags behind e.m.f. by π

(d) Current is ahead of e.m.f. by π

8. An ac source is connected to a resistive circuits. Which of the following is true [CPMT 1985]

(a) Current leads the voltage and both are in same phase

(b) Current lags behind the voltage and both are in same phase

(c) Current and voltage are in same phase

(d) Any of the above may be true depending upon the value of resistance

9. The average power dissipated in a pure inductor of inductance *L* when an ac current is passing through it, is

[CPMT 1974; RPMT 1997; MP PET 1999]

(a) $\frac{1}{2}LI^2$ (b) $\frac{1}{4}LI^2$

(c) $2\,Li^2$ (d) Zero

(Inductance of the coil *L* and current *I*)

10. An alternating current of frequency $'f'$ is flowing in a circuit containing a resistance R and a choke L in series. The impedance of this circuit is

[CPMT 1978; MP PMT 1993; MP PET 1999; AIIMS 2000; Pb. PET 2004; RPET 2001, 03]

(a) $R + 2\pi fL$ (b) $\sqrt{R^2 + 4\pi^2 f^2 L^2}$

(c) $\sqrt{R^2 + L^2}$ (d) $\sqrt{R^2 + 2\pi fL}$

11. A resonant ac circuit contains a capacitor of capacitance $10^{-6} F$ and an inductor of $10^{-4} H$. The frequency of electrical oscillations will be

(a) $10^5\ Hz$ (b) 10 Hz

(c) $\frac{10^5}{2\pi} Hz$ (d) $\frac{10}{2\pi} Hz$

12. Power delivered by the source of the circuit becomes maximum, when [DCE 2004]

(a) $\omega L = \omega C$ (b) $\omega L = \frac{1}{\omega C}$

(c) $\omega L = -\left(\frac{1}{\omega C}\right)^2$ (d) $\omega L = \sqrt{\omega C}$

13. An alternating voltage is connected in series with a resistance R and an inductance L If the potential drop across the resistance is 200 V and across the inductance is 150 V, then the applied voltage is

(a) 350 V (b) 250 V

(c) 500 V (d) 300 V

14. An inductive circuit contains resistance of 10 Ω and an inductance of 20 H. If an ac voltage of 120 V and frequency 60 Hz is applied to this circuit, the current would be nearly

(a) 0.32 *amp* (b) 0.016 *amp*

(c) 0.48 *amp* (d) 0.80 *amp*

15. Same current is flowing in two alternating circuits. The first circuit contains only inductance and the other contains only a capacitor. If the frequency of the e.m.f. of ac is increased, the effect on the value of the current will be [MP PET 1993]

(a) Increases in the first circuit and decreases in the other

(b) Increases in both the circuits

(c) Decreases in both the circuits

(d) Decreases in the first circuit and increases in the other

16. A capacitor is a perfect insulator for

(a) Alternating currents (b) Direct currents

(c) Both ac and dc (d) None of these

17. In a circuit containing an inductance of zero resistance, the e.m.f. of the applied ac voltage leads the current by

[CPMT 1990]

(a) 90 (b) 45

(c) 30 (d) 0

18. In a pure inductive circuit or In an ac circuit containing inductance only, the current

[MP PMT 1993; CPMT 1996; Kerala PET 2002]

(a) Leads the e.m.f. by 90

(b) Lags behind the e.m.f. by 90

(c) Sometimes leads and sometime lags behind the e.m.f.

(d) Is in phase with the e.m.f.

19. A 20 *volts* ac is applied to a circuit consisting of a resistance and a coil with negligible resistance. If the voltage across the resistance is 12 V, the voltage across the coil is

[MP PMT 1989; RPMT 1997]

(a) 16 *volts* (b) 10 *volts*

(c) 8 *volts* (d) 6 *volts*

20. A resistance of 300 Ω and an inductance of $\frac{1}{\pi}$ henry are connected in series to a ac voltage of 20 *volts* and 200 Hz frequency. The phase angle between the voltage and current is

(a) $\tan^{-1}\frac{4}{3}$ (b) $\tan^{-1}\frac{3}{4}$

(c) $\tan^{-1}\frac{3}{2}$ (d) $\tan^{-1}\frac{2}{5}$

21. The power factor of LCR circuit at resonance is

[MP PMT 1991; RPMT 1999; RPET 2001; UPSEAT 1999]

(a) 0.707 (b) 1

(c) Zero (d) 0.5

22. An inductance of 1 mH a condenser of 10 μF and a resistance of 50 Ω are connected in series. The reactances of inductor and condensers are same. The reactance of either of them will be [CPMT 1990]

(a) 100 Ω (b) 30 Ω

(c) 3.2 Ω (d) 10 Ω

23. The natural frequency of a L-C circuit is equal to

[CPMT 1978, 97]

(a) $\frac{1}{2\pi}\sqrt{LC}$ (b) $\frac{1}{2\pi\sqrt{LC}}$

(c) $\frac{1}{2\pi}\sqrt{\frac{L}{C}}$ (d) $\frac{1}{2\pi}\sqrt{\frac{C}{L}}$

24. An alternating voltage $E = 200\sqrt{2}\sin(100\,t)$ is connected to a 1 *microfarad* capacitor through an ac ammeter. The reading of the ammeter shall be [NCERT 1984; MNR 1995; MP PET 1999; RPET 1999; UPSEAT 2000]

(a) 10 mA (b) 20 mA

(c) 40 mA (d) 80 mA

25. An ac circuit consists of an inductor of inductance 0.5 H and a capacitor of capacitance 8 μF in series. The current in the circuit is maximum when the angular frequency of ac source is

(a) 500 *rad/sec* (b) 2 × 10 *rad/sec*

(c) 4000 *rad/sec* (d) 5000 *rad/sec*

26. The average power dissipation in a pure capacitance in ac circuit is [DPMT 198

(a) $\frac{1}{2}CV^2$ (b) CV^2

(c) $\frac{1}{4}CV^2$ (d) Zero

27. In a region of uniform magnetic induction $B = 10^{-2}\ tesla$, a circular coil of radius 30 cm and resistance π *ohm* is rotated about an axis which is perpendicular to the direction of B and which forms

a diameter of the coil. If the coil rotates at 200 *rpm* the amplitude of the alternating current induced in the coil is

(a) 4π *mA* (b) 30 *mA*

(c) 6 *mA* (d) 200 *mA*

28. An inductive circuit contains a resistance of 10 *ohm* and an inductance of 2.0 *henry*. If an ac voltage of 120 *volt* and frequency of 60 *Hz* is applied to this circuit, the current in the circuit would be nearly [CPMT 1990; MP PET 2002]

(a) 0.32 *amp* (b) 0.16 *amp*

(c) 048 *amp* (d) 0.80 *amp*

29. In a *LCR* circuit having *L* = 8.0 *henry*, *C* = 0.5 μF and *R* = 100 *ohm* in series. The resonance frequency in *per second* is

(a) 600 *radian* (b) 600 *Hz*

(c) 500 *radian* (d) 500 *Hz*

30. In *LCR* circuit, the capacitance is changed from *C* to 4*C*. For the same resonant frequency, the inductance should be changed from *L* to [MP PMT 1986; BHU 1998]

(a) 2*L* (b) *L* / 2

(c) *L* / 4 (d) 4 *L*

31. A 120 *volt* ac source is connected across a pure inductor of inductance 0.70 henry. If the frequency of the source is 60 *Hz*, the current passing through the inductor is

[MP PET 1994]

(a) 4.55 *amps* (b) 0.355 *amps*

(c) 0.455 amps (d) 3.55 amps

32. The impedance of a circuit consists of 3 *ohm* resistance and 4 *ohm* reactance. The power factor of the circuit is

[MP PMT 1994]

(a) 0.4 (b) 0.6

(c) 0.8 (d) 1.0

33. *L*, *C* and *R* denote inductance, capacitance and resistance respectively. Pick out the combination which does not have the dimensions of frequency [MP PMT 1994]

(a) $\frac{1}{RC}$ (b) $\frac{R}{L}$

(c) $\frac{1}{\sqrt{LC}}$ (d) $\frac{C}{L}$

34. The power factor of a good choke coil is [MP PMT 1994]

(a) Nearly zero (b) Exactly zero

(c) Nearly one (d) Exactly one

35. If resistance of 100 Ω , inductance of 0.5 *henry* and capacitance of $10\times10^{-6}F$ are connected in series through 50 *Hz* ac supply, then impedance is [BHU 1995]

(a) 1.876 (b) 18.76

(c) 189.72 (d) 101.3

36. An alternating current source of frequency 100 *Hz* is joined to a combination of a resistance, a capacitance and a coil in series. The potential difference across the coil, the resistance and the capacitor is 46, 8 and 40 *volt* respectively. The electromotive force of alternating current source in *volt* is

[MP PET 1995]

(a) 94 (b) 14

(c) 10 [CBSE PMT 1990] (d) 76

37. A 10 *ohm* resistance, 5 *mH* coil and 10 μF capacitor are joined in series. When a suitable frequency alternating current source is joined to this combination, the circuit resonates. If the resistance is halved, the resonance frequency [MP PET 1995]

(a) Is halved (b) Is doubled

(c) Remains unchanged (d) In quadrupled

38. *L*, *C* and *R* represent physical quantities inductance, capacitance and resistance respectively. The combination representing dimension of frequency is
[CPMT 1990] [MP PET 1995; DCE 2001]

(a) *LC* (b) $(LC)^{-1/2}$

(c) $\left(\frac{L}{C}\right)^{-1/2}$ (d) $\frac{C}{L}$

39. In a series circuit $R = 300\ \Omega$, $L = 0.9\ H$, $C = 2.0\ \mu F$ and $\omega = 1000\ rad/sec$. The impedance of the circuit is

(a) 1300 Ω (b) 900 Ω

(c) 500 Ω (d) 400 Ω

40. In a *L-R* circuit, the value of *L* is $\left(\frac{0.4}{\pi}\right) henry$ and the value of *R* is 30 *ohm*. If in the circuit, an alternating *e.m.f.* of 200 *volt* at 50 cycles per sec is connected, the impedance of the circuit and current will be [MP PET 1996; DPMT 2003]

(a) $11.4\,\Omega, 17.5\,A$ (b) $30.7\,\Omega, 6.5A$

(c) $40.4\,\Omega, 5\,A$ (d) $50\,\Omega, 4A$

41. The reactance of a coil when used in the domestic ac power supply (220 *volt*, 50 *cycles*) is 100 *ohm*. The self inductance of the coil is nearly [MP PMT 1996]

(a) 3.2 *henry* (b) 0.32 *henry*

(c) 2.2 *henry* (d) 0.22 *henry*

42. In a series *LCR* circuit, operated with an ac of angular frequency ω , the total impedance is [MP PET 1996]

(a) $[R^2+(L\omega-C\omega)^2]^{1/2}$

(b) $\left[R^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]^{1/2}$

(c) $\left[R^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]^{-1/2}$

(d) $\left[(R\omega)^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]^{1/2}$

43. The reactance of a $25\,\mu F$ capacitor at the ac frequency of 4000 *Hz* is

(a) $\frac{5}{\pi}$ *ohm* (b) $\sqrt{\frac{5}{\pi}}$ *ohm*

(c) 10 *ohm* (d) $\sqrt{10}$ *ohm*

44. The frequency for which a $5\,\mu F$ capacitor has a reactance of $\frac{1}{1000}$ *ohm* is given by [MP PET 1997]

(a) $\frac{100}{\pi}\,MHz$ (b) $\frac{1000}{\pi}\,Hz$

(c) $\frac{1}{1000}\,Hz$ (d) 1000 *Hz*

45. An e.m.f. $E = 4\cos(1000t)$ *volt* is applied to an LR-circuit of inductance 3 *mH* and resistance 4 *ohms*. The amplitude of current in the circuit is [MP PMT 1997]

(a) $\frac{4}{\sqrt{7}}\,A$ (b) 1.0 *A*

(c) $\frac{4}{7}\,A$ (d) 0.8 *A*

46. In an ac circuit, a resistance of R *ohm* is connected in series with an inductance *L*. If phase angle between voltage and current be 45°, the value of inductive reactance will be

[MP PMT/PET 1998]

(a) $\frac{R}{4}$

(b) $\frac{R}{2}$

(c) R

(d) Cannot be found with the given data

47. A coil of inductance L has an inductive reactance of X_L in an AC circuit in which the effective current is *I*. The coil is made from a super-conducting material and has no resistance. The rate at which power is dissipated in the coil is

[MP PMT 1999]

(a) 0 (b) IX_L

(c) I^2X_L (d) IX_L^2

48. The phase difference between the current and voltage of *LCR* circuit in series combination at resonance is

[CPMT 1999; Pb. PET 2001]

(a) 0 (b) $\pi/2$

(c) π (d) $-\pi$

49. In a series resonant circuit, the ac voltage across resistance *R*, inductance *L* and capacitance *C* are 5 *V*, 10 *V* and 10 *V* respectively. The ac voltage applied to the circuit will be

[KCET 1994]

(a) 20 *V* (b) 10 *V*

(c) 5 *V* (d) 25 *V*

50. When 100 *volt* dc is applied across a coil, a current of 1 *amp* flows through it. When 100 volt ac at 50 cycle s^{-1} is applied to the same coil, only 0.5 ampere current flows. The impedance of the coil is

(a) $100\,\Omega$ (b) $200\,\Omega$

(c) $300\,\Omega$ (d) $400\,\Omega$

51. The coefficient of induction of a choke coil is 0.1*H* and resistance is $12\,\Omega$. If it is connected to an alternating current source of frequency 60 *Hz*, then power factor will be

[RPET 1997]

(a) 0.32 (b) 0.30

(c) 0.28 (d) 0.24

52. For series *LCR* circuit, wrong statement is [RPMT 1997]

(a) Applied e.m.f. and potential difference across resistance are in same phase

(b) Applied e.m.f. and potential difference at inductor coil have phase difference of $\pi/2$

(c) Potential difference at capacitor and inductor have phase difference of $\pi/2$

(d) Potential difference across resistance and capacitor have phase difference of $\pi/2$

53. In a purely resistive *ac* circuit, the current [Roorkee 1992]

(a) Lags behind the e.m.f. in phase

(b) Is in phase with the e.m.f.

(c) Leads the e.m.f. in phase

(d) Leads the e.m.f. in half the cycle and lags behind it in the other half

54. If an $8\,\Omega$ resistance and $6\,\Omega$ reactance are present in an ac series circuit then the impedance of the circuit will be

[MP PMT 2003]

(a) 20 *ohm* (b) 5 *ohm*

(c) 10 *ohm* (d) $14\sqrt{2}$ *ohm*

55. A 12 *ohm* resistor and a 0.21 henry inductor are connected in series to an ac source operating at 20 *volts*, 50 cycle/second. The phase angle between the current and the source voltage is

(a) 30° (b) 40°

(c) 80° (d) 90°

56. What will be the phase difference between virtual voltage and virtual current, when the current in the circuit is wattless

[RPET 1996]

(a) 90° (b) 45°

(c) 180° (d) 60°

57. The resonant frequency of a circuit is *f*. If the capacitance is made 4 times the initial values, then the resonant frequency will become

(a) $f/2$ (b) $2f$

(c) f (d) $f/4$

58. In the non-resonant circuit, what will be the nature of the circuit for frequencies higher than the resonant frequency

[RPET 1996]

(a) Resistive (b) Capacitive

(c) Inductive (d) None of the above

59. In an ac circuit, the potential difference across an inductance and resistance joined in series are respectively 16 *V* and 20 *V*. The total potential difference across the circuit is

[Bihar MEE 1995] [AFMC 1998; BHU 1999]

(a) 20.0 *V* (b) 25.6 *V*

(c) 31.9 *V* (d) 53.5 *V*

60. A 220 *V*, 50 *Hz* ac source is connected to an inductance of 0.2 *H* and a resistance of 20 *ohm* in series. What is the current in the circuit [MNR 1998; JIPMER 2001, 02]

(a) 10 *A* (b) 5 *A*

(c) 33.3 A (d) 3.33 A

61. An LCR circuit contains R = 50 Ω , L = 1 mH and C = 0.1 μF. The impedance of the circuit will be minimum for a frequency of [Bihar MEE 1995]

(a) $\frac{10^5}{2\pi} s^{-1}$ (b) $\frac{10^6}{2\pi} s^{-1}$

(c) $2\pi \times 10^5 s^{-1}$ (d) $2\pi \times 10^6 s^{-1}$

62. In a series LCR circuit, resistance $R = 10\Omega$ and the impedance $Z = 20\Omega$. The phase difference between the current and the voltage is [KCET (Engg./Med.) 1999]

(a) 30^o (b) 45^o

(c) 60^o (d) 90^o

63. A series ac circuit consist of an inductor and a capacitor. The inductance and capacitance is respectively 1 *henry* and $25\mu F$. If the current is maximum in circuit then angular frequency will be

(a) 200 (b) 100

(c) 50 (d) 200/2 π

64. An alternating e.m.f. of frequency $\nu \left(= \frac{1}{2\pi\sqrt{LC}} \right)$ is applied to a series LCR circuit. For this frequency of the applied e.m.f.

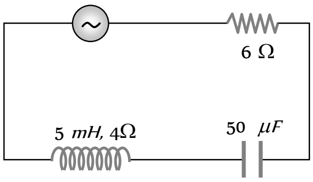
(a) The circuit is at resonance and its impedance is made up only of a reactive part

(b) The current in the circuit is in phase with the applied e.m.f. and the voltage across R equals this applied emf

(c) The sum of the p.d.'s across the inductance and capacitance equals the applied e.m.f. which is 180^o ahead of phase of the current in the circuit

(d) The quality factor of the circuit is $\omega L / R$ or $1/\omega CR$ and this is a measure of the voltage magnification (produced by the circuit at resonance) as well as the sharpness of resonance of the circuit

65. In the circuit shown below, the ac source has voltage $V = 20\cos(\omega t)$ volts with ω = 2000 *rad/sec*. the amplitude of the current will be nearest to [AMU (Engg.) 2000]



(a) $2A$

(b) $3.3A$

(c) $2/\sqrt{5}A$

(d) $\sqrt{5}A$

66. The value of the current through an inductance of $1H$ and of negligible resistance, when connected through an ac source of 200 V and 50 Hz, is [AFMC 2000]

(a) 0.637 A (b) 1.637 A

(c) 2.637A (d) 3.637 A

67. The quality factor of LCR circuit having resistance (R) and inductance (L) at resonance frequency (ω) is given by [AFMC 2000; CBSE PMT 2000]

(a) $\frac{\omega L}{R}$ (b) $\frac{R}{\omega L}$

(c) $\left(\frac{\omega L}{R}\right)^{1/2}$ (d) $\left(\frac{\omega L}{R}\right)^2$

68. Power factor is maximum in an LCR circuit when [RPET 2000]

(a) $X_L = X_C$ (b) $R = 0$

(c) $X_L = 0$ (d) $X_C = 0$

69. In an ac circuit the reactance of a coil is $\sqrt{3}$ times its resistance, the phase difference between the voltage across the coil to the current through the coil will be [KCET (Engg.) 2000]

(a) $\pi/3$ (b) $\pi/2$

(c) $\pi/4$ (d) $\pi/6$

70. The capacity of a pure capacitor is 1 *farad*. In dc circuits, its effective resistance will be [MP PMT 2000]

(a) Zero (b) Infinite

(c) 1 *ohm* (d) 1/2 *ohm*

71. In an ac circuit, the current lags behind the voltage by $\pi/3$. The components in the circuit are [RPMT 1999] [MP PMT 2000]

(a) R and L (b) R and C

(c) L and C (d) Only R

72. The reactance of a coil when used in the domestic ac power supply (220 *volts*, 50 cycles per second) is 50 *ohms*. The inductance of the coil is nearly [Roorkee 1999] [MP PMT 2000]

(a) 2.2 *henry* (b) 0.22 *henry*

(c) 1.6 *henry* (d) 0.16 *henry*

73. In an ac circuit, the power factor [Roorkee 2000]

(a) Is zero when the circuit contains an ideal resistance only

(b) Is unity when the circuit contains an ideal resistance only

(c) Is zero when the circuit contains an ideal inductance only

(d) Is unity when the circuit contains an ideal inductance only

74. A resistance of 40 *ohm* and an inductance of 95.5 *millihenry* are connected in series in a 50 *cycles/second* ac circuit. The impedance of this combination is very nearly [MP PET 2000]

(a) 30 *ohm* (b) 40 *ohm*

(c) 50 *ohm* (d) 60 *ohm*

75. For high frequency, a capacitor offers [CPMT 1999; CBSE PMT 1999; AFMC 2001; Pb. PET 2001; J & K CET 2004]

(a) More reactance (b) Less reactance

(c) Zero reactance (d) Infinite reactance

76. The coil of choke in a circuit [AIIMS 2001]

(a) Increases the current

(b) Decreases the current

(c) Does not change the current

(d) Has high resistance to dc circuit

77. In a circuit, the current lags behind the voltage by a phase difference of $\pi/2$. The circuit contains which of the following

(a) Only R (b) Only L

(c) Only C (d) R and C

78. The inductive reactance of an inductor of $\frac{1}{\pi}$ *henry* at 50 Hz frequency is [MP PET 2001, 02]

(a) $\frac{50}{\pi}$ *ohm* (b) $\frac{\pi}{50}$ *ohm*
(c) 100 *ohm* (d) 50 *ohm*

79. An oscillator circuit consists of an inductance of 0.5mH and a capacitor of 20 μF. The resonant frequency of the circuit is nearly
(a) 15.92 *Hz* (b) 159.2 *Hz*
(c) 1592 *Hz* (d) 15910 *Hz*

80. Reactance of a capacitor of capacitance $C\mu F$ for ac frequency $\frac{400}{\pi}$ *Hz* is 25Ω. The value *C* is [MH CET 2002]
(a) $50\mu F$ (b) $25\mu F$
(c) $100\mu F$ (d) $75\mu F$

81. The power factor of an ac circuit having resistance (*R*) and inductance (*L*) connected in series and an angular velocity ω is
(a) $R/\omega L$ (b) $R/(R^2+\omega^2L^2)^{1/2}$
(c) $\omega L/R$ (d) $R/(R^2-\omega^2L^2)^{1/2}$

82. A circuit has a resistance of 11Ω, an inductive reactance of 25Ω and a capacitative resistance of 18Ω. It is connected to an ac source of 260 *V* and 50*Hz*. The current through the circuit (in amperes) is
(a) 11 (b) 15
(c) 18 (d) 20

83. A 0.7 *henry* inductor is connected across a 120 *V* – 60 *Hz* ac source. The current in the inductor will be very nearly [MP PMT 2002]
(a) 4.55 *amp* (b) 0.355 *amp*
(c) 0.455 *amp* (d) 3.55 *amp*

84. There is a 5Ω resistance in an ac, circuit. Inductance of 0.1*H* is connected with it in series. If equation of ac e.m.f. is $5\sin 50t$ then the phase difference between current and e.m.f. is
(a) $\frac{\pi}{2}$ (b) $\frac{\pi}{6}$
(c) $\frac{\pi}{4}$ (d) 0

85. An inductor of inductance *L* and resistor of resistance *R* are joined in series and connected by a source of frequency ω. Power dissipated in the circuit is [AIEEE 2002; RPET 2003]
(a) $\frac{(R^2+\omega^2L^2)}{V}$ (b) $\frac{V^2R}{(R^2+\omega^2L^2)}$
(c) $\frac{V}{(R^2+\omega^2L^2)}$ (d) $\frac{\sqrt{R^2+\omega^2L^2}}{V^2}$

86. In a ac circuit of capacitance the current from potential is [CPMT 2003]
(a) Forward
(b) Backward
(c) Both are in the same phase
(d) None of these

87. A coil of 200Ω resistance and 1.0 *H* inductance is connected to an ac source of frequency $200/2\pi\ Hz$. Phase angle between potential and current will be [MP PMT 2003]
(a) 30° (b) 90°
(c) 45° (d) 0°

88. In a *LCR* circuit the pd between the terminals of the inductance is 60 *V*, between the terminals of the capacitor is 30 *V* and that between the terminals of resistance is 40 *V*. the supply voltage will be equal to ...... [KCET 2004]
(a) 50 *V* (b) 70 *V*
[Kerala PET 2002]
(c) 130 *V* (d) 10 *V*

89. Radio frequency choke uses core of [AFMC 2004]
(a) Air (b) Iron
(c) Air and iron (d) None of these

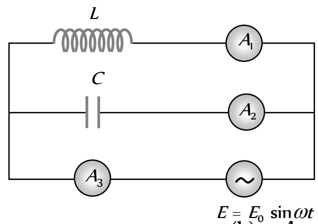
90. In a *LCR* circuit capacitance is changed from *C* to 2*C*. For the resonant frequency to remain unchanged, the inductance should be change from *L* to [AIEEE 2004]
(a) 4*L* (b) 2*L*
(c) *L*/2 (d) *L*/4

91. [AIEEE 2002; MP PET 2000] In an *LCR* series ac circuit, the voltage across each of the components, *L*, *C* and *R* is 50*V*. the voltage across the *LC* combination will be [AIEEE 2004]
(a) 50*V* (b) $50\sqrt{2}\ V$
(c) 100*V* (d) 0 *V* (zero)

92. A coil has *L* = 0.04 *H* and $R = 12\,\Omega$. When it is connected to 220*V*, 50*Hz* supply the current flowing through the coil, in amperes is [Kerala PMT 2002] [Kerala PMT 2004]
(a) 10.7 (b) 11.7
(c) 14.7 (d) 12.7

93. The current in series *LCR* circuit will be maximum when ω is [Kerala PMT 2004]
(a) As large as possible
(b) Equal o natural frequency of *LCR* system
(c) $\sqrt{LC}$
(d) $\sqrt{1/LC}$
[RPET 2003]

94. An inductor *L* and a capacitor *C* are connected in the circuit as shown in the figure. The frequency of the power supply is equal to the resonant frequency of the circuit. Which ammeter will read zero ampere [DCE 2002]



(a) A_1 (b) A_2
(c) A_3 (d) None of these

95. Which of the following components of a *LCR* circuit, with ac supply, dissipates energy [DCE 2004]
(a) *L* (b) *R*
(c) *C* (d) All of these

96. In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is [CBSE PMT 2005]
(a) $\frac{1}{2\pi f(2\pi fL+R)}$

(b) $\dfrac{1}{\pi f(2\pi fL + R)}$

(c) $\dfrac{1}{2\pi f(2\pi fL - R)}$

(d) $\dfrac{1}{\pi f(2\pi fL - R)}$

97. In an *A.C.* circuit the current [CPMT 2005]

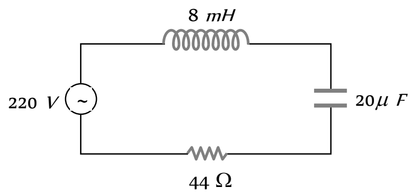
(a) Always leads the voltage

(b) Always lags behind the voltage

(c) Is always in phase with the voltage

(d) May lead or lag behind or be in phase with the voltage

98. For the series LCR circuit shown in the figure, what is the resonance frequency and the amplitude of the current at the resonating frequency [Kerala PET 2005]



(a) $2500\,rad - s^{-1}$ and $5\sqrt{2}\,A$

(b) $2500\,rad - s^{-1}$ and $5A$

(c) $2500\,rad - s^{-1}$ and $\dfrac{5}{\sqrt{2}}A$

(d) $25\,rad - s^{-1}$ and $5\sqrt{2}\,A$

Critical Thinking

Objective Questions

1. When 100 *volts* dc is supplied across a solenoid, a current of 1.0 amperes flows in it. When 100 *volts* ac is applied across the same coil, the current drops to 0.5 ampere. If the frequency of ac source is 50 *Hz*, then the impedance and inductance of the solenoid are

(a) 200 Ω and 0.55 *henry* (b) 100 Ω and 0.86 *henry*

(c) 200 Ω and 1.0 *henry* (d) 100 Ω and 0.93 *henry*

2. In an *LR*-circuit, the inductive reactance is equal to the resistance R of the circuit. An e.m.f. $E = E_0\cos(\omega t)$ applied to the circuit. The power consumed in the circuit is

[MP PMT 1997]

(a) $\dfrac{E_0^2}{R}$ (b) $\dfrac{E_0^2}{2R}$

(c) $\dfrac{E_0^2}{4R}$ (d) $\dfrac{E_0^2}{8R}$

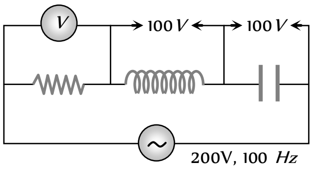
3. One 10 *V*, 60 *W* bulb is to be connected to 100 *V* line. The required induction coil has self inductance of value $(f = 50\,Hz)$

(a) 0.052 *H* (b) 2.42 *H*

(c) 16.2 *mH* (d) 1.62 *mH*

4. In the circuit given below, what will be the reading of the voltmeter

(a) 300 *V*

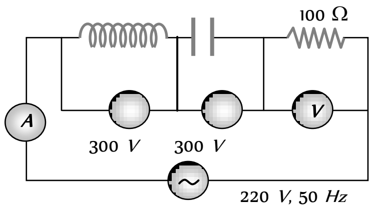


(b) 900 *V*

(c) 200 *V*

(d) 400 *V*

5. In the circuit shown below, what will be the readings of the voltmeter and ammeter [RPMT 1996]



(a) 800 *V*, 2*A* (b) 300 *V*, 2*A*

(c) 220 *V*, 2.2 *A* (d) 100 *V*, 2*A*

6. A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then

[Roorkee 1999]

(a) Bulb will give more intense light

(b) Bulb will give less intense light

(c) Bulb will give light of same intensity as before

(d) Bulb will stop radiating light

7. An alternating e.m.f. of angular frequency ω is applied across an inductance. The instantaneous power developed in the circuit has an angular frequency [Roorkee 1999]

(a) $\dfrac{\omega}{4}$ (b) $\dfrac{\omega}{2}$

(c) ω (d) 2ω

8. The voltage of an ac source varies with time according to the equation $V = 100\sin 100\pi t\cos 100\pi t$ where t is in seconds and V is in volts. Then [MP PMT 1996; 2000]

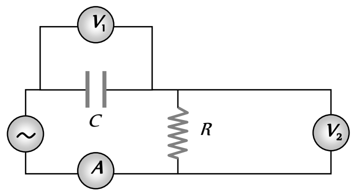
(a) The peak voltage of the source is 100 *volts*

(b) The peak voltage of the source is 50 *volts*

(c) The peak voltage of the source is $100/\sqrt{2}$ *volts*

(d) The frequency of the source is 50 *Hz* [CPMT 1990]

9. The diagram shows a capacitor C and a resistor R connected in series to an ac source. V_1 and V_2 are voltmeters and A is an ammeter



Consider now the following statements

I. Readings in A and V_2 are always in phase

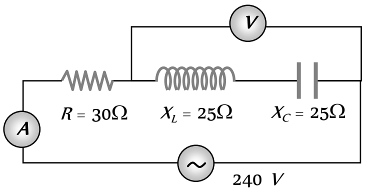
II. Reading in V is ahead in phase with reading in V_2 [RPET 1997]

III. Readings in A and V_1 are always in phase which of these statements are/is correct [AMU (Med.) 2001]

(a) I only (b) II only

(c) I and II only [RPET 1996] (d) II and III only

10. In the circuit shown in figure neglecting source resistance the voltmeter and ammeter reading will respectively, will be [KCET (Engg.) 2001]

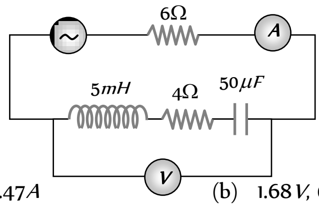


(a) 0 *V*, 3*A* (b) 150 *V*, 3*A*
(c) 150 *V*, 6*A* (d) 0 *V*, 8*A*

11. The voltage of an ac supply varies with time (t) as $V = 120 \sin 100\pi t \cos 100\pi t$. The maximum voltage and frequency respectively are [MP PMT 2001; MP PET 2002]

(a) 120 *volts*, 100 *Hz* (b) $\frac{120}{\sqrt{2}}$ *volts*, 100 *Hz*
(c) 60 *volts*, 200 *Hz* (d) 60 *volts*, 100 *Hz*

12. In the circuit shown in the figure, the ac source gives a voltage $V = 20\cos(2000\,t)$. Neglecting source resistance, the voltmeter and ammeter reading will be [KCET (Engg.) 2002]



(a) 0 *V*, 0.47*A* (b) 1.68 *V*, 0.47*A*
(c) 0 *V*, 1.4 *A* (d) 5.6 *V*, 1.4 *A*

13. A telephone wire of length 200 *km* has a capacitance of 0.014 μF per *km*. If it carries an ac of frequency 5 *kHz*, what should be the value of an inductor required to be connected in series so that the impedance of the circuit is minimum

(a) 0.35 *mH* (b) 35 *mH*
(c) 3.5 *mH* (d) Zero

14. In a certain circuit current changes with time according to $i = 2\sqrt{t}$. *r.m.s.* value of current between $t = 2$ to $t = 4s$ will be

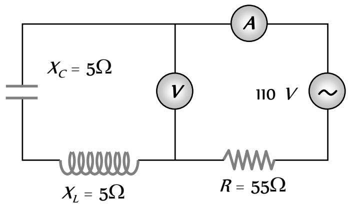
(a) $3A$ (b) $3\sqrt{3}A$
(c) $2\sqrt{3}A$ (d) $(2-\sqrt{2})A$

15. Match the following

Currents	*r.m.s.* values
(1) $x_0 \sin\omega t$	(i) x_0
(2) $x_0 \sin\omega t \cos\omega t$	(ii) $\frac{x_0}{\sqrt{2}}$
(3) $x_0 \sin\omega t + x_0 \cos\omega t$	(iii) $\frac{x_0}{(2\sqrt{2})}$

(a) 1. (i), 2. (ii), 3. (iii) (b) 1. (ii), 2. (iii), 3. (i)
(c) 1. (i), 2. (iii), 3. (ii) (d) None of these

16. The reading of ammeter in the circuit shown will be



(a) 2*A*
(b) 2.4 *A*
(c) Zero
(d) 1.7 *A*

17. An ac source of angular frequency ω is fed across a resistor *r* and a capacitor *C* in series. The current registered is *I*. If now the frequency of source is changed to $\omega/3$ (but maintaining the same voltage), the current in then circuit is found to be halved. Calculate the ratio of reactance to resistance at the original frequency ω [Roorkee 1996]

(a) $\sqrt{\frac{3}{5}}$ (b) $\sqrt{\frac{2}{5}}$
(c) $\sqrt{\frac{1}{5}}$ (d) $\sqrt{\frac{4}{5}}$

18. An *LCR* series circuit with a resistance of 100 *ohm* is connected to an ac source of 200 *V* (*r.m.s.*) and angular frequency 300 *rad/s*. When only the capacitor is removed, the current lags behind the voltage by 60^o. When only the inductor is removed the current leads the voltage by 60^o. The average power dissipated is

(a) 50 *W* (b) 100 *W*
(c) 200 *W* (d) 400 *W*

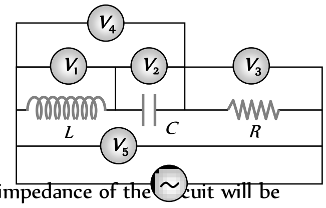
19. A virtual current of 4*A* and 50 *Hz* flows in an ac circuit containing a coil. The power consumed in the coil is 240 *W*. If the virtual voltage across the coil is 100 *V* its inductance will be

(a) $\frac{1}{3\pi}H$ (b) $\frac{1}{5\pi}H$
(c) $\frac{1}{7\pi}H$ (d) $\frac{1}{9\pi}H$

20. For a series *RLC* circuit $R = X_L = 2X_C$. The impedance of the circuit and phase difference (between) *V* and *i* will be

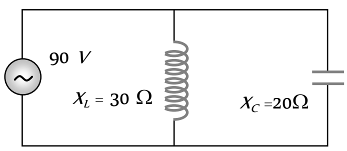
(a) $\frac{\sqrt{5}R}{2}, \tan^{-1}(2)$ (b) $\frac{\sqrt{5}R}{2}, \tan^{-1}\left(\frac{1}{2}\right)$
(c) $\sqrt{5}X_C, \tan^{-1}(2)$ (d) $\sqrt{5}R, \tan^{-1}\left(\frac{1}{2}\right)$

21. In the adjoining ac circuit the voltmeter whose reading will be zero at resonance is



(a) V
(b) V
(c) V
(d) V

22. In the adjoining figure the impedance of the circuit will be

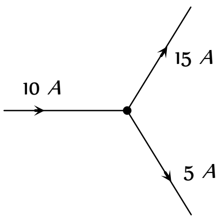


(a) 120 *ohm*
(b) 50 *ohm*
(c) 60 *ohm*
(d) 90 *ohm*

23. If $i = t^2$ $0 < t < T$ then *r.m.s.* value of current is

(a) $\frac{T^2}{\sqrt{2}}$ (b) $\frac{T^2}{2}$
(c) $\frac{T^2}{\sqrt{5}}$ (d) None of these

24. Is it possible



(a) Yes
(b) No

(c) Cannot be predicted

(d) Insufficient data to reply

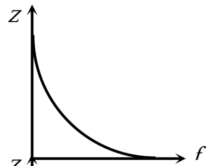
25. In a series circuit $C = 2\mu F, L = 1mH$ and $R = 10\,\Omega$, when the current in the circuit is maximum, at that time the ratio of the energies stored in the capacitor and the inductor will be

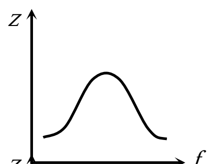
(a) 1 : 1 (b) 1 : 2

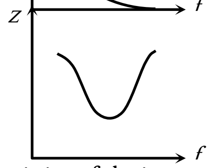
(c) 2 : 1 (d) 1 : 5

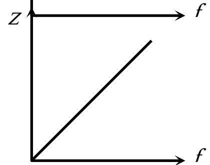
Graphical Questions

1. Which one of the following curves represents the variation of impedance (Z) with frequency f in series LCR circuit

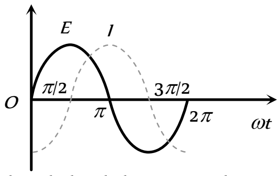
(a)


(b)


(c)


(d)


2. The variation of the instantaneous current (I) and the instantaneous emf (E) in a circuit is as shown in fig. Which of the following statements is correct



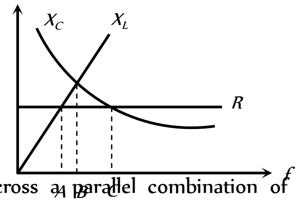
(a) The voltage lags behind the current by $\pi / 2$

(b) The voltage leads the current by $\pi / 2$

(c) The voltage and the current are in phase

(d) The voltage leads the current by π

3. The figure shows variation of R, X_L and X_C with frequency f in a series L, C, R circuit. Then for what frequency point, the circuit is inductive



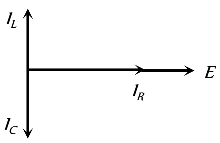
(a) A

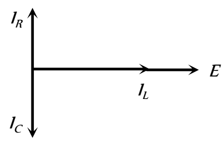
(b) B

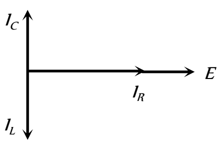
(c) C

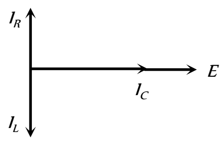
(d) All points

4. An alternating emf is applied across a parallel combination of a resistance R, capacitance C and an inductance L. If I_R, I_L, I_C are the currents through R, L and C respectively, then the diagram which correctly represents, the phase relationship among I_R, I_L, I_C and source emf E, is given by

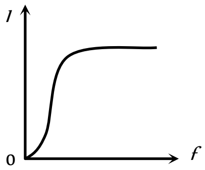
(a)


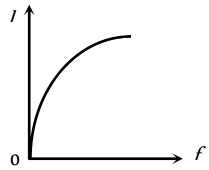
(b)


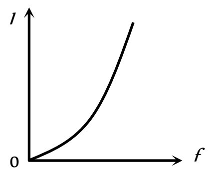
(c)


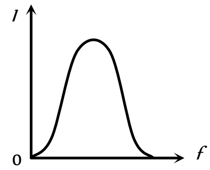
(d)


5. An ac source of variable frequency f is connected to an LCR series circuit. Which one of the graphs in figure. represents the variation of current of current I in the circuit with frequency f

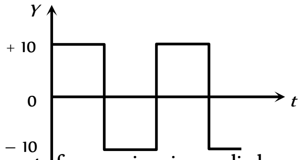
(a)


(b)


(c)


(d)


6. The $r.m.s.$ voltage of the wave form shown is



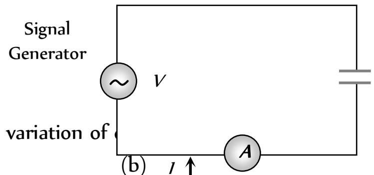
(a) 10 V

(b) 7 V

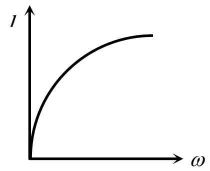
(c) 6.37 V

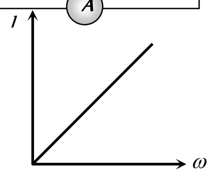
(d) None of these

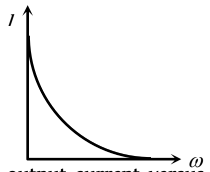
7. A constant voltage at different frequencies is applied across a capacitance C as shown in the figure. Which of the following graphs

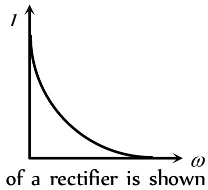


Correctly depicts the variation of current with frequency

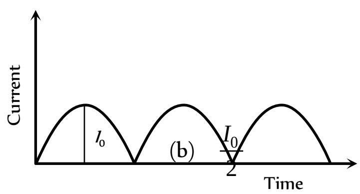
(a)


(b)


(c)


(d)


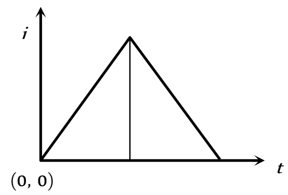
8. The output current versus time curve of a rectifier is shown in the figure. The average value of output current in this case is



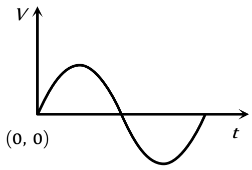
(a) 0 (b) $\frac{I_0}{2}$

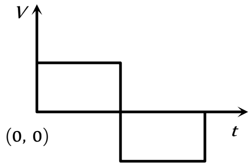
(c) $\frac{2I_0}{\pi}$ (d) I_0

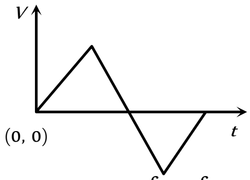
9. The current 'i' in an inductance coil varies with time 't' according to following graph

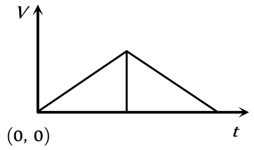


Which one of the following plots shows the variations of voltage in the coil [CBSE PMT 1994]

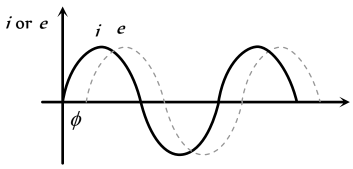
(a)


(b)


(c)


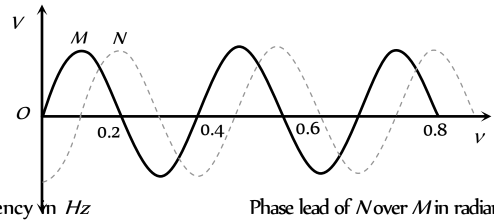
(d)


10. When an ac source of e.m.f. $e = E_0 \sin(100\,t)$ is connected across a circuit, the phase difference between the e.m.f. e and the current i in the circuit is observed to be $\pi/4$, as shown in the diagram. If the circuit consists possibly only of RC or LC in series, find the relationship between the two elements



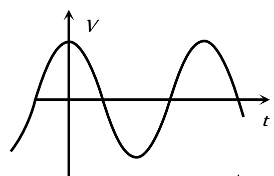
(a) $R = 1k\Omega, C = 10\mu F$
(b) $R = 1k\Omega, C = 1\mu F$
(c) $R = 1k\Omega, L = 10H$
(d) $R = 1k\Omega, L = 1H$

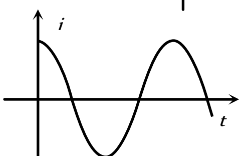
11. Two sinusoidal voltages of the same frequency are shown in the diagram. What is the frequency, and the phase relationship between the voltages

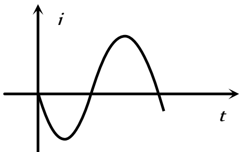


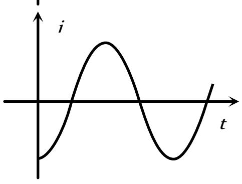
Frequency in Hz	Phase lead of N over M in radians
(a) 0.4	$-\pi/4$
(b) 2.5	$-\pi/2$
(c) 2.5	$+\pi/2$
(d) 2.5	$-\pi/4$

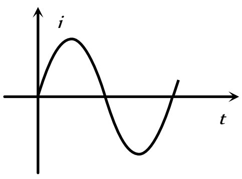
12. The voltage across a pure inductor is represented by the following diagram. Which one of the following diagrams will represent the current [MP PMT 1995]



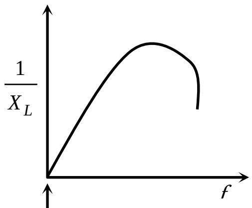
(a)


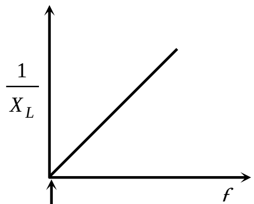
(b)


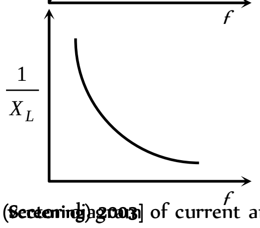
(c)


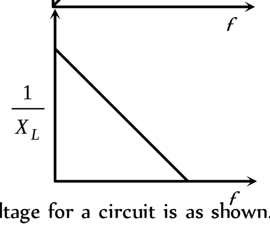
(d)


13. In pure inductive circuit, the curves between frequency f and reciprocal of inductive reactance $1/X_L$ is

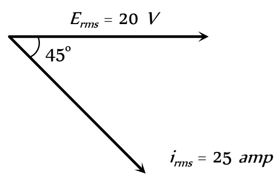
(a)


(b)


(c)


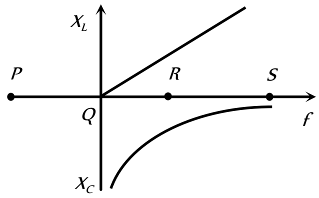
(d)


14. [IIT-JEE (Screening) 2003] The (vector) diagram of current and voltage for a circuit is as shown. The components of the circuit will be



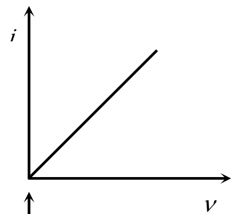
(a) LCR
(b) LR
(c) LCR or LR
(d) None of these

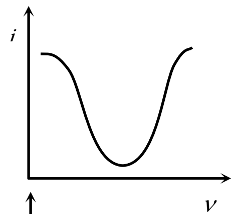
15. The resonance point in $X_L - f$ and $X_C - f$ curves is

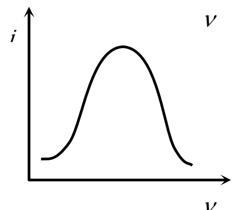


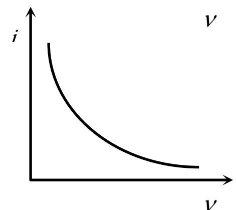
(a) P
(b) Q
(c) R
(d) S

16. The i - V curve for anti-resonant circuit is

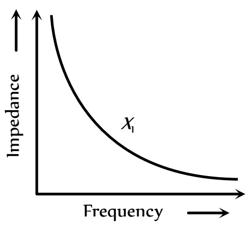
(a)


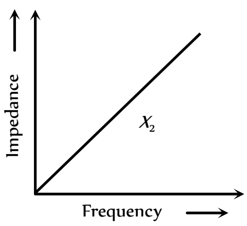
(b)


(c)


(d)


17. The graphs given below depict the dependence of two reactive impedances X_1 and X_2 on the frequency of the alternating e.m.f. applied individually to them. We can then say that [Haryana CEE 1996; RPMT 2004]





(a) X_1 is an inductor and X_2 is a capacitor

(b) X_1 is a resistor and X_2 is a capacitor

(c) X_1 is a capacitor and X_2 is an inductor

(d) X_1 is an inductor and X_2 is a resistor

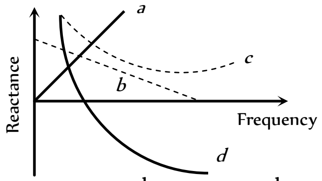
18. Which of the following plots may represent the reactance of a series LC combination [MP PMT 1999]

(a) a

(b) b

(c) c

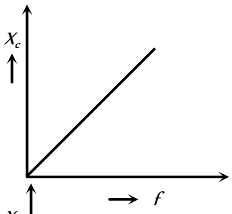
(d) d



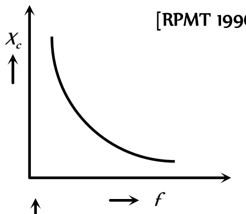
19. Which of the following curves correctly represents the variation of capacitive reactance X_c with frequency f

[RPMT 1996]

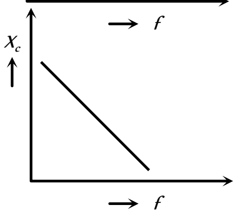
(a)



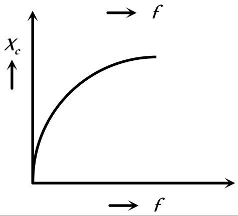
(b)



(c)



(d)



Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.

(c) If assertion is true but reason is false.

(d) If the assertion and reason both are false.

(e) If assertion is false but reason is true.

1. Assertion : In series LCR circuit resonance can take place.

Reason : Resonance takes place if inductance and capacitive reactances are equal and opposite.

[AIIMS 1998]

2. Assertion : The alternating current lags behind the e.m.f. by a phase angle of $\pi / 2$, when ac flows through an inductor.

Reason : The inductive reactance increases as the frequency of ac source decreases.

3. Assertion : Capacitor serves as a block for dc and offers an easy path to ac.

Reason : Capacitive reactance is inversely proportional to frequency.

4. Assertion : When capacitive reactance is smaller than the inductive reactance in LCR current, e.m.f. leads the current .

Reason : The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

5. Assertion : Chock coil is preferred over a resistor to adjust current in an ac circuit.

Reason : Power factor for inductance is zero.

6. Assertion : If the frequency of alternating current in an ac circuit consisting of an inductance coil is increased then current gets decreased.

Reason : The current is inversely proportional to frequency of alternating current.

7. Assertion : A bulb connected in series with a solenoid is connected to ac source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

Reason : On introducing soft iron core in the solenoid, the inductance increases.

8. Assertion : An alternating current does not show any magnetic effect.

Reason : Alternating current varies with time.

9. Assertion : The dc and ac both can be measured by a hot wire instrument.

Reason : The hot wire instrument is based on the principle of magnetic effect of current.

10. Assertion : ac is more dangerous than dc

Reason : Frequency of ac is dangerous for human body.

11. Assertion : Average value of ac over a complete cycle is always zero.

Reason : Average value of ac is always defined over half cycle.

12. Assertion : The division are equally marked on the scale of ac ammeter.

Reason : Heat produced is directly proportional to the current.

13. Assertion : When ac circuit contain resistor only, its power is minimum.

Reason : Power of a circuit is independent of phase angle.

14. Assertion : An electric lamp connected in series with a variable capacitor and ac source, its brightness increases with increase in capacitance.

Reason : Capacitive reactance decrease with increase in capacitance of capacitor.

15. Assertion : An inductance and a resistance are connected in series with an ac circuit. In this circuit the current and the potential difference across the resistance lag behind potential difference across the inductance by an angle $\pi/2$.

Reason : In LR circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

16. Assertion : A capacitor of suitable capacitance can be used in an ac circuit in place of the choke coil.

Reason : A capacitor blocks dc and allows ac only.

Answers

Alternating Current, Voltage and Power

1	b	2	a	3	c	4	b	5	b
6	b	7	c	8	d	9	c	10	c
11	d	12	c	13	b	14	c	15	b
16	d	17	c	18	b	19	d	20	c
21	c	22	a	23	c	24	d	25	c
26	c	27	d	28	b	29	c	30	d
31	d	32	d	33	b	34	b	35	d
36	c	37	a	38	b	39	a	40	c
41	a	42	d	43	b	44	b	45	c
46	c								

ac Circuits

1	b	2	a	3	a	4	b	5	a
6	a	7	b	8	c	9	d	10	b
11	c	12	b	13	b	14	b	15	d
16	b	17	a	18	b	19	a	20	a
21	b	22	d	23	b	24	b	25	a
26	d	27	c	28	b	29	c	30	c
31	c	32	b	33	d	34	a	35	c
36	c	37	c	38	b	39	c	40	d
41	b	42	b	43	a	44	a	45	d
46	c	47	a	48	a	49	c	50	b
51	b	52	c	53	b	54	c	55	c
56	a	57	a	58	b	59	b	60	d
61	a	62	c	63	a	64	bd	65	a
66	a	67	a	68	a	69	a	70	b
71	a	72	d	73	bc	74	c	75	b
76	b	77	b	78	c	79	c	80	a
81	b	82	d	83	c	84	c	85	b
86	a	87	c	88	a	89	a	90	c
91	d	92	d	93	d	94	c	95	b
96	a	97	d	98	b				

Critical Thinking Questions

1	a	2	c	3	a	4	c	5	c
6	a	7	d	8	b	9	b	10	d
11	d	12	d	13	a	14	c	15	b
16	c	17	a	18	d	19	b	20	b
21	d	22	c	23	c	24	a	25	d

Graphical Questions

1	c	2	b	3	c	4	c	5	d
6	a	7	b	8	c	9	b	10	a
11	b	12	d	13	c	14	c	15	c
16	b	17	c	18	d	19	b		

Assertion and Reason

1	a	2	c	3	a	4	b	5	a
6	a	7	e	8	b	9	c	10	a
11	b	12	d	13	d	14	a	15	b
16	b								

AS Answers and Solutions

Alternating Current, Voltage and Power

1. (b) Power loss $\propto \dfrac{1}{(\text{Voltage})^2}$

2. (a) $V = 5\cos\omega t = 5\sin\left(\omega t + \dfrac{\pi}{2}\right)$ and $i = 2\sin\omega t$

Power $= V_{r.m.s.} \times i_{r.m.s.} \times \cos\phi = 0$

(Since $\phi = \dfrac{\pi}{2}$, therefore $\cos\phi = \cos\dfrac{\pi}{2} = 0$)

3. (c) $P = V_{r.m.s.} \times i_{r.m.s.} \times \cos\phi = \dfrac{100}{\sqrt{2}} \times \dfrac{100 \times 10^{-3}}{\sqrt{2}} \times \cos\dfrac{\pi}{3}$

$= \dfrac{10^4 \times 10^{-3}}{2} \times \dfrac{1}{2} = \dfrac{10}{4} = 2.5\ watt$

4. (b) In dc ammeter, a coil is free to rotate in the magnetic field of a fixed magnet.

If an alternating current is passed through such a coil, the torque will reverse it's direction each time the current changes direction and the average value of the torque will be zero.

5. (b) The coil having inductance L besides the resistance R. Hence for ac it's effective resistance $\sqrt{R^2 + X_L^2}$ will be larger than it's resistance R for dc.

6. (b) $i_{r.m.s.} = \dfrac{i_o}{\sqrt{2}} = \dfrac{4}{\sqrt{2}} = 2\sqrt{2}\ ampere$

7. (c) Effective voltage $V_{r.m.s.} = \dfrac{V_o}{\sqrt{2}} = \dfrac{423}{\sqrt{2}} = 300\ V$

8. (d) The current takes $\frac{T}{4}$ *sec* to reach the peak value.

In the given question $\frac{2\pi}{T} = 200\pi \Rightarrow T = \frac{1}{100} sec$

$\therefore$ Time to reach the peak value $= \frac{1}{400} sec$

9. (c) $i_{r.m.s} = \frac{6}{\sqrt{2}} = 3\sqrt{2}\ A$

10. (c) $\nu = \frac{\omega}{2\pi} = \frac{120 \times 7}{2 \times 22} = 19\ Hz$

$V_{r.m.s.} = \frac{240}{\sqrt{2}} = 120\sqrt{2} \approx 170\ V$

11. (d)

12. (c) Peak value = $220\sqrt{2} = 311\ V$

13. (b) Power $= I^2R = \left(\frac{I_p}{\sqrt{2}}\right)^2 R = \frac{I_p^2 R}{2}$

14. (c) $i_{r.m.s.} = \frac{V_{r.m.s.}}{R} = \frac{200}{40} = 5\ A \Rightarrow i_0 = i_{r.m.s.}\sqrt{2} = 7.07\ A$

15. (b)

16. (d) Time taken by the current to reach the maximum value $t = \frac{T}{4} = \frac{1}{4\nu} = \frac{1}{4 \times 50} = 5 \times 10^{-3} sec$

and $i_o = i_{rms}\sqrt{2} = 10\sqrt{2} = 14.14\ amp$

17. (c)

18. (b) $E = E_0 \cos \omega t = E_0 \cos \frac{2\pi t}{T}$

$= 10 \cos \frac{2\pi \times 50 \times 1}{600} = 10 \cos \frac{\pi}{6} = 5\sqrt{3}\ volt.$

19. (d) Phase angle $\phi = 90^o$, so power $P = Vi \cos \phi = 0$

20. (c) $V_{rms} = \frac{200}{\sqrt{2}},\ i_{rms} = \frac{1}{\sqrt{2}}$

$\therefore P = V_{rms}\ i_{rms} \cos \phi = \frac{200}{\sqrt{2}} \frac{1}{\sqrt{2}} \cos \frac{\pi}{3} = 50\ watt$

21. (c) $2\pi\nu = 377 \Rightarrow \nu = 60.03\ Hz$

22. (a)

23. (c) $i_{rms} = \sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$

24. (d) $P = Vi \cos \phi$

Phase difference $\phi = \frac{\pi}{2} \Rightarrow P = zero$

25. (c) $V_0 = V_{rms} \times \sqrt{2} = 220 \times \sqrt{2} = 310$

26. (c) Hot wire ammeter reads *rms* value of current. Hence its peak value $= i_{rms} \times \sqrt{2} = 14.14\ amp$

27. (d)

28. (b) Peak voltage $= \sqrt{2} \times 220 = 311\ V$

29. (c)

30. (d) $\because P = Vi \cos \phi,\ \therefore P \propto \cos \phi$

31. (d) $P = V_{rms} I_{rms} \cos \phi$; since $\phi = 90^o$. So $P = 0$

32. (d) Brightness $\propto P_{consumed} \propto \frac{1}{R}$ for Bulb, $R_{ac} = R_{dc}$, so brightness will be equal in both the cases.

33. (b) $P = \frac{V_{rms}^2}{R} = \frac{(30)^2}{10} = 90\ W$

34. (b) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{120}{1.414} = 84.8\ V$

35. (d) Peak value to *r.m.s.* value means, current becomes $\frac{1}{\sqrt{2}}$ times.

So from $i = i_0 \sin 100\pi t \Rightarrow \frac{1}{\sqrt{2}} \times i_0 = i_0 \sin 100\pi t$

$\Rightarrow \sin \frac{\pi}{4} = \sin 100\pi t \Rightarrow t = \frac{1}{400} sec = 2.5 \times 10^{-3} sec.$

36. (c) Phase difference $\Delta\phi = \phi_2 - \phi_1 = \frac{\pi}{6} - \left(\frac{-\pi}{6}\right) = \frac{\pi}{3}$

37. (a) $V_{av} = \frac{2}{\pi} V_0 = \frac{2}{\pi} \times (V_{rms} \times \sqrt{2}) = \frac{2\sqrt{2}}{\pi}.V_{rms}$

$= \frac{2\sqrt{2}}{\pi} \times 220 = 198\ V$

38. (b)

39. (a)

40. (c)

41. (a) $i_{rms} = \frac{200}{280} = \frac{5}{7} A$. So $i_0 = i_{rms} \times \sqrt{2} = \frac{5}{7} \times \sqrt{2} \approx 1A.$

42. (d) Required time $t = T/4 = \frac{1}{4 \times 50} = 5 \times 10^{-3} sec$

43. (b) $V_0 = \sqrt{2}\ V_{rms} = 10\sqrt{2}$

44. (b) $P = \frac{1}{2} V_o i_o \cos \phi \Rightarrow P = P_{Peak}.\cos \phi$

$\Rightarrow \frac{1}{2}(P_{peak}) = P_{peak} \cos \phi \Rightarrow \cos \phi = \frac{1}{2} \Rightarrow \phi = \frac{\pi}{3}$

45. (c) $E = 141 \sin(628\, t)$,

$E_{rms} = \frac{E_0}{\sqrt{2}} = \frac{141}{1.41} = 100V$ and $2\pi f = 628$

$\Rightarrow f = 100 Hz$

46. (c) $E_{rms} = \frac{E_0}{\sqrt{2}} = \frac{707}{1.41} = 500V$

ac Circuits

1. (b)

2. (a)

3. (a) The choke coil can be used only in ac circuits, not in *dc* circuits, because for dc ($\omega = 0$) the inductive reactance $X_L = \omega L$ of the coil is zero, only the resistance of the coil remains effective which too is almost zero.

4. (b) Because power $= i^2R$, if $R = 0$, then $P = 0$.

5. (a)

6. (a) A choke coil contains high inductance but negligible resistance, due to which power loss becomes appreciably small.

7. (b) For purely capacitive circuit $e = e_0 \sin\omega t$

$i = i_o \sin\left(\omega t + \frac{\pi}{2}\right)$ *i.e.* current is ahead of emf by $\frac{\pi}{2}$

8. (c)

9. (d)

10. (b) $Z = \sqrt{R^2 + X_L^2}$, $X_L = \omega L$ and $\omega = 2\pi f$

$\therefore Z = \sqrt{R^2 + 4\pi^2 f^2 L^2}$

11. (c) $\nu = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-6} \times 10^{-4}}} = \frac{10^5}{2\pi} Hz$

12. (b)

13. (b) The applied voltage is given by $V = \sqrt{V_R^2 + V_L^2}$

$V = \sqrt{(200)^2 + (150)^2} = 250\ volt$

14. (b) $i = \frac{V}{\sqrt{R^2 + \omega^2 L^2}} = \frac{120}{\sqrt{100 + 4\pi^2 \times 60^2 \times 20^2}}$ =0.016 A

15. (d) For the first circuit $i = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \omega^2 L^2}}$

$\therefore$ Increase in ω will cause a decrease in *i*.

For the second circuit $i = \frac{V}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$

$\therefore$ Increase in ω will cause an increase in *i*.

16. (b) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$; For dc $\nu = 0$, $\therefore X_C = \infty$

17. (a) In a pure inductor (zero resistance), voltage leads the current by 90^o *i.e.* $\pi/2$.

18. (b)

19. (a) The voltage across a *L–R* combination is given by

$V^2 = V_R^2 + V_L^2$

$V_L = \sqrt{V^2 - V_R^2} = \sqrt{400 - 144} = \sqrt{256} = 16\ volt.$

20. (a) Phase angle $\tan\phi = \frac{\omega L}{R} = \frac{2\pi \times 200}{300} \times \frac{1}{\pi} = \frac{4}{3}$

$\therefore \phi = \tan^{-1}\frac{4}{3}$

21. (b) At resonance, *LCR* circuit behaves as purely resistive circuit, for purely resistive circuit power factor = 1

22. (d) Given $\omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC}$

or $\omega = \frac{1}{\sqrt{10^{-3} \times 10 \times 10^{-6}}} = \frac{1}{\sqrt{10^{-8}}} = 10^4$

$X_L = \omega L = 10^4 \times 10^{-3} = 10\,\Omega$

23. (b)

24. (b) Reading of ammeter $= i_{rms} = \frac{V_{rms}}{X_C} = \frac{V_0 \omega C}{\sqrt{2}}$

$= \frac{200\sqrt{2} \times 100 \times (1 \times 10^{-6})}{\sqrt{2}} = 2 \times 10^{-2} A = 20\ mA$

25. (a) Current will be maximum at the condition of resonance. So resonant frequency $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.5 \times 8 \times 10^{-6}}}$

= 500 *rad/s*

26. (d) Average power in ac circuits is given by $P = V_{rms} i_{rms} \cos\phi$

For pure capacitive circuit $\phi = 90^o$ so $P = 0$

27. (c) Amplitude of $ac = i_0 = \frac{V_0}{R} = \frac{\omega NBA}{R} = \frac{(2\pi\nu)NB(\pi r^2)}{R}$

$\Rightarrow i_0 = \frac{2\pi \times \frac{200}{60} \times 1 \times 10^{-2} \times \pi \times (0.3)^2}{\pi^2} = 6\ mA$

28. (b) $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (2\pi \times 60 \times 2)^2} = 753.7$

$\therefore i = \frac{120}{753.7} = 0.159\ A$

29. (c) Resonance frequency in *radian/second* is

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8 \times 0.5 \times 10^{-6}}} = 500\ rad/sec$

30. (c) $\omega = \frac{1}{\sqrt{L_1 C_1}} = \frac{1}{\sqrt{L_2 C_2}} \Rightarrow L_2 = \frac{L_1}{4}$

31. (c) $Z = X_L = 2\pi \times 60 \times 0.7$

$\therefore i = \frac{120}{Z} = \frac{120}{2\pi \times 60 \times 0.7} = 0.455\ ampere$

32. (b) $Z = \sqrt{R^2 + X^2} = \sqrt{4^2 + 3^2} = 5$

$\therefore \cos\phi = \frac{R}{Z} = \frac{3}{5} = 0.6$

33. (d)

34. (a) $\cos\phi = \frac{R}{Z}$. In choke coil $\phi \approx 90°$ so $\cos\phi \approx 0$

35. (c) $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{100^2 + \left(0.5 \times 100\pi - \frac{1}{10 \times 10^{-6} \times 100\pi}\right)^2} = 189.72\Omega$

36. (c) $V_L = 46\,volts$, $V_C = 40\,volts$, $V_R = 8\,volts$

E.M.F. of source $V = \sqrt{8^2 + (46 - 40)^2} = 10\,volts$

37. (c) Resonant frequency $= \frac{1}{2\pi\sqrt{LC}}$ does not depend on resistance.

38. (b) Frequency $= \frac{1}{2\pi\sqrt{LC}}$

So the combination which represents dimension of frequency is $\frac{1}{\sqrt{LC}} = (LC)^{-1/2}$

39. (c) For series *R-L-C* circuit, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{(300)^2 + \left(1000 \times 0.9 - \frac{10^6}{1000 \times 2}\right)^2} = 500\Omega$

40. (d) $Z = \sqrt{R^2 + X^2} = \sqrt{R^2 + (2\pi f L)^2}$

$= \sqrt{(30)^2 + \left(2\pi \times 50 \times \frac{0.4}{\pi}\right)^2} = \sqrt{900 + 1600} = 50\Omega$

$i = \frac{V}{Z} = \frac{200}{50} = 4\, ampere$

41. (b) Reactance $= 2\pi \nu L \Rightarrow 100\,\Omega = 2 \times \frac{22}{7} \times 50 \times L$

$\therefore\ L = 0.32\ henry$

42. (b)

43. (a) $X_C = \frac{1}{2\pi \nu C} = \frac{1}{2\pi \times 4000 \times 25 \times 10^{-6}} = \frac{5}{\pi}\Omega$

44. (a) $X_C = \frac{1}{2\pi \nu C} \Rightarrow \frac{1}{1000} = \frac{1}{2\pi \times \nu \times 5 \times 10^{-6}}$

$\Rightarrow \nu = \frac{100}{\pi} MHz$

45. (d) $i = \frac{V}{Z} = \frac{4}{\sqrt{4^2 + (1000 \times 3 \times 10^{-3})^2}} = 0.8\ A$

46. (c) $\tan\phi = \frac{X_L}{R} \Rightarrow \tan 45^o = \frac{X_L}{R} = 1 \Rightarrow X_L = R$

47. (a) For purely L-circuit $P = 0$

48. (a) At resonance LCR series circuit behaves as pure resistive circuit. For resistive circuit $\phi = 0^o$

49. (c) $V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(5)^2 + (10 - 10)^2} = 5\ Volt$

50. (b) When dc is supplied $R = \frac{V}{i} = \frac{100}{1} = 100\,\Omega$

When ac is supplied $Z = \frac{V}{i} = \frac{100}{0.5} = 200\,\Omega$

51. (b) $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$

$= \frac{12}{\sqrt{(12)^2 + 4 \times \pi^2 \times (60)^2 \times (0.1)^2}} \Rightarrow \cos\phi = 0.30$

52. (c)

53. (b)

54. (c) Impedance $Z = \sqrt{R^2 + X^2} = \sqrt{(8)^2 + (6)^2} = 10\Omega$

55. (c) $\tan\phi = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.21}{12} = 5.5 \Rightarrow \phi = 80^o$

56. (a) If the current is wattless then power is zero. Hence phase difference $\phi = 90^o$

57. (a) $f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow f \propto \frac{1}{\sqrt{C}}$

58. (b) In non resonant circuits impedance $Z = \frac{1}{\sqrt{\frac{1}{R^2} + \left(\omega C - \frac{1}{\omega L}\right)^2}}$, with rise in frequency Z decreases *i.e.* current increases so circuit behaves as capacitive circuit.

59. (b) $V = \sqrt{V_R^2 + V_L^2} = \sqrt{(20)^2 + (16)^2} = \sqrt{656} = 25.6\ V$

60. (d) $i = \frac{220}{\sqrt{(20)^2 + (2 \times \pi \times 50 \times 0.2)^2}} = \frac{220}{66} = 3.33\ A$

61. (a) Impedance of LCR circuit will be minimum at resonant frequency so $\nu_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1 \times 10^{-3} \times 0.1 \times 10^{-6}}}$

$= \frac{10^5}{2\pi} Hz$

62. (c) $\cos\phi = \frac{R}{Z} = \frac{10}{20} = \frac{1}{2} \Rightarrow \phi = 60^o$

63. (a) Current in LC circuit becomes maximum when resonance occurs. So

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1 \times 25 \times 10^{-6}}} = \frac{1000}{5} = 200\, rad/\sec$

64. (b, d)

65. (a) $R = 6 + 4 = 10\,\Omega$

$X_L = \omega L = 2000 \times 5 \times 10^{-3} = 10\,\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2000 \times 50 \times 10^{-6}} = 10\,\Omega$

$\therefore Z = \sqrt{R^2 + (X_L - X_C)^2} = 10\,\Omega$

Amplitude of current $= i_0 = \frac{V_0}{Z} = \frac{20}{10} = 2A$

66. (a) $i = \frac{V}{X_L} = \frac{200}{\omega L} = \frac{200}{2\pi \times 50 \times 1} = 0.637\ A$

67. (a)

68. (a) In LCR circuit; in the condition of resonance $X_L = X_C$ *i.e.* circuit behaves as resistive circuit. In resistive circuit power factor is maximum.

69. (a) $\tan\phi = \frac{X_L}{R} = \frac{\sqrt{3}\,R}{R} = \sqrt{3} \Rightarrow \phi = 60^o = \pi/3$

70. (b) $X_C = \frac{1}{2\pi\nu C} = \frac{1}{0} = \infty$

71. (a)

72. (d) $X_L = 2\pi\nu L \Rightarrow L = \frac{X_L}{2\pi\nu} = \frac{50}{2 \times 3.14 \times 50} = 0.16\ H$

73. (b, c)

74. (c) $Z = \sqrt{R^2 + (2\pi\nu L)^2}$

$= \sqrt{(40)^2 + 4\pi^2 \times (50)^2 \times (95.5 \times 10^{-3})^2} = 50\ ohm$

75. (b) $X_C = \frac{1}{2\pi\nu C} \Rightarrow X_C \propto \frac{1}{\nu}$

76. (b)

77. (b)

78. (c) $X_L = 2\pi\nu L = 2\times\pi\times 50\times\frac{1}{\pi} = 100\,\Omega$

79. (c) $\nu_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times 3.14\sqrt{5\times 10^{-4}\times 20\times 10^{-6}}}$

$\nu_0 = \frac{10^4}{6.28} = 1592\,Hz$

80. (a) $X_C = \frac{1}{2\pi\nu C} \Rightarrow C = \frac{1}{2\pi\nu X_C} = \frac{1}{2\times\pi\times\frac{400}{\pi}\times 25} = 50\,\mu F$

81. (b) $\cos\phi = \frac{R}{Z} = \frac{R}{(R^2+\omega L^2)^{1/2}}$

82. (d) $Z = \sqrt{R^2+(X_L-X_C)^2} = \sqrt{(11)^2+(25-18)^2} = 13\,\Omega$

Current $i = \frac{260}{13} = 20\,A$

83. (c) $i = \frac{V}{X_L} = \frac{120}{2\times 3.14\times 60\times 0.7} = 0.455\,A$

84. (c) $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2+\omega^2L^2}} = \frac{5}{\sqrt{25+(50)^2\times(0.1)^2}}$

$= \frac{5}{\sqrt{25+25}} = \frac{1}{\sqrt{2}} \Rightarrow \phi = \pi/4$

85. (b) $P = Vi\cos\phi = V\left(\frac{V}{Z}\right)\left(\frac{R}{Z}\right) = \frac{V^2R}{Z^2} = \frac{V^2R}{(R^2+\omega^2L^2)}$

86. (a)

87. (c) $\tan\phi = \frac{X_L}{R} = \frac{2\pi\nu L}{R} = \frac{2\pi\times\frac{200}{2\pi}\times 1}{200} = 1 \Rightarrow \phi = 45^o$

88. (a) $V = \sqrt{V_R^2+(V_L-V_C)^2} = \sqrt{(40)^2+(60-30)^2} = 50V$

89. (a)

90. (c) $\nu_0 = \frac{1}{2\pi\sqrt{LC}}$

If C changes to $2C$ then for keeping ν constant L must change to $L/2$.

91. (d) Net voltage across LC combination $= V_L - V_C = 0\ V$

92. (d) Impedance $Z = \sqrt{R^2+4\pi^2\nu^2L^2}$

$= \sqrt{(12)^2+4\times(3.14)^2\times(50)^2\times(0.04)} = 17.37\ A$

Now current $i = \frac{V}{Z} = \frac{220}{17.37} = 12.7\Omega$

93. (d) At resonant frequency current in series LCR circuit is maximum.

94. (c)

95. (b)

96. (a) $\tan\phi = \frac{X_C - X_L}{R} \Rightarrow \tan 45^o = \frac{\frac{1}{2\pi fC} - 2\pi fL}{R}$

$\Rightarrow C = \frac{1}{2\pi f(2\pi fL + R)}$

97. (d)

98. (b) Resonance frequency

$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8\times 10^{-3}\times 20\times 10^{-6}}} = 2500\ rad/\sec$

Resonance current $= \frac{V}{R} = \frac{220}{44} = 5A$

Critical Thinking Questions

1. (a) For dc, $R = \frac{V}{i} = \frac{100}{1} = 100\ \Omega$

For ac, $Z = \frac{V}{i} = \frac{100}{0.5} = 200\ \Omega$

$\because\ Z = \sqrt{R^2 + (\omega L)^2} \Rightarrow 200 = \sqrt{(100)^2 + 4\pi^2(50)^2 L^2}$

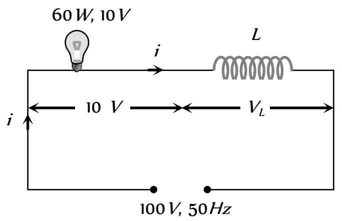
$\therefore\ L = 0.55\ H$

2. (c) $P = E_{rms}\, i_{rms} \cos\phi = \frac{E_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}} \times \frac{R}{Z}$

$\Rightarrow \frac{E_0}{\sqrt{2}} \times \frac{E_0}{Z\sqrt{2}} \times \frac{R}{Z} \Rightarrow P = \frac{E_0^2 R}{2Z^2}$

Given $X_L = R$ so, $Z = \sqrt{2}R \Rightarrow P = \frac{E_0^2}{4R}$

3. (a) Current through the bulb $i = \frac{P}{V} = \frac{60}{10} = 6A$



$V = \sqrt{V_R^2 + V_L^2}$

$(100)^2 = (10)^2 + V_L^2 \Rightarrow V_L = 99.5\ Volt$

Also $V_L = iX_L = i \times (2\pi\nu L)$

$\Rightarrow 99.5 = 6 \times 2 \times 3.14 \times 50 \times L \Rightarrow L = 0.052\ H$

4. (c) $V^2 = V_R^2 + (V_L - V_C)^2$

Since $V_L = V_C$ hence $V = V_R = 200\ V$

5. (c) $V^2 = V_R^2 + (V_L - V_C)^2 \Rightarrow V_R = V = 220\ V$

Also $i = \frac{220}{100} = 2.2\ A$

6. (a) When a bulb and a capacitor are connected in series to an ac source, then on increasing the frequency the current in the circuit is increased, because the impedance of the circuit is decreased. So the bulb will give more intense light.

7. (d) The instantaneous values of emf and current in inductive circuit are given by $E = E_0 \sin\omega t$ and $i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ respectively.

So, $P_{inst} = Ei = E_0 \sin\omega t \times i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

$= E_0 i_0 \sin\omega t\left(\sin\omega t \cos\frac{\pi}{2} - \cos\omega t \sin\frac{\pi}{2}\right)$

$= E_0 i_0 \sin\omega t \cos\omega t$

$= \frac{1}{2} E_0 i_0 \sin 2\omega t$ $\quad (\sin 2\omega t = 2\sin\omega t \cos\omega t)$

Hence, angular frequency of instantaneous power is 2ω.

8. (b) $V = 50 \times 2 \sin 100\pi t \cos 100\pi t = 50 \sin 200\pi t$

$\Rightarrow V_0 = 50\ Volts$ and $\nu = 100 Hz$

9. (b) In RC series circuit voltage across the capacitor leads the voltage across the resistance by $\frac{\pi}{2}$

10. (d) The voltage V_L and V_C are equal and opposite so voltmeter reading will be zero.

Also $R = 30\,\Omega$, $X_L = X_C = 25\Omega$

So $i = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V}{R} = \frac{240}{30} = 8\ A$

11. (d) $V = 120 \sin 100\pi t \cos 100\pi t \Rightarrow V = 60 \sin 200\pi t$

$V_{max} = 60V$ and $\nu = 100 Hz$

12. (d) $Z = \sqrt{(R)^2 + (X_L - X_C)^2}$;

$R = 10\,\Omega$, $X_L = \omega L = 2000 \times 5 \times 10^{-3} = 10\,\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2000 \times 50 \times 10^{-6}} = 10\,\Omega$ *i.e.* $Z = 10\,\Omega$

Maximum current $i_0 = \frac{V_0}{Z} = \frac{20}{10} = 2A$

Hence $i_{rms} = \frac{2}{\sqrt{2}} = 1.4\ A$

and $V_{rms} = 4 \times 1.41 = 5.64\ V$

13. (a) Capacitance of wire

$C = 0.014 \times 10^{-6} \times 200 = 2.8 \times 10^{-6} F = 2.8 \mu F$

For impedance of the circuit to be minimum $X_L = X_C \Rightarrow$

$2\pi\nu L = \frac{1}{2\pi\nu C}$

$\Rightarrow L = \frac{1}{4\pi^2\nu^2 C} = \frac{1}{4(3.14)^2 \times (5 \times 10^3)^2 \times 2.8 \times 10^{-6}}$

$= 0.35 \times 10^{-3} H = 0.35\, mH$

14. (c) $\overline{i^2} = \frac{\int i^2 dt}{\int dt} = \frac{\int_2^4 (4t)dt}{\int_2^4 dt} = \frac{4\int_2^4 t\, dt}{2} = 2\left[\frac{t^2}{2}\right]_2^4 = \left[t^2\right]_2^4 = 12$

$\Rightarrow i_{rms} = \sqrt{\bar{i^2}} = \sqrt{12} = 2\sqrt{3}\ A$

15. (b) 1. *rms* value $= \frac{x_0}{\sqrt{2}}$

2. $x_0 \sin\omega t \cos\omega t = \frac{x_0}{2}\sin 2\omega t \Rightarrow rms$ value $= \frac{x_0}{2\sqrt{2}}$

3. $x_0 \sin\omega t + x_0 \cos\omega t \Rightarrow rms$ value $= \sqrt{\left(\frac{x_0}{\sqrt{2}}\right)^2 + \left(\frac{x_0}{\sqrt{2}}\right)^2}$

$= \sqrt{x_0^2} = x_0$

16. (c) Given $X_L = X_C = 5\Omega$, this is the condition of resonance. So $V_L = V_C$, so net voltage across L and C combination will be zero.

17. (a) At angular frequency ω, the current in RC circuit is given by

$$i_{rms} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}} \quad ......(i)$$

Also $\frac{i_{rms}}{2} = \frac{V_{rms}}{\sqrt{R^2 + \left(\frac{1}{\frac{\omega}{3}C}\right)^2}} = \frac{V_{rms}}{\sqrt{R^2 + \frac{9}{\omega^2 C^2}}}$ ......(ii)

From equation (i) and (ii) we get

$$3R^2 = \frac{5}{\omega^2 C^2} \Rightarrow \frac{\frac{1}{\omega C}}{R} = \sqrt{\frac{3}{5}} \Rightarrow \frac{X_C}{R} = \sqrt{\frac{3}{5}}$$

18. (d) $\tan\phi = \frac{X_L}{R} = \frac{X_C}{R} \Rightarrow \tan 60^o = \frac{X_L}{R} = \frac{X_C}{R}$

$\Rightarrow X_L = X_C = \sqrt{3}\ R$

i.e. $Z = \sqrt{R^2 + (X_L - X_C)^2} = R$

So average power $P = \frac{V^2}{R} = \frac{200 \times 200}{100} = 400\ W$

19. (b) $R = \frac{P}{i_{rms}^2} = \frac{240}{16} = 15\Omega$

$Z = \frac{V}{i} = \frac{100}{4} = 25\Omega$

Now $X_L = \sqrt{Z^2 - R^2} = \sqrt{(25)^2 - (15)^2} = 20\Omega$

$\therefore 2\pi\nu L = 20 \Rightarrow L = \frac{20}{2\pi \times 50} = \frac{1}{5\pi}\ Hz$

20. (b) $X_L = R,\ X_C = R/2$

$\therefore \tan\phi = \frac{X_L - X_C}{R} = \frac{R - \frac{R}{2}}{R} = \frac{1}{2}$

$\Rightarrow \phi = \tan^{-1}(1/2)$

Also $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \frac{R^2}{4}} = \frac{\sqrt{5}}{2}R$

21. (d) At resonance net voltage across L and C is zero.

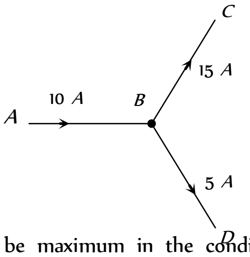
22. (c) $i_L = \frac{90}{30} = 3\ A,\quad i_C = \frac{90}{20} = 4.5\ A$

Net current through circuit $i = i_C - i_L = 1.5\ A$

$\therefore Z = \frac{V}{i} = \frac{90}{1.5} = 60\Omega$

23. (c) $i_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2 dt} = \frac{T^2}{\sqrt{5}}$

24. (a) Yes, in AC if branch AB has R, BC has a capacitor C, and BD has a pure inductance L



25. (d) Current will be maximum in the condition of resonance so $i_{max} = \frac{V}{R} = \frac{V}{10}A$

Energy stored in the coil $W_L = \frac{1}{2}Li_{max}^2 = \frac{1}{2}L\left(\frac{E}{10}\right)^2$

$= \frac{1}{2} \times 10^{-3}\left(\frac{E^2}{100}\right) = \frac{1}{2} \times 10^{-5}E^2\ joule$

$\therefore$ Energy stored in the capacitor

$W_C = \frac{1}{2}CE^2 = \frac{1}{2} \times 2 \times 10^{-6}E^2 = 10^{-6}E^2\ joule$

$\therefore \frac{W_C}{W_L} = \frac{1}{5}$

Graphical Questions

1. (c) $Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$

From above equation at $f = 0 \Rightarrow z = \infty$

When $f = \frac{1}{2\pi\sqrt{LC}}$ (resonant frequency) $\Rightarrow Z = R$

For $f > \frac{1}{2\pi\sqrt{LC}} \Rightarrow Z$ starts increasing.

i.e., for frequency 0 – f, Z decreases

and for f to ∞, Z increases. This is justified by graph c.

2. (b) At $t = 0$, phase of the voltage is zero, while phase of the current is $-\frac{\pi}{2}$ i.e., voltage leads by $\frac{\pi}{2}$

3. (c) At $A : X_C > X_L$

At $B : X_C = X_L$

At $C : X_C < X_L$

4. (c) I_L lags behind I_R by a phase of $\frac{\pi}{2}$, while I_C leads by a phase of $\frac{\pi}{2}$.

5. (d) As explained in solution (1) for frequency $0 - f_r$, Z decreases hence $(i = V/Z)$, increases and for frequency $f_r - \infty$, Z increases hence i decrees.

6. (a) $V_{rms} = \sqrt{\frac{1}{T}\int_0^T 10^2\,dt} = 10\ V$

7. (b) For capacitive circuits $X_C = \frac{1}{\omega C}$

$\therefore i = \frac{V}{X_C} = V\omega C \Rightarrow i \propto \omega$

8. (c) $I_{av} = \frac{\int_0^{T/2} i\,dt}{\int_0^{T/2} dt} = \frac{\int_0^{T/2} I_0 \sin(\omega t)dt}{T/2}$

$$= \frac{2I_0}{T}\left[\frac{-\cos\omega t}{\omega}\right]_0^{T/2} = \frac{2I_0}{T}\left[-\frac{\cos\left(\frac{\omega T}{2}\right)}{\omega} + \frac{\cos 0^o}{\omega}\right]$$

$$= \frac{2I_0}{\omega T}[-\cos\pi + \cos 0^o] = \frac{2I_0}{2\pi}[1+1] = \frac{2I_0}{\pi}$$

9. (b) (1) For time interval $0 < t < T/2$

$I = kt$, where k is the slope

For inductor as we know, induced voltage $V = -L\frac{di}{dt}$

$\Rightarrow V_1 = -KL$

(2) For time interval $\frac{T}{2} < t < T$

$I = -Kt \Rightarrow V_2 = KL$

10. (a) As the current i leads the voltage by $\frac{\pi}{4}$, it is an RC circuit, hence

$\tan\phi = \frac{X_C}{R} \Rightarrow \tan\frac{\pi}{4} = \frac{1}{\omega CR}$

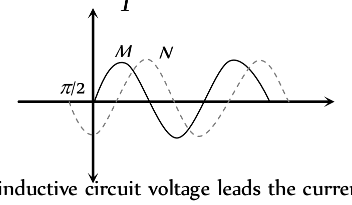
$\Rightarrow \omega CR = 1$ as $\omega = 100$ *rad/sec*

$\Rightarrow CR = \frac{1}{100} sec^{-1}$.

From all the given options only option (a) is correct.

11. (b) From the graph shown below. It is clear that phase lead of N over M is $-\frac{\pi}{2}$. Since time period (*i.e.* taken to complete one cycle) = 0.4 *sec*.

Hence frequency $\nu = \frac{1}{T} = 2.5\ Hz$



12. (d) In purely inductive circuit voltage leads the current by 90°.

13. (c) $X_L = 2\pi fL \Rightarrow X_L \propto f \Rightarrow \frac{1}{X_L} \propto \frac{1}{f}$

i.e., graph between $\frac{1}{X_L}$ and f will be a hyperbola.

14. (c) From phasor diagram it is clear that current is lagging with respect to E_-. This may be happen in LCR or LR circuit.

15. (c) At resonance $X_L = X_C$

16. (b) For anti-resonant circuit current is minimum at resonant frequency and at frequencies other than resonant frequency current rises with frequency.

17. (c) We have $X_C = \frac{1}{C \times 2\pi f}$ and $X_L = L \times 2\pi f$

18. (d) Reactance $X = X_L - X_C = 2\pi fL - \frac{1}{2\pi fC}$

19. (b) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$ *i.e.* $X_C \propto \frac{1}{f}$

Assertion and Reason

1. (a) At resonant frequency, $X_L = X_C$ $\therefore$ $Z = R$ (minimum) there for current in the circuit is maximum.

2. (c) When ac flows through an inductor current lags behind the *emf.*, by phase of $\pi/2$, inductive reactance, $X_L = \omega L = \pi.2f.L$, so when frequency increases correspondingly inductive reactance also increases.

3. (a) The capacitive reactance of capacitor is given by

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

So this is infinite for dc ($f = 0$) and has a very small value for ac. Therefore a capacitor blocks dc.

4. (b) The phase angle for the LCR circuit is given by

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\omega L - 1/\omega C}{R}$$

Where X_L, X_C are inductive reactance and capacitive reactance respectively when $X_L > X_C$ then $\tan\phi$ is positive *i.e.* ϕ is positive (between 0 and $\pi/2$). Hence emf leads the current.

5. (a) If resistor is used in controlling ac supply, electrical energy will be wasted in the form of heat energy across the resistance wire. However, ac supply can be controlled with choke without any wastage of energy. This is because, power factor ($\cos\phi$) for resistance is unity and is zero for an inductance. [$P = EI\cos\phi$].

6. (a) When frequency of alternating current is increased, the effective resistance of the inductive coil increases. Current $(X_L = \omega L = 2\pi f L)$ in the circuit containing inductor is given by $I = \frac{V}{X_L} = \frac{V}{2\pi f L}$. As inductive resistance of the inductor increases, current in the circuit decreases.

7. (e) On introducing soft iron core, the bulb will glow dimmer. This is because on introducing soft iron core in the solenoid, its inductance L increases, the inductive reactance, $X_L = \omega L$ increases and hence the current through the bulb decreases.

8. (b) Like direct current, an alternating current also produces magnetic field. But the magnitude and direction of the field goes on changing continuously with time.

9. (c) Both ac and dc produce heat, which is proportional to square of the current. The reversal of direction of current in ac is immaterial so far as production of heat is concerned.

10. (a) The effect of ac on the body depends largely on the frequency. Low frequency currents of 50 to 60 *Hz* (*cycles/sec*), which are commonly used, are usually more dangerous than high frequency currents and are 3 to 5 times more dangerous than dc of same voltage and amperage (current). The usual frequency of 50 *cps* (or 60 *cps*) is extremely dangerous as it corresponds to the fibrillation frequency of the myocardium. This results in ventricular fibrillation and instant death.

11. (b) The mean average value of alternating current (or emf) during a half, cycle is given by $I_m = 0.636\, I_0$ (or $E_m = 0.636 E_0$)

During the next half cycle, the mean value of ac will be equal in magnitude but opposite in direction.

For this reason the average value of ac over a complete cycle is always zero. So the average value is always defined over a half cycle of ac.

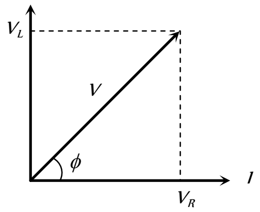
12. (d) An ac ammeter is constructed on the basics of heating effect of the electric current. Since heat produced varies as square of current $(H = I^2 R)$. Therefore the division marked on the scale of ac ammeter are not equally spaced.

13. (d) The power of a ac circuit is given by $P = EI\cos\phi$

where $\cos\phi$ is power factor and ϕ is phase angle. In case of circuit containing resistance only, phase angle is zero and power factor is equal to one. Therefore power is maximum in case of circuit containing resistor only.

14. (a) Capacitive reactance $X_C = \frac{1}{\omega C}$. When capacitance (C) increases, the capacitive reactance decreases. Due to decrease in its values, the current in the circuit will increases $\left(I = \frac{E}{\sqrt{R^2 + X_C^2}} \right)$ and hence brightness of source (or electric lamp) will also increases.

15. (b) As both the inductance and resistance are joined in series, hence current through both will be same. But in case of resistance, both the current and potential vary simultaneously, hence they are in same phase. In case of an inductance when current is zero, potential difference across it is maximum and when current reaches maximum (at $\omega t = \pi/2$), potential difference across it becomes zero *i.e.* potential difference leads the current by $\pi/2$ or current lags behind the potential difference by $\pi/2$, Phase angle in case of *LR* circuit is given as $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$.



16. (b) We can use a capacitor of suitable capacitance as a chock coil, because average power consumed per cycle in an ideal capacitor is zero. Therefore, like a choke coil, a condenser can reduce ac without power dissipation.

Alternating Current

SET Self Evaluation Test - 24

1. A bulb and a capacitor are in series with an ac source. On increasing frequency how will glow of the bulb change

(a) The glow decreases (b) The glow increases

(c) The glow remain the same (d) The bulb quenches

2. The *r.m.s.* current in an ac circuit is 2 *A*. If the wattless current be $\sqrt{3}A$, what is the power factor

(a) $\frac{1}{\sqrt{3}}$ (b) $\frac{1}{\sqrt{2}}$

(c) $\frac{1}{2}$ (d) $\frac{1}{3}$

3. $\frac{2.5}{\pi}\mu F$ capacitor and 3000-*ohm* resistance are joined in series to an ac source of 200 *volt* and $50 sec^{-1}$ frequency. The power factor of the circuit and the power dissipated in it will respectively

(a) 0.6, 0.06 *W* (b) 0.06, 0.6 *W*

(c) 0.6, 4.8 *W* (d) 4.8, 0.6 *W*

4. The self inductance of a choke coil is 10 *mH*. When it is connected with a 10 *V* dc source, then the loss of power is 20 *watt*. When it is connected with 10 *volt* ac source loss of power is 10 *watt*. The frequency of ac source will be

(a) 50 *Hz* (b) 60 *Hz*

(c) 80 *Hz* (d) 100 *Hz*

5. In an *LCR* circuit $R = 100$ *ohm*. When capacitance *C* is removed, the current lags behind the voltage by $\pi/3$. When inductance *L* is removed, the current leads the voltage by $\pi/3$. The impedance of the circuit is

(a) 50 *ohm* (b) 100 *ohm*

(c) 200 *ohm* (d) 400 *ohm*

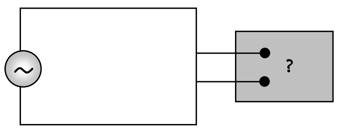
6. A group of electric lamps having a total power rating of 1000 *watt* is supplied by an ac voltage $E = 200\sin(310t + 60°)$. Then the *r.m.s.* value o the circuit current is

(a) 10 *A* (b) $10\sqrt{2}\ A$

(c) 20 *A* (d) $20\sqrt{2}\ A$

7. Following figure shows an ac generator connected to a "block box" through a pair of terminals. The box contains possible *R, L, C* or their combination, whose elements and arrangements are not known to us. Measurements outside the box reveals that

e = 75 sin (sin ωt) *volt*, i = 1.5 sin (ωt + 45°) *amp* then, the wrong statement is



(a) There must be a capacitor in the box

(b) There must be an inductor in the box

(c) There must be a resistance in the box

(d) The power factor is 0.707

8. A resistor *R*, an inductor *L* and a capacitor *C* are connected in series to an oscillator of frequency *n*. if the resonant frequency is n_r, then the current lags behind voltage, when

(a) $n = 0$ (b) $n < n_r$

(c) $n = n_r$ (d) $n > n_r$

9. If power factor is 1/2 in a series *RL* circuit $R = 100\,\Omega$. ac mains is used then *L* is

(a) $\frac{\sqrt{3}}{\pi}$ *Henry* (b) π *Henry*

(c) $\frac{\pi}{\sqrt{3}}$ *Henry* (d) None of these

10. What will be the self inductance of a coil, to be connected in a series with a resistance of $\pi\sqrt{3}\,\Omega$ such that the phase difference between the emf and the current at 50 *Hz* frequency is 30°

(a) 0.5 *Henry* (b) 0.03 *Henry*

(c) 0.05 *Henry* (d) 0.01 *Henry*

11. The phase difference between the voltage and the current in an ac circuit is $\pi/4$. If the frequency is 50 *Hz* then this phase difference will be equivalent to a time of

(a) 0.02 *s* (b) 0.25 *s*

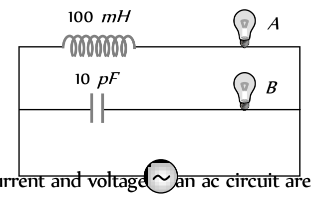
(c) 2.5 *ms* (d) 25 *ms*

12. The instantaneous values of current and emf in an ac circuit are $I = 1/\sqrt{2}\sin 314\,t\ amp$ and $E = \sqrt{2}\sin(314\,t - \pi/6)V$ respectively. The phase difference between *E* and *I* will be

(a) $-\pi/6\ rad$ (b) $-\pi/3\ rad$

(c) $\pi/6\ rad$ (d) $\pi/3\ rad$

13. If *A* and *B* are identical bulbs which bulbs glows brighter



(a) *A*

(b) *B*

(c) Both equally bright

(d) Cannot say

14. The instantaneous values of current and voltage in an ac circuit are $i = 100\sin 314\,t\,amp$ and $e = 200\sin(314\,t + \pi/3)V$ respectively. If the resistance is 1Ω then the reactance of the circuit will be

(a) $-200\sqrt{3}\,\Omega$ (b) $\sqrt{3}\,\Omega$

(c) $-200/\sqrt{3}\,\Omega$ (d) $100\sqrt{3}\,\Omega$

15. What is the *r.m.s.* value of an alternating current which when passed through a resistor produces heat which is thrice of that produced by a direct current of 2 amperes in the same resistor

(a) 6 *amp* (b) 2 *amp*

(c) 3.46 *amp* (d) 0.66 *amp*

AS Answers and Solutions

(SET -24)

1. (b) This is because, when frequency ν is increased, the capacitive reactance $X_C = \frac{1}{2\pi\nu C}$ decreases and hence the current through the bulb increases.

2. (c) $i_{WL} = i_{rms} \sin\phi \Rightarrow \sqrt{3} = 2\sin\phi \Rightarrow \sin\phi = \frac{\sqrt{3}}{2}$

$\Rightarrow \phi = 60^o$ so p.f. $= \cos\phi = \cos 60^o = \frac{1}{2}$.

3. (c) $Z = \sqrt{R^2 + \left(\frac{1}{2\pi\nu C}\right)^2} = \sqrt{(3000)^2 + \frac{1}{\left(2\pi \times 50 \times \frac{2.5}{\pi} \times 10^{-6}\right)^2}}$

$\Rightarrow Z = \sqrt{(3000)^2 + (4000)^2} = 5 \times 10^3 \Omega$

So power factor $\cos\phi = \frac{R}{Z} = \frac{3000}{5 \times 10^3} = 0.6$ and power

$P = V_{rms} i_{rms} \cos\phi = \frac{V_{rms}^2 \cos\phi}{Z} \Rightarrow P = \frac{(200)^2 \times 0.6}{5 \times 10^3} = 4.8W$

4. (c) With dc : $P = \frac{V^2}{R} \Rightarrow R = \frac{(10)^2}{20} = 5\,\Omega$;

With ac : $P = \frac{V_{rms}^2 R}{Z^2} \Rightarrow Z^2 = \frac{(10)^2 \times 5}{10} = 50\,\Omega^2$

Also $Z^2 = R^2 + 4\pi^2\nu^2 L^2$

$\Rightarrow 50 = (5)^2 + 4(3.14)^2 \nu^2 (10 \times 10^{-3})^2 \Rightarrow \nu = 80\,Hz.$

5. (b) When C is removed circuit becomes RL circuit hence

$\tan\frac{\pi}{3} = \frac{X_L}{R}$ .....(i)

When L is removed circuit becomes RC circuit hence

$\tan\frac{\pi}{3} = \frac{X_C}{R}$ .....(ii)

From equation (i) and (ii) we obtain $X_L = X_C$. This is the condition of resonance and in resonance $Z = R = 100\Omega$.

6. (b) $P = \frac{1}{2} V_0 i_0 \cos\phi \Rightarrow 1000 = \frac{1}{2} \times 200 \times i_0 \cos 60^o$

$\Rightarrow i_0 = 20A \Rightarrow i_{rms} = \frac{i_0}{\sqrt{2}} = \frac{20}{\sqrt{2}} = 10\sqrt{2}A.$

7. (b) Since voltage is lagging behind the current, so there must be no inductor in the box.

8. (d) The current will lag behind the voltage when reactance of inductance is more than the reactance of condenser. Thus,

$\omega L > \frac{1}{\omega C}$ or $\omega > \frac{1}{\sqrt{LC}}$

or $n > \frac{1}{2\pi\sqrt{LC}}$ or $n > n_r$ where n_r = resonant frequency.

9. (a) $\cos\phi = \frac{1}{2} \Rightarrow \phi = 60^o$ $\tan 60^o = \frac{\omega L}{R} \Rightarrow L = \frac{\sqrt{3}}{\pi} H$

10. (d) $\tan\phi = \frac{X_L}{R} = \frac{2\pi\nu L}{R} \Rightarrow \tan 30^o = \frac{2\pi \times 50 \times L}{\pi\sqrt{3}}$ = 0.01 H.

11. (c) Time difference $= \frac{T}{2\pi} \times \phi = \frac{(1/50)}{2\pi} \times \frac{\pi}{4} = \frac{1}{400} s = 2.5\,m\text{-}s$

12. (a) Phase difference relative to the current

$\phi = (314\,t - \frac{\pi}{6}) - (314\,t) = -\frac{\pi}{6}$

13. (a) $\because (X_C) >> (X_L)$

14. (b) $V_0 = i_0 Z \Rightarrow 200 = 100\,Z \Rightarrow Z = 2\Omega$

Also $Z^2 = R^2 + X_L^2 \Rightarrow (2)^2 = (1)^2 + X_L^2 \Rightarrow X_L = \sqrt{3}\Omega$

15. (c) Heat produced by ac = 3 × Heat produced by dc

$\therefore i_{rms}^2 Rt = 3 \times i^2 Rt \Rightarrow i_{rms}^2 = 3 \times 2^2$

$\Rightarrow i_{rms} = 2\sqrt{3} = 3.46\,A$

***

Chapter 25

Electron, Photon, Photoelectric Effect and X-rays

Electric Discharge Through Gases

At normal atmospheric pressure, the gases are poor conductor of electricity. If we establish a potential difference (of the order of 30 *kV*) between two electrodes placed in air at a distance of few *cm* from each other, electric conduction starts in the form of sparks.

The discharge of electricity through gases can be systematically studied with the help of discharge tube shown below

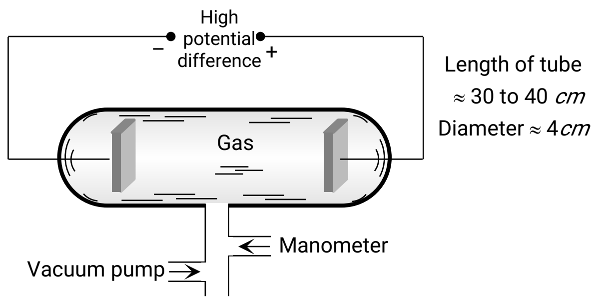


Fig. 25.1

As the pressure inside the discharge tube is gradually reduced, the following is the sequence of phenomenon that are observed.

(1) At normal pressure no discharge takes place.

(2) At the pressure 10 *mm* of *Hg*, a zig-zag thin red spark runs from one electrode to other and cracking sound is heard.

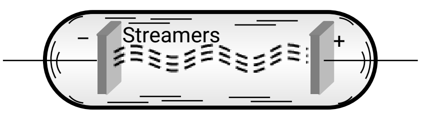


Fig. 25.2

(3) At the pressure 4 *mm.* of *Hg*, an illumination is observed at the electrodes and the rest of the tube appears dark. This type of discharge is called dark discharge.

(4) When the pressure falls below 4 *mm* of *Hg* then the whole tube is filled with bright light called positive column and colour of light depends upon the nature of gas in the tube as shown in the following table.

Table 25.1 : Colour for different gases

Gas	Air	H_2	N_2	Cl_2	CO_2	Neon
Colour	Purple red	Blue	Red	Green	Bluish white	Dark red

(5) At a pressure of 1.65 *mm* of *Hg* :

Sky colour light is produced at the cathode it is called as negative glow. Positive column shrinks towards the anode and the dark space between positive column and negative glow is called Faradays dark space (*FDS*).

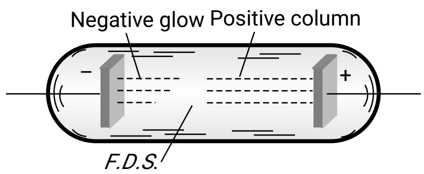


Fig. 25.3

(6) At a pressure of 0.8 *mm Hg* : At this pressure, negative glow is detached from the cathode and moves towards the anode. The dark space created between cathode and negative glow is called as Crook's dark space. Length of positive column further reduced. A glow appear at cathode called cathode glow.

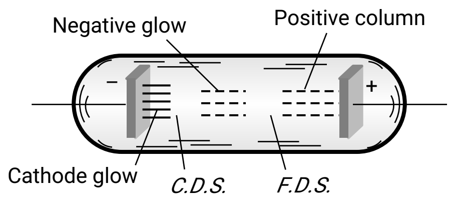


Fig. 25.4

(7) At a pressure of 0.05 *mm* of *Hg* : The positive column splits into dark and bright disc of light called striations.

(8) At the pressure of 0.01 or 10^{-2} *mm* of *Hg* some invisible

particles move from cathode which on striking with the glass tube on the opposite side of cathode cause the tube to glow. These invisible rays emerging from cathode are called cathode rays.

(9) Finally when pressure drops to nearly 10^{-4} *mm* of *Hg*, there is no discharge in tube.

Cathode Rays

(1) Cathode rays, discovered by Sir William Crooke

(2) They are streams of fast moving electrons.

(3) They can be produced by using a discharge tube containing gas at a low pressure of the order of 10^{-2} *mm* of *Hg*.

(4) The cathode rays in the discharge tube are the electrons produced due to ionisation of gas and that emitted by cathode due to collision of positive ions.

(5) Cathode rays travel in straight lines.

(6) Cathode rays are emitted normally from the cathode surface. Their direction is independent of the position of the anode.

(7) Cathode rays exert mechanical force on the objects they strike.

(8) Cathode rays produce heat when they strikes a metal surface.

(9) Cathode rays produce fluorescence.

(10) When cathode rays strike a solid object, specially a metal of high atomic weight and high melting point *X*-rays are emitted from the objects.

(11) Cathode rays are deflected by an electric field and also by a magnetic field.

(12) Cathode rays ionise the gases through which they are passed.

(13) Cathode rays can penetrate through thin foils of metal.

(14) Cathode rays are found to have velocity ranging $\frac{1}{30}th$ to $\frac{1}{10}th$ of velocity of light.

J.J. Thomson's Experiment

(1) It's working is based on the fact that if a beam of electron is subjected to the crossed electric field $\vec{E}$ and magnetic field $\vec{B}$, it experiences a force due to each field. In case the forces on the electrons in the electron beam due to these fields are equal and opposite, the beam remains undeflected.

(2) When no field is applied, the electron beam produces illuminations at point *P*.

(3) In the presence of any field (electric and magnetic) electron beam deflected up or down (illumination at P' or P'')

(4) If both the fields are applied simultaneously and adjusted such that electron beam passes undeflected and produces illumination at point *P*.

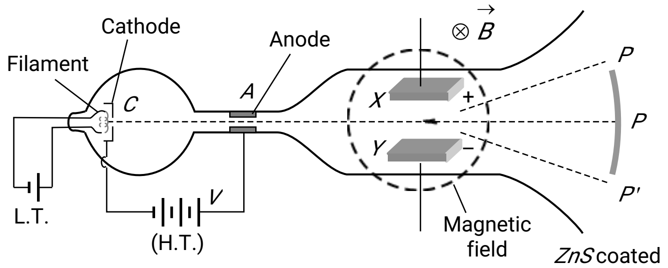


Fig. 25.5

In this case; Electric force = Magnetic force $\Rightarrow eE = evB$

$\Rightarrow v = \frac{E}{B}$; v = velocity of electron

(5) As electron beam accelerated from cathode to anode its loss in potential energy appears as gain in the K.E. at the anode. If suppose V is the potential difference between cathode and anode then, loss in potential energy = eV

And gain in kinetic energy at anode will be K.E. $= \frac{1}{2}mv^2$

i.e. $eV = \frac{1}{2}mv^2 \Rightarrow \frac{e}{m} = \frac{v^2}{2V} \Rightarrow \frac{e}{m} = \frac{E^2}{2VB^2}$

Thomson found, $\frac{e}{m} = 1.77 \times 10^{11}\ C/kg$.

If one includes the relativistic variation of mass with speed $(m = m_0/\sqrt{1 - v^2/c^2})$, then specific charge of an electron decreases with the increase in its velocity.

(6) The deflection of an electron in a purely electric field is given by $y = \frac{1}{2}\left(\frac{eE}{m}\right)\cdot\frac{l^2}{v^2}$; where l = Length of each plate, y = deflection of electron in the field region, v = speed of the electron.

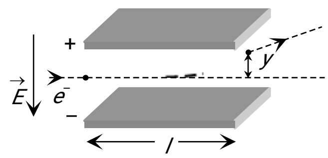


Fig. 25.6

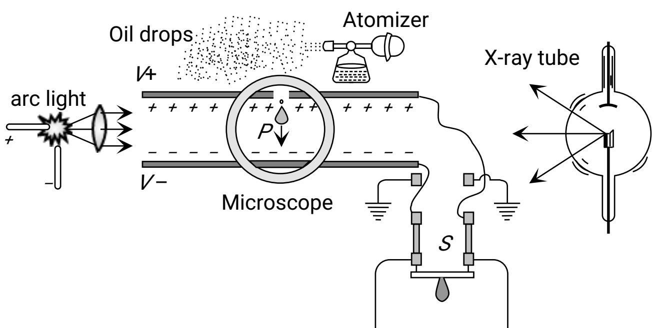
Millikans Oil Drop Experiment

(1) Millikan performed the pioneering oil drop experiment for the precise measurement of the charge on the electron.

(2) By applying suitable electric field across two metal plates, the charged oil droplets could be caused to rise or fall or even held stationary in the field of view for sufficiently long time. He found that the charge on an oil droplet was always an integral multiple of an elementary charge $1.602 \times 10^{-19}\ C$.

(3) In this experiment charge on the drop is given by

$$q = \frac{6\pi\eta(v_1 + v_2)d}{V}\left[\frac{9\eta v_1}{2g(\rho - \sigma)}\right]^{1/2}$$



where η = Coefficient of viscosity of air, v_1 = Terminal velocity of drop when no electric field is applied between the plates, v_2 = Terminal velocity of drop when electric field is applied between the plates.

V = Potential difference between the plates, d = Separation between plates, ρ = density of oil, σ = Density of air.

Positive Rays

When potential difference is applied across the electrodes of a discharge tube (10^{-3} *mm* of *Hg*), electrons are emitted from the perforated cathode. As they move towards anode, they gain energy. These energetic electrons when collide with the atoms of the gas in the discharge tube, they ionize the atoms. The positive ions so formed at various places between cathode and anode, travel towards the cathode. Since during their motion, the positive ions when reach the cathode, some pass through the holes in the cathode and a faint luminous glow comes out from each hole on the backside of the cathode. It is called positive rays, which are coming out from the holes.

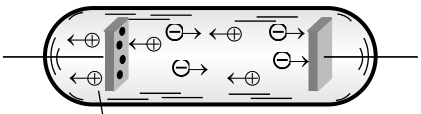


Fig. 25.8

(1) Positive rays are positive ions having same mass if the experimental gas does not have isotopes. However if the gas has isotopes then positive rays are group of positive ions having different masses.

(2) They travel in straight lines and cast shadows of objects placed in their path. But the speed of the positive rays is much smaller than that of cathode rays.

(3) They are deflected by electric and magnetic fields but the deflections are small as compared to that for cathode rays.

(4) They show a spectrum of velocities. Different positive ions move with different velocities. Being heavy, their velocity is much less than that of cathode rays.

(5) q/m ratio of these rays depends on the nature of the gas in the tube (while in case of the cathode rays q/m is constant and doesn't depend on the nature of gas in the tube). q/m for hydrogen is maximum.

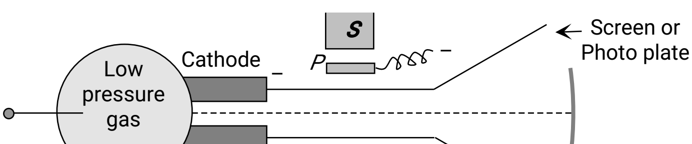
(6) They carry energy and momentum. The kinetic energy of positive rays is more than that of cathode rays.

(7) The value of charge on positive rays is an integral multiple of electronic charge.

(8) They cause ionisation (which is much more than that produced by cathode rays).

Thomson's Mass Spectrograph

It is used to measure atomic masses of various isotopes in gas. This is done by measuring q/m of singly ionised positive ion of the gas.



(1) The positive ions are produced in the bulb at the left hand side. These ions are accelerated towards cathode. Some of the positive ions pass through the fine hole in the cathode. This fine ray of positive ions is subjected to electric field E and magnetic field B and then allowed to strike a fluorescent screen ($\vec{E} \parallel \vec{B}$ but $\vec{E}$ or $\vec{B} \perp \vec{v}$).

(2) If the initial motion of the ions is in $+x$ direction and electric and magnetic fields are applied along $+y$ axis then force due to electric field is in the direction of y-axis and due to magnetic field it is along z-direction.

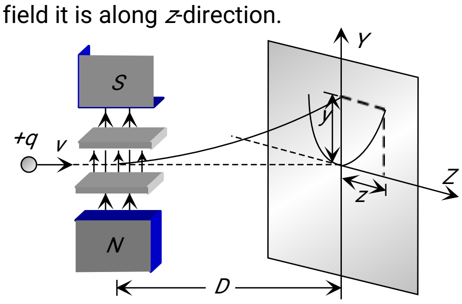


Fig. 25.10

The deflection due to electric field alone $y = \frac{qELD}{mv^2}$ .....(i)

The deflection due to magnetic field alone $z = \frac{qBLD}{mv}$ .....(ii)

From equation (i) and (ii), $z^2 = k\left(\frac{q}{m}\right)y$

where $k = \frac{B^2LD}{E}$; This is the equation of parabola. It means all the charged particles moving with different velocities but of same q/m value will strike the screen placed in yz plane on a parabolic track as shown in the above figure.

(3) All the positive ions of same. q/m moving with different velocity lie on the same parabola. Higher is the velocity lower is the value of y and z. The ions of different specific charge will lie on different parabola.

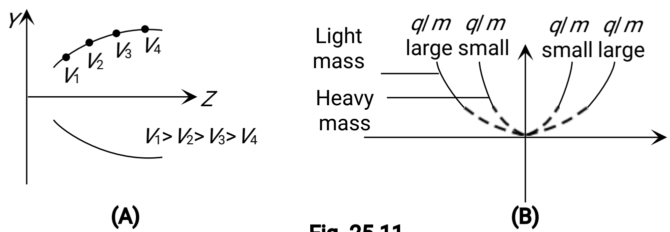


Fig. 25.11

(4) The number of parabola tells the number of isotopes present in the given ionic beam.

Bainbridge Mass Spectrograph

In Bainbridge mass spectrograph, field particles of same velocity are selected by using a velocity selector and then they are subjected to a uniform magnetic field perpendicular to the velocity of the particles. The particles corresponding to different isotopes follow different circular paths as shown in the figure.

(1) **Velocity selector :** The positive ions having a certain velocity v gets isolated from all other velocity particles. In this chamber the electric and magnetic fields are so balanced that the particle moves undeflected. For this the necessary condition is $v = \frac{E}{B}$ and E, B and v should be mutually perpendicular to each other.

(2) **Analysing chamber :** In this chamber magnetic field B is applied perpendicular to the direction of motion of the particle. As a result the particles move along a circular path of radius

$$r = \frac{mE}{qBB'} \Rightarrow \frac{q}{m} = \frac{E}{BB'r} \quad \text{also} \quad \frac{r_1}{r_2} = \frac{m_1}{m_2}$$

In this way the particles of different masses gets deflected on circles of different radii and reach on different points on the photo plate.

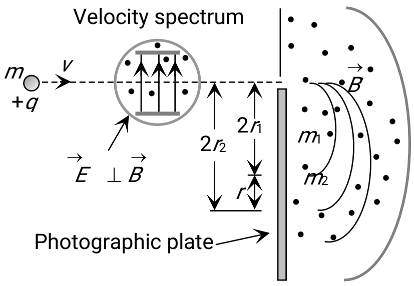


Fig. 25.12

Separation between two traces $= d = 2r_2 - 2r_1 = \frac{2v(m_2 - m_1)}{qB'}$.

Matter Waves (de-Broglie Waves)

According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle.

The wave associated with moving particle is called matter wave or de-Broglie wave and it propagates in the form of wave packets with group velocity.

(1) **de-Broglie wavelength :** According to de-Broglie theory, the wavelength of de-Broglie wave is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{p} \propto \frac{1}{v} \propto \frac{1}{\sqrt{E}}$$

Where h = Plank's constant, m = Mass of the particle, v = Speed of the particle, E = Energy of the particle.

The smallest wavelength whose measurement is possible is that of γ-rays.

The wavelength of matter waves associated with the microscopic particles like electron, proton, neutron, α-particle *etc.* is of the order of 10^{-10} *m.*

(2) **de-Broglie wavelength associated with the charged particles :** The energy of a charged particle accelerated through potential difference V is $E = \frac{1}{2}mv^2 = qV$

Hence de-Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$

$$\lambda_{Electron} = \frac{12.27}{\sqrt{V}} Å, \quad \lambda_{Proton} = \frac{0.286}{\sqrt{V}} Å,$$

$$\lambda_{Deutron} = \frac{0.202}{\sqrt{V}} Å, \quad \lambda_{\alpha-particle} = \frac{0.101}{\sqrt{V}} Å$$

(3) **de-Broglie wavelength associated with uncharged particles :** For *Neutron* de-Broglie wavelength is given as

$$\lambda_{Neutron} = \frac{0.286 \times 10^{-10}}{\sqrt{E \text{ (in } eV)}} m = \frac{0.286}{\sqrt{E \text{ (in } eV)}} Å$$

Energy of thermal neutrons at ordinary temperature

$\because$ $E = kT \Rightarrow \lambda = \frac{h}{\sqrt{2mkT}}$; where T = Absolute temperature, k = Boltzman's constant = 1.38×10^{-23} *Joule/kelvin*, So,

$$\lambda_{Thermal \quad neutron} = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 1.38 \times 10^{-23} T}} = \frac{30.83}{\sqrt{T}} Å$$

(4) **Ratio of wavelength of photon and electron :** The wavelength of a photon of energy E is given by $\lambda_{ph} = \frac{hc}{E}$

While the wavelength of an electron of kinetic energy K is given by $\lambda_e = \frac{h}{\sqrt{2mK}}$. Therefore, for the same energy,

the ratio $\frac{\lambda_{ph}}{\lambda_e} = \frac{c}{E}\sqrt{2mK} = \sqrt{\frac{2mc^2 K}{E^2}}$

Characteristics of Matter Waves

(1) Matter wave represents the probability of finding a particle in space.

(2) Matter waves are not electromagnetic in nature.

(3) de-Brogile or matter wave is independent of the charge on the material particle. It means, matter wave of de-Broglie wave is associated with every moving particle (whether charged or uncharged).

(4) Practical observation of matter waves is possible only when the de-Broglie wavelength is of the order of the size of the particles.

(5) Electron microscope works on the basis of de-Broglie waves.

(6) The phase velocity of the matter waves can be greater than the speed of the light.

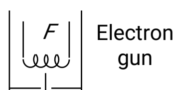
(7) Matter waves can propagate in vacuum, hence they are not mechanical waves.

(8) The number of de-Broglie waves associated with n^{th} orbital electron is n.

(9) Only those circular orbits around the nucleus are stable whose circumference is integral multiple of de-Broglie wavelength associated with the orbital electron.

Davision and Germer Experiment

(1) It is used to study the scattering of electron from a solid or to verify the wave nature of electron. A beam of electrons



emitted by electron gun is made to fall on nickel crystal cut along cubical axis at a particular angle. *Ni* crystal behaves like a three dimensional diffraction grating and it diffracts the electron beam obtained from electron gun.

(2) The diffracted beam of electrons is received by the detector which can be positioned at any angle by rotating it about the point of incidence. The energy of the incident beam of electrons can also be varied by changing the applied voltage to the electron gun.

(3) According to classical physics, the intensity of scattered beam of electrons at all scattering angle will be same but Davisson and Germer, found that the intensity of scattered beam of electrons was not the same but different at different angles of scattering. It is maximum for diffracting angle 50° at 54 *volt* potential difference.

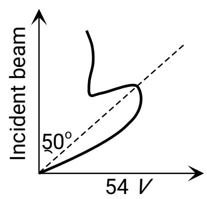


Fig. 25.14

(4) If the de-Broglie waves exist for electrons then these should be diffracted as *X*-rays. Using the Bragg's formula $2d\sin\theta = n\lambda$, we can determine the wavelength of these waves.

where d = distance between diffracting planes, $\theta = \frac{(180-\phi)}{2}$ = glancing angle for incident beam = Bragg's angle.

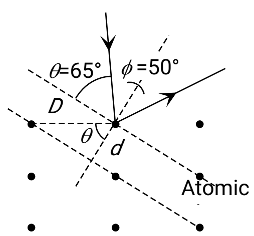


Fig. 25.15

The distance between diffracting planes in *Ni*-crystal for this experiment is $d = 0.91 \mathring{A}$ and the Bragg's angle = 65°. This gives for $n = 1$, $\lambda = 2 \times 0.91 \times 10^{-10} \sin 65^{\circ} = 1.65\ \mathring{A}$

Now the de-Broglie wavelength can also be determined by using the formula $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.67\ \mathring{A}$. Thus the de-Broglie hypothesis is verified.

(5) The Bragg's formula can be rewritten in the form containing interatomic distance D and angle ϕ

$$\because\ \theta = 90 - \frac{\phi}{2} \text{ and } d = D\cos\theta = D\sin\frac{\phi}{2}$$

Using $\sin\theta = \cos\frac{\phi}{2}$

$$2d\sin\theta = \lambda \Rightarrow 2(D\sin\frac{\phi}{2}).\cos\frac{\phi}{2} = \lambda \Rightarrow D\sin\phi = \lambda$$

Heisenberg Uncertainty Principle

(1) According to Heisenberg's uncertainty principle, it is impossible to measure simultaneously both the position and the momentum of the particle.

(2) Let Δx and Δp be the uncertainty in the simultaneous measurement of the position and momentum of the particle, then $\Delta x \Delta p = \hbar$; where $\hbar = \frac{h}{2\pi}$ and $h = 6.63 \times 10^{-34}$ *J-s* is the Planck's constant. $(\frac{h}{2\pi} = 1.05 \times 10^{-34}\ J\cdot sec)$

A more rigorous treatment gives $\Delta x..\Delta p \geq \frac{\hbar}{2}\left(\text{or } \frac{h}{4\pi}\right)$.

(3) If $\Delta x = 0$ then $\Delta p = \infty$ and if $\Delta p = 0$ then $\Delta x = \infty$

i.e., if we are able to measure the exact position of the particle (say an electron) then the uncertainty in the measurement of the linear momentum of the particle is infinite. Similarly, if we are able to measure the exact linear momentum of the particle *i.e.*, $\Delta p = 0$, then we can not measure the exact position of the particle at that time.

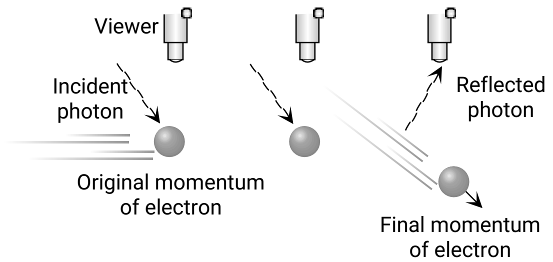


Fig. 25.16

An electron cannot be observed without changing it's momentum

(4) Uncertainty principle successfully explains

(i) Non-existence of electrons in the nucleus

(ii) Finite size of spectral lines.

(5) The Heisenberg uncertainty principle is also applicable to energy and time, angular momentum and angular displacement. Hence $\Delta E.\Delta t \geq \frac{h}{2\pi}$ and $\Delta L.\Delta\theta \geq \frac{h}{2\pi}$

(6) If the radius of the nucleus is r then the probability of finding the electron inside the nucleus is $\Delta x = 2r$ and uncertainty in momentum is $\Delta p = \frac{h}{4\pi r}$

Photon

According to Eienstein's quantum theory light propagates in the bundles (packets or quanta) of energy, each bundle being called a photon and possessing energy.

(1) **Energy of photon :** Energy of photon is given by

$E = h\nu = \frac{hc}{\lambda}$; where c = Speed of light, h = Plank's constant = 6.6×10^{-34} *J-sec*, ν = Frequency in *Hz*, λ = Wavelength of light.

In electron volt $E(eV) = \frac{hc}{e\lambda} = \frac{12375}{\lambda(Å)} \approx \frac{12400}{\lambda(Å)}$

(2) **Mass of photon :** Actually rest mass of the photon is zero. But it's effective mass is given as

$E = mc^2 = h\nu \Rightarrow m = \frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$. This mass is also known as kinetic mass of the photon

(3) **Momentum of the photon**

Momentum $p = m \times c = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

(4) **Number of emitted photons :** The number of photons emitted per second from a source of monochromatic radiation of wavelength λ and power P is given as $(n) = \frac{P}{E} = \frac{P}{h\nu} = \frac{P\lambda}{hc}$; where E = energy of each photon

(5) **Intensity of light (I) :** Energy crossing per unit area normally per second is called intensity or energy flux

i.e. $I = \frac{E}{At} = \frac{P}{A}$ $\left(\frac{E}{t} = P = \text{radiation power}\right)$

At a distance r from a point source of power P intensity is given by $I = \frac{P}{4\pi r^2} \Rightarrow I \propto \frac{1}{r^2}$

(6) **Number of photons falling per second (n) :** If P is the power of radiation and E is the energy of a photon then $n = \frac{P}{E}$

Photo-Electric Effect

The photo-electric effect is the emission of electrons (called photo-electrons when light strikes a surface. To escape from the surface, the electron must absorb enough energy from the incident radiation to overcome the attraction of positive ions in the material of the surface.

The photoelectric effect was first observed by Heinrich Hertz and it was investigated in detail by Whilelm Hallwachs and Philipp Lenard.

The photoelectric effect is based on the principle of conservation of energy.

(1) **Work function (or threshold energy) (W_0) :** The minimum energy of incident radiation, required to eject the electrons from metallic surface is defined as work function of that surface.

$W_0 = h\nu_0 = \frac{hc}{\lambda_0}$ *Joules* ; ν_0 = Threshold frequency;

λ_0 = Threshold wavelength

Work function in electron volt $W_0(eV) = \frac{hc}{e\lambda_0} = \frac{12375}{\lambda_0(Å)}$

Table 25.2 : Work function of several elements

Element	Work function (eV)	Element	Work function (eV)
Platinum	6.4	Aluminum	4.3
Gold	5.1	Silver	4.3
Nickel	5.1	Sodium	2.7
Carbon	5.0	Lithium	2.5
Silicon	4.8	Potassium	2.2
Copper	4.7	Cesium	1.9

(2) **Threshold frequency (ν_0) :** The minimum frequency of incident radiations required to eject the electron from metal surface is defined as threshold frequency.

If incident frequency $\nu < \nu_0 \Rightarrow$ No photoelectron emission

For most metals the threshold frequency is in the ultraviolet (corresponding to wavelengths between 200 and 300 *nm*), but for potassium and cesium oxides it is in the visible spectrum (λ between 400 and 700 *nm*)

(3) **Threshold wavelength (λ_0) :** The maximum wavelength of incident radiations required to eject the electrons from a metallic surface is defined as threshold wavelength.

If incident wavelength $\lambda > \lambda_0 \Rightarrow$ No photoelectron emission

(4) **Einstein's photoelectric equation :** According to Einstein, photoelectric effect is the result of one to one inelastic collision between photon and electron in which photon is completely absorbed

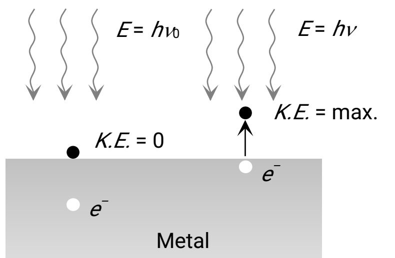


Fig. 25.17

Einstein's photoelectric equation is $E = W_0 + K_{max}$

where $K_{max} = \frac{1}{2}mv^2_{max}$ = maximum kinetic energy of emitted electrons.

Experimental Setup for Photoelectric Effect

(1) Two conducting electrodes, the anode (Q) and cathode (P) are enclosed in an evacuated glass tube as shown

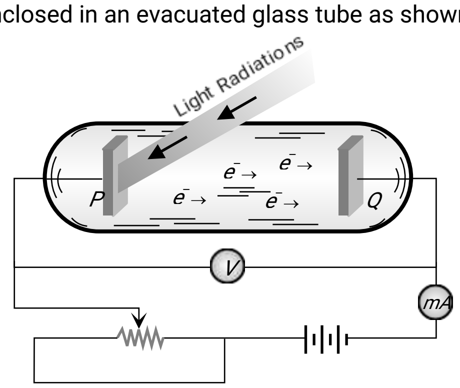


Fig. 25.18

(2) The battery or other source of potential difference creates an electric field in the direction from anode to cathode.

(3) Light of certain wavelength or frequency falling on the surface of cathode causes a current in the external circuit called photoelectric current.

(4) As potential difference increases, photo electric current also increases till saturation is reached.

(5) When polarity of battery is reversed (*i.e.* plate Q is at negative potential *w.r.t.* plate P) electrons start moving back towards the cathode.

(6) At a particular negative potential of plate Q no electron will reach the plate Q and the current will become zero, this negative potential is called **stopping potential** denoted by V_0. Maximum kinetic energy of photo electrons in terms of stopping potential will therefore be $K_{max} = (|V_0|)\ eV$

Effect of Intensity and Frequency of Light

(1) **Effect of intensity :** If the intensity of light is increased (while it's frequency is kept the same) the current levels off at a higher value, showing that more electrons are being emitted per unit time. But the stopping potential V_0 doesn't change *i.e.*

Intensity $\propto$ no. of incident photon $\propto$ no. of emitted photoelectron per time $\propto$ photo current

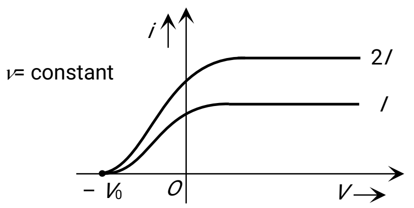


Fig. 25.19

(2) **Effect of frequency :** If frequency of incident light increases, (keeping intensity is constant) stopping potential increases but their is no change in photoelectric current

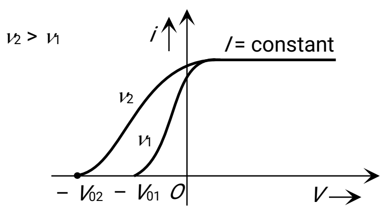


Fig. 25.20

Important Formulae for Photoelectric Effect

(1) $h\nu = h\nu_0 + K_{max}$ and $K_{max} = eV_0$

(2) $K_{max} = eV_0 = h(\nu - \nu_0) \Rightarrow \frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)$

(3) $v_{max} = \sqrt{\frac{2h(\nu - \nu_0)}{m}}$

(4) $K_{max} = \frac{1}{2}mv_{max}^2 = eV_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$

(5) $v_{max} = \sqrt{\frac{2hc}{m}\frac{(\lambda_0 - \lambda)}{\lambda\lambda_0}}$

(6) $V_0 = \frac{h}{e}(\nu - \nu_0) = \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 12375\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

Compton Effect

(1) The scattering of a photon by an electron is called Compton effect.

(2) The energy and momentum is conserved.

(3) Scattered photon will have less energy (more wavelength) as compare to incident photon (less wavelength).

(4) The energy lost by the photon is taken by electron as kinetic energy.

(5) The change in wavelength due to Compton effect is called Compton shift. Compton shift $\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\phi)$

If $\phi = 0^\circ$, $\Delta\lambda = 0$

$\phi = 90^\circ$, $\Delta\lambda = \frac{h}{m_0 c} = 0.24\ nm$

$\phi = 180^\circ$, $\Delta\lambda = \frac{2h}{m_0 c} = 0.48\ nm$ (called Compton wave length)

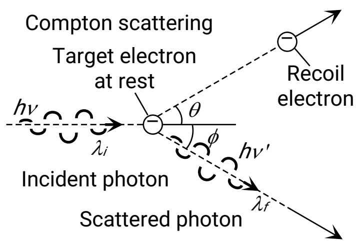


Fig. 25.21

X-Rays

(1) X-rays were discovered by scientist Rontgen thats why they are also called Rontgen rays.

(2) Rontgen discovered that when pressure inside a discharge tube is kept 10^{-3} *mm* of *Hg* and potential difference is kept 25 *kV*, then some unknown radiations (X-rays) are emitted by anode.

(3) There are three essential requirements for the production of X-rays.

(i) A source of electron

(ii) An arrangement to accelerate the electrons

(iii) A target of suitable material of high atomic weight and high melting point on which these high speed electrons strike.

Coolidge X-Ray Tube

(1) It consists of a highly evacuated glass tube containing cathode and target (also known as filament type X-ray tube). The cathode consist of a tungsten filament. The filament is coated with oxides of barium or strontium to have an emission of electrons even at low temperature. The filament is surrounded by a molybdenum cylinder kept at negative potential *w.r.t.* the target.

(2) The target (It is a material of high atomic weight, high melting point and high thermal conductivity) made of tungsten or molybdenum is embedded in a copper block.

(3) The face of the target is set at 45° to the incident electron stream.

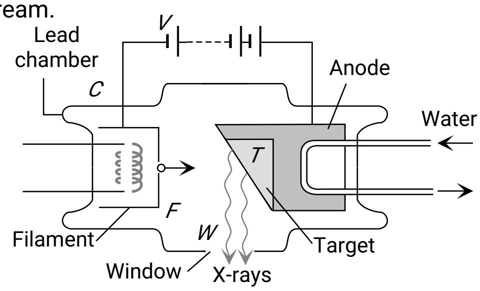


Fig. 25.22

(4) The filament is heated by passing the current through it. A high potential difference (≈ 10 *kV* to 80 *kV*) is applied between the target and cathode to accelerate the electrons which are emitted by filament. The stream of highly energetic electrons are focussed on the target.

(5) Most of the energy of the electrons is converted into heat (above 98%) and only a fraction of the energy of the electrons (about 2%) is used to produce X-rays.

(6) During the operation of the tube, a huge quantity of heat is produced in this target, this heat is conducted through the copper anode to the cooling fins from where it is dissipated by radiation and convection.

(7) **Control of intensity of X-rays** : Intensity implies the number of X-ray photons produced from the target. The intensity of X-rays emitted is directly proportional to the electrons emitted per second from the filament and this can be increased by increasing the filament current. So *intensity of X-rays* $\propto$ *Filament current*

(8) **Control of quality or penetration power of *X*-rays :** Quality of X-rays implies the penetrating power of X-rays, which can be controlled by varying the potential difference between the cathode and the target.

For large potential difference, energy of bombarding electrons will be large and hence larger is the penetration power of X-rays.

Table 25.3 : Types of X-rays

Hard X-rays	Soft X-rays
More penetration power	Less penetration power
More frequency of the order of ≈ 10^{19} *Hz*	Less frequency of the order of ≈ 10^{16} *Hz*
Lesser wavelength range (0.1Å – 4Å)	More wavelength range (4Å – 100Å)

Properties of X-Rays

(1) X-rays are electromagnetic waves with wavelength range 0.1Å – 100Å.

(2) The wavelength of X-rays is very small in comparison to the wavelength of light. Hence they carry much more energy (This is the only difference between X-rays and light)

(3) X-rays are invisible.

(4) They travel in a straight line with speed of light.

(5) X-rays are measured in Rontgen (measure of ionization power).

(6) X-rays carry no charge so they are not deflected in magnetic field and electric field.

(7) $\lambda_{Gama\ \ rays} < \lambda_{X\text{-}rays} < \lambda_{UV\ \ rays}$

(8) They used in the study of crystal structure.

(9) They ionise gases

(10) X-rays do not pass through heavy metals and bones.

(11) They affect photographic plates.

(12) Long exposure to X-rays is injurious for human body.

(13) Lead is the best absorber of X-rays.

(14) For X-ray photography of human body parts, $BaSO_4$ is the best absorber.

(15) They produce photoelectric effect and Compton effect

(16) X-rays are not emitted by hydrogen atom.

(17) These cannot be used in Radar because they are not reflected by the target.

(18) They show all the important properties of light rays like; reflection, refraction, interference, diffraction and polarization *etc*.

Absorption of X-Rays

X-rays are absorbed when they incident on substance.

Intensity of emergent *X*-rays $I = I_0 e^{-\mu x}$

So intensity of absorbed X-rays

$I' = I_0 - I = I_0(1 - e^{-\mu x})$

where x = thickness of absorbing medium, μ = absorption coefficient

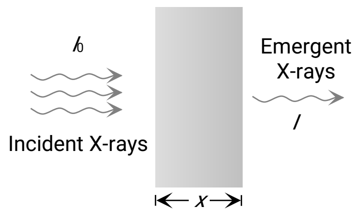


Fig. 25.23

$\mu \propto \lambda^3$; (λ = Wavelength of X-ray)

$\mu \propto \overline{\nu}^3$ (ν = Frequency of X-ray)

$\mu \propto Z^4$ (Z = Atomic number of target)

Classification of X-Rays

In X-ray tube, when high speed electrons strikes the target, they penetrate the target. They loses their kinetic energy and comes to rest inside the metal. The electron before finally being stopped makes several collisions with the atoms in the target. At each collision one of the following two types of X-rays may get formed.

(1) Continuous X-rays

(2) Characteristic X-rays

Continuous X-Rays

As an electron passes close to the positive nucleus of atom of the target, the electron is deflected from it's path as shown in figure. This results in deceleration of the electron. The loss in energy of the electron during deceleration is emitted in the form of X-rays.

The X-ray photons so emitted form the continuous X-ray spectrum.

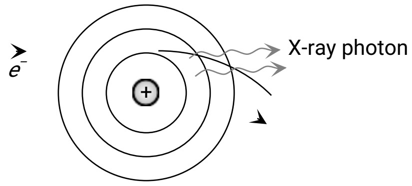


Fig. 25.24

(1) **Minimum wavelength :** When the electron looses whole of it's energy in a single collision with the atom, an X-ray photon of maximum energy $h\nu_{max}$ is emitted *i.e.*

$$\frac{1}{2}mv^2 = eV = h\nu_{max} = \frac{hc}{\lambda_{min}}$$

where v = velocity of electron before collision with target atom, V = potential difference through which electron is accelerated, c = speed of light = 3×10^8 *m/s*

Maximum frequency of radiations (X-rays) $\nu_{max} = \frac{eV}{h}$

Minimum wavelength = cut off wavelength of X-ray

$$\lambda_{min} = \frac{hc}{eV} = \frac{12375}{V}\ Å$$

(2) **Intensity wavelength graph :** The continuous X-ray spectra consist of all the wavelengths over a given range. These wavelength are of different intensities. Following figure shows the intensity variation of different wavelengths for various accelerating voltages applied to X-ray tube.

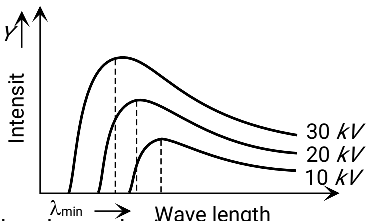


Fig. 25.25

For each voltage, the intensity curve starts at a particular minimum wavelength (λ_{min}). Rises rapidly to a maximum and then drops gradually.

The wavelength at which the intensity is maximum depends on the accelerating voltage, being shorter for higher voltage and vice-versa.

Characteristic X-Rays

Few of the fast moving electrons having high velocity penetrate the surface atoms of the target material and knock out the tightly bound electrons even from the inner most shells of the atom. Now when the electron is knocked out, a vacancy is created at that place.

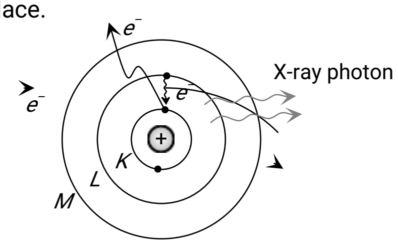


Fig. 25.26

To fill this vacancy electrons from higher shells jump to fill the created vacancies, we know that when an electron jumps from a higher energy orbit E_1 to lower energy orbit E_2, it radiates energy ($E_1 - E_2$). Thus this energy difference is radiated in the form of X-rays of very small but definite wavelength which depends upon the target material. The X-ray spectrum consists of sharp lines and is called characteristic X-ray spectrum.

(1) ***K, L, M, …… series* :** If the electron striking the target eject an electron from the *K*-shell of the atom, a vacancy is created in the *K*-shell. Immediately an electron from one of the outer shell, say *L*-shell jumps to the *K*-shell, emitting an X-ray photon of energy equal to the energy difference between the two shells. Similarly, if an electron from the *M*-shell jumps to the *K*-shell, X-ray photon of higher energy is emitted. The X-ray photons emitted due to the jump of electron from the *L*, *M*, *N* shells to the K-shells gives K_α, K_β, K_γ lines of the *K*-series of the spectrum.

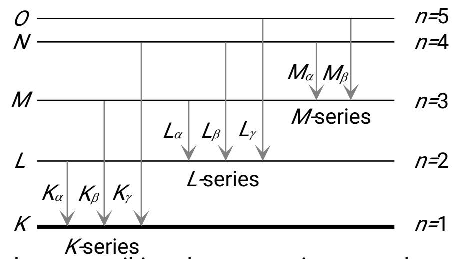


Fig. 25.27

If the electron striking the target ejects an electron from the *L*-shell of the target atom, an electron from the *M*, *N* ….. shells jumps to the *L*-shell so that X-rays photons of lesser energy are emitted.

These photons form the *L*-series of the spectrum. In a similar way the formation of *M* series, *N* series *etc*. may be explained.

(2) **Intensity-wavelength graph :** At certain sharply defined wavelengths, the intensity of X-rays is very large as marked K_α, K_β …. as shown in figure. These X-rays are known as characteristic X-rays. At other wavelengths the intensity varies gradually and these X-rays are called continuous X-rays.

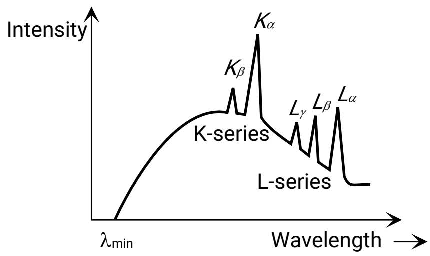


Fig. 25.28

Mosley's Law

Mosley studied the characteristic *X*-ray spectrum of a number of a heavy elements and concluded that the spectra of different elements are very similar and with increasing atomic number, the spectral lines merely shift towards higher frequencies.

He also gave the following relation $\sqrt{\nu} = a(Z - b)$

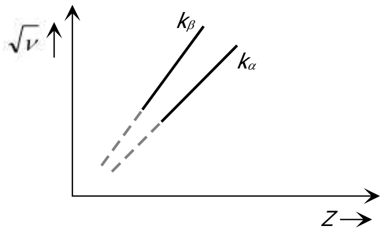


Fig. 25.29

where ν = Frequency of emitted line, Z = Atomic number of target, a = Proportionality constant, b = Screening constant or Shielding constant.

$(Z - b)$ = Effective atomic number

a and b doesn't depend on the nature of target. Different values of b are as follows

$b = 1$	for	K-series
$b = 7.4$	for	L-series
$b = 19.2$	for	M-series

(1) Mosley's law supported Bohr's theory

(2) It experimentally determined the atomic number (Z) of elements.

(3) This law established the importance of ordering of elements in periodic table by atomic number and not by atomic weight.

(4) Gaps in Moseley's data for A = 43, 61, 72, 75 suggested existence of new elements which were later discovered.

(5) The atomic numbers of Cu, Ag and Pt were established to be 29, 47 and 78 respectively.

(6) When a vacancy occurs in the K-shell, there is still one electron remaining in the K-shell. An electron in the L-shell will feel an effective charge of $(Z - 1)e$ due to $+Ze$ from the nucleus and $-e$ from the remaining K-shell electron, because L-shell orbit is well outside the K-shell orbit.

(7) Wave length of characteristic spectrum $\frac{1}{\lambda} = R(Z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ and energy of X-ray radiations.

$$\Delta E = h\nu = \frac{hc}{\lambda} = Rhc\,(Z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(8) If transition takes place from $n_2 = 2$ to $n_1 = 1$ (K_α - line)

(i) $a = \sqrt{\frac{3RC}{4}} = 2.47 \times 10^{15}\ Hz$

(ii) $\nu_{K\alpha} = RC\,(Z-1)^2\left(1 - \frac{1}{2^2}\right) = \frac{3RC}{4}(Z-1)^2$

$$= 2.47 \times 10^{15}(Z-1)^2\ Hz$$

(iii) In general the wavelength of all the K-lines are given by

$\frac{1}{\lambda_K} = R(Z-1)^2\left(1 - \frac{1}{n^2}\right)$ where n = 2, 3, 4, ….

While for K_α line $\lambda_{K\alpha} = \frac{1216}{(Z-1)^2}\ Å$

(iv) $E_{K\alpha} = 10.2(Z-1)^2\ eV$

Uses of X-Rays

(i) In study of crystal structure : Structure of DNA was also determined using X-ray diffraction.

(ii) In medical science

(iii) In radiography

(iv) In radio therapy

(v) In engineering

(vi) In laboratories

(vii) In detective department

(viii) In art the change occurring in old oil paintings can be examined by X-rays.

Tips & Tricks

✍ Discovery of positive rays helps in discovering of isotopes.

✍ The de-Broglie wavelength of electrons in first Bohr orbit of an atom is equal to circumference of orbit.

✍ A particle having zero rest mass and non zero energy and momentum must travels with a speed equal to speed of light.

✍ **de-Broglie wave length associates with gas molecules** is given as $\lambda = \frac{h}{mv_{rms}} = \frac{h}{\sqrt{3\ mkT}}$ (Energy of gas molecules at temperature T is $E = \frac{3}{2}kT$)

✍ A photon is not a material particle. It is a quanta of energy.

✍ When a particle exhibits wave nature, it is associated with a wave packet, rather then a wave.

✍ By coating the metal surface with a layer of barium oxide or strontium oxide it's work function is lowered.

✍ We must remember that intensity of incident light radiation is inversely proportional to the square of distance between source of light and photosensitive plate P *i.e.*, $I \propto \frac{1}{d^2}$ so $I \propto i \propto \frac{1}{d^2}$)

✍ The photoelectric current can be increased by filling some inert gas like Argon into the bulb. The photoelectrons emitted by cathode ionise the gas by collision and hence the current is increased.

✍ Compton effect shows that photon have momentum.

✍ Production of X-ray is the reverse phenomenon of photoelectric effect.

✍ The thickness of medium at which intensity of emergent X-rays becomes half *i.e.* $I' = \frac{I_0}{2}$ is called half value thickness ($x_{1/2}$) and it is given as $x_{1/2} = \frac{0.693}{\mu}$.

✍ Continuos X-rays are produced due to the phenomenon called "Bremsstrahlung". It means slowing down or braking radiation.

✍ The wavelength of characteristic X-ray doesn't depend on accelerating voltage. It depends on the atomic number (Z) of the target material.

✍ In characteristic X-ray spectrum $\lambda_{K\alpha} < \lambda_{L\alpha} < \lambda_{M\alpha}$ and $\nu_{K\alpha} > \nu_{L\alpha} > \nu_{M\alpha}$ also $\lambda_{K\alpha} > \lambda_{K\beta} > \lambda_{K\gamma}$

✍ Nearly all metals emits photoelectrons when exposed to UV light. But alkali metals like lithium, sodium, potassium, rubidium and cesium emit photoelectrons even when exposed to visible light.

✍ Oxide coated filament in vacuum tubes is used to emit electrons at relatively lower temperature.

✍ Conduction of electricity in gases at low pressure takes because colliding electrons acquire higher kinetic energy due to increase in mean free path.

✍ Kinetic energy of cathode rays depends on both voltage and work function of cathode.

✍ Photoelectric effect is due to the particle nature of light.

✍ Hydrogen atom does not emit X-rays because it's energy levels are too close to each other.

✍ The essential difference between X-rays and of γ-rays is that, γ-rays emits from nucleus while X-rays from outer part of atom.

✍ There is no time delay between emission of electron and incidence of photon *i.e.* the electrons are emitted out as soon as the light falls on metal surface.

✍ If light were wave (not photons) it will take about an year to eject a photoelectron out of the metal surface.

✍ Doze of X-ray are measured in terms of produced ions or free energy via ionisaiton.

✍ Safe doze for human body per week is one Rontgen (One Rontgon is the amount of X-rays which emits 2.5×10^4 *J* free energy through ionization of 1 *gm* air at NTP

✍ The photoelectrons emitted from the metallic surface have different kinetic energies even when the incident photons have same energy. This happens because all the electrons do not exist in the surface layer.

Those coming from below the surface loose more energy in getting themselves free.

✍ Einstein was awarded Nobel prize for explaining the photoelectric effect.

✍ Uncertainty in the measurement of momentum of photon within the nucleus is $\Delta p = \frac{h}{2\pi d}$

where d = diameter of the nucleus and Δx = d = uncertainty in the measurement of position of proton.

Ordinary Thinking

Objective Questions

Cathode Rays and Positive Rays

1. In the Millikan's experiment, the distance between two horizontal plates is 2.5 *cm* and the potential difference applied is 250 *V*. The electric field between the plates will be

(a) 900 *V/m* **(b)** 10000 *V/m*

(c) 625 *V/m* (d) 6250 *V/m*

2. The cathode rays have particle nature because of the fact that **[CPMT 1986; MNR 1986]**

(a) They can propagate in vacuum

(b) They are deflected by electric and magnetic fields

(c) They produced fluorescence

(d) They cast shadows

3. In Millikan's experiment for the determination of the charge on the electron, the reason for using the oil is

(a) It is a lubricant (b) Its density is higher

(c) It vapourises easily **(d)** It does not vapourise

4. The mass of a particle is 400 times than that of an electron and the charge is double. The particle is accelerated by 5 *V*. Initially the particle remained in rest, then its final kinetic energy will be **[MP PMT 1990]**

(a) 5 *eV* (b) 10 *eV*

(c) 100 *eV* (d) 2000 *eV*

5. An electron (charge = 1.6×10^{-19} C) is accelerated through a potential of 100,000 *V*. The energy acquired by the electron is **[MP PET 1989]**

(a) 1.6×10^{-24} J (b) 1.6×10^{-14} erg

(c) 0.53×10^{-17} J **(d)** 1.6×10^{-14} J

6. While doing his experiment, Millikan one day observed the following charges on a single drop

(i) 6.563×10^{-19} C (ii) 8.204×10^{-19} C

(iii) 11.50×10^{-19} C (iv) 13.13×10^{-19} C

(v) 16.48×10^{-19} C (vi) 18.09×10^{-19} C

From this data the value of the elementary charge (e) was found to be **[MP PMT 1993]**

(a) $1.641 \times 10^{-19}\ C$ (b) $1.630 \times 10^{-19}\ C$

(c) $1.648 \times 10^{-19}\ C$ (d) $1.602 \times 10^{-19}\ C$

7. When electron beam passes through an electric field, they gain kinetic energy. If the same beam passes through magnetic field, then

(a) Their energy increases

(b) Their momentum increases

(c) Their potential energy increases

(d) Energy and momentum both remains unchanged

8. Which of the following law is used in the Millikan's method for the determination of charge **[DPMT 2002]**

(a) Ampere's law **(b)** Stoke's law

(c) Fleming's left hand rule (d) Fleming's right hand rule

9. The mass of the electron varies with

(a) The size of the cathode ray tube

(b) The variation of *'g'*

(c) Velocity

(d) Size of the electron

10. When the speed of electrons increases, then the value of its specific charge **[MP PMT 1994]**

(a) Increases

(b) Decreases

(c) Remains unchanged

(d) Increases upto some velocity and then begins to decrease

11. An electron is accelerated through a potential difference of 1000 *volts*. Its velocity is nearly

[MP PMT 1985; Pb. PET 2003]

(a) $3.8 \times 10^{7}\ m/s$ (b) $1.9 \times 10^{6}\ m/s$

(c) $1.9 \times 10^{7}\ m/s$ (d) $5.7 \times 10^{7}\ m/s$

12. In an electron gun the control grid is given a negative potential relative to cathode in order to **[NCERT 1988]**

(a) Decelerate electrons

(b) Repel electrons and thus to control the number of electrons passing through it

(c) To select electrons of same velocity and to converge them along the axis

(d) To decrease the kinetic energy of electrons

13. The ratio of momenta of an electron and an $\alpha-$particle which are accelerated from rest by a potential difference of 100 V is

(a) 1 (b) $\sqrt{\frac{2m_e}{m_\alpha}}$

(c) $\sqrt{\frac{m_e}{m_\alpha}}$ (d) $\sqrt{\frac{m_e}{2m_\alpha}}$

14. When subjected to a transverse electric field, cathode rays move

(a) Down the potential gradient

(b) Up the potential gradient

(c) Along a hyperbolic path

(d) Along a circular path

15. The fact that electric charges are integral multiples of the fundamental electronic charge was proved experimentally by

(a) Planck (b) J.J. Thomson

(c) Einstein (d) Millikan

16. In Millikan oil drop experiment, a charged drop of mass $1.8\times10^{-14}\,kg$ is stationary between its plates. The distance between its plates is 0.90 *cm* and potential difference is 2.0 *kilo volts*. The number of electrons on the drop is

[MP PMT 1994, 2003; MP PET 1997]

(a) 500 (b) 50

(c) 5 (d) 0

17. The charge on electron was discovered by

[BHU 1995; RPMT 1999; DCE 2004]

(a) J.J. Thomson (b) Neil Bohr

(c) Millikan (d) Chadwick

18. From the following, what charges can be present on oil drops in Millikan's experiment [MP PET 1995]

(a) Zero, equal to the magnitude of charge on $\alpha-$particle

(b) $2e, 1.6\times10^{-18}\,C,$

(c) $1.6\times10^{-19}\,C, 2.5e$

(d) $1.5e, e$

(Here *e* is the electronic charge)

19. A narrow electron beam passes undeviated through an electric field $E=3\times10^4\,volt/m$ and an overlapping magnetic field $B=2\times10^{-3}\,Weber/m^2$. If electric field and magnetic field are mutually perpendicular. The speed of the electrons is

(a) 60 *m/s* (b) $10.3\times10^7\,m/s$

(c) $1.5\times10^7\,m/s$ (d) $0.67\times10^{-7}\,m/s$

20. In Thomson's method of determining *e/m* of electrons

[MP PMT 1997]

(a) Electric and magnetic fields are parallel to electrons beam

(b) Electric and magnetic fields are perpendicular to each other and perpendicular to electrons beam

(c) Magnetic field is parallel to the electrons beam

(d) Electric field is parallel to the electrons beam

[MNR 1994; RPET 1997]

21. Cathode rays enter into a uniform magnetic field perpendicular to the direction of the field. In the magnetic field their path will be

(a) Straight line (b) Circle

(c) Parabolic (d) Ellipse

22. The specific charge of an electron is [MP PMT/PET 1998; J&K CET 2004; Pb. PET 2002; MH CET 1999]

[MP PET 1994]

(a) $1.6\times10^{-19}\,coulomb$

(b) $4.8\times10^{-10}\,statcoulomb$

(c) $1.76\times10^{11}\,coulomb/kg$

(d) $1.76\times10^{-11}\,coulomb/kg$

[MP PET 1994]

23. An electron is moving with constant velocity along $x-$axis. If a uniform electric field is applied along $y-$axis, then its path in the $x-y$ plane will be [MP PMT 1999]

(a) A straight line (b) A circle

(c) A parabola (d) An ellipse

24. Cathode rays are similar to visible light rays in that

[SCRA 1994]

(a) They both can be deflected by electric and magnetic fields

(b) They both have a definite magnitude of wavelength

(c) They both can ionise a gas through which they pass

(d) They both can expose a photographic plate

25. Which one of the following devices makes use of the electrons to strike certain substances to produce fluorescence

[SCRA 1994]

(a) Thermionic valve (b) Photoelectric cell

(c) Cathode ray oscilloscope (d) Electron gun

26. An oxide coated filament is useful in vacuum tubes because essentially [SCRA 1994]

(a) It has high melting point

(b) It can withstand high temperatures

(c) It has good machanical strength

(d) It can emit electrons at relatively lower temperatures

27. Gases begin to conduct electricity at low pressure because

[CBSE PMT 1994]

[MP PET 1995]

(a) At low pressure, gases turn to plasma

(b) Colliding electrons can acquire higher kinetic energy due to increased mean free path leading to ionisation of atoms

(c) Atoms break up into electrons and protons

(d) The electrons in atoms can move freely at low pressure

28. A beam of electrons is moving with constant velocity in a region having electric and magnetic fields of strength $20\,Vm^{-1}$ and 0.5 T at right angles to the direction of motion of the electrons. What is the velocity of the electrons

[CBSE PMT 1996]

(a) 20 ms^{-1} (b) 40 ms^{-1}

(c) 8 ms^{-1} (d) 5.5 ms^{-1}

29. Kinetic energy of emitted cathode rays is dependent on [CPMT 1996]

(a) Only voltage

(b) Only work function

(c) Both (a) and (b)

(d) It does not depend upon any physical quantity

30. The radius of the orbital of electron in the hydrogen atom 0.5 Å. The speed of the electron is $2\times10^6 m/s$. Then the current in the loop due to the motion of the electron is [RPMT 1996]

(a) 1 *mA* (b) 1.5 *mA*

(c) 2.5 *mA* (d) $1.5\times10^{-2} mA$

31. The kinetic energy of an electron which is accelerated through a potential of 100 *volts* is [MP PET 1986; CBSE PMT 1997; AIIMS 1998]

(a) $1.602\times10^{-17} J$ (b) 418.6 *calories*

(c) $1.16\times10^4 K$ (d) 6.626×10^{-34} *W- sec*

32. When a proton is accelerated with 1 *volt* potential difference, then its kinetic energy is [CPMT 1997; CBSE PMT 1999; RPET 2003]

(a) $\frac{1}{1840}eV$ (b) 1840 *eV*

(c) 1 *eV* (d) 1840 *c eV*

33. Energy of electrons can be increased by allowing them [JIPMER 1997]

(a) To fall through electric potential

(b) To move in high magnetic field

(c) To fall from great heights

(d) To pass through lead blocks

34. Cathode rays and canal rays produced in a certain discharge tube are deflected in the same direction if [SCRA 1998]

(a) A magnetic field is applied normally

(b) An electric field is applied normally

(c) An electric field is applied tangentially

(d) A magnetic field is applied tangentially

35. In a Millikan's oil drop experiment the charge on an oil drop is calculated to be $6.35\times10^{-19} C$. The number of excess electrons on the drop is [MNR 1998]

(a) 3.9 (b) 4

(c) 4.2 (d) 6

36. Cathode rays consist of [DCE 1999]

(a) Photons (b) Electrons

(c) Protons (d) α -particles

37. A metal plate gets heated, when cathode rays strike against, it due to [CPMT 2000; Pb. PET 2000]

(a) Kinetic energy of cathode rays

(b) Potential energy of cathode rays

(c) Linear velocity of cathode rays

(d) Angular velocity of cathode rays

38. Cathode rays are [RPET 2000]

(a) Positive rays (b) Neutral rays

(c) He rays (d) Electron waves

39. An electron of charge '*e*' coulomb passes through a potential difference of V *volts*. Its energy in '*joules*' will be [MP PET 2000]

(a) V/e (b) eV

(c) e/V (d) V

40. An electron is accelerated through a potential difference of 200 *volts*. If e/m for the electron be 1.6×10^{11} *coulomb/kg*, the velocity acquired by the electron will be [MP PET 2000]

(a) $8\times10^6 m/s$ (b) $8\times10^5 m/s$

(c) $5.9\times10^6 m/s$ (d) $5.9\times10^5 m/s$

41. Which is not true with respect to the cathode rays [Kerala PET 2001]

(a) A stream of electrons

(b) Charged particles

(c) Move with speed same as that of light

(d) Can be deflected by magnetic fields

42. In Milikan's experiment, an oil drop having charge q gets stationary on applying a potential difference V in between two plates separated by a distance 'd'. The weight of the drop is

(a) qVd (b) $q\frac{d}{V}$

(c) $\frac{q}{Vd}$ (d) $q\frac{V}{d}$

43. Electron volt is a unit of [MP PMT 2001]

(a) Potential (b) Charge

(c) Power (d) Energy

44. In Thomson experiment of finding e/m for electrons, beam of electron is replaced by that of muons (particle with same charge as of electrons but mass 208 times that of electrons). No deflection condition in this case satisfied if [Orissa (Engg.) 2002]

(a) B is increased 208 times

(b) E is increased 208 times

(c) B is increased 14.4 times

(d) None of these

45. The colour of the positive column in a gas discharge tube depends on [Kerala (Engg.) 2002]

(a) The type of glass used to construct the tube

(b) The gas in the tube

(c) The applied voltage

(d) The material of the cathode

46. Cathode rays are produced when the pressure is of the order of

(a) 2 *cm* of *Hg* (b) 0.1 *cm* of *Hg*

(c) 0.01 *mm* of *Hg* (d) 1 μm of *Hg*

47. The speed of an electron having a wavelength of $10^{-10}\ m$ is [AIIMS 2002]

(a) $7.25\times10^{6}\ m/s$ (b) $6.26\times10^{6}\ m/s$

(c) $5.25\times10^{6}\ m/s$ (d) $4.24\times10^{6}\ m/s$

48. Which of the following is not the property of a cathode ray [CBSE PMT 2002]

(a) It casts shadow

(b) It produces heating effect

(c) It produces flurosence

(d) It does not deflect in electric field

49. In a Thomson set-up for the determination of *e/m*, electrons accelerated by 2.5 kV enter the region of crossed electric and magnetic fields of strengths $3.6\times10^{4}\,Vm^{-1}$ and $1.2\times10^{-3}\,T$ respectively and go through undeflected. The measured value of e/m of the electron is equal to [AMU 2002]

(a) $1.0\times10^{11}\,C\text{-}kg^{-1}$ (b) $1.76\times10^{11}\,C\text{-}kg^{-1}$

(c) $1.80\times10^{11}\,C\text{-}kg^{-1}$ (d) $1.85\times10^{11}\,C\text{-}kg^{-1}$

50. The ratio of specific charge of an α -particle to that of a proton is

(a) 2 : 1 (b) 1 : 1

(c) 1 : 2 (d) 1 : 3

51. In Bainbridge mass spectrograph a potential difference of 1000 *V* is applied between two plates distant 1 *cm* apart and magnetic field in *B* = 1*T*. The velocity of undeflected positive ions in *m/s* from the velocity selector is [RPMT 1998]

(a) $10^{7}\,m/s$ (b) $10^{4}\,m/s$

(c) $10^{5}\,m/s$ (d) $10^{2}\,m/s$

52. When cathode rays (tube voltage ~ 10 *kV*) collide with the anode of high atomic weight then we get [MP PET 1985]

(a) Positive rays (b) *X*-rays

(c) Gamma rays (d) Canal rays

53. In Thomson's experiment if the value of *q/m* is the same for all positive ions striking the photographic plate, then the trace would be [RPMT 1986]

(a) Straight line (b) Parabolic

(c) Circular (d) Elliptical

54. In a discharge tube at 0.02 *mm*, there is a formation of [CBSE PMT 1996]

(a) FDS (b) CDS

(c) Both space (d) None of these

55. Electric field and magnetic field in Thomson mass spectrograph are applied [RPMT 1998]

(a) Simultaneously, perpendicular

(b) Perpendicular but not simultaneously

(c) Parallel but not simultaneously

(d) Parallel simultaneously

56. The current conduction in a discharged tube is due to [CBSE PMT 1999]

(a) Electrons only

(b) +*ve* ions and electrons

(c) – *ve* ions and electrons

(d) + *ve* ions, – *ve* ions and electrons

57. In Milikan's oil drop experiment, a charged drop falls with terminal velocity *V*. If an electric field *E* is applied in vertically upward direction then it starts moving in upward direction with terminal velocity 2*V*. If magnitude of electric field is decreased to $\frac{E}{2}$, then terminal velocity will become [CBSE PMT 1999]

(a) $\frac{V}{2}$ (b) V

(c) $\frac{3V}{2}$ (d) $2V$

58. An electron is accelerated through a p.d. of 45.5 *volt*. The velocity acquired by it is (in *ms*) [AIIMS 2004]

(a) 4×10^{6} (b) 4×10^{4}

(c) 10^{6} (d) Zero

59. A cathode emits 1.8×10^{14} electrons per second, when heated. [BCECE 2003] When 400*V* is applied to anode all the emitted electrons reach the anode. The charge on electron is $1.6\times10^{-19}\,C$. The maximum anode current is [MP PMT 2004]

(a) $2.7\,\mu A$ (b) $29\,\mu A$

(c) $72\,\mu A$ (d) 29 *mA*

60. Order of *q/m* ratio of proton, α -particle and electron is [AFMC 2004]

(a) $e > p > \alpha$ (b) $p > \alpha > e$

(c) $e > \alpha > p$ (d) None of these

61. A charge of magnitude $3e$ and mass $2m$ is moving in an electric field $\vec{E}$. The acceleration imparted to the charge is [DCE 2004]

(a) $2Ee/3m$ (b) $3Ee/2m$

(c) $2m/3Ee$ (d) $3m/2Ee$

62. An electron initially at rest, is accelerated through a potential difference of 200 *volt*, so that it acquires a velocity $8.4\times10^{6}\,m/s$. The value of *e/m* of electron will be [DPMT 2003]

(a) $2.76\times10^{12}\,C/kg$ (b) $1.76\times10^{11}\,C/kg$

(c) $0.76\times10^{12}\,C/kg$ (d) None of these

63. An α particle is accelerated through a *p.d* of 10^{6} volt then *K.E.* of particle will be [Pb. PET 2003]

(a) 8 *MeV* (b) 4 *MeV*

(c) 2 *MeV* (d) 1 *MeV*

64. Positive rays consists of [RPMT 1996, 2003]

(a) Electrons (b) Neutrons

(c) Positive ions (d) Electro magnetic waves

65. O^{++}, C^{+}, He^{++} and H^{+} ions are projected on the photographic plate with same velocity in a mass spectrograph. Which one will strike farthest [RPMT 2003]

(a) O^{++} (b) C^{+}

(c) He^{++} (d) H_2^{+}

66. An electron beam is moving between two parallel plates having electric field $1.125\times10^{-6}\,N/m$. A magnetic field $3\times10^{-10}\,T$ is also applied so that beam of electrons do not deflect. The velocity of the electron is [MH CHT 2004]

(a) $4225\,m/s$ (b) $3750\,m/s$

(c) $2750\,m/s$ (d) $3200\,m/s$

67. Positive rays was discovered by [RPMT 1998]

(a) Thomson (b) Goldstem

(c) W. Crookes (d) Rutherford

68. An electron is moving in electric field and magnetic field it will gain energy from [DCE 1998]

(a) Electric field (b) Magnetic field

(c) Both of these (d) None of these

69. If an electron oscillates at a frequency of 1 *GHz* it gives [DCE 1999]

(a) *X*-rays (b) Mirowaves

(c) Infrared rays (d) None of these

70. In an electron gun, the electrons are accelerated by the potential *V*. If *e* is the charge and *m* is the mass of an electron, then the maximum velocity of these electrons will be

(a) $\frac{2eV}{m}$ (b) $\sqrt{\frac{2eV}{m}}$

(c) $\sqrt{\frac{2m}{eV}}$ (d) $\frac{V^2}{2em}$

71. Which of the following have highest specific charge [BHU 2005]

(a) Positron (b) Proton

(c) *He* (d) None of these

72. In Millikan's oil drop experiment, an oil drop of mass $16\times10^{-6}\,kg$ is balanced by an electric field of $10^{6}\,V/m$. The charge in coulomb on the drop, assuming $g=10\,m/s^2$ is

(a) 6.2×10^{-11} (b) 16×10^{-9}

(c) 16×10^{-11} (d) 16×10^{-13}

Matter Waves

1. The idea of matter waves was given by

(a) Davisson and Germer (b) de-Broglie

(c) Einstein (d) Planck

2. Wave is associated with matter

(a) When it is stationary

(b) When it is in motion with the velocity of light only

(c) When it is in motion with any velocity

(d) None of the above

3. The de-Broglie wavelength associated with the particle of mass *m* moving with velocity *v* is [CBSE PMT 1992]

(a) h/mv (b) mv/h

(c) mh/v (d) m/hv

4. A photon, an electron and a uranium nucleus all have the same wavelength. The one with the most energy [MP PMT 1992]

(a) Is the photon

(b) Is the electron

(c) Is the uranium nucleus

(d) Depends upon the wavelength and the properties of the particle.

5. A particle which has zero rest mass and non-zero energy and momentum must travel with a speed [MP PMT 1992; DPMT 2001; Kerala PMT 2004]

(a) Equal to *c*, the speed of light in vacuum

(b) Greater than *c*

(c) Less than *c*

(d) Tending to infinity

6. When the kinetic energy of an electron is increased, the wavelength of the associated wave will

(a) Increase

(b) Decrease

(c) Wavelength does not depend on the kinetic energy

(d) None of the above

[MP PMT 1987, 96; BHU 1995; MNR 1998]

7. If the de-Broglie wavelengths for a proton and for a $\alpha-$particle are equal, then the ratio of their velocities will be

(a) 4 : 1 (b) 2 : 1

(c) 1 : 2 (d) 1 : 4

8. The de-Broglie wavelength λ associated with an electron having kinetic energy E is given by the expression [MP PMT 1990; CPMT 1996]

(a) $\frac{h}{\sqrt{2mE}}$ (b) $\frac{2h}{mE}$

(c) $2mhE$ (d) $\frac{2\sqrt{2mE}}{h}$

[UP SEAT 2005]

9. Dual nature of radiation is shown by [MP PET 1991]

(a) Diffraction and reflection

(b) Refraction and diffraction

(c) Photoelectric effect alone

(d) Photoelectric effect and diffraction

10. For the Bohr's first orbit of circumference $2\pi r$, the de-Broglie wavelength of revolving electron will be [MP PMT 1987]

(a) $2\pi r$ (b) πr

(c) $\frac{1}{2\pi r}$ (d) $\frac{1}{4\pi r}$

11. An electron of mass *m* when accelerated through a potential difference *V* has de-Broglie wavelength λ. The de-Broglie

wavelength associated with a proton of mass M accelerated through the same potential difference will be

[CBSE PMT 1995; EAMCET 2001; J & K CET 2004]

(a) $\lambda \frac{m}{M}$ (b) $\lambda \sqrt{\frac{m}{M}}$

(c) $\lambda \frac{M}{m}$ (d) $\lambda \sqrt{\frac{M}{m}}$

12. What will be the ratio of de-Broglie wavelengths of proton and $\alpha -$particle of same energy

[RPET 1991, 96; DCE 2002; Kerala PET 2005]

(a) 2 : 1 (b) 1 : 2

(c) 4 : 1 (d) 1 : 4

13. What is the de-Broglie wavelength of the $\alpha -$particle accelerated through a potential difference V [RPMT 1996]

(a) $\frac{0.287}{\sqrt{V}}$ Å (b) $\frac{12.27}{\sqrt{V}}$ Å

(c) $\frac{0.101}{\sqrt{V}}$ Å (d) $\frac{0.202}{\sqrt{V}}$ Å

14. de-Broglie hypothesis treated electrons as

[BHU 2000]

(a) Particles (b) Waves

(c) Both '*a*' and '*b*' (d) None of these

15. The energy that should be added to an electron, to reduce its de-Broglie wavelengths from 10^{-10} *m* to 0.5×10^{-10} *m*, will be [KCET (Engg./Med.) 2000]

(a) Four times the initial energy

(b) Thrice the initial energy

(c) Equal to the initial energy

(d) Twice the initial energy

16. The de-Broglie wavelength of an electron having $80eV$ of energy is nearly

($1eV$ = 1.6 × 10^{-19} *J*, Mass of electron = 9 × 10^{-31} *kg*

Plank's constant = 6.6 × 10^{-34} *J-sec*)

[EAMCET (Engg.) 2001]

(a) 140 Å (b) 0.14 Å

(c) 14 Å (d) 1.4 Å

17. If particles are moving with same velocity, then maximum de-Broglie wavelength will be for [CBSE PMT 2002]

(a) Neutron (b) Proton

(c) β-particle (d) α -particle

18. If an electron and a photon propagate in the form of waves having the same wavelength, it implies that they have the same [CBSE PMT 1995; DCE 2001; AIIMS 2003]

(a) Energy (b) Momentum

(c) Velocity (d) Angular momentum

19. The de-Broglie wavelength is proportional to [RPET 2003]

(a) $\lambda \propto \frac{1}{v}$ (b) $\lambda \propto \frac{1}{m}$

(c) $\lambda \propto \frac{1}{p}$ (d) $\lambda \propto p$

20. Particle nature and wave nature of electromagnetic waves and electrons can be shown by [AIIMS 2000]

(a) Electron has small mass, deflected by the metal sheet

(b) X-ray is diffracted, reflected by thick metal sheet

(c) Light is refracted and defracted

(d) Photoelectricity and electron microscopy

21. The de-Broglie wavelength of a particle moving with a velocity 2.25 × 10^{8} *m/s* is equal to the wavelength of photon. The ratio of kinetic energy of the particle to the energy of the photon is (velocity of light is 3 × 10^{8} *m/s*)

[EAMCET (Med.) 2003]

(a) 1/8 (b) 3/8

(c) 5/8 (d) 7/8

22. According to de-Broglie, the de-Broglie wavelength for electron in an orbit of hydrogen atom is 10^{-9} *m*. The principle quantum number for this electron is [RPMT 2003]

(a) 1 (b) 2

(c) 3 (d) 4

23. The speed of an electron having a wavelength of $10^{-10} m$ is

[Manipal 1997; AIIMS 2002]

(a) 7.25×10^{6} *m/s* (b) $6.26 \times 10^{6} m/s$

(c) $5.25 \times 10^{6} m/s$ (d) $4.24 \times 10^{6} m/s$

24. The kinetic energy of electron and proton is $10^{-32} J$. Then the relation between their de-Broglie wavelengths is

[CPMT 1999]

(a) $\lambda_p < \lambda_e$ (b) $\lambda_p > \lambda_e$

(c) $\lambda_p = \lambda_e$ (d) $\lambda_p = 2\lambda_e$

25. The de-Broglie wavelength of a particle accelerated with 150 *volt* potential is 10^{-10} *m*. If it is accelerated by 600 *volts* p.d., its wavelength will be [RPET 1988]

(a) 0.25 *Å* (b) 0.5 *Å*

(c) 1.5 *Å* (d) 2 *Å*

26. The de-Broglie wavelength associated with a hydrogen molecule moving with a thermal velocity of 3 *km/s* will be

(a) 1 *Å* (b) 0.66 *Å*

(c) 6.6 *Å* (d) 66 *Å*

27. When the momentum of a proton is changed by an amount p, the corresponding change in the de-Broglie wavelength is found to be 0.25%. Then, the original momentum of the proton was

(a) p (b) 100 p

(c) 400 p (d) 4 p

28. The de-Broglie wavelength of a neutron at $27^{\circ}C$ is λ. What will be its wavelength at $927^{\circ}C$ [DPMT 2002]

(a) $\lambda / 2$ (b) $\lambda / 3$

(c) $\lambda / 4$ (d) $\lambda / 9$

29. An electron and proton have the same de-Broglie wavelength. Then the kinetic energy of the electron is

[Kerala PMT 2004]

(a) Zero
(b) Infinity
(c) Equal to the kinetic energy of the proton
(d) Greater than the kinetic energy of the proton

30. For moving ball of cricket, the correct statement about de-Broglie wavelength is [RPMT 2001]

(a) It is not applicable for such big particle
(b) $\frac{h}{\sqrt{2mE}}$
(c) $\sqrt{\frac{h}{2mE}}$
(d) $\frac{h}{2mE}$

31. Photon and electron are given same energy $(10^{-20} J)$. Wavelength associated with photon and electron are λ_{Ph} and λ_{el} then correct statement will be [RPMT 2001]

(a) $\lambda_{Ph} > \lambda_{el}$ (b) $\lambda_{Ph} < \lambda_{el}$
(c) $\lambda_{Ph} = \lambda_{el}$ (d) $\frac{\lambda_{el}}{\lambda_{Ph}} = C$

32. The kinetic energy of an electron with de-Broglie wavelength of 0.3 nanometer is [UPSEAT 2004]

(a) 0.168 *eV* (b) 16.8 *eV*
(c) 1.68 *eV* (d) 2.5 *eV*

33. A proton and an α-particle are accelerated through a potential difference of 100 *V*. The ratio of the wavelength associated with the proton to that associated with an α-particle is

(a) $\sqrt{2} : 1$ (b) $2 : 1$
(c) $2\sqrt{2} : 1$ (d) $\frac{1}{2\sqrt{2}} : 1$

34. The wavelength of de-Broglie wave is $2\mu m$, then its momentum is ($h = 6.63 \times 10^{-34}$ *J-s*) [DCE 2004]

(a) 3.315×10^{-28} *kg-m/s* (b) 1.66×10^{-28} *kg-m/s*
(c) 4.97×10^{-28} *kg-m/s* (d) 9.9×10^{-28} *kg-m/s*

35. de-Broglie wavelength of a body of mass 1 *kg* moving with velocity of 2000 *m/s* is [Pb. PMT 2003]

(a) 3.32×10^{-27} Å (b) 1.5×10^{7} Å
(c) 0.55×10^{-22} Å (d) None of these

36. The kinetic energy of an electron is 5 *eV*. Calculate the de-Broglie wavelength associated with it ($h = 6.6 \times 10^{-34}$ *Js*, $m_e = 9.1 \times 10^{-31}$ *kg*)

(a) 5.47 Å (b) 10.9 Å
(c) 2.7 Å (d) None of these

37. The wavelength associated with an electron accelerated through a potential difference of 100 *V* is nearly

[RPMT 2003]

(a) 100 Å (b) 123 Å
(c) 1.23 Å (d) 0.123 Å

38. The de-Broglie wavelength λ [RPMT 2004]

(a) is proportional to mass
(b) is proportional to impulse
(c) Inversely proportional to impulse
(d) does not depend on impulse

39. Davission and Germer experiment proved

[RPET 2002; DCE 2004]

(a) Wave nature of light (b) Particle nature of light
(c) Both (a) and (b) (d) Neither (a) nor (b)

40. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor [AIEEE 2005]

(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$
(c) $\frac{1}{2}$ (d) 2

41. The energy that should be added to an electron to reduce its de Broglie wavelength from one *nm* to 0.5 *nm* is

[KCET 2005]

(a) Four times the initial energy
(b) Equal to the initial energy
(c) Twice the initial energy
(d) Thrice the initial energy

42. de-Broglie wavelength of a body of mass *m* and kinetic energy *E* is given by [BCECE 2005]

(a) $\lambda = \frac{h}{mE}$ (b) $\lambda = \frac{\sqrt{2mE}}{h}$
(c) $\lambda = \frac{h}{2mE}$ (d) $\lambda = \frac{h}{\sqrt{2mE}}$

43. The wavelength of the matter wave is independent of

[Kerala PMT 2005]

[DCE 2002; DPMT 2003]

(a) Mass (b) Velocity
(c) Momentum (d) Charge

Photon and Photoelectric Effect

1. The momentum of a photon is 3.3×10^{-29} *kg – m/sec*. Its frequency will be

[CPMT 1980; MP PET 1992; DPMT 1999]

(a) $3 \times 10^{3} Hz$ (b) $6 \times 10^{3} Hz$
(c) $7.5 \times 10^{12} Hz$ (d) $1.5 \times 10^{13} Hz$

2. The energy of a photon of wavelength λ is given by

[CPMT 1974; CBSE PMT 1992; DCE 1998; BHU 2000; DPMT 2001]

(a) $h\lambda$ (b) $ch\lambda$
(c) λ / hc (d) hc / λ

3. The momentum of a photon is 2×10^{-16} *gm-cm/sec*. Its energy is [Pb. PMT 2004]

(a) $0.61 \times 10^{-26} erg$ (b) $2.0 \times 10^{-26} erg$
(c) $6 \times 10^{-6} erg$ (d) $6 \times 10^{-8} erg$

4. The rest mass of the photon is

[MP PET 1994; CPMT 1996; RPMT 1999; JIPMER 2002]

(a) 0
(b) ∞

(c) Between 0 and ∞

(d) Equal to that of an electron

5. The momentum of the photon of wavelength 5000Å will be [CPMT 1987]

(a) $1.3\times10^{-27}\,kg\text{ - }m/sec$ (b) $1.3\times10^{-28}\,kg\text{ - }m/sec$

(c) $4\times10^{29}\,kg\text{ - }m/sec$ (d) $4\times10^{-18}\,kg\text{ - }m/sec$

6. The momentum of a photon of energy $h\nu$ will be [DCE 2000]

(a) $h\nu$ (b) $h\nu/c$

(c) $h\nu c$ (d) h/ν

7. A photon in motion has a mass [MP PMT 1992]

(a) $c/h\nu$ (b) h/ν

(c) $h\nu$ (d) $h\nu/c^2$

8. If the momentum of a photon is p, then its frequency is [MP PET 1989]

(a) $\frac{ph}{c}$ (b) $\frac{pc}{h}$

(c) $\frac{mh}{c}$ (d) $\frac{mc}{h}$

Where m is the rest mass of the photon

9. An AIR station is broadcasting the waves of wavelength 300 metres. If the radiating power of the transmitter is 10 *kW*, then the number of photons radiated per second is [MP PET 1989; RPMT 2000]

(a) 1.5×10^{29} (b) 1.5×10^{31}

(c) 1.5×10^{33} (d) 1.5×10^{35}

10. The energy of a photon is $E=h\nu$ and the momentum of photon $p=\frac{h}{\lambda}$, then the velocity of photon will be [CPMT 1991]

(a) *E/p* (b) *Ep*

(c) $\left(\frac{E}{p}\right)^2$ (d) $3\times10^8\,m/s$

11. The approximate wavelength of a photon of energy 2.48 *eV* is

(a) 500 Å (b) 5000 Å

(c) 2000 Å (d) 1000 Å

12. An important spectral emission line has a wavelength of 21 *cm*. The corresponding photon energy is [MP PMT 1993]

(a) $5.9\times10^{-4}\,eV$ (b) $5.9\times10^{-6}\,eV$

(c) $5.9\times10^{-8}\,eV$ (d) $11.8\times10^{-6}\,eV$

$(h=6.62\times10^{-34}\,Js;\ c=3\times10^8\,m/s)$

13. The momentum of a photon in an *X*-ray beam of 10^{-10} metre wavelength is [MP PET 1996]

(a) $1.5\times10^{-23}\,kg-m/sec$ (b) $6.6\times10^{-24}\,kg-m/sec$

(c) $6.6\times10^{-44}\,kg-m/sec$ (d) $2.2\times10^{-52}\,kg-m/sec$

14. The energy of a photon of light with wavelength 5000 Å is approximately 2.5 *eV*. This way the energy of an *X*-ray photon with wavelength 1Å would be [MP PET 1997]

(a) 2.5/5000 *eV* (b) $2.5/(5000)^2\,eV$

(c) $2.5\times5000\,eV$ (d) $2.5\times(5000)^2\,eV$

15. Energy of a quanta of frequency $10^{15}\,Hz$ and $h=6.6\times10^{-34}\,J\text{-sec}$ will be [RPMT 1997]

(a) $6.6\times10^{-19}\,J$ (b) $6.6\times10^{-12}\,J$

(c) $6.6\times10^{-49}\,J$ (d) $6.6\times10^{-41}\,J$

16. Momentum of a photon of wavelength λ is [CBSE PMT 1993; JIPMER 2001, 02]

(a) $\frac{h}{\lambda}$ (b) Zero

(c) $\frac{h\lambda}{c^2}$ (d) $\frac{h\lambda}{c}$

17. Wavelength of a 1 *keV* photon is $1.24\times10^{-9}\,m$. What is the frequency of 1 *MeV* photon [CBSE PMT 1993; MP PET 2005]

(a) $1.24\times10^{15}\,Hz$ (b) $2.4\times10^{20}\,Hz$

(c) $1.24\times10^{18}\,Hz$ (d) $2.4\times10^{23}\,Hz$

18. What is the momentum of a photon having frequency $1.5\times10^{13}\,Hz$ [BHU 1997]

(a) $3.3\times10^{-29}\,kg\ m/s$ (b) $3.3\times10^{-34}\,kg\ m/s$

(c) $6.6\times10^{-34}\,kg\ m/s$ (d) $6.6\times10^{-30}\,kg\ m/s$

19. The energy of a photon of light of wavelength 450 *nm* is [BHU 1997; JIPMER 2000]

(a) $4.4\times10^{-19}\,J$ (b) $2.5\times10^{-19}\,J$

(c) $1.25\times10^{-17}\,J$ (d) $2.5\times10^{-17}\,J$

20. Frequency of photon having energy 66 *eV* is [CPMT PMT 1997]

(a) $8\times10^{-15}\,Hz$ (b) $12\times10^{-15}\,Hz$

(c) $16\times10^{15}\,Hz$ (d) None of these

21. Which of the following statement is not correct [AFMC 1999]

(a) Photographic plates are sensitive to infrared rays

(b) Photographic plates are sensitive to ultraviolet rays

(c) Infra-red rays are invisible but can cast shadows like visible light

(d) Infrared photons have more energy than photons of visible light [MP PMT 1987]

22. If we express the energy of a photon in *KeV* and the wavelength in angstroms, then energy of a photon can be calculated from the relation [AMU (Engg.) 1999]

(a) $E=12.4\,h\nu$ (b) $E=12.4\,h/\lambda$

(c) $E=12.4/\lambda$ (d) $E=h\nu$

23. The frequency of a photon, having energy 100 *eV* is $(h=6.6\,10^{-34}\ J\text{-}sec)$ [AFMC 2000]

(a) $2.42\times10^{26}\,Hz$ (b) $2.42\times10^{16}\,Hz$

(c) $2.42\times10^{12}\,Hz$ (d) $2.42\times10^{9}\,Hz$

24. A photon of wavelength 4400 Å is passing through vacuum. The effective mass and momentum of the photon are respectively

(a) $5\times10^{-36}\,kg,\ 1.5\times10^{-27}\,kg\text{ - }m/s$

(b) $5\times10^{-35}\,kg,\ 1.5\times10^{-26}\,kg\text{ - }m/s$

(c) Zero, $1.5\times10^{-26}\ kg\text{-}m/s$

(d) $5\times10^{-36}kg, 1.67\times10^{-43}kg\text{-}m/s$

25. Which of the following is true for photon **[RPET 2001]**

(a) $E=\dfrac{hc}{\lambda}$ (b) $E=\dfrac{1}{2}mu^2$

(c) $p=\dfrac{E}{2v}$ (d) $E=\dfrac{1}{2}mc^2$

26. Which of the following is incorrect statement regarding photon **[MH CET (Med.) 2001]**

(a) Photon exerts no pressure

(b) Photon energy is $h\nu$

(c) Photon rest mass is zero

(d) None of these

27. If a photon has velocity *c* and frequency ν, then which of following represents its wavelength **[AIEEE 2002]**

(a) $\dfrac{hc}{E}$ (b) $\dfrac{h\nu}{c}$

(c) $\dfrac{h\nu}{c^2}$ (d) $h\nu$

28. The mass of a photo electron is **[MP PMT 2002]**

(a) $9.1\times10^{-27}\ kg$ (b) $9.1\times10^{-29}\ kg$

(c) $9.1\times10^{-31}\ kg$ (d) $9.1\times10^{-34}\ kg$

29. Energy of photon whose frequency is $10^{12}\ MHz$, will be **[MH CET 2002]**

(a) $4.14\times10^3 keV$ (b) $4.14\times10^2 eV$

(c) $4.14\times10^3 MeV$ (d) $4.14\times10^3 eV$

30. There are n_1 photons of frequency γ_1 in a beam of light. In an equally energetic beam, there are n_2 photons of frequency γ_2. Then the correct relation is **[KCET 2003]**

(a) $\dfrac{n_1}{n_2}=1$ (b) $\dfrac{n_1}{n_2}=\dfrac{\gamma_1}{\gamma_2}$

(c) $\dfrac{n_1}{n_2}=\dfrac{\gamma_2}{\gamma_1}$ (d) $\dfrac{n_1}{n_2}=\dfrac{\gamma_1^2}{\gamma_2^2}$

31. Einstein's photoelectric equation states that $E_k=h\nu-\phi$. In this equation E_k refers to **[CPMT 1982; MP PMT 1997]**

(a) Kinetic energy of all the emitted electrons

(b) Mean kinetic energy of the emitted electrons

(c) Maximum kinetic energy of the emitted electrons

(d) Minimum kinetic energy of the emitted electrons

32. Kinetic energy with which the electrons are emitted from the metal surface due to photoelectric effect is **[CPMT 1973]**

(a) Independent of the intensity of illumination

(b) Independent of the frequency of light

(c) Inversely proportional to the intensity of illumination

(d) Directly proportional to the intensity of illumination

33. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photo-electrons will be emitted when this material is illuminated with monochromatic radiation from a **[IIT JEE 1982; MP PMT 1994; MP PET 1995; UPSEAT 2001; KCET 2004; J & K CET 2004; BHU 2004]**

(a) 50 watt infrared lamp

(b) 1 watt infrared lamp

(c) 50 watt ultraviolet lamp

(d) 1 watt ultraviolet lamp

(e) Both (c) and (d)

34. Threshold frequency for a metal is 10^{15} *Hz*. Light of $\lambda=4000\mathring{A}$ falls on its surface. Which of the following statements is correct

(a) No photoelectric emission takes place

(b) Photo-electrons come out with zero speed

(c) Photo-electrons come out with 10^3 *m/sec* speed

(d) Photo-electrons come out with 10^5 *m/sec* speed

35. Photo cells are used for the

(a) Reproduction of pictures from the cinema film

(b) Reproduction of sound from the cinema film

(c) Automatic switching of street light

(d) (b) and (c) both

36. Einstein got Nobel prize on which of the following works **[DCE 1995]**

(a) Mass-energy relation

(b) Special theory of relativity

(c) Photoelectric equation

(d) (a) and (b) both

37. The photo-electrons emitted from a surface of sodium metal are such that **[MP PMT 1992]**

(a) They all are of the same frequency

(b) They have the same kinetic energy

(c) They have the same de Broglie wavelength

(d) They have their speeds varying from zero to a certain maximum

38. A metal surface of work function 1.07 *eV* is irradiated with light of wavelength 332 *nm*. The retarding potential required to stop the escape of photo-electrons is **[MP PMT 1992]**

(a) 4.81 *eV* (b) 3.74 *eV*

(c) 2.66 *eV* (d) 1.07 *eV*

39. In a photo cell, the photo-electrons emission takes place

(a) After 10^{-1} *sec* on incident of light rays

(b) After 10^{-3} *sec* on incident of light rays

(c) After 10^{-6} *sec* on incident of light rays

(d) After 10^{-8} *sec* on incident of light rays

40. When light falls on a metal surface, the maximum kinetic energy of the emitted photo-electrons depends upon **[MP PMT 1989; MP PET 1992, 93]**

(a) The time for which light falls on the metal

(b) Frequency of the incident light

(c) Intensity of the incident light

(d) Velocity of the incident light

41. The electrons are emitted in the photoelectric effect from a metal surface **[MP PET 1992]**

(a) Only if the frequency of the incident radiation is above a certain threshold value

(b) Only if the temperature of the surface is high

(c) At a rate that is independent of the nature of the metal

(d) With a maximum velocity proportional to the frequency of the incident radiation

42. The work function of a metal is 4.2 eV, its threshold wavelength will be [BHU 2003; CPMT 2004]

(a) 4000 $\AA$ (b) 3500 $\AA$

(c) 2955 $\AA$ (d) 2500 $\AA$

43. The number of photo-electrons emitted per second from a metal surface increases when

[EAMCET (Med.) 1995; CBSE PMT 1993; MP PMT 1994, 2002; MH CET 1999; KCET 2003]

(a) The energy of incident photons increases

(b) The frequency of incident light increases

(c) The wavelength of the incident light increases

(d) The intensity of the incident light increases

44. The work function of metal is 1 eV. Light of wavelength 3000 $\AA$ is incident on this metal surface. The velocity of emitted photo-electrons will be [MP PMT 1990]

(a) 10 *m/sec* (b) 1×10^3 *m/sec*

(c) 1×10^4 *m/sec* (d) 1×10^6 *m/sec*

45. The retarding potential for having zero photo-electron current

(a) Is proportional to the wavelength of incident light

(b) Increases uniformly with the increase in the wavelength of incident light

(c) Is proportional to the frequency of incident light

(d) Increases uniformly with the increase in the frequency of incident light wave

46. In a dark room of photography, generally red light is used. The reason is

(a) Most of the photographic films are not sensitive to red light

(b) The frequency for red light is low and hence the energy $h\nu$ of photons is less

(c) (a) and (b) both

(d) None of the above

47. The work function of a metal is 1.6×10^{-19} *J*. When the metal surface is illuminated by the light of wavelength 6400 Å, then the maximum kinetic energy of emitted photo-electrons will be

(Planck's constant $h = 6.4 \times 10^{-34}$ Js) [MP PMT 1989]

(a) 14×10^{-19} J (b) 2.8×10^{-19} J

(c) 1.4×10^{-19} J (d) 1.4×10^{-19} eV

48. Ultraviolet radiations of $6.2\,eV$ falls on an aluminium surface (work function 4.2 eV). The kinetic energy in joules of the fastest electron emitted is approximately

[MNR 1987; MP PET 1990; CBSE PMT 1993; Pb. PMT 2001; BVP 2003; Pb. PET 2004]

(a) 3.2×10^{-21} (b) 3.2×10^{-19}

(c) 3.2×10^{-17} (d) 3.2×10^{-15}

49. The work function for tungsten and sodium are 4.5 eV and 2.3 eV respectively. If the threshold wavelength λ for sodium is $5460\AA$, the value of λ for tungsten is

[MP PET 1990]

(a) 5893 $\AA$ (b) 10683 $\AA$

(c) 2791 $\AA$ (d) 528 $\AA$

50. A photon of energy 3.4 eV is incident on a metal having work function 2 eV. The maximum K.E. of photo-electrons is equal to

(a) 1.4 eV (b) 1.7 eV

(c) 5.4 eV (d) 6.8 eV

51. The work function of a metallic surface is 5.01 eV. The photo-electrons are emitted when light of wavelength 2000$\AA$ falls on it. The potential difference applied to stop the fastest photo-electrons is $[h = 4.14 \times 10^{-15}$ eV sec$]$

[MP PET 1991; DPMT 1999]

(a) 1.2 *volts* (b) 2.24 *volts*

(c) 3.6 *volts* (d) 4.8 *volts*

52. The photoelectric threshold wavelength for a metal surface is 6600 $\AA$. The work function for this is [MP PET 1991]

(a) 1.87 V (b) 1.87 eV

(c) 18.7 eV (d) 0.18 eV

53. Photoelectric effect was successfully explained first by

(a) Planck (b) Hallwash

(c) Hertz (d) Einstein

[MP PMT/PET 1988]

54. The spectrum of radiation 1.0×10^{14} Hz is in the infrared region. The energy of one photon of this in joules will be

[MP PET 1982]

(a) 6.62×10^{-48} (b) 6.62×10^{-20}

(c) $\dfrac{6.62}{3} \times 10^{-28}$ (d) $3 \times 6.62 \times 10^{-28}$

55. A radio transmitter operates at a frequency of 880 *kHz* and a power of 10 *kW*. The number of photons emitted per second are[CBSE PMT 1990; MP P

(a) 1.72×10^{31} (b) 1327×10^{34}

(c) 13.27×10^{34} (d) 0.075×10^{-34}

56. A photo cell is receiving light from a source placed at a distance of 1 *m*. If the same source is to be placed at a distance of 2 *m*, then the ejected electron

[MNR 1986; UPSEAT 2000, 01]

(a) Moves with one-fourth energy as that of the initial energy

(b) Moves with one-fourth of momentum as that of the initial momentum

(c) Will be half in number

(d) Will be one-fourth in number

57. In a photoelectric experiment for 4000 $\AA$ incident radiation, the potential difference to stop the ejection is 2 V. If the incident light is changed to 3000 $\AA$, then the potential required to stop the ejection of electrons will be

[MP PET 1995]

(a) 2 V (b) Less than 2 V

(c) Zero (d) Greater than 2 V

58. Light of wavelength 4000 Å is incident on a sodium surface for which the threshold wave length of photo – electrons is 5420 Å. The work function of sodium is

[MP PMT 1993; Pb. PMT 2002]

(a) 4.58 eV (b) 2.29 eV

(c) 1.14 eV (d) 0.57 eV

59. Photo cell is a device to [MP PET 1993]

(a) Store photons

(b) Measure light intensity

(c) Convert photon energy into mechanical energy

(d) Store electrical energy for replacing storage batteries

60. If the work function for a certain metal is 3.2×10^{-19} *joule* and it is illuminated with light of frequency 8×10^{14} *Hz*. The maximum kinetic energy of the photo-electrons would be

[MP PET 1993]

(a) $2.1\times10^{-19}\,J$ (b) $8.5\times10^{-19}\,J$

(c) $5.3\times10^{-19}\,J$ (d) $3.2\times10^{-19}\,J$

$(h=6.63\times10^{-34}\,Js)$

61. Stopping potential for photoelectrons [MP PET 1994]

(a) Does not depend on the frequency of the incident light

(b) Does not depend upon the nature of the cathode material

(c) Depends on both the frequency of the incident light and nature of the cathode material

(d) Depends upon the intensity of the incident light

62. The maximum wavelength of radiation that can produce photoelectric effect in a certain metal is 200 *nm*. The maximum kinetic energy acquired by electron due to radiation of wavelength 100 *nm* will be [MP PMT 1994]

(a) 12.4 *eV* (b) 6.2 *eV*

(c) 100 *eV* (d) 200 *eV*

63. When the light source is kept 20 *cm* away from a photo cell, stopping potential 0.6 *V* is obtained. When source is kept 40 *cm* away, the stopping potential will be [MP PMT 1994]

(a) 0.3 *V* (b) 0.6 *V*

(c) 1.2 *V* (d) 2.4 *V*

64. The minimum energy required to remove an electron is called[AFMC 1995; DPMT 2001]

(a) Stopping potential (b) Kinetic energy

(c) Work function (d) None of these

65. Light of wavelength 4000 Å falls on a photosensitive metal and a negative 2 *V* potential stops the emitted electrons. The work function of the material (in *eV*) is approximately

$(h=6.6\times10^{-34}\,Js,\ e=1.6\times10^{-19}\,C,\ c=3\times10^{8}\,ms^{-1})$

[MP PMT 1995; MH CET 2004]

(a) 1.1 (b) 2.0

(c) 2.2 (d) 3.1

66. Assuming photoemission to take place, the factor by which the maximum velocity of the emitted photoelectrons changes when the wavelength of the incident radiation is increased four times, is

(a) 4 (b) $\frac{1}{4}$

(c) 2 (d) $\frac{1}{2}$

67. Work function of a metal is 2.51 *eV*. Its threshold frequency is

(a) 5.9×10^{14} *cycle/sec* (b) 6.5×10^{14} *cycle/sec*

(c) 9.4×10^{14} *cycle/sec* (d) 6.08×10^{14} *cycle/sec*

68. Energy conversion in a photoelectric cell takes place from

[AFMC 1993; MP PET 1996; MP PMT 1996]

(a) Chemical to electrical (b) Magnetic to electrical

(c) Optical to electrical (d) Mechanical to electrical

69. Which one of the following is true in photoelectric emission

[MP PMT 1996; JIPMER 2001, 02]

(a) Photoelectric current is directly proportional to the amplitude of light of a given frequency

(b) Photoelectric current is directly proportional to the intensity of light of a given frequency at moderate intensities

(c) Above the threshold frequency, the maximum K.E. of photoelectrons is inversely proportional to the frequency of incident light

(d) The threshold frequency depends upon the wavelength of incident light

70. When a point source of light is at a distance of one metre from a photo cell, the cut off voltage is found to be *V*. If the same source is placed at 2 *m* distance from photo cell, the cut off voltage will be

(a) *V* (b) *V*/2

(c) *V*/4 (d) $V/\sqrt{2}$

71. The work function of a photoelectric material is 3.3 *eV*. The threshold frequency will be equal to [UPSEAT 1999]

(a) $8\times10^{4}\,Hz$ (b) $8\times10^{56}\,Hz$

(c) $8\times10^{10}\,Hz$ (d) $8\times10^{14}\,Hz$

72. If the work function of a metal is 'ϕ' and the frequency of the incident light is 'ν', there is no emission of photoelectron if

(a) $\nu<\frac{\phi}{h}$ (b) $\nu=\frac{\phi}{h}$

(c) $\nu>\frac{\phi}{h}$ (d) $\nu>=<\frac{\phi}{h}$

73. A photoelectric cell is illuminated by a point source of light 1 *m* away. When the source is shifted to 2 *m* then

[CBSE PMT 2003]

(a) Number of electrons emitted is half the initial number

(b) Each emitted electron carries half the initial energy

(c) Number of electrons emitted is a quarter of the initial number

(d) Each emitted electron carries one quarter of the initial energy

74. Light of wavelength λ strikes a photo-sensitive surface and electrons are ejected with kinetic energy *E*. If the kinetic energy is to be increased to 2*E*, the wavelength must be changed to λ' where

(a) $\lambda'=\frac{\lambda}{2}$ (b) $\lambda'=2\lambda$

(c) $\frac{\lambda}{2}<\lambda'<\lambda$ (d) $\lambda'>\lambda$

[Haryana CEE 1996]

75. If in a photoelectric experiment, the wavelength of incident radiation is reduced from 6000 Å to 4000 Å then

[MP PMT 1999]

(a) Stopping potential will decrease

(b) Stopping potential will increase

(c) Kinetic energy of emitted electrons will decrease

(d) The value of work function will decrease

76. The photoelectric work function for a metal surface is 4.125 *eV*. The cut-off wavelength for this surface is

[CBSE PMT 1999; KCET 2001]

(a) 4125 Å (b) 2062.5 Å

(c) 3000 Å (d) 6000 Å

77. As the intensity of incident light increases

[CPMT 1999; CBSE PMT 1999; MH CET (Med.) 2000; KCET (Engg./Med.) 2001; Pb. PET 2001]

(a) Photoelectric current increases

(b) Photoelectric current decreases

(c) Kinetic energy of emitted photoelectrons increases

(d) Kinetic energy of emitted photoelectrons decreases

78. Light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function of 1.9 *eV*. The kinetic energy of the photoelectron emitted will be [CBSE PMT 1998]

(a) 0.58 *eV* (b) 2.48 *eV*

(c) 1.24 *eV* (d) 1.16 *eV*

79. Which of the following is dependent on the intensity of incident radiation in a photoelectric experiment

[AIIMS 1998]

(a) Work function of the surface

(b) Amount of photoelectric current

(c) Stopping potential will be reduced

(d) Maximum kinetic energy of photoelectrons

80. The work function of a substance is 4.0 *eV*. The longest wavelength of light that can cause photoelectron emission from this substance is approximately

[IIT JEE 1998; UPSEAT 2002, 03; AIEEE 2004]

(a) 540 *nm* (b) 400 *nm*

(c) 310 *nm* (d) 220 *nm*

81. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 *eV* fall on it is 4 *eV*. The stopping potential in *volts* is

[IIT JEE 1997 Re-Exam]

(a) 2 (b) 4

(c) 6 (d) 10

82. Work function of a metal is 2.1 *eV*. Which of the waves of the following wavelengths will be able to emit photoelectrons from its surface [Bihar MEE 1995]

(a) 4000 Å, 7500 Å (b) 5500 Å, 6000 Å

(c) 4000 Å, 6000 Å (d) None of these

83. If mean wavelength of light radiated by 100 *W* lamp is 5000 Å, then number of photons radiated per second are

[RPET 1997]

(a) 3×10^{23} (b) 2.5×10^{22}

(c) 2.5×10^{20} (d) 5×10^{17}

84. The frequency of the incident light falling on a photosensitive metal plate is doubled, the kinetic energy of the emitted photoelectrons is

(a) Double the earlier value (b) Unchanged

(c) More than doubled (d) Less than doubled

85. When light of wavelength 300 *nm* (nanometer) falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however light of 600 *nm* wavelength is sufficient for creating photoemission. What is the ratio of the work functions of the two emitters

[CBSE PMT 1993; JIPMER 2000]

(a) 1 : 2 (b) 2 : 1

(c) 4 : 1 (d) 1 : 4

86. Threshold wavelength for photoelectric effect on sodium is 5000 Å. Its work function is [CBSE PMT 1993]

(a) 15 *J* (b) $16 \times 10^{-14}\ J$

(c) $4 \times 10^{-19}\ J$ (d) $4 \times 10^{-81}\ J$

87. The cathode of a photoelectric cell is changed such that the work function changes from W_1 to W_2 ($W_2 > W_1$). If the current before and after change are I_1 and I_2, all other conditions remaining unchanged, then (assuming $h\nu > W_2$)

[CBSE PMT 1992]

(a) $I_1 = I_2$ (b) $I_1 < I_2$

(c) $I_1 > I_2$ (d) $I_1 < I_2 < 2I_1$

88. A beam of light of wavelength λ and with illumination *L* falls on a clean surface of sodium. If *N* photoelectrons are emitted each with kinetic energy *E*, then [BHU 1994]

(a) $N \propto L$ and $E \propto L$ (b) $N \propto L$ and $E \propto \frac{1}{\lambda}$

(c) $N \propto \lambda$ and $E \propto L$ (d) $N \propto \frac{1}{\lambda}$ and $E \propto \frac{1}{L}$

89. Which of the following statements is correct

[CBSE PMT 1997]

(a) The current in a photocell increases with increasing frequency of light

(b) The photocurrent is proportional to applied voltage

(c) The photocurrent increases with increasing intensity of light

(d) The stopping potential increases with increasing intensity of incident light

90. What is the stopping potential when the metal with work function 0.6 *eV* is illuminated with the light of 2 *eV*

[BHU 1998; MH CET 2003]

(a) 2.6 *V* (b) 3.6 *V*

(c) 0.8 *V* (d) 1.4 *V*

91. When yellow light is incident on a surface, no electrons are emitted while green light can emit. If red light is incident on the surface, then

[MNR 1998; MP PET 2000; MH CET 2000]

(a) No electrons are emitted

(b) Photons are emitted

(c) Electrons of higher energy are emitted

(d) Electrons of lower energy are emitted

92. The photoelectric threshold wavelength of a certain metal is 3000Å. If the radiation of 2000Å is incident on the metal

[MNR 1998; KCET 1994]

(a) Electrons will be emitted

(b) Positrons will be emitted [Roorkee 1992]

(c) Protons will be emitted

(d) Electrons will not be emitted

93. A photocell stops emission if it is maintained at 2 *V* negative potential. The energy of most energetic photoelectron is

[JIPMER 1999]

(a) $2eV$ (b) $2J$
(c) $2kJ$ (d) $2keV$

94. The work functions for sodium and copper are $2eV$ and $4eV$. Which of them is suitable for a photocell with 4000 Å light
(a) Copper (b) Sodium
(c) Both (d) Neither of them

95. For intensity *I* of a light of wavelength 5000Å the photoelectron saturation current is 0.40 μA and stopping potential is 1.36 *V*, the work function of metal is [RPET 1999]
(a) 2.47 *eV* (b) 1.36 *eV*
(c) 1.10 *eV* (d) 0.43 *eV*

96. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons will be [AFMC 1999]
(a) Possible
(b) Not possible
(c) Data is incomplete
(d) Depend upon the density of the surface

97. In photoelectric effect if the intensity of light is doubled then maximum kinetic energy of photoelectrons will become [RPMT 1999]
(a) Double (b) Half
(c) Four time (d) No change

98. Energy required to remove an electron from aluminium surface is 4.2 *eV*. If light of wavelength 2000 $\mathring{A}$ falls on the surface, the velocity of the fastest electron ejected from the surface will be
(a) $8.4\times10^5 m/sec$ (b) $7.4\times10^5 m/sec$
(c) $6.4\times10^5 m/sec$ (d) $8.4\times10^6 m/sec$

99. Mercury violet light $(\lambda = 4558\mathring{A})$ is falling on a photosensitive material $(\phi = 2.5eV)$. The speed of the ejected electrons is in ms^{-1}, about [AMU (Engg.) 1999]
(a) 3×10^5 (b) 2.65×10^5
(c) 4×10^4 (d) 3.65×10^7

100. The work functions of metals *A* and *B* are in the ratio 1 : 2. If light of frequencies f and $2f$ are incident on the surfaces of *A* and *B* respectively, the ratio of the maximum kinetic energies of photoelectrons emitted is (*f* is greater than threshold frequency of *A*, 2*f* is greater than threshold frequency of *B*)
(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 1 : 4

101. Light of frequency ν is incident on a substance of threshold frequency $\nu_0(\nu_0 < \nu)$. The energy of the emitted photo-electron will be
(a) $h(\nu-\nu_0)$ (b) h/ν
(c) $he(\nu-\nu_0)$ (d) h/ν_0

102. The stopping potential (V_0) [BHU 2000]
(a) Depends upon the angle of incident light
(b) Depends upon the intensity of incident light
(c) Depends upon the surface nature of the substance
(d) Is independent of the intensity of the incident light

103. If work function of metal is $3\,eV$ then threshold wavelength will be [RPMT 2000]
(a) 4125 $\mathring{A}$ (b) 4000 $\mathring{A}$
(c) 4500 $\mathring{A}$ [RPET 1999] (d) 5000 $\mathring{A}$

104. When wavelength of incident photon is decreased then [RPET 2000]
(a) Velocity of emitted photo-electron decreases
(b) Velocity of emitted photoelectron increases
(c) Velocity of photoelectron do not charge
(d) Photo electric current increases

105. Quantam nature of light is explained by which of the following phenomenon [RPET 2000]
(a) Huygen wave theory
(b) Photoelectric effect
(c) Maxwell electromagnetic theory
(d) de-Broglie theory

106. When a metal surface is illuminated by light of wavelengths 400 *nm* and 250 *nm*, the maximum velocities of the photoelectrons ejected are v and $2v$ respectively. The work function of the metal is (*h* = Planck's constant, *c* = velocity of light in air)
(a) $2hc\times10^6\ J$ (b) $1.5hc\times10^6\ J$
(c) $hc\times10^6\ J$ (d) $0.5\ hc\times10^6\ J$

107. 4 *eV* is the energy of the incident photon and the work function in $2eV$. What is the stopping potential [AMU 1999] [DCE 2000; AIIMS 2004]
(a) $2V$ (b) $4V$
(c) $6V$ (d) $2\sqrt{2}V$

108. Light of frequency ν is incident on a certain photoelectric substance with threshold frequency ν_0. The work function for the substance is
(a) $h\nu$ (b) $h\nu_0$
(c) $h(\nu-\nu_0)$ (d) $h(\nu+\nu_0)$

109. If threshold wavelength for sodium is 6800Å then the work function will be [RPET 2001]
(a) $1.8eV$ (b) $2.5eV$
(c) $2.1eV$ (d) $1.4eV$

110. If intensity of incident light is increased in PEE then which of the following is true [RPET 2001]
(a) Maximum *K.E.* of ejected electron will increase
[EAMCET (Med.) 2000]
(b) Work function will remain unchanged
(c) Stopping potential will decrease
(d) Maximum *K.E.* of ejected electron will decrease

111. Light of frequency $8\times10^{15} Hz$ is incident on a substance of photoelectric work function $6.125eV$. The maximum kinetic energy of the emitted photoelectrons is [MP PET 2000; 03] [AFMC 2001]
(a) 17 eV (b) 22 eV
(c) 27 eV (d) 37 eV

112. The photoelectric threshold wavelength for potassium (work function being $2eV$) is [CPMT 2001]
(a) 310 *nm* (b) 620 *nm*
(c) 1200 *nm* (d) 2100 *nm*

113. Photons of energy 6 eV are incident on a metal surface whose work function is 4 eV. The minimum kinetic energy of the emitted photo-electrons will be [MP PET 2001]

(a) 0 eV (b) 1 eV
(c) 2 eV (d) 10 eV

114. According to photon theory of light which of the following physical quantities associated with a photon do not/does not change as it collides with an electron in vacuum [AMU (Engg.) 2001]

(a) Energy and momentum (b) Speed and momentum
(c) Speed only (d) Energy only

115. The lowest frequency of light that will cause the emission of photoelectrons from the surface of a metal (for which work function is 1.65 eV) will be [JIPMER 2002]

(a) $4\times10^{10}\,Hz$ (b) $4\times10^{11}\,Hz$
(c) $4\times10^{14}\,Hz$ (d) $4\times10^{-10}\,Hz$

116. Light of two different frequencies whose photons have energies $1eV$ and $2.5eV$ respectively, successively illuminates a metal of work function $0.5eV$. The ratio of maximum kinetic energy of the emitted electron will be [AIEEE 2002]

(a) 1 : 5 (b) 1 : 4
(c) 1 : 2 (d) 1 : 1

117. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of their threshold wavelengths is nearest to [AIEEE 2002]

(a) 1: 2 (b) 4 : 1
(c) 2 : 1 (d) 1 : 4

118. Photon of 5.5 eV energy fall on the surface of the metal emitting photoelectrons of maximum kinetic energy 4.0 eV. The stopping voltage required for these electrons are [Orissa (Engg.) 2002; DPMT 2004]

(a) 5.5 V (b) 1.5 V
(c) 9.5 V (d) 4.0 V

119. A caesium photocell, with a steady potential difference of 60 V across, is illuminated by a bright point source of light 50 cm away. When the same light is placed 1m away the photoelectrons emitted from the cell [KCET 2002]

(a) Are one quarter as numerous
(b) Are half as numerous
(c) Each carry one quarter of their previous momentum
(d) Each carry one quarter of their previous energy

120. A radio transmitter radiates 1 kW power at a wavelength 198.6 *metres*. How many photons does it emit per second [Kerala (Engg.) 2002]

(a) 10^{10} (b) 10^{20}
(c) 10^{30} (d) 10^{40}

121. The number of photons of wavelength 540 nm emitted per second by an electric bulb of power 100 W is (taking $h = 6\times10^{-34}\ J\text{-}sec$) [Kerala (Engg.) 2002; Pb. PET 2001]

(a) 100 (b) 1000
(c) 3×10^{20} (d) 3×10^{18}

122. When radiation is incident on a photoelectron emitter, the stopping potential is found to be 9 volts. If e/m for the electron is $1.8\times10^{11}\,C\,kg^{-1}$ the maximum velocity of the ejected electrons is [Kerala (Engg.) 2002]

(a) $6\times10^5\,ms^{-1}$ (b) $8\times10^5\,ms^{-1}$
(c) $1.8\times10^6\,ms^{-1}$ (d) $1.8\times10^5\,ms^{-1}$

123. Two identical metal plates show photoelectric effect by a light of wavelength λ_A falls on plate A and λ_B on plate B $(\lambda_A = 2\lambda_B)$. The maximum kinetic energy is [CPMT 2002]

(a) $2K_A = K_B$ (b) $K_A < K_B/2$
(c) $K_A = 2K_B$ (d) $K_A = K_B/2$

124. The threshold wavelength for photoelectric effect of a metal is 6500 Å. The work function of the metal is approximately [MP PMT 2002]

(a) 2 eV (b) 1 eV
(c) 0.1 eV (d) 3 eV

125. When ultraviolet rays are incident on metal plate, then photoelectric effect does not occurs. It occurs by the incidence of [CBSE PMT 2002; DCE 1997;

(a) X-rays (b) Radio wave
(c) Infrared rays (d) Green house effect

126. Light of frequency $4\nu_0$ is incident on the metal of the threshold frequency ν_0. The maximum kinetic energy of the emitted photoelectrons is [MP PET 2002]

(a) $3h\nu_0$ (b) $2h\nu_0$
(c) $\frac{3}{2}h\nu_0$ (d) $\frac{1}{2}h\nu_0$

127. By photoelectric effect, Einstein, proved [MP PET 2003]

(a) $E = hv$ (b) $K.E. = \frac{1}{2}mv^2$
(c) $E = mc^2$ (d) $E = \frac{Rhc^2}{n^2}$

128. The work function of sodium is 2.3 eV. The threshold wavelength of sodium will be [BHU 2003]

(a) 2900 Å (b) 2500 Å
(c) 5380 Å (d) 2000 Å

129. Which of the following shown particle nature of light [AFMC 2003; CBSE PMT 2001]

(a) Refraction (b) Interference
(c) Polarization (d) Photoelectric effect

130. Two identical photo-cathodes receive light of frequencies f_1 and f_2. If the velocities of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then [AIEEE 2003]

(a) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$ (b) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$
(c) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$ (d) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$

131. Consider the two following statements A and B and identify the correct choice given in the answers;

(A) In photovlotaic cells the photoelectric current produced is not proportional to the, intensity of incident light.

(B) In gas filled photoemissive cells, the velocity of photoelectrons depends on the wavelength of the incident radiation.

(a) Both *A* and *B* are true (b) Both *A* and *B* are false

(c) *A* is true but *B* is false (d) *A* is false *B* is true

132. When radiation of wavelength λ is incident on a metallic surface, the stopping potential is 4.8 volts. If the same surface is illuminated with radiation of double the wavelength, then the stopping potential becomes 1.6 *volts*. Then the threshold wavelength for the surface is [EAMCET (Engg.) 2003]

(a) 2λ (b) 4λ

(c) 6λ (d) 8λ

133. The frequency and work function of an incident photon are ν and ϕ_0. If ν is the threshold frequency then necessary condition for the emission of photo electron is [RPET 2003]

(a) $\nu < \nu_0$ (b) $\nu = \frac{\nu_0}{2}$

(c) $\nu \geq \nu_0$ (d) None of these

134. Light of wavelength 1824 Å, incident on the surface of a metal, produces photo-electrons with maximum energy 5.3 *eV*. When light of wavelength 1216 Å is used, the maximum energy of photoelectrons is 8.7 *eV*. The work function of the metal surface is

(a) 3.5 *eV* (b) 13.6 *eV*

(c) 6.8 *eV* (d) 1.5 *eV*

135. If the energy of a photon corresponding to a wavelength of 6000 Å is $3.32 \times 10^{-19}\, J$, the photon energy for a wavelength of 4000 Å will be [DPMT 2004]

(a) 1.4 *eV* (b) 4.9 *eV*

(c) 3.1 *eV* (d) 1.6 *eV*

136. If the wavelength of light is 4000 Å, then the number of waves in 1 *mm* length will be [J & K CET 2004]

(a) 25 (b) 0.25

(c) 0.25×10^4 (d) 25×10^4

137. The velocity of photon is proportional to (where ν is frequency)

(a) $\frac{\nu^2}{2}$ (b) $\frac{1}{\sqrt{\nu}}$

(c) $\sqrt{\nu}$ (d) ν

138. If the work function of a photometal is 6.825 *eV*. Its threshold wavelength will be $(c = 3 \times 10^8\, m/s)$

[Pb. PET 2000; BHU 2004]

(a) 1200 Å (b) 1800 Å

(c) 2400 Å (d) 3600 Å

139. A photon of energy 8 *eV* is incident on a metal surface of threshold frequency $1.6 \times 10^{15}\, Hz$, then the maximum kinetic energy of photoelectrons emitted is $(h = 6.6 \times 10^{-34}\, Js)$

(a) 4.8 *eV* (b) 2.4 *eV*

(c) 1.4 *eV* (d) 0.8 *eV*

140. If the energy of the photon is increased by a factor of 4, then its momentum [UPSEAT 2004]

(a) Does not change

(b) Decreases by a factor of 4

(c) Increases by a factor of 4

(d) Decreases by a factor of 2

141. The ratio of the energy of a photon with $\lambda = 150\, nm$ to that with $\lambda = 300\, nm$ is [DCE 2003]

(a) 2 [EAMCET (Engg.) 2003] (b) 1/4

(c) 4 (d) 1/2

142. Photo-electric effect can be explained by [DCE 2003]

(a) Corpusular theory of light (b) Wave nature of light

(c) Bohr's theory (d) Quantum theory of light

143. In photoelectric effect, the K.E. of electrons emitted from the metal surface depends upon [DCE 2003]

(a) Intensity of light

(b) Frequency of incident light

(c) Velocity of incident light

(d) Both intensity and velocity of light

144. The photoelectric effect can be understood on the basis of

[Pb. PET 2004]

(a) The principle of superposition

(b) The electromagnetic theory of light

(c) The special theory of relativity

(d) Line spectrum of the atom

145. If the threshold wavelength for sodium is 5420 Å, then the work function of sodium is [RPMT 2003]

(a) 4.58 *eV* [MP PMT 2004] (b) 2.28 *eV*

(c) 1.14 *eV* (d) 0.23 *eV*

146. The work function of a metal is [RPMT 2004]

(a) The energy for the electron to enter into the metal

(b) The energy for producing X-ray

(c) The energy for the electron to come out from metal surface

(d) None of these

147. The minimum wavelength of photon is 5000 Å, its energy will be

(a) 2.5 *eV* (b) 50 *V*

(c) 5.48 *eV* (d) 7.48 *eV*

148. Which of one is correct [DCE 1998]

(a) $E^2 = p^2c^2$ (b) $E^2 = p^2c$

(c) $E^2 = pc^2$ [Pb. PMT 2004] (d) $E^2 = p^2/c^2$

149. The work function for metals *A*, *B* and *C* are respectively 1.92 *eV*, 2.0 *eV* and 5 *eV*. According to Einstein's equation, the metals which will emit photo electrons for a radiation of wavelength 4100 Å is/are[CBSE PMT

(a) None of these (b) *A* only

(c) *A* and *B* only (d) All the three metals

150. A photosensitive metallic surface has work function $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface the electrons come out with a maximum velocity of $4 \times 10^6\, m/s$. When the photon energy is increases to $5h\nu_0$ then maximum velocity of photo electron will be[CBSE PMT

(a) $2 \times 10^6\, m/s$ [Pb. PET 2002] (b) $2 \times 10^7\, m/s$

(c) $8 \times 10^5\, m/s$ (d) $8 \times 10^6\, m/s$

151. A photocell is illuminated by a small bright source placed 1 *m* away. When the same source of light is placed $\frac{1}{2} m$ away, the number of electrons emitted by photo cathode would[CBSE PMT 2001; AIEEE 2005]

(a) Decrease by a factor of 2 (b) Increase by a factor of 2

(c) Decrease by a factor of 4 (d) Increase by a factor of 4

152. The magnitude of saturation photoelectric current depends upon[AFMC 2005]

(a) Frequency (b) Intensity
(c) Work function (d) Stopping potential

153. For photoelectric emission, tungsten requires light of 2300 $\mathring{A}$. If light of 1800 $\mathring{A}$ wavelength is incident then emission [AFMC 2005]
(a) Takes place
(b) Don't take place
(c) May or may not take place
(d) Depends on frequency

154. The light rays having photons of energy 1.8 eV are falling on a metal surface having a work function 1.2 eV. What is the stopping potential to be applied to stop the emitting electrons
(a) 3 eV (b) 1.2 eV
(c) 0.6 eV (d) 1.4 eV

155. The incident photon involved in the photoelectric effect experiment.
(a) Completely disappears
(b) Comes out with an increased frequency
(c) Comes out with a decreased frequency
(d) Comes out without change in frequency

156. A photon of energy 8 eV is incident on metal surface of threshold frequency $1.6\times10^{15}\,Hz$. The maximum kinetic energy of the photoelectrons emitted (in eV) (Take $h=6\times10^{-34}\,Js$).
(a) 1.6 (b) 6
(c) 2 (d) 1.2

X-Rays

1. An X-ray tube is operated at 50 kV. The minimum wavelength produced is [CPMT 1996]
(a) 0.5 Å (b) 0.75 Å
(c) 0.25 Å (d) 1 Å

2. Which of the following wavelength falls in X-ray region [CPMT 1975; MP PMT 1984]
(a) 10000 Å (b) 1000 Å
(c) 1 Å (d) 10^{-2} Å

3. A metal block is exposed to beams of X-ray of different wavelength. X-rays of which wavelength penetrate most [NCERT 1980; JIPMER 2002]
(a) 2 Å (b) 4 Å
(c) 6 Å (d) 8 Å

4. X-rays and gamma rays are both electromagnetic waves. Which of the following statements is true [NCERT 1973]
(a) In general X-rays have larger wavelength than of gamma rays
(b) X-rays have smaller wavelength than that of gamma rays
(c) Gamma rays have smaller frequency than that of X-rays
(d) Wavelength and frequency of X-rays are both larger than that of gamma rays

5. In producing X-rays a beam of electrons accelerated by a potential difference V is made to strike a metal target. For what value of V, X-rays will have the lowest wavelength of 0.3094 Å [CPMT 1982; NCERT 1986, 87]
(a) 10 kV (b) 20 kV
(c) 30 kV (d) 40 kV

6. In radio theraphy, X-rays are used to [CPMT 1972; BHU 2005]
(a) Detect bone fractures
(b) Treat cancer by controlled exposure
(c) Detect heart diseases
(d) Detect fault in radio receiving circuits

7. Hydrogen atom does not emit X-rays because [NCERT 1979; CPMT 1980, 90; RPET 1999]
(a) Its energy levels are too close to each other
(b) Its energy levels are too apart
(c) It is too small in size
(d) It has a single electron

8. X-rays were discovered by [NCERT 1977; BHU 2005]
(a) Becquerel (b) Roentgen
(c) Marie Curie (d) Von Laue

[BHU 2005]

9. X-rays are [CPMT 1975; EAMCET 1995; RPET 2000; SCRA 1994]
(a) Stream of electrons

[EAMCET 2005]

(b) Stream of positively charged particles
(c) Electromagnetic radiations of high frequency
(d) Stream of uncharged particles

10. The voltage applied across an X-rays tube is nearly [CPMT 1983]
(a) 10 V (b) 100 V
(c) 10000 V [MP PET 2005] (d) 10^6 V

11. The characteristic X-ray radiation is emitted, when [CPMT 1975, 80, 90; RPET 1999]
(a) The electrons are accelerated to a fixed energy
(b) The source of electrons emits a monoenergetic beam
(c) The bombarding electrons knock out electrons from the inner shell of the target atoms and one of the outer electrons falls into this vacancy
(d) The valence electrons in the target atoms are removed as a result of the collision

12. Molybdenum is used as a target element for production of X-rays because it is [CPMT 1980; RPET 1999]
(a) A heavy element and can easily absorb high velocity electrons
(b) A heavy element with a high melting point
(c) An element having high thermal conductivity
(d) Heavy and can easily deflect electrons

13. Mosley's law relates the frequencies of line X-rays with the following characteristics of the target element [CPMT 1980; NCERT 1985]
(a) Its density
(b) Its atomic weight
(c) Its atomic number
(d) Interplaner spacing of the atomic planes

14. Compton effect is associated with [CPMT 1971]
(a) $\alpha-$rays (b) $\beta-$rays
(c) X-rays (d) Positive rays

15. X-rays are in nature similar to
(a) Beta rays (b) Gamma rays
(c) de-Broglie waves (d) Cathode rays

16. If the cathode–anode potential difference in an X-ray tube be 10^5 V, then the maximum energy of X-ray photon can be
(a) 10^5 J (b) 10^5 MeV
(c) 10^{-1} MeV (d) 10^5 KeV

17. The shortest wavelength of X-rays emitted from an X-ray tube depends on the

[MP PMT 1987; CPMT 1988, 92; IIT 1982]

(a) Current in the tube

(b) Voltage applied to the tube

(c) Nature of gas in the tube

(d) Atomic number of target material

18. The wavelength of X-rays is of the order of

[CPMT 1983; MP PMT 1987; KCET 1994; JIPMER 1997]

(a) *Centimetre* (b) *Micron* (10^{-6} *m*)

(c) *Angstrom* (10^{-10} *m*) (d) *Metre*

19. X – rays and γ – rays of the same energies may be distinguished by

(a) Their velocity (b) Their ionising power

(c) Their intensity (d) Method of production

20. When a beam of accelerated electrons hits a target, a continuous X-ray spectrum is emitted from the target. Which of the following wavelength is absent in the X-ray spectrum, if the X-ray tube is operating at 40,000 *volts*

[MP PMT 1993; NCERT 1984; MNR 1995; RPMT 2002]

(a) 0.25 Å (b) 0.5 Å

(c) 1.5 Å (d) 1.0 Å

21. For continuous X-rays produced wavelength is

(a) Inversely proportional to the energy of the electrons hitting the target

(b) Inversely proportional to the intensity of the electron beam

(c) Proportional to intensity of the electron beam

(d) Proportional to target temperature

22. An X-ray has a wavelength of 0.010 Å. Its momentum is

[AFMC 1980; RPMT 1995; Pb. PMT 2004]

(a) 2.126×10^{-23} *kg-m/sec* (b) 6.626×10^{-22} *kg-m/sec*

(c) 3.456×20^{-25} *kg-m/sec* (d) 3.313×10^{-22} *kg-m/sec*

23. X-rays are not used for radar purpose because

(a) They are not reflected by the target

(b) They are not electromagnetic waves

(c) They are completely absorbed by the air

(d) They sometimes damage the target

24. A direct X-ray photograph of the intestines is not generally taken by the radiologists because **[CPMT 1986, 88]**

(a) Intestines would burst on exposure to X-rays

(b) The X-rays would not pass through the intestines

(c) The X-rays will pass through the intestines without causing a good shadow for any useful diagnosis

(d) A very small exposure of X-rays causes cancer in the intestines

25. The patient is asked to drink $BaSO_4$ for examining the stomach by *X*-rays because *X*-rays are

(a) Reflected by heavy atoms

(b) Refracted by heavy atoms

(c) Less absorbed by heavy atoms

(d) More absorbed by heavy atoms

26. X-rays can be used to study crystal structure, if the wavelength lies in the range

(a) 2 Å to 0.1 Å (b) 10 Å to 5 Å

(c) 50 Å to 10 Å (d) 100 Å to 50 Å

27. When the accelerating voltage applied on the electrons increased beyond a critical value **[CPMT 1975]**

(a) Only the intensity of the various wavelengths is increased

(b) Only the wavelength of characteristic relation is affected

(c) The spectrum of white radiation is unaffected

(d) The intensities of characteristic lines relative to the white spectrum are increased but there is no change in their wavelength

28. The *X*-ray beam coming from an *X*-ray tube will be

[IIT 1985; SCRA 1996; MP PET 1999]

[CPMT 1985]

(a) Monochromatic

(b) Having all wavelengths smaller than a certain maximum wavelength

(c) Having all wavelengths larger than a certain minimum wavelength

(d) Having all wavelengths lying between a minimum and a maximum wavelength

29. The continuous X-rays spectrum produced by an X-ray machine at constant voltage has **[DPMT 1999]**

(a) A maximum wavelength (b) A minimum wavelength

(c) A single wavelength (d) A minimum frequency

30. The penetrating power of X-rays increases with the

[MP PMT 1984]

(a) Increase in its velocity (b) Increase in its frequency

(c) Increase in its intensity (d) Decrease in its velocity

31. If λ_1 and λ_2 are the wavelengths of characteristic X-rays and gamma rays respectively, then the relation between them is

(a) $\lambda_1 = \dfrac{1}{\lambda_2}$ (b) $\lambda_1 = \lambda_2$

(c) $\lambda_1 > \lambda_2$ (d) $\lambda_1 < \lambda_2$

32. The wavelength λ of the K_α line of characteristic *X*-ray spectra varies with atomic number approximately

[MP PMT 1987]

(a) $\lambda \propto Z$ (b) $\lambda \propto \sqrt{Z}$

(c) $\lambda \propto \dfrac{1}{Z^2}$ (d) $\lambda \propto \dfrac{1}{\sqrt{Z}}$

33. The minimum frequency ν of continuous *X*-rays is related to the applied potential difference *V* as

(a) $\nu \propto \sqrt{V}$ (b) $\nu \propto V$

(c) $\nu \propto V^{3/2}$ (d) $\nu \propto V^2$

34. If *V* be the accelerating voltage, then the maximum frequency of continuous *X*-rays is given by

[NCERT 1971; CPMT 1991; MP PET 2000; RPMT 2001; MP PMT 2002]

(a) $\dfrac{eh}{V}$ (b) $\dfrac{hV}{e}$

(c) $\dfrac{eV}{h}$ (d) $\dfrac{h}{eV}$

35. The minimum wavelength of *X*-rays produced by electrons accelerated by a potential difference of *volts* is equal to

[CPMT 1986, 88, 91; RPMT 1997; RPMT 1997, 98; MP PET 1997, 98; MP PMT 1996, 98, 2003; UPSEAT 2005]

(a) $\frac{eV}{hc}$ (b) $\frac{eh}{cV}$

(c) $\frac{hc}{eV}$ (d) $\frac{cV}{eh}$

36. The potential difference applied to an *X*-ray tube is increased. As a result, in the emitted radiation [IIT 1988; ISM Dhanbad 1994; AIIMS 1997; MP PMT 1995, 2004]

(a) The intensity increases
(b) The minimum wavelength increases
(c) The intensity decreases
(d) The minimum wavelength decreases

37. A potential difference of 42,000 *volts* is used in an *X*-ray tube to accelerate electrons. The maximum frequency of the *X*–radiations produced is [MP PMT 1993]

(a) 10^{19} Hz (b) 10^{18} Hz

(c) 10^{16} Hz (d) 10^{20} Hz

$(1eV = 1.6\times10^{-19}\,J$ and $h = 6.63\times10^{-34}\,J-\text{sec})$

38. Which of the following is accompanied by the characteristic *X*-ray emission [MP PET 1993]

(a) $\alpha-$particle emission (b) Electron emission

(c) Positron emission (d) *K*–electron capture

39. *X*-rays are known to be electromagnetic radiations. Therefore the *X*-ray photon has [MP PET 1993]

(a) Electric charge
(b) Magnetic moment
(c) Both electric charge and magnetic moment
(d) Neither electric charge nor magnetic moment

40. *X*-rays of which of the following wavelengths are hardest

(a) 4 Å (b) 1 Å

(c) 0.1 Å (d) 2 Å

41. *X*-ray beam can be deflected by [CPMT 2000; BHU 2001; Pb. PMT 2002]

(a) Magnetic field (b) Electric field

(c) Both (a) and (b) (d) None of these

42. *X*-rays are produced due to [CPMT 1985; JIPMER 2002]

(a) Break up of molecules
(b) Changing in atomic energy level
(c) Changing in nuclear energy level
(d) Radioactive disintegration

43. *X*-rays region lies between [CPMT 1990]

(a) Short radiowave and visible region
(b) Visible and ultraviolet region
(c) Gamma rays and ultraviolet region
(d) Short radiowave and long radiowave

44. The structure of solid crystals is investigated by using [CPMT 1992; NCERT 1975; CBSEPMT 1992]

(a) Cosmic rays (b) *X*-rays

(c) Infrared radiations (d) $\gamma-$ rays

45. In an *X*-rays tube, the intensity of the emitted *X*-rays beam is increased by [MNR 1992; RPMT 1996; UPSEAT 2000]

(a) Increasing the filament current
(b) Decreasing the filament current
(c) Increasing the target potential
(d) Decreasing the target potential

46. The binding energy of the innermost electron in tungsten is 40 *keV*. To produce characteristic *X*-rays using a tungsten target in an *X*-rays tube the potential difference *V* between the cathode and the anti-cathode should be [IIT 1985]

(a) V< 40 *kV* (b) V ≤ 40 *kV*

(c) V > 40 *kV* (d) V >/< 40 *kV*

47. In above question the energy of the characteristic *X*-rays given out is

(a) Less than 40 *keV* (b) More than 40 *keV*

(c) Equal to 40 *keV* (d) ≥ 40 *keV*

48. The wavelength of most energetic *X*-rays emitted when a metal target is bombarded by $40KeV$ electrons, is approximately

$(h = 6.62\times10^{-34}$ *J-sec*; 1 *eV* = 1.6×10^{-19} *J*; *c* = $3\times10^{8}\,m/s)$

[MNR 1991; MP PMT 1999; UPSEAT 2000; Pb. PET 2004]

(a) 300 Å (b) 10 Å

(c) 4 Å (d) 0.31 Å

49. *X*-rays which can penetrate through longer distances in substance are called [EAMCET 1983]

(a) Soft *X*-rays (b) Continuous *X*-rays

(c) Hard *X*-rays (d) None of the above

50. An *X*-ray machine has an accelerating potential difference of 25,000 volts. By calculation the shortest wavelength will be obtained as

$(h = 6.62\times10^{-34}$ *J–sec*; e = 1.6×10^{-19} *coulomb*)

[MP PET 1994]

(a) 0.25 Å (b) 0.50 Å

(c) 1.00 Å (d) 2.50 Å

51. For the production of *X*-rays of wavelength 0.1 Å the minimum potential difference will be [MP PMT 1994; RPMT 1995]

(a) 12.4 *kV* (b) 24.8 *kV*

(c) 124 *kV* (d) 248 *kV*

52. Mosley measured the frequency (*f*) of the characteristic *X*-rays from many metals of different atomic number (Z) and represented his results by a relation known as Mosley's law. This law is (a, b are constants) [MP PMT 1994; RPMT 1996]

(a) $f = a(Z-b)^2$ (b) $Z = a(f-b)^2$

(c) $f^2 = a(Z-b)$ (d) $f = a(Z-b)^{1/2}$

53. Penetrating power of *X*-rays depends on [MP PMT 1994]

(a) Current flowing in the filament
(b) Applied potential difference
(c) Nature of the target
(d) All the above

54. The energy of a photon of characteristic *X*-rays from a Coolidge tube comes from [MP PET 1995]

(a) The kinetic energy of the striking electron
(b) The kinetic energy of the free electrons of the target
(c) The kinetic energy of the ions of the target
(d) An electronic transition of the target atom

55. An *X*-ray tube operates on 30 *kV*. What is the minimum wavelength emitted

$(h = 6.6\times10^{-34}$ *Js*, $e = 1.6\times10^{-19}$ *Coulomb*, $c = 3\times10^{8}$ *ms*)

[MP PMT 1995; DPMT 2001, 03]

(a) 0.133 Å (b) 0.4 Å

(c) 1.2 Å (d) 6.6 Å

56. The wavelength of the most energetic X–ray emitted when a metal target is bombarded by 100 KeV electrons is approximately
(a) 12 Å (b) 4
(c) 0.31 Å (d) 0.124 Å

57. An electron beam in an *X*-ray tube is accelerated through a potential difference of 50000 *volts*. These are then made to fall on a tungsten target. The shortest wavelength of the *X*-ray emitted by the tube is
(a) 2.5 Å (b) 0.25 *nm*
(c) 0.25 *cm* (d) 0.025 *nm*

58. For harder *X*-rays [MP PET 1997]
(a) The wavelength is higher
(b) The intensity is higher
(c) The frequency is higher
(d) The photon energy is lower

59. When cathode rays strike a metal target of high melting point with very high velocity, then [MP PMT 1997; AIIMS 1999]
(a) *X*-rays are produced
(b) Ealpha-rays are produced
(c) TV waves are produced
(d) Ultrasonic waves are produced

60. Penetrating power of *X*-rays can be increased by [MP PMT 1997, 2000]
(a) Increasing the potential difference between anode and cathode
(b) Decreasing the potential difference between anode and cathode
(c) Increasing the cathode filament current
(d) Decreasing the cathode filament current

61. K_α characteristic *X*-ray refers to the transition [MP PMT 1999]
(a) $n = 2$ to $n = 1$ (b) $n = 3$ to $n = 2$
(c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 2$

62. *X*-rays are produced in *X*-ray tube operating at a given accelerating voltage. The wavelength of the continuous *X*-rays has values from
(a) 0 to ∞
(b) $\lambda_{\min}$ to ∞, where $\lambda_{\min} > 0$
(c) 0 to $\lambda_{\max}$ where $\lambda_{\max} < \infty$
(d) $\lambda_{\min}$ to $\lambda_{\max}$, where $0 < \lambda_{\min} < \lambda_{\max} < \infty$

63. The wavelength of *X*-rays is [EAMCET (Med.) 1995]
(a) 2000 Å (b) 2 Å
(c) 1 *mm* (d) 1 *cm*

64. The ratio of the energy of an *X*-ray photon of wavelength 1 Å to that of visible light of wavelength 5000 Å is [EAMCET (Med.) 1995]
(a) 1: 5000 (b) 5000 : 1
(c) 1 :25 $\times 10^{6}$ (d) 25 $\times 10^{6}$

65. According to Mosley's law, the frequency of a spectral line in *X*-ray spectrum varies as [EAMCET (Med.) 1995; Pb. PMT 1999]
(a) Atomic number of the element
(b) Square of the atomic number of the element
(c) Square root of the atomic number of the element
(d) Fourth power of the atomic number of the element

66. For the structural analysis of crystals, *X*-rays are used because
(a) *X*-rays have wavelength of the order of interatomic spacing
(b) *X*-rays are highly penetrating radiations
(c) Wavelength of *X*-rays is of the order of nuclear size
(d) *X*-rays are coherent radiations [MP PET 1996]

67. The essential distinction between *X*-rays and $\gamma -$ rays is that [BHU 1994; RPMT 1991; JIPMER 2001, 02]
(a) $\gamma -$ rays have smaller wavelength than *X*-rays
(b) $\gamma -$ rays emanate from nucleus while *X*-rays emanate from outer part of the atom [MP PET 1997]
(c) $\gamma -$ rays have greater ionizing power than *X*-rays
(d) $\gamma -$ rays are more penetrating than *X*-rays

68. The minimum wavelength of the *X*-rays produced by electrons accelerated through a potential difference of V *volts* is directly proportional to [CBSE PMT 1996]
(a) $\sqrt{V}$ (b) V^2
(c) $1/\sqrt{V}$ (d) $1/V$

69. What determines the hardness of the *X*-rays obtained from the Coolige tube [RPMT 1996]
(a) Current in the filament
(b) Pressure of air in the tube
(c) Nature of target
(d) Potential difference between cathode and target

70. The most penetrating radiation out of the following is [CBSE PMT 1997]
(a) *X*-rays (b) β -rays
(c) $\alpha -$ particles (d) $\gamma -$ rays

71. On increasing the number of electrons striking the anode of an *X*-ray tube, which one of the following parameters of the resulting *X*-rays would increase [IIT 1998; BVP 2003] [SCRA 1998; DPMT 2000]
(a) Penetration power (b) Frequency
(c) Wavelength (d) Intensity

72. What kV potential is to be applied on *X*-ray tube so that minimum wavelength of emitted *X*-rays may be 1Å ($h = 6.625 \times 10^{-34}$ *J-sec*)
(a) $12.42 kV$ (b) $12.84 kV$
(c) $11.98 kV$ (d) $10.78 kV$

73. *X*-rays cannot be deflected by means of an ordinary grating due to [Pb. PMT 199
(a) Large wavelength (b) High speed
(c) Short wavelength (d) None of these

74. Consider the following two statements A and B and identify the correct choice in the given answer
A: The characteristic *X*-ray spectrum depends on the nature of the material of the target.
B: The short wavelength limit of continuous *X*-ray spectrum varies inversely with the potential difference applied to the *X*-rays tube [EAMCET (Med.) 2000]
(a) A is true and B is false (b) A is false and B is true
(c) Both A and B are true (d) Both A and B are false

75. The energy of an *X*- ray photon of wavelength 1.65 Å is [IIT 1992; JIPMER 2000]
($h = 6.6 \times 10^{-34}$ *J-sec*, $c = 3 \times 10^8 ms^{-1}$, $1eV = 1.6 \times 10^{-19} J$)
[EAMCET (Engg.) 2000]

(a) 3.5 keV (b) 5.5 keV
(c) 7.5 keV (d) 9.5 keV

76. If λ =10Å, then it corresponds to [DCE 2000]
(a) Infra-red (b) Microwave
(c) Ultra-violet (d) X-rays

77. Bragg's law for X-rays is [UPSEAT 2001]
(a) $d\sin\theta = 2n\lambda$ (b) $2d\sin\theta = n\lambda$
(c) $n\sin\theta = 2\lambda d$ (d) None of these

78. The X-rays produced in a coolidge tube of potential difference 40 V have minimum wavelength of [MH CET (Med.) 2001]
(a) $3.09\times10^{-8} m$ (b) $5.09\times10^{8} m$
(c) $4.09\times10^{-8} m$ (d) $1.09\times10^{8} m$

79. For the production of X-rays, the target should be made of
(a) Steel (b) Copper
(c) Aluminum (d) Tungsten

80. Intensity of X-rays depends upon the number of [SCRA 1998; DPMT 2000; AFMC 2001]
(a) Electrons (b) Protons
(c) Neutrons (d) Positrons

81. In an X-ray tube electrons bombarding the target produce X-rays of minimum wavelength 1 Å. What must be the energy of bombarding electrons [KCET 2001]
(a) 13375 eV (b) 12375 eV
(c) 14375 eV (d) 15375 eV

82. If energy of K-shell electron is – 40000 eV and If 60000 V potential is applied at coolidge tube then which of the following X-ray will get form [RPET 2001]
(a) Continuous
(b) White X-rays
(c) Continuous and all series of characteristic
(d) None of these

83. For production of characteristic K_β X-rays, the electron transition is [MP PET 2001]
(a) $n = 2$ to $n = 1$ (b) $n = 3$ to $n = 2$
(c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 2$

84. Penetrating power of X-rays does not depend on [MP PET 2001]
(a) Wavelength (b) Energy
(c) Potential difference (d) Current in the filament

85. The potential difference applied to an X-ray tube is 5kV and the current through it is 3.2 mA. Then the number of electrons striking the target per second is [IIT-JEE (Screening) 2002]
(a) 2×10^{16} (b) 5×10^{16}
(c) 1×10^{17} (d) 4×10^{15}

86. For the production of characteristic K_γ, X-ray, the electron transition is [BHU 2002]
(a) $n = 2$ to $n = 1$ (b) $n = 3$ to $n = 2$
(c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 1$

87. When X rays pass through a strong uniform magnetic field, Then they [MP PET 2002; RPMT 2002, 03]
(a) Do not get deflected at all
(b) Get deflected in the direction of the field
(c) Get deflected in the direction opposite to the field
(d) Get deflected in the direction perpendicular to the field

88. If the potential difference applied across X-ray tube is V volts, then approximately minimum wavelength of the emitted X-rays will be RPMT 1995; CBSE PMT 1996]
(a) $\frac{1227}{\sqrt{V}}Å$ (b) $\frac{1240}{V}Å$
(c) $\frac{2400}{V}Å$ (d) $\frac{12400}{V}Å$

89. What is the difference between soft and hard X-rays [MP PMT 2002; AIIMS 2002] [BHU 2000; CPMT 2001]
(a) Velocity (b) Intensity
(c) Frequency (d) Polarization

90. X-ray will travel minimum distance in [MP PET 2003]
(a) Air (b) Iron
(c) Wood (d) Water

91. The minimum wavelength of X-ray emitted by X-rays tube is 0.4125 Å. The accelerating voltage is [BHU 2003; CPMT 2004; MP PMT 2005]
(a) 30 kV (b) 50 kV
(c) 80 kV (d) 60 kV

92. Characteristic X-rays are produced due to [AIIMS 2003]
(a) Transfer of momentum in collision of electrons with target atoms
(b) Transition of electrons from higher to lower electronic orbits in an atom
(c) Heating of the target
(d) Transfer of energy in collision of electrons with atoms in the target

93. X-rays when incident on a metal [BCECE 2003; RPMT 2003]
(a) Exert a force on it (b) Transfer energy to it
(c) Transfer pressure to it (d) All of the above

94. The minimum wavelength of X-rays produced in a coolidge tube operated at potential difference of 40 kV is [BCECE 2003; RPET 2002, 03]
(a) 0.31 $Å$ (b) 3.1 $Å$
(c) 31 $Å$ (d) 311 $Å$

95. The potential difference between the cathode and the target in a Collidge tube is 100 kV. The minimum wavelength of the X-rays emitted by the tube is [Pb. PMT 2004]
(a) 0.66 $Å$ (b) 9.38 $Å$
(c) 0.246 $Å$ (d) 0.123 $Å$

96. X-rays are produced by accelerating electrons by voltage V and let they strike a metal of atomic number Z. The highest frequency of X-rays produced is proportional to [UPSEAT 2004]
(a) V (b) Z
(c) $(Z-1)$ (d) $(Z-1)^2$

97. If the operating potential of an X-ray tube is 50 kV, the velocity of X-rays coming out of it is [RPMT 2003]
(a) $4\times10^{4}\ m/s$ (b) $3\times10^{8}\ m/s$
(c) $10^{8}\ m/s$ (d) $3\ m/s$

98. If the voltage of X-ray tube is doubled, the intensity of X-rays will become [RPMT 2003]

(a) Half (b) Unchanged

(c) Double (d) Four times

99. If the minimum wavelength obtained in an X-ray tube is $2.5\times10^{-10}m$, the operating potential of the tube will be [RPMT 2003]

(a) 2 kV (b) 3 kV

(c) 4 kV (d) 5 kV

100. The wavelength of X-rays decreases, when [RPMT 2002]

(a) Temperature of target is increased

(b) Intensity of electron beam is increased

(c) K.E. of electrons striking the target is increased

(d) K.E. of electrons striking the target is decreased

101. X-rays are produced in laboratory by [RPMT 1998]

(a) Radiation

(b) Decomposition of the atom

(c) Bombardment of high energy electron on heavy metal

(d) None of these

102. In vacuum an electron of energy 10 keV hits tungsten target, then emitted radiation will be [RPMT 2001]

(a) Cathode rays (b) X-rays

(c) Infrared rays (d) Visible spectrum

103. X-rays of $\lambda = 1\,Å$ have frequency [DCE 1998]

(a) $3\times10^{8}\,Hz$ (b) $3\times10^{18}\,Hz$

(c) $3\times10^{10}\,Hz$ (d) $3\times10^{15}\,Hz$

104. Solid targets of different elements are bombarded by highly energetic electron beams. The frequency (f) of the characteristic X-rays emitted from different targets varies with atomic number Z as [AIIMS 2005]

(a) $f\propto\sqrt{Z}$ (b) $f\propto Z^2$

(c) $f\propto Z$ (d) $f\propto Z^{3/2}$

105. Compton effect shows that [DPMT 1995]

(a) X-rays are waves

(b) X-rays have high energy

(c) X-rays can penetrate matter

(d) Photons have momentum

106. An X-ray tube with a copper target emits $Cu\ K_\alpha$ line of wavelength 1.50 $Å$. What should be the minimum voltage through which electrons are to be accelerated to produce this wavelength of X rays

$(h = 6.63\times10^{-34}$ J-sec, $c = 3\times10^{8}m/s)$ [Orissa JEE 1996]

(a) 8280 V (b) 828 V

(c) 82800 V (d) 8.28 V

107. In X-ray spectrum wavelength λ of line K_α depends on atomic number Z as [RPMT 1995; DCE 2002]

(a) $\lambda\propto Z^2$ (b) $\lambda\propto(Z-1)^2$

(c) $\lambda\propto\frac{1}{(Z-1)}$ (d) $\lambda\propto\frac{1}{(Z-1)^2}$

108. Absorption of X-ray is maximum in which of the following different sheets [RPMT 1995]

(a) Copper (b) Gold

(c) Beryllium (d) Lead

109. The wavelength of K_α line in copper is 1.54 $Å$. The ionisation energy of K electron in copper in *Joule* is [EAMCET 1984]

(a) 11.2×10^{-27} (b) 12.9×10^{-16}

(c) 1.7×10^{-15} (d) 10×10^{-16}

110. The wavelength of K_α line for an element of atomic number 43 is λ. Then the wavelength of K_α line for an element of atomic number 29 is

(a) $\frac{43}{29}\lambda$ (b) $\frac{42}{28}\lambda$

(c) $\frac{9}{4}\lambda$ (d) $\frac{4}{9}\lambda$

111. In X-ray experiment K_α, K_β denotes [DCE 2005]

(a) Characteristic

(b) Continuous wavelength

(c) α, β-emissions respectively

(d) None of these

Critical Thinking

Objective Questions

1. A 1μA beam of protons with a cross-sectional area of 0.5 *sq. mm* is moving with a velocity of $3 \times 10^4 ms^{-1}$. Then charge density of beam is [CPMT 2002]

(a) $6.6 \times 10^{-4} C/m^3$ (b) $6.6 \times 10^{-5} C/m^3$

(c) $6.6 \times 10^{-6} C/m^3$ (d) None of these

2. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles, λ_1/λ_2 is

[IIT-JEE 1999; KCET 2003]

(a) m_1/m_2 (b) m_2/m_1

(c) 1.0 (d) $\sqrt{m_2}/\sqrt{m_1}$

3. A photon and an electron have equal energy E. $\lambda_{photon}/\lambda_{electron}$ is proportional to

[UPSEAT 2003; IIT-JEE (Screening) 2004]

(a) $\sqrt{E}$ (b) $1/\sqrt{E}$

(c) $1/E$ (d) Does not depend upon E

4. When photon of energy 4.25 *eV* strike the surface of a metal *A*, the ejected photoelectrons have maximum kinetic energy T_A *eV* and de-Brolie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal *B* by photon of energy 4.70 *eV* is $T_B = (T_A - 1.50)\,eV$. If the de-Broglie wavelength of these photoelectrons is $\lambda_B = 2\lambda_A$, then

(a) The work function of *A* is 2.25 *eV*

(b) The work function of *B* is 4.20 *eV*

(c) $T_A = 2.00\,eV$

(d) $T_B = 2.75\,eV$

5. An image of the sun is formed by a lens of focal length of 30 *cm* on the metal surface of a photoelectric cell and a photoelectric current *I* is produced. The lens forming the image is then replaced by another of the same diameter but of focal length 15 *cm*. The photoelectric current in this case is

(a) $\frac{I}{2}$ (b) *I*

(c) 2*I* (d) 4*I*

6. When an inert gas is filled in the place vacuum in a photo cell, then

(a) Photo-electric current is decreased

(b) Photo-electric current is increased

(c) Photo-electric current remains the same

(d) Decrease or increase in photo-electric current does not depend upon the gas filled

7. A photon of 1.7×10^{-13} *Joules* is absorbed by a material under special circumstances. The correct statement is

[MP PET 1999; JIPMER 2000]

(a) Electrons of the atom of absorbed material will go the higher energy states

(b) Electron and positron pair will be created

(c) Only positron will be produced

(d) Photoelectric effect will occur and electron will be produced

8. The maximum velocity of an electron emitted by light of wavelength λ incident on the surface of a metal of work function ϕ, is[MP PMT/PET 1998]

(a) $\left[\frac{2(hc+\lambda\phi)}{m\lambda}\right]^{1/2}$ (b) $\frac{2(hc-\lambda\phi)}{m}$

(c) $\left[\frac{2(hc-\lambda\phi)}{m\lambda}\right]^{1/2}$ (d) $\left[\frac{2(h\lambda-\phi)}{m}\right]^{1/2}$

Where h = Planck's constant, m = mass of electron and c = speed of light.

9. When a point source of monochromatic light is at a distance of 0.2 *m* from a photoelectric cell, the cut-off voltage and the saturation current are 0.6 *volt* and 18 *mA* respectively. If the same source is placed 0.6 *m* away from the photoelectric cell, then[IIT JEE 1992; MP PMT 1999]

(a) The stopping potential will be 0.2 *V*

(b) The stopping potential will be 0.6 *V*

(c) The saturation current will be 6 *mA*

(d) The saturation current will be 18 *mA*

10. In a photoemissive cell with executing wavelength λ, the fastest electron has speed *v*. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be

(a) $v(3/4)^{1/2}$ (b) $v(4/3)^{1/2}$

(c) Less than $v(4/3)^{1/2}$ (d) Greater than $v(4/3)^{1/2}$

11. Ultraviolet light of wavelength 300 *nm* and intensity 1.0 *watt/m* falls on the surface of a photosensitive material. If 1% of the incident photons produce photoelectrons, then the number of photoelectrons emitted from an area of 1.0 *cm* of the surface is nearly

(a) 9.61×10^{14} *per sec* (b) 4.12×10^{13} *per sec*

(c) 1.51×10^{12} *per sec* [IIT-JEE 1994] (d) 2.13×10^{11} *per sec*

12. Photoelectric emission is observed from a metallic surface for frequencies ν_1 and ν_2 of the incident light rays $(\nu_1 > \nu_2)$. If the maximum values of kinetic energy of the photoelectrons emitted in the two cases are in the ratio of $1:k$, then the threshold frequency of the metallic surface is

[EAMCET (Engg.) 2001]

(a) $\frac{\nu_1 - \nu_2}{k-1}$ (b) $\frac{k\nu_1 - \nu_2}{k-1}$

(c) $\frac{k\nu_2 - \nu_1}{k-1}$ [Manipal MEE 1995] (d) $\frac{\nu_2 - \nu_1}{k}$

13. Light from a hydrogen discharge tube is incident on the cathode of a photoelectric cell the work function of the cathode surface is 4.2 *eV*. In order to reduce the photo-current to zero the voltage of the anode relative to the cathode must be made [MP PMT 1997]

(a) – 4.2 *V* (b) – 9.4 *V*

(c) – 17.8 *V* (d) +9.4 *V*

14. Work function of lithium and copper are respectively 2.3 *eV* and 4.0 *eV*. Which one of the metal will be useful for the photoelectric cell working with visible light ? (h = 6.6 × 10^{-34} *J-s*, c = 3 × 10^{8} *m/s*)

(a) Lithium (b) Copper

(c) Both (d) None of these

15. X-rays of wavelength 0.1 Å allowed to fall on a metal get scattered. The wavelength of scattered radiation is 0.111 Å. If h = 6.624 × 10^{-34} *J-s* and m_0 = 9 × 10^{-31} *kg*, then the direction of the scattered photons will be

(a) $\cos^{-1}$ (0.547) (b) $\cos^{-1}$(0.4484)

(c) $\cos^{-1}(0.5)$ (d) $\cos^{-1}(0.3)$

16. The largest distance between the interatomic planes of a crystal is 10^{-7} *cm*. The upper limit for the wavelength of *X*-rays which can be usefully studied with this crystal is

[CPMT 1984]

(a) 1 Å (b) 2 Å

(c) 10 Å (d) 20 Å

17. An *X*-ray tube is operating at 50 *kV* and 20 *mA*. The target material of the tube has a mass of 1.0 *kg* and specific heat 495 $J\ kg^{\ o}C^{-1}$. One percent of the supplied electric power is converted into *X*-rays and the entire remaining energy goes into heating the target. Then

(a) A suitable target material must have a high melting temperature

(b) A suitable target material must have low thermal conductivity

(c) The average rate of rise of temperature of target would be 2 $^{\circ}C/s$

(d) The minimum wavelength of the *X*-rays emitted is about $0.25 \times 10^{-10}\ m$

18. The wavelength of K_α *X*-rays produced by an *X*-ray tube is 0.76 Å. The atomic number of the anode material of the tube is

(a) 20 (b) 60

(c) 40 (d) 80

19. *X*-ray beam of intensity I_0 passes through an absorption plate of thickness *d*. If absorption coefficient of material of plate is μ, the correct statement regarding the transmitted intensity *I* of *X*-ray is

(a) $I = I_0(1 - e^{-\mu d})$ (b) $I = I_0 e^{-\mu d}$

(c) $I = I_0(1 - e^{-\mu / d})$ (d) $I = I_0 e^{-\mu / d}$

20. The K_α *X*-ray emission line of tungsten occurs at $\lambda = 0.021\ nm$. The energy difference between *K* and *L* levels in this atom is about

(a) 0.51*MeV* (b) 1.2 *MeV*

(c) 59 *KeV* (d) 13.6 eV

21. Electrons with energy 80 *keV* are incident on the tungsten target of an *X*-ray tube. *K* shell electrons of tungsten have ionization energy 72.5 *keV*. *X*-rays emitted by the tube contain only

(a) A continuous *X*-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å

(b) A continuous *X*-ray spectrum (Bremsstrahlung] with all wavelengths

(c) The characteristic *X*-rays spectrum of tungsten

(d) A continuous *X*-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å and the characteristic *X*-ray spectrum of tungsten

22. The *X*-ray wavelength of L_α line of platinum (Z=78) is $1.30 Å$. The X –ray wavelength of L_α line of Molybdenum (Z=42) is

(a) 5.41Å (b) 4.20Å

(c) 2.70Å (d) 1.35 Å

23. The ratio of de-Broglie wavelengths of molecules of hydrogen and helium which are at temperature 27°*C* and 127°*C* respectively is

(a) $\frac{1}{2}$ (b) $\sqrt{\frac{3}{8}}$

(c) $\sqrt{\frac{8}{3}}$ (d) 1

24. A silver ball of radius 4.8 *cm* is suspended by a thread in the vacuum chamber. *UV* light of wavelength 200 *nm* is incident on the ball for some times during which a total energy of 1×10^{-7} *J* falls on the surface. Assuming on an average one out of 10^3 photons incident is able to eject electron. The potential on sphere will be

(a) 1 *V* (b) 2 *V*

(c) 3 *V* (d) Zero

25. A photon of wavelength 6630 Å is incident on a totally reflecting surface. The momentum delivered by the photon is equal to

[IIT 1995]

(a) 6.63×10^{-27} *kg-m/sec* (b) 2×10^{-27} *kg-m/sec*

(c) 10^{-27} *kg-m/sec* (d) None of these

26. The ratio of de-Broglie wavelength of a α-particle to that of a proton being subjected to the same magnetic field so that the radii of their path are equal to each other assuming the field induction vector $\vec{B}$ is perpendicular to the velocity vectors of the α-particle and the proton is

[IIT 1996]

(a) 1 (b) $\frac{1}{4}$

(c) $\frac{1}{2}$ (d) 2

27. K_α wavelength emitted by an atom of atomic number *Z* = 11 is λ. Find the atomic number for an atom that emits K_α radiation with wavelength 4λ.

[MP PET 1999] [IIT-JEE (Screening) 2005]

(a) *Z* = 6 (b) *Z* = 4

(c) *Z* = 11 (d) *Z* = 44

28. The potential energy of a particle of mass *m* is given by

$$U(x) = \begin{cases} E_0; & 0 \le x \le 1 \\ 0; & x > 1 \end{cases}$$

[IIT 1997 Cancelled]

λ_1 and λ_2 are the de-Broglie wavelengths of the particle, when $0 \le x \le 1$ and $x > 1$ respectively. If the total energy of particle is $2E_0$, the ratio $\frac{\lambda_1}{\lambda_2}$ will be

[IIT-JEE (Screening) 2000]

[Based on IIT-JEE (Mains) 2005]

(a) 2 (b) 1

(c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

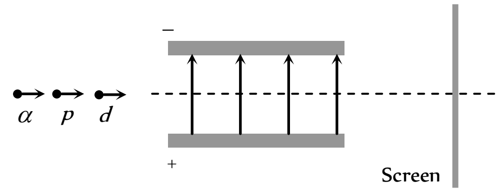
29. Rest mass energy of an electron is 0.51 *MeV*. If this electron is moving with a velocity 0.8 *c* (where *c* is velocity of light in vacuum), then kinetic energy of the electron should be.

[EAMCET (Eng.) 2000]

(a) 0.28 *MeV* (b) 0.34 *MeV*

(c) 0.39 *MeV* (d) 0.46 *MeV*

30. A proton, a deutron and an α-particle having the same momentum, enters a region of uniform electric field between the parallel plates of a capacitor. The electric field is perpendicular to the initial path of the particles. Then the ratio of deflections suffered by them is



(a) 1 : 2 : 8 (b) 1 : 2 : 4

(c) 1 : 1 : 2 (d) None of these

31. In order to coincide the parabolas formed by singly ionised ions in one spectrograph and doubly ionized ions in the other Thomson's mass spectrograph, the electric fields and magnetic fields are kept in the ratios 1 : 2 and 3 : 2 respectively. Then the ratio of masses of the ions is

(a) 3 : 4 (b) 1 : 3

(c) 9 : 4 (d) None of these

32. Let λ_α, λ_β and λ'_α denote the wavelengths of the X-rays of the K_α, K_β and L_α lines in the characteristic X-rays for a metal

(a) $\lambda_\alpha > \lambda'_\alpha > \lambda_\beta$ (b) $\lambda'_\alpha > \lambda_\beta > \lambda_\alpha$

(c) $\frac{1}{\lambda_\beta} = \frac{1}{\lambda_\alpha} + \frac{1}{\lambda'_\alpha}$ (d) $\frac{1}{\lambda_\alpha} + \frac{1}{\lambda_\beta} = \frac{1}{\lambda'_\alpha}$

33. The minimum intensity of light to be detected by human eye is $10^{-10} W/m^2$. The number of photons of wavelength $5.6 \times 10^{-7} m$ entering the eye, with pupil area $10^{-6} m^2$, per second for vision will be nearly

(a) 100 (b) 200

(c) 300 (d) 400

34. In X-ray tube when the accelerating voltage V is halved, the difference between the wavelength of K_α line and minimum wavelength of continuous *X*-ray spectrum

(a) Remains constant

(b) Becomes more than two times

(c) Becomes half

(d) Becomes less than two times

35. In a photocell bichromatic light of wavelength 2475 Å and 6000 Å are incident on cathode whose work function is 4.8 *eV*. If a uniform magnetic field of 3 × 10 *Tesla* exists parallel to the plate, the radius of the path describe by the photoelectron will be (mass of electron = 9 × 10 *kg*)

(a) 1 *cm* (b) 5 *cm*

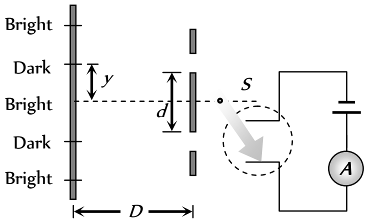
(c) 10 *cm* (d) 25 *cm*

36. Two metallic plates *A* and *B*, each of area 5 × 10 *m* are placed parallel to each other at a separation of 1 *cm*. Plate *B* carries a positive charge of 33.7 *pc*. A monochromatic beam of light, with photons of energy 5 *eV* each, starts falling on plate *A* at *t* = 0, so that 10 photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10 incident photons. Also assume that all the emitted photoelectrons are collected by plate *B* and the work function of plate *A* remains constant at the value 2 *eV*. Electric field between the plates at the end of 10 seconds is

(a) 2 × 10 *N/C* (b) 10 *N/C*

(c) 5 × 10 *N/C* (d) Zero

37. In the following arrangement *y* = 1.0 *mm*, *d* = 0.24 *mm* and *D* = 1.2 *m*. The work function of the material of the emitter is 2.2 *eV*. The stopping potential *V* needed to stop the photo current will be



(a) 0.9 *V* (b) 0.5 *V*

(c) 0.4 *V* (d) 0.1 *V*

38. The eye can detect 5 × 10 photons per square metre per sec of green light (λ = 5000 Å) while the ear can detect $10^{-13} (W/m^2)$. The factor by which the eye is more sensitive as a power detector than the ear is close to

(a) 5 (b) 10

(c) 10 (d) 15

39. A photon collides with a stationary hydrogen atom in ground state inelastically. Energy of the colliding photon is 10.2 *eV*. After a time interval of the order of micro second another photon collides with same hydrogen atom inelastically with an energy of 15 *eV*. What will be observed by the detector **[IIT-JEE (Screening) 2005]**

(a) 2 photon of energy 10.2 *eV*

(b) 2 photon of energy of 1.4 *eV*

(c) One photon of energy 10.2 *eV* and an electron of energy 1.4 *eV*

(d) One photon of energy 10.2 *eV* and another photon of 1.4 *eV*

GQ Graphical Questions

1. The curve drawn between velocity and frequency of photon in vacuum will be a **[MP PET 2000]**

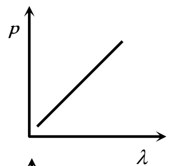
(a) Straight line parallel to frequency axis

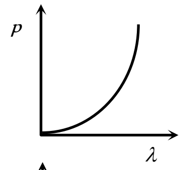
(b) Straight line parallel to velocity axis

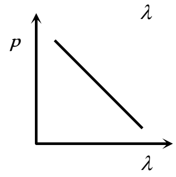
(c) Straight line passing through origin and making an angle of 45° with frequency axis

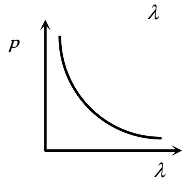
(d) Hyperbola

2. Which of the following figure represents the variation of particle momentum and the associated de-Broglie wavelength

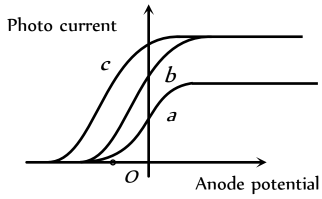
(a) 

(b) 

(c) 

(d) 

3. The figure shows the variation of photocurrent with anode potential for a photo-sensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves *a*, *b* and *c* respectively **[IIT-JEE (Screening) 2004]**



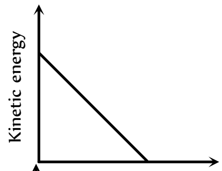
(a) $f_a = f_b$ and $I_a \neq I_b$

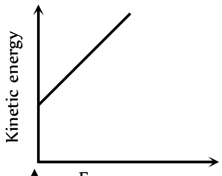
(b) $f_a = f_c$ and $I_a = I_c$

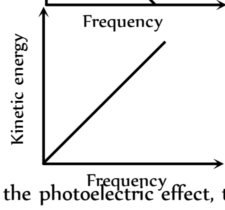
(c) $f_a = f_b$ and $l_a = l_b$

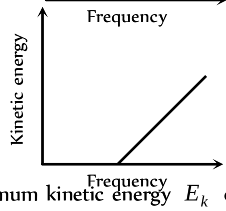
(d) $f_a = f_b$ and $l_a = l_b$

4. According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is [MP PMT 1994; CBSE PMT 1996; CBSE PMT 2004]

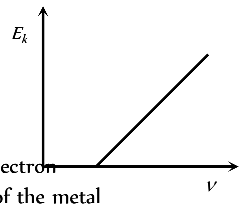
(a) 

(b) 

(c) 

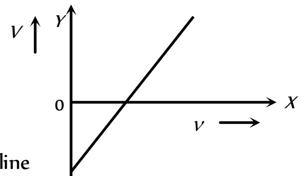
(d) 

5. For the photoelectric effect, the maximum kinetic energy E_k of the emitted photoelectrons is plotted against the frequency ν of the incident photons as shown in the figure. The slope of the curve gives [CPMT 1987; MP PET 2001; DPMT 2002]



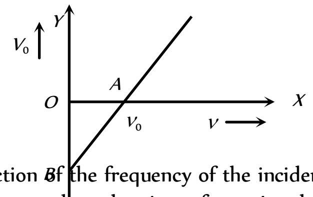
(a) Charge of the electron
(b) Work function of the metal
(c) Planck's constant
(d) Ratio of the Planck's constant to electronic charge

6. The stopping potential V for photoelectric emission from a metal surface is plotted along Y-axis and frequency ν of incident light along X-axis. A straight line is obtained as shown. Planck's constant is given by [CPMT 1987; Similar to MP PMT 2000; Kerala PET 2001]



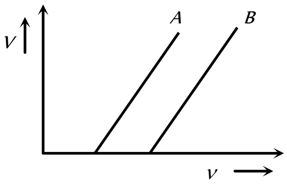
(a) Slope of the line
(b) Product of slope on the line and charge on the electron
(c) Product of intercept along Y-axis and mass of the electron
(d) Product of Slope and mass of electron

7. In an experiment on photoelectric effect the frequency f of the incident light is plotted against the stopping potential V_0. The work function of the photoelectric surface is given by (e is electronic charge) [CPMT 1987]



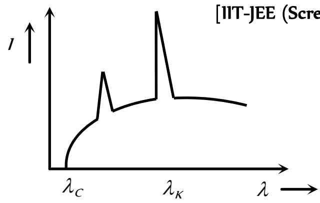
(a) $OB \times e$ in eV
(b) OB in *volt*
(c) OA in eV
(d) The slope of the line AB

8. The stopping potential as a function of the frequency of the incident radiation is plotted for two different photoelectric surfaces A and B. The graphs show that work function of A is



(a) Greater than that of B
(b) Smaller than that of B
(c) Equal to that of B
(d) No inference can be drawn about their work functions from the given graphs

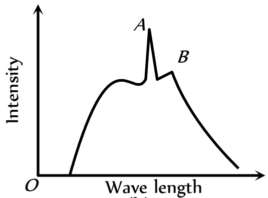
9. The intensity of X-rays from a Coolidge tube is plotted against wavelength as shown in the figure. The minimum wavelength found is λ_c and the wavelength of the K_α line is λ_k. As the accelerating voltage is increased [IIT-JEE (Screening) 2001]



(a) $(\lambda_K - \lambda_C)$ increases (b) $(\lambda_K - \lambda_C)$ decreases

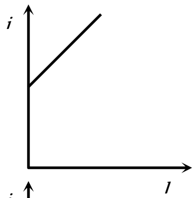
(c) λ_K increases (d) λ_K decreases

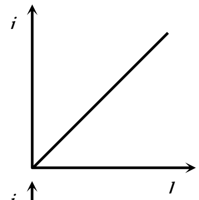
10. The figure represents the observed intensity of X-rays emitted by an X-ray tube as a function of wavelength. The sharp peaks A and B denote [CBSE PMT 1995]

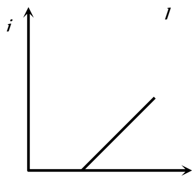


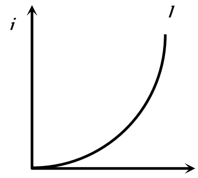
(a) Band spectrum (b) Continuous spectrum
(c) Characteristic radiations (d) White radiations

11. The graph between intensity of light falling on a metallic plate (I) with the current (i) generated is [DCE 2001]

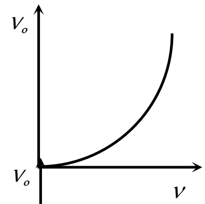
(a) 

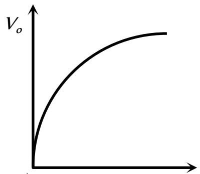
(b) 

(c) 

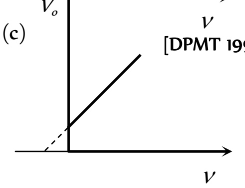
(d) 

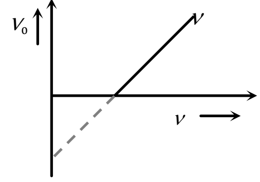
12. For a photoelectric cell the graph showing the variation of cut of voltage (V) with frequency (ν) of incident light is best represented by [DCE 2001; MP PET 2003]

(a) 

(b) 

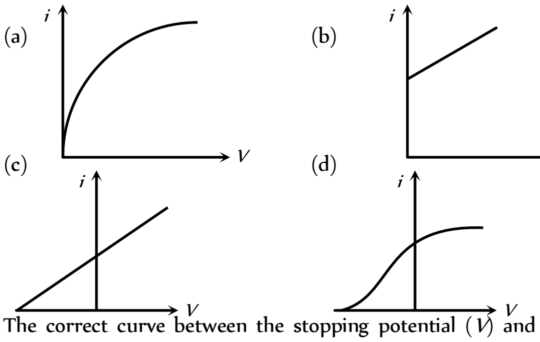
[DPMT 1992]

(c) 

(d) 

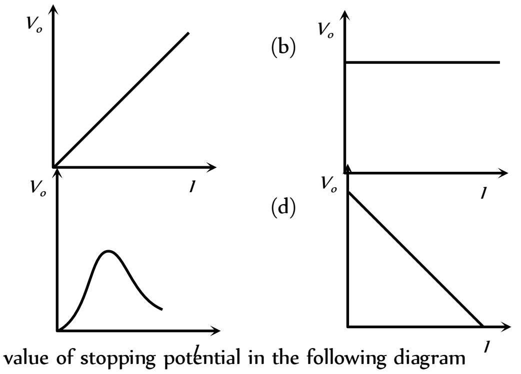
13. The curve between current (i) and potential difference (V) for a photo cell will be

(a) (b) (c) (d)

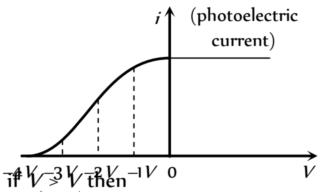


14. The correct curve between the stopping potential (V) and intensity of incident light (I) is

(a) (b) (c) (d)

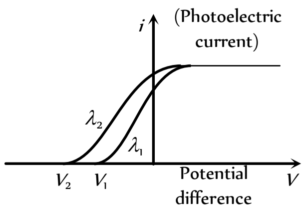


15. The value of stopping potential in the following diagram



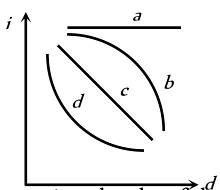
(a) – 4V
(b) – 3 V
(c) – 2V
(d) – 1 V

16. In the following diagram if $V_2 > V_1$ then



(a) $\lambda_1 = \sqrt{\lambda_2}$
(b) $\lambda_1 < \lambda_2$
(c) $\lambda_1 = \lambda_2$
(d) $\lambda_1 > \lambda_2$

17. A point source of light is used in an experiment on photoelectric effect. Which of the following curves best represents the variation of photo current (i) with distance (d) of the source from the emitter

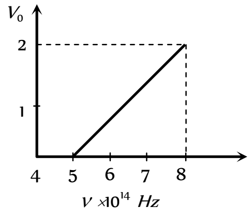


(a) a
(b) b
(c) c
(d) d

18. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal versus the frequency, of the incident radiation gives a straight line whose slope

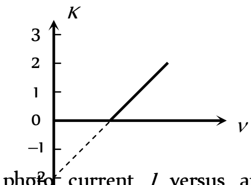
(a) Is the same for all metals and independent of the intensity of the radiation
(b) Depends on the intensity of the radiation
(c) Depends both on the intensity of the radiation and the metal used
(d) Depends on the nature of the metals used

19. The stopping potential (V_0) versus frequency (ν) plot of a substance is shown in figure the threshold wave length is



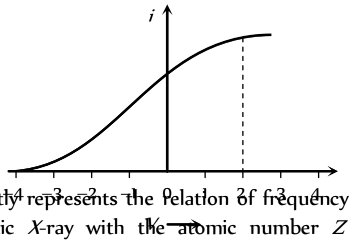
(a) $5 \times 10^{14} m$
(b) 6000Å
(c) 5000 Å
(d) Can not be estimated from given data

20. Figure represents a graph of kinetic energy (K) of photoelectrons (in eV) and frequency (ν) for a metal used as cathode in photoelectric experiment. The work function of metal is



(a) 1 eV
(b) 1.5 eV
(c) 2 eV
(d) 3 eV

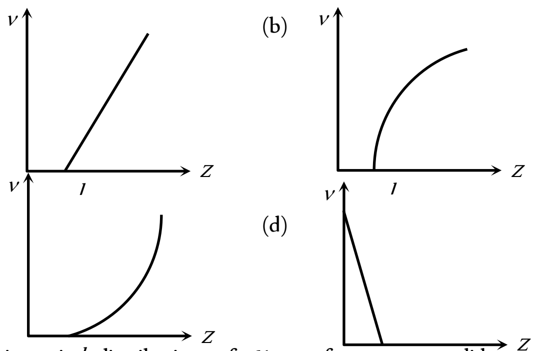
21. Figure represents the graph of photo current I versus applied voltage (V). The maximum energy of the emitted photoelectrons is



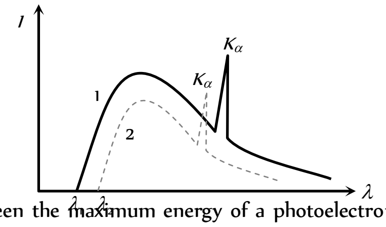
(a) 2eV
(b) 4 eV
(c) 0 eV
(d) 4 J

22. The graph that correctly represents the relation of frequency ν of a particular characteristic X-ray with the atomic number Z of the material is

(a) (b) (c) (d)

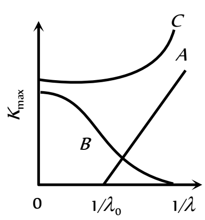


23. The intensity distribution of X-rays from two coolidge tubes operated on different voltages V_1 and V_2 and using different target materials of atomic numbers Z_1 and Z_2 is shown in the figure. Which one of the following inequalities is true? [AIEEE 2004]



(a) $V_1 > V_2, Z_1 < Z_2$
(b) $V_1 > V_2, Z_1 > Z_2$
(c) $V_1 < V_2, Z_1 > Z_2$
(d) $V_1 = V_2, Z_1 < Z_2$

24. The correct graph between the maximum energy of a photoelectron and the inverse of wavelength of the incident radiation is given by the curve



(a) A
(b) B
(c) C
(d) None of the above

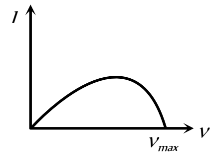
(a) A

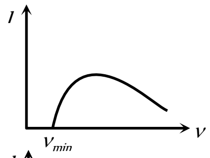
(b) B

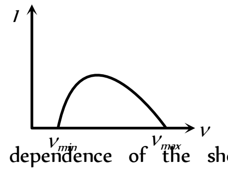
(c) C

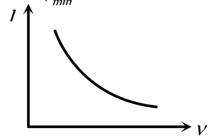
(d) None of the above

25. The continuous x-ray spectrum obtained from a Coolidge tube is of the form

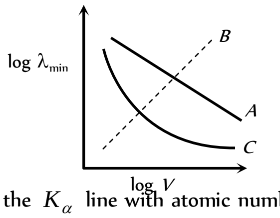
(a) 

(b) 

(c) 

(d) 

26. The dependence of the short wavelength limit $\lambda_{\min}$ on the accelerating potential V is represented by the curve of figure



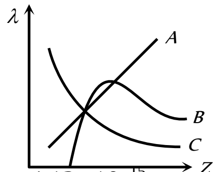
(a) A

(b) B

(c) C

(d) None of these

27. The variation of wavelength λ of the K_α line with atomic number Z of the target is shown by the following curve of



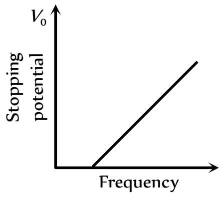
(a) A

(b) B

(c) C

(d) None of these

28. In the graph given below. If the slope is 4.12×10^{-15} V-sec, then value of 'h' should be



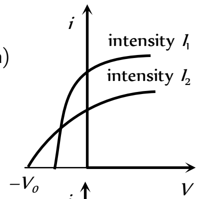
(a) 6.6×10^{-31} J-sec

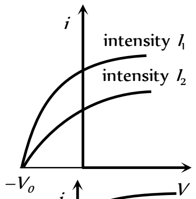
(b) 6.6×10^{-34} J-sec

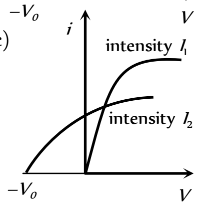
(c) $9.1 \times 10 - 31$ J-sec

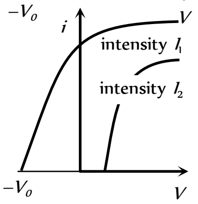
(d) None of these

29. The curves (a), (b) (c) and (d) show the variation between the applied potential difference (V) and the photoelectric current (i), at two different intensities of light ($I_1 > I_2$). In which figure is the correct variation shown

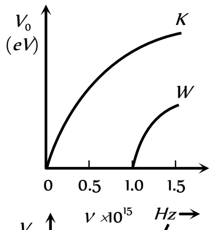
(a) 

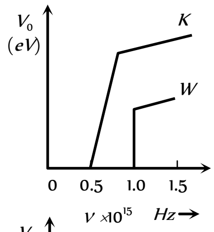
(b) 

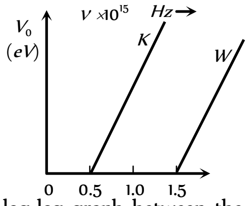
(c) 

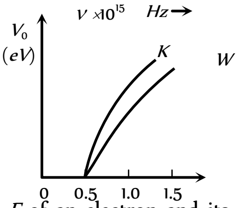
(d) 

30. The figure showing the correct relationship between the stopping potential V_0 and the frequency ν of light for potassium and tungsten is

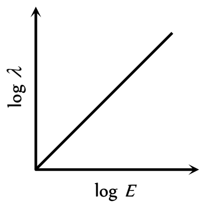
(a) 

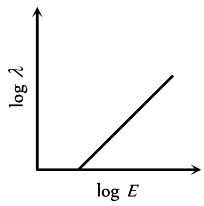
(b) 

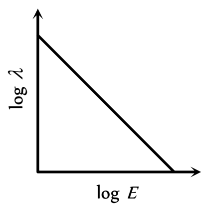
(c) 

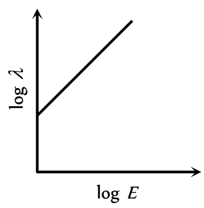
(d) 

31. The log-log graph between the energy E of an electron and its de-Broglie wavelength λ will be

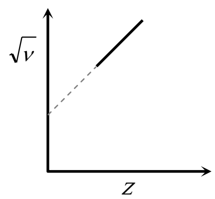
(a) 

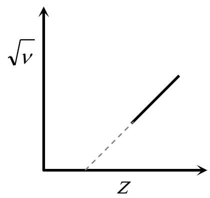
(b) 

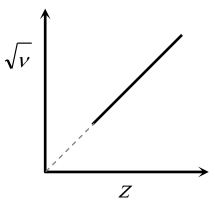
(c) 

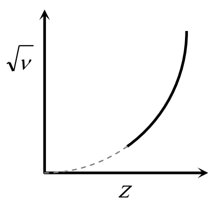
(d) 

32. The graph between the square root of the frequency of a specific line of characteristic spectrum of X-rays and the atomic number of the target will be

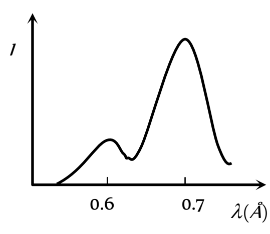
(a) 

(b) 

(c) 

(d) 

33. In the diagram a graph between the intensity of X-rays emitted by a molybdenum target and the wavelength is shown, when electrons of 30 keV are incident on the target. In the graph one peak is of K_α line and the other peak is of K_β line



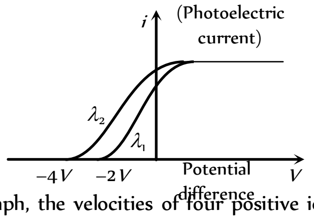
(a) First peak is of K_α line at 0.6 Å

(b) Highest peak is of K_α line at 0.7 Å

(c) If the energy of incident particles is increased, then the peaks will shift towards left

(d) If the energy of incident particles is increased, then the peaks will shift towards right

34. The maximum value of stopping potential in the following diagram is



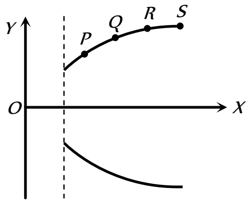
(a) – 4 V

(b) – 1 V

(c) – 3 V

(d) – 2 V

35. In a parabola spectrograph, the velocities of four positive ions P,Q,R and S are v_1, v_2, v_3 and v_4 respectively



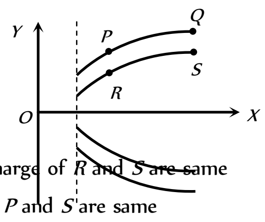
(a) $v_1 > v_2 > v_3 > v_4$

(b) $v_1 < v_2 < v_3 < v_4$

(c) $v_1 = v_2 = v_3 = v_4$

(d) $v_1 << v_2 > v_3 < v_4$

36. In Thomson spectrograph experiment, four positive ions P,Q,R and S are situated on Y-X curve a shown in the figure



(a) The specific charge of R and S are same

(b) The masses of P and S are same

(c) The specific charges of Q and R are same

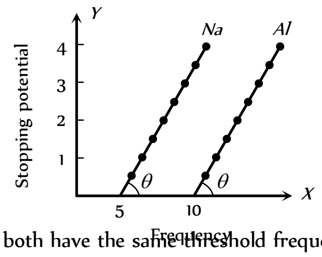
(d) The velocities of R and S are same

37. The slope of frequency of incident light and stopping potential graph for a given surface will be [MP PET 1999; MP PMT 2000; JIPMER 2001, 02; UPSEAT 2003]

(a) h (b) h/e

(c) eh (d) e

38. From the figure describing photoelectric effect we may infer correctly that [KCET 2005]



(a) Na and Al both have the same threshold frequency

(b) Maximum kinetic energy for both the metals depend linearly on the frequency

(c) The stopping potentials are different for Na and Al for the same change in frequency

(d) Al is a better photo sensitive material than Na

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : The energy (E) and momentum (p) of a photon are related by $p = E/c$.

Reason : The photon behaves like a particle. [AIIMS 2005]

2. Assertion : Photoelectric effect demonstrates the wave nature of light.

Reason : The number of photoelectrons is proportional to the frequency of light. [AIIMS 2004]

3. Assertion : When the speed of an electron increases its specific charge decreases.

Reason : Specific charge is the ratio of the charge to mass. [AIIMS 2001]

4. Assertion : X-ray travel with the speed of light.

Reason : X-rays are electromagnetic rays. [AIIMS 2001]

5. Assertion : Mass of moving photon varies inversely as the wavelength.

Reason : Energy of the particle $= \text{Mass} \times (\text{Speed of light})^2$ [AIIMS 2000]

6. Assertion : Kinetic energy of photo electrons emitted by a photosensitive surface depends upon the intensity of incident photon.

Reason : The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency. [AIIMS 1999]

7. Assertion : Separation of isotope is possible because of the difference in electron numbers of isotope.

Reason : Isotope of an element can be separated by using a mass spectrometer. [AIIMS 1999]

8. Assertion : The specific charge of positive rays is not constant.

Reason : The mass of ions varies with speed. [AIIMS 1999]

9. Assertion : Photosensitivity of a metal is high if its work function is small.

Reason : Work function $= hf_0$ where f_0 is the threshold frequency. [AIIMS 1997]

10. Assertion : The de-Broglie wavelength of a molecule varies inversely as the square root of temperature.

Reason : The root mean square velocity of the molecule depends on the temperature.

[AIIMS 1997]

11. Assertion : An electron is not deflected on passing through certain region of space. This observation confirms that there is no magnetic field in that region.

Reason : The deflection of electron depends on angle between velocity of electron and direction of magnetic field.

12. Assertion : Electric conduction in gases is possible at normal pressure.

Reason : The electric conduction in gases depends only upon the potential difference between the electrodes.

13. Assertion : Light is produced in gases in the process of electric discharge through them at high pressure.

Reason : At high pressure electrons of gaseous atoms collide and reach and excited state.

14. Assertion : If different gases are filled turn by turn at the same pressure in the discharge tube the discharge in them takes place at the same potential.

Reason : The discharge depends only on the pressure of discharge tube and not on the ionisation potential of gas.

15. Assertion : An electric field is preferred in comparison to magnetic field for detecting the electron beam in a television picture tube.

Reason : Electric field require low voltage.

16. Assertion : The specific charge for positive rays is a characteristic constant.

Reason : The specific charge depends on charge and mass of positive ions present in positive rays.

17. Assertion : In Millikan's experiment for the determination of charge on an electron, oil drops of any size can be used.

Reason : Millikan's experiment determine the charge on electron, by simply measuring the terminal velocity.

18. Assertion : In the process of photoelectric emission, all the emitted photoelectrons have the same kinetic energy.

Reason : The photon transfers its whole energy to the electron of the atom in photoelectric effect.

19. Assertion : In photoelectric effect, on increasing the intensity of light, both the number of electrons emitted and kinetic energy of each of them get increased but photoelectric current remains unchanged.

Reason : The photoelectric current depends only on wavelength of light.

20. Assertion : Though light of a single frequency (monochromatic) is incident on a metal, the energies of emitted photoelectrons are different.

Reason : The energy of electrons emitted from inside the metal surface is lost in collision with the other atoms in the metal.

21. Assertion : The threshold frequency of photoelectric effect supports the particle nature of sunlight.

Reason : If frequency of incident light is less than the threshold frequency, electrons are not emitted from metal surface.

22. Assertion : In photoemissive cell inert gas is used.

Reason : Inert gas in the photoemissive cell gives greater current.

23. Assertion : *X*-rays cannot be diffracted by means of grating.

Reason : *X*-rays does not obey Bragg's law.

24. Assertion : *X*-rays can penetrate through the flesh but not through the bones.

Reason : The penetrating power of *X*-rays depends on voltage.

25. Assertion : Intensity of *X*-rays can be controlled by adjusting the filament current and voltage.

Reason : The intensity of *X*-rays does not depend on number of *X*-ray photons emitted per second from the target.

26. Assertion : Anode of Coolidge tube gets heated up at time of emission of *X*-rays.

Reason : The anode of Coolidge tube is made of a material of high melting point.

27. Assertion : Penetrating power of *X*-rays increases with the increasing the wavelength.

Reason : The penetrating power of *X*-rays increases with the frequency of *X*-rays.

28. Assertion : *X*-rays are used for studying the structure of crystals.

Reason : The distance between the atoms of crystals is of the order of wavelength of *X*-rays.

29. Assertion : The phenomenon of *X*-ray production is basically inverse of photoelectric effect.

Reason : *X*-rays are electromagnetic waves.

30. Assertion : Soft and hard *X*-rays differ in frequency as well as velocity.

Reason : The penetrating power of hard *X*-rays is more than the penetrating power of soft *X*-rays.

Answers

Cathode Rays and Positive Rays

1	b	2	b	3	d	4	b	5	d
6	a	7	d	8	b	9	c	10	b
11	c	12	b	13	d	14	b	15	d
16	c	17	c	18	b	19	c	20	b
21	b	22	c	23	c	24	d	25	c
26	d	27	b	28	b	29	c	30	a
31	a	32	c	33	a	34	a	35	b
36	b	37	a	38	d	39	b	40	a
41	c	42	d	43	d	44	c	45	b
46	c	47	a	48	d	49	c	50	c
51	c	52	b	53	b	54	b	55	d
56	d	57	c	58	a	59	b	60	a

61	b	62	b	63	c	64	c	65	b
66	b	67	a	68	a	69	d	70	b
71	a	72	c						

Matter Waves

1	b	2	c	3	a	4	a	5	a
6	b	7	a	8	a	9	d	10	a
11	b	12	a	13	c	14	b	15	b
16	d	17	c	18	b	19	c	20	d
21	b	22	c	23	a	24	a	25	b
26	b	27	c	28	a	29	d	30	b
31	a	32	b	33	c	34	a	35	a
36	a	37	c	38	c	39	d	40	a
41	d	42	d	43	d				

Photon and Photoelectric Effect

1	d	2	d	3	c	4	a	5	a
6	b	7	d	8	b	9	b	10	a
11	b	12	b	13	b	14	c	15	a
16	a	17	b	18	a	19	a	20	c
21	d	22	c	23	b	24	a	25	a
26	a	27	a	28	c	29	d	30	c
31	c	32	a	33	e	34	a	35	d
36	c	37	d	38	c	39	d	40	b
41	a	42	c	43	d	44	d	45	d
46	c	47	c	48	b	49	c	50	a
51	a	52	b	53	d	54	b	55	a
56	d	57	d	58	b	59	b	60	a
61	c	62	b	63	b	64	c	65	a
66	d	67	d	68	c	69	b	70	a
71	d	72	a	73	c	74	c	75	b
76	c	77	a	78	a	79	b	80	c
81	b	82	d	83	c	84	c	85	b
86	c	87	a	88	b	89	c	90	d
91	a	92	a	93	a	94	b	95	c
96	b	97	d	98	a	99	b	100	b
101	a	102	d	103	a	104	b	105	b
106	a	107	a	108	b	109	a	110	b
111	c	112	b	113	a	114	c	115	c
116	b	117	c	118	d	119	a	120	c
121	c	122	c	123	b	124	a	125	a
126	a	127	a	128	c	129	d	130	b
131	d	132	b	133	c	134	d	135	c
136	c	137	d	138	b	139	c	140	c
141	a	142	d	143	b	144	d	145	b
146	c	147	a	148	a	149	c	150	d
151	d	152	b	153	a	154	c	155	a
156	a								

X-Rays

1	c	2	c	3	a	4	a	5	d
6	b	7	a	8	b	9	c	10	c
11	c	12	b	13	c	14	c	15	b
16	c	17	b	18	c	19	d	20	a
21	a	22	b	23	a	24	c	25	d
26	a	27	d	28	c	29	b	30	b
31	c	32	c	33	b	34	c	35	c
36	d	37	a	38	d	39	d	40	c
41	d	42	b	43	c	44	b	45	a
46	c	47	a	48	d	49	c	50	b
51	c	52	a	53	b	54	d	55	b
56	d	57	d	58	c	59	a	60	a
61	a	62	b	63	b	64	b	65	b
66	a	67	b	68	d	69	d	70	d
71	d	72	a	73	c	74	c	75	c
76	d	77	b	78	a	79	d	80	a
81	b	82	c	83	c	84	d	85	a
86	d	87	a	88	d	89	c	90	b
91	a	92	b	93	d	94	a	95	d
96	d	97	b	98	b	99	d	100	c
101	c	102	b	103	b	104	b	105	d
106	a	107	d	108	d	109	b	110	c
111	a								

Critical Thinking Questions

1	b	2	c	3	b	4	abc	5	d
6	b	7	b	8	c	9	b	10	d
11	c	12	b	13	b	14	a	15	a
16	d	17	acd	18	c	19	b	20	c
21	d	22	a	23	c	24	c	25	b
26	c	27	a	28	c	29	b	30	a
31	c	32	c	33	c	34	d	35	b
36	a	37	a	38	a	39	c		

Graphical Questions

1	a	2	d	3	a	4	d	5	c
6	b	7	a	8	b	9	a	10	c
11	b	12	d	13	d	14	b	15	a

16	d	17	d	18	a	19	b	20	c
21	b	22	c	23	a	24	a	25	a
26	a	27	c	28	b	29	b	30	c
31	c	32	b	33	b	34	a	35	a
36	a	37	b	38	b				

Assertion and Reason

1	a	2	d	3	b	4	a	5	b
6	d	7	e	8	b	9	b	10	a
11	e	12	d	13	d	14	d	15	d
16	b	17	e	18	e	19	d	20	a
21	b	22	a	23	c	24	b	25	c
26	b	27	e	28	a	29	b	30	e

Answers and Solutions

Cathode Rays and Positive Rays

1. (b) Electric field $=\frac{V}{d}=\frac{250}{2.5\times10^{-2}}=10000\ V/m$.

2. (b)

3. (d) In Millikan's experiment, drops of non-volatile liquid (cloak oil) are used to prevent evaporation.

4. (b) $E=eV=2e\times5=10\ eV$

5. (d) $E=eV=1.6\times10^{-19}\times10^{5}=1.6\times10^{-14}\ J$

6. (a) Any charge in the universe is given by

$q=ne\Rightarrow e=\frac{q}{n}$ (where n is an integer)

$q_1:q_2:q_3:q_4:q_5:q_6::n_1:n_2:n_3:n_4:n_5:n_6$

$6.563:8.204:11.5:13.13:16.48:18.09::n_1:n_2:n_3:n_4:n_5:n_6$

Divide by 6.563

$1:1.25:1.75:2.0:2.5:2.75::n_1:n_2:n_3:n_4:n_5:n_6$

Multiplied by 4

$4:5:7:8:10:11::n_1:n_2:n_3:n_4:n_5:n_6$

$$e=\frac{q_1+q_2+q_3+q_4+q_5+q_6}{n_1+n_2+n_3+n_4+n_5+n_6}=\frac{73.967\times10^{-19}}{45}$$

$=1.641\times10^{-19}C$

(**Note :** If you take 45.0743 in place of 45, you will get the exact value)

7. (d) Because magnetic force always points perpendicular to the particle velocity. That is why velocity remains unchanged thereby keeping energy $\left(\frac{1}{2}mv^2\right)$ and momentum (mv) unchanged.

8. (b)

9. (c) Mass is basically a constant term for any physical application at low velocity. But in accordance with Einstein's theory of relativity, at higher speeds the mass of the particle change according to formula

$$m=\frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

10. (b) Refer Q.No. 9. Here the velocity of electron increases, so as per Einstein's equation mass of the electron increases, hence the specific charge $\frac{e}{m}$ decreases.

11. (c) If the voltage given is V, then the energy of electron

$$\frac{1}{2}mv^2=eV\Rightarrow v=\sqrt{\frac{2eV}{m}}$$

$$=\sqrt{\frac{2\times1.6\times10^{-19}\times1000}{9.1\times10^{-31}}}=1.875\times10^{7}\approx1.9\times10^{7}m/s$$

12. (b)

13. (d) Momentum $p=mv$ and $v=\sqrt{\frac{2QV}{m}}$

$$\Rightarrow p=\sqrt{2QmV}\Rightarrow p\propto\sqrt{Qm}\Rightarrow\frac{p_e}{p_\alpha}=\sqrt{\frac{e\times m_e}{2e\times m_\alpha}}=\sqrt{\frac{m_e}{2m_\alpha}}$$

14. (b) In an electric field, a force opposite to the direction of electric field acts on negatively charged particles (*i.e.* from lower potential to higher potential).

15. (d)

16. (c) $QE=mg\Rightarrow Q=\frac{mg}{E}\Rightarrow n=\frac{mgd}{Ve}$

$$\Rightarrow n=\frac{1.8\times10^{-14}\times10\times0.9\times10^{-2}}{2\times10^{3}\times1.6\times10^{-19}}=5$$

17. (c)

18. (b) In Millikan's experiment, the charges present on the oil drops are the integral multiples, so $2e$ and $10e(1.6\times10^{-18}\ C)$ charges are present.

19. (c) $eE=evB\Rightarrow v=\frac{E}{B}=\frac{3\times10^{4}}{2\times10^{-3}}=1.5\times10^{7}m/s$

20. (b)

21. (b) Charged particles trace a circular path in a perpendicular magnetic field.

22. (c) $\frac{e}{m}=\frac{1.6\times10^{-19}}{9.1\times10^{-31}}=1.76\times10^{11}C/kg$

23. (c)

24. (d) Light consists of photons and cathode rays consists of electrons. However both effect the photographic plate.

25. (c)

26. (d)

27. (b) For ionisation, high energy electrons are required.

28. (b) $v=\frac{E}{B}=\frac{20}{0.5}=40\ m/\sec$.

29. (c) Higher the voltage, higher is the KE. Higher the work function, smaller is the KE.

30. (a) Time period of revolution of electron $T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$

Hence corresponding electric current $i = \frac{e}{T} = \frac{ev}{2\pi r}$

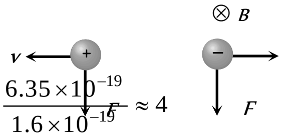
$\Rightarrow i = \frac{1.6\times10^{-19}\times2\times10^{6}}{2\times3.14\times0.5\times10^{-10}} = 1\,mA.$

31. (a) $K = Q.V = 1.6\times10^{-19}\times100 = 1.6\times10^{-17}$ $Joules$

32. (c) $K = Q.V = 1e\times1\,Volt = 1\,e\,V$

33. (a) Kinetic energy $\propto$ Potential difference

34. (a) In discharge tube cathode rays (a beam of negative particles) and canal rays (positive rays) moves opposite to each other. They will experience a magnetic force in the same direction, if a normal magnetic field is switched on



35. (b) $n = \frac{Q}{e} = \frac{6.35\times10^{-19}}{1.6\times10^{-19}} \approx 4$

36. (b)

37. (a) When cathode rays strike the metal plate, they transfer their energy to plate.

38. (d) Cathode rays are beam of electrons.

39. (b) $K = QV = e\times V = eV$

40. (a) $\frac{1}{2}mv^2 = QV \Rightarrow v = \sqrt{\frac{2QV}{m}} = \sqrt{2\left(\frac{e}{m}\right)V}$

$\Rightarrow v = \sqrt{2\times1.6\times10^{11}\times200} = 8\times10^{6}\,m/s$.

41. (c) Speed of the cathode rays is $10^7\,m/\sec - 3\times10^7\,m/s$

42. (d) $QE = mg \Rightarrow mg = \frac{QV}{d}$

43. (d)

44. (c) In the condition of no deflection $\frac{e}{m} = \frac{E^2}{2VB^2} \Rightarrow$ If m is increased by 208 times then B should be increased $\sqrt{208} = 14.4$ times

45. (b) The colour of the positive column in a discharge tube depends on the type of gas e.g. For air, colour is purple red, for H_2, colour is Blue etc.

46. (c)

47. (a) $v = \frac{p}{m} = \frac{h}{m\lambda} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^{-10}} = 7.25\times10^{6}\ m/s$

48. (d) Cathode rays are stream of negative charged particle, so they deflect in electric field.

49. (c) $\frac{e}{m} = \frac{E^2}{2VB^2} = \frac{(3.6\times10^4)^2}{2\times2.5\times10^3\times(1.2\times10^{-3})^2}$

$= 1.8\times10^{11}\,C/kg$.

50. (c) Specific charge $= \frac{q}{m}$; Ratio $= \frac{\left(\frac{q}{m}\right)_\alpha}{\left(\frac{q}{m}\right)_p} = \frac{q_\alpha}{q_p}\times\frac{m_p}{m_\alpha} = \frac{1}{2}$.

51. (c) $v = \frac{E}{B}$; where $E = \frac{V}{d} = \frac{1000}{1\times10^{-2}} = 10^5\ V/m$

$\Rightarrow v = \frac{10^5}{1} = 10^5\,m/s$.

52. (b)

53. (b)

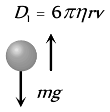
54. (b)

55. (d) In Thomson's mass spectrograph $\vec{E}\,||\,\vec{B}$

56. (d)

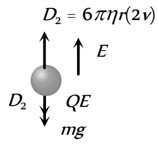
57. (c) In the absence of electric field (*i.e.* $E = 0$)

$mg = 6\pi\eta rv$ ...(i)



In the presence of Electric field

$mg + QE = 6\pi\eta r(2v)$ ...(ii)

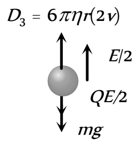


When Electric field to reduced to $E/2$

$mg + Q(E/2) = 6\pi\eta r(v')$ ...(iii)

After solving (i), (ii) and (iii)

We get $v' = \frac{3}{2}v$



58. (a) $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times45.5}{9.1\times10^{-31}}} = 4\times10^{6}\ m/s$

59. (b) $i = \frac{Q}{t} = \frac{ne}{t} = 1.8\times10^{14}\times1.6\times10^{-19} = 28.8\times10^{-6}\,A$

$= 29\,\mu A$

60. (a) $\because\ m_e < m_p < m_\alpha \Rightarrow \left(\frac{q}{m}\right)_e > \left(\frac{q}{m}\right)_p > \left(\frac{q}{m}\right)_\alpha$

61. (b) Acceleration $a = \frac{QE}{m} = \frac{(3e)E}{2m}$

62. (b) $\frac{1}{2}mv^2 = eV \Rightarrow \frac{e}{m} = \frac{v^2}{2V} = \frac{(8.4\times10^6)^2}{2\times200} = 1.76\times10^{11}\,\frac{C}{kg}$.

63. (c) $K = Q.\Delta V = (2e)\times10^6\,V = 2\times10^6\,eV = 2M\,eV$

64. (c) Positive rays consist of positive ions.

65. (b) $2r = \frac{2mv}{qB} \Rightarrow 2r \propto \frac{m}{q} \Rightarrow \frac{m}{q}$ is maximum for C^+

66. (b) $v = \frac{E}{B} = \frac{1.125\times10^{-6}}{3\times10^{-10}} = 3750\,m/s$

67. (a) Positive rays was discovered by J.J. Thomson.

68. (a)

69. (d) If electron oscillate with a frequency of 1 *GHz*, it does not radiate any energy, which corresponds a definite wavelength. It only radiate when it jump from one orbit to another orbit.

70. (b) $eV = \frac{1}{2}mv^2 \Rightarrow v^2 = \frac{2eV}{m} \Rightarrow v = \sqrt{\frac{2eV}{m}}$

71. (a)

72. (c) $eE = mg \Rightarrow e = \frac{mg}{E} = \frac{16\times10^{-6}\times10}{10^6} = 16\times10^{-11}\ C.$

Matter Waves

1. (b)

2. (c) According to de-Broglie hypothesis.

3. (a) $\lambda = \frac{h}{p} = \frac{h}{mv}$

4. (a) $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$: $\therefore E = \frac{h^2}{2m\lambda^2}$

λ is same for all, so $E \propto \frac{1}{m}$. Hence energy will be maximum for particle with lesser mass.

5. (a) Particle is photon and it travels with the velocity equal to light in vacuum.

6. (b) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$; $\therefore \lambda \propto \frac{1}{\sqrt{E}}$ (h and m = constant)

7. (a) $\lambda = \frac{h}{m_1v_1} = \frac{h}{m_2v_2}$; $\therefore \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{4}{1}$

8. (a) $\frac{1}{2}mv^2 = E \Rightarrow mv = \sqrt{2mE}$; $\therefore \lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

9. (d) $\left.\begin{matrix}\text{Photoelectric effect} \rightarrow \text{Particle nature} \\ \text{Diffraction} \rightarrow \text{Wave nature}\end{matrix}\right\}\text{Dual nature}$

10. (a) $mvr = \frac{nh}{2\pi}$ According to Bohr's theory

$\Rightarrow 2\pi r = n\left(\frac{h}{mv}\right) = n\lambda$ for $n = 1$, $\lambda = 2\pi r$

11. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ (E = same)

12. (a) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} = \frac{2}{1}$

13. (c) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m_\alpha Q_\alpha V}}$

On putting $Q_\alpha = 2\times1.6\times10^{-19}\ C$

$m_\alpha = 4m_p = 4\times1.67\times10^{-27}\ kg \Rightarrow \lambda = \frac{0.101}{\sqrt{V}}\ Å$

14. (b)

15. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{E}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{E_2}{E_1}}$

$\Rightarrow \frac{10^{-10}}{0.5\times10^{-10}} = \sqrt{\frac{E_2}{E_1}} \Rightarrow E_2 = 4E_1$

Hence added energy $= E_2 - E_1 = 3E_1$

16. (d) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9\times10^{-31}\times80\times1.6\times10^{-19}}} = 1.4Å$

17. (c) $\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{m}$

18. (b) If an electron and a photon propagates in the from of waves having the same wavelength, it implies that they have same momentum. This is according to de-Broglie equation, $p \propto \frac{1}{\lambda}$

19. (c) $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

20. (d) In photoelectric effect particle nature of electron is shown. While in electron microscope, beam of electron is considered as electron wave.

21. (b) $K_{\text{particle}} = \frac{1}{2}mv^2$ also $\lambda = \frac{h}{mv}$

$\Rightarrow K_{\text{particle}} = \frac{1}{2}\left(\frac{h}{\lambda v}\right).v^2 = \frac{vh}{2\lambda}$ ...(i)

$K_{\text{photon}} = \frac{hc}{\lambda}$ ...(ii)

$\therefore \frac{K_{\text{particle}}}{K_{\text{photon}}} = \frac{v}{2c} = \frac{2.25\times10^8}{2\times3\times10^8} = \frac{3}{8}$

22. (c) $2\pi r n = \lambda \Rightarrow n = \frac{\lambda}{2\pi r} = \frac{10^{-9}}{2\times3.14\times5.13\times10^{-11}} = 3$

23. (a) By using $\lambda_{electron} = \frac{h}{m_e v} \Rightarrow v = \frac{h}{m_e\lambda_e}$

$= \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^{-10}} = 7.25\times10^6\ m/s.$

24. (a) By using $\lambda = \frac{h}{\sqrt{2mE}}$ $E = 10^{-32}\ J$ = Constant for both particles. Hence $\lambda \propto \frac{1}{\sqrt{m}}$ Since $m_p > m_e$ so $\lambda_p < \lambda_e$.

25. (b) By using $\lambda \propto \frac{1}{\sqrt{V}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}}$

$\Rightarrow \frac{10^{-10}}{\lambda_2} = \sqrt{\frac{600}{150}} = 2 \Rightarrow \lambda_2 = 0.5\ Å.$

26. (b) $\lambda = \frac{h}{mv_{rms}} \Rightarrow \lambda = \frac{6.6\times10^{-34}}{2\times1.67\times10^{-27}\times3\times10^3} = 0.66\ Å$

27. (c) $\lambda \propto \frac{1}{p} \Rightarrow \frac{\Delta p}{p} = -\frac{\Delta\lambda}{\lambda} \Rightarrow \left|\frac{\Delta p}{p}\right| = \left|\frac{\Delta\lambda}{\lambda}\right|$

$\Rightarrow \frac{p_0}{p} = \frac{0.25}{100} = \frac{1}{400} \Rightarrow p = 400\ p_0.$

28. (a) $\lambda_{neutron} \propto \frac{1}{\sqrt{T}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{T_2}{T_1}}$

$\Rightarrow \frac{\lambda}{\lambda_2} = \sqrt{\frac{(273+927)}{(273+27)}} = \sqrt{\frac{1200}{300}} = 2 \Rightarrow \lambda_2 = \frac{\lambda}{2}.$

29. (d) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E \propto \frac{1}{\sqrt{m}}$ (λ = constant)

$\because m_e < m_p$ so $E_e > E_p$

30. (b)

31. (a) Wavelength of photon will be greater than that of electron because mass of photon is less than that of electron $\Rightarrow \lambda_{ph} > \lambda_e$

32. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E = \frac{h^2}{2m\lambda^2}$

$= \frac{(6.6\times10^{-34})^2}{2\times9.1\times10^{-31}\times(0.3\times10^{-9})^2} = 2.65\times10^{-18}\,J$

$= 16.8\,eV$

33. (c) $\lambda = \frac{h}{\sqrt{2mQV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mQ}} \Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha Q_\alpha}{m_p Q_p}}$

$= \sqrt{\frac{4m_p\times2Q_p}{m_p\times Q_p}} = 2\sqrt{2}$

34. (a) $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{2\times10^{-6}}$

$= 3.31\times10^{-28}\,kg\text{-}m/\sec$

35. (a) $\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{1\times2000} = 3.3\times10^{-37}m = 3.3\times10^{-27}\,Å$

36. (a) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times5\times1.6\times10^{-19}}}$

$= 5.469\times10^{-10}m = 5.47\,Å$

37. (c) $\lambda = \frac{h}{\sqrt{2mQV}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times100}}$

$= 1.23\,Å$

38. (c) The De-Broglie wavelength is $\lambda = \frac{h}{|p|} = \frac{h}{|I|} \Rightarrow \lambda \propto \frac{1}{|I|}$

39. (d) Davission and Germer proved the wave nature of electron by performing an experiment.

40. (a) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{E}}$.

41. (d) $\lambda = \frac{\hbar}{\sqrt{2mE}}$; $\frac{\lambda'}{\lambda} = \sqrt{\frac{E}{E'}} \Rightarrow \frac{E}{E} = \left(\frac{0.5}{1}\right)^2 \Rightarrow E' = \frac{E}{0.25} = 4E$

The energy should be added to decrease wavelength.

$= E' - E = 3E$

42. (d)

43. (d)

Photon and Photoelectric Effect

1. (d) $p = \frac{h\nu}{c} \Rightarrow \nu = \frac{pc}{h} = \frac{3.3\times10^{-29}\times3\times10^8}{6.6\times10^{-34}} = 1.5\times10^{13}\,Hz$

2. (d)

3. (c) $p = \frac{E}{c} \Rightarrow E = p\times c = 2\times10^{-16}\times(3\times10^{10}) = 6\times10^{-6}\,erg.$

4. (a)

5. (a) $p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{(5000\times10^{-10})} = 1.3\times10^{-27}\,kg\text{ - }m/s$

6. (b) $p = \frac{E}{c} = \frac{h\nu}{c}$

7. (d) $E = h\nu = mc^2 \Rightarrow m = \frac{h\nu}{c^2}$

8. (b) $p = \frac{E}{c} = \frac{h\nu}{c} \Rightarrow \nu = \frac{pc}{h}$

9. (b) $P = \frac{W}{t} = \frac{nhc}{\lambda t} \Rightarrow \left(\frac{n}{t}\right) = \frac{P\lambda}{hc} = \frac{10\times10^3\times300}{6.6\times10^{-34}\times3\times10^8}$

$= 1.5\times10^{31}$

10. (a) Momentum of photon $p = \frac{E}{c}$

$\Rightarrow$ Velocity of photon $c = \frac{E}{p}$

11. (b) By using $E(eV) = \frac{12375}{\lambda(Å)}$

$\Rightarrow \lambda = \frac{12375}{2.48} = 4989.9\,Å \approx 5000\,Å$

12. (b) $E = \frac{hc}{\lambda} = \frac{3\times10^8\times6.62\times10^{-34}}{0.21\times1.6\times10^{-19}} = 5.9\times10^{-6}\,eV$

13. (b) Momentum of photon

$p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{10^{-10}} = 6.6\times10^{-24}\,kg\text{ - }m/sec.$

14. (c) $E \propto \frac{1}{\lambda} \Rightarrow \frac{2.5}{E'} = \frac{1}{5000} \Rightarrow E' = (2.5)\times5000\,eV$

15. (a) $E = h\nu = 6.6\times10^{-34}\times10^{15} = 6.6\times10^{-19}\,J$

16. (a) Since $h\nu = mc^2$, hence $p = mc = \frac{h\nu}{c} = \frac{h}{\lambda}$

17. (b) $E = h\nu \Rightarrow \nu = \frac{E}{h} = \frac{1\times10^6\times1.6\times10^{-19}}{6.6\times10^{-34}} = 2.4\times10^{20}\,Hz$

18. (a) $p = \frac{h\nu}{c} = \frac{6.6\times10^{-34}\times1.5\times10^{13}}{3\times10^8} = 3.3\times10^{-29}\,kg\text{-}m/\sec$

19. (a) $E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^8}{450\times10^{-9}} = 4.4\times10^{-19}\,J$

20. (c) $E = h\nu \Rightarrow \nu = \frac{E}{h} = \frac{66\times1.6\times10^{-19}}{6.6\times10^{-34}} = 16\times10^{15}\,Hz$

21. (d) $E \propto \frac{1}{\lambda}$; also $\lambda_{infrared} > \lambda_{visible}$ so $E_{infrared} < E_{visible}$

22. (c) Energy of photon $E = \frac{hc}{\lambda}$ (Joules) $= \frac{hc}{e\lambda}(eV)$

$\Rightarrow E_{(eV)} = \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}\times\lambda(Å)} = \frac{12375}{\lambda(Å)}$

$\Rightarrow E(keV) = \frac{12.37}{\lambda(Å)} \approx \frac{12.4}{\lambda}$

23. (b) $E = h\nu \Rightarrow 100\times1.6\times10^{-19} = 6.6\times10^{-34}\times\nu$

$\Rightarrow \nu = 2.42\times10^{16}\,Hz$.

24. (a) $p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{4400\times10^{-10}} = 1.5\times10^{-27}\,kg.m/s$

and mass $m = \frac{p}{c} = \frac{1.5 \times 10^{-27}}{3 \times 10^{8}} = 5 \times 10^{-36} kg$

25. (a)

26. (a)

27. (a) $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

28. (c)

29. (d) $E(eV) = \frac{h\nu}{e} = \frac{6.0 \times 10^{-34} \times 10^{12} \times 10^{6}}{1.6 \times 10^{-19}} = 4.14 \times 10^{3} eV$.

30. (c) $E = nh\nu \Rightarrow \nu \propto \frac{1}{n} \Rightarrow \frac{n_1}{n_2} = \frac{\gamma_2}{\gamma_1}$.

31. (c) According to Einstein's photoelectric equation.

32. (a) Kinetic energy of photoelectrons depends on the frequency of incident radiations and is independent of the intensity of illumination.

33. (e) In this case, for photoelectric emission the wavelength of incident radiations must be less then $5200 Å$. Wavelength of ultraviolet radiations is less then this value (5200 Å) but wavelength of infrared radiations is higher than this value.

34. (a) Frequency of light of wavelength $(\lambda = 4000\ Å)$ is $\nu = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{4000 \times 10^{-10}} = 0.75 \times 10^{15}$ which is less than the given threshold frequency. Hence no photoelectric emisssion takes place.

35. (d) Refer to the application of photo-cell.

36. (c) Albert Einstein was awarded Nobel Prize in 1921 for discovering the photoelectric effect.

37. (d)

38. (c) Energy of incident light $E(eV) = \frac{12375}{3320} = 3.72\,eV$

$(332\,nm = 3320\ Å)$

According to the relation $E = W_0 + eV_0$

$\Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{3.72\,eV - 1.07\,eV}{e} = 2.65\ Volt$

39. (d)

40. (b) $K_{max} = (h\nu - W_0)$; $\nu =$ frequency of incident light.

41. (a) Refer to threshold frequency.

42. (c) $W_0(eV) = \frac{12375}{\lambda_0} \Rightarrow \lambda_0 = \frac{12375}{4.2} \approx 2955\ Å$

43. (d) Intensity ∝ (No. of photons) ∝ (No. of photoelectrons)

44. (d) $E = W_0 + K_{max}$; $E = \frac{12375}{3000} = 4.125\ eV$

$\Rightarrow K_{max} = E - W_0 = 4.125\ eV - 1\ eV = 3.125\ eV$

$\Rightarrow \frac{1}{2} mv_{max}^2 = 3.125 \times 1.6 \times 10^{-19}\ J$

$\Rightarrow v_{max} = \sqrt{\frac{2 \times 3.125 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}} = 1 \times 10^{6} m/s$

45. (d) Retarding potential $V_0 = \frac{h}{e}(\nu - \nu_0)$

46. (c)

47. (c) $K_{max} = \frac{hc}{\lambda} - W_0 = \frac{6.4 \times 10^{-34} \times 3 \times 10^{8}}{6400 \times 10^{-10}} - 1.6 \times 10^{-19}$

$= 1.4 \times 10^{-19}\ J$

48. (b) $K_{max}(eV) = E(eV) - W_0(eV) = 6.2 - 4.2 = 2\ eV$

$\therefore\ K_{max}(Joules) = 2 \times 1.6 \times 10^{-19}\ J = 3.2 \times 10^{-19}\ J$

49. (c) Since $W_0 = \frac{hc}{\lambda_0}$; $\therefore \frac{(W_0)_T}{(W_0)_{Na}} = \frac{\lambda_{Na}}{\lambda_T}$ or

$\lambda_T = \frac{\lambda_{Na} \times (W_0)_{Na}}{(W_0)_T} = \frac{5460 \times 2.3}{4.5} = 2791\ Å$

50. (a) $K_{max} = (E - W_0) = (3.4 - 2)\ eV = 1.4\ eV$

51. (a) Energy of incident light $E = \frac{12375}{2000} = 6.18\,eV$

According to relation $E = W_0 + eV_0$

$\Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{(6.18\,eV - 5.01\,eV)}{e} = 1.17\ V \approx 1.2\ V$

52. (b) $W_0 = \frac{12375}{6600} = 1.87\,eV$.

53. (d)

54. (b) $E = h\nu = 6.64 \times 10^{-34} \times 1.0 \times 10^{14} = 6.62 \times 10^{-20}\ J$

55. (a) Number of photons emitted per second

$n = \frac{p}{h\nu} = \frac{10 \times 10^{3}}{6.6 \times 10^{-34} \times 880 \times 10^{3}} = 1.72 \times 10^{31}$

56. (d) Number of ejected electrons ∝ (Intensity) ∝ $\frac{1}{(\text{Distance})^2}$

Therefore an increment of distance two times will reduce the number of ejected electrons to $\frac{1}{4}th$ of the previous one.

57. (d) According to Einstein's photoelectric equation

$E = W_0 + K_{max} \Rightarrow V_0 = \frac{hc}{e}\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$

Hence if λ decreases V_0 increases.

58. (b) $W_0 = \frac{12375}{\lambda_0(Å)} = \frac{12375}{5420} = 2.28\,eV$

59. (b) Number of electrons can be measured which are directly proportional to the intensity of radiation.

60. (a) $K_{max} = h\nu - W_0 = 6.6 \times 10^{-34} \times 8 \times 10^{14} - 3.2 \times 10^{-19}$

$= 2.1 \times 10^{-19}\ J$

61. (c)

62. (b) $K_{max}(eV) = 12375\left[\frac{1}{\lambda(Å)} - \frac{1}{\lambda_0(Å)}\right]$

$= 12375\left[\frac{1}{1000} - \frac{1}{2000}\right] = 6.2\,eV$

63. (b) Stopping potential does not depend on the relative distance between the source and the cell.

64. (c)

65. (a) Energy of incident light $E(eV)=\frac{12375}{4000}=3.09\,eV$

Stopping potential is $-2V$ so $K_{max}=2\,eV$

Hence by using $E=W_0+K_{max}$; $W=1.09\,eV\approx 1.1\,eV$

66. (d) $\frac{hc}{\lambda}=W_0+\frac{1}{2}mv^2_{max}$

Assuming W_0 to be negligible in comparison to $\frac{hc}{\lambda}$

i.e. $v^2_{max}\propto\frac{1}{\lambda}\Rightarrow v_{max}\propto\frac{1}{\sqrt{\lambda}}$.

(On increasing wavelength λ to 4λ, v_{max} becomes half).

67. (d) $W_0=h\nu_0\Rightarrow\nu_0=\frac{W_0}{h}=\frac{2.51\times1.6\times10^{-19}}{6.6\times10^{-34}}$

$=6.08\times10^{14}\,Cycle/\sec$.

68. (c)

69. (b)

70. (a) By changing distance of source, photoelectric current changes. But there is no change in stopping potential.

71. (d) $\nu_0=\frac{W_0}{h}=\frac{3.3\times1.6\times10^{-19}}{6.6\times10^{-34}}=8\times10^{14}\,Hz$

72. (a) For no emission of photoelectron, energy of incident light < Work function $\Rightarrow h\nu<\phi\Rightarrow\nu<\frac{\phi}{h}$

73. (c) Number of electrons emitted $\propto$ intensity $\propto\frac{1}{(\text{distance})^2}$

$\Rightarrow\frac{n_1}{n_2}=\left(\frac{d_2}{d_1}\right)^2=\left(\frac{2}{1}\right)=4\Rightarrow n_2=\frac{n_1}{4}$

74. (c) $E=\frac{hc}{\lambda}-W_0$ and $2E=\frac{hc}{\lambda'}-W_0$

$\Rightarrow\frac{\lambda'}{\lambda}=\frac{E+W_0}{2E+W_0}\Rightarrow\lambda'=\lambda\left(\frac{1+W_0/E}{2+W_0/E}\right)$

Since $\frac{(1+W_0/E)}{(2+W_0/E)}>\frac{1}{2}$ so $\lambda'>\frac{\lambda}{2}$

75. (b) Stopping potential $V_0=\frac{hc}{e}\left[\frac{1}{\lambda}-\frac{1}{\lambda_0}\right]$. As λ decreases so V_0 increases.

76. (c) $W.(eV)=\frac{12375}{\lambda_0(Å)}\Rightarrow\lambda_0=\frac{12375}{4.125}=3000Å$

77. (a) Intensity increases means more photons of same energy will emit more electrons of same energy, hence only photoelectric current increases.

78. (a) $E=W_0+K_{max}$; $E=\frac{12375}{5000}=2.475\,eV$

$\therefore K_{max}=E-W_0=2.475-1.9=0.57\,eV$

79. (b)

80. (c) $\lambda_0=\frac{hc}{W_0}=\frac{12400}{4}=3100Å=310\,nm$

81. (b) $K_{max}=(|V_s|)eV\Rightarrow|V_s|=4V$

82. (d) Threshold wavelength $\lambda_0=\frac{12375}{2.1}=5892.8\,Å$

83. (c) $P=\frac{nhc}{\lambda t}\Rightarrow\frac{n}{t}=\frac{P.\lambda}{hc}=\frac{100\times5000\times10^{-10}}{6.6\times10^{-34}\times3\times10^8}$

$=2.50\times10^{20}$

84. (c) $E=W_0+K_{max}\Rightarrow K_{max}=E-W_0=h\nu-W_0$

$\Rightarrow K_1=h\nu-W_0$ and $K_2=2h\nu-W_0\Rightarrow K_2>2K_1$

85. (b) Work function $=\frac{hc}{\lambda_0}$; where λ_0 is threshold wavelength.

$\therefore\frac{W_{0_1}}{W_{0_2}}=\frac{\lambda_{0_2}}{\lambda_{0_1}}=\frac{2}{1}$

86. (c) $W_0=\frac{hc}{\lambda_0}=\frac{6.625\times10^{-34}\times3\times10^8}{5000\times10^{-10}}J=4\times10^{-19}J$

87. (a) The work function has no effect on current so long as $h\nu>W_0$. The photoelectric current is proportional to the intensity of light. Since there is no change in the intensity of light, therefore $I_1=I_2$.

88. (b) Number of photons emitted is proportional to the intensity.

Also $\frac{hc}{\lambda}=W_0+E$.

89. (c) Photoelectric current $\propto$ Intensity of light

90. (d) $V_0=\frac{(E-W_0)}{e}=\frac{(2eV-0.6\,eV)}{e}=1.4V$

91. (a) $\lambda_r>\lambda_y>\lambda_g$. Here threshold wavelength $<\lambda_y$.

92. (a) For electron emission $\lambda_{incident}<\lambda_0$

93. (a) $K_{max}=(|V_0|)eV=2eV$.

94. (b) Threshold wavelength for *Na*, $\lambda_{Na}=\frac{12375}{2}=6187.5Å$

Also $\lambda_{Cu}=\frac{12375}{4}=3093.75$

Since $\lambda_{Na}>4000Å$; So *Na* is suitable.

95. (c) By using $E=W_0+K_{max}$

$E=\frac{12375}{5000}=2.475\,eV$ and $K_{max}=eV_0=1.36\,eV$

So $2.475=W_0+1.36\Rightarrow W_0=1.1\,eV$.

96. (b) For emission of electrons incident energy of each photon must be greater than work function (threshold energy).

97. (d) K_{max} of photoelectrons doesn't depends upon intensity of incident light.

98. (a) By using $E=W_0+\frac{1}{2}mv^2_{max}$ where $E=\frac{12375}{2000}=6.18\,eV$

$\Rightarrow 6.18\,eV=4.2\,eV+\frac{1}{2}mv^2_{max}\Rightarrow 1.98\,eV=\frac{1}{2}mv^2_{max}$

$\Rightarrow 1.98\times1.6\times10^{-19}=\frac{1}{2}\times9.1\times10^{-31}\times v^2_{max}$

$\Rightarrow v_{max}=8.4\times10^5\,m/s$

99. (b) By using $E=W_0+\frac{1}{2}mv^2_{max}$; where $E=\frac{12375}{4558}=2.71\,eV$

$\Rightarrow 2.71\ eV = 2.5\ eV + \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow 0.21 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow v_{max} = 2.65 \times 10^5\ m/s$

100. (b) $E = W_0 + K_{max}$ .....(i)

$\Rightarrow hf = W_A + K_A$ .....(ii)

and $2hf = W_B + K_B = 2W_A + K_B$ $\left(\because \frac{W_A}{W_B} = \frac{1}{2}\right)$

Dividing equation (i) by (ii)

$\frac{1}{2} = \frac{W_A + K_A}{2W_A + K_B} \Rightarrow \frac{K_A}{K_B} = \frac{1}{2}$

101. (a)

102. (d) Stopping potential depends upon the energy of photon

103. (a) $\lambda_0 = \frac{12375}{W_0(eV)} = \frac{12375}{3} = 4125Å$

104. (b) With decrease in wavelength of incident photons, energy of photoelectrons increases.

105. (b)

106. (a) By using $\frac{hc}{\lambda} = W_0 + \frac{1}{2}mv^2$

$\Rightarrow \frac{hc}{400 \times 10^{-9}} = W_0 + \frac{1}{2}mv^2$ .....(i)

and $\frac{hc}{250 \times 10^{-9}} = W_0 + \frac{1}{2}m(2v)^2$ .....(ii)

On solving (i) and (ii)

$\frac{1}{2}mv^2 = \frac{hc}{3}\left[\frac{1}{250 \times 10^{-9}} - \frac{1}{400 \times 10^{-9}}\right]$ .....(iii)

From equation (i) and (iii) $W_0 = 2hc \times 10^6\ J$.

107. (a) $E = W_0 + eV_0 \Rightarrow 4eV = 2eV + eV_0 \Rightarrow V_0 = 2\ volt$

108. (b)

109. (a) $W_0 = \frac{12375}{6800} = 1.8eV$

110. (b) With the increase in intensity of light photoelectric current increases, but Kinetic energy of ejected electron, stopping potential and work function remains unchanged.

111. (c) $E = h\nu = 6.6 \times 10^{-34} \times 8 \times 10^{15} = 5.28 \times 10^{-18}\ J = 33eV$ By using $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0$

$= 33 - 6.125 = 27eV$

112. (b) $\lambda = \frac{12375}{W_0} = \frac{12375}{2} = 6187.5Å = 620\ nm$

113. (a) Minimum kinetic energy is always zero.

114. (c) Speed of photon is $3 \times 10^8\ m/s$ in vacuum.

115. (c) Minimum frequency : $W_0 = h\nu_0$

$\Rightarrow \nu_0 = \frac{W_0}{h} = \frac{1.65 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 4 \times 10^{14}\ Hz$

116. (b) By using $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0$

Hence, $K_1 = 1 - 0.5 = 0.5$

and $K_2 = 2.5 - 0.5 = 2 \Rightarrow \frac{K_1}{K_2} = \frac{1}{4}$.

117. (c) $W_0 \propto \frac{1}{\lambda} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{(W_0)_2}{(W_0)_1} = \frac{4.5}{2.3} = \frac{2}{1}$.

118. (d) $K_{max} = eV_0 \Rightarrow eV_0 = 4eV \Rightarrow V_0 = 4V$

119. (a) Number of photo electrons

$(N) \propto$ Intensity $\propto \frac{1}{d^2} \Rightarrow \frac{N_1}{N_2} = \left(\frac{d_2}{d_1}\right)^2$

$\Rightarrow \frac{N_1}{N_2} = \left(\frac{100}{50}\right)^2 = \frac{4}{1} \Rightarrow N_2 = \frac{N_1}{4}$.

120. (c) $P = \frac{W}{t} = \frac{nhc}{\lambda t} \Rightarrow 10^3 = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^8}{198.6 \times 1}$

$\Rightarrow n = 10^{30}$.

121. (c) $p = \frac{nhc}{\lambda t} \Rightarrow 100 = \frac{n \times 6 \times 10^{-34} \times 3 \times 10^8}{540 \times 10^{-9} \times 1} \Rightarrow n = 3 \times 10^{20}$

122. (c) $\frac{1}{2}mv_{max}^2 = eV_0 \Rightarrow v_{max} = \sqrt{2\left(\frac{e}{m}\right)V_0}$

$= \sqrt{2 \times 1.8 \times 10^{11} \times 9} = 1.8 \times 10^6\ m/s.$

123. (b) $\frac{hc}{\lambda} = W_0 + K_{max} \Rightarrow \frac{hc}{\lambda_A} = W_0 + K_A$ ...(i)

and $\frac{hc}{\lambda_B} = W_0 + K_B$ ...(ii)

Subtracting (i) from (ii), $hc\left[\frac{1}{\lambda_B} - \frac{1}{\lambda_A}\right] = K_B - K_A$

$\Rightarrow hc\left[\frac{1}{\lambda_B} - \frac{1}{2\lambda_B}\right] = K_B - K_A \Rightarrow \frac{hc}{2\lambda_B} = K_B - K_A$ ...(iii)

From (ii) and (iii), $2K_B - 2K_A = W_0 + K_B$

$\Rightarrow K_B - 2K_A = W_0$

$\Rightarrow K_A = \frac{K_B}{2} - \frac{W_0}{2}$ which gives $K_A < \frac{K_B}{2}$.

124. (a) $\lambda_0 = \frac{12375}{6500} = 1.9\ eV \approx 2eV$.

125. (a) $\lambda_{X-ray} < \lambda_{UV-ray}$

126. (a) $E = h\nu_0 + K_{max} \Rightarrow h(4\nu_0) = h\nu_0 + K_{max} \Rightarrow K_{max} = 3h\nu_0$.

127. (a)

128. (c) $W_0 = \frac{12375}{2.3} = 5380Å$.

129. (d)

130. (b) Using Einstein photoelectric equation $E = W_0 + K_{max}$

$hf_1 = W_0 + \frac{1}{2}mv_1^2$ .....(i)

$hf_2 = W_0 + \frac{1}{2}mv_2^2$ .....(ii)

$\Rightarrow h(f_1 - f_2) = \frac{1}{2}m(v_1^2 - v_2^2) \Rightarrow (v_1^2 - v_2^2) = \frac{2h}{m}(f_1 - f_2)$

131. (d)

132. (b) By using $\frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = V_0$

$\Rightarrow \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 4.8$ .....(i)

and $\frac{hc}{e}\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) = 1.6$ .....(ii)

From equation (i) by (ii), $\frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)}{\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right)} = \frac{4.8}{1.6} \Rightarrow \lambda_0 = 4\lambda$.

133. (c)

134. (d) $E = W_0 + K_{max}$. From the given data E is 6.78 eV (for λ= 1824 $Å$) or $10.17\, eV$ (for $\lambda = 1216$ $Å$)

$\therefore\ W_0 = E - K_{max} = 6.78 - 5.3 = 1.48\, eV$

or

$W_0 = 10.17 - 8.7 = 1.47\, eV$.

135. (c) $E = \frac{hc}{\lambda} \Rightarrow \frac{E_1}{E_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{3.32 \times 10^{-19}}{E_2} = \frac{4000}{6000}$

$\Rightarrow E_2 = 4.98 \times 10^{-19}\, J = 3.1\, eV$.

136. (c) Number of waves $= \frac{10^{-3}}{4000 \times 10^{-10}} = 0.25 \times 10^4$

137. (d) Velocity of photon $c = \nu\lambda$

138. (b) $\lambda_0 = \frac{12375}{6.825} = 1813\, Å \approx 1800 Å$

139. (c) Work function $W_0 = h\nu_0 = 6.6 \times 10^{-34} \times 1.6 \times 10^{15}$

$= 1.056 \times 10^{-18}\, J = 6.6\, eV$

From $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0 = 1.4\, eV$

140. (c) $P = \frac{h}{\lambda}, E = \frac{hc}{\lambda} \Rightarrow E = Pc.$

141. (a) $E = \frac{hc}{\lambda} \Rightarrow \frac{E_1}{E_2} = \frac{300}{150} = \frac{2}{1}$

142. (d)

143. (b) If frequency of incident light increases, kinetic energy of photoelectron also increases.

144. (d) Photoelectric effect can be explained on the basis of spectrum of an atom.

145. (b) $W_0 = \frac{12375}{\lambda_0} = \frac{12375}{5420} = 2.28\, eV$

146. (c)

147. (a) $E = \frac{12375}{\lambda} = \frac{12375}{5000} = 2.47\, eV \approx 2.5\, eV$

148. (a) Momentum $p = \frac{E}{c} \Rightarrow E^2 = p^2c^2$

149. (c) Energy of incident radiations (in eV) $= \frac{12375}{4100} = 3.01\, eV$

Work function of metal A and B are less then $3.01 eV$, so A and B will emit photo electrons.

150. (d) From $E = W_0 + \frac{1}{2}mv_{max}^2$

$\Rightarrow 2h\nu_0 = h\nu_0 + \frac{1}{2}mv_1^2 \Rightarrow h\nu_0 = \frac{1}{2}mv_1^2$ .....(i)

and $5h\nu_0 = h\nu_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\nu_0 = \frac{1}{2}mv_2^2$ .....(ii)

Dividing equation (ii) by (i) $\left(\frac{v_2}{v_1}\right)^2 = \frac{4}{1}$

$\Rightarrow v_2 = 2v_1 = 2 \times 4 \times 10^6 = 8 \times 10^6\, m/s$

151. (d) Number of photoelectrons $\propto \frac{1}{(\text{Distance})^2}$.

152. (b) The value of saturation current depends on intensity. It is independent of stopping potential

153. (a) In tungsten, photoemission take place with a light of wavelength 2300 $Å$. As emission of electron is inversely proportional to wavelength, all the wavelengths smaller then 2300 $Å$ will cause emission of electrons.

154. (c) Stopping potential = $1.8\, eV - 1.2\, eV = 0.6\, eV$.

155. (a)

156. (a) $K.E. = h\nu - h\nu_0 = 8\ eV - \left(\frac{6 \times 10^{-34} \times 1.6 \times 10^{15}}{1.6 \times 10^{-19}} eV\right)$

$= 8\ eV - 6\ eV = 2\ eV$

X-Rays

1. (c) $\lambda_{min} = \frac{12375}{50 \times 10^3} Å = 0.247 = 0.25\, Å$.

2. (c) X-rays are electromagnetic waves of wavelength ranging from 0.1 to $100\, Å$.

3. (a) Penetrating power is greater for lower wavelength.

4. (a)

5. (d) From the formula

$V = \frac{12375}{\lambda_{min}} = \frac{12375}{0.3094} = 39.99\ kV \approx 40\, kV$

6. (b) Refer to the application of X-rays.

7. (a)

8. (b)

9. (c)

10. (c) The voltage applied across the X-ray tube is of the range of 10 kV – 80 kV.

11. (c)

12. (b) In X-ray tube, target must be heavy element with high melting point.

13. (c) $\nu \propto (Z - b)^2 \Rightarrow \nu = a(Z - b)^2$

Z = atomic number of element (a, b are constant).

14. (c)

15. (b) *X*-rays and gamma rays are electromagnetic waves.

16. (c) Since $\lambda_{\min} = \frac{12375}{V} Å = \frac{12375}{10^5} Å = 0.123 Å$

$E_{\max} = \frac{hc}{\lambda_{\min}}$;

On putting the values. $E_{\max} \cong 10^{-1} MeV$.

17. (b) $\lambda_{\min} = \frac{hc}{eV}$. where *h*, *c* and *e* are constants. Hence $\lambda_{\min} \propto \frac{1}{V}$

18. (c) Range of *X*-rays is 0.1Å to 100 Å.

19. (d) The production of *X*-rays is an atomic property whereas the production of γ -rays is a nuclear property.

20. (a) $\lambda_{\min} = \frac{12375}{40,000} = 0.30 Å$ Hence wavelength less than 0.30 Å is not possible.

21. (a) $\lambda_{\min} = \frac{hc}{eV}$

22. (b) $p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{0.01 \times 10^{-10}} = 6.6 \times 10^{-22}\ kg\text{-}m/\sec$.

23. (a) *X*-rays are absorbed by the target; they are not reflected by the target.

24. (c)

25. (d)

26. (a)

27. (d)

28. (c)

29. (b) Continuous spectrum of *X*-rays consists of radiations of all possible wavelength range having a definite short wavelength limit.

30. (b) $\frac{E}{t} = P = \frac{h\nu}{t}$

i.e. Penetrating power $\propto$ energy $\propto$ Frequency

31. (c) In general *X*-rays have larger wavelength than that of gamma rays.

32. (c) According to Mosley's law $\nu = a(Z-b)^2$ and $\nu \propto \frac{1}{\lambda}$

33. (b) $E = h\nu = eV \Rightarrow \nu \propto V$

34. (c) $E = eV = h\nu_{\max} \Rightarrow \nu_{\max} = \frac{eV}{h}$

35. (c) $E = eV = h\nu_{\max} = \frac{hc}{\lambda_{\min}} \Rightarrow \lambda_{\min} = \frac{hc}{eV}$

36. (d) $\lambda_{\min} = \frac{hc}{eV}$ or $\lambda_{\min} \propto \frac{1}{V}$ On increasing potential, $\lambda_{\min}$ decreases.

37. (a) $h\nu_o = eV \therefore \nu_o = \frac{eV}{h} = \frac{1.6 \times 10^{-19} \times 42000}{6.63 \times 10^{-34}} = 10^{19}\ Hz$

38. (d) Nucleus of heavy atom captures electron of *k*-orbit. This is a radioactive process, so vacancy of this electron is filled by an outer electron and *x*-rays are produces.

39. (d) Because they are electromagnetic waves.

40. (c) $\nu_{\max} \propto \frac{1}{\lambda_{\min}}$ Hard *X*-rays have high frequency and low wavelength.

41. (d) X-rays are electromagnetic in nature so they remains unaffected in electric and magnetic field.

42. (b)

43. (c)

44. (b) *X*-rays have high energy. They penetrate into the solid crystal and used to find out the internal structure.

45. (a) By changing the filament current with the help of rheostat, thermionic emission intensity of *X*-rays can be changed.

46. (c) Applied voltage must be greater than binding energy.

47. (a)

48. (d) $\lambda = \frac{12375}{(40 \times 10^3)} = 0.309 Å \approx 0.31 Å$

49. (c)

50. (b) $\lambda_{\min} = \frac{hc}{eV} = \frac{12375}{V} Å = 0.495\ Å \approx 0.5\ Å$

51. (c) $\lambda_{\min} = \frac{hc}{eV} = \frac{12375}{V} Å;\ \therefore\ V = \frac{12375}{\lambda \text{ in } Å} = 124\ kV$

52. (a) Mosley's law is $f = a(Z-b)^2$

53. (b) The potential difference across the filament and target determines the energy and thence the penetrating power of *X*-rays.

54. (d) The energy of *X*-ray photon obtained from a coolidge tube by an electronic transition of target atom such as K_α line is obtained from transition from *L* orbit in *K* orbit.

55. (b) $\lambda_{\min} = \frac{12375}{V} = \frac{12375}{30 \times 10^3} = 0.4 Å$

56. (d) $\lambda_{\min} = \frac{12375}{100 \times 10^3} Å = 0.124\ Å$

57. (d) $\lambda_{\min} = \frac{12375}{50000} = 0.025\ nm$

58. (c)

59. (a) Refer theory

60. (a) With the increase in potential difference between anode and cathode energy of striking electrons increases which in turn increases the energy (penetration power) of X-rays.

61. (a)

62. (b)

63. (b) The wavelength range of *X*-ray is 0.1 Å – 100 Å.

64. (b) Energy $E = h\nu = h\frac{c}{\lambda}\ \therefore\ \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{5000}{1}$

65. (b)

66. (a) Interatomic spacing in a crystal acts as a diffraction grating.

67. (b) The wavelength of the γ-rays is shorter. However the main distinguishing feature is the nature of emission.

68. (d) $h\nu_{\max} = eV \Rightarrow \frac{hc}{\lambda_{\min}} = eV\ \therefore \lambda_{\min} \propto \frac{1}{V}$

69. (d) Hard X-rays are of higher energy and the energy of X-rays depends on the potential difference between the cathode and the target.

70. (d) Penetration is directly proportional to the energy of radiations.

71. (d) Greater the number of electrons striking the anode, larger is the number of X-ray photons emitted.

72. (a) $\lambda_{\min} = \frac{12375}{V} \mathring{A} \Rightarrow V = \frac{12375}{1} = 12375\, V$

$= 12.375\, kV \approx 12.42\, kV$

73. (c)

74. (c)

75. (c) $E(eV) = \frac{12375}{1.65} = 7500 eV = 7.5\ keV$.

76. (d)

77. (b)

78. (a) $\lambda_{\min} = \frac{12375}{40} \mathring{A} = 3.09 \times 10^{-8} m$

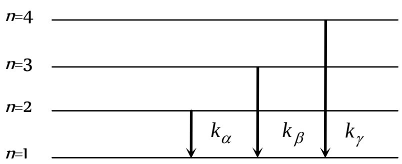
79. (d) Target should be of high atomic number and high melting point

80. (a) Intensity of X-rays depends upon the number of electron striking the target.

81. (b) $E(eV) = \frac{hc}{e\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 1 \times 10^{-10}} = 12375\, eV$

82. (c) When applied voltage is greater then energy of K-electron, continuous and all characterstic X-rays are emitted.

83. (c)



84. (d) When current through the filament increases, number of emitted electrons also increases. Hence intensity of X-ray increases but no effect on penetration power.

85. (a) $i = \frac{Ne}{t} \Rightarrow \frac{N}{t} = \frac{i}{e} = \frac{3.2 \times 10^{-3}}{1.6 \times 10^{-19}} = 2 \times 10^{16}\ / sec$

86. (d)

87. (a) Because X-rays are electromagnetic (Neutral) in nature.

88. (d) $\lambda_{\min} = \frac{hc}{eV} = \frac{6.6 \times^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} V} = \frac{12375}{V} \approx \frac{12400}{V} \mathring{A}$

89. (c) Frequency of hard X-rays is greater than that of soft X-rays.

90. (b)

91. (a) $\lambda_{\min} = \frac{12375}{V} \mathring{A} \Rightarrow V = \frac{12375}{0.4125} = 30\, kV$

92. (b)

93. (d)

94. (a) $\lambda_{\min} = \frac{12375}{40 \times 10^{3}} = 0.309\, \mathring{A} \approx 0.31\, \mathring{A}$

95. (d) $\lambda_{\min} = \frac{hc}{eV} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 100 \times 10^{3}} = 0.123 \mathring{A}$

96. (d) According to Mosley's law $\nu \propto (Z - b)^2$

For k_α line, $b = 1$, and it has maximum frequency so $\nu_{\max} \propto (Z-1)^2$

97. (b) The velocity of X-rays is always equal to that of light.

98. (b)

99. (d) $\lambda_{\min} = \frac{12375}{V} \mathring{A} \Rightarrow V = \frac{12375}{2.5} = 4950\ V \simeq 5\ kV.$

100. (c) $\lambda_{\min} = \frac{hc}{eV(\text{energy})}$; when KE (or eV) increases, λ decreases.

101. (c)

102. (b) When a high energy electron incident on heavy metal, it produces X-rays.

103. (b) $\nu = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{1 \times 10^{-10}} = 3 \times 10^{18}\, Hz$

104. (b) $\lambda \propto \frac{1}{Z^2} \Rightarrow \frac{c}{\nu} \propto \frac{1}{Z^2} \Rightarrow \nu \propto Z^2$

105. (d)

106. (a) $eV = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.5 \times 10^{-10}}$

$\Rightarrow V = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 1.5 \times 10^{-10}} = 8280\ Volt.$

107. (d)

108. (d)

109. (b) Required ionisation energy

$= \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.54 \times 10^{-10}} J = 12.9 \times 10^{-16} J$

110. (c) $\lambda \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_2}{\lambda_1} = \left(\frac{Z_1 - 1}{Z_2 - 1}\right)^2$

$\Rightarrow \frac{\lambda_2}{\lambda} = \left(\frac{43-1}{29-1}\right)^2 = \left(\frac{42}{28}\right)^2 \Rightarrow \lambda_2 = \frac{9}{4}\lambda.$

111. (a)

Critical Thinking Questions

1. (b) For one second, distance = Velocity $= 3 \times 10^4 m/\text{sec}$ and $Q = i \times 1 = 10^{-6} C$. Charge density $= \frac{\text{Charge}}{\text{Volume}}$

$= \frac{10^{-6}}{3 \times 10^{4} \times 0.5 \times 10^{-6}} = 6.6 \times 10^{-5} C/m^3.$

2. (c) By law of conservation of momentum

$0 = m_1 \vec{v_1} + m_2 \vec{v_2} \Rightarrow m_1 \vec{v_1} = -m_2 \vec{v_2}$

– *ve* sign indicates that both he particles are moving in opposite direction. Now de-Broglie wavelengths

$\lambda_1 = \frac{h}{m_1 v_1}$ and $\lambda_2 = \frac{h}{m_2 v_2}$; $\therefore \frac{\lambda_1}{\lambda_2} = \frac{m_2 v_2}{m_1 v_1} = 1$

3. (b) $\lambda_{\text{photon}} = \frac{hc}{E}$ and $\lambda_{\text{proton}} = \frac{h}{\sqrt{2mE}}$

$$\Rightarrow \frac{\lambda_{\text{photon}}}{\lambda_{\text{electron}}} = c\sqrt{\frac{2m}{E}} \Rightarrow \frac{\lambda_{\text{photon}}}{\lambda_{\text{electron}}} \propto \frac{1}{\sqrt{E}}$$

4. (a,b,c) $K_{max} = E - W_0$

$\therefore T_A = 4.25 - (W_0)_A$ ...(i)

$T_B = (T_A - 1.5) = 4.70 - (W_0)_B$ ...(ii)

Equation (i) and (ii) gives $(W_0)_B - (W_0)_A = 1.95\ eV$

De Broglie wave length $\lambda = \frac{h}{\sqrt{2mK}} \Rightarrow \lambda \propto \frac{1}{\sqrt{K}}$

$$\Rightarrow \frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}} \Rightarrow 2 = \sqrt{\frac{T_A}{T_A - 1.5}} \Rightarrow T_A = 2eV$$

From equation (i) and (iii)

$W_A = 2.25\ eV$ and $W_B = 4.20\ eV$.

5. (d)

6. (b) In the presence of inert gas photoelectrons emitted by cathode ionise the gas by collision and hence the current increases.

7. (b) For electron and positron pair production, minimum energy is 1.02 MeV.

Energy of photon is given $1.7 \times 10^{-13} J = \frac{1.7 \times 10^{-13}}{1.6 \times 10^{-19}}$

$= 1.06\ MeV$.

Since energy of photon is greater than 1.02 MeV,

So electron, positron pair will be created.

8. (c) According to Einstein's photoelectric equation

$$\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^2 \Rightarrow v = \left[\frac{2(hc - \lambda\phi)}{m\lambda}\right]^{1/2}$$

9. (b) Cut off voltage is independent of intensity and hence remains the same. Since distance becomes 3 times, so intensity (I) becomes $\frac{I}{9}$. Hence photo current also decreases by this factor *i.e.* becomes $\frac{18}{9} = 2mA$.

10. (d) $h\nu - W_0 = \frac{1}{2}mv_{\max}^2 \Rightarrow \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{1}{2}mv_{\max}^2$

$$\Rightarrow hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right) = \frac{1}{2}mv_{\max}^2 \Rightarrow v_{\max} = \sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$$

When wavelength is λ and velocity is v, then

$$v = \sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)} \quad \text{.... (i)}$$

When wavelength is $\frac{3\lambda}{4}$ and velocity is v' then

$$v' = \sqrt{\frac{2hc}{m}\left[\frac{\lambda_0 - (3\lambda/4)}{(3\lambda/4) \times \lambda_0}\right]} \quad \text{....(ii)}$$

Divide equation (ii) by (i), we get

$$\frac{v'}{v} = \sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\frac{3}{4}\lambda\lambda_0} \times \frac{\lambda\lambda_0}{\lambda_0 - \lambda}}$$

$$v' = v\left(\frac{4}{3}\right)^{1/2}\sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\lambda_0 - \lambda}} \quad \textit{i.e. } v' > v\left(\frac{4}{3}\right)^{1/2}$$

11. (c) Intensity of light

$I = \frac{Watt}{Area} = \frac{nhc}{A\lambda} \Rightarrow$ Number of photon $n = \frac{IA\lambda}{hc}$

$\therefore$ Number of photo electron $= \frac{1}{100} \times \frac{IA\lambda}{hc}$

$$= \frac{1}{100} \frac{1 \times 10^{-4} \times 300 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 1.5 \times 10^{12}$$

12. (b) By using $h\nu - h\nu_0 = K_{\max}$

$\Rightarrow h(\nu_1 - \nu_0) = K_1$ ....(i)

And $h(\nu_2 - \nu_0) = K_2$ ....(ii)

$\Rightarrow \frac{\nu_1 - \nu_0}{\nu_2 - \nu_0} = \frac{K_1}{K_2} = \frac{1}{K}$, Hence $\nu_0 = \frac{K\nu_1 - \nu_2}{K - 1}$.

13. (b) $E = W_0 + eV_0$

For hydrogen atom, $E = +13.6\,eV$

$\therefore +13.6 = 4.2 + eV_0$

$\Rightarrow V_0 = \frac{(13.6 - 4.2)eV}{e} = 9.4\ V$

Potential at anode $= -9.4\ V$

14. (a) From $\lambda_0 = \frac{12375}{W_0}$

The maximum wavelength of light required for the photoelectron emission, $(\lambda_0)_{Li} = \frac{12375}{2.3} = 5380\text{Å}$.

Similarly $(\lambda_0)_{Cu} = \frac{12375}{4} = 3094$ Å.

Since the wavelength 3094 Å does not in the visible region, but it is in the ultraviolet region. Hence to work with visible light, lithium metal will be used for photoelectric cell.

15. (a) Direction of scattered photon $\cos\phi = 1 - \frac{\Delta\lambda m_e c}{h}$

Here $\Delta\lambda = 0.011\ \text{Å}$

$$\therefore \cos\phi = 1 - \frac{0.011 \times 10^{-10} \times 9.1 \times 10^{-31} \times 3 \times 10^8}{6.624 \times 10^{-34}}$$

$$= 1 - 0.453 = 0.547$$

$\therefore \phi = \cos^{-1}(0.547)$

16. (d) Bragg's law, $2d\sin\theta = n\lambda$ or $\lambda = \frac{2d\sin\theta}{n}$

For maximum wavelength, $n_{\min} = 1$, $(\sin\theta)_{\max} = 1$

$\therefore \lambda_{\max} = 2d$ or $\lambda_{\max} = 2 \times 10^{-7}\,cm = 20\ \text{Å}$

17. (a,c,d) $P = VI = 50 \times 10^3 \times 20 \times 10^{-3} = 1000\ W$

Power converted into heat = 990 W

$ms\Delta T = 990 \Rightarrow \Delta T = 2^o\,C/\sec$

Now $\frac{hc}{\lambda_{\min}} = eV \Rightarrow \lambda_{\min} = \frac{hc}{eV} = 0.248 \times 10^{-10}\,m$

18. (c) The wavelength of X-ray lines is given by Rydberg

Formula $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K_α line, $n_1 = 1$ and $n_2 = 2$

$$\therefore \frac{1}{\lambda} = RZ^2\left(\frac{3}{4}\right) \Rightarrow Z = \left(\frac{4}{3R\lambda}\right)^{1/2}$$

$$= \left[\frac{4}{3(1.097\times10^7 m^{-1})(0.76\times10^{-10} m)}\right]^{1/2} = 39.99 \approx 40$$

19. (b) If intensity of *X*-ray is decreased by *dI*, when it passes through a length *dx* of absorbing material then, the amount of observed intensity is $\mu I\, dx$.

Thus, $-dI = \mu I\, dx$ or $\frac{dI}{dx} + \mu I = 0$

On solving this equation $I = I_0 e^{\mu x} = I_0 e^{\mu d}$ $(x = d)$

20. (c) $E_K - E_L = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})\,(3\times10^8)}{(0.021\times10^{-9})\,(1.6\times10^{-19})} eV = 59 keV$

21. (d) Minimum wavelength of continuous *X*-ray spectrum is given by

$$\lambda_{min}(\text{in Å}) = \frac{12375}{E(eV)} = \frac{12375}{80\times10^3} \approx 0.155$$

Also the energy of the incident electrons (80 *KeV*) is more than the ionization energy of the *K*-shell electrons (*i.e.* 72.5 *KeV*). Therefore characteristic *X*-ray spectrum will also be obtained because energy of incident electron is enough to knock out the electron from *K* or *L* shells.

22. (a) The wave length of L_α line is given by

$$\frac{1}{\lambda} = R(z-7.4)^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \lambda \propto \frac{1}{(Z-7.4)^2}$$

$$\Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{(z_2-7.4)^2}{(z_1-7.4)^2} \Rightarrow \frac{1.30}{\lambda_2} = \frac{(42-7.4)^2}{(78-7.4)^2} \Rightarrow \lambda_2 = 5.41 Å$$

23. (c) de-Broglie wavelength $\lambda = \frac{h}{mv_{rms}}$, *rms* velocity of a gas particle at the given temperature (*T*) is given as

$$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT \Rightarrow v_{rms} = \sqrt{\frac{3kT}{m}} \Rightarrow mv_{rms} = \sqrt{3mk\,T}$$

$$\therefore \lambda = \frac{h}{mv_{rms}} = \frac{h}{\sqrt{3mkT}}$$

$$\Rightarrow \frac{\lambda_H}{\lambda_{He}} = \sqrt{\frac{m_{He}T_{He}}{m_H T_H}} = \sqrt{\frac{4(273+127)}{2(273+27)}} = \sqrt{\frac{8}{3}}$$

24. (c) $n = \frac{E\lambda}{hc} = \frac{1\times10^{-7}\times200\times10^{-9}}{6.6\times10^{-34}\times3\times10^8} = 1\times10^{11}$

Number of electrons ejected $= \frac{10^{11}}{10^3} = 10^8$

$$\therefore V = \frac{q}{4\pi\varepsilon_0 r} = \frac{(10^8\times1.6\times10^{-19})\times9\times10^9}{4.8\times10^{-2}} = 3\,V$$

25. (b) The momentum of the incident radiation is given as $p = \frac{h}{\lambda}$.

When the light is totally reflected normal to the surface the direction of the ray is reversed. That means it reverses the direction of it's momentum without changing it's magnitude

$$\therefore \Delta p = 2p = \frac{2h}{\lambda} = \frac{2\times6.6\times10^{-34}}{6630\times10^{-10}} = 2\times10^{-27}\ kg\text{-}m/sec.$$

26. (c) When a charged particle (charge *q*, mass *m*) enters perpendicularly in a magnetic field (*B*) than, radius of the path described by it $r = \frac{mv}{qB} \Rightarrow mv = qBr$.

Also de-Broglie wavelength $\lambda = \frac{h}{mv}$

$$\Rightarrow \lambda = \frac{h}{qBr} \Rightarrow \frac{\lambda_\alpha}{\lambda_p} = \frac{q_p r_p}{q_\alpha r_\alpha} = \frac{1}{2}$$

27. (a) $\sqrt{f_1} = \sqrt{\frac{v}{\lambda_1}} = a(11-1)$ and $\sqrt{f_2} = \sqrt{\frac{v}{\lambda_2}} = a(Z-1)$

By dividing, $\sqrt{\frac{\lambda_2}{\lambda_1}} = \frac{10}{Z-1} \Rightarrow \sqrt{\frac{4}{1}} = \frac{10}{Z-1} \Rightarrow Z = 6$

28. (c) $K.E. = 2E_0 - E_0 = E_0$ (for $0 \le x \le 1$) $\Rightarrow \lambda_1 = \frac{h}{\sqrt{2mE_0}}$

$K.E. = 2E_0$ (for $x > 1$) $\Rightarrow \lambda_2 = \frac{h}{\sqrt{4mE_0}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{2}$.

29. (b) Given $m_0c^2 = 0.51\ MeV$ and $v = 0.8\,c$

K.E. of the electron $= mc^2 - m_0c^2$

$$\text{But } m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1-\left(\frac{0.8\,c}{c}\right)^2}} = \frac{m_0}{\sqrt{0.36}} = \frac{m_0}{0.6}$$

Now, $mc^2 = \frac{0.51}{0.6}\ MeV = 0.85\ MeV$

$\therefore$ *K.E.* = (0.85 – 0.51)*MeV* = 0.34 *MeV*.

30. (a) The deflection suffered by charged particle in an electric field is

$$y = \frac{q\,ELD}{mu^2} = \frac{q\,ELD}{p^2/m} \qquad (p = mu)$$

$$\Rightarrow y \propto \frac{qm}{p^2} \Rightarrow y_p : y_d : y_\alpha = \frac{q_p m_p}{p_p^2} : \frac{q_d m_d}{p_d^2} : \frac{q_\alpha m_\alpha}{p_\alpha^2}$$

Since $p_\alpha = p_d = p_p$ (given)

$m_p : m_d : m_\alpha = 1 : 2 : 4$ and $q_p : q_d : q_\alpha = 1 : 1 : 2$

$\Rightarrow y_p : y_d : y_\alpha = 1\times1 : 1\times2 : 2\times4 = 1 : 2 : 8$

31. (c) Using $Z^2 = k\left(\frac{q}{m}\right)y$; where $k = \frac{B^2LD}{E}$. For parabolas to coincide in the two photographs, the $\frac{kq}{m}$ should be same for the two cases. Thus, $\frac{B_1^2\,LDe}{E_1m_1} = \frac{B_2^2LD(2e)}{E_2m_2}$

$$\Rightarrow \frac{m_1}{m_2} = \left(\frac{B_1}{B_2}\right)^2 \times \left(\frac{E_2}{E_1}\right) \times \frac{1}{2} = \frac{9}{4} \times \frac{2}{1} \times \frac{1}{2} = \frac{9}{4}$$

32. (c) According to the energy diagram of *X*-ray spectra

$$\because \Delta E = \frac{hc}{\lambda} \Rightarrow \lambda \propto \frac{1}{\Delta E}$$

(ΔE = Energy radiated when *e* jumps from, higher energy orbit to lower energy orbit)

$\because (\Delta E)_{k_\beta} > (\Delta E)_{k_\alpha} > (\Delta E)_{L_\alpha} \therefore \lambda'_\alpha > \lambda_\alpha > \lambda_\beta$

Also $(\Delta E)_{k_\beta} = (\Delta E)_{k_\alpha} + (\Delta E)_{L_\alpha}$

$$\Rightarrow \frac{hc}{\lambda_\beta} = \frac{hc}{\lambda_\alpha} + \frac{hc}{\lambda'_\alpha} \Rightarrow \frac{1}{\lambda_\beta} = \frac{1}{\lambda_\alpha} + \frac{1}{\lambda'_\alpha}$$

33. (c) By using $I = \frac{P}{A}$; where P = radiation power

$$\Rightarrow P = I \times A \Rightarrow \frac{nhc}{t\lambda} = IA \Rightarrow \frac{n}{t} = \frac{IA\lambda}{hc}$$

Hence number of photons entering per sec the eye $\left(\frac{n}{t}\right) = \frac{10^{-10} \times 10^{-6} \times 5.6 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$ = 300.

34. (d) $\Delta\lambda = \lambda_{K_\alpha} - \lambda_{\min}$ When V is halved $\lambda_{\min}$ becomes two times but λ_{K_α} remains the same.

$\therefore \quad \Delta\lambda' = \lambda_{K_\alpha} - 2\lambda_{\min} = 2(\Delta\lambda) - \lambda_{K_\alpha}$

$\therefore \quad \Delta\lambda' < 2(\Delta\lambda)$

35. (b) Energy of photons corresponding to light of wave length λ_1 = 2475 Å is $E_1 = \frac{12375}{2475} = 5\,eV$.

and that corresponding to λ_2 = 6000 Å is

$$E_2 = \frac{12375}{6000} = 2.06\,eV$$

As $E_1 < W_0$ and $E_2 > W_0$

Photoelectric emission is possible with λ_2 only. Maximum kinetic energy of emitted photoelectrons $K = E - W_0$ = 5 – 4.8 = 0.2 eV.

Photo electrons experiences magnetic force and move along a circular path of radius

$$r = \frac{\sqrt{2mk}}{QB} = \frac{\sqrt{2 \times 9 \times 10^{-31} \times 0.2 \times 1.6 \times 10^{-19}}}{1.6 \times 10^{-19} \times 3 \times 10^{-5}}$$

= 0.05 m = 5 cm.

36. (a) Number of photoelectrons emitted up to t = 10 sec are

$$n = \frac{(\text{Number of photons per unit area per unit time}) \times (\text{Area} \times \text{Time})}{10^6}$$

$$= \frac{1}{10^6}[(10)^{16} \times (5 \times 10^{-4}) \times (10)] = 5 \times 10^7$$

At time t = 10 sec

Charge on plate A ; $q_A = +ne$ = 5 × 10^7 × 1.6 × 10^{-19}

= 8 × 10^{-12} C = 8 pC

and charge on plate B ; q_B = 33.7 – 8 = 25.7 pc

Electric field between the plates

$$E = \frac{(q_B - q_A)}{2\varepsilon_0 A} = \frac{(25.7 - 8) \times 10^{-12}}{2 \times 8.85 \times 10^{-12} \times 5 \times 10^{-4}} = 2 \times 10^3 \frac{N}{C}.$$

37. (a) As we know in Young's double slit experiment fringe width = separation between two consecutive fringe or dark fringes $= \beta = \frac{\lambda D}{d}$

Here $\beta = 2y \Rightarrow 2y = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{2yd}{D}$

$$\Rightarrow \lambda = \frac{2 \times 1 \times 10^{-3} \times 0.24 \times 10^{-3}}{1.2} = 4 \times 10^{-7} m = 4000\,Å$$

Energy of light incident on photo plate

$$E(eV) = \frac{12375}{4000} = 3.1\,eV$$

According to Eienstein photoelectric equation

$$E = W_0 + eV_0 \Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{(3 + 2.2)}{e} eV \approx 0.9\,V$$

38. (a) $E = \frac{12375}{5000} = 2.475\,eV \approx 4 \times 10^{-19}\,J$

So the minimum intensity to which the eye can respond

I_{Eye} = (Photon flux) × (Energy of a photon)

$\Rightarrow I_{Eye} = (5 \times 10^4) \times (4 \times 10^{-19}) \simeq 2 \times 10^{-14}\,(W/m^2)$

Now as lesser the intensity required by a detector for detection, more sensitive it will be

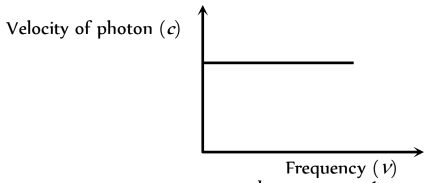
$\frac{S_{Eye}}{S_{Ear}} = \frac{I_{Ear}}{I_{Eye}} = \frac{10^{-13}}{2 \times 10^{-14}} = 5$ *i.e.* as intensity (power) detector, the eye is five times more sensitive than ear.

39. (c) Due to 10.2 eV photon one photon of energy 10.2 eV will be detected.

Due to 15 eV photon the electron will come out of the atom with energy (15 - 13.6) = 1.4 eV.

Graphical Questions

1. (a) Velocity of photon (*i.e.* light) does not depend upon frequency. Hence the graph between velocity of photon and frequency will be as follows



2. (d) De-Broglie wavelength $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

i.e. graph will be a rectangular hyperbola.

3. (a) The stopping potential for curves a and b is same.

$\therefore \quad f_a = f_b$

Also saturation current is proportional to intensity

$\therefore \quad I_a < I_b$

4. (d) According to Einstein equation

$h\nu = h\nu_0 + K_{\max} \Rightarrow K_{\max} = h\nu - h\nu_0$ on comparing it with $y = mx + c$, it is clear to say that,

This is the equation of straight line having positive slope (h) and negative intercept ($h\nu_0$) on KE axis.

5. (c) Comparing Einstein's equation

$K_{\max} = h\nu - h\nu_0$, with $y = mx + c$, we get slope, $m = h$

6. (b) $K_{max} = h\nu - h\nu_0 \Rightarrow eV_0 = h\nu - h\nu_0 \Rightarrow V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$

Comparing this equation with $y = mx + c$, we get slope $m = \frac{h}{e} \Rightarrow h = m \times e$.

7. (a) Using Einstein's equation, $V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$

Comparing this equation with $y = mx + c$

We get intercept on $-V$ axis $= \frac{W_0}{e}$

$\Rightarrow OB = \frac{W_0}{e} \Rightarrow W_0 = OB \times e$

8. (b) From the given graph it is clear that if we extend the given graph for *A* and *B*, intercept of the line *A* on *V* axis will be smaller as compared to line *B* means work function of *A* is smaller than that of *B*.

9. (a) Wavelength λ_k is independent of the accelerating voltage (V), while the minimum wavelength λ_c is inversely proportional to V. Therefore as V increases, λ_k remains unchanged whereas λ_c decreases or $\lambda_k - \lambda_c$ will increase.

10. (c) In *X*-ray spectra, depending on the accelerating voltage and the target element, we may find sharp peaks super imposed on continuous spectrum. These are at different wavelengths for different elements. They form characteristic *X*-ray spectrum.

11. (b) Photo current (i) directly proportional to light intensity (I) falling on a photosensitive plate. $\Rightarrow i \propto I$

12. (d) According to Einstein's equation

$h\nu = W_0 + K_{max} \Rightarrow V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$

This is the equation of straight line having positive slope (h/e) and intercept on $-V_0$ axis, equals to $\frac{W_0}{e}$

13. (d) In photocell, at a particular negative potential (stopping potential V) of anode, photoelectric current is zero,

At the potential difference between cathode and anode increases current through the circuit increases but after some time constant current (saturation current) flows through the circuit even if potential difference still increasing.

14. (b) Stopping potential does not depend upon intensity of incident light (I).

15. (a) Stopping potential is that negative potential for which photo electric current is zero.

16. (d) $\because V_0 = \left(\frac{h}{e}\right)\nu - \left(\frac{W_0}{e}\right)$. From the graph $V_2 > V_1$

$\Rightarrow \frac{h\nu_2}{e} - \frac{W_0}{e} > \frac{h\nu_1}{e} - \frac{W_0}{e} \Rightarrow \nu_2 > \nu_1$

$\Rightarrow \lambda_1 > \lambda_2$ (as $\lambda \propto \frac{1}{\nu}$)

17. (d) $I \propto \frac{1}{d^2}$ and photo current $i \propto I \Rightarrow i \propto \frac{1}{d^2}$

18. (a) $h\nu = h\nu_0 + KE_{max} \Rightarrow KE_{max} = h\nu - h\nu_0$

On comparing this equation with $y = mx + c$ we get

$m = h =$ Universal constant

19. (b) $\lambda_0 = \frac{c}{\nu_0} = \frac{3 \times 10^8}{5 \times 10^{14}} = 6 \times 10^{-7} m = 6000\ Å$

20. (c) Work function is the intercept on *K.E.* axis *i.e.* $2eV$.

21. (b) From the graph stopping potential $|V| = -V$

Also $k_{max} = (|V|)eV = 4eV$.

22. (c) By Moseley's law, $\sqrt{\nu} = a(Z - b)$ or, $\nu = a^2(Z - b)^2$

Comparing with the equation of a parabola, $y^2 = 4ax$ it conforms to graph *c*.

23. (a) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \lambda \propto \frac{1}{V}$

$\because \lambda_2 > \lambda_1$ (see graph) $\Rightarrow V_1 > V_2$

$\sqrt{\nu} = a(Z - b)$ Moseley's law

$\nu \propto (Z-1)^2 \Rightarrow \lambda \propto \frac{1}{(Z-1)^2}$ $\left(\because \nu \propto \frac{1}{\lambda}\right)$

$\lambda_1 > \lambda_2$ (see graph for characteristic lines) $\Rightarrow Z_2 > Z_1$.

24. (a) $K_{max} = h\nu - h\nu_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$ *i.e.* graph between K_{max} and $\frac{1}{\lambda}$ will be straight line having slope (hc) and intercept $\frac{hc}{\lambda_0}$ on $-KE$ axis.

25. (a) ν varies from 0 to ν_{max}.

26. (a) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \log.\lambda_{min} = \log\frac{hc}{e} - \log V$

$\Rightarrow \log\lambda_{min} = -\log V + \log\frac{hc}{e}$

This is the equation of straight line having slope (–1) and intercept $\log\frac{hc}{e}$ on $+\log_e \lambda_{min}$ axis.

27. (c) For K_α line $\nu \propto (Z-1)^2 \Rightarrow \lambda \propto \frac{1}{(Z-1)^2}$

i.e. the graph between λ and z will be (c).

28. (b) Slope of $V_0 - \nu$ curve $= \frac{h}{e}$

$\Rightarrow h = \text{Slope} \times e = 1.6 \times 10^{-19} \times 4.12 \times 10^{-15}$

$= 6.6 \times 10^{-34}$ *J*-sec.

29. (b) $I_1 > I_2$ (given) $\Rightarrow i_1 > i_2$ $(\because i \propto I)$

and stopping potential does not depend upon intensity. So its value will be same (V_0).

30. (c) Slope of $V_0 - \nu$ curve for all metals be same $\left(\frac{h}{e}\right)$ *i.e.* curves should be parallel.

31. (c) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m}} \cdot \frac{1}{\sqrt{E}}$. Taking log of both sides

$\log\lambda = \log\frac{h}{\sqrt{2m}} + \log\frac{1}{\sqrt{E}} \Rightarrow \log\lambda = \log\frac{h}{\sqrt{2m}} - \frac{1}{2}\log E$

$\Rightarrow \log\lambda = -\frac{1}{2}\log E + \log\frac{h}{\sqrt{2m}}$

This is the equation of straight line having slope (–1/2) and positive intercept on log λ axis.

32. (b) $\sqrt{\nu} \propto (Z-b)$

33. (b) Peak of K_α is greater than peak of K_β line.

34. (a) $|-4V| > |-2V|$

35. (a) $\because x \propto \frac{1}{v^2}$. The ion whose deflection is less, its velocity will be more. From the curve $x_1 < x_2 < x_3 < x_4$, therefore $v_1 > v_2 > v_3 > v_4$.

36. (a) All the positive ions of same specific charge moving with different velocity lie on the same parabola.

37. (b) The equation of curve between V and ν is $\frac{h\nu}{e} - \frac{h\nu_0}{e} = V_0$.

This is equation of a straight line with slope $= \frac{h}{e}$.

38. (b) Stopping potential equals to maximum kinetic energy.
Since stopping potential is varying linearly with the frequency. There fore max. *KE* for both the metals also vary linearly with frequency.

Assertion and Reason

1. (a) Momentum of a photon is given by $p = \frac{h}{\lambda}$

Also the photon is a form of energy packets behaves as a particle having energy $E = \frac{hc}{\lambda}$. So $p = \frac{E}{c}$

2. (d) Photoelectric effect demonstrates the particle nature of light. Number of emitted photoelectrons depends upon the intensity of light.

3. (b) Charge does not change with speed but mass varies with the speed as per relation $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$. Hence specific charge

e/m decreases with increase in speed.

4. (a) X-rays lies in electromagnetic spectrum.

5. (b) Mass of moving photon $m = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$ and $E = mc^2$.

6. (d) According Einstein equation $KE = h\nu - h\nu_0$; *i.e., KE* depends upon the frequency. Photoelectron emitted only if incident frequency more than threshold frequency.

7. (e) The atomic number (number of electrons or protons) remains same in isotope. Isotope of an element can be separated on account of their different atomic weight by using mass spectrograph.

8. (b) The specific charge (e/m) of the positive rays is not universal constant because these rays may consists of ions of different element.

9. (b) Less work function means less energy is required for ejecting out the electrons.

10. (a) de-Broglie wavelength associated with gas molecules varies as $\lambda \propto \frac{1}{\sqrt{T}}$

11. (e) If electron is moving parallel to the magnetic field, then the electron is not deflected *i.e.,* if electron is not deflected we cannot be sure that there is no magnetic field in that region.

12. (d) At normal pressure positive ions and electrons liberated by ionisation of gas atoms, due to cosmic rays are very small in number and they collide constantly with the gas atoms which are present in large numbers, and hence are unable to move a long distance under the electric field and soon get recombined *i.e.,* flow of ions in the gas does not take place.

13. (d) Light is produced in gases in the process of electric discharge at low pressure. When accelerated electrons collide with atoms of the gas, atoms get excited. The excited atoms return to their normal state and in this process light radiations are emitted.

14. (d) The discharge depends on both pressure of discharge tube and ionisation potential of gas. Since the ionisation potential of different gases are different, hence the discharge in different gases takes place at different potential.

15. (d) If electric field is used for detecting the electron beam, then very high voltage will have to be applied or very long tube will have to be taken.

16. (b) Specific charge of a positive ion corresponding to one gas is fixed but it is different for different gases.

17. (e) In Millikan's experiment oil drops should be of microscopic sizes. If much bigger oil drops are used, then a very high electric field will be required to balance it which is not possible to achieve practically.

Further, the apparent weight of the liquid $\frac{4}{3}\pi a^3 g$ $(\rho_{\text{liquid}} - \sigma_{\text{air}}) = 6\pi a \eta v$.

If a is large, v will be large and the experimental errors will be high.

18. (e) Only the photoelectrons emitted from the surface of the metal have maximum kinetic energy. Those emitted from inside the metal loses part of their energy in collision with the other atoms inside the metal.

19. (d) On increasing the intensity of incident light, the current in photoelectric cell will increase. The energy of the photons $(h\nu)$ will, however not increase with increase in intensity, and hence the kinetic energy of the emitted electrons will not increase.

20. (a) When a light of single frequency falls on the electron of inner layer of metal, then this electron comes out of the metal surface after a large number of collisions with atoms of its upper layer.

21. (b) There is no emission of photoelectrons till the frequency of incident light is less than a minimum frequency, however intense light it may be. In photoelectric effect, it is a single particle collision. Intensity is $h\nu \times N$, where $h\nu$ is the individual energy of the photon and *N* is the total number of photon. In the wave theory, the intensity is proportional, not only to ν^2 but also to the amplitude squared. For the same frequency, increase in intensity only increase the number of photons (in the quantum theory of Einstein).

22. (a) The photoemissive cell may be evacuated contain an inert gas at low pressure. An inert gas in the cell gives greater current but causes a time lag in the response of the cell to very rapid changes of radiation which may make it unsuitable for some purpose.

23. (c) Wavelength of *X*-rays is very small $(\approx Å)$. Hence they are not diffracted by means of ordinary grating. *X*-rays follows the Bragg's law.

24. (b) The penetrating power of *X*-rays depends upon the voltage applied across the tube producing *X*-rays. *X*-rays can pass through matter of lighter elements such as flesh (which is composed of oxygen, hydrogen and carbon) but cannot pass through substances made of heavier elements like bones (which are made of phosphorus and calcium).

25. (c) Intensity of *X*-rays (I) is proportional to the filament current and also to the square of the voltage. It is well known that

intensity of *X*-rays depends on the number of photons emitted per second from target.

26. (b) When fast moving electrons strike the atoms of the target, then most of their kinetic energy is used in increasing the thermal agitation of the atoms of the target and only a small part is radiated in the form of *X*-rays. So the temperature of the target rises.

27. (e) Higher is the wavelength of *X*-ray, lesser is the frequency and penetration power.

28. (a) The distance between the atoms of crystals is of the order of wavelength of *X*-rays. When they fall on a crystal, they are diffracted. The diffraction pattern is helpful in the study of crystal structure.

29. (b) In photoelectric effect, the photon falling on some matter is absorbed by the matter and its energy is transferred to an electron of the matter. In *X*-ray production, photons are produced which get energy from energetic electrons ionising the inner shells of the target which in turn cause a cascade of emission lines.

30. (e) Soft and hard *X*-rays differ only in frequency. But both types of *X*-ray travel with speed of light.

Electron, Photon, Photoelectric Effect and X-rays

SET Self Evaluation Test - 25

1. Which of the following will have the least value of $\frac{q}{m}$

(a) Electron (b) Proton

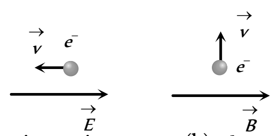
(c) α-particle (d) β-particle

2. When green light is incident on the surface of metal, it emits photo-electrons but there is no such emission with yellow colour light. Which one of the colour can produce emission of photo-electrons

(a) Orange (b) Red

(c) Indigo (d) None of the above

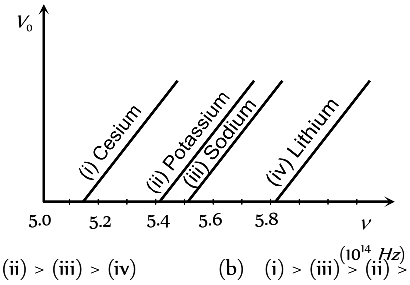
3. An electron is moving through a field. It is moving (i) opposite an electric field (ii) perpendicular to a magnetic field as shown. For each situation the de-Broglie wave length of electron



(a) Increasing, increasing (b) Increasing, decreasing

(c) Decreasing, same (d) Same, Same

4. The figure shows different graphs between stopping potential (V_0) and frequency (ν) for photosensitive surface of cesium, potassium, sodium and lithium. The plots are parallel. Correct ranking of the targets according to their work function greatest first will be



(a) (i) > (ii) > (iii) > (iv) (b) (i) > (iii) > (ii) > (iv)

(c) (iv) > (iii) > (ii) < (i) (d) (i) = (iii) > (ii) = (iv)

5. The K_α X-rays arising from a cobalt (z = 27) target have a wavelength of 179 *pm*. The K_α X-rays arising from a nickel target (z = 28) is

(a) > 179 *pm* (b) < 179 *pm*

(c) = 179 *pm* (d) None of these

6. If a voltage applied to an X-ray tube is increased to 1.5 times the minimum wavelength $(\lambda_{\min})$ of an X-ray continuous spectrum shifts by $\Delta\lambda = 26\ pm$. The initial voltage applied to the tube is

(a) ≈ 10 *kV* (b) ≈ 16 *kV*

(c) ≈ 50 *kV* (d) ≈ 75 *kV*

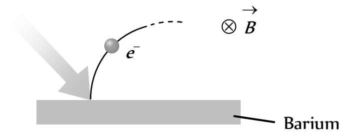
7. Light of wavelength 2475 Å is incident on barium. Photoelectrons emitted describe a circle of radius 100 *cm* by a magnetic field of flux density $\frac{1}{\sqrt{17}} \times 10^{-5}$ *Tesla*. Work function of the barium is (Given $\frac{e}{m} = 1.7 \times 10^{11}$)

(a) 1.8 *eV*

(b) 2.1 *eV*

(c) 4.5 *eV*

(d) 3.3 *eV*



8. Five elements *A*, *B*, *C*, *D* and *E* have work functions 1.2 *eV*, 2.4 *eV*, 3.6 *eV*, 4.8 *eV* and 6 *eV* respectively. If light of wavelength 4000 Å is allowed to fall on these elements, then photoelectrons are emitted by

(a) *A*, *B* and *C* (b) *A*, *B*, *C*, *D* and *E*

(c) *A* and *B* (d) Only *E*

9. If light of wavelength λ_1 is allowed to fall on a metal, then kinetic energy of photoelectrons emitted is E_1. If wavelength of light changes to λ_2 then kinetic energy of electrons changes to E_2. Then work function of the metal is

(a) $\frac{E_1E_2(\lambda_1 - \lambda_2)}{\lambda_1\lambda_2}$ (b) $\frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_1 - \lambda_2)}$

(c) $\frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_2 - \lambda_1)}$ (d) $\frac{\lambda_1\lambda_2\ E_1E_2}{(\lambda_2 - \lambda_1)}$

10. If maximum velocity with which an electron can be emitted from a photo cell is $4 \times 10^8\ cm/\sec$, the stopping potential is (mass of electron = $9 \times 10^{-}$ *kg*)

(a) 30 *volt* (b) 45 *volt*

(c) 59 *volt* (d) Information is insufficient

11. Three particles having their charges in the ratio of 1 : 3 : 5 produce the same spot on the screen in Thomson's experiment. Their masses are in the ratio of

(a) 5 : 3 : 1 (b) 3 : 1 : 5

(c) 1 : 3 : 5 (d) 5 : 1 : 3

12. If the momentum of an electron is changed by Δp, then the de-Broglie wavelength associated with it changes by 0.50%. The initial momentum of the electron will be

(a) $\frac{\Delta p}{200}$ (b) $\frac{\Delta p}{199}$

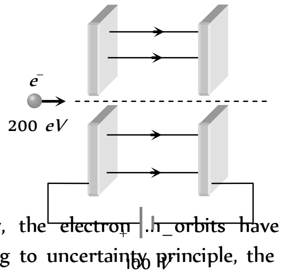
(c) $199\,\Delta p$ (d) $400\,\Delta p$

13. If 10000 *V* is applied across an X-ray tube, what will be the ratio of de-Broglie wavelength of the incident electrons to the shortest wavelength of X-ray produced ($\frac{e}{m}$ for electron is $1.8 \times 10^{11}\ c\,kg^{-1}$)

(a) 1 (b) 0.1

(c) 0.2 (d) 0.3

14. Two large parallel plates are connected with the terminal of 100 V power supply. These plates have a fine hole at the centre. An electron having energy 200 eV is so directed that it passes through the holes. When it comes out it's de-Broglie wavelength is



(a) 1.22 Å

(b) 1.75 Å

(c) 2 Å

(d) None of these

15. According to Bohr's theory, the electron in orbits have definite energy values, then according to uncertainty principle, the life time of an excited state will be

(a) Zero (b) Finite

(c) 10^{-8} sec (d) Infinite

16. Monochromatic light of wavelength 3000 Å is incident on a surface area 4cm^2. If intensity of light is 150 mW/m^2, then rate at which photons strike the target is

(a) $3 \times 10^{10}/sec$ (b) $9 \times 10^{13}/sec$

(c) $7 \times 10^{15}/sec$ (d) $6 \times 10^{19}/sec$

17. For characteristic X-ray of some material

(a) $E(K_\gamma) < E(K_\beta) < E(K_\alpha)$ (b) $E(K_\alpha) < E(L_\alpha) < E(M_\alpha)$

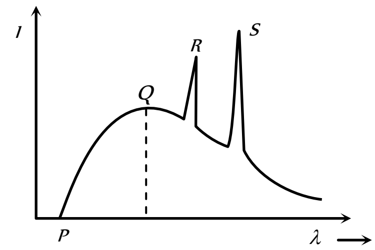
(c) $\lambda(K_\gamma) < \lambda(K_\beta) < \lambda(K_\alpha)$ (d) $\lambda(M_\alpha) < \lambda(L_\alpha) < \lambda(K_\alpha)$

18. The maximum velocity of electrons emitted from a metal surface is V. When frequency of light falling on it is f. The maximum velocity when frequency becomes $4f$ is

(a) 2 V (b) > 2 V

(c) < 2 V (d) Between 2 V and 4 V

19. If the potential difference between the anode and cathode of the X-ray tube is increases



(a) The peaks at R and S would move to shorter wavelength

(b) The peaks at R and S would remain at the same wavelength

(c) The cut off wavelength at P would decrease

(d) (b) and (c) both are correct

20. The collector plate in an experiment on photoelectric effect is kept vertically above the emitter plate. Light source is put on and a saturation photo current is recorded. An electric field is switched on which has a vertically downward direction

(a) The photo current will increase

(b) The kinetic energy of the electrons will increase

(c) The stopping potential will decrease

(d) The threshold wavelength will increase

Answers and Solutions

(SET -25)

1. (c) Mass of α-particle is maximum so $\left(\frac{q}{m}\right)_\alpha$ is least.

2. (c) Wave length of green light is threshold wave length.
Hence for emission of electron, wave length of incident light < wavelength of green light.

3. (c) $\lambda = \frac{h}{mv}$. Since v is increasing in case (i), but it is not changing in case (ii). Hence, in the first case de-Broglie wavelength will change, but it second case, it remain the same

4. (c) The graph between V_0 and ν cut the ν-axis at ν_0.
For the given graphs $(\nu_0)_{(iv)} > (\nu_0)_{(iii)} > (\nu_0)_{(ii)} > (\nu_0)_{(i)}$

$\therefore (W_0)_{(iv)} > (W_0)_{(iii)} > (W_0)_{(ii)} > (W_0)_{(i)}$.

5. (b) $\lambda_{k\alpha} \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_{Ni}}{\lambda_{Co}} = \left(\frac{Z_{Co}-1}{Z_{Ni}-1}\right)^2 = \left(\frac{27-1}{28-1}\right)^2$

$\Rightarrow \lambda_{Ni} = \left(\frac{26}{27}\right)^2 \times \lambda_{Co} = \left(\frac{26}{27}\right)^2 \times 179 = 165.9\ pm < 179\ pm$.

6. (b) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \lambda_1 = \frac{hc}{eV_1}$ and $\lambda_2 = \frac{hc}{eV_2}$

$\therefore\ \Delta\lambda = \lambda_2 - \lambda_1 = \frac{hc}{e}\left[\frac{1}{V_2} - \frac{1}{V_1}\right]$. Given $V_2 = 1.5\ V_1$

on solving we get $V_1 = 16000\ volt = 16\ kV$.

7. (c) Radius of circular path described by a charged particle in a magnetic field is given by $r = \frac{\sqrt{2mK}}{qB}$; where K = Kinetic energy of electron $\Rightarrow K = \frac{q^2B^2r^2}{2m} = \left(\frac{e}{m}\right)\frac{eB^2r^2}{2}$

$= \frac{1}{2} \times 1.7 \times 10^{11} \times 1.6 \times 10^{-19} \times \left(\frac{1}{\sqrt{17}} \times 10^{-5}\right)^2 \times (1)^2$

$= 8 \times 10^{-20}\ J = 0.5\ eV$

By using $E = W_0 + K_{max}$

$\Rightarrow W_0 = E - K_{max} = \left(\frac{12375}{2475}\right)eV - 0.5\ eV = 4.5\ eV$

8. (c) $E = \frac{12375}{4000} = 3.09\ eV$ Photoelectrons emits if energy of incident light > work function.

9. (c) $E = W_0 + K_{max} \Rightarrow \frac{hc}{\lambda_1} = W_0 + E_1$ and $\frac{hc}{\lambda_2} = W_0 + E_2$

$\Rightarrow hc = W_0\lambda_1 + E_1\lambda_1$ and $hc = W_0\lambda_2 + E_2\lambda_2$

$\Rightarrow W_0\lambda_1 + E_1\lambda_1 = W_0\lambda_2 + E_2\lambda_2 \Rightarrow W_0 = \frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_2 - \lambda_1)}$.

10. (b) $v_{max} = 4 \times 10^8\ cm/sec = 4 \times 10^6\ m/sec$.

$\therefore\ K_{max} = \frac{1}{2}mv_{max}^2 = \frac{1}{2} \times 9 \times 10^{-31} \times (4 \times 10^6)^2$

$= 7.2 \times 10^{-18}\ J = 45\ eV$.

Hence, stopping potential $|V_0| = \frac{K_{max}}{e} = \frac{45\ eV}{e} = 45\ volt$.

11. (c) Since spot is same, hence $\frac{e}{m}$ should be same *i.e.*,

As $q_1 : q_2 : q_3 = 1 : 3 : 5$. Hence $m_1 : m_2 : m_3 = 1 : 3 : 5$

12. (c) $\lambda = \frac{h}{p} \Rightarrow \lambda - \frac{0.5}{100}\lambda = \frac{h}{p+\Delta p} \Rightarrow \frac{199\lambda}{200} = \frac{h}{p+\Delta p} = \frac{199}{200}\frac{h}{p}$

$\Rightarrow p + \Delta p = \frac{200}{199}p \Rightarrow p = 199\ \Delta p$

13. (b) For the incident electron $\frac{1}{2}mv^2 = eV$ or $p^2 = 2m\,eV$

$\therefore$ de-Broglie wavelength $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2m\,eV}}$

Shortest X-ray wavelength $\lambda_2 = \frac{hc}{eV}$

$\therefore\ \frac{\lambda_1}{\lambda_2} = \frac{1}{c}\sqrt{\left(\frac{V}{2}\right)\left(\frac{e}{m}\right)} = \frac{\sqrt{\frac{10^4}{2} \times 1.8 \times 10^{11}}}{3 \times 10^8} = 0.1$

14. (a) Energy of the electron, when it comes out from the second plate = 200 eV – 100 eV = 100 eV

Hence accelerating potential difference = 100 V

$\lambda_{Electron} = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.23\mathring{A}$

15. (d) According to Bohr's theory $\Delta E = 0$, since $\Delta E \cdot \Delta t \geq h$

$\Rightarrow \Delta t \rightarrow \infty$

16. (b) $\frac{n}{t} = \frac{I A\lambda}{hc} = \frac{150 \times 10^{-3} \times 4 \times 10^{-4} \times 3 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 9 \times 10^{13}\ \frac{1}{sec}$

17. (c) $\because E(K_\gamma) > E(K_\beta) > E(K_\alpha) \Rightarrow \lambda(K_\gamma) < \lambda(K_\beta) < \lambda(K_\alpha)$

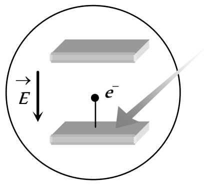
18. (b) $\because E = W_0 + \frac{1}{2}mv_{max}^2 \Rightarrow v_{max} = \sqrt{\frac{2(hf - W_0)}{m}}$

If frequency becomes $4f$ then

$V' = \sqrt{\frac{2(h \times 4f - W_0)}{m}} = 2\sqrt{\frac{2\left(hf - \frac{W_0}{4}\right)}{m}} \Rightarrow V' > 2V$

19. (d) Peaks on the graph represent characteristic X-ray spectrum. Every peak has a certain wavelength, which depends upon the transition of electron inside the atom of the target. While λ_{min} depends upon the accelerating voltage (As. $\lambda_{min} \propto 1/V$).

20. (b) In electric field photoelectron will experience force and accelerate opposite to the field so it's *K.E.* increases (*i.e.* stopping potential will increase), no change in photoelectric current, and threshold wavelength.



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Chapter
26
Atomic and Nuclear Physics

Thomson's Atomic Model

J.J. Thomson gave the first idea regarding structure of atom. According to this model.

(1) An atom is a solid sphere in which entire and positive charge and it's mass is uniformly distributed and in which negative charge (*i.e.* electron) are embedded like seeds in watermelon.

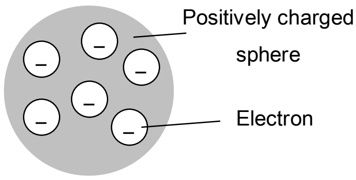


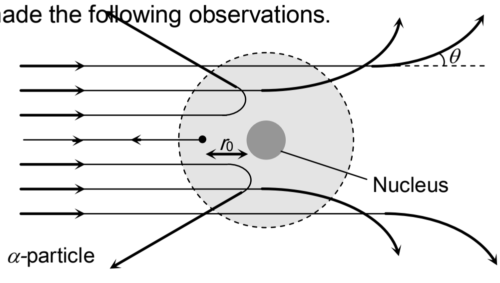
Fig. 26.1

(2) This model explained successfully the phenomenon of thermionic emission, photoelectric emission and ionization.

(3) The model fail to explain the scattering of α- particles and it cannot explain the origin of spectral lines observed in the spectrum of hydrogen and other atoms.

α-Scattering Experiment

'Geiger and Marsden (students of Rutherford) studied the scattering of α-particles by gold foil on the advice of Rutherford and made the following observations.



(1) Most of the α-particles pass through the foil straight away undeflected.

(2) Some of them are deflected through small angles.

(3) A few α-particles (1 in 1000) are deflected through the angle more than 90°.

(4) A few α -particles (very few) returned back *i.e.* deflected by 180°.

(5) Number of scattered particles : $N \propto \frac{1}{\sin^4(\theta/2)}$

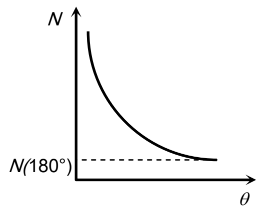


Fig. 26.3

(6) If t is the thickness of the foil and N is the number of α-particles scattered in a particular direction (*i.e.* θ = constant), it was observed that $\frac{N}{t} = \text{constant} \Rightarrow \frac{N_1}{N_2} = \frac{t_1}{t_2}$

(7) **Distance of closest approach** (Nuclear dimension) :

The minimum distance from the nucleus up to which the α-particle approach, is called the distance of closest approach (r_0). At this distance the entire initial kinetic energy has been converted into potential energy so

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}.\frac{(Ze)2e}{r_0} \Rightarrow r_0 = \frac{Ze^2}{mv^2\pi\varepsilon_0} = \frac{4kZe^2}{mv^2}$$

(8) **Impact parameter** (b) : The perpendicular distance of the velocity vector ($\vec{v}$) of the α-particle from the centre of the nucleus when it is far away from the nucleus is known as impact parameter. It is given as

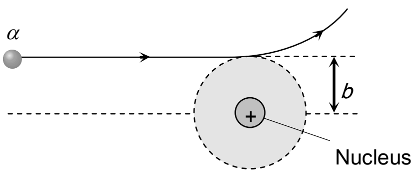


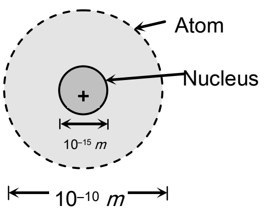
Fig. 26.4

$$b = \frac{Ze^2 \cot(\theta/2)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)} \Rightarrow b \propto \cot(\theta/2)$$

For large b, α particles will go undeviated and for small b the α-particle will suffer large scattering.

Rutherford's Atomic Model

After α-particles scattering experiment, following conclusions were made by Rutherford as regard as atomic structure :



Size of the nucleus = 1 *Fermi* = 10^{-15} *m*

Size of the atom 1 Å = 10^{-10} *m*

Fig. 26.5

(1) Most of the mass (at least 99.95%) and all of the charge of an atom concentrated in a very small region is called atomic nucleus.

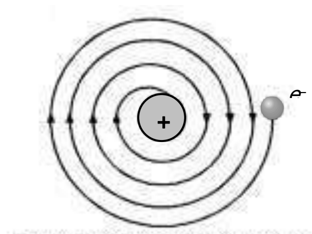
(2) Nucleus is positively charged and it's size is of the order of

10^{-15} *m* ≈ 1 *Fermi*. The nucleus occupies only about 10^{-12} of the total volume of the atom or less.

(3) In an atom there is maximum empty space and the electrons revolve around the nucleus in the same way as the planets revolve around the sun.

Failure of Rutherford's Model

(1) **Stability of atom :** It could not explain stability of atom because according to classical electrodynamics theory an accelerated charged particle should continuously radiate energy. Thus an electron moving in an circular path around the nucleus should ove into smaller and smaller orb us and it should ultimately fall int



Instability of atom

Fig. 26.6

(2) According to this model the spectrum of atom must be continuous where as practically it is a line spectrum.

(3) It did not explain the distribution of electrons outside the nucleus.

Bohr's Atomic Model

Bohr proposed a model for hydrogen atom which is also applicable for some lighter atoms in which a single electron revolves around a stationary nucleus of positive charge *Ze* (called hydrogen like atom)

Bohr's model is based on the following postulates.

(1) He postulated that an electron in an atom can move around the nucleus in certain circular stable orbits without emitting radiations.

(2) Bohr found that the magnitude of the electron's

Angular momentum is quantized *i.e.* $L = mv_n r_n = n\left(\frac{h}{2\pi}\right)$

where n = 1, 2, 3, ... each value of n corresponds to a permitted value of the orbit radius.

r_n = Radius of n^{th} orbit, v_n = corresponding speed

(3) The radiation of energy occurs only when an electron jumps from one permitted orbit to another.

When electron jumps from higher energy orbit (E_2) to lower energy orbit (E_1) then difference of energies of these orbits *i.e.* $E_2 - E_1$ emits in the form of photon. But if electron goes from E_1 to E_2 it absorbs the same amount of energy.

Draw Backs of Bohr's Atomic Model

(1) It is valid only for one electron atoms, *e.g.* : H, He^+, Li^{+2}, Na^{+1} *etc.*

(2) Orbits were taken as circular but according to Sommerfield these are elliptical.

(3) Intensity of spectral lines could not be explained.

(4) Nucleus was taken as stationary but it also rotates on its own axis.

(5) It could not be explained the minute structure in spectrum line.

(6) This does not explain the Zeeman effect (splitting up of spectral lines in magnetic field) and Stark effect (splitting up in electric field)

(7) This does not explain the doublets in the spectrum of some of the atoms like sodium (5890 Å & 5896 Å)

Bohr's Orbits (for Hydrogen and H_2-like Atoms)

(1) **Radius of orbit :** For an electron around a stationary nucleus the electrostatics force of attraction provides the necessary centripetal force

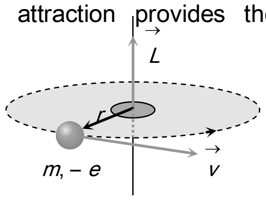


Fig. 26.7

i.e. $\frac{1}{4\pi\varepsilon_0}\frac{(Ze)e}{r^2} = \frac{mv^2}{r}$ .... (i)

also $mvr = \frac{nh}{2\pi}$ ....(ii)

From equation (i) and (ii) radius of n^{th} orbit

$$r_n = \frac{n^2h^2}{4\pi^2 kZme^2} = \frac{n^2h^2\varepsilon_0}{\pi mZe^2} = 0.53\frac{n^2}{Z}\text{Å} \qquad \left(k = \frac{1}{4\pi\varepsilon_0}\right)$$

$$\Rightarrow r_n \propto \frac{n^2}{Z}$$

(2) **Speed of electron :** From the above relations, speed of electron in n^{th} orbit can be calculated as

$$v_n = \frac{2\pi kZe^2}{nh} = \frac{Ze^2}{2\varepsilon_0 nh} = \left(\frac{c}{137}\right).\frac{Z}{n} = 2.2\times10^6\frac{Z}{n}\,m/sec$$

where (c = speed of light 3×10^8 *m/s*)

Table 26.1 : Some other quantities for revolution of electron in n^{th} orbit

Quantity	Formula	Dependency on n and Z
(1) Angular speed	$\omega_n = \frac{v_n}{r_n} = \frac{\pi mz^2e^4}{2\varepsilon_0^2 n^3h^3}$	$\omega_n \propto \frac{Z^2}{n^3}$
(2) Frequency	$\nu_n = \frac{\omega_n}{2\pi} = \frac{mz^2e^4}{4\varepsilon_0^2n^3h^3}$	$\nu_n \propto \frac{Z^2}{n^3}$
(3) Time period	$T_n = \frac{1}{\nu_n} = \frac{4\varepsilon_0^2n^3h^3}{mz^2e^4}$	$T_n \propto \frac{n^3}{Z^2}$
(4) Angular momentum	$L_n = mv_nr_n = n\left(\frac{h}{2\pi}\right)$	$L_n \propto n$
(5) Corresponding current	$i_n = e\nu_n = \frac{mz^2e^5}{4\varepsilon_0^2n^3h^3}$	$i_n \propto \frac{Z^2}{n^3}$
(6) Magnetic moment	$M_n = i_nA = i_n(\pi r_n^2)$ (where $\mu_0 = \frac{eh}{4\pi m}$ = Bohr magneton)	$M_n \propto n$
(7) Magnetic field	$B = \frac{\mu_0 i_n}{2r_n} = \frac{\pi m^2z^3e^7\mu_0}{8\varepsilon_0^3n^5h^5}$	$B \propto \frac{Z^3}{n^5}$

Energy

(1) **Potential energy :** An electron possesses some potential energy because it is found in the field of nucleus potential energy of electron in n^{th} orbit of radius r_n is given by $U = k.\frac{(Ze)(-e)}{r_n} = -\frac{kZe^2}{r_n}$

(2) **Kinetic energy :** Electron posses kinetic energy because of it's motion. Closer orbits have greater kinetic energy than outer ones.

As we know $\frac{mv^2}{r_n} = \frac{k.(Ze)(e)}{r_n^2}$

$\Rightarrow$ Kinetic energy $K = \frac{kZe^2}{2r_n} = \frac{|U|}{2}$

(3) **Total energy :** Total energy (E) is the sum of potential energy and kinetic energy *i.e.* $E = K + U$

$$\Rightarrow \quad E = -\frac{kZe^2}{2r_n} \text{ also } r_n = \frac{n^2h^2\varepsilon_0}{\pi mze^2}.$$

Hence $E = -\left(\frac{me^4}{8\varepsilon_0^2h^2}\right).\frac{z^2}{n^2} = -\left(\frac{me^4}{8\varepsilon_0^2ch^3}\right)ch\frac{z^2}{n^2}$

$$= -R\,ch\frac{Z^2}{n^2} = -13.6\frac{Z^2}{n^2}eV$$

where $R = \frac{me^4}{8\varepsilon_0^2ch^3}$ = Rydberg's constant = 1.09 $\times$ 10^7 *per m*.

(4) **Ionisation energy and potential :** The energy required to ionise an atom is called ionisation energy. It is the energy required to make the electron jump from the present orbit to the infinite orbit.

Hence $E_{ionisation} = E_\infty - E_n = 0 - \left(-13.6\frac{Z^2}{n^2}\right) = +\frac{13.6Z^2}{n^2}eV$

For H_2-atom in the ground state

$$E_{ionisation} = \frac{+13.6(1)^2}{n^2} = 13.6\,eV$$

The potential through which an electron need to be accelerated so that it acquires energy equal to the ionisation energy is called ionisation potential. $V_{ionisation} = \frac{E_{ionisation}}{e}$

(5) **Excitation energy and potential :** When energy is given to an electron from external source, it jumps to higher energy level. This phenomenon is called excitation.

The minimum energy required to excite an atom is called excitation energy of the particular excited state and corresponding potential is called exciting potential.

$E_{Excitation} = E_{Final} - E_{Initial}$ and $V_{Excitation} = \frac{E_{excitation}}{e}$

(6) **Binding energy (B.E.) :** Binding energy of a system is defined as the energy released when it's constituents are brought from infinity to form the system. It may also be defined as the energy needed to separate it's constituents to large distances. If an electron and a proton are initially at rest and brought from large distances to form a hydrogen atom, 13.6 *eV* energy will be released. The binding energy of a hydrogen atom is therefore 13.6 *eV*.

(7) **Energy level diagram :** The diagrammatic description of the energy of the electron in different orbits around the nucleus is called energy level diagram.

Table 26.2 : Energy level diagram of hydrogen/hydrogen like atom

	Principle quantum number	Orbit	Excited state	Energy for H_2 – atom
- - - - - -	$n = \infty$	Infinite	Infinite	0 *eV*
———	$n = 4$	Fourth	Third	– 0.85 *eV*
———	$n = 3$	Third	Second	– 1.51 *eV*
———	$n = 2$	Second	First	– 3.4 *eV*
	$n = 1$	First	Ground	– 13.6 *eV*

Transition of Electron

When an electron makes transition from higher energy level having energy $E_2(n_2)$ to a lower energy level having energy E_1 (n_1) then a photon of frequency ν is emitted

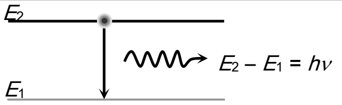


Fig. 26.8

(1) **Energy of emitted radiation**

$$\Delta E = E_2 - E_1 = \frac{-Rch Z^2}{n_2^2} - \left(-\frac{Rch Z^2}{n_1^2}\right)$$

$$= 13.6 Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(2) **Frequency of emitted radiation**

$$\Delta E = h\nu \Rightarrow \nu = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h} = Rc Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(3) **Wave number/wavelength**

Wave number is the number of waves in unit length $\bar{\nu} = \frac{1}{\lambda} = \frac{\nu}{c} \Rightarrow \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{13.6Z^2}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

(4) **Number of spectral lines** : If an electron jumps from higher energy orbit to lower energy orbit it emits raidations with various spectral lines.

If electron falls from orbit n_2 to n_1 then the number of spectral lines emitted is given by

$$N_E = \frac{(n_2 - n_1 + 1)(n_2 - n_1)}{2}$$

If electron falls from n^{th} orbit to ground state (*i.e.* $n_2 = n$ and $n_1 = 1$) then number of spectral lines emitted $\boldsymbol{N_E = \frac{n(n-1)}{2}}$

(5) **Recoiling of an atom** : Due to the transition of electron, photon is emitted and the atom is recoiled

Recoil momentum of atom = momentum of photon $= \frac{h}{\lambda} = hRZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Also recoil energy of atom $= \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$ (where m = mass of recoil atom)

Hydrogen Spectrum and Spectral Series

When hydrogen atom is excited, it returns to its normal unexcited (or ground state) state by emitting the energy it had absorbed earlier. This energy is given out by the atom in the form of radiations of different wavelengths as the electron jumps down from a higher to a lower orbit. Transition from different orbits cause different wavelengths, these constitute spectral series which are characteristic of the atom emitting them. When observed through a spectroscope, these radiations are imaged as sharp and straight vertical lines of a single colour.

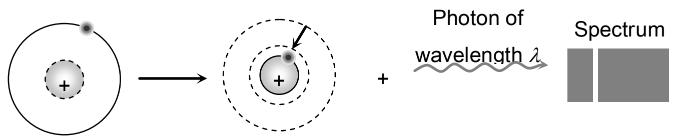


Fig. 26.9 : Emission spectra

The spectral lines arising from the transition of electron forms a spectra series.

(1) Mainly there are five series and each series is named after it's discover as Lymen series, Balmer series, Paschen series, Bracket series and Pfund series.

(2) According to the Bohr's theory the wavelength of the radiations emitted from hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \lambda = \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)R} = \frac{n_1^2}{\left(1 - \frac{n_1^2}{n_2^2}\right)R}$$

where n_2 = outer orbit (electron jumps from this orbit), n_1 = inner orbit (electron falls in this orbit)

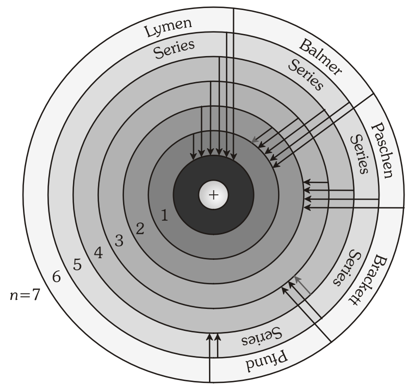


Fig. 26.10

(3) First line of the series is called first member, for this line wavelength is maximum (λ_{max})

For maximum wavelength if $n_1 = n$ then $n_2 = n + 1$

So $\lambda_{max} = \frac{n^2(n+1)^2}{(2n+1)R}$

(4) Last line of the series is called series limit, for this line wavelength is minimum (λ_{min})

For minimum wavelength $n_2 = \infty, n_1 = n$ So $\lambda_{min} = \frac{n^2}{R}$

(5) The ratio of first member and series limit can be calculated as $\frac{\lambda_{max}}{\lambda_{min}} = \frac{(n+1)^2}{(2n+1)}$

Table 26.3 : Different spectral series

Spectral series	Transition	λ_{max}	λ_{min}	$\frac{\lambda_{max}}{\lambda_{min}}$	Region
1. Lymen series	$n_2 = 2, 3, 4 \ldots\infty$ $n_1 = 1$	$\frac{4}{3R}$	$\frac{1}{R}$	$\frac{4}{3}$	Ultraviolet region
2.Balmer series	$n_2 = 3, 4, 5 \ldots\infty$ $n_1 = 2$	$\frac{36}{5R}$	$\frac{4}{R}$	$\frac{9}{5}$	Visible region
3. Paschen series	$n_2 = 4, 5, 6 \ldots\infty$ $n_1 = 3$	$\frac{144}{7R}$	$\frac{9}{R}$	$\frac{16}{7}$	Infrared region
4. Bracket series	$n_2 = 5, 6, 7 \ldots \infty$ $n_1 = 4$	$\frac{400}{9R}$	$\frac{16}{R}$	$\frac{25}{9}$	Infrared region
5. Pfund series	$n_2 = 6, 7, 8 \ldots \infty$ $n_1 = 5$	$\frac{900}{11R}$	$\frac{25}{R}$	$\frac{36}{11}$	Infrared region

Quantum Numbers

An atom contains large number of shells and subshells. These are distinguished from one another on the basis of their size, shape and orientation (direction) in space. The parameters are expressed in terms of different numbers called quantum number.

Quantum numbers may be defined as a set of four number with the help of which we can get complete information about all the electrons in an atom. It tells us the address of the electron *i.e.* location, energy, the type of orbital occupied and orientation of that orbital.

(1) **Principal Quantum number (n) :** This quantum number determines the main energy level or shell in which the electron is present. The average distance of the electron from the nucleus and the energy of the electron depends on it.

$E_n \propto \frac{1}{n^2}$ and $r_n \propto n^2$ (in *H*-atom)

The principal quantum number takes whole number values, $n = 1, 2, 3, 4, \ldots.. \infty$

(2) **Orbital quantum number (l) or azimuthal quantum number (l) :** This represents the number of subshells present in the main shell. These subsidiary orbits within a shell will be denoted as 1, 2, 3, 4 … or *s*, *p*, *d*, *f* … This tells the shape of the subshells.

The orbital angular momentum of the electron is given as $L = \sqrt{l(l+1)}\frac{h}{2\pi}$ (for a particular value of n).

For a given value of n the possible values of l are $l = 0, 1, 2, \ldots..$ upto $(n - 1)$

(3) **Magnetic quantum number (m_l) :** An electron due to it's angular motion around the nucleus generates an electric field. This electric field is expected to produce a magnetic field. Under the influence of external magnetic field, the electrons of a subshell can orient themselves in certain preferred regions of space around the nucleus called orbitals.

The magnetic quantum number determines the number of preferred orientations of the electron present in a subshell.

The angular momentum quantum number m can assume all integral value between $-l$ to $+l$ including zero. Thus m_l can be $-1, 0, +1$ for $l = 1$. Total values of m_l associated with a particular value of l is given by $(2l + 1)$.

(4) **Spin (magnetic) quantum number (m_s) :** An electron in atom not only revolves around the nucleus but also spins about its own axis. Since an electron can spin either in clockwise direction or in anticlockwise direction. Therefore for any particular value of magnetic quantum number, spin quantum number can have two values, *i.e.* $m_s = \frac{1}{2}$ (Spin up) or $m_s = -\frac{1}{2}$ (Spin down)

This quantum number helps to explain the magnetic properties of the substance.

Table 26.4 : Quantum states of the hydrogen atom

n	l	m_l	Spectroscopic notation	Shell
1	0	0	1 s	K
2	0	0	2 s }	L
2	1	– 1, 0, 1	2 p	
3	0	0	3 s }	
3	1	– 1, 0, 1	3 p	M
3	2	– 2, – 1, 0, 1, 2	3 d	
4	0	0	4 s	N

Electronic Configurations of Atoms

The distribution of electrons in different orbitals of an atom is called the electronic configuration of the atom. The filling of electrons in orbitals is governed by the following rules.

(1) **Pauli's exclusion principle :** "It states that no two electrons in an atom can have all the four quantum number (n, l, m_l and m_s) the same."

It means each quantum state of an electron must have a different set of quantum numbers n, l, m_l and m_s. This principle sets an upper limit on the number of electrons that can occupy a shell.

$N_{\max}$ in one shell = $2n^2$; Thus N_{max} in K, L, M, N …. shells are 2, 8, 18, 32,

(2) **Aufbau principle :** Electrons enter the orbitals of lowest energy first.

As a general rule, a new electron enters an empty orbital for which ($n + l$) is minimum. In case the value $(n+l)$ is equal for two orbitals, the one with lower value of n is filled first.

Thus the electrons are filled in subshells in the following order (memorize)

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p, ……

(3) **Hund's Rule :** When electrons are added to a subshell where more than one orbital of the same energy is available, their spins remain parallel. They occupy different orbitals until each one of them has at least one electron. Pairing starts only when all orbitals are filled up.

Pairing takes place only after filling 3, 5 and 7 electrons in p, d and f orbitals, respectively.

Nucleus

(1) Rutherford's α-scattering experiment established that the mass of atom is concentrated with small positively charged region at the centre which is called 'nucleus'.

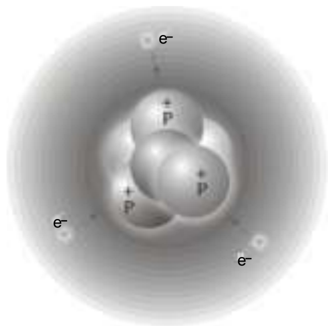


Fig. 26.11

(2) The stability or instability of a particular nucleus is determined by the competition between the attractive nuclear force among the protons and neutrons and the repulsive electrical interactions among the protons. Unstable nuclei *decay*, transforming themselves spontaneously into other structure by a variety of decay processes.

(3) We could not survive without the 3.90×10^{26} *watt* output of one near by fusion reactor, our sun.

(4) Nuclei are made up of proton and neutron. The number of protons in a nucleus (called the atomic number or proton number) is represented by the symbol *Z*. The number of neutrons (neutron number) is represented by *N*. The total number of neutrons and protons in a nucleus is called it's mass number *A* so *A* = *Z* + *N*.

(5) Neutrons and proton, when described collectively are called ***nucleons***. A single nuclear species having specific values of both *Z* and *N* is called a nuclide.

(6) Nuclides are represented as $_Z X^A$; where *X* denotes the chemical symbol of the element.

Neutron

Neutron is a fundamental particle which is essential constituent of all nuclei except that of hydrogen atom. It was discovered by Chadwick. A free neutron outside the nucleus is unstable and decays into proton and electron.

$$_0n^1 \rightarrow \underset{\text{Proton}}{_1H^1} + \underset{\text{Electron}}{_{-1}\beta^0} + \underset{\text{Antinutrino}}{\overline{\nu}}$$

(1) The charge of neutron : It is neutral

(2) The mass of neutron : 1.6750×10^{-27} *kg*

(3) It's spin angular momentum : $\frac{1}{2} \times \left(\frac{h}{2\pi}\right) J\text{-}s$

(4) It's magnetic moment : 9.57×10^{-27} *J/Tesla*

(5) It's half life : 12 minutes

(6) Penetration power : High

(7) Types : Neutrons are of two types slow neutron and fast neutron, both are fully capable of penetrating a nucleus and causing artificial disintegration.

Thermal Neutrons

Fast neutrons can be converted into slow neutrons by certain materials called moderator's (Paraffin wax, heavy water, graphite) when fast moving neutrons pass through a moderator, they collide with the molecules of the moderator, as a result of this, the energy of moving neutron decreases while that of the molecules of the moderator increases. After sometime they both attains same energy. The neutrons are then in thermal equilibrium with the molecules of the moderator and are called thermal neutrons.

Energy of thermal neutron is about 0.025 *eV* and speed is about 2.2 *km/s*.

Types of Nuclei

The nuclei have been classified on the basis of the number of protons (atomic number) or the total number of nucleons (mass number) as follows

(1) **Isotopes :** The atoms of element having same atomic number but different mass number are called isotopes. All isotopes have the same chemical properties. The isotopes of some elements are the following

$$_1H^1,\ _1H^2,\ _1H^3 \qquad _8O^{16},\ _8O^{17},\ _8O^{18} \qquad _2He^3,\ _2He^4$$
$$_{17}Cl^{35},\ _{17}Cl^{37} \qquad _{92}U^{235},\ _{92}U^{238}$$

(2) **Isobars :** The nuclei which have the same mass number (*A*) but different atomic number (*Z*) are called isobars. Isobars occupy different positions in periodic table so all isobars have different chemical properties. Some of the examples of isobars are

$$_1H^3 \text{ and } _2He^3, \quad _6C^{14} \text{ and } _7N^{14},\ _8O^{17} \text{ and } _9F^{17}$$

(3) **Isotones :** The nuclei having equal number of neutrons are called isotones. For them both the atomic number (*Z*) and mass number (*A*) are different, but the value of (*A* – *Z*) is same. Some examples are

$$_4Be^9 \text{ and } _5B^{10},\ _6C^{13} \text{ and } _7N^{14},\ _8O^{18} \text{ and } _9F^{19}$$
$$_3Li^7 \text{ and } _4Be^8,\ _1H^3 \text{ and } _2He^4$$

(4) **Mirror nuclei :** Nuclei having the same mass number *A* but with the proton number (*Z*) and neutron number (*A* – *Z*) interchanged (or whose atomic number differ by 1) are called mirror nuclei for example.

$_1H^3$ and $_2He^3$, $_3Li^7$ and $_4Be^7$

Size of Nucleus

(1) **Nuclear radius :** Experimental results indicates that the nuclear radius is proportional to $A^{1/3}$, where A is the mass number of nucleus *i.e.* $R \propto A^{1/3} \Rightarrow R = R_0 A^{1/3}$, where R_0 = 1.2×10^{-15} *m* = 1.2 *fm*.

(2) **Nuclear volume :** The volume of nucleus is given by $V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A \Rightarrow V \propto A$

(3) **Nuclear density** : Mass per unit volume of a nucleus is called nuclear density.

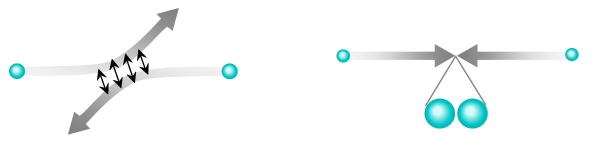
$$\text{Nuclear density}(\rho) = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi (R_0 A^{1/3})^3}$$

where *m* = Average of mass of a nucleon (= mass of proton + mass of neutron = 1.66×10^{-27} *kg*) and *mA* = Mass of nucleus

$$\Rightarrow \rho = \frac{3m}{4\pi R_0^3} = 2.38 \times 10^{17}\, kg/m^3$$

Nuclear Force

Forces that keep the nucleons bound in the nucleus are called nuclear forces.



(A) At low speeds, electromagnetic repulsion

(B) At high speeds, nuclei come close enough for the strong

Fig. 26.12

(1) Nuclear forces are short range forces. These do not exist at large distances greater than 10^{-15} *m*.

(2) Nuclear forces are the strongest forces in nature.

(3) These are attractive force and causes stability of the nucleus.

(4) These forces are charge independent.

(5) Nuclear forces are non-central force.

(6) **Nuclear forces are exchange forces :** According to scientist Yukawa the nuclear force between the two nucleons is the result of the exchange of particles called mesons between the nucleons.

π - mesons are of three types – Positive π meson (π^+), negative π meson (π^-), neutral π *meson* (π^0)

The force between neutron and proton is due to exchange of charged meson between them *i.e.*

$$p \to \pi^+ + n, \quad n \to p + \pi^-$$

The forces between a pair of neutrons or a pair of protons are the result of the exchange of neutral meson (π^0) between them *i.e.* $p \to p' + \pi^0$ and $n \to n' + \pi^0$

Thus exchange of π meson between nucleons keeps the nucleons bound together. It is responsible for the nuclear forces.

Dog-Bone analogy

The above interactions can be explained with the dog bone analogy according to which we consider the two interacting nucleons to be two dogs having a common bone clenched in between their teeth very firmly. Each one of these dogs wants to take the bone and hence they cannot be separated easily. They seem to be bound to each other with a strong attractive force (which is the bone) thc emselves are strong enemies. The meson pla of the common bone in between two nucleons

Fig. 26.13

Atomic Mass Unit (*amu*)

(1) In nuclear physics, a convenient unit of mass is the unified atomic mass unit abbreviated *u*.

(2) The *amu* is defined as $\frac{1}{12}th$ mass of a ${}_BC^{12}$ at on.

(3) 1 *amu* (or 1 *u*) = 1.6605402 × 10^{-27} *kg* .

(4) **Masses of electron, proton and neutrons :**

Mass of electron (m_e) = 9.1 × 10^{-31} *kg* = 0.0005486 *amu*, Mass of proton (m_p) = 1.6726 × 10^{-27} *kg* = 1.007276 *amu*

Mass of neutron (m_n) = 1.6750 × 10^{-27} *kg* = 1.00865 *amu*, Mass of hydrogen atom ($m_e + m_p$) = 1.6729 × 10^{-27} *kg* = 1.0078 *amu*

(5) The energy associated with a nuclear process is usually large, of the order of *MeV*.

(6) According to Einstein, mass and energy are inter convertible. The Einstein's mass energy relationship is given by $E = mc^2$

If *m* = 1 *amu*, *c* = 3 × 10^8 *m/sec* then *E* = 931 *MeV* *i.e.* 1 *amu* is equivalent to 931 *MeV* or **1 *amu* (or 1 *u*) = 931 *MeV***

(1 *u*) c^2 = 931 *MeV* ⇒ $1u = 931\frac{MeV}{c^2}$ or $c^2 = 931\frac{MeV}{u}$

Table 26.5 : Neutral atomic masses for some light nuclides

Element and isopore	Atomic mass (*u*)
Hydrogen $({}_1^1H)$	1.007825
Deuterium $({}_1^2H)$	2.014102
Tritium $({}_1^3H)$	3.016049
Helium $({}_2^3He)$	3.016029
Helium $({}_2^4He)$	4.002603
Lithium $({}_3^7Li)$	7.016004
Beryllium $({}_4^9Be)$	9.012182
Carbon $({}_6^{12}C)$	12.000000
Nitrogen $({}_7^{14}N)$	14.003074
Oxygen $({}_8^{16}O)$	15.994915

Pair Production and Pair-Annihilation

When an energetic γ-ray photon falls on a heavy substance. It is absorbed by some nucleus of the substance and an electron and a positron are produced. This phenomenon is called pair production and may be represented by the following equation

$$\underset{(\gamma-\text{photon})}{h\nu} = \underset{(\text{Positron})}{{}_1\beta^0} + \underset{(\text{Electron})}{{}_{-1}\beta^0}$$

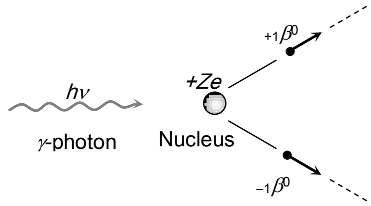


Fig. 26.14

The rest-mass energy of each of positron and electron is

$E_0 = m_0c^2$ = (9.1 × 10^{-31} *kg*) × (3.0 × 10^8 *m/s*)^2

= 8.2 × 10^{-14} *J* = **0.51 *MeV***

Hence, for pair-production it is essential that the energy of γ-photon must be at least 2 × 0.51 = 1.02 *MeV*. If the energy of γ-photon is less than this, it would cause photo-electric effect or Compton effect on striking the matter.

The converse phenomenon pair-annihilation is also possible. Whenever an electron and a positron come very close to each other, they annihilate each other by combining together and two γ-photons (energy) are produced. This phenomenon is called pair annihilation and is represented by the following equation.

$$\underset{(\text{Positron})}{{}_{+1}\beta^0} + \underset{(\text{Electron})}{{}_{-1}\beta^0} = \underset{(\gamma\text{-photon})}{h\nu} + \underset{(\gamma\text{-photon})}{h\nu}$$

Nuclear Stability

Among about 1500 known nuclides, less than 260 are stable. The others are unstable that decay to form other nuclides by emitting α, β-particles and γ - EM waves. (This process is called radioactivity). The stability of nucleus is determined by many factors. Few such factors are given below :

(1) **Neutron-proton ratio** $\left(\frac{N}{Z}\text{Ratio}\right)$: The chemical properties of an atom are governed entirely by the number of protons (*Z*) in the nucleus, the stability of an atom appears to

depend on both the number of protons and the number of neutrons.

(i) For lighter nuclei, the greatest stability is achieved when the number of protons and neutrons are approximately equal ($N \approx Z$) *i.e.* $\frac{N}{Z} = 1$

(ii) Heavy nuclei are stable only when they have more neutrons than protons. Thus heavy nuclei are neutron rich compared to lighter nuclei (for heavy nuclei, more is the number of protons in the nucleus, greater is the electrical repulsive force between them. Therefore more neutrons are added to provide the strong attractive forces necessary to keep the nucleus stable.)

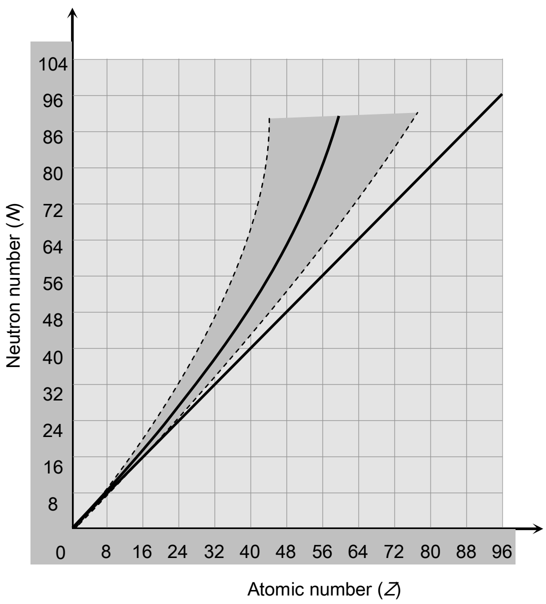


Fig. 26.15

(iii) Figure shows a plot of N verses Z for the stable nuclei. For mass number upto about A = 40. For larger value of Z the nuclear force is unable to hold the nucleus together against the electrical repulsion of the protons unless the number of neutrons exceeds the number of protons. At Bi (Z = 83, A = 209), the neutron excess in $N - Z$ = 43. There are no stable nuclides with Z > 83.

(2) **Even or odd numbers of Z or N :** The stability of a nuclide is also determined by the consideration whether it contains an even or odd number of protons and neutrons.

(i) It is found that an even-even nucleus (even Z and even N) is more stable (60% of stable nuclide have even Z and even N).

(ii) An even-odd nucleus (even Z and odd N) or odd-even nuclide (odd Z and even N) is found to be lesser sable while the odd-odd nucleus is found to be less stable.

(iii) Only five stable odd-odd nuclides are known : ${}_1H^2,\ {}_3Li^6,\ {}_5Be^{10},\ {}_7N^{14}$ and ${}_{75}Ta^{180}$

(3) **Binding energy per nucleon :** The stability of a nucleus is determined by value of it's binding energy per nucleon. In general higher the value of binding energy per nucleon, more stable the nucleus is

Mass Defect and Binding Energy

(1) **Mass defect (Δm) :** It is found that the mass of a nucleus is always less than the sum of masses of it's constituent nucleons in free state. This difference in masses is called mass defect. Hence mass defect

Δm = Sum of masses of nucleons – Mass of nucleus

$$= \{Zm_p + (A-Z)m_n\} - M = \{Zm_p + Zm_e + (A-Z)m_z\} - M'$$

where m_p = Mass of proton, m_n = Mass of each neutron, m_e = Mass of each electron

M = Mass of nucleus, Z = Atomic number, A = Mass number, M' = Mass of atom as a whole.

(2) **Packing fraction :** Mass defect per nucleon is called packing fraction

Packing fraction $(f) = \frac{\Delta m}{A} = \frac{M - A}{A}$ where M = Mass of nucleus, A = Mass number

Packing fraction measures the stability of a nucleus. Smaller the value of packing fraction, larger is the stability of the nucleus.

(i) Packing fraction may be of positive, negative or zero value.

(ii) At A = 16, $f \to$ Zero

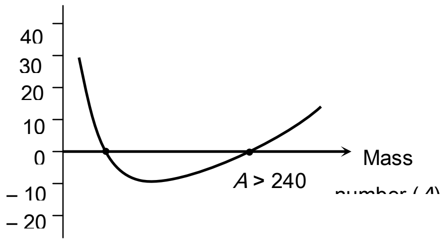


Fig. 26.16

(3) **Binding energy (B.E.) :** The neutrons and protons in a stable nucleus are held together by nuclear forces and energy is needed to pull them infinitely apart (or the same energy is released during the formation of the nucleus). This energy is called the binding energy of the nucleus.

or

The binding energy of a nucleus may be defined as the energy equivalent to the mass defect of the nucleus.

If Δm is mass defect then according to Einstein's mass energy relation

Binding energy = $\Delta m \cdot c^2 = [\{m_p Z + m_n(A - Z)\} - M] \cdot c^2$

(This binding energy is expressed in *joule*, because Δm is measured in *kg*)

If Δm is measured in *amu* then binding energy = Δm *amu* = $[\{m_p Z + m_n(A - Z)\} - M]$ *amu* = $\Delta m \times 931$ *MeV*

(4) **Binding energy per nucleon :** The average energy required to release a nucleon from the nucleus is called binding energy per nucleon.

Binding energy per nucleon

$$= \frac{\text{Total binding energy}}{\text{Mass number } (i.e. \text{ total number of nucleons})} = \frac{\Delta m \times 931}{A} \frac{MeV}{Nucleon}$$

Binding energy per nucleon $\propto$ Stability of nucleus

Binding Energy Curve

It is the graph between binding energy per nucleon and total number of nucleons (*i.e.* mass number *A*)

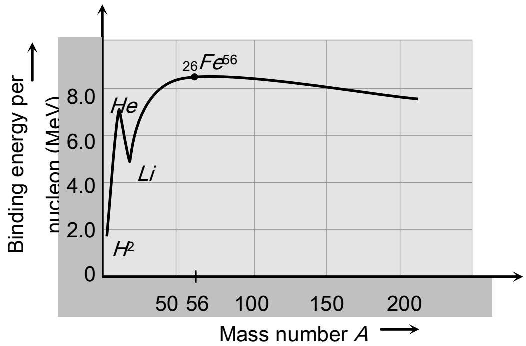


Fig. 26.17

(1) Some nuclei with mass number A < 20 have large binding energy per nucleon than their neighbour nuclei. For example $_2He^4$, $_4Be^8$, $_6C^{12}$, $_8O^{16}$ and $_{10}Ne^{20}$. These nuclei are more stable than their neighbours.

(2) The binding energy per nucleon is maximum for nuclei of mass number A = 56 ($_{26}Fe^{56}$). It's value is 8.8 *MeV* per nucleon.

(3) For nuclei having A > 56, binding energy per nucleon gradually decreases for uranium (A = 238), the value of binding energy per nucleon drops to 7.5 *MeV*.

Nuclear Reactions

The process by which the identity of a nucleus is changed when it is bombarded by an energetic particle is called nuclear reaction. The general expression for the nuclear reaction is as follows.

$$\underset{\text{(Parent nucleus)}}{X} + \underset{\text{(Incident particle)}}{a} \longrightarrow$$

$$\underset{\text{(Compound nucleus)}}{C} \longrightarrow \underset{\text{(Compound nucleus)}}{Y} + \underset{\text{(Product particles)}}{b} + \underset{\text{(Energy)}}{Q}$$

Here *X* and *a* are known as reactants and *Y* and *b* are known as products. This reaction is known as (*a*, *b*) reaction and can be represented as *X*(*a*, *b*) *Y*

(1) **Q value or energy of nuclear reaction :** The energy absorbed or released during nuclear reaction is known as *Q*-value of nuclear reaction.

Q-value = (Mass of reactants – mass of products)c^2 *Joules*

= (Mass of reactants – mass of products) *amu*

If $Q < 0$, The nuclear reaction is known as endothermic. (The energy is absorbed in the reaction)

If $Q > 0$, The nuclear reaction is known as exothermic (The energy is released in the reaction)

(2) **Law of conservation in nuclear reactions**

(i) Conservation of mass number and charge number : In the following nuclear reaction

$${}_2He^4 + {}_7N^{14} \to {}_8O^{17} + {}_1H^1$$

Mass number (*A*) $\to$ Before the reaction After the reaction

4 +14 = 18 17 + 1 = 18

Charge number (*Z*) $\to$ 2 + 7 = 9 8 + 1 = 9

(ii) Conservation of momentum : Linear momentum/angular momentum of particles before the reaction is equal to the linear/angular momentum of the particles after the reaction. That is $\Sigma p = 0$

(iii) Conservation of energy : Total energy before the reaction is equal to total energy after the reaction. Term *Q* is added to balance the total energy of the reaction.

(3) **Common nuclear reactions :** The nuclear reactions lead to artificial transmutation of nuclei. Rutherford was the first to carry out artificial transmutation of nitrogen to oxygen in the year 1919.

$${}_2He^4 + {}_7N^{14} \to {}_9F^{18} \to {}_8O^{17} + {}_1H^1$$

It is called (α, *p*) reaction. Some other nuclear reactions are given as follows.

(*p*, *n*) reaction $\Rightarrow$ ${}_1H^1 + {}_5B^{11} \to {}_6C^{12} \to {}_6C^{11} + {}_0n^1$

(*p*, α) reaction $\Rightarrow$ ${}_1H^1 + {}_3Li^{11} \to {}_4Be^8 \to {}_2He^4 + {}_2He^4$

(*p*, γ) reaction $\Rightarrow$ ${}_1H^1 + {}_6C^{12} \to {}_7N^{13} \to {}_7N^{13} + \gamma$

(*n*, *p*) reaction $\Rightarrow$ ${}_0n^1 + {}_7N^{14} \to {}_7N^{15} \to {}_6C^{14} + {}_1H^1$

(γ, *n*) reaction $\Rightarrow$ $\gamma + {}_1H^2 \to {}_1H^1 + {}_0n^1$

Nuclear Fission

(1) The process of splitting of a heavy nucleus into two lighter nuclei of comparable masses (after bombardment with a energetic particle) with liberation of energy is called nuclear fission.

(2) The phenomenon of nuclear fission was discovered by scientist Ottohann and F. Strassman and was explained by N. Bohr and J.A. Wheeler on the basis of liquid drop model of nucleus.

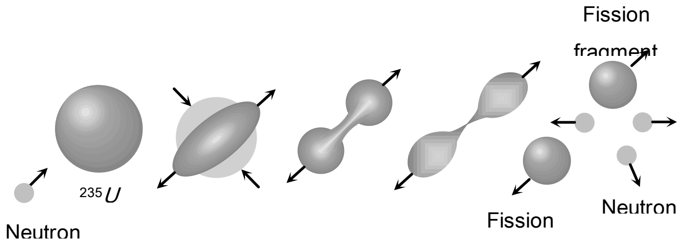


Fig. 26.18

(3) **Fission reaction of U^{235}**

$${}_{92}U^{235} + {}_0n^1 \rightarrow \underset{\text{(unstable nucleus)}}{{}_{92}U^{236}} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + Q$$

(4) The energy released in U^{235} fission is about 200 *MeV* or 0.8 *MeV* per nucleon.

(5) By fission of ${}_{92}U^{235}$, on an average 2.5 neutrons are liberated. These neutrons are called fast neutrons and their energy is about 2 *MeV* (for each). These fast neutrons can escape from the reaction so as to proceed the chain reaction they are need to slow down.

(6) Fission of U^{235} occurs by slow neutrons only (of energy about 1*eV*) or even by thermal neutrons (of energy about 0.025 *eV*).

(7) 50 *kg* of U^{235} on fission will release $\approx 4 \times 10^{15}$ *J* of energy. This is equivalence to 20,000 tones of *TNT* explosion. The nuclear bomb dropped at Hiroshima had this much explosion power.

(8) The mass of the compound nucleus must be greater than the sum of masses of fission products.

(9) The $\frac{\text{Binding energy}}{\text{A}}$ of compound nucleus must be less than that of the fission products.

(10) It may be pointed out that it is not necessary that in each fission of uranium, the two fragments ${}_{56}Ba$ and ${}_{36}Kr$ are formed but they may be any stable isotopes of middle weight atoms.

(11) Same other U^{235} fission reactions are

$${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{54}Xe^{140} + {}_{38}Sr^{94} + 2{}_0n^1$$

$$\rightarrow {}_{57}La^{148} + {}_{35}Br^{85} + 3\,{}_0n^1$$

$\rightarrow$ Many more

(12) The neutrons released during the fission process are called prompt neutrons.

(13) Most of energy released appears in the form of kinetic energy of fission fragments.

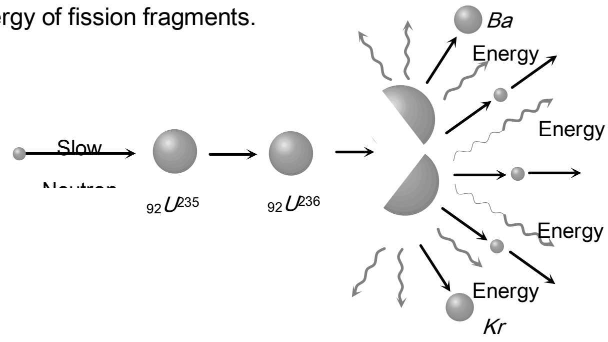


Fig. 26.19

Chain Reaction

In nuclear fission, three neutrons are produced along with the release of large energy. Under favourable conditions, these neutrons can cause further fission of other nuclei, producing large number of neutrons. Thus a chain of nuclear fissions is established which continues until the whole of the uranium is consumed.

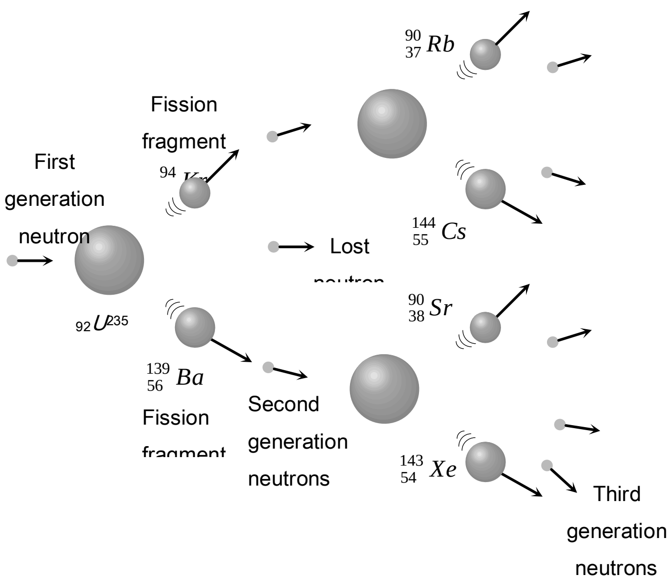


Fig. 26.20

In the chain reaction, the number of nuclei undergoing fission increases very fast. So, the energy produced takes a tremendous magnitude very soon.

Difficulties in Chain Reaction

In chain reaction following difficulties are observed

(1) **Absorption of neutrons by U^{238} :** the major part in natural uranium is the isotope U^{238} (99.3%), the isotope U^{235} is very little (0.7%). It is found that U^{238} is fissionable with fast neutrons, whereas U^{235} is fissionable with slow neutrons. Due to the large percentage of U^{238}, there is more possibility of collision of neutrons with U^{238}. It is found that the neutrons get slowed on coliding with U^{238}, as a result of it further fission of U^{238} is not possible (Because they are slow and they are absorbed by U^{238}). This stops the chain reaction.

Removal : (i) To sustain chain reaction $_{92}U^{235}$ is separated from the ordinary uranium. Uranium so obtained $\left({}_{92}U^{235}\right)$ is known as enriched uranium, which is fissionable with the fast and slow neutrons and hence chain reaction can be sustained.

(ii) If neutrons are slowed down by any method to an energy of about 0.3 *eV*, then the probability of their absorption by U^{238} becomes very low, while the probability of their fissioning U^{235} becomes high. This job is done by moderators. Which reduce the speed of neutron rapidly graphite and heavy water are the example of moderators.

(2) **Critical size :** The neutrons emitted during fission are very fast and they travel a large distance before being slowed down. If the size of the fissionable material is small, the neutrons emitted will escape the fissionable material before they are slowed down. Hence chain reaction cannot be sustained.

Removal : The size of the fissionable material should be large than a critical size.

The chain reaction once started will remain steady, accelerate or retard depending upon, a factor called neutron reproduction factor (*k*). It is defined as follows.

$$k = \frac{\text{Rate of production of neutrons}}{\text{Rate of loss of neutrons}}$$

If $k = 1$, the chain reaction will be steady. The size of the fissionable material used is said to be the critical size and it's mass, the critical mass.

If $k > 1$, the chain reaction accelerates, resulting in an explosion. The size of the material in this case is super critical. (Atom bomb)

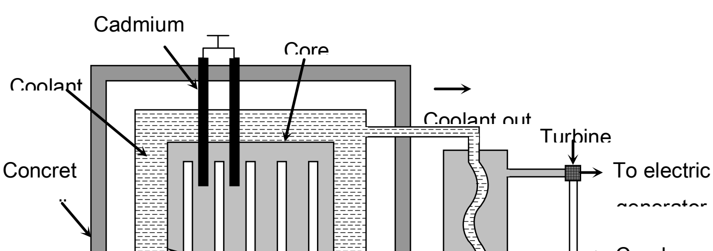
If $k < 1$, the chain reaction gradually comes to a halt. The size of the material used us said to be sub-critical.

Table 26.6 : Types of chain reaction

Controlled chain reaction	Uncontrolled chain reaction
Controlled by artificial method	No control over this type of nuclear reaction
All neurons are absorbed except one	More than one neutron takes part into reaction
It's rate is slow	Fast rate
Reproduction factor $k = 1$	Reproduction factor $k > 1$
Energy liberated in this type of reaction is always less than explosive energy	A large amount of energy is liberated in this type of reaction
Chain reaction is the principle of nuclear reactors	Uncontrolled chain reaction is the principle of atom bomb.

Nuclear Reactor

A nuclear reactor is a device in which nuclear fission can be carried out through a sustained and a controlled chain reaction. It is also called an atomic pile. It is thus a source of controlled energy which is utilised for many useful purposes.



(1) **Fissionable material (Fuel) :** The fissionable material used in the reactor is called the fuel of the reactor. Uranium isotope (U^{235}) Thorium isotope (Th^{232}) and Plutonium isotopes (Pu^{239}, Pu^{240} and Pu^{241}) are the most commonly used fuels in the reactor.

(2) **Moderator :** Moderator is used to slow down the fast moving neutrons. Most commonly used moderators are graphite and heavy water (D_2O).

(3) **Control Material :** Control material is used to control the chain reaction and to maintain a stable rate of reaction. This material controls the number of neutrons available for the fission. For example, cadmium rods are inserted into the core of the reactor because they can absorb the neutrons. The neutrons available for fission are controlled by moving the cadmium rods in or out of the core of the reactor.

(4) **Coolant :** Coolant is a cooling material which removes the heat generated due to fission in the reactor. Commonly used coolants are water, CO_2 nitrogen *etc.*

(5) **Protective shield :** A protective shield in the form a concrete thick wall surrounds the core of the reactor to save the persons working around the reactor from the hazardous radiations.

(6) **Uses of nuclear reactor**

(i) In electric power generation.

(ii) To produce radioactive isotopes for their use in medical science, agriculture and industry.

(iii) In manufacturing of Pu^{239} which is used in atom bomb.

(iv) They are used to produce neutron beam of high intensity which is used in the treatment of cancer and nuclear research.

Nuclear Fusion

(1) In nuclear fusion two or more than two lighter nuclei combine to form a single heavy nucleus. The mass of single nucleus so formed is less than the sum of the masses of parent nuclei. This difference in mass results in the release of tremendous amount of energy

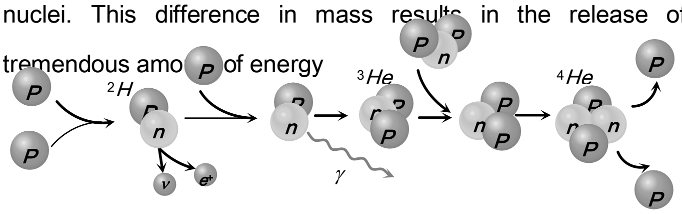


Fig. 26.22

(2) For fusion high pressure (≈ 10^6 *atm*) and high temperature (of the order of 10^7 *K* to 10^8 *K*) is required and so the reaction is called thermonuclear reaction.

(3) Here are three examples of energy-liberating fusion reactions, written in terms of the neutral atoms. Together the reactions make up the process called the proton-proton chain.

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + \beta^+ + \nu_e$$

$${}_1^2H + {}_1^1H \rightarrow {}_2^3He + \gamma$$

$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1H + {}_1^1H$$

$$4\ {}_1H^1 \rightarrow {}_2He^4 + 2\,\beta^+ + 2\gamma + 26.73\ MeV$$

(4) The proton-proton chain takes place in the interior of the sun and other stars. Each gram of the suns mass contains about 4.5 × 10^{23} protons. If all of these protons were fused into helium, the energy released would be about 130,000 *kWh*. If the sun were to continue to radiate at its present rate, it would take about $75\times10^{9}\ years$ to exhaust its supply of protons.

(5) For the same mass of the fuel, the energy released in fusion is much larger than in fission.

(6) **Plasma :** The temperature of the order of 10^8 *K* required for thermonuclear reactions leads to the complete ionisation of the atom of light elements. The combination of base nuclei and electron cloud is called plasma. The enormous gravitational field of the sun confines the plasma in the interior of the sun.

The main problem to carryout nuclear fusion in the laboratory is to contain the plasma at a temperature of 10^8K. No solid container can tolerate this much temperature. If this problem of containing plasma is solved, then the large quantity of deuterium present in sea water would be able to serve as in-exhaustible source of energy.

Table 26.7 : Nuclear bomb (Based on uncontrolled nuclear reactions)

Atom bomb	Hydrogen bomb
Based on fission process it involves the fission of U^{235}	Based on fusion process. Mixture of deutron and tritium is used in it
In this critical size is important	There is no limit to critical size
Explosion is possible at normal temperature and pressure	High temperature and pressure are required
Less energy is released compared to hydrogen bomb	More energy is released as compared to atom bomb so it is more dangerous than atom bomb

Radioactivity

The phenomenon of spontaneous emission of radiatons by heavy elements is called radioactivity. The elements which shows this phenomenon are called radioactive elements.

(1) Radioactivity was discovered by Henery Becquerel in uranium salt in the year 1896.

(2) After the discovery of radioactivity in uranium, Piere Curie and Madame Curie discovered a new radioactive element called radium (which is 10^6 times more radioactive than uranium)

(3) Some examples of radio active substances are : Uranium, Radium, Thorium, Polonium, Neptunium *etc.*

(4) Radioactivity of a sample cannot be controlled by any physical (pressure, temperature, electric or magnetic field) or chemical changes.

(5) All the elements with atomic number (Z) > 82 are naturally radioactive.

(6) The conversion of lighter elements into radioactive elements by the bombardment of fast moving particles is called artificial or induced radioactivity.

(7) Radioactivity is a nuclear event and not atomic. Hence electronic configuration of atom don't have any relationship with radioactivity.

Nuclear Radiations

According to Rutherford's experiment when a sample of radioactive substance is put in a lead box and allow the emission of radiation through a small hole only. When the radiation enters into the external electric field, they splits into three parts (α-rays, β-rays and γ-rays)

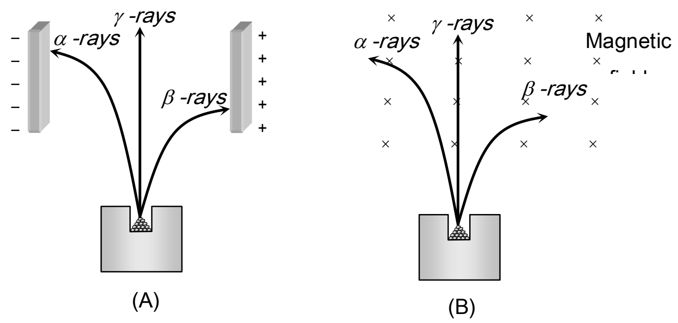


Fig. 26.23

(1) **α-decay** : Nearly 90% of the 2500 known nuclides are radioactive ; they are not stable but decay into other nuclides

(i) When unstable nuclides decay into different nuclides, they usually emit alpha (α) or beta (β) particles.

(ii) Alpha emission occurs principally with nuclei that are too large to be stable. When a nucleus emits an alpha particle, its *N* and *Z* values each decrease by two and *A* decreases by four.

(iii) Alpha decay is possible whenever the mass of the original neutral atom is greater than the sum of the masses of the final neutral atom and the neutral helium- atom.

(2) **β-decay** : There are different simple type of β-decay β^-, β^+ and electron capture.

(i) A beta minus particle (β^-) is an electron. Emission of β^- involves transformation of a neutron into a proton, an electron and a third particle called an antineutrino ($\bar{\nu}$).

(ii) β^- decay usually occurs with nuclides for which the neutron to proton ratio $\left(\frac{N}{Z} ratio\right)$ is too large for stability.

(iii) In β^- decay, *N* decreases by one, *Z* increases by one and *A* doesn't change.

(iv) β^- decay can occur whenever the neutral atomic mass of the original atom is larger than that of the final atom.

(v) Nuclides for which *N*/*Z* is too small for stability can emit a positron, the electron's antiparticle, which is identical to the electron but with positive charge. The basic process called beta plus β^+ decay

$p \rightarrow n + \beta^+ + \nu$ (ν = neutrino)

(vi) β^+ decay can occur whenever the neutral atomic mass of the original atom is at least two electron masses larger than that of the final atom

(vii) The mass of ν and $\bar{\nu}$ is zero. The spin of both is $\frac{1}{2}$ in units of $\frac{h}{2\pi}$. The charge on both is zero. The spin of neutrino is antiparallel to it's momentum while that of antineutrino is parallel to it's momentum.

(viii) There are a few nuclides for which β^+ emission is not energetically possible but in which an orbital electron (usually in the *k*-shell) can combine with a proton in the nucleus to form a neutron and a neutrino. The neutron remains in the nucleus and the neutrino is emitted.

$p + \beta^+ \rightarrow n + \nu$

(3) **γ-decay** : The energy of internal motion of a nucleus is quantized. A typical nucleus has a set of allowed energy levels, including a *ground state* (state of lowest energy) and several excited states. Because of the great strength of nuclear interactions, excitation energies of nuclei are typically of the order of the order of 1 *MeV*, compared with a few *eV* for atomic energy levels. In ordinary physical and chemical transformations the nucleus always remains in its ground state. When a nucleus is placed in an excited state, either by bombardment with high-energy particles or by a radioactive transformation, it can decay to the ground state by emission of one or more photons called gamma rays or gamma-ray photons, with typical energies of 10 *keV* to 5 *MeV*. This process is called gamma (γ) decay.

All the known conservation laws are obeyed in γ-decay.

The intensity of γ-decay after passing through *x* thickness of a material is given by $I = I_0 e^{-\mu x}$ (μ = absorption co-efficient)

Radioactive Disintegration

(1) **Law of radioactive disintegration :** According to Rutherford and Soddy law for radioactive decay is as follows.

"At any instant the rate of decay of radioactive atoms is proportional to the number of atoms present at that instant" *i.e.*

$-\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$. It can be proved that $N = N_0 e^{-\lambda t}$

In terms of mass $M = M_0 e^{-\lambda t}$

where *N* = Number of atoms remains undecayed after time *t*, N_0 = Number of atoms present initially (*i.e.* at *t* = 0), *M* = Mass of radioactive nuclei at time *t*, M_0 = Mass of radioactive nuclei at time *t* = 0, $N_0 - N$ = Number of disintegrated nucleus in time *t*

$\frac{dN}{dt}$ = rate of decay, λ = Decay constant or disintegration constant or radioactivity constant or Rutherford Soddy's constant or the probability of decay per unit time of a nucleus.

Table 26.8 : Properties of α, β and γ-rays

Features	α- particles	β - particles	γ - rays
1. Identity	Helium nucleus or doubly ionised helium atom ($_2He^4$)	Fast moving electron $(-\beta^0 \text{ or } \beta^-)$	Photons (E.M. waves)
2. Charge	+ 2*e*	– *e*	Zero
3. Mass 4 m_p (m_p = mass of proton = 1.87 × 10^{-27}	4 m_p	m_e	Massless
4. Speed	≈ 10^7 *m/s*	1% to 99% of speed of light	Speed of light
5. Range of kinetic energy	4 *MeV* to 9 *MeV*	All possible values between a minimum certain value to 1.2 *MeV*	Between a minimum value to 2.23 *MeV*
6. Penetration power (γ, β, α)	1 (Stopped by a paper)	100 (100 times of α)	10,000 (100 times of β upto 30 *cm* of iron (or *Pb*) sheet
7. Ionisation power ($\alpha > \beta > \gamma$)	10,000	100	1
8. Effect of electric or magnetic field	Deflected	Deflected	Not deflected
9. Energy spectrum	Line and discrete	Continuous	Line and discrete
10. Mutual interaction with matter	Produces heat	Produces heat	Produces, photo-electric effect, Compton effect, pair production
11. Equation of decay	$_ZX^A \xrightarrow{\alpha-decay} {}_{Z-2}Y^{A-4} + {}_2He^4$ $_ZX^A \xrightarrow{n\alpha} {}_{Z'}Y^{A'}$ $\Rightarrow \boldsymbol{n_\alpha = \frac{A-A'}{4}}$	$_ZX^A \rightarrow {}_{Z+1}Y^A + {}_{-1}e^0 + \bar{\nu}$ $_ZX^A \xrightarrow{n\beta} {}_{Z'}X^A$ $\Rightarrow \boldsymbol{n_\beta = (2n_\alpha - Z + Z')}$	$_ZX^A \rightarrow {}_ZX^a + \gamma$

(2) **Activity :** It is defined as the rate of disintegration (or count rate) of the substance (or the number of atoms of any material decaying per second) *i.e.*

$$A = -\frac{dN}{dt} = \lambda N = \lambda N_0 e^{-\lambda t} = A_0 e^{-\lambda t}$$

where A_0 = Activity of t = 0, A = Activity after time t

Units of activity (Radioactivity)

It's units are *Becqueral* (*Bq*), Curie (*Ci*) and Rutherford (*Rd*)

1 *Becquerel* = 1 *disintegration/sec*,

1 *Rutherford* = 10^6 *dis/sec*, 1 *Curie* = 3.7×10^{11} *dis/sec*

(3) **Half life ($T_{1/2}$)** : Time interval in which the mass of a radioactive substance or the number of it's atom reduces to half of it's initial value is called the half life of the substance.

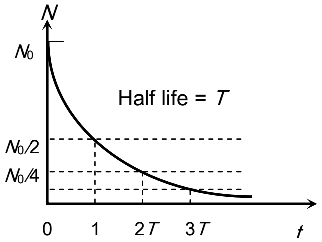


Fig. 26.24

i.e. if $N = \frac{N_0}{2}$

then $t = T_{1/2}$

Hence from $N = N_0 e^{-\lambda t}$

$$\frac{N_0}{2} = N_0 e^{-\lambda (T_{1/2})} \Rightarrow T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{0.693}{\lambda}$$

Table 26.9 : Fraction of active/decayed atom at different time

Time (*t*)	Remaining fraction of active atoms (N/N_0) probability of survival	Fraction of atoms decayed $(N_0 - N)/N_0$ probability of decay
$t = 0$	1 (100%)	0
$t = T_{1/2}$	$\frac{1}{2}$ (50%)	$\frac{1}{2}$ (50%)
$t = 2(T_{1/2})$	$\frac{1}{4}$ (25%)	$\frac{3}{4}$ (75%)
$t = 3(T_{1/2})$	$\frac{1}{8}$ (12.5%)	$\frac{7}{8}$ (87.5%)
$t = 10\ (T_{1/2})$	$\left(\frac{1}{2}\right)^{10} \approx 0.1\%$	$\approx 99.9\%$
$t = n\ (N_{1/2})$	$\left(\frac{1}{2}\right)^n$	$\left\{1 - \left(\frac{1}{2}\right)^n\right\}$

(4) **Mean (or average) life (τ)** : The time for which a radioactive material remains active is defined as mean (average) life of that material.

(i) or it is defined as the sum of lives of all atoms divided by the total number of atoms

i.e. $$\tau = \frac{\text{Sum of the lives of all the atoms}}{\text{Total number of atoms}} = \frac{1}{\lambda}$$

(ii) From $N = N_0 e^{-\lambda t} \Rightarrow \frac{\ln \frac{N}{N_0}}{t} = -\lambda$ slope of the line shown in the graph *i.e.* the magnitude of inverse of slope of $\ln \frac{N}{N_0}$ *vs* t curve is known as mean life (τ).

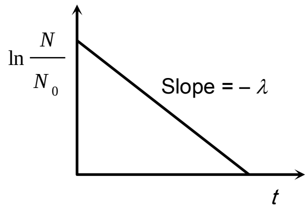


Fig. 26.25

(iii) From $N = N_0 e^{-\lambda t}$, if $t = \frac{1}{\lambda} = \tau$

$$\Rightarrow N = N_0 e^{-1} = N_0 \left(\frac{1}{e}\right) = 0.37 N_0 = 37\% \text{ of } N_0.$$

i.e. mean life is the time interval in which number of undecayed atoms (*N*) becomes $\frac{1}{e}$ times or 0.37 times or 37% of original number of atoms. or

It is the time in which number of decayed atoms ($N_0 - N$) becomes $\left(1 - \frac{1}{e}\right)$ times or 0.63 times or 63% of original number of atoms.

(iv) From $T_{1/2} = \frac{0.693}{\lambda} \Rightarrow \frac{1}{\lambda} = \tau = \frac{1}{0.693}.(t_{1/2}) = 1.44 (T_{1/2})$

i.e. mean life is about 44% more than that of half life. Which gives us $\tau > T_{(1/2)}$

Radioactive Series

(1) If the isotope that results from a radioactive decay is itself radioactive then it will also decay and so on.

(2) The sequence of decays is known as radioactive decay series. Most of the radio-nuclides found in nature are members of four radioactive series. These are as follows

Table 26.10 : Four radioactive series

Mass number	Series (Nature)	Parent	Stable end product	Integer *n*
4*n*	Thorium (natural)	$_{90}Th^{232}$	$_{82}Pb^{208}$	52
4*n* + 1	Neptunium	$_{93}Np^{237}$	$_{83}Bi^{209}$	52

	(Artificial)			
$4n + 2$	Uranium (Natural)	$_{92}U^{238}$	$_{82}Pb^{206}$	51
$4n + 3$	Actinium (Natural)	$_{89}Ac^{227}$	$_{82}Pb^{207}$	51

(3) The $4n + 1$ series starts from $_{94}Pu^{241}$ but commonly known as neptunium series because neptunium is the longest lived member of the series.

(4) The $4n + 3$ series actually starts from $_{92}U^{235}$.

Successive Disintegration and Radioactive Equilibrium

Suppose a radioactive element *A* disintegrates to form another radioactive element *B* which intern disintegrates to still another element *C*; such decays are called successive disintegration.

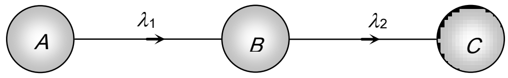


Fig. 26.26

Rate of disintegration of $A = \frac{dN_1}{dt} = -\lambda_1 N_1$ (which is also the rate of formation of *B*)

Rate of disintegration of $B = \frac{dN_2}{dt} = -\lambda_2 N_2$

$\therefore$ Net rate of formation of *B* = Rate of disintegration of *A* – Rate of disintegration of *B*

$$= \lambda_1 N_1 - \lambda_2 N_2$$

Equilibrium

In radioactive equilibrium, the rate of decay of any radioactive product is just equal to it's rate of production from the previous member.

i.e. $\lambda_1 N_1 = \lambda_2 N_2 \Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{N_2}{N_2} = \frac{\tau_2}{\tau_1} = \frac{(T_{1/2})}{(T_{1/2})_1}$

Uses of Radioactive Isotopes

(1) **In medicine**

(i) For testing blood-chromium - 51

(ii) For testing blood circulation - *Na* - 24

(iii) For detecting brain tumor- Radio mercury - 203

(iv) For detecting fault in thyroid gland - Radio iodine - 131

(v) For cancer - cobalt - 60

(vi) For blood - Gold - 189

(vii) For skin diseases - Phospohorous - 31

(2) **In Archaeology**

(i) For determining age of archaeological sample (carbon dating) C^{14}

(ii) For determining age of meteorites - K^{40}

(iii) For determining age of earth-Lead isotopes

(3) **In agriculture**

(i) For protecting potato crop from earthworm- CO^{60}

(ii) For artificial rains - *AgI* (iii) As fertilizers - P^{32}

(4) **As tracers** - (Tracer) : Very small quantity of radioisotopes present in a mixture is known as tracer

(i) Tracer technique is used for studying biochemical reaction in tracer and animals.

(5) **In industries**

(i) For detecting leakage in oil or water pipe lines (ii) For determining the age of planets.

Tips & Tricks

✍ According to Bohr theory the momentum of an e^- revolving in second orbit of H_2 atom will be $\frac{h}{\pi}$

✍ For an electron in the n^{th} orbit of hydrogen atom in Bohr model, circumference of orbit $= n\lambda$; where λ = de-Broglie wavelength.

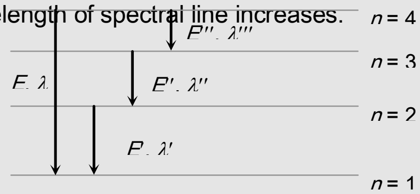
✍ *Rch* = Rydberg's energy $\simeq 2.17 \times 10^{-18}\, J \simeq 13.6\, eV$.

✍ For hydrogen atom principle quantum number $n = \sqrt{\frac{13.6}{(\text{B.E.})}}$.

✍ In an H_2 atom when e^- makes a transition from an excited state to the ground state it's kinetic energy increases while potential and total energy decreases.

✍ The maximum number of electrons in a subshell with orbital quantum number *l* is 2(2*l* + 1).

✍ With the increase in principal quantum number the energy difference between the two successive energy level decreases, while wavelength of spectral line increases.



$E' > E'' > E'''$

$\lambda' < \lambda'' < \lambda'''$

$E = E' + E'' + E'''$

$$\frac{1}{\lambda} = \frac{1}{\lambda'} + \frac{1}{\lambda''} + \frac{1}{\lambda'''}$$

✍ **Rydberg constant is different for different elements**

R(=1.09 × 10^7 m^{-1}) is the value of Rydberg constant when the nucleus is considered to be infinitely massive as compared to the revolving electron. In other words, the nucleus is considered to be stationary.

In case, the nucleus is not infinitely massive or stationary, then the value of Rydberg constant is given as $R' = \frac{R}{1 + \frac{m}{M}}$ where m is the mass of electron and *M* is the mass of nucleus.

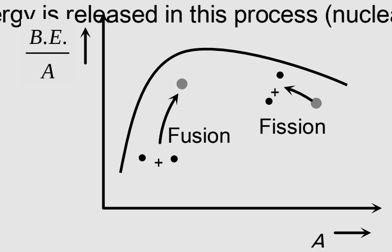
✍ **Atomic spectrum is a line spectrum**

Each atom has it's own characteristic allowed orbits depending upon the electronic configuration. Therefore photons emitted during transition of electrons from one allowed orbit to inner allowed orbit are of some definite energy only. They do not have a continuous graduation of energy. Therefore the spectrum of the emitted light has only some definite lines and therefore atomic spectrum is line spectrum.

✍ Just as dots of light of only three colours combine to form almost every conceivable colour on T.V. screen, only about 100 distinct kinds of atoms combine to form all the materials in the universe.

✍ Density of a nucleus is maximum at it's centre and decreases as we move outwards from the nucleus.

✍ When two very light nuclei combines to form a relatively heavy nucleus, then binding energy per nucleon increases. Thus, energy is released in this process (nuclear fusion).



✍ It may be noted that Plutonium is the best fuel as compared to other fissionable material. It is because fission in Plutonium can be initiated by both slow and fast neutrons. Moreover it can be obtained from U^{238}.

✍ Nuclear reactor is firstly devised by fermi.

✍ Apsara was the first Indian nuclear reactor.

✍ A type of reactor that can produce more fissile fuel than it consumes is the breeder reactor.

✍ To achieve fusion in laboratory a device is used to confine the plasma, called **Tokamak**.

✍ A test tube full of base nuclei will weight heavier than the earth.

✍ The nucleus of hydrogen contains only one proton. Therefore we may say that the proton is the nucleus of hydrogen atom.

✍ If the relative abundance of isotopes in an element has a ratio $n_1 : n_2$ whose atomic masses are m_1 and m_2 then atomic mass of the element is $M = \frac{n_1 m_1 + n_2 m_2}{n_1 + n_2}$

✍ No radioactive substance emits both α and β particles simultaneously. Also γ-rays are emitted after the emission of α or β-particles.

✍ β-particles are not orbital electrons they come from nucleus. The neutron in the nucleus decays into proton and an electron. This electron is emitted out of the nucleus in the form of β-rays.

✍ Activity per *gm* of a substance is known as specific activity. The specific activity of 1 *gm* of radium – 226 is 1 *Curie*.

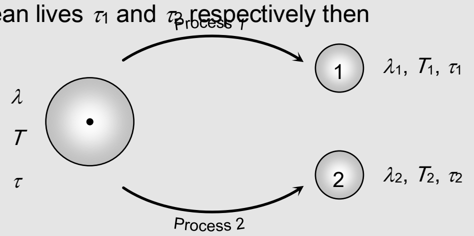
✍ 1 *millicurie* = 37 *Rutherford*

✍ The activity of a radioactive substance decreases as the number of undecayed nuclei decreases with time.

✍ $\text{Activity} \propto \frac{1}{\text{Half life}}$

✍ Half life and mean life of a substance doesn't change with time or with pressure, temperature *etc*.

✍ If a nuclide can decay simultaneously by two different process which have decay constant λ_1 and λ_2, half life T_1 and T_2 and mean lives τ_1 and τ_2 respectively then



$\Rightarrow \lambda = \lambda_1 + \lambda_2$ $\Rightarrow T = \frac{T_1 T_2}{T_1 + T_2}$

✍ There are at least three varieties of neutranas, each with it's corresponding antineutrino; one is associated with beta decay and the other two are associated with the decay of two unstable particles, the muon and the tau particles.

✍ Are all fusion reaction exoergic ?

Fusion reaction between sufficiently light nuclei are exoergic because the $\frac{B.E.}{A}$ increases. If the nuclei are too massive, however $\frac{B.E.}{A}$ decreases and fusion is endoergic (*i.e.* it takes in energy rather than releasing it)

✍ The Zeeman effect is the spliting of atomic energy levels and the associated spectrum lines when the atoms are placed in a magnetic field. This effect confirms experimentally the quantization of angular momentum.

Ordinary Thinking

Objective Questions

Atomic Structure

1. If in nature there may not be an element for which the principal quantum number $n > 4$, then the total possible number of elements will be [IIT 1983; MP PET 1999; RPMT 1999; RPET 2001]
   (a) 60 (b) 32
   (c) 4 (d) 64

2. In the Bohr's hydrogen atom model, the radius of the stationary orbit is directly proportional to (n = principle quantum number) [MNR 1988; SCRA 1994; CBSE PMT 1996; AIIMS 1999; DCE 2002]
   (a) n^{-1} (b) n
   (c) n^{-2} (d) n^2

3. In the n orbit, the energy of an electron $E_n = -\frac{13.6}{n^2} eV$ for hydrogen atom. The energy required to take the electron from first orbit to second orbit will be [MP PMT 1987; CPMT 1991, 97; RPMT 1999; DCE 2001; Kerala PMT 2004]
   (a) $10.2\ eV$ (b) $12.1\ eV$
   (c) $13.6\ eV$ (d) $3.4\ eV$

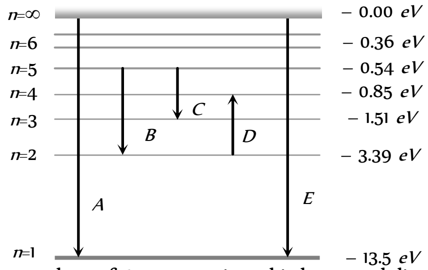
4. In the following atoms and molecules for the transition from $n = 2$ to $n = 1$, the spectral line of minimum wavelength will be produced by [IIT 1983]
   (a) Hydrogen atom (b) Deuterium atom
   (c) Uni-ionized helium (d) di-ionized lithium

5. The Lyman series of hydrogen spectrum lies in the region [MNR 1993; MP PMT 1995; UPSEAT 2002]
   (a) Infrared (b) Visible
   (c) Ultraviolet (d) Of $X-$ rays

6. The size of an atom is of the order of [CPMT 1990; MP PMT 1984; KCET 1994]
   (a) $10^{-8} m$ (b) $10^{-10} m$
   (c) $10^{-12} m$ (d) $10^{-14} m$

7. Which one of the series of hydrogen spectrum is in the visible region [RPMT 1999;MP PET 1990; MP PMT 1994; AFMC 1998; CBSE PMT 1990; MH CET 2004]
   (a) Lyman series (b) Balmer series
   (c) Paschen series (d) Bracket series

8. The energy levels of the hydrogen spectrum is shown in figure. There are some transitions A, B, C, D and E. Transition A, B and C respectively represent [CPMT 1986, 88]



   (a) First member of Lyman series, third spectral line of Balmer series and the second spectral line of Paschen series
   (b) Ionization potential of hydrogen, second spectral line of Balmer series and third spectral line of Paschen series
   (c) Series limit of Lyman series, third spectral line of Balmer series and second spectral line of Paschen series
   (d) Series limit of Lyman series, second spectral line of Balmer series and third spectral line of Paschen series

9. In the above figure D and E respectively represent [CPMT 1986, 88]
   (a) Absorption line of Balmer series and the ionization potential of hydrogen
   (b) Absorption line of Balmer series and the wavelength lesser than lowest of the Lyman series
   (c) Spectral line of Balmer series and the maximum wavelength of Lyman series
   (d) Spectral line of Lyman series and the absorption of greater wavelength of limiting value of Paschen series

10. The Rutherford α-particle experiment shows that most of the α-particles pass through almost unscattered while some are scattered through large angles. What information does it give about the structure of the atom [AFMC 1997]
    (a) Atom is hollow
    (b) The whole mass of the atom is concentrated in a small centre called nucleus
    (c) Nucleus is positively charged
    (d) All the above

11. Which of the following is true [MP PET 1993]
    (a) Lyman series is a continuous spectrum
    (b) Paschen series is a line spectrum in the infrared
    (c) Balmer series is a line spectrum in the ultraviolet
    (d) The spectral series formula can be derived from the Rutherford model of the hydrogen atom

12. The energy required to knock out the electron in the third orbit of a hydrogen atom is equal to [DPMT 1987]
    (a) $13.6\ eV$ (b) $+\frac{13.6}{9} eV$
    (c) $-\frac{13.6}{3} eV$ (d) $-\frac{3}{13.6} eV$

13. An electron has a mass of $9.1 \times 10^{-31} kg$. It revolves round the nucleus in a circular orbit of radius 0.529×10^{-10} $metre$ at a speed of $2.2 \times 10^6 m/s$. The magnitude of its linear momentum in this motion is

[AFMC 1988]

(a) $1.1\times10^{-34}\,kg-m/s$ (b) $2.0\times10^{-24}\,kg-m/s$

(c) $4.0\times10^{-24}\,kg-m/s$ (d) $4.0\times10^{-31}\,kg-m/s$

14. In a beryllium atom, if a_0 be the radius of the first orbit, then the radius of the second orbit will be in general

[CBSE PMT 1992; Roorkee 1993; BHU 1998]

(a) na_0 (b) a_0

(c) n^2a_0 (d) $\frac{a_0}{n^2}$

15. The ionization potential for second *He* electron is

(a) 13.6 *eV* (b) 27.2 *eV*

(c) 54.4 *eV* (d) 100 *eV*

16. The energy required to remove an electron in a hydrogen atom from $n=10$ state is [MP PMT 1993]

(a) 13.6 *eV* (b) 1.36 *eV*

(c) 0.136 *eV* (d) 0.0136 *eV*

17. Every series of hydrogen spectrum has an upper and lower limit in wavelength. The spectral series which has an upper limit of wavelength equal to 18752 Å is [MP PMT 1993]

(a) Balmer series (b) Lyman series

(c) Paschen series (d) Pfund series

(Rydberg constant $R=1.097\times10^7$ *per metre*)

18. The kinetic energy of the electron in an orbit of radius *r* in hydrogen atom is (*e* = electronic charge) [MP PMT 1987]

(a) $\frac{e^2}{r^2}$ (b) $\frac{e^2}{2r}$

(c) $\frac{e^2}{r}$ (d) $\frac{e^2}{2r^2}$

19. Ionization potential of hydrogen atom is 13.6 *V*.

Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 *eV*. The spectral lines emitted by hydrogen atoms according to Bohr's theory will be

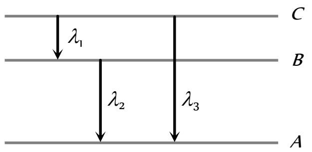
CBSE PMT 1996; MP PMT 1999; AMU (Med.) 2002]

(a) One (b) Two

(c) Three (d) Four

20. Energy levels A, B, C of a certain atom corresponding to increasing values of energy *i.e.* $E_A<E_B<E_C$. If $\lambda_1,\lambda_2,\lambda_3$ are the wavelengths of radiations corresponding to the transitions *C* to *B*, *B* to *A* and *C* to *A* respectively, which of the following statements is correct

[AIIMS 1995; CBSE PMT 1990, 2005]



(a) $\lambda_3=\lambda_1+\lambda_2$ (b) $\lambda_3=\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$

(c) $\lambda_1+\lambda_2+\lambda_3=0$ (d) $\lambda_3^2=\lambda_1^2+\lambda_2^2$

21. The angular momentum of electron in *n* orbit is given by

[Roorkee 1993]

(a) nh (b) $\frac{h}{2\pi n}$

(c) $n\frac{h}{2\pi}$ (d) $n^2\frac{h}{2\pi}$

22. The ratio of the energies of the hydrogen atom in its first to second excited state is [CPMT 1978]

(a) 1/ 4 (b) 4/9

(c) 9/ 4 (d) 4

23. An electron jumps from the 4th orbit to the 2nd orbit of hydrogen atom. Given the Rydberg's constant $R=10^5\,cm^{-1}$. The frequency in *Hz* of the emitted radiation will be

(a) $\frac{3}{16}\times10^5$ (b) $\frac{3}{16}\times10^{15}$

(c) $\frac{9}{16}\times10^{15}$ (d) $\frac{3}{4}\times10^{15}$

24. The ionisation potential of hydrogen atom is 13.6 *volt*. The energy required to remove an electron in the *n* = 2 state of the hydrogen atom is [NCERT 1983; MP PET 2005]

(a) 27.2 *eV* (b) 13.6 *eV*

(c) 6.8 *eV* (d) 3.4 *eV*

25. The ionisation energy of 10 times ionised sodium atom is

[DPMT 1991]

(a) 13.6 *eV* (b) $13.6\times11\,eV$

(c) $\frac{13.6}{11}eV$ (d) $13.6\times(11)^2\,eV$

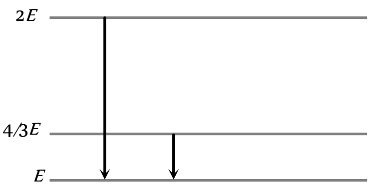
26. If the wavelength of the first line of the Balmer series of hydrogen is $6561\,Å$, the wavelength of the second line of the series should be [CPMT 1984; DPMT 2004]

(a) $13122\,Å$ (b) $3280\,Å$

(c) $4860\,Å$ (d) $2187\,Å$

27. The following diagram indicates the energy levels of a certain atom [CPMT 1990] when the system moves from $2E$ level to *E*, a photon of wavelength λ is emitted. The wavelength of photon produced during its transition from $\frac{4E}{3}$ level to *E* is

[CPMT 1989]

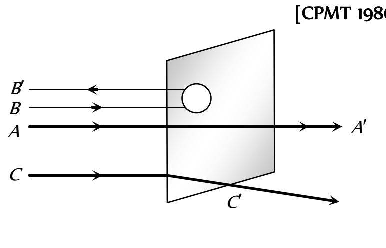


(a) $\lambda/3$ (b) $3\lambda/4$

(c) $4\lambda/3$ (d) 3λ

28. A beam of fast moving alpha particles were directed towards a thin film of gold. The parts A', B' and C' of the transmitted and reflected beams corresponding to the incident parts *A*, *B* and *C* of the beam, are shown in the adjoining diagram. The number of alpha particles in

[CPMT 1986, 88; RPET 2000]



(a) B' will be minimum and in C' maximum

(b) A' will be maximum and in B' minimum

(c) A' will be minimum and in B' maximum

(d) C' will be minimum and in B' maximum

29. According to Bohr's theory the radius of electron in an orbit described by principal quantum number n and atomic number Z is proportional to [CPMT 1988]

(a) Z^2n^2 (b) $\frac{Z^2}{n^2}$

(c) $\frac{Z^2}{n}$ (d) $\frac{n^2}{Z}$

30. The radius of electron's second stationary orbit in Bohr's atom is R. The radius of the third orbit will be

[EAMCET 1992; DPMT 1999]

(a) 3 R (b) 2.25 R

(c) 9 R (d) $\frac{R}{3}$

31. If m is mass of electron, v its velocity, r the radius of stationary circular orbit around a nucleus with charge Ze, then from Bohr's first postulate, the kinetic energy $K = \frac{1}{2}mv^2$ of the electron in *C.G.S.* system is equal to

[NCERT 1977]

(a) $\frac{1}{2}\frac{Ze^2}{r}$ (b) $\frac{1}{2}\frac{Ze^2}{r^2}$

(c) $\frac{Ze^2}{r}$ (d) $\frac{Ze}{r^2}$

32. Consider an electron in the n orbit of a hydrogen atom in the Bohr model. The circumference of the orbit can be expressed in terms of the de Broglie wavelength λ of that electron as

(a) $(0.259)\,n\lambda$ (b) $\sqrt{n}\lambda$

(c) $(13.6)\,\lambda$ (d) $n\lambda$

33. In any Bohr orbit of the hydrogen atom, the ratio of kinetic energy to potential energy of the electron is [MP PET 1994]

(a) 1/2 (b) 2

(c) $-1/2$ (d) -2

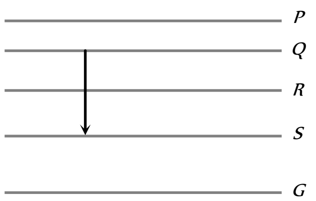
34. The spectral series of the hydrogen spectrum that lies in the ultraviolet region is the

[CPMT 1990; MP PET 1994; MP PMT 2000]

(a) Balmer series (b) Pfund series

(c) Paschen series (d) Lyman series

35. Figure shows the energy levels P, Q, R, S and G of an atom where G is the ground state. A red line in the emission spectrum of the atom can be obtained by an energy level change from Q to S. A blue line can be obtained by following energy level change



(a) P to Q (b) Q to R

(c) R to S (d) R to G

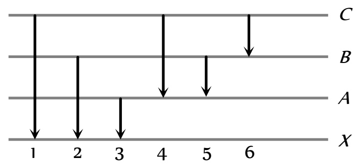
36. A hydrogen atom (ionisation potential 13.6 eV) makes a transition from third excited state to first excited state. The energy of the photon emitted in the process is [MNR 1995]

(a) 1.89 eV (b) 2.55 eV

(c) 12.09 eV (d) 12.75 eV

37. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (*e.g.* line no. 5 arises from the transition from level B to A). The following spectral lines will also occur in the absorption spectrum

[CBSE PMT 1995]



(a) 1, 4, 6 (b) 4, 5, 6

(c) 1, 2, 3 (d) 1, 2, 3, 4, 5, 6

38. When a hydrogen atom is raised from the ground state to an excited state [CBSE PMT 1995; AMU (Med.) 1999]

(a) P.E. increases and K.E. decreases

(b) P.E. decreases and K.E. increases

(c) Both kinetic energy and potential energy increase

(d) Both K.E. and P.E. decrease

39. An electron makes a transition from orbit $n = 4$ to the orbit $n = 2$ of a hydrogen atom. The wave number of the emitted radiations (R = Rydberg's constant) will be [CBSE PMT 1990]

[CBSE PMT 1995]

(a) $\frac{16}{3R}$ (b) $\frac{2R}{16}$

(c) $\frac{3R}{16}$ (d) $\frac{4R}{16}$

40. In Bohr model of the hydrogen atom, the lowest orbit corresponds to [Manipal MEE 1995]

(a) Infinite energy (b) The maximum energy

(c) The minimum energy (d) Zero energy

41. The ratio of the kinetic energy to the total energy of an electron in a Bohr orbit is [Roorkee 1995; BHU 2002]

(a) -1 (b) 2

(c) 1 : 2 (d) None of these

42. An electron in the $n = 1$ orbit of hydrogen atom is bound by 13.6 eV. If a hydrogen atom is in the $n = 3$ state, how much energy is required to ionize it [MP PMT 1995]

[MP PMT 1994]

(a) 13.6 eV (b) 4.53 eV

(c) 3.4 eV (d) 1.51 eV

43. Which of the following statements about the Bohr model of the hydrogen atom is false [MP PMT 1995]
   (a) Acceleration of electron in $n = 2$ orbit is less than that in $n = 1$ orbit
   (b) Angular momentum of electron in $n = 2$ orbit is more than that in $n = 1$ orbit
   (c) Kinetic energy of electron in $n = 2$ orbit is less than that in $n = 1$ orbit
   (d) Potential energy of electron in $n = 2$ orbit is less than that in $n = 1$ orbit

44. If an electron jumps from 1st orbital to 3rd orbital, then it will
   (a) Absorb energy (b) Release energy
   (c) No gain of energy (d) None of these

45. The ratio of the frequencies of the long wavelength limits of Lyman and Balmer series of hydrogen spectrum is [KCEE 1996]
   (a) 27 : 5 (b) 5 : 27
   (c) 4 : 1 (d) 1 : 4

46. Which of the following transitions in a hydrogen atom emits photon of the highest frequency [MP PET 1996; DPMT 2001]
   (a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 1$
   (c) $n = 2$ to $n = 6$ (d) $n = 6$ to $n = 2$

47. In terms of Rydberg's constant R, the wave number of the first Balmer line is [MP PMT 1996]
   (a) R (b) $3R$
   (c) $\frac{5R}{36}$ (d) $\frac{8R}{9}$

48. If the ionisation potential of helium atom is 24.6 *volt*, the energy required to ionise it will be [MP PMT 1996]
   (a) 24.6 eV (b) 24.6 V
   (c) 13.6 V (d) 13.6 eV

49. Which of the transitions in hydrogen atom emits a photon of lowest frequency (n = quantum number) [BHU 1999]
   (a) $n = 2$ to $n = 1$ (b) $n = 4$ to $n = 3$
   (c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 2$

50. According to Bohr's theory, the expressions for the kinetic and potential energy of an electron revolving in an orbit is given respectively by
   (a) $+\frac{e^2}{8\pi\varepsilon_0 r}$ and $-\frac{e^2}{4\pi\varepsilon_0 r}$ (b) $+\frac{8\pi\varepsilon_0 e^2}{r}$ and $-\frac{4\pi\varepsilon_0 e^2}{r}$
   (c) $-\frac{e^2}{8\pi\varepsilon_0 r}$ and $-\frac{e^2}{4\pi\varepsilon_0 r}$ (d) $+\frac{e^2}{8\pi\varepsilon_0 r}$ and $+\frac{e^2}{4\pi\varepsilon_0 r}$

51. In a hydrogen atom, which of the following electronic transitions would involve the maximum energy change [MP PET 1997]
   (a) From $n = 2$ to $n = 1$ (b) From $n = 3$ to $n = 1$
   (c) From $n = 4$ to $n = 2$ (d) From $n = 3$ to $n = 2$

52. In the lowest energy level of hydrogen atom, the electron has the angular momentum [MP PET 1997; BCECE 2003]
   (a) π / h (b) h / π
   (c) $h / 2\pi$ (d) $2\pi / h$

53. The minimum energy required to excite a hydrogen atom from its ground state is [EAMCET (Engg.) 1995; MP PMT 1997; CPMT 1999; DCE 1999]
   (a) 13.6 eV (b) $-13.6\ eV$
   (c) 3.4 eV (d) 10.2 eV

54. Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is [AFMC 1996] [EAMCET (Engg.) 1995; MP PMT 1997]
   (a) 1: 3 (b) 27 : 5
   (c) 5 : 27 (d) 4 : 9

55. The Rydberg constant R for hydrogen is [MP PMT/PET 1998]
   (a) $R = -\left(\frac{1}{4\pi\varepsilon_0}\right).\frac{2\pi^2 me^2}{ch^2}$ (b) $R = \left(\frac{1}{4\pi\varepsilon_0}\right).\frac{2\pi^2 me^4}{ch^2}$
   (c) $R = \left(\frac{1}{4\pi\varepsilon_0}\right)^2.\frac{2\pi^2 me^4}{c^2h^2}$ (d) $R = \left(\frac{1}{4\pi\varepsilon_0}\right)^2.\frac{2\pi^2 me^4}{ch^3}$

56. The wavelength of the first line of Balmer series is $6563\ Å$. The Rydberg constant for hydrogen is about [MP PMT/PET 1998]
   (a) $1.09 \times 10^7\ per\ m$ (b) $1.09 \times 10^8\ per\ m$
   (c) $1.09 \times 10^9\ per\ m$ (d) $1.09 \times 10^5\ per\ m$

57. According to Bohr's theory the moment of momentum of an electron revolving in second orbit of hydrogen atom will be [MP PET 1999; KCET 2003]
   (a) $2\pi h$ (b) πh
   (c) $\frac{h}{\pi}$ (d) $\frac{2h}{\pi}$

58. The velocity of an electron in the second orbit of sodium atom (atomic number = 11) is v. The velocity of an electron in its fifth orbit will be [MP PET 1999]
   (a) v (b) $\frac{22}{5}v$
   (c) $\frac{5}{2}v$ (d) $\frac{2}{5}v$

59. The absorption transitions between the first and the fourth energy states of hydrogen atom are 3. The emission transitions between these states will be [MP PET 1999]
   (a) 3 (b) 4
   (c) 5 (d) 6

60. The ratio of longest wavelength and the shortest wavelength observed in the five spectral series of emission spectrum of hydrogen is [MP PET 1999]
   (a) $\frac{4}{3}$ (b) $\frac{525}{376}$
   (c) 25 (d) $\frac{900}{11}$

61. In the Bohr model of a hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass, e is the charge on the electron and ε_0 is the vacuum permittivity, the speed of the electron is

[CBSE PMT 1998]

(a) 0 (b) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(c) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (d) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

62. The electron in a hydrogen atom makes a transition $n_1 \to n_2$, where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n and n are [IIT 1998; KCET 2005]

(a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$

(c) $n_1 = 8, n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

63. As per Bohr model, the minimum energy (in *eV*) required to remove an electron from the ground state of doubly ionized *Li* atom (*Z* = 3) is [IIT 1997 Re-Exam; MH CET 2000]

(a) 1.51 (b) 13.6

(c) 40.8 (d) 122.4

64. Which one of these is non-divisible [KCET 1994]

(a) Nucleus (b) Photon

(c) Proton (d) Atom

65. In Bohr's model of hydrogen atom, let *PE* represents potential energy and *TE* the total energy. In going to a higher level

(a) *PE* decreases, *TE* increases

(b) *PE* increases, *TE* increases

(c) *PE* decreases, *TE* decreases

(d) *PE* increases, *TE* decreases

66. According to Bohr's model, the radius of the second orbit of helium atom is [Bihar MEE 1995]

(a) 0.53 Å (b) 1.06 Å

(c) 2.12 Å (d) 0.265 Å

67. The fact that photons carry energy was established by

[ISM Dhanbad 1994]

(a) Doppler's effect (b) Compton's effect

(c) Bohr's theory (d) Diffraction of light

68. An ionic atom equivalent to hydrogen atom has wavelength equal to 1/4 of the wavelengths of hydrogen lines. The ion will be

(a) He^+ (b) Li^{++}

(c) Ne^{9+} (d) Na^{10+}

69. The extreme wavelengths of Paschen series are

[RPET 1997]

(a) $0.365\mu m$ and $0.565\mu m$ (b) $0.818\mu m$ and $1.89\mu m$

(c) $1.45\mu m$ and $4.04\mu m$ (d) $2.27\mu m$ and $7.43\mu m$

70. The third line of Balmer series of an ion equivalent to hydrogen atom has wavelength of 108.5 *nm*. The ground state energy of an electron of this ion will be [RPET 1997]

(a) 3.4 *eV* (b) 13.6 *eV*

(c) 54.4 *eV* (d) 122.4 *eV*

71. An electron in the *n* = 1 orbit of hydrogen atom is bound by 13.6 *eV* energy is required to ionize it is [MP PMT 2003]

(a) 13.6 *eV* (b) 6.53 *eV*

(c) 5.4 *eV* (d) 1.51 *eV*

72. Ionization energy of hydrogen is 13.6 *eV*. If $h = 6.6 \times 10^{-34}\ J - sec$, the value of *R* will be of the order of

[RPMT 1997]

(a) $10^{10} m^{-1}$ (b) $10^7 m^{-1}$

(c) $10^4 m^{-1}$ (d) $10^{-7} m^{-1}$

73. To explain his theory, Bohr used

[CBSE PMT 1993; MP PET 2002]

(a) Conservation of linear momentum

(b) Conservation of angular momentum

(c) Conservation of quantum frequency

(d) Conservation of energy

74. The ionisation energy of hydrogen atom is 13.6 *eV*. Following Bohr's theory, the energy corresponding to a transition between the 3rd and the 4th orbit is

[KCET 1994] [CBSE PMT 1992; DPMT 2000; RPMT 1999; AMU (Med.) 2001]

(a) 3.40 *eV* (b) 1.51 *eV*

(c) 0.85 *eV* (d) 0.66 *eV*

75. Hydrogen atoms are excited from ground state of the principal quantum number 4. Then the number of spectral lines observed will be [CBSE PMT 1993]

(a) 3 (b) 6

(c) 5 (d) 2

76. Hydrogen atom emits blue light when it changes from *n* = 4 energy level to the *n* = 2 level. Which colour of light would the atom emit when it changes from the *n* = 5 level to the *n* = 2 level

(a) Red (b) Yellow

(c) Green (d) Violet

77. In Rutherford scattering experiment, what will be the correct angle for α scattering for an impact parameter *b* = 0

[RPET 1997] [CBSE PMT 1994; JIPMER 2000]

(a) 90^o (b) 270^o

(c) 0^o (d) 180^o

78. The radius of hydrogen atom in its ground state is $5.3 \times 10^{-11} m$. After collision with an electron it is found to have a radius of

$21.2 \times 10^{-11} m$. What is the principal quantum number n of the final state of the atom

[CBSE PMT 1994; CPMT 2001; MH CET 2000]

(a) $n = 4$ (b) $n = 2$

(c) $n = 16$ (d) $n = 3$

79. The splitting of line into groups under the effect of electric or magnetic field is called [AFMC 1995]

(a) Zeeman's effect (b) Bohr's effect

(c) Heisenberg's effect (d) Magnetic effect

80. The energy of a hydrogen atom in its ground state is $-13.6\ eV$. The energy of the level corresponding to the quantum number $n = 2$ (first excited state) in the hydrogen atom is [CBSE PMT 1996; CBSE PMT 1997, 2001; MP PET 2000; AFMC 2000, 01, 02; BCECE 2003]

(a) – 2.72 eV (b) – 0.85 eV

(c) – 0.54 eV (d) – 3.4 eV

81. The first line of Balmer series has wavelength 6563 Å. What will be the wavelength of the first member of Lyman series

[RPMT 1996]

(a) 1215.4 Å (b) 2500 Å

(c) 7500 Å (d) 600 Å

82. The wavelength of Lyman series is [BHU 1997]

(a) $\frac{4}{3 \times 10967} cm$ (b) $\frac{3}{4 \times 10967} cm$

(c) $\frac{4 \times 10967}{3} cm$ (d) $\frac{3}{4} \times 10967\ cm$

83. When hydrogen atom is in its first excited level, its radius is .... its ground state radius [CBSE PMT 1997]

(a) Half (b) Same

(c) Twice (d) Four times

84. Hydrogen atom excites energy level from fundamental state to $n = 3$. Number of spectrum lines according to Bohr, is

[CPMT 1997]

(a) 4 (b) 3

(c) 1 (d) 2

85. Number of spectral lines in hydrogen atom is [CPMT 1997]

(a) 3 (b) 6

(c) 15 (d) Infinite

86. In Bohr's model, the atomic radius of the first orbit is r_0, then the radius of the third orbit is

[AIIMS 1997; CPMT 2001; KCET (Engg./Med.) 1999; Pb. PMT 2004]

(a) $\frac{r_0}{9}$ (b) r_0

(c) $9r_0$ (d) $3r_0$

87. The wavelength of the energy emitted when electron come from fourth orbit to second orbit in hydrogen is $20.397\ cm$. The wavelength of energy for the same transition in He^+ is

[AIIMS 1997; JIPMER 2000]

(a) $5.099\ cm^{-1}$ (b) $20.497\ cm^{-1}$

(c) $40.994\ cm^{-1}$ (d) $81.988\ cm^{-1}$

88. Minimum excitation potential of Bohr's first orbit in hydrogen atom is

[BHU 1998; JIPMER 2001, 02; Pb. PMT 2004]

(a) 13.6 V (b) 3.4 V

(c) 10.2 V (d) 3.6 V

89. Which of the following statements are true regarding Bohr's model of hydrogen atom

(I) Orbiting speed of electron decreases as it shifts to discrete orbits away from the nucleus

(II) Radii of allowed orbits of electron are proportional to the principal quantum number

(III) Frequency with which electrons orbits around the nucleus in discrete orbits is inversely proportional to the principal quantum number

(IV) Binding force with which the electron is bound to the nucleus increases as it shifts to outer orbits

Select correct answer using the codes given below

Codes : [SCRA 1998]

(a) I and III (b) II and IV

(c) I, II and III (d) II, III and IV

90. The wavelength of radiation emitted is λ_0 when an electron jumps from the third to the second orbit of hydrogen atom. For the electron jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(a) $\frac{16}{25}\lambda_0$ (b) $\frac{20}{27}\lambda_0$

(c) $\frac{27}{20}\lambda_0$ (d) $\frac{25}{16}\lambda_0$

91. For electron moving in n^{th} orbit of H-atom the angular velocity is proportional to [RPET 1999]

(a) n (b) $1/n$

(c) n^3 (d) $1/n^3$

92. The energy of electron in first excited state of H-atom is $-3.4\ eV$ its kinetic energy is

[RPET 1999; CBSE PMT 2005]

(a) – 3.4 eV (b) + 3.4 eV

(c) – 6.8 eV (d) 6.8 eV

93. The energy required to excite an electron from the ground state of hydrogen atom to the first excited state, is

[Pb. PMT 1999]

(a) $1.602 \times 10^{-14}\ J$ (b) $1.619 \times 10^{-16}\ J$

(c) $1.632 \times 10^{-18}\ J$ (d) $1.656 \times 10^{-20}\ J$

94. Which of the following phenomena suggests the presence of electron energy levels in atoms [JIPMER 1999]

(a) Radio active decay

(b) Isotopes

(c) Spectral lines

(d) α-particles scattering

95. Which of the following spectral series in hydrogen atom give spectral line of 4860 Å [Roorkee 1999]

(a) Lyman (b) Balmer

(c) Paschen (d) Brackett

96. If scattering particles are 56 for 90^o angle then this will be at 60^o angle [RPMT 2000]

(a) 224 (b) 256

(c) 98 (d) 108

97. When an electron in hydrogen atom is excited, from its 4^{th} to 5^{th} stationary orbit, the change in angular momentum of electron is (Planck's constant: $h = 6.6\times10^{-34}$ *J*- s) [AFMC 2000; Pb. PET 2001]

(a) 4.16×10^{-34} *J- s* (b) 3.32×10^{-34} *J-s*

(c) 1.05×10^{-34} *J-s* (d) 2.08×10^{-34} *J-s*

98. Energy of electron in a orbit of *H*-atom is [RPET 2000]

(a) Positive (b) Negative

(c) Zero (d) Nothing can be said

99. The concept of stationary orbits was proposed by [Pb. PMT 2000]

(a) Neil Bohr (b) J.J. Thomson

(c) Ruther ford (d) I. Newton

100. In a hydrogen atom, the distance between the electron and proton is $2.5\times10^{-11}\ m$. The electrical force of attraction between them will be [Pb. PMT 2000]

(a) $2.8\times10^{-7}\ N$ (b) $3.7\times10^{-7}\ N$

(c) $6.2\times10^{-7}\ N$ (d) $9.1\times10^{-7}\ N$

101. If λ_{max} is 6563 Å, then wave length of second line for Balmer series will be [RPMT 2000]

(a) $\lambda = \frac{16}{3R}$ (b) $\lambda = \frac{36}{5R}$

(c) $\lambda = \frac{4}{3R}$ (d) None of the above

102. What will be the angular momentum of a electron, if energy of this electron in *H*-atom is 1.5eV (in *J-sec*) [RPMT 2000]

(a) 1.05×10^{-34} (b) 2.1×10^{-34}

(c) 3.15×10^{-34} (d) -2.1×10^{-34}

103. Who discovered spin quantum number [RPMT 2000]

(a) Unlenbeck and Goudsmit

(b) Nell's Bohr

(c) Zeeman

(d) Sommerfield

104. The time of revolution of an electron around a nucleus of charge *Ze* in *n* Bohr orbit is directly proportional to [MP PET 2003]

(a) n (b) $\frac{n^3}{Z^2}$

(c) $\frac{n^2}{Z}$ (d) $\frac{Z}{n}$

105. In Bohr's model, if the atomic radius of the first orbit is r_0, then the radius of the fourth orbit is [CBSE PMT 2000]

(a) r_0 (b) $4r_0$

(c) $r_0/16$ (d) $16r_0$

106. If *R* is the Rydberg's constant for hydrogen the wave number of the first line in the Lyman series will be [KCET 2000]

(a) $\frac{R}{4}$ (b) $\frac{3R}{4}$

(c) $\frac{R}{2}$ (d) $2R$

107. In hydrogen atom, if the difference in the energy of the electron in $n = 2$ and $n = 3$ orbits is *E*, the ionization energy of hydrogen atom is [EAMCET (Med.) 2000]

(a) 13.2 *E* (b) 7.2 *E*

(c) 5.6 *E* (d) 3.2 *E*

108. The first member of the Paschen series in hydrogen spectrum is of wavelength 18,800 Å. The short wavelengths limit of Paschen series is [EAMCET (Med.) 2000]

(a) 1215 Å (b) 6560 Å

(c) 8225 Å (d) 12850 Å

109. The ratio of the largest to shortest wavelengths in Lyman series of hydrogen spectra is [EAMCET (Med.) 2000]

(a) $\frac{25}{9}$ (b) $\frac{17}{6}$

(c) $\frac{9}{5}$ (d) $\frac{4}{3}$

110. In Bohr model of hydrogen atom, the ratio of periods of revolution of an electron in $n = 2$ and $n = 1$ orbits is [EAMCET (Engg.) 2000]

(a) 2 : 1 (b) 4 : 1

(c) 8 : 1 (d) 16 : 1

111. The ratio of the longest to shortest wavelengths in Brackett series of hydrogen spectra is [EAMCET (Engg.) 2000]

(a) $\frac{25}{9}$ (b) $\frac{17}{6}$

(c) $\frac{9}{5}$ (d) $\frac{4}{3}$

112. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true

(a) Its kinetic energy increases and its potential and total energies decrease

(b) Its kinetic energy decreases, potential energy increases and its total energy remains the same

(c) Its kinetic and total energies decrease and its potential energy increases

(d) Its kinetic, potential and total energies decreases

113. The ratio of minimum to maximum wavelength in Balmer series is

(a) 5 : 9 (b) 5 : 36

(c) 1 : 4 (d) 3 : 4

114. The radius of the Bohr orbit in the ground state of hydrogen atom is 0.5 $\mathring{A}$. The radius of the orbit of the electron in the third excited state of He^+ will be **[MP PMT 2000]**

(a) 8 $\mathring{A}$ (b) 4 $\mathring{A}$

(c) 0.5 $\mathring{A}$ (d) 0.25 $\mathring{A}$

115. The ratio of the speed of the electron in the first Bohr orbit of hydrogen and the speed of light is equal to (where *e*, *h* and *c* have their usual meanings) **[MP PMT 2000]**

(a) $2\pi hc/e^2$ (b) $e^2h/2\pi c$

(c) $e^2c/2\pi h$ (d) $2\pi e^2/hc$

116. According to the Rutherford's atomic model, the electrons inside the atom are **[KCET (Med.) 2000]**

(a) Stationary (b) Not stationary

(c) Centralized (d) None of these

117. The energy of hydrogen atom in its ground state is – 13.6 *eV*. The energy of the level corresponding to the quantum number *n* is equal 5 is **[KCET (Engg./Med.) 2001]**

(a) – 5.40 *eV* (b) – 2.72 *eV*

(c) – 0.85 *eV* (d) – 0.54 *eV*

118. According to classical theory, the circular path of an electron in Rutherford atom is **[BHU 2001]**

(a) Spiral (b) Circular

(c) Parabolic (d) Straight line

119. Rutherford's α-particle experiment showed that the atoms have

(a) Proton (b) Nucleus

(c) Neutron (d) Electrons

120. Orbital acceleration of electron is **[RPET 2001]**

(a) $\dfrac{n^2h^2}{4\pi^2m^2r^3}$ (b) $\dfrac{n^2h^2}{2n^2r^3}$

(c) $\dfrac{4n^2h^2}{\pi^2m^2r^3}$ (d) $\dfrac{4n^2h^2}{4\pi^2m^2r^3}$

121. Which of the following is true for number of spectral lines in going form Layman series to Pfund series **[RPET 2001]**

(a) Increases

(b) Decreases

(c) Unchanged

(d) May decreases or increases

122. The wavelength of yellow line of sodium is 5896 $\mathring{A}$. Its wave number will be **[MP PET 2001]**

(a) 50883×10^{10} per *second*

(b) 16961 per *cm*

(c) 17581 per *cm*

(d) 50883 per *cm*

123. Radius of the first orbit of the electron in a hydrogen atom is 0.53 $\mathring{A}$. So, the radius of the third orbit will be **[MP PET 2000]** **[Kerala (Engg.) 2001]**

(a) 2.12 $\mathring{A}$ (b) 4.77 $\mathring{A}$

(c) 1.06 $\mathring{A}$ (d) 1.59 $\mathring{A}$

124. The first line in the Lyman series has wavelength λ. The wavelength of the first line in Balmer series is **[MH CET (Med.) 2001]**

(a) $\dfrac{2}{9}\lambda$ (b) $\dfrac{9}{2}\lambda$

(c) $\dfrac{5}{27}\lambda$ (d) $\dfrac{27}{5}\lambda$

125. In hydrogen atom which quantity is integral multiple of $\dfrac{h}{2\pi}$ **[DCE 2001]**

(a) Angular momentum (b) Angular velocity

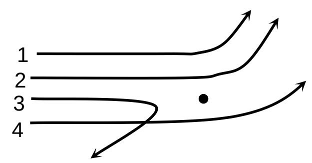
(c) Angular acceleration (d) Momentum

126. In the following transitions, which one has higher frequency **[UPSEAT 2001]**

(a) 3 – 2 (b) 4 – 3

(c) 4 – 2 (d) 3 – 1

127. The diagram shows the path of four α-particles of the same energy being scattered by the nucleus of an atom simultaneously. Which of these are/is not physically possible **[AMU (Med.) 2001]**



(a) 3 and 4 (b) 2 and 3

(c) 1 and 4 (d) 4 only

[AFMC 2001]

128. An electron jumps from 5^{th} orbit to 4^{th} orbit of hydrogen atom. Taking the Rydberg constant as 10^7 *per metre*. What will be the frequency of radiation emitted **[Pb. PMT 2001]**

(a) $6.75 \times 10^{12}\ Hz$ (b) $6.75 \times 10^{14}\ Hz$

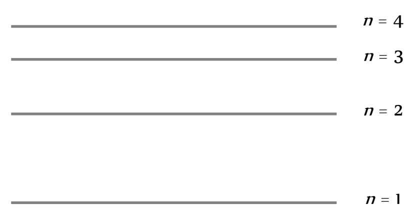
(c) $6.75 \times 10^{13}\ Hz$ (d) None of these

129. For principal quantum number $n = 3$, the possible values of orbital quantum number '*l*' are **[MP PET 2001; MP PMT 2001]**

(a) 1, 2, 3 (b) 0, 1, 2, 3

(c) 0, 1, 2 (d) –1, 0, +1

130. Four lowest energy levels of *H*-atom are shown in the figure. The number of possible emission lines would be **[MP PMT 2001]**



(a) 3 (b) 4

(c) 5 (d) 6

131. The order of the size of nucleus and Bohr radius of an atom respectively are [MP PET 2001; MP PMT 2001]

(a) $10^{-14}m, 10^{-10}m$ (b) $10^{-10}m, 10^{-8}m$

(c) $10^{-20}m, 10^{-16}m$ (d) $10^{-8}m, 10^{-6}m$

132. Energy of an electron in an excited hydrogen atom is – 3.4 *eV*. Its angular momentum will be: $h = 6.626\times10^{-34}\ J-s$

[UPSEAT 1999; Kerala PET 2002]

(a) $1.11\times10^{34}\ J$ sec (b) $1.51\times10^{-31}\ J$ sec

(c) $2.11\times10^{-34}\ J$ sec (d) $3.72\times10^{-34}\ J$ sec

133. The ratio of the wavelengths for 2 $\rightarrow$ 1 transition in *Li*, *He* and *H* is

(a) 1 : 2 : 3 (b) 1 : 4 : 9

(c) 4 : 9 : 36 (d) 3 : 2 : 1

134. The wavelength of light emitted from second orbit to first orbits in a hydrogen atom is [Pb. PMT 2002]

(a) $1.215\times10^{-7}m$ (b) $1.215\times10^{-5}m$

(c) $1.215\times10^{-4}m$ (d) $1.215\times10^{-3}m$

135. Energy of the electron in *n* orbit of hydrogen atom is given by $E_n = -\frac{13.6}{n^2}eV$. The amount of energy needed to transfer electron from first orbit to third orbit is

[MH CET 2002; Kerala PMT 2002]

(a) 13.6 *eV* (b) 3.4 *eV*

(c) 12.09 *eV* (d) 1.51 *eV*

136. The ratio of speed of an electron in ground state in Bohrs first orbit of hydrogen atom to velocity of light in air is

[MH CET 2002]

(a) $\frac{e^2}{2\varepsilon_0 hc}$ (b) $\frac{2e^2\varepsilon_0}{hc}$

(c) $\frac{e^3}{2\varepsilon_0 hc}$ (d) $\frac{2\varepsilon_0 hc}{e^2}$

137. Whenever a hydrogen atom emits a photon in the Balmer series [KCET 2002]

(a) It need not emit any more photon

(b) It may emit another photon in the Paschen series

(c) It must emit another photon in the Lyman series

(d) It may emit another photon in the Balmer series

138. The de-Broglie wavelength of an electron in the first Bohr orbit is

(a) Equal to one fourth the circumference of the first orbit

(b) Equal to half the circumference of the first orbit

(c) Equal to twice the circumference of the first orbit

(d) Equal to the circumference of the first orbit

139. In hydrogen atom, when electron jumps from second to first orbit, then energy emitted is [AIEEE 2002]

(a) – 13.6 *eV* (b) – 27.2 *eV*

(c) – 6.8 *eV* (d) None of these

140. Minimum energy required to takeout the only one electron from ground state of He^+ is [CPMT 2002]

(a) 13.6 *eV* (b) 54.4 *eV*

(c) 27.2 *eV* (d) 6.8 *eV*

141. The frequency of 1st line of Balmer series in H_2 atom is ν_0. The frequency of line emitted by singly ionised *He* atom is

[CPMT 2002]

(a) $2\nu_0$ (b) $4\nu_0$

(c) $\nu_0/2$ (d) $\nu_0/4$

142. When the electron in the hydrogen atom jumps from 2nd orbit to 1st orbit, the wavelength [UPSEAT 2003] of radiation emitted is λ. When the electrons jump from 3rd orbit to 1st orbit, the wavelength of emitted radiation would be [MP PMT 2002]

(a) $\frac{27}{32}\lambda$ (b) $\frac{32}{27}\lambda$

(c) $\frac{2}{3}\lambda$ (d) $\frac{3}{2}\lambda$

143. The possible quantum number for 3*d* electron are

[MP PMT 2002]

(a) $n = 3, l = 1, m_l = +1, m_s = -\frac{1}{2}$

(b) $n = 3, l = 2, m_l = +2, m_s = -\frac{1}{2}$

(c) $n = 3, l = 1, m_l = -1, m_s = +\frac{1}{2}$

(d) $n = 3, l = 0, m_l = +1, m_s = -\frac{1}{2}$

144. The radius of the first (lowest) orbit of the hydrogen atom is a_0. The radius of the second (next higher) orbit will be

[MP PET 2002; MP PMT 2004]

(a) $4a_0$ (b) $6a_0$

(c) $8a_0$ (d) $10a_0$

145. Which of the following transition will have highest emission wavelength [BHU 2003]

(a) $n = 2$ to $n = 1$ (b) $n = 1$ to $n = 2$

(c) $n = 2$ to $n = 5$ (d) $n = 5$ to $n = 2$

146. When the wave of hydrogen atom comes from infinity into the first orbit then the value of wave number is [RPET 2003]

(a) 109700 *cm* (b) 1097*cm*

(c) 109 *cm* (d) None of these

147. [KCET 2002] With the increase in principle quantum number, the energy difference between the two successive energy levels

[RPET 2003]

(a) Increases

(b) Decreases

(c) Remains constant

(d) Sometimes increases and sometimes decreases

148. In which of the following systems will the radius of the first orbit $(n = 1)$ be minimum

[Kerala PET 2002; CBSE PMT 2003]

(a) Single ionized helium
(b) Deuterium atom
(c) Hydrogen atom
(d) Doubly ionized lithium

149. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is [AIEEE 2003]

(a) 122.4 eV (b) 30.6 eV
(c) 13.6 eV (d) 3.4 eV

150. Which of the following is quantised according to Bohr's theory of hydrogen atom [MP PMT 2004]

(a) Linear momentum of electron
(b) Angular momentum of electron
(c) Linear velocity of electron
(d) Angular velocity of electron

151. The shortest wavelength in the Lyman series of hydrogen spectrum is 912 $\AA$ corresponding to a photon energy of 13.6 eV. The shortest wavelength in the Balmer series is about

[MP PMT 2004]

(a) 3648 $\AA$ (b) 8208 $\AA$
(c) 1228 $\AA$ (d) 6566 $\AA$

152. Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2} eV$. The energy of a photon ejected when the electron jumps from $n = 3$ state to $n = 2$ state of hydrogen is approximately [CBSE PMT 2004]

(a) 1.5 eV (b) 0.85 eV
(c) 3.4 eV (d) 1.9 eV

153. The Bohr model of atoms [CBSE PMT 2004]

(a) Assumes that the angular momentum of electrons is quantized
(b) Uses Einstein's photo-electric equation
(c) Predicts continuous emission spectra for atoms
(d) Predicts the same emission spectra for all types of atoms

154. The colour of the second line of Balmer series is

[J & K CET 2004]

(a) Blue (b) Yellow
(c) Red (d) Violet

155. Which state of triply ionised Baryllium (Be^{+++}) has the same orbital radius as that of the ground state of hydrogen

[KCET 2004]

(a) $n = 4$ (b) $n = 3$
(c) $n = 2$ (d) $n = 1$

156. The ratio of areas within the electron orbits for the first excited state to the ground state for hydrogen atom is

[BCECE 2004]

(a) 16 : 1 (b) 18 : 1
(c) 4 : 1 (d) 2 : 1

157. The kinetic energy of an electron revolving around a nucleus will be

(a) Four times of P.E. (b) Double of P.E.
(c) Equal to P.E. (d) Half of its P.E.

158. Taking Rydberg's constant $R_H = 1.097 \times 10^7 m$ first and second wavelength of Balmer series in hydrogen spectrum is

[Pb. PMT 2004]

(a) 2000 $\AA$, 3000 $\AA$ (b) 1575 $\AA$, 2960 $\AA$
(c) 6529 $\AA$, 4280 $\AA$ (d) 6552 $\AA$, 4863 $\AA$

159. The kinetic energy of electron in the first Bohr orbit of the hydrogen atom is [Pb. PET 2000]

(a) – 6.5 eV (b) – 27.2 eV
(c) 13.6 eV (d) – 13.6 eV

160. In the spectrum of hydrogen atom, the ratio of the longest wavelength in Lyman series to the longest wavelength in the Balmer series is [UPSEAT 2004]

(a) 5/27 (b) 1/93
(c) 4/9 (d) 3/2

161. In Bohr's model of hydrogen atom, which of the following pairs of quantities are quantized [UPSEAT 2004]

(a) Energy and linear momentum
(b) Linear and angular momentum
(c) Energy and angular momentum
(d) None of the above

162. The energy of the highest energy photon of Balmer series of hydrogen spectrum is close to [UPSEAT 2004]

(a) 13.6 eV (b) 3.4 eV
(c) 1.5 eV (d) 0.85 eV

163. Energy of an electron in n orbit of hydrogen atom is $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $-\frac{2\pi^2 k^2 me^4}{n^2h^2}$ (b) $-\frac{4\pi^2 m ke^2}{n^2h^2}$
(c) $-\frac{n^2h^2}{2\pi k me^4}$ (d) $-\frac{n^2h^2}{4\pi^2 k me^2}$

164. Which one of the relation is correct between time period and number of orbits while an electron is revolving in a orbit

[DPMT 2003]

(a) n^2 (b) $\frac{1}{n^2}$
(c) n^3 (d) $\frac{1}{n}$

165. An electron changes its position from orbit $n = 4$ to the orbit $n = 2$ of an atom. The wavelength of the emitted radiation's is (R = Rydberg's constant) [BHU 2004]

(a) $\frac{16}{R}$ (b) $\frac{16}{3R}$
(c) $\frac{16}{5R}$ (d) $\frac{16}{7R}$

166. If the energy of a hydrogen atom in nth orbit is E_n, then energy in the nth orbit of a singley ionized helium atom will be [BCECE 2004]

(a) $4E_n$ (b) $E_n / 4$
(c) $2E_n$ (d) $E_n / 2$

167. What is the ratio of wavelength of radiations emitted when an electron in hydrogen atom jump from fourth orbit to second orbit and from third orbit to second orbit

[MH CET 2004]

(a) 27 : 25 (b) 20 : 27

(c) 20 : 25 (d) 25 : 27

168. The energy of electron in the *n*th orbit of hydrogen atom is expressed as $E_n = \frac{-13.6}{n^2} eV$. The shortest and longest wavelength of Lyman series will be [Pb. PET 2003]

(a) 910 $\AA$, 1213 $\AA$ (b) 5463 $\AA$, 7858 $\AA$

(c) 1315 $\AA$, 1530 $\AA$ (d) None of these

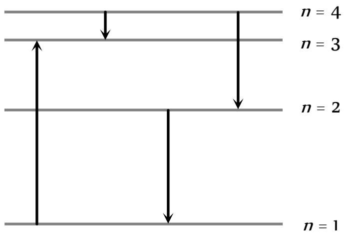
169. The ground state energy of hydrogen atom is – 13.6 *eV*. What is the potential energy of the electron in this state

[AIIMS 2005]

(a) 0 *eV* (b) – 27.2 *eV*

(c) 1 *eV* (d) 2 *eV*

170. The diagram shows-the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy [AIEEE 2005]



(a) I (b) II

(c) III (d) IV

171. As the electron in Bohr orbit of Hydrogen atom passes from state $n = 2$ to $n = 1$, the kinetic energy *K* and potential energy *U* change as [MP PET 2005]

(a) *K* two-fold, *U* four-fold

(b) *K* four-fold, *U* two-fold

(c) *K* four-fold, *U* also four-fold

(d) *K* two-fold, *U* also two-fold

172. The magnetic moment (μ) of a revolving electron around the nucleus varies with principal quantum number *n* as

[AIIMS 2005]

(a) $\mu \propto n$ (b) $\mu \propto 1/n$

(c) $\mu \propto n^2$ (d) $\mu \propto 1/n^2$

173. Bohr's atom model assumes [KCET 2005]

(a) The nucleus is of infinite mass and is at rest

(b) Electrons in a quantized orbit will not radiate energy

(c) Mass of electron remains constant

(d) All the above conditions

174. Radius of first Bohr orbit is *r*. What is the radius of 2nd Bohr orbit? [BHU 2005]

(a) 8*r* (b) 2*r*

(c) 4*r* (d) $2\sqrt{2r}$

Nucleus, Nuclear Reaction

1. Which of the following particles are constituents of the nucleus [CBSE PMT 199

(a) Protons and electrons (b) Protons and neutrons

(c) Neutrons and electrons (d) Neutrons and positrons

2. The particles which can be added to the nucleus of an atom without changing its chemical properties are called

[NCERT 1979]

(a) Electrons (b) Protons

(c) Neutrons (d) None of the above

3. The neutron was discovered by

[MP PMT 1992; RPMT 1996]

(a) Marie Curie (b) Pierre Curie

(c) James Chadwick (d) Rutherford

4. The mass number of a nucleus is

[IIT 1986; ISM Dhanbad 1994; MP PMT 1997; CBSE PMT 2003; MH CET (Med.) 2001]

(a) Always less than its atomic number

(b) Always more than its atomic number

(c) Always equal to its atomic number

(d) Sometimes more than and sometimes equal to its atomic number

5. The energy equivalent of 1 *kilogram* of matter is about

[MP PET/PMT 1988; MNR 1987]

(a) 10^{-15} *J* (b) 1 *J*

(c) 10^{-12} *J* (d) 10^{17} *J*

6. Nuclear binding energy is equivalent to [MP PET/PMT 1988]

(a) Mass of proton (b) Mass of neutron

(c) Mass of nucleus (d) Mass defect of nucleus

7. If the binding energy of the deutrium is 2.23 *MeV*. The mass defect given in *a.m.u.* is [MP PET 1993]

(a) – 0.0024 (b) – 0.0012

(c) 0.0012 (d) 0.0024

8. Which of the following has the mass closest in value to that of the positron [AFMC 1993]

(a) Proton (b) Electron

(c) Photon (d) Neutrino

$(1\ a.m.u = 931\ MeV)$

9. Size of nucleus is of the order of

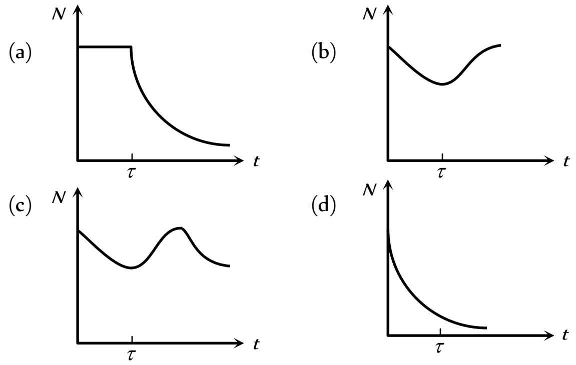
[CPMT 1983; MP PET 2002, 03]

(a) $10^{-10} m$ (b) $10^{-15} m$

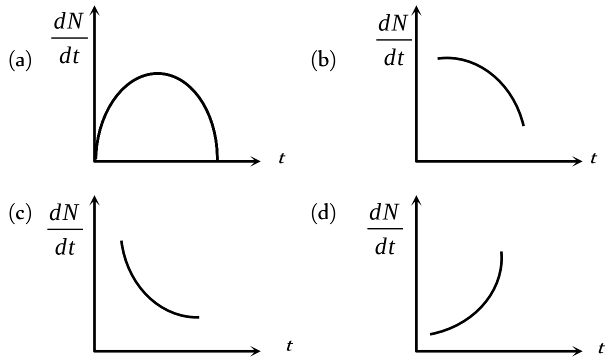
(c) $10^{-12} m$ (d) $10^{-19} m$

4. A radioactive sample consists of two distinct species having equal number of atoms initially. The mean life time of one species is τ and that of the other is 5τ. The decay products in both cases are stable. A plot is made of the total number of radioactive nuclei as a function of time. Which of the following figures best represents the form of this plot

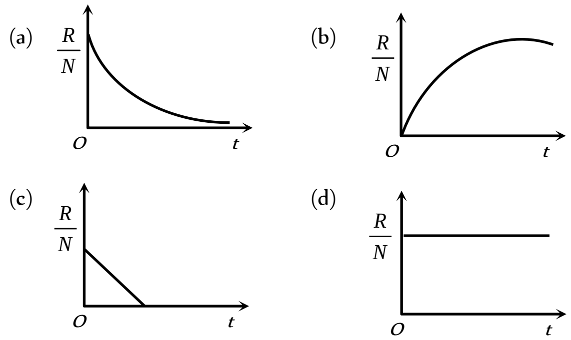
[IIT-JEE (Screening) 2001]



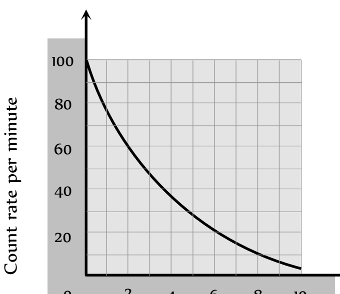
5. Radioactive element decays to form a stable nuclide, then the rate of decay of reactant $\left(\frac{dN}{dt}\right)$ will vary with time (t) as shown in figure



6. A radioactive sample has N_0 active atoms at $t = 0$. If the rate of disintegration at any time is R and the number of atoms is N, then the ratio R/N varies with time as



7. The count rate of 10*g* of radioactive material was measured at different times and this has been shown in the figure. The half life of material and the total counts (approximately) in the first half life period, respectively are [CPMT 1986]



(a) 4*h*, 9000 (b) 3*h*, 14000

(c) 3*h*, 235 (d) 3*h*, 50

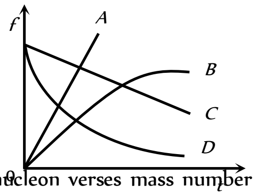
8. The fraction *f* of radioactive material that has decayed in time *t*, varies with time *t*. The correct variation is given by the curve

(a) *A*

(b) *B*

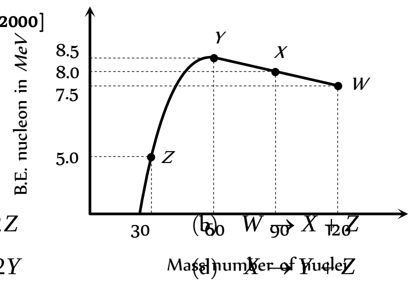
(c) *C*

(d) *D*



9. Binding energy per nucleon verses mass number curve for nuclei is shown in the figure. *W, X, Y and Z* are four nuclei indicated on the curve. The process that would release energy is

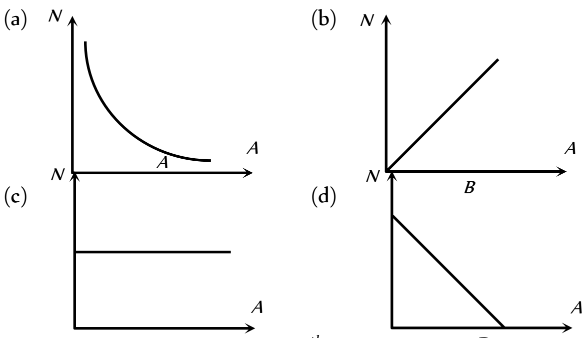
[DCE 2000]



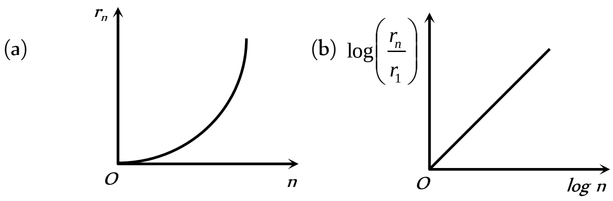
(a) $Y \to 2Z$ (b) $W \to X + Z$

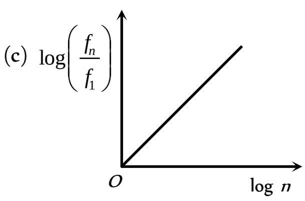
(c) $W \to 2Y$ (d) $X \to Y + Z$

10. The plot of the number (N) of decayed atoms versus activity (A) of a radioactive substance is



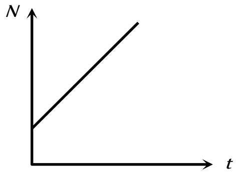
11. If in hydrogen atom, radius of n^{th} Bohr orbit is r_n, frequency of revolution of electron in n^{th} orbit is f_n choose the correct option

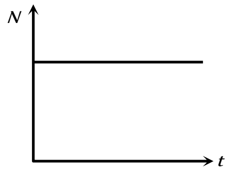


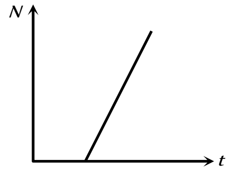


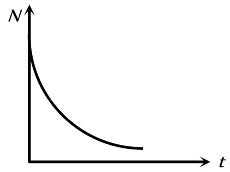
(d) Both (a) and (b)

12. The graph between the instantaneous concentration (N) of a radioactive element and time (t) is

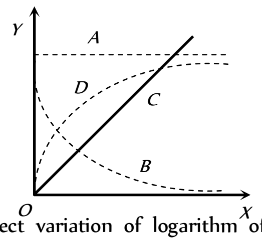
(a) 

(b) 

(c) 

(d) 

13. In Fig. X represents time and Y represent activity of a radioactive sample. Then the activity of sample, varies with time according to the curve



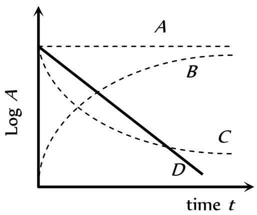
(a) A

(b) B

(c) C

(d) D

14. The graph which represents the correct variation of logarithm of activity (log A) versus time, in figure is



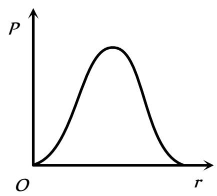
(a) A

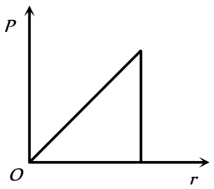
(b) B

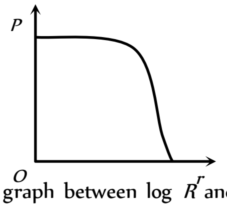
(c) C

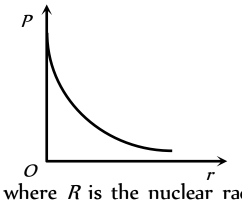
(d) D

15. The charge density in a nucleus varies with distance from the centre of the nucleus according to the curve in Fig.

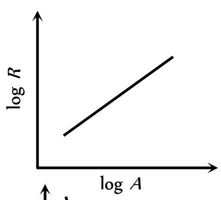
(a) 

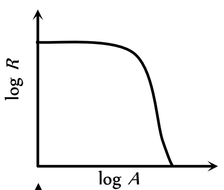
(b) 

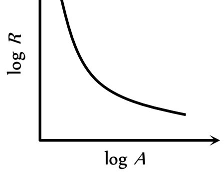
(c) 

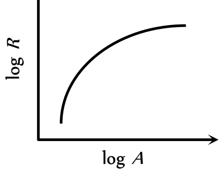
(d) 

16. The graph between log R and log A where R is the nuclear radius and A *is the mass number is*

(a) 

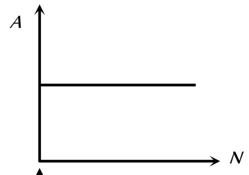
(b) 

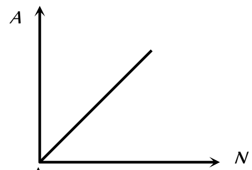


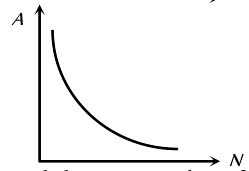


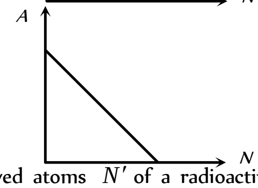
(c) (d)

17. The curve between the activity A of a radioactive sample and the number of active atoms N is

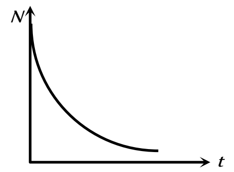
(a) 

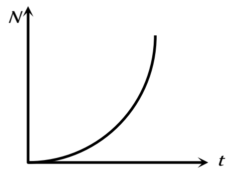
(b) 

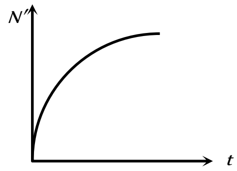
(c) 

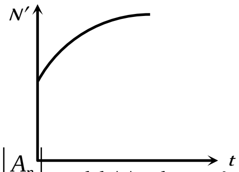
(d) 

18. The graph between number of decayed atoms N' of a radioactive element and time t is

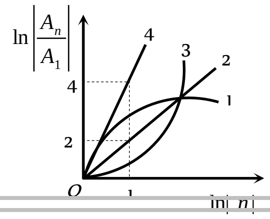
(a) 

(b) 

(c) 

(d) 

19. The figure shows a graph between $\ln\left|\frac{A_n}{A_1}\right|$ and $\ln|n|$, where A_n is the area enclosed by the nth orbit in a hydrogen like atom. The correct curve is



(a) 4

(b) 3

(c) 2

(d) 1

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*

(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*

(c) *If assertion is true but reason is false.*

(d) *If the assertion and reason both are false.*

(e) *If assertion is false but reason is true.*

1. Assertion : It is not possible to use ^{35}Cl as the fuel for fusion energy.

Reason : The binding energy of ^{35}Cl is too small.

[AIIMS 2005]

2. Assertion : ^{90}Sr from the radioactive fall out from a nuclear bomb ends up in the bones of human beings through the milk consumed by them. It causes impairment of the production of red blood cells.

Reason : The energetics β-particles emitted in the decay of ^{90}Sr damage the bone marrow.

[AIIMS 2004]

3. Assertion : Neutrons penetrate matter more readily as compared to protons.

Reason : Neutrons are slightly more massive than protons. [AIIMS 2003]

4. Assertion : Bohr had to postulate that the electrons in stationary orbits around the nucleus do not radiate.

Reason : According to classical physics all moving electrons radiate. [AIIMS 2003]

5. Assertion : Radioactive nuclei emit β^{-1} particles.

Reason : Electrons exist inside the nucleus.

[AIIMS 2003]

6. Assertion : $_ZX^A$ undergoes $2\alpha -$ decays. $2\beta -$ decays and $2\gamma -$decays and the daughter product is $_{Z-2}Y^{A-8}$.

Reason : In α-decay the mass number decreases by 4 and atomic number decreases by 2. In β- decay the mass number remains unchanged, but atomic number increases by 1 only.

[AIIMS 2001]

7. Assertion : Density of all the nuclei is same.

Reason : Radius of nucleus is directly proportional to the cube root of mass number.

[AIIMS 2000]

8. Assertion : Isobars are the element having same mass number but different atomic number.

Reason : Neutrons and protons are present inside nucleus. [AIIMS 1997]

9. Assertion : The force of repulsion between atomic nucleus and α-particle varies with distance according to inverse square law.

Reason : Rutherford did α-particle scattering experiment.

10. Assertion : The positively charged nucleus of an atom has a radius of almost $10^{-15}\,m$.

Reason : In α-particle scattering experiment, the distance of closest approach for α-particles is $\simeq 10^{-15}\,m$.

11. Assertion : According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic.

Reason : According to electromagnetic theory an accelerated particle continuously emits radiation.

12. Assertion : Electrons in the atom are held due to coulomb forces.

Reason : The atom is stable only because the centripetal force due to Coulomb's law is balanced by the centrifugal force.

13. Assertion : The electron in the hydrogen atom passes from energy level $n=4$ to the $n=1$ level. The maximum and minimum number of photon that can be emitted are six and one respectively.

Reason : The photons are emitted when electron make a transition from the higher energy state to the lower energy state.

14. Assertion : Hydrogen atom consists of only one electron but its emission spectrum has many lines.

Reason : Only Lyman series is found in the absorption spectrum of hydrogen atom whereas in the emission spectrum, all the series are found.

15. Assertion : It is essential that all the lines available in the emission spectrum will also be available in the absorption spectrum.

Reason : The spectrum of hydrogen atom is only absorption spectrum.

16. Assertion : For the scattering of α-particles at a large angles, only the nucleus of the atom is responsible.

Reason : Nucleus is very heavy in comparison to electrons.

17. Assertion : All the radioactive elements are ultimately converted in lead.

Reason : All the elements above lead are unstable.

18. Assertion : Amongst alpha, beta and gamma rays, α-particle has maximum penetrating power.

Reason : The alpha particle is heavier than beta and gamma rays.

19. Assertion : The ionising power of β-particle is less compared to α-particles but their penetrating power is more.

Reason : The mass of β-particle is less than the mass of α-particle.

20. Assertion : The mass of β-particles when they are emitted is higher than the mass of electrons obtained by other means.

Reason : β-particle and electron, both are similar particles.

21. Assertion : Radioactivity of 10^8 undecayed radioactive nuclei of half life of 50 days is equal to that of 1.2×10^8 number of undecayed nuclei of some other material with half life of 60 days

Reason : Radioactivity is proportional to half-life.

22. Assertion : Fragments produced in the fission of U^{235} are radioactive.

Reason : The fragments have abnormally high proton to neutron ratio.

23. Assertion : Electron capture occurs more often than positron emission in heavy elements.

Reason : Heavy elements exhibit radioactivity.

24. Assertion : The mass of a nucleus can be either less than or more than the sum of the masses of nucleons present in it.

Reason : The whole mass of the atom is considered in the nucleus.

Answers

Atomic Structure

1	a	2	d	3	a	4	d	5	c
6	b	7	b	8	c	9	a	10	d
11	b	12	b	13	b	14	c	15	c
16	c	17	c	18	b	19	c	20	b
21	c	22	c	23	c	24	d	25	d
26	c	27	d	28	b	29	d	30	b
31	a	32	d	33	c	34	d	35	d
36	b	37	c	38	a	39	c	40	c
41	a	42	d	43	d	44	a	45	a
46	a	47	c	48	a	49	b	50	a
51	b	52	c	53	d	54	c	55	d
56	a	57	c	58	d	59	d	60	d
61	c	62	ad	63	d	64	b	65	b
66	b	67	c	68	a	69	b	70	c
71	a	72	b	73	b	74	d	75	b
76	d	77	d	78	b	79	a	80	d
81	a	82	a	83	b	84	b	85	d
86	c	87	a	88	c	89	a	90	b
91	d	92	b	93	c	94	c	95	b
96	a	97	c	98	b	99	a	100	b
101	a	102	c	103	a	104	b	105	d
106	b	107	b	108	c	109	d	110	c
111	a	112	a	113	a	114	b	115	d
116	b	117	d	118	a	119	b	120	a
121	b	122	b	123	b	124	d	125	a
126	d	127	d	128	c	129	c	130	d
131	a	132	c	133	c	134	a	135	c
136	a	137	c	138	d	139	d	140	b
141	b	142	a	143	b	144	a	145	d
146	a	147	b	148	d	149	b	150	b
151	a	152	d	153	a	154	a	155	c
156	d	157	d	158	d	159	c	160	a
161	c	162	b	163	a	164	c	165	b
166	a	167	b	168	a	169	b	170	c
171	c	172	a	173	d	174	c		

Nucleus, Nuclear Reaction

1	b	2	c	3	c	4	d	5	d
6	d	7	d	8	b	9	b	10	c
11	a	12	b	13	d	14	c	15	c
16	c	17	c	18	c	19	d	20	c
21	b	22	d	23	a	24	b	25	c
26	b	27	c	28	c	29	a	30	a
31	b	32	a	33	d	34	c	35	c
36	b	37	a	38	a	39	d	40	c
41	b	42	a	43	c	44	a	45	c
46	c	47	d	48	b	49	a	50	b
51	d	52	b	53	d	54	c	55	a
56	a	57	d	58	ad	59	c	60	a
61	c	62	b	63	a	64	a	65	d
66	c	67	a	68	b	69	b	70	d
71	b	72	d	73	bc	74	d	75	c
76	d	77	d	78	c	79	b	80	b
81	c	82	d	83	c	84	b	85	d
86	b	87	a	88	d	89	d	90	a
91	c	92	b	93	a	94	c	95	a
96	b	97	c	98	d	99	d	100	b
101	c	102	b	103	a	104	d	105	c
106	b	107	a	108	b	109	d	110	c
111	c	112	c	113	b	114	b	115	d
116	a	117	b	118	a	119	c	120	b
121	d	122	d	123	a	124	a	125	c
126	c	127	b	128	d	129	c	130	a
131	c	132	a	133	a	134	b	135	b
136	c	137	a	138	c	139	b	140	a
141	b	142	b	143	b	144	d	145	d
146	a	147	b	148	b	149	d	150	a
151	c	152	b	153	d	154	c	155	c
156	a	157	b	158	a	159	c	160	c
161	a	162	a	163	b	164	b	165	c
166	b	167	d	168	d	169	a	170	b
171	b	172	a	173	c	174	b	175	a
176	b	177	a	178	c	179	b		

Radioactivity

1	a	2	a	3	d	4	c	5	a
6	c	7	c	8	d	9	c	10	c
11	b	12	c	13	c	14	c	15	a
16	c	17	a	18	c	19	b	20	a
21	a	22	c	23	a	24	d	25	d
26	d	27	c	28	b	29	a	30	c
31	c	32	c	33	d	34	c	35	c
36	b	37	b	38	d	39	d	40	d
41	a	42	b	43	c	44	d	45	b
46	b	47	d	48	d	49	b	50	a
51	b	52	c	53	a	54	d	55	c
56	d	57	b	58	d	59	d	60	b
61	a	62	d	63	a	64	d	65	b
66	a	67	b	68	c	69	d	70	c
71	d	72	a	73	a	74	d	75	c
76	d	77	d	78	c	79	a	80	d
81	d	82	b	83	a	84	a	85	b

86	c	87	d	88	d	89	b	90	a
91	b	92	d	93	c	94	c	95	a
96	d	97	d	98	a	99	b	100	c
101	a	102	d	103	b	104	b	105	b
106	d	107	a	108	d	109	c	110	b
111	c	112	c	113	d	114	d	115	c
116	b	117	a	118	a	119	d	120	a
121	c	122	d	123	a	124	d	125	d
126	d	127	c	128	d	129	c	130	b
131	d	132	b	133	c	134	a	135	a
136	b	137	ac	138	b	139	c	140	c
141	d	142	c	143	a	144	d	145	c
146	b	147	d	148	b	149	b	150	c
151	c	152	a	153	b	154	b	155	d
156	b	157	c	158	c	159	d	160	c
161	a	162	d	163	c	164	c	165	d
166	d	167	c	168	c	169	b	170	d
171	b	172	c	173	b	174	a	175	c
176	d								

Critical Thinking Questions

1	c	2	c	3	b	4	a	5	a
6	a	7	a	8	d	9	b	10	d
11	a	12	a	13	a	14	d	15	c
16	d	17	c	18	d	19	c	20	d
21	b	22	c	23	d	24	a	25	d
26	d	27	c	28	c	29	cd	30	a
31	a	32	c	33	a	34	a	35	b
36	b	37	b	38	c	39	b	40	a
41	a	42	b	43	c	44	c	45	d
46	a	47	b	48	d	49	a	50	b
51	d	52	a	53	b	54	b	55	a
56	a	57	b	58	b	59	b	60	a
61	a	62	a	63	b	64	c	65	a

Graphical Questions

1	a	2	a	3	c	4	d	5	c
6	d	7	b	8	b	9	c	10	d
11	d	12	d	13	b	14	d	15	c
16	a	17	b	18	c	19	a		

Assertion and Reason

1	c	2	a	3	b	4	b	5	c
6	a	7	a	8	b	9	b	10	a
11	e	12	c	13	b	14	b	15	d
16	a	17	c	18	d	19	b	20	b
21	c	22	c	23	b	24	e		

AS Answers and Solutions

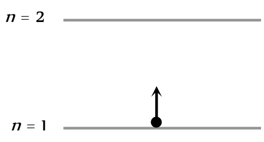
Atomic Structure

1. (a) For $n=1$, maximum number of states $= 2n^2 = 2$ and for $n = 2$, 3, 4, maximum number of states would be 8, 18, 32 respectively, Hence number of possible elements

= 2 + 8 + 18 + 32 = 60.

2. (d) Bohr radius $r = \frac{\varepsilon_0 n^2 h^2}{\pi Zme^2}$; $\therefore r \propto n^2$

3. (a)



$E_2 = -\frac{13.6}{(2)^2} = -3.4\, eV$

$E_1 = -13.6\, eV$

$E_{1\to 2} = -3.4 - (13.6) = +10.2\, eV$

4. (d) $\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

For di-ionised lithium the value of Z is maximum.

5. (c) Lyman series lies in the UV region.

6. (b) The size of the atom is of the order of $1Å = 10^{-10} m$.

7. (b) Balmer series lies in the visible region.

8. (c) Transition A ($n = \infty$ to 1) : Series limit of Lyman series

Transition B ($n = 5$ to $n = 2$) : Third spectral line of Balmer series

Transition C ($n = 5$ to $n = 3$) : Second spectral line of Paschen series

9. (a) D is excitation of electron from 2^{nd} orbit corresponding to absorption line in Balmer series and E is the energy released to bring the electron from ∞ to ground state *i.e.* ionisation potential.

10. (d)

11. (b) Paschen series lies in the infrared region.

12. (b) Energy required to knock out the electron in the n^{th} orbit $= +\frac{13.6}{n^2} eV \Rightarrow E_3 = +\frac{13.6}{9} eV$.

13. (b) Linear momentum $= mv = 9.1\times 10^{-31} \times 2.2\times 10^{6}$

$= 2.0\times 10^{-24}\, kg - m/s$

14. (c) $r \propto n^2 \Rightarrow r_n = n^2 a_0 \quad (\because r_1 = a_0)$

15. (c) For the ionization of second He electron. He^+ will act as hydrogen like atom.

Hence ionization potential

$= Z^2 \times 13.6\, volt = (2)^2 \times 13.6 = 54.4\, V$

16. (c) Energy required $= \frac{13.6}{n^2} = \frac{13.6}{10^2} = 0.136\, eV$

17. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{1}{R\lambda}$

$= \frac{1}{1.097\times 10^7 \times 18752\times 10^{-10}} = 0.0486 = \frac{7}{144}$. But

$\frac{1}{3^2} - \frac{1}{4^2} = \frac{7}{144} \Rightarrow n_1 = 3$ and $n_2 = 4$ (Paschen series)

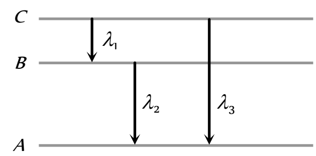
18. (b) Potential energy of electron in n^{th} orbit of radius r in H-atom

$U = -\frac{e^2}{r}$ (in CGS)

$\because$ K.E. $= \frac{1}{2}|\, P.E.| \Rightarrow K = \frac{e^2}{2r}$

19. (c) Final energy of electron $= -13.6 + 12.1 = -1.51\, eV$. which is corresponds to third level *i.e.* $n = 3$. Hence number of spectral lines emitted $= \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 3$

20. (b) Let the energy in A, B and C state be E_A, E_B and E_C, then from the figure



$(E_C - E_B) + (E_B - E_A) = (E_C - E_A)$ or $\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$

$\Rightarrow \lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$

21. (c) According to Bohr's second postulate.

22. (c) First excited state *i.e.* second orbit ($n = 2$)

Second excited state *i.e.* third orbit ($n = 3$)

$\because E = -\frac{13.6}{n^2} \Rightarrow \frac{E_2}{E_3} = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$

23. (c) $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16} \Rightarrow \lambda = \frac{16}{3R} = \frac{16}{3}\times 10^{-5} cm$

Frequency $n = \frac{c}{\lambda} = \frac{3\times 10^{10}}{\frac{16}{3}\times 10^{-5}} = \frac{9}{16}\times 10^{15}\, Hz$

24. (d) Energy required to remove electron in the $n = 2$ state $= +\frac{13.6}{(2)^2} = +3.4\, eV$

25. (d) $(E)_{\ } = Z^2 (E_{ion})_H = (11)^2 13.6\, eV$

26. (c) The wavelength of spectral line in Balmer series is given by $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$

For first line of Balmer series, $n = 3$

$\Rightarrow \frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$; For second line $n = 4$.

$\Rightarrow \frac{1}{\lambda_2} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{16}$

$\therefore \frac{\lambda_2}{\lambda_1} = \frac{20}{27} \Rightarrow \lambda_1 = \frac{20}{27} \times 6561 = 4860\ Å$

27. (d) $2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$

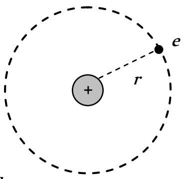
$\frac{4E}{3} - E = \frac{hc}{\lambda'} \Rightarrow \frac{E}{3} = \frac{hc}{\lambda'}\ \therefore \frac{\lambda'}{\lambda} = 3 \Rightarrow \lambda' = 3\lambda$

28. (b) Because atom is hollow and whole mass of atom is concentrated in a small centre called nucleus.

29. (d) $r = \frac{\varepsilon_0 n^2 h^2}{\pi Z m e^2}$; $\therefore r \propto \frac{n^2}{Z}$

30. (b) $r \propto n^2 \Rightarrow \frac{r_{(n=2)}}{r_{(n=3)}} = \frac{4}{9} \Rightarrow r_{(n=3)} = \frac{9}{4}R = 2.25\,R$

31. (a) In the revolution of electron, coulomb force provides the necessary centripetal force



$\Rightarrow \frac{ze^2}{r^2} = \frac{mv^2}{r} \Rightarrow mv^2 = \frac{ze^2}{r}$

$\therefore$ K.E. $= \frac{1}{2}mv^2 = \frac{ze^2}{2r}$

32. (d) According to Bohr's theory $mvr = n\frac{h}{2\pi}$

$\Rightarrow$ Circumference $2\pi r = n\left(\frac{h}{mv}\right) = n\lambda$

33. (c) $K.E = \frac{kZe^2}{2r}$ and $P.E. = -\frac{kZe^2}{r}$; $\therefore \frac{K.E.}{P.E.} = -\frac{1}{2}$.

34. (d) Lyman series lies in the UV region.

35. (d) If E is the energy radiated in transition

then $E_{R\to G} > E_{Q\to S} > E_{R\to S} > E_{Q\to R} > E_{P\to Q}$

For getting blue line energy radiated should be maximum $\left(E \propto \frac{1}{\lambda}\right)$. Hence (d) is the correct option.

36. (b) Energy released $= 13.6\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = 2.55\,eV$

37. (c) The absorption lines are obtained when the electron jumps from ground state ($n = 1$) to the higher energy states. Thus only 1, 2 and 3 lines will be obtained.

38. (a) P.E. $\propto -\frac{1}{r}$ and K.E. $\propto \frac{1}{r}$

As r increases so K.E. decreases but P.E. increases.

39. (c) Wave number $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16}$

40. (c) In hydrogen atom, the lowest orbit ($n = 1$) corresponds to minimum energy (– 13.6 eV).

41. (a) K.E. = – (T.E.)

42. (d) Required energy $E_3 = \frac{+13.6}{3^2} = 1.51eV$

43. (d) As n increases P.E. also increases.

44. (a) When an electron jumps from the orbit of lower energy (n=1) to the orbit of higher energy (n=3), energy is absorbed.

45. (a) For Lyman series

$\nu_{\text{Lymen}} = \frac{c}{\lambda_{\max}} = Rc\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] = \frac{3RC}{4}$

For Balmer series

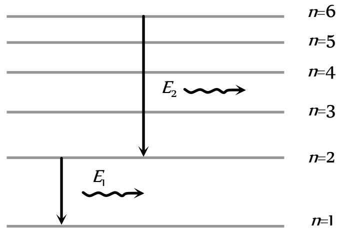
$\nu_{\text{Balmer}} = \frac{c}{\lambda_{\max}} = Rc\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5RC}{36}$

$\therefore \frac{\nu_{\text{Lymen}}}{\nu_{\text{Balmer}}} = \frac{27}{5}$

46. (a) $\because E_1 > E_2$

$\therefore \nu_1 > \nu_2$

i.e. photons of higher frequency will be emitted if transition takes place from n = 2 to 1.



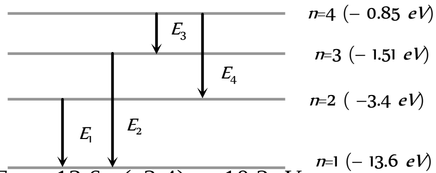
47. (c) Wave number $= \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first Balmer line n_1= 2, n_2=3

$\therefore$ Wave number $= R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R\left(\frac{9-4}{9\times 4}\right) = \frac{5R}{36}$

48. (a) Energy required to ionise helium atom = 24.6 eV

49. (b) From diagram



$E_1 = -13.6 - (-3.4) = -10.2\,eV$

$E_2 = -13.6 - (-1.51) = -12.09\,eV$

$E_3 = -1.51 - (-0.85) = -0.66\,eV$

$E_4 = -3.4 - (-1.51) = -1.89\,eV$

E_3 is least *i.e.* frequency is lowest.

50. (a) P.E. $= -\frac{ke^2}{r} = -\frac{e^2}{4\pi\varepsilon_0 r}$; K.E. $= -\frac{1}{2}$(P.E.) $= \frac{e^2}{8\pi\varepsilon_0 r}$

51. (b) Similar to Q. 49

52. (c) $mvr = \frac{nh}{2\pi}$, for n =1 it is $\frac{h}{2\pi}$

53. (d) Minimum energy required to excite from ground state

$= 13.6\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 10.2\ eV$

54. (c) $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For first line of Lymen series $n_i = 1$ and $n_f = 2$

For first line of Balmer series $n_i = 2$ and $n_f = 3$

So, $\frac{\lambda_{\text{Lymen}}}{\lambda_{\text{Balmer}}} = \frac{5}{27}$

55. (d) $R = \frac{2\pi^2 k^2 e^4 m}{ch^3} = \left(\frac{1}{4\pi\varepsilon_0}\right)^2 \frac{2\pi^2 me^4}{ch^3}$

56. (a) $\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

$\therefore R = \frac{36}{5\lambda} = \frac{36}{5 \times 6563 \times 10^{-10}} = 1.09 \times 10^7 m^{-1}$

57. (c) Angular momentum $L = n\left(\frac{h}{2\pi}\right)$

For this case n=2, hence $L = 2 \times \frac{h}{2\pi} = \frac{h}{\pi}$

58. (d) $v \propto \frac{1}{n} \Rightarrow \frac{v_5}{v_2} = \frac{2}{5} \Rightarrow v_5 = \frac{2}{5}v_2 = \frac{2}{5}v$

59. (d) By using $N_E = \frac{n(n-1)}{2} \Rightarrow N_E = \frac{4(4-1)}{2} = 6$

60. (d) Shortest wavelength comes from $n_1 = \infty$ to $n_2 = 1$ and longest wavelength comes from $n_1 = 6$ to $n_2 = 5$ in the given case. Hence $\frac{1}{\lambda_{\min}} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R$

$\frac{1}{\lambda_{\max}} = R\left(\frac{1}{5^2} - \frac{1}{6^2}\right) = R\left(\frac{36-25}{25 \times 36}\right) = \frac{11}{900}R$

$\therefore \frac{\lambda_{\max}}{\lambda_{\min}} = \frac{900}{11}$

61. (c) $\frac{mv^2}{a_0} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{a_0^2} \Rightarrow v = \frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$

62. (a,d) $T \propto n^3$. Given $T_{n_1} = 8\, T_{n_2}$, hence $n_1 = 2n_2$

Therefore, option (a) and (d) both are correct.

63. (d) $E = -Z^2 \times 13.6\, eV = -9 \times 13.6\, eV = -122.4\, eV$

So ionisation energy = + 122.4 eV.

64. (b)

65. (b) As n increases P.E. increases and K.E. decreases.

66. (b) $r = \frac{n^2}{Z}(r_0)$; $\Rightarrow r_{(n=2)} = \frac{(2)^2}{2} \times 0.53 = 1.06\, Å$

67. (c)

68. (a) $\bar{v} \propto \frac{1}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant} \Rightarrow \lambda = \frac{\lambda}{4}Z^2 \Rightarrow Z = 2$

69. (b) In Paschen series $\frac{1}{\lambda_{\max}} = R\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right]$

$\Rightarrow \lambda_{\max} = \frac{144}{7R} = \frac{144}{7 \times 1.1 \times 10^7} = 1.89 \times 10^{-6} m = 1.89\, \mu m$

Similarly $\lambda_{\min} = \frac{9}{R} = \frac{9}{1.1 \times 10^7} = 0.818\, \mu m$

70. (c) For third line of Balmer series $n_1 = 2$, $n_2 = 5$

$\therefore \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ gives $Z^2 = \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)\lambda R}$

On putting values $Z = 2$

From $E = -\frac{13.6 Z^2}{n^2} = \frac{-13.6(2)^2}{(1)^2} = -54.4\, eV$

71. (a) Ionization energy = Binding energy.

72. (b) $E = -Rch \Rightarrow R = -\frac{E}{ch} = -\frac{13.6 \times 1.6 \times 10^{-19}}{3 \times 10^8 \times 6.6 \times 10^{-34}}$

$= 1.098 \times 10^7$ *per m*

73. (b) Bohr postulated that the angular momentum of the electron is conserved.

74. (d) $E_3 = -\frac{13.6}{9} = -1.51\, eV$; $E_4 = -\frac{13.6}{16} = -0.85\, eV$

$\therefore E_4 - E_3 = 0.66\, eV$

75. (b) Number of spectral lines $N_E = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

76. (d) In the transition from orbit $5 \to 2$, more energy is liberated as compared to transition from $4 \to 2$.

77. (d) Impact parameter $b \propto \cot\frac{\theta}{2}$

Here $b = 0$, hence $\theta = 180^o$

78. (b) $r \propto n^2$ *i.e.* $\frac{r_f}{r_i} = \left(\frac{n_f}{n_i}\right)^2$

$\Rightarrow \frac{21.2 \times 10^{-11}}{5.3 \times 10^{-11}} = \left(\frac{n}{1}\right)^2 \Rightarrow n^2 = 4 \Rightarrow n = 2$

79. (a)

80. (d) $E_n = \frac{-13.6}{n^2} = \frac{-13.6}{4} = -3.4 eV$

81. (a) $\frac{1}{\lambda_{\text{Balmer}}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$, $\frac{1}{\lambda_{\text{Lyman}}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$

$\therefore \lambda_{\text{Lyman}} = \lambda_{\text{Balmer}} \times \frac{5}{27} = 1215.4\, Å$

82. (a) $\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For Lyman series n_1=1 and n_2=2, 3, 4,

When n_2=2, we get $\lambda = \frac{4}{3R_H} = \frac{4}{3 \times 10967} cm$

83. (b) $r \propto n^2$. For ground state n=1 and for first excited state n=2.

84. (b) No. of lines $N_E = \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 3$

85. (d) Infinitely large transitions are possible (in principle) for the hydrogen atom.

86. (c) $r_n \propto n^2$

87. (a) $E\left(= \frac{hc}{\lambda}\right) \propto \frac{Z^2}{n^2} \Rightarrow \lambda \propto \frac{1}{Z^2}$

Hence $\lambda_{He^+} = \frac{20.397}{4} = 5.099\,cm$

88. (c) Excitation potential $= \frac{\text{Excitation energy}}{e}$

Minimum excitation energy corresponds to excitation from $n=1$ to $n=2$

$\therefore$ Minimum excitation energy in hydrogen atom $= -3.4-(-13.6) = +10.2\,eV$

so minimum excitation potential = 10.2 eV.

89. (a) Orbital speed varies inversely as the radius of the orbit. Energy increases with the increase in quantum number.

90. (b) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{\lambda_{3\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5R}{36}$

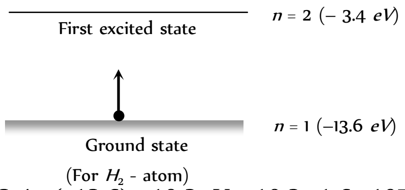
and $\frac{1}{\lambda_{4\to 2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = \frac{3R}{16}$

$\therefore \frac{\lambda_{4\to 2}}{\lambda_{3\to 2}} = \frac{20}{27} \Rightarrow \lambda_{4\to 2} = \frac{20}{27}\lambda_0$

91. (d)

92. (b) Kinetic energy = |Total energy|

93. (c) Energy to excite the e^- from $n=1$ to $n=2$



$E = -3.4-(-13.6) = 10.2\,eV = 10.2\times 1.6\times 10^{-19}$

$= 1.632\times 10^{-18}\,J$

94. (c)

95. (b)

96. (a) According to scattering formula

$N \propto \frac{1}{\sin^4(\theta/2)} \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin(\theta_1/2)}{\sin(\theta_2/2)}\right]^4$

$\Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\frac{90^o}{2}}{\sin\frac{60^o}{2}}\right]^4 = \left[\frac{\sin 45^o}{\sin 30^o}\right]^4$

$\Rightarrow N_2 = (\sqrt{2})^4 \times N_1 = 4\times 56 = 224$

97. (c) Change in the angular momentum

$\Delta L = L_2 - L_1 = \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} \Rightarrow \Delta L = \frac{h}{2\pi}(n_2 - n_1)$

$= \frac{6.6\times 10^{-34}}{2\times 3.14}(5-4) = 1.05\times 10^{-34}\,J\text{-}S$

98. (b) $E_n = -\frac{13.6}{n^2}eV$

99. (a)

100. (b) $F = \frac{9\times 10^9 \times 1.6\times 10^{-19}\times 1.6\times 10^{-19}}{(2.5\times 10^{-11})^2} = 3.7\times 10^{-7}\,N$

101. (a) For Balmer series $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where n = 3, 4, 5

For second line n = 4

So $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3}{16}R \Rightarrow \lambda = \frac{16}{3R}$

102. (c) Energy of electron in H atom $E_n = \frac{-13.6}{n^2}eV$

$\Rightarrow -1.5 = \frac{-13.6}{n^2} \Rightarrow n^2 = \frac{13.6}{1.5} = 3$

Now angular momentum

$p = n\frac{h}{2\pi} = \frac{3\times 6.6\times 10^{-34}}{2\times 3.14} = 3.15\times 10^{-34}\,J\times\sec$

103. (a)

104. (b) $T = \frac{2\pi r}{v}$; r = radius of n orbit $= \frac{n^2h^2}{\pi m Ze^2}$

v = speed of e^- in n orbit $= \frac{ze^2}{2\varepsilon_0 nh}$

$\therefore T = \frac{4\varepsilon_0^2 n^3 h^3}{mZ^2e^4} \Rightarrow T \propto \frac{n^3}{Z^2}$

105. (d) $r_n \propto n^2 \Rightarrow \frac{r_4}{r_1} = \left(\frac{4}{1}\right)^2 = \frac{16}{1} \Rightarrow r_4 = 16\,r_1 \Rightarrow r_4 = 16\,r_0$

106. (b) For Lyman series

$\bar{v} = \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$ here n=2, 3, 4, 5.....

For first line

$\bar{v} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \bar{v} = R\left(1 - \frac{1}{4}\right) = \frac{3R}{4}$

107. (b) Energy $E = K\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ (K = constant)

n = 2 and n = 3, so $E = K\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = K\left[\frac{5}{36}\right]$

For removing an electron n = 1 to $n_2 = \infty$

Energy $E_1 = K[1] = \frac{36}{5}E = 7.2\,E$

$\therefore$ Ionization energy = 7.2 E

108. (c) For Paschen series $\bar{v} = \frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$; n=4, 5, 6....

For first member of Paschen series n = 4

$\frac{1}{\lambda_1} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right] \Rightarrow \frac{1}{\lambda_1} = \frac{7R}{144}$

$\Rightarrow R = \frac{144}{7\lambda_1} = \frac{144}{7\times 18800\times 10^{-10}} = 1.1\times 10^{-7}$

For shortest wave length $n = \infty$

So $\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right] = \frac{R}{9}$

$\Rightarrow \lambda = \frac{9}{R} = \frac{9}{1.1\times10^{-7}} = 8.225\times10^{-7}m = 8225\,\AA$

109. (d) For Lyman series $\frac{1}{\lambda_{\max}} = R\left[\frac{1}{1^2}-\frac{1}{2^2}\right] = \frac{3}{4}R$ and

$\frac{1}{\lambda_{\min}} = R\left[\frac{1}{1^2}-\frac{1}{\infty^2}\right] = \frac{R}{1} \Rightarrow \frac{\lambda_{\max}}{\lambda_{\min}} = \frac{4}{3}$

110. (c) $T \propto n^3 \Rightarrow \frac{T_2}{T_1} = \frac{2^3}{1^3} = \frac{8}{1}$

111. (a) For Bracket series $\frac{1}{\lambda_{\max}} = R\left[\frac{1}{4^2}-\frac{1}{5^2}\right] = \frac{9}{25\times16}R$

and $\frac{1}{\lambda_{\min}} = R\left[\frac{1}{4^2}-\frac{1}{\infty^2}\right] = \frac{R}{16} \Rightarrow \frac{\lambda_{\max}}{\lambda_{\min}} = \frac{25}{9}$

112. (a) For hydrogen and hydrogen like atoms $E_n = -13.6\frac{z^2}{n^2}eV$

$U_n = 2E_n = -27.2\frac{z^2}{n^2}eV$ and $K_n = |E_n| = 13.6\frac{z^2}{n^2}eV$

From these three relations we can see that as n decreases, K will increase but E and U will decreases.

113. (a) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right] \Rightarrow \frac{\lambda_{\min}}{\lambda_{\max}} = \frac{\left[\frac{1}{2^2}-\frac{1}{3^2}\right]}{\left[\frac{1}{2^2}-\frac{1}{\infty}\right]} = \frac{5}{9}$

114. (b) By using $r_n = r_0\frac{n^2}{Z}$; Where r_0 = Radius of the Bohr orbit in the ground state atom . So for He^+ third excited state

$n = 4,\ Z = 2,\ r_0 = 0.5\AA \Rightarrow r_4 = 0.5\times\frac{4^2}{2} = 4\AA$

115. (d) Speed of electron in n orbit (in CGS) $v_n = \frac{2\pi Ze^2}{nh}$ $(k = 1)$

For first orbit H_2; $n = 1$ and $Z = 1$

So $v = \frac{2\pi e^2}{h} \Rightarrow \frac{v}{c} = \frac{2\pi e^2}{hc}$

116. (b)

117. (d) $E_n = -\frac{13.6}{n^2}eV \Rightarrow E_5 = \frac{-13.6}{5^2} = \frac{-13.6}{25} = -0.54\ eV$

118. (a)

119. (b)

120. (a) $mvr = \frac{nh}{2\pi} \Rightarrow v = \frac{nh}{2\pi mr} \Rightarrow \frac{v^2}{r} = \frac{n^2h^2}{4\pi^2m^2r^3}$.

121. (b) Maximum number of spectral lines are observed in Lymen series.

122. (b) Wave number $\bar{\nu} = \frac{1}{\lambda} = \frac{1}{5896\times10^{-8}} = 16961$ per cm

123. (b) $r_n \propto n^2 \Rightarrow \frac{r_3}{r_1} = \frac{3^2}{1} \Rightarrow r_3 = 9r_1 = 9\times0.53 = 4.77\AA$

124. (d) For first line in Lyman series $\lambda_{L_1} = \frac{4}{3\,R}$ ..... (i)

For first line in Balmer series $\lambda_{B_1} = \frac{36}{5\,R}$ ..... (ii)

From equation (i) and (ii)

$\frac{\lambda_{B_1}}{\lambda_{L_1}} = \frac{27}{5} \Rightarrow \lambda_{B_1} = \frac{27}{5}\lambda_{L_1} \Rightarrow \lambda_{B_1} = \frac{27}{5}\lambda$

125. (a)

126. (d) 3 – 1 transition has higher energy so it has higher frequency $\left(\nu = \frac{E}{h}\right)$

127. (d) α-particles cannot be attracted by the nucleus.

128. (c) By using $\nu = RC\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

$\Rightarrow \nu = 10^7\times(3\times10^8)\left[\frac{1}{4^2}-\frac{1}{5^2}\right] = 6.75\times10^{13}\ Hz$

129. (c) For M shell ($n = 3$), orbital quantum number $l = 0, 1, 2$.

130. (d) Number of possible emission lines $= \frac{n(n-1)}{2}$

Where $n = 4$; Number $= \frac{4(4-1)}{2} = 6$.

131. (a) Diameter of nucleus is of the order of $10^{-14}\,m$ and radius of first Bohr orbit of hydrogen atom $r = 0.53\times10^{-10}\,m$.

132. (c) The electron is in the second orbit (n=2)

Hence $L = \frac{nh}{2\pi} = \frac{2h}{2\pi} = \frac{6.6\times10^{-34}}{\pi} = 2.11\times10^{-34}\ J\text{ - }sec$

133. (c) $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) \Rightarrow \lambda \propto \frac{1}{Z^2}$

$\lambda_{Li^{++}} : \lambda_{He^+} : \lambda_H = 4 : 9 : 36$

134. (a) Energy radiated $E = 10.2\,eV = 10.2\times1.6\times10^{-19}\,J$

$\Rightarrow E = \frac{hc}{\lambda} \Rightarrow \lambda = 1.215\times10^{-7}m$

135. (c) For $n = 1,\ E_1 = -\frac{13.6}{(1)^2} = -13.6\ eV$

and for $n = 3$, $E_3 = -\frac{13.6}{(3)^2} = -1.51\ eV$

So required energy

$= E_3 - E_1 = -1.51-(-13.6) = 12.09\ eV$

136. (a) Similar to Q. 115

137. (c) Since in spectral series of hydrogen atom, Lymen series lies lower Balmer series.

138. (d) $mvr_n = \frac{nh}{2\pi} \Rightarrow pr_n = \frac{nh}{2\pi} \Rightarrow \frac{h}{\lambda}\times r_n = \frac{nh}{2\pi}$

$\Rightarrow \lambda = \frac{2\pi r_n}{n}$, for first orbit $n = 1$ so $\lambda = 2\pi r_1$

= circumference of first orbit

139. (d) $E_{n_1\to n_2} = -13.6\left[\frac{1}{n_2^2}-\frac{1}{n_1^2}\right]; n_1 = 2\ \&\ n_2 = 1$

$\Rightarrow E_{II} \to E_I = -13.6\times\frac{3}{4} = -10.2\ eV$

140. (b) $E_n = -\frac{13.6z^2}{n^2}eV \Rightarrow E_1 = -\frac{13.6\times(2)^2}{(1)^2} = -54.4\ eV$

141. (b) $\nu \propto Z^2 \Rightarrow \frac{\nu_{H_2}}{\nu_{He}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4} \Rightarrow \nu_{He} = 4\nu_{H_2} = 4\nu$.

142. (a) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

First condition $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow R = \frac{4}{3\lambda}$

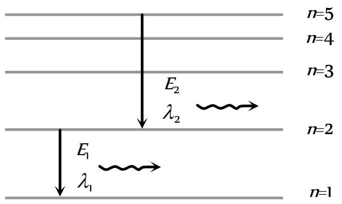
Second condition $\frac{1}{\lambda'} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$

$\Rightarrow \lambda' = \frac{9}{8R} \Rightarrow \lambda' = \frac{9}{8 \times \frac{4}{3\lambda}} = \frac{27\lambda}{32}$

143. (b)

144. (a) $r_n \propto n^2$

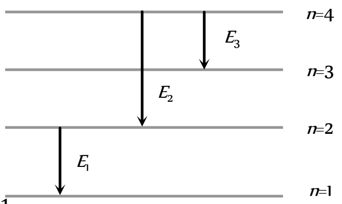
145. (d) $\because E_2 < E_1 \Rightarrow \lambda_2 > \lambda_1$



146. (a) Wave number $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]; n_2 = \infty$ and $n_1 = 1$

$\Rightarrow \bar{\nu} = R = 1.097 \times 10^7 m^{-1} = 109700\, cm^{-1}$

147. (b) $E_1 > E_2 > E_3$



148. (d) $r \propto \frac{1}{Z}$, for double ionized lithium $Z(=3)$ will be maximum. So r will be minimum

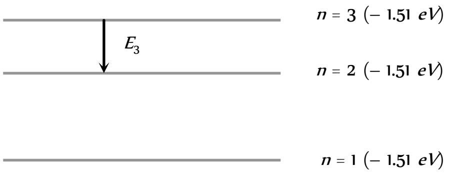
149. (b) $E_n = \frac{13.6}{n^2} \times Z^2$. For first excited state $n = 2$ and for $Li^{++}, z = 3 \Rightarrow E = \frac{13.6}{4} \times 9 = 30.6\, eV$

150. (b)

151. (a) In Lyman series $(\lambda_{\min})_L = \frac{1}{R}$ and $(\lambda_{\min})_B = \frac{4}{R}$

$\Rightarrow (\lambda_{\min})_B = 4 \times (\lambda_{\min})_L = 4 \times 912 = 3648\, Å$

152. (d)



$E_{3\to 2} = -3.4 - (-1.51) = -1.89\, eV \Rightarrow |\, E_{3\to 2}| \approx 1.9\, eV$

153. (a)

154. (a)

155. (c) Radius of n orbit for any hydrogen like atom

$r_n = r_0\left(\frac{n^2}{Z}\right)$ (r_0 = radius of first orbit of H_2 -atom)

If $r_n = r_0 \Rightarrow n = \sqrt{Z}$. For Be, $Z = 4 \Rightarrow n = 2$.

156. (d) $r_n \propto n^4 \Rightarrow A_n \propto n^4 \Rightarrow \frac{A_1}{A_0} = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$

157. (d)

158. (d) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For first wavelength, $n_1 = 2$, $n_2 = 3$

$\Rightarrow \lambda_1 = 6563\, Å$. For second wavelength, $n_1 = 2$, $n_2 = 4$

$\Rightarrow \lambda_2 = 4861\, Å$

159. (c) K.E. = – (Total energy) = – (–13.6 eV) = + 13.6 eV

160. (a) In Lyman series $\lambda_{\max} = \frac{4}{3R}$

In Balmer series $\lambda_{\max} = \frac{36}{5R}$. So required ratio $= \frac{5}{27}$

161. (c)

162. (b) $E = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$. For highest energy in Balmer series

$n_1 = 2$ and $n_2 = \infty \Rightarrow E = 13.6\left[\frac{1}{(2)^2} - \frac{1}{(\infty)^2}\right] = 3.4\, eV$

163. (a)

164. (c) $T \propto n^3$

165. (b) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] \Rightarrow \lambda = \frac{16}{3R}$

166. (a) $E_n \propto Z^2 \Rightarrow \frac{(E_n)_{He}}{(E_n)_H} = \frac{Z_{He}^2}{Z_H^2} = 4 \Rightarrow (E_n)_{He} = 4 \times (E_n)_H$

167. (b) By using $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

168. (a) $\frac{1}{\lambda_{\max}} = R\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] \Rightarrow \lambda_{\max} = \frac{4}{3R} \approx 1213\, Å$

and $\frac{1}{\lambda_{\min}} = R\left[\frac{1}{(1)^2} - \frac{1}{\infty}\right] \Rightarrow \lambda_{\min} = \frac{1}{R} \approx 910\, Å$

169. (b) P.E. $= 2 \times$ Total energy $= 2 \times (-13.6) = -27.2$ eV

170. (c) Emitted energy $\Delta E = \frac{hc}{\lambda}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

171. (c) $U = 2E$, $K = -E$ and $E = -\frac{13.6}{n^2} = eV$.

172. (a)

173. (d)

174. (c) $r \propto n^2$

Nucleus, Nuclear Reaction

1. (b)

2. (c) Neutrons are neutral particles.

3. (c) James Chadwick discovered the neutron.

4. (d) In hydrogen, atomic number and mass number are equal.

5. (d) $E = mc^2 = 1 \times (3 \times 10^8)^2 = 9 \times 10^{16} \approx 10^{17}\ J$

6. (d) $B.E. = \Delta m\ amu = \Delta m \times 931\ MeV.$

7. (d) Mass defect $\Delta m = \frac{2.23}{931} = 0.0024.$

8. (b) Positron is the antiparticle of electron.

9. (b)

10. (c)

11. (a) B.E.$= \Delta mc = [2(1.0087 + 1.0073) - 4.0015] = 28.4\ MeV$

12. (b) $\frac{\text{Binding energy}}{\text{Nucleon}} = \frac{0.0303 \times 931}{4} \approx 7$

13. (d) Energy / day $= 200 \times 10^6 \times 24 \times 3600$

$= 2 \times 2.4 \times 3.6 \times 10^{12} = 1728 \times 10^{10}\ J$

14. (c) $E = \Delta mc^2 = 10^{-6} \times (3 \times 10^8)^2 = 9 \times 10^{10}\ J$

15. (c)

16. (c) Mass of ${}_1H^2 = 2.01478\ a.m.u.$

Mass of ${}_2He^4 = 4.00388\ a.m.u.$

Mass of two deuterium $= 2 \times 2.01478 = 4.02956$

Energy equivalent to $2\,{}_1H^2$

$= 4.02956 \times 1.112\ MeV = 4.48\ MeV$

Energy equivalent to ${}_2H^4$

$= 4.00388 \times 7.047\ MeV = 28.21\ MeV$

Energy released $= 28.21 - 4.48 = 23.73\ MeV = 24\ MeV$

17. (c) Energy released while forming a nucleus is known as binding energy (by definition).

18. (c) Nuclear force is stronger than coulomb force.

19. (d)

20. (c)

21. (b) $Q = 4\ (x_2 - x_1)$

22. (d)

23. (a) Rest energy of an electron $= m_e c^2$

Here $m_e = 9.1 \times 10^{-31} kg$ and c = velocity of light

$\therefore$ Rest energy $= 9.1 \times 10^{-31} \times (3 \times 10^8)^2\ joule$

$= \frac{9.1 \times 10^{-31} \times (3 \times 10^8)^2}{1.6 \times 10^{-19}} eV = 510\ keV$

24. (b) ${}_Z X^A = {}_{88}Ra^{226}$

Number of protons $= Z = 88$

Number of neutrons $= A - Z = 226 - 88 = 138.$

25. (c) Out side the Nucleus, neutron is unstable (life $\approx$ 932 *sec*).

26. (b) The order of magnitude of mass and volume of uranium nucleus will be

$m \simeq A(1.67 \times 10^{-27}\ kg)$ (A is atomic number)

$V = \frac{4}{3}\pi r^3 \simeq \frac{4}{3}\pi\,[(1.25 \times 10^{-15} m)A^{1/3}]^3$

$\simeq (8.2 \times 10^{-45} m^3)A$

Hence, $\rho = \frac{m}{V} = \frac{A(1.67 \times 10^{-27} kg)}{(8.2 \times 10^{-45} m^3)A}$

$\simeq 2.0 \times 10^{17} kg / m^3.$

27. (c) We have $r \propto A^{1/3} \Rightarrow \frac{r_2}{r_1} = \left(\frac{A_2}{A_1}\right)^{1/3} = \left(\frac{206}{4}\right)^{1/3}$

$\therefore r_2 = 3\left(\frac{206}{4}\right)^{1/3} = 11.6\ Fermi.$

28. (c) Nucleus does not contains electron.

29. (a) Let the percentage of B^{10} atoms be x, then Average atomic weight

$= \frac{10x + 11(100 - x)}{100} = 10.81 \Rightarrow x = 19 \quad \therefore \frac{N_{B^{10}}}{N_{B^{11}}} = \frac{19}{81}$

30. (a)

31. (b)

32. (a) Nuclear force is charge independent, it also acts between two neutrons.

33. (d) $p \to \pi^+ + n,\ \ n \to p + \pi^-$ and $n \to n' + \pi^0$

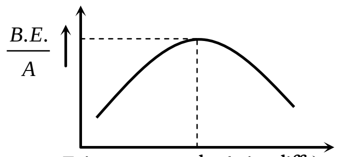
34. (c) Helium nucleus $\to {}_2He^4$.

Number of protons $= Z = 2$

Number of Neutrons $= A - Z = 2.$

35. (c)

36. (b) Binding energy per nucleon increases with atomic number and is maximum for iron. After that it decrease.



37. (a) For isotopes Z is same and A is different. Therefore the number of neutrons $A - Z$ will also be different.

38. (a) This is due to mass defect because a part of mass is used in keeping the neutrons and protons bound as $\alpha -$ particle.

39. (d) B.E. of $Li^7 = 39.20\ MeV$ and $He^4 = 28.24\ MeV$

Hence binding energy of $2He^4 = 56.48\ MeV$

Energy of reaction $= 56.48 - 39.20 = 17.28\ MeV.$

40. (c) $r \propto (A)^{1/3}$

41. (b) $r \propto A^{1/3}$

42. (a) $E = mc^2 = (1 \times 10^{-3})(3 \times 10^8)^2 = 9 \times 10^{13}\ J.$

43. (c) $\Delta E = 8.5 \times 234 - 7.6 \times 236 = 195.4\ MeV = 200\ MeV.$

44. (a) $N = M - Z =$ Total no. of nucleons – no. of protons.

45. (c)

46. (c) Both coulomb and nuclear force act inside the nucleus.

47. (d) For stability in case of lighter nuclei $\frac{N}{Z} = 1$ and for heavier nuclei $\frac{N}{Z} > 1.$

48. (b) Nuclear forces are charge independent.

49. (a) Actual mass of the nucleus is always less than total mass of nucleons so

$M < (NM_n + Zm_p)$.

50. (b) Mass of H_2 nucleus =mass of proton =1 *amu* energy equivalent to 1 *amu* is 931 *MeV* so correct option is *(b).*

51. (d) $R = R_0 A^{1/3} \Rightarrow R \propto A^{1/3}$.

52. (b)

53. (d) Number of neutrons = $A - Z = 23 - 11 = 12$.

54. (c) For ${}_6C^{12}$, $p = 6, e = 6, n = 6$

For ${}_6C^{14}$, $p = 6, e = 6, n = 8$

55. (a)

56. (a) The mass of nucleus formed is always less than the sum of the masses of the constituent protons and neutrons *i.e.* $m < (A - Z)m_n + zm_p$.

57. (d) $E = \Delta m.c^2 \Rightarrow E = \frac{0.3}{1000} \times (3 \times 10^8)^2 = 2.7 \times 10^{13} J$

$= \frac{2.7 \times 10^{13}}{3.6 \times 10^6} = 7.5 \times 10^6 kWh$.

58. (a, d)

59. (c) ${}_5B^{10} + {}_0n^1 \rightarrow {}_3Li^7 + {}_2He^4$.

60. (a)

61. (c) ${}_{92}U^{235}$ is normally fissionable.

62. (b)

63. (a)

64. (a) In atom bomb nuclear fission takes place with huge temperature.

65. (d) The given equation is ${}_2He^4 +_z X^A \rightarrow_{z+2} Y^{A+3} + A$

Applying charge and mass conservation

$4 + A = A + 3 + x \Rightarrow x = 1 \Rightarrow 2 + z = z + 2 + n \Rightarrow n = 0$

Hence *A* is a neutron.

66. (c) Energy of stars is due to the fusion of light hydrogen nuclei into *He*. In this process much energy is released.

67. (a) ${}_1H^2 +_1 H^2 \rightarrow_2 He^4 + 24\ MeV$.

68. (b) Energy $\propto c^2$; $\therefore$ Decrease in energy $\propto \frac{4}{9}$.

69. (b) Fusion reaction requires a very high temperature =(10^7 *K*).

70. (d) ${}_4Be^9 + {}_2He^4 \rightarrow {}_6C^{12} + {}_0n^1$.

71. (b)

72. (d)

73. (b, c)

74. (d)

75. (c) Cadmium rods absorb the neutrons so they are used to control the chain reaction process.

76. (d)

77. (d) No energy and mass enters or goes out of the system of the reaction and no external force is assumed to act.

78. (c)

79. (b)

80. (b) Energy of γ-ray photon = $0.5 + 0.5 + 0.78 = 1.78\ MeV$.

81. (c)

82. (d)

83. (c) When fast moving neutrons pass through a moderator, they collide with the molecules of the moderator. As a result of this the neutrons are in thermal equilibrium with the surrounding molecules of moderator. These neutrons are called thermal neutrons.

84. (b) $E_b + E_c > E_a$

85. (d) Because sound waves require medium to travel through and there is no medium (air) on moon's surface.

86. (b) Heavy water is used as moderators in nuclear reactions to slow down the neutrons.

87. (a) $m = \frac{E}{c^2} = \frac{931 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2} = 1.66 \times 10^{-27} kg$.

88. (d) $E = \Delta mc^2, \Delta m = \frac{0.1}{100} = 10^{-3} kg$

$\therefore E = 10^{-3} \times (3 \times 10^8)^2 = 10^{-3} \times 9 \times 10^{16} = 9 \times 10^{13} J$.

89. (d) Energy released by γ – rays for pair production must be greater than 1.02 *MeV.*

90. (a) ${}_8O^{18} + {}_1H^1 \rightarrow {}_9F^{18} + {}_on^1$

91. (c) Power $= 1000\ kW = 10^6 J/s$

Rate of nuclear fission $= \frac{10^6}{200 \times 1.6 \times 10^{-13}}$ = 3.125×10^{16}.

92. (b) A = 238 – 4 = 234 and Z = 92 – 2 = 90.

93. (a) $P = n\left(\frac{E}{t}\right) \Rightarrow 1000 = \frac{n \times 200 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$\Rightarrow \frac{n}{t} = 3.125 \times 10^{13}$.

94. (c) Due to the production of neutrons, a chain of nuclear fission is established which continues until the whole of the source substance is consumed.

95. (a) ${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{38}Sr^{90} + {}_{54}Xe^{143} + 3{}_0n^1$

96. (b) ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + Q$.

97. (c) Fast neutrons can escape from the reaction. So as to proceed the chain reaction. Slow neutrons are best.

98. (d) ${}_1H^2 +_1 H^2 \rightarrow_1 H^3 +_1 H^1$

99. (d)

100. (b) $\Delta m = 1 - 0.993 = 0.007\ gm$

$\therefore E = (\Delta m)c^2 = (0.007 \times 10^{-3})(3 \times 10^8)^2 = 63 \times 10^{10} J$.

101. (c) ${}_{85}X^{297} \rightarrow {}_{77}Y^{281} + 4\left({}_2He^4\right)$

102. (b) x+1= 24 + 4 $\Rightarrow$ x = 27.

103. (a)

104. (d) ${}_6C^{11} \rightarrow_5 B^{11} + \beta^+ + \gamma$ because $\beta^+ =_1 e^0$

105. (c)

106. (b) $\frac{\text{Energy}}{\text{Fission}} = 200\ MeV = 200 \times 10^6 \times 1.6 \times 10^{-19} J$

Fission rate $=\dfrac{5}{200\ MeV}=1.56\times10^{11}$ fission/sec.

107. (a)

108. (b) Energy is released in the sun due to fusion.

109. (d)

110. (c) In nuclear fission, neutrons are released.

111. (c) ${}_1H^1+{}_1H^1+{}_1H^2\rightarrow{}_2He^4+{}_{+1}e^0$ + energy.

112. (c)

113. (b) ${}_0n^1={}_1p^1+{}_{-1}e^0+\bar{\nu}$

Antineutrino is required for conservation of spin.

114. (b)

115. (d) Fusion is the main process of energy production in the sun.

116. (a)

117. (b) Mass of proton = mass of antiproton

$=1.67\times10^{-27}\,kg=1amu$

Energy equivalent to $1\ amu=931\ MeV$

So energy equivalent to 2 *amu* $=2\times931\ MeV$

$=1862\times10^{6}\times1.6\times10^{-19}=2.97\times10^{-10}\,J=3\times10^{-10}\,J$.

118. (a) In fusion reaction, two lighter nuclei combines.

119. (c)

120. (b) Hydrogen bomb is based on nuclear fusion.

121. (d) ${}_{92}U^{235}+{}_0n^1\rightarrow{}_{92}U^{236}$ and

${}_{92}U^{236}\rightarrow{}_{56}Ba^{144}+{}_{36}Kr^{89}+3{}_0n^1+Q$.

122. (d) Fusion reaction of deuterium is

${}_1H^2+{}_1H^2\rightarrow{}_2He^3+{}_0n^1+3.27\ MeV$

So $E=\dfrac{6.02\times10^{23}\times10^{3}\times3.27\times1.6\times10^{-13}}{2\times2}=7.8\times10^{13}\,J$

$=8\times10^{13}\,J$.

123. (a)

124. (a)

125. (c)

126. (c)

127. (b)

128. (d) Energy released in the fission of one nucleus = 200 *MeV*

$=200\times10^{6}\times1.6\times10^{-19}\,J=3.2\times10^{-11}\,J$

$P=16KW=16\times10^{3}\,Watt$

Now, number of nuclei required per *second*

$n=\dfrac{P}{E}=\dfrac{16\times10^{3}}{3.2\times10^{-11}}=5\times10^{14}$.

129. (c)

130. (a) Number of fissions per second

$=\dfrac{\text{Power output}}{\text{Energy released per fission}}$

$=\dfrac{3.2\times10^{6}}{200\times10^{6}\times1.6\times10^{-19}}=1\times10^{17}$

$\Rightarrow$ Number of fission per minute $=60\times10^{17}=6\times10^{18}$

131. (c)

132. (a) $X(n,\alpha)\,{}^7_3Li\Rightarrow{}_ZX^A+{}_0n^1\rightarrow3Li^7+{}_2He^4$

$Z=3+2=5$ and $A=7+4-1=10$

$\therefore{}_5X^{10}={}_5B^{10}$

133. (a)

134. (b) Mass of electron = mass of positron = $9.1\times10^{-31}\,kg$

Energy released $E=(2m).c^2$

$=2\times9.1\times10^{-31}\times(3\times10^{8})^2=1.6\times10^{-13}\,J$.

135. (b) ${}_1H^2+{}_1H^2\rightarrow{}_2He^4$ + energy

Binding energy of a $({}_1H^2)$ deuterium nuclei

$=2\times1.1=2.2\ MeV$

Total binding energy of two deuterium nuclei

$=2.2\times2=4.4\ MeV$

Binding energy of a $({}_2He^4)$ nuclei $=4\times7=28\ MeV$

So, energy released in fusion $=28-4.4=23.6\ MeV$

136. (c) Mass of a uranium nucleus

$=92\times1.6725\times10^{-27}+143\times1.6747\times10^{-27}$

$=393.35\times10^{-27}\,kg$

Number of nuclei in the given mass

$=\dfrac{1}{393.35\times10^{-27}}=2.542\times10^{24}$

Energy released $=200\times2.542\times10^{24}\,MeV$

$=5.08\times10^{26}\,MeV=8.135\times10^{13}\,J=8.2\times10^{13}\,J$

137. (a)

138. (c)

139. (b) In a material medium, when a positron meets an electron both the particles annihilate leading to the emission of two γ ray photons. This process forms the basis of an important diagnostic procedure called PET.

140. (a) Total mass of reactants

$=(2.0141)\times2=4.0282\ amu$

Total mass of products $=4.0024\ amu$

Mass defect $=4.0282\ amu-4.0024\ amu$

$=0.0258\ amu$

$\therefore$ Energy released $E=931\times0.0258=24\ MeV$

141. (b) ${}_7N^{14}+{}_2He^4\rightarrow{}_8O^{17}+{}_1H^1$

142. (b)

143. (b)

144. (d) ${}_8O^{16}+{}_1H^2\rightarrow{}_7N^{14}+{}_2He^4$

145. (d)

146. (a)

147. (b) Nuclear fusion takes place in stars which results in joining of nuclei accompanied by release of tremendous amount of energy.

148. (b)

149. (d) *B.E.* per nucleon $\propto$ stability.

150. (a) Nuclei of different elements having the same mass number are called isotones *e.g.,* ${}_4Be^9$ and ${}_5B^{10}$

151. (c)

152. (b)

153. (d) Packing fraction $= \dfrac{M-A}{A}$

154. (c) $B = [Z M_p + N M_n - M(N, Z)]c^2$

$$\Rightarrow M(M, Z) = Z M_p + N M_n - B/c^2$$

155. (c)

156. (a) In nuclear reacter, nuclear fission can be carried out through a sustained and a controlled chain reaction.

157. (b) ${}_6C^{12} + {}_0n^1 \rightarrow {}_7N^{13} + {}_{-1}\beta^o$

158. (a) ${}_0n^1 + {}_{92}U^{235} \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\ {}_0n^1$

159. (c) The energy released in sun and hydrogen bomb are due to nuclear fusion.

160. (c)

161. (a)

162. (a) ${}_{84}Po^{210} \rightarrow {}_{82}X^{206} + {}_2He^4$

Using conservation of linear moments

$$206v' + 4v = 0 \Rightarrow v' = -\frac{4v}{(206)} \Rightarrow |v'| = \frac{4v}{206}$$

163. (b) Power $P = \dfrac{\text{Energy}}{\text{time}} = \dfrac{mc^2}{t}$, $= 1 \times 10^{-6} \times (3 \times 10^8)^2$

$= 9 \times 10^{10}\ W = 9 \times 10^7\ kW.$

164. (b)

165. (c)

166. (b) The elements high on the *B.E.* versus mass number plot are very tightly bound and hence, are stable. And the elements those are lower on this plot, are less tightly bound and hence, are unstable.

Since helium nucleus shows a peak on this plot so, it is very stable.

167. (d)

168. (d) $E = \Delta mc^2 = 1 \times (3 \times 10^8)^2 = 9 \times 10^{10}\ J$

$$\Rightarrow E = \frac{9 \times 10^{16}}{1.6 \times 10^{-19}} = 5.625 \times 10^{35}\ eV = 5.625 \times 10^{29}\ MeV.$$

169. (a) $E = \Delta mc^2 = 0.5 \times 10^{-3} \times (3 \times 10^8)^2 = 4.5 \times 10^{13}\ j$

$$\Rightarrow E = \frac{4.5 \times 10^{13}}{3.6 \times 10^6} = 1.25 \times 10^7\ kWH.$$

170. (b) ${}_0n^1 + {}_{92}U^{235} \rightarrow {}_{36}Kr^{94} + {}_{56}Ba^{139} + 3\ {}_0n^1$

171. (b)

172. (a) Number of protons = 2 + 2 + 6 + 2 + 6 = 18

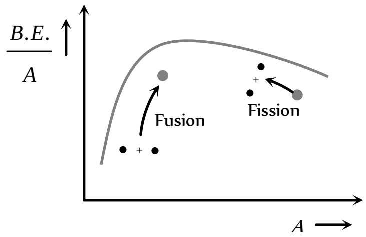
Number of neutrons = 40 – 18 = 22.

173. (c) Neutrons are unstable and having mean life time of 32 *sec,* decaying by emitting an electron and antineutrino to become proton.

174. (b) During fusion binding energy of daughter nucleus is always greater than the total energy of the parent nuclei so energy released = *c* – (*a* + *b*) = *c* – *a* – *b*

175. (a) These nuclei having different *Z* and *A* but equal (*A* – *Z*) are called isotones.

176. (b)



177. (a)

178. (c) $r \propto A^{1/3} \Rightarrow \dfrac{r_1}{r_2} = \left(\dfrac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{3.6}{r_2} = \left(\frac{27}{125}\right)^{1/3} = \frac{3}{5} \Rightarrow r_2 = 6\ Fermi$$

179. (b)

Radioactivity

1. (a)

2. (a) By formula $N = N_0\left(\dfrac{1}{2}\right)^{t/T}$ or $10^4 = 8 \times 10^4\left(\dfrac{1}{2}\right)^{t/3}$

or $\left(\dfrac{1}{8}\right) = \left(\dfrac{1}{2}\right)^{t/3}$ or $\left(\dfrac{1}{2}\right)^3 = \left(\dfrac{1}{2}\right)^{t/3} \Rightarrow 3 = \dfrac{t}{3}$

Hence *t* = 9 *years*.

3. (d) Fraction $= \dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^{\frac{6400}{1600}} = \left(\dfrac{1}{2}\right)^4 = \dfrac{1}{16}$

4. (c) Negative $\beta -$ decay is expressed by the equation

$$n = p^+ + e^- + v^-$$

5. (a) No radioactive substance emit both α and β particles simultaneously. Some substances emit $\alpha -$ particles and some other emits $\beta -$ particles. $\gamma -$ rays are emitted along with both α and $\beta -$ particles.

6. (c) γ-rays are highly penetrating.

7. (c) Average life $\frac{1}{\lambda}=\frac{1600}{0.693}=2308\approx 2319$ years.

8. (d) Fraction of atoms remains after five half lives

$$\frac{N}{N_0}=\left(\frac{1}{2}\right)^{t/T}=\left(\frac{1}{2}\right)^{5T/T}=\frac{1}{32}$$

$\Rightarrow$ Percentage atom remains $=\frac{1}{32}\times 100=3.125\%$

9. (c) β-rays emitted from nucleus and they carry negative charge.

10. (c)

11. (b) ${}_Z X^A \xrightarrow{{}_{-1}\beta^0} {}_{Z+1}Y^A \xrightarrow{2He^4(\alpha)}$

$${}_{Z-1}K^{A-4} \xrightarrow{{}_0\gamma^0} {}_{Z-1}K^{A-4}$$

12. (c) $N_t=N_0\left(\frac{1}{2}\right)^{t/T}=50000\left(\frac{1}{2}\right)^{10/5}=12500$

13. (c) ${}_Z X^A \xrightarrow{{}_{-1}\beta^0} {}_{Z+1}X^A$

14. (c) $N=N_0\left(\frac{1}{2}\right)^{t/T}\Rightarrow\frac{N_0}{64}=N_0\left(\frac{1}{2}\right)^{30/T}\Rightarrow T=\frac{30}{6}=5\text{ sec}$

15. (a)

16. (c)

17. (a) Average life $T=\frac{\text{Sum of all lives of all the atom}}{\text{Total number of atoms}}=\frac{1}{\lambda}$

$\Rightarrow T\lambda=1$

18. (c) Fraction remains after n half lives $\frac{N}{N_0}=\left(\frac{1}{2}\right)^n=\left(\frac{1}{2}\right)^{t/T}$

$$\therefore\ \frac{N}{N_0}=\left(\frac{1}{2}\right)^{\frac{T/2}{T}}=\left(\frac{1}{2}\right)^{1/2}=\frac{1}{\sqrt{2}}$$

19. (b)

20. (a) Penetration power of γ is 100 times of β, while that of β is 100 times of α.

21. (a) $\frac{N_0}{32}=N_0\left(\frac{1}{2}\right)^{60/T}\Rightarrow 5=\frac{60}{T}\Rightarrow T=12$ days

22. (c) By using $N=N_0\left(\frac{1}{2}\right)^{t/T}$; where $N=\left(1-\frac{7}{8}\right)N_0=\frac{1}{8}N_0$

So $\frac{1}{8}N_0=N_0\left(\frac{1}{2}\right)^{t/T}\Rightarrow\left(\frac{1}{2}\right)^3=\left(\frac{1}{2}\right)^{t/5}\Rightarrow t=15$ *days.*

23. (a) ${}_{72}A^{180}\xrightarrow{\alpha}{}_{70}A_1^{176}\xrightarrow{\beta}{}_{71}A_2^{176}\xrightarrow{\alpha}{}_{69}A_3^{172}$

$$\xrightarrow{\gamma}{}_{69}A_4^{172}$$

24. (d)

25. (d) Half life of a substance doesn't depends upon Amount, temperature and pressure. It depends upon the nature of the substance.

26. (d) $T=\frac{0.6931\times 1}{\lambda}=\frac{0.6931\times 1}{4.28\times 10^{-4}}\,year=1620\,years$

27. (c) In fusion two lighter nuclei combines, it is not the radioactive decay.

28. (b) $n_\alpha=\frac{A-A'}{4}=\frac{232-208}{4}=6$

and $n_\beta=(2n_\alpha-Z+Z')=(2\times 6-90+82)=4$

29. (a) Remaining amount

$$=16\times\left(\frac{1}{2}\right)^{32/2}=16\times\left(\frac{1}{2}\right)^{16}=\left(\frac{1}{2}\right)^{12}<1\,mg$$

30. (c) $\frac{N}{N_0}=\left(\frac{1}{2}\right)^{15/5}=\frac{1}{8}\Rightarrow$ Decayed fraction $=1-\frac{1}{8}=\frac{7}{8}$

31. (c)

32. (c) By using $n_\alpha=\frac{A-A'}{4}$ and $n_\beta=2n_\alpha-Z+Z'$

$\Rightarrow A'=A-4n_\alpha=236-4\times 3=224$

and $Z'=(n_\beta-2n_\alpha+Z)=(1-2\times 3+88)=83$

33. (d) Uncertain, because it is infinite. No radioactive element can be disintegrated fully.

34. (c) $\frac{N}{N_0}=\left(\frac{1}{2}\right)^{t/140}\Rightarrow\frac{1}{16}=\left(\frac{1}{2}\right)^{t/140}$.

$\Rightarrow\frac{t}{140}=4\Rightarrow t=560\,days$

35. (c) $\frac{C_{14}}{C_{12}}=\frac{1}{4}=\left(\frac{1}{2}\right)^{t/5700}\Rightarrow\frac{t}{5700}=2\Rightarrow t=11400\,years$

36. (b) Ionising property depends upon the charge and mass.

37. (b) $R=\frac{dN}{dt}\propto N\Rightarrow\frac{R_2}{R_1}=\frac{N_2}{N_1}$

But $\frac{N_2}{N_1}=\left(\frac{1}{2}\right)^{t_{1/2}}\Rightarrow\frac{25}{200}=\frac{1}{8}=\left(\frac{1}{2}\right)^3\Rightarrow\frac{t}{t_{1/2}}=3$

$\therefore t_{1/2}=\frac{t}{3}=\frac{3}{3}=1\,hour=60$ *minutes*

38. (d) $t_{1/2}=\frac{0.6931}{0.01}=69.31$ *seconds.*

39. (d) Because radioactivity is a spontaneous phenomenon.

40. (d) Undecayed isotope $=1-\frac{7}{8}=\frac{1}{8}$

$\therefore\frac{N}{N_0}=\left(\frac{1}{2}\right)^{t/T}\Rightarrow\left(\frac{1}{8}\right)=\left(\frac{1}{2}\right)^{t/15}\Rightarrow\frac{t}{15}=3$

or $t=45$ *hours*

41. (a) Mean life $=\frac{\text{Half life}}{0.6931}=\frac{10}{0.6931}=14.4\,hours$

42. (b) 20 *gm* substance reduces to 10 *gm* (*i.e.* becomes half in 4 min.

So $T_{1/2} = 4$ min . Again $M = M_0\left(\frac{1}{2}\right)^{t/T_{1/2}}$

$\Rightarrow 10 = 80\left(\frac{1}{2}\right)^{t/4} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^{t/4} \Rightarrow t = 12$ *min.*

43. (c) $N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 1 = 16\left(\frac{1}{2}\right)^{\frac{2}{T_{1/2}}} \Rightarrow T_{1/2} = \frac{1}{2}\,hour$

44. (d)

45. (b) $\beta-$ decay from nuclei based on this process only.

46. (b) $A = A_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 5 = A_0\left(\frac{1}{2}\right)^{\frac{2\times60}{30}} = \frac{A_0}{16} \Rightarrow A_0 = 80\,sec^{-1}$

47. (d) $n_\alpha = \frac{A-A'}{4} = \frac{200-168}{4} = 8$

$n_\beta = 2n_a - Z + Z' = 2\times8 - 90 + 80 = 6$

48. (d) Similar to Q. 47

49. (b) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$. Hence fraction of atoms decayed

$= 1 - \frac{N}{N_0} = 1 - \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = 1 - \left(\frac{1}{2}\right)^{\frac{3\times60}{60}} = \frac{7}{8}$

In percentage it is $\frac{7}{8}\times100 = 87.5\%$

50. (a) *C*-14 is carbon dating substance.

51. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} \Rightarrow \left(\frac{1}{16}\right) = \left(\frac{1}{2}\right)^{2/T} \Rightarrow \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{2/T}$

$\Rightarrow T = 0.5\,hour = 30$ *minutes.*

52. (c) $\frac{dN}{dt} = -\lambda N \Rightarrow n = -\lambda N$ (Given $\frac{dN}{dt} = n$)

$\therefore \lambda = -\frac{n}{N}$ $\therefore$ Half life $= \frac{0.693}{\lambda} = \frac{0.693}{\lambda} = \frac{0.693\,N}{n}$ sec

53. (a) ${}_{92}X^{235} \xrightarrow{\alpha} {}_{90}X^{231} \xrightarrow{{}_{-1}e^0} {}_{91}Y^{231}$

54. (d) ${}_7N^{13} \rightarrow {}_6C^{13} + {}_{+1}e^0$

55. (c) $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 100 = 1600\left(\frac{1}{2}\right)^{\frac{8}{T_{1/2}}} \Rightarrow T_{1/2} = 2sec$

Again at $t = 6$ *sec*, $A = 1600\left(\frac{1}{2}\right)^{\frac{6}{2}} = 200$ *counts/sec*

56. (d) ${}_{92}U^{238} \rightarrow {}_{92}Th^{234} + {}_2He^4$

57. (b)

58. (d)

59. (d)

60. (b) By using $N = N_0 e^{-\lambda t} \Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}} \Rightarrow 2 = e^{\lambda T_{1/2}}$

By taking log both the side

$\log_e 2 = \lambda T_{1/2} \Rightarrow \lambda T_{1/2} = 0.693$

61. (a) Number of half lives in 20 min $= n = \frac{20}{5} = 4$

Fraction of material remains after four half lives $= \frac{1}{16}$

Hence fraction that decays $= 1 - \frac{1}{16} = \frac{15}{16} = 93.75\%$

62. (d) In the given case, 12 days = 3 half lives Number of atoms left after 3 half lives.

$= 6.4\times10^{10}\times\frac{1}{2^3} = 0.8\times10^{10}$

63. (a) Decay constant remains unchanged in a chemical reaction.

64. (d) $n_\alpha = \frac{A-A'}{4} = \frac{238-206}{4} = 8$

65. (b) ${}_ZX^A \xrightarrow{\alpha} {}_{Z-2}Y^{A-4} \xrightarrow{2\beta} {}_ZX^{A-4}$

66. (a) Both the β-rays and the cathode rays are made up of electrons. γ-rays are EM waves, α-particles are doubly ionized helium atoms and protons and neutrons have approximately the same mass.

67. (b) ${}^{22}_{10}Ne \rightarrow {}^4_2He + {}^4_2He + {}^{14}_6X$; hence *X* is carbon.

68. (c) For 80 minutes, number of half lives of sample $A = n_A = \frac{80}{20} = 4$ and number of half lives of sample $B = n_B = \frac{80}{40} = 2$. Also by using $N = N_0\left(\frac{1}{2}\right)^n$

$\Rightarrow N \propto \frac{1}{2^n} \Rightarrow \frac{N_A}{N_B} = \frac{2^{n_B}}{2^{n_A}} = \frac{2^2}{2^4} = \frac{1}{4}$

69. (d) ${}_nX^m \xrightarrow{\alpha} {}_{n-2}X^{m-4} \xrightarrow{-\beta} {}_{n-1}X^{m-4}$

70. (c) Half-life $T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{1.07\times10^{-4}} = 6476\,years$

71. (d) Number of nuclei decreases exponentially

$N = N_0 e^{-\lambda t}$ and Rate of decay $\left(-\frac{dN}{dt}\right) = \lambda N$

Therefore, decay process losts up to $t = \infty$.

Therefore, a given nucleus may decay at any time after $t = 0$.

72. (a) To becomes $\frac{1}{4}$ *th*, it requires time of two half lives

i.e., $t = 2(T_{1/2}) = 2\times5800 = 2\times58$ *centuries*

73. (a) Carbon dating

74. (d) ${}_7X^{15} + {}_2He^4 \rightarrow {}_1P^1 + {}_8Y^{18}$

75. (c)

76. (d) ${}_{92}U^{238} \xrightarrow{\alpha} {}_{90}X^{234} \xrightarrow{\beta^-} {}_{91}Y^{234}$

77. (d)

78. (c) After three half lives (*i.e.*, 30 days) it remains $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$, so it will remain $\frac{1}{10}th$, approximately in 33 days.

79. (a) $_{92}U^{238} \xrightarrow{\alpha} {_{90}Th^{234}} \xrightarrow{\beta} {_{91}Pa^{234}} \xrightarrow{E(_{-1}\beta^o)} {_{92}U^{234}}$

80. (d) By using $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{A}{A_0} = \left(\frac{1}{2}\right)^{9/3} = \frac{1}{8}$

81. (d) $_{48}Cd^{115} \xrightarrow{2(_{-1}\beta^o)} {_{50}Sn^{115}}$

82. (b) In two half lives, the activity becomes one fourth.

83. (a) α decay decreases the mass number by 4 and atomic number by 2, β decay increases the atomic number by 1. Here atomic number of C is same as that of A.

84. (a) Number of half lives in two days four substance 1 and 2 respectively are $n_1 = \frac{2 \times 24}{12} = 4$ and $n_2 = \frac{2 \times 24}{1.6} = 3$

By using $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow \frac{N_1}{N_2} = \frac{(N_0)_1}{(N_0)_2} \times \frac{\left(\frac{1}{2}\right)^{n_1}}{\left(\frac{1}{2}\right)^{n_2}}$

$= \frac{2}{1} \times \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^3} = \frac{1}{1}$

85. (b)

86. (c) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{2.3} = 0.3$

87. (d) Number of $\alpha -$ particles emitted $= \frac{238-222}{4} = 4$

This decreases atomic number to $90 - 4 \times 2 = 82$

Since atomic number of $_{83}Y^{222}$ is 83, this is possible if one $\beta -$ particle is emitted.

88. (d) Number of half lives in 150 years $n = \frac{150}{75} = 2$

Fraction of the atom of decayed $= 1 - \left(\frac{1}{2}\right)^n$

$= 1 - \left(\frac{1}{2}\right)^2 = \frac{3}{4} = 0.75 \Rightarrow$ Percentage decay = 75%

89. (b) $A = A_0 e^{-\lambda t} \Rightarrow 975 = 9750\, e^{-\lambda \times 5} \Rightarrow e^{5\lambda} = 10$

$\Rightarrow 5\lambda = \log_e 10 = 2.3026 \log_{10} 10 = 2.3026$

$\Rightarrow \lambda = 0.461$

90. (a) Mass number decreases by $8 \times 4 = 32$

Atomic number decreases by $8 \times 2 - 5 = 11$

91. (b)

92. (d) $A = A_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow 5 \times 10^{-6} = 64 \times 10^{-5}\left(\frac{1}{2}\right)^{t/3}$

$\Rightarrow \frac{1}{128} = \left(\frac{1}{2}\right)^{t/3} \Rightarrow t = 21$ *days*

93. (c) Decayed fraction $= \frac{3}{4}$, so undecayed fraction $= \frac{1}{4}$

Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n \Rightarrow n = 2$

$\Rightarrow t = n \times T_{1/2} = 2 \times 3.8 = 7.6$ *days*

94. (c) $_{84}X^{202} \xrightarrow{\alpha-\text{decay}} {_{82}Y^{198}} + {_2He^4}$ and

$_{82}Y^{198} \xrightarrow{\beta-\text{decay}} {_{83}Z^{198}} + {_{-1}\beta^0}$

95. (a) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$

Now $t = n \times T_{1/2} = 3 \times 3.8 = 11.4$ *days*

96. (d) $n = \frac{72000}{24000} = 3$; Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \frac{1}{8}$

97. (d)

98. (a)

99. (b) $n_\alpha = \frac{A - A'}{4} = \frac{232-208}{4} = 6$

$n_\beta = 2n_\alpha - Z + Z' = 2 \times 6 - 90 + 82 = 4$

100. (c)

101. (a) Number of half lives $n = \frac{5}{1} = 5$

Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^5 = \frac{1}{32}$

102. (d)

103. (b) Number of half lives $n = \frac{10}{5} = 2$, now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

Fraction decayed $= 1 - \frac{N}{N_0} = 1 - \frac{1}{4} = \frac{3}{4}$

$\Rightarrow$ In percentage $= \frac{3}{4} \times 100 = 75\%$

104. (b) Number of half lives $n = \frac{19}{3.8} = 5$; Now $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n$

$\Rightarrow \frac{N}{10.38} = \left(\frac{1}{2}\right)^5 \Rightarrow N = 10.38 \times \left(\frac{1}{2}\right)^5 = 0.32gm$

105. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^5$

106. (d) $T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{2.303 \log_{10} 2}{\lambda}$

107. (a) ${}_{Z}^{A}X \rightarrow {}_{Z-2}^{A-4}Y + {}_{2}^{4}He \rightarrow {}_{Z-3}^{A-4}Z + {}_{1}^{0}B$

108. (d) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n, n = 2 \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

So disintegrated part $= 1 - \frac{N}{N_0} = 1 - \frac{1}{4} = \frac{3}{4}$

109. (c) Number of half lives $n = \frac{10}{2.5} = 4$

$\Rightarrow \frac{A}{A_0} = \frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow A = 1.6 \times \left(\frac{1}{2}\right)^4 = 0.1\, curie$

110. (b) By using $N = N_0 e^{-\lambda t}$ and $t = \tau = \frac{1}{\lambda}$

Substance remains $= N = \frac{N_0}{e} = 0.37 N_0 \simeq \frac{N_0}{3}$

$\therefore$ Substance disintegrated $= N_0 - \frac{N_0}{3} = \frac{2N_0}{3}$

111. (c) $\frac{3}{4} th$ active decay takes place in time

$t = 2(T_{1/2}) \Rightarrow \frac{3}{4} = 2(T_{1/2}) \Rightarrow T_{1/2} = \frac{3}{8}\sec$

112. (c) By using $N = N_0 e^{-\lambda t}$ and average life time $t = \frac{1}{\lambda}$

So $N = N_0 e^{-\lambda \times 1/\lambda} = N_0 e^{-1} \Rightarrow \frac{N}{N_0} = e^{-1} = \frac{1}{e}$

Now disintegrated fraction $= 1 - \frac{N}{N_0} = 1 - \frac{1}{e} = \frac{e-1}{e}$

113. (d) Complete reaction will be as follows

${}_{92}X^{235} \rightarrow {}_{82}Y^{207} + 7\,{}_{2}He^4 + 4\,{}_{-1}e^0$

i.e., seven $\alpha -$ particles and four $\beta -$ particles will be emitted.

114. (d) $n_\alpha = \frac{A - A'}{4} = \frac{235 - 207}{4} = 7$

$n_\beta = (2n_\alpha - Z + Z') = (2 \times 7 - 92 + 82) = 4$

115. (c) During β-decay, a neutron is transformed into a proton and an electron.

116. (b) ${}_{Z}X^A \xrightarrow{\alpha} {}_{Z-2}X^{A-4}$

117. (a)

118. (a)

119. (d) After emitting β-particle (e) mass of nucleus doesn't change.

120. (a) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{16} = \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n \Rightarrow n = 4.$

Also $n = \frac{t}{T_{1/2}} \Rightarrow T_{1/2} = \frac{40}{4} = 10\, days$

121. (c) As the $\gamma -$ particle has no charge and mass.

122. (d) With emission of an α particle $({}_2He^4)$ mass number decreases by 4 unit and atomic number decrease by 2 units and with emission of $2\beta^{-1}$ particle atomic number increases by 2 units. So Z will remain same and *N* will become $N - 4$.

123. (a) $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \frac{1}{100} = \left(\frac{1}{2}\right)^n \Rightarrow 2^n = 100$

n comes out in between 6 and 7.

124. (d) $N = N_0\left(\frac{1}{2}\right)^n \Rightarrow N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}}$

$\Rightarrow N = 1 \times \left(\frac{1}{2}\right)^{\frac{8.1}{2.7}} = \left(\frac{1}{2}\right)^3 = \frac{1}{8} \Rightarrow N = \frac{1}{8} mg = 0.125\, mg$

125. (d) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T}} \Rightarrow \frac{N_0}{4} = N_0\left(\frac{1}{2}\right)^{\frac{16}{T}} \Rightarrow T = 8$ days.

126. (d) ${}_{92}U^{238} \rightarrow {}_2He^4 + {}_{90}X^{234} \rightarrow {}_{-1}e^0 + {}_{91}U^{234}$

Hence, $A = 234$, $Z = 91$

127. (c) Mean life $= \frac{1}{\lambda} = 6.67 \times 10^8 \sec$.

128. (d) $\frac{dN}{dt} = -\lambda N \Rightarrow \left|\frac{dN}{dt}\right| = \frac{0.693}{T_{1/2}} \times N$

$= \frac{0.693}{1.2 \times 10^7} \times 4 \times 10^{15} = 2.3 \times 10^8\, atoms/\sec$

129. (c) Remaining material $N = \frac{N_0}{2^{t/T}}$

$\Rightarrow N = \frac{10}{(2)^{20/15}} = \frac{10}{2.15} = 3.96\, gm$

So decayed material $= 10 - 3.96 = 6.04\, gm$

130. (b) Number of atoms remains undecayed $N = N_0 e^{-\lambda t}$

Number of atoms decayed $= N_0(1 - e^{-\lambda t})$

$= N_0\left(1 - e^{-\lambda \times \frac{1}{\lambda}}\right) = N_0\left(1 - \frac{1}{e}\right) = 0.63\, N_0 = 63\%$ of N_0.

131. (d)

132. (b) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{16}\right) = \left(\frac{1}{2}\right)^n \Rightarrow n = 4$

also $n = \frac{t}{T_{1/2}} \Rightarrow T_{1/2} = \frac{120}{4} = 30\, days$

133. (c) $N = N_0 e^{-t/T_{1/2}} \Rightarrow \frac{1}{4} = e^{-t/10}$

$\Rightarrow \left(\frac{1}{2}\right)^2 = \frac{1}{e^{t/10}} \Rightarrow t = 20\, years$

134. (a) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = N_0\left(\frac{1}{2}\right)^{\frac{15}{5}} = \frac{N_0}{8}$

135. (a)

136. (b) $A = A_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{64} = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}}$

$\Rightarrow \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}} \Rightarrow T_{1/2} = 10 \sec$

137. (a, c)

138. (b) ${}_{(Z=92)}U^{(A=238)} \xrightarrow{(8\alpha, 6\beta)} {}_{Z'}X^{A'}$

so $A' = A - 4n_\alpha$ = 238 – 4 × 8 = 206

and $Z' = n_\beta - 2n_\alpha + z$ = 6 – 2 × 8 + 92 = 82.

139. (c) $A = A_0 e^{-\lambda t} = A_0 e^{-t/\tau}$; where τ = mean life

So $A_1 = A_0 e^{-t_1/T} \Rightarrow A_0 = \frac{A_1}{e^{-t_1/T}} = A_1 e^{t_1/T}$

$\therefore A_2 = A_0 e^{-t/T} = (A_1 e^{t_1/T})e^{-t_2/T} \Rightarrow A_2 = A_1 e^{(t_1-t_2)/T}$

140. (c)

141. (d) $n_\alpha = \frac{228-212}{4} = 4$ and $n_\beta = 2\times 4 - 90 + 83 = 1$

142. (c) In a gamma decay process. There is no change in either A or Z.

143. (a) The radioactivity of a sample decays to $\frac{1}{16}th$ of its initial value in four half lives.

144. (d) $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T} \Rightarrow \frac{1}{16} = \left(\frac{1}{2}\right)^{t/48}$

$\Rightarrow \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{t/48} \Rightarrow t = 192\ hour.$

145. (c) If λ is the decay constant of a radioactive substance than average life = $\frac{1}{\lambda}$

Also half life $= \frac{0.693}{\lambda} = 0.693 \times (\text{Average life})$

in single average life, more than 63% of radioactive nuclei decay

146. (b)

147. (d) $M = M_0 e^{-\lambda t}$; given $t = 2\left(\frac{1}{\lambda}\right)$

$\Rightarrow M = 10 e^{-\lambda\left(\frac{2}{\lambda}\right)} = 10\left(\frac{1}{e}\right)^2 \Rightarrow M = 1.35\ gm$

148. (b)

149. (b) $\lambda = \frac{\log_e \frac{A_1}{A_2}}{t} = \frac{\log_e \frac{5000}{1250}}{5}$ = 0.4 *ln* 2

150. (c) $Z_{\text{Resuting nucleus}} = 92 - 8\times 2 + 4\times 1 - 2\times 1 = 78$

151. (c) Radioactive nuclei that are injected into a patient collected at certain sites within it's body, undergoing radioactive decay and emitting electromagnetic radiation. These radiation can than be recorded by a detector. This procedure provides an important diagnostic tool called radio tracer technique.

152. (a) By using $n_\alpha = \frac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

153. (b) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

No of atoms at t = 2*hr*, $N_1 = 8\times 10^{10}\left(\frac{1}{2}\right)^{\frac{2}{1}} = 2\times 10^{10}$

No. of atoms at t = 4*hr*, $N_2 = 8\times 10^{10}\left(\frac{1}{2}\right)^{\frac{4}{1}} = \frac{1}{2}\times 10^{10}$

$\therefore$ No. of atoms decayed in given duration

$= \left(2 - \frac{1}{2}\right)\times 10^{10} = 1.5\times 10^{10}$

154. (b)

155. (d) $A = A_0\left(\frac{1}{2}\right)^n \Rightarrow 30 = 240\left(\frac{1}{2}\right)^n \Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n \Rightarrow n=3$

$\therefore \frac{t}{T_{1/2}} = 3 \Rightarrow T_{1/2} = \frac{t}{3} = \frac{1}{3}hr$ = 20 *min.*

156. (b) $M = M_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 25 = 100\left(\frac{1}{2}\right)^{\frac{t}{1600}} \Rightarrow t$= 3200 *years.*

157. (c) Activity $R = R_0 e^{-\lambda t}$

$\frac{R_0}{3} = R_0 e^{-\lambda\times 9} \Rightarrow e^{-9\lambda} = \frac{1}{3}$ ...(i)

After further 9 years $R' = R e^{-\lambda t} = \frac{R_0}{3}\times e^{-\lambda\times 9}$ ...(ii)

From equation (i) and (ii) $R' = \frac{R_0}{9}$.

158. (c) To reduce one fourth it takes time $t = 2(T_{1/2})$= 2 × 40 = 80 *years.*

Decay constant $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{40} = 0.0173\,years$

159. (d) $M = M_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} = 20\times\left(\frac{1}{2}\right)^{\frac{3.6}{3.6}} = 20\times\left(\frac{1}{2}\right)^{10} = 0.019\,mg$

160. (c) $N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{30}{10}} = \frac{1}{8} = 0.125$.

161. (a) $\frac{7}{8}$ part decays *i.e.* remaining part is $\frac{1}{8}$

$N = N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^{\frac{15}{T_{1/2}}} \Rightarrow T_{1/2}$ =5 *min.*

162. (d) $\frac{A}{A_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^{t/8} \Rightarrow t = 24\,years.$

163. (c) After $\beta^+({}_{+1}e^0)$ emission atomic number decreases by one and mass number remain unchanged. γ-emission, there will be no change on mass number and atomic number.

164. (c) New mass number $A' = A - 4n_\alpha = 232 - 4\times 6 = 208$

atomic number $Z' = Z + n_\beta - 2n_\alpha = 90 + 4 - 2\times 6 = 82$

165. (d)

166. (d) Using conservation of momentum $P_{daughter} = P_\alpha$

$$\Rightarrow \frac{E_d}{E_\alpha} = \frac{m_\alpha}{m_d} \Rightarrow E_d = \frac{E_\alpha \times m_\alpha}{m_d} = \frac{6.7\times 4}{214} = 0.125\, MeV$$

167. (c)

168. (c)

169. (b) $N = N_0 \times \left(\frac{1}{2}\right)^{11400/5700} = N_0\left(\frac{1}{2}\right)^2 = 0.25 N_0$.

170. (d) Mean life $(T) = 1/\lambda$ = 100 *second*

Half-life = $\frac{0.693}{\lambda} = \frac{0.693\times 100}{60}$ =1.155 *min.*

171. (b) By using $n_\alpha = \frac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

172. (c)

173. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{77} = 9\times 10^{-3}\,/\,day$.

174. (a) By using $n_\alpha = \frac{A - A'}{4} = \frac{232 - 204}{4} = 7$.

175. (c) $\therefore \frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}} \left(\frac{1}{2}\right)^{1/2} = \frac{1}{\sqrt{2}}$.

176. (d)

Critical Thinking Questions

1. (c) At closest distance of approach

Kinetic energy = Potential energy

$$\Rightarrow 5\times 10^6 \times 1.6\times 10^{-19} = \frac{1}{4\pi\varepsilon_0} \times \frac{(ze)(2e)}{r}$$

For uranium *z*= 92, so $r = 5.3\times 10^{-12}\,cm$

2. (c) Speed of electron in *n* orbit of hydrogen atom $v = \frac{e^2}{2\varepsilon_0 n h}$

In ground state *n* = 1 $\Rightarrow v = \frac{e^2}{2\varepsilon_0 h}$

$$\Rightarrow \frac{v}{c} = \frac{e^2}{2\varepsilon_0 ch} = \frac{(1.6\times 10^{-19})^2}{2\times 8.85\times 10^{-12} \times 3\times 10^8 \times 6.6\times 10^{-34}}$$

$$= \frac{1}{137}.$$

3. (b) Recoil momentum = momentum of photon $= \frac{h}{\lambda}$

$$= hR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{hR\times 15}{16} = 6.8\times 10^{-27}\, N\times \sec$$

4. (a) The average time that the atom spends in this excited state is equal to Δt, so by using $\Delta E.\Delta t = \frac{h}{2\pi}$

$\Rightarrow$ Uncertainty in energy $= \frac{h/2\pi}{\Delta t}$

$= \frac{6.6\times10^{-34}}{2\times3.14\times10^{-8}} = 1.05\times10^{-26}\,J = 6.56\times10^{-8}\,eV$

5. (a) After the removal of first electron remaining atom will be hydrogen like atom.

So energy required to remove second electron from the atom

$E = 13.6\times\frac{2^2}{1} = 54.4\,eV$

$\therefore$ Total energy required = 24.6 + 54.4 = 79 eV.

6. (a) Electron after absorbing 10.2 eV energy goes to its first excited state (n=2) from ground state (n = 1).

$\therefore$ Increase in momentum $= \frac{h}{2\pi}$

$= \frac{6.6\times10^{-34}}{6.28} = 1.05\times10^{-34}\,J\text{-}s$.

7. (a) Using $\Delta E \propto Z^2$ ($\because$ n_1 and n_2 are same)

$\Rightarrow \frac{hc}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant}$

$\Rightarrow \lambda_1 Z_1^2 = \lambda_2 Z_2^2 = \lambda_3 Z_3^2 = \lambda_4 Z_4^2$

$\Rightarrow \lambda_1\times1 = \lambda_2\times1^2 = \lambda_3\times2^2 = \lambda_4\times3^3$

$\Rightarrow \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$.

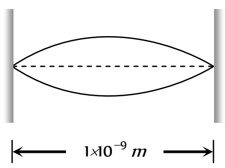
8. (d) $mvr = \frac{h}{2\pi}$ (for first orbit)

$\Rightarrow m\omega r^2 = \frac{h}{2\pi} \Rightarrow m\times2\pi\nu\times r^2 = \frac{h}{2\pi} \Rightarrow \nu = \frac{h}{4\pi^2 mr^2}$

$= \frac{6.6\times10^{-34}}{4(3.14)^2\times9.1\times10^{-31}\times(0.53\times10^{-10})^2} = 6.5\times10^{15}\,\frac{rev}{sec}$

9. (b) It will form a stationary wave

$\lambda = 2l = 2\times10^{-9}\,m$



$\Rightarrow \lambda = \frac{h}{\sqrt{2mE}}$

$\Rightarrow E = \frac{h^2}{2m\lambda^2} = 6\times10^{-20}\,J$

10. (d) Suppose closest distance is r, according to conservation of energy.

$400\times10^3\times1.6\times10^{-19} = 9\times10^9\,\frac{(ze)(2e)}{r}$

$\Rightarrow 6.4\times10^{-14} = \frac{9\times10^9\times(82\times1.6\times10^{-19})\times(2\times1.6\times10^{-19})}{r}$

$\Rightarrow r = 5.9\times10^{-13}\,m = 0.59\,pm$.

11. (a) Here radius of electron orbit $r \propto 1/m$ and energy $E \propto m$, where m is the mass of the electron.

Hence energy of hypothetical atom

$E_0 = 2\times(-13.6\,eV) = -27.2\,eV$ and radius $r_0 = \frac{a_0}{2}$

12. (a) Electronic configuration of iodine is 2, 8, 18, 18, 7,

Here $r_n = (0.053\times10^{-9}\,m)\frac{n^2}{Z}$

Here $n = 5$ and $Z = 53$, hence $r_n = 2.5\times10^{-11}\,m$.

13. (a) $N \propto \left[\frac{1}{\sin^4\theta/2}\right] \Rightarrow N_1 = 7\times\frac{1}{(\sin30^o)^4} = 112$

and $N_2 = 7\times\frac{1}{(\sin60^o)^4} = 12.5$.

14. (d) $E_n = -13.6\,\frac{Z^2}{n^2}\,eV$. Required energy for said transition

$\Delta E = E_3 - E_1 = 13.6\,Z^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$

$\Rightarrow \Delta E = 13.6\times3^2\left[\frac{8}{9}\right] = 108.8\,eV$

$\Rightarrow \Delta E = 108.8\times1.6\times10^{-19}\,J$

Now $\Delta E = \frac{hc}{\lambda} = 108.8\times1.6\times10^{-19}$

$\Rightarrow \lambda = \frac{6.6\times10^{-34}\times3\times10^8}{108.8\times1.6\times10^{-19}} = 0.11374\times10^{-7}\,m = 113.74\,Å$

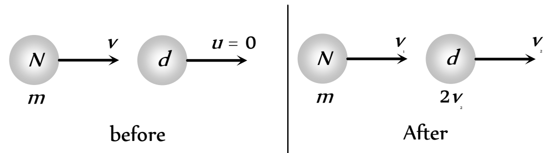
15. (c) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$\Rightarrow \frac{1}{970.6\times10^{-10}} = 1.097\times10^7\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right] \Rightarrow n_2 = 4$

$\therefore$ Number of emission lines $N = \frac{n(n-1)}{2} = \frac{4\times3}{2} = 6$

16. (d) Neutron velocity = v, mass = m

Deuteron contains 1 neutron and 1 proton, mass = $2m$



In elastic collision both momentum and $K.E.$ are conserved $p_i = p_f$

$mv = mv_1 + mv_2 \Rightarrow mv = mv_1 + 2mv_2$ ... (i)

By conservation of kinetic energy

$\frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(2m)v_2^2$ ... (ii)

By solving (i) and (ii) we get

$v_1 = \frac{m_1 - m_2}{m_1 + m_2}v + \frac{2m_2}{(m_1 + m_2)}v \Rightarrow v_1 = \frac{m_1 + 2m}{3m} = -\frac{v}{3}$

$K_i = \frac{1}{2}mv^2,\; K_f = \frac{1}{2}mv_1^2 \Rightarrow \frac{K_i - K_f}{K_i} = 1 - \frac{v_1^2}{v^2}$

$= 1 - \frac{1}{9} = \frac{8}{9}$ (Fractional change in $K.E.$)

17. (c) In hydrogen atom $E_n = -\frac{Rhc}{n^2}$

Also $E_n \propto m$; where m is the mass of the electron. Here the electron has been replaced by a particle whose mass is double of an electron. Therefore, for this hypothetical atom energy in n orbit will be given by $E_n = -\frac{2Rhc}{n^2}$

The longest wavelength λ_{max} (or minimum energy) photon will correspond to the transition of particle from $n = 3$ to $n = 2$

$$\Rightarrow \frac{hc}{\lambda_{max}} = E_3 - E_2 = Rhc\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

This gives $\lambda_{max} = \frac{18}{5R}$.

18. (d) As the transition $n = 4$ and $n = 3$, results in UV radiation and infrared radiation involves smaller amounts of energy UV. So we require a transition involving initial values of n greater than 4 *e.g.* $5 \to 4$.

19. (c) $\frac{hc}{\lambda} = E = eV$

$$\Rightarrow \lambda = \frac{hc}{eV} - \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}\times4.9} = 2525\,\mathring{A}$$

20. (d) Rydberg constant $R = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}$

Velocity $v = \frac{Ze^2}{2\varepsilon_0 nh}$ and energy $E = -\frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$

Now, it is clear from above expressions $R.v \propto n$

21. (b) In second excited state $n = 3$

So $l_H = l_{Li} = 3\left(\frac{h}{2\pi}\right)$

While $E \propto Z^2$ and $Z_H = 1$, $Z_{Li} = 3$

So $|E_{Li}| = 9|E_H|$ or $|E_H| < |E_{Li}|$

22. (c) Since the $^{133}_{55}Cs$ has larger size among the four atoms gives, thus the electrons present in the outermost orbit will be away from the nucleus and the electrostatic force experienced by electrons due to nucleus will be minimum. Therefore the energy required to liberate electron from outer will be minimum in the case of $^{133}_{55}Cs$.

23. (d)

24. (a) Potential energy $U = eV = eV_0 \ln\frac{r}{r_0}$

$\therefore$ Force $F = -\left|\frac{dU}{dr}\right| = \frac{eV_0}{r}$.

$\therefore$ The force will provide the necessary centripetal force. Hence $\frac{mv^2}{r} = \frac{eV_0}{r} \Rightarrow v = \sqrt{\frac{eV_0}{m}}$ .....(i)

and $mvr = \frac{nh}{2\pi}$ .....(ii)

From equation (i) and(ii) $mr = \left(\frac{nh}{2\pi}\right)\sqrt{\frac{m}{eV_0}}$ or $r \propto n$

25. (d) $(r_m) = \left(\frac{m^2}{Z}\right)(0.53\mathring{A}) = (n\times0.53\mathring{A}) \Rightarrow \frac{m^2}{Z} = n$

$m = 5$ for $_{100}Fm^{257}$ (the outermost shell)

and $z = 100 \Rightarrow n = \frac{(5)^2}{100} = \frac{1}{4}$

26. (d) Energy radiated $= 1.4\ kW/m^2$

$$= 1.4\ kJ/\sec m^2 = \frac{1.4\ kJ}{\frac{1}{86400} day\, m^2} = \frac{1.4\times86400}{day\, m^2}$$

Total energy radiated/day

$$= \frac{4\pi\times(1.5\times10^{11})^2\times1.4\times86400}{1}\frac{kJ}{day} = E$$

$$\therefore E = mc^2 \Rightarrow m = \frac{E}{c^2}$$

$$= \frac{4\pi(1.5\times10^{11})^2\times1.4\times86400}{(3\times10^8)^2} = 3.8\times10^{14}\,kg.$$

27. (c) The equation is $O^{17} \to _0n^1 + O^{16}$

$\therefore$ Energy required = B.E. of O – B.E. of O

= 17 × 7.75 – 16 × 7.97 = 4.23 MeV

28. (c) $\Delta = mc^2 - m_0c^2 = \frac{m_0c^2}{\sqrt{1-(v^2/c^2)}} - m_0c^2$

$$= m_0c^2\left(\frac{1}{\sqrt{1-(v^2/c^2)}} - 1\right) = 0.511\left(\frac{1}{\sqrt{0.75}} - 1\right)$$

= 0.079 MeV

29. (c,d) Due to mass defect (which is finally responsible for the binding energy of the nucleus), mass of a nucleus is always less then the sum of masses of it's constituent particles $^{20}_{10}Ne$ is made up of 10 protons plus 10 neutrons. Therefore, mass of $^{20}_{10}Ne$ nucleus $M_1 < 10(m_p + m_n)$

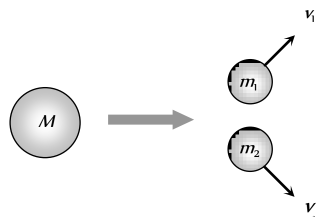
Also heavier the nucleus, more is he mass defect thus $20(m_n + m_p) - M_2 > 10(m_p + m_n) - M_1$

or $10(m_p + m_n) > M_2 - M_1$

$\Rightarrow M_2 < M_1 + 10(m_p + m_n) \Rightarrow M_2 < M_1 + M_1$

$\Rightarrow M_2 < 2M_1$.

30. (a)



By conservation of momentum $m_1v_1 = m_2v_2$

$\Rightarrow \frac{v_1}{v_2} = \frac{8}{1} = \frac{m_2}{m_1}$ ...... (i)

Also from $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{8}\right)^{1/3} = \frac{1}{2}$.

31. (a) Since nuclear density is constant hence mass $\propto$ volume.

32. (c) Mass defect $= 3\times2.014 - 4.001 - 1.007 - 1.008$

$= 0.026\ amu = 0.026\times931\times10^6\times1.6\times10^{-19}\ J$

$= 3.82\times10^{-12}\ J$

Power of star $=10^{16}W$

Number of deuterons used $=\dfrac{10^{16}}{\Delta M}=0.26\times10^{28}$

Deuteron supply exhausts in $\dfrac{10^{40}}{0.26\times10^{28}}=10^{12}\,s$.

33. (a) Since electron and positron annihilate

$$\lambda=\frac{hc}{E_{Total}}=\frac{6.6\times10^{-34}\times3\times10^{8}}{(0.51+0.51)\times10^{6}\times1.6\times10^{-19}}$$

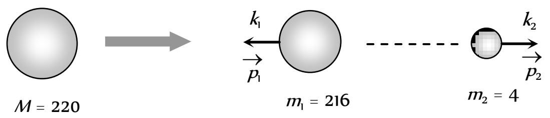
$=1.21\times10^{-12}\,m=0.012\,\AA$.

34. (a) Kinetic energy of the molecules of a gas at a temp. T is $\dfrac{3}{2}kT$

$\therefore$ To initiate the reaction $\dfrac{3}{2}kT=7.7\times10^{-14}\,J$

$\Rightarrow\dfrac{3}{2}\times1.38\times10^{-23}T=7.7\times10^{-14}\Rightarrow T=3.7\times10^{9}\,K$.

35. (b)



Q-value of the reaction is 5.5 eV

i.e. $k_1+k_2=5.5\,MeV$ ......(i)

By conservation of linear momentum

$p_1=p_2\Rightarrow\sqrt{2(216)k_1}=\sqrt{2(4)k_2}$

$\Rightarrow\ k_2=54\ k_1$ ......(ii)

On solving equation (i) and (ii) we get k_2 = 5.4 MeV.

36. (b) By the formula $N=N_0e^{-\lambda t}$

Given $\dfrac{N}{N_0}=\dfrac{1}{20}$ and $\lambda=\dfrac{0.6931}{3.8}\Rightarrow 20=e^{\frac{0.6931\times t}{3.8}}$

Taking log of both sides

or log 20 $=\dfrac{0.6931\times t}{3.8}\log_{10}e$

or 1.3010 $=\dfrac{0.6931\times t\times0.4343}{3.8}\Rightarrow t=16.5$ days.

37. (b) $N=N_0e^{-\lambda t}$

$\therefore 0.9N_0=N_0e^{-\lambda\times5}\Rightarrow5\lambda=\log_e\dfrac{1}{0.9}$ ...... (i)

and $xN_0=N_0e^{-\lambda\times20}\Rightarrow20\lambda=\log_e\left(\dfrac{1}{x}\right)$ ...... (ii)

Dividing (i) by (ii), we get

$$\frac{1}{4}=\frac{\log_e(1/0.9)}{\log_e(1/x)}=\frac{\log_{10}(1/0.9)}{\log_{10}(1/x)}=\frac{\log_{10}0.9}{\log_{10}x}$$

$\Rightarrow\log_{10}x=4\log_{10}0.9\Rightarrow x=0.658=65.8\%$

38. (c) If in the rock there is no Y element, then the time taken by element X to reduce to $\dfrac{1}{8}th$ the initial value will be equal to

$\dfrac{1}{8}=\left(\dfrac{1}{2}\right)^n$ or $n=3$

Therefore, from the beginning three half life time is spent. Hence the age of the rock is

$=3\times1.37\times10^{9}=4.11\times10^{9}\,years$.

39. (b) $\dfrac{N}{N_0}=\left(\dfrac{1}{2}\right)^n\Rightarrow\dfrac{1}{64}=\left(\dfrac{1}{2}\right)^6=\left(\dfrac{1}{2}\right)^n\Rightarrow n=6.$

After 6 half lives intensity emitted will be safe.

$\therefore$ Total time taken $=6\times2=12\,hrs$.

40. (a) $\dfrac{dN}{dt}=\lambda N;\ \lambda=\dfrac{0.6931}{t_{12}}=\dfrac{0.6931}{1620\times365\times24\times60\times60}$,

$N=\dfrac{6.023\times10^{23}}{226}$

$\therefore\dfrac{dN}{dt}=\dfrac{0.6931\times6.023\times10^{23}}{1620\times365\times24\times60\times60\times226}=3.61\times10^{10}$

41. (a) $\lambda=\lambda_1+\lambda_2\Rightarrow\dfrac{1}{T}=\dfrac{1}{T_1}+\dfrac{1}{T_2}$

$\therefore T=\dfrac{T_1T_2}{T_1+T_2}=\dfrac{810\times1620}{810+1620}=540\ years$

Hence $\dfrac{1}{4}\,th$ of material remain after 1080 *years*.

42. (b) Similar to Q. 40.

43. (c) $(T_{1/2})_x=(t_{\text{mean}})_y$

$\Rightarrow\dfrac{0.693}{\lambda_x}=\dfrac{1}{\lambda_y}\Rightarrow\lambda_x=0.693\,\lambda_y$ or $\lambda_x<\lambda_y$

Also rate of decay = λN

Initially number of atoms (N) of both are equal but since $\lambda_y>\lambda_x$, therefore, y will decay at a faster rate than x.

44. (c) $\lambda_\alpha=\dfrac{1}{1620}$ *per year* and $\lambda_\beta=\dfrac{1}{405}$ *per year* and it is given that the fraction of the remained activity $\dfrac{A}{A_0}=\dfrac{1}{4}$

Total decay constant

$\lambda=\lambda_\alpha+\lambda_\beta=\dfrac{1}{1620}+\dfrac{1}{405}=\dfrac{1}{324}\,per\,year$

We know that $A=A_0e^{-\lambda t}\Rightarrow t=\dfrac{1}{\lambda}\log_e\dfrac{A_0}{A}$

$\Rightarrow t=\dfrac{1}{\lambda}\log_e4=\dfrac{2}{\lambda}\log_e2=324\times2\times0.693$ = 449 *years*.

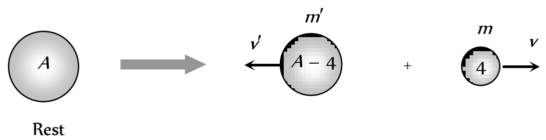
45. (d) $n=\dfrac{24}{24\times138.6}=\dfrac{1}{138.6}$; Now $\dfrac{N}{N_0}=\left(\dfrac{1}{2}\right)^n=\left(\dfrac{1}{2}\right)^{1/138.6}$

$\Rightarrow N=10{,}00000\left(\dfrac{1}{2}\right)^{1/138.6}=995011$

So number of disintegration

$=1000000-995011=4989\approx5000$.

46. (a)



According to conservation of momentum $4v=(A-4)v'\Rightarrow$ $v'=\dfrac{4v}{A-4}$.

47. (b) $\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{20} = 0.03465$

Now time of decay $t = \frac{2.303}{\lambda}\log\frac{N_0}{N}$

$\Rightarrow t_1 = \frac{2.303}{0.03465}\log\frac{100}{67} = 11.6\,\text{min}\ min$

and $t_2 = \frac{2.303}{0.03465}\log\frac{100}{33} = 32 min$

Thus time difference between points of time

$= t_2 - t_1 = 32 - 11.6 = 20.4\ min \approx 20\ min.$

48. (d) $N_1 = N_0 e^{-10\lambda t}$ and $N_2 = N_0 e^{-\lambda t}$

$\Rightarrow \frac{N_1}{N_2} = \frac{1}{e} = e^{-1} = e^{(-10\lambda + \lambda)t} = e^{-9\lambda t} \Rightarrow t = \frac{1}{9\lambda}.$

49. (a) $N = N_0\left(\frac{1}{2}\right)^{t/T_{1/2}} \Rightarrow N_A = 10\left(\frac{1}{2}\right)^{t/1}$ and $N_B = 1\left(\frac{1}{2}\right)^{t/2}$

Given $N_A = N_B \Rightarrow 10\left(\frac{1}{2}\right)^{t} = \left(\frac{1}{2}\right)^{t/2}$

$\Rightarrow 10 = \left(\frac{1}{2}\right)^{-t/2} \Rightarrow 10 = 2^{t/2}$. Taking log both the sides.

$\log_{10} 10 = \frac{t}{2}\log_{10} 2 \Rightarrow 1 = \frac{t}{2} \times 0.3010 \Rightarrow t = 6.62$ years.

50. (b) Here $T_{1/2} = 20$ *minutes;* we know $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T_{1/2}}$

For 20% decay $\frac{N}{N_0} = \frac{80}{100} = \left(\frac{1}{2}\right)^{t_1/20}$ ..... (i)

For 80% decay $\frac{N}{N_0} = \frac{20}{100} = \left(\frac{1}{2}\right)^{t_2/20}$ ..... (ii)

Dividing (ii) by (i)

$\frac{1}{4} = \left(\frac{1}{2}\right)^{\frac{(t_2 - t_1)}{20}}$; on solving we get $t_2 - t_1 = 40\ min.$

51. (d) Here the activity of the radioactive sample reduces to half in 140 days. Therefore, the half life of the sample is 140 days. 280 days is it's two half lives. So before two half lives it's activity was ($2^2 \times$ present activity).

$\therefore$ Initial activity = $2^2 \times 6000 = 24000\,dps.$

52. (a) Excitation energy $\Delta E = E_2 - E_1 = 13.6\ Z^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\Rightarrow 40.8 = 13.6 \times \frac{3}{4} \times Z^2 \Rightarrow Z = 2.$

Now required energy to remove the electron from ground state

$= \frac{+13.6 Z^2}{(1)^2} = 13.6(Z)^2 = 54.4\,eV.$

53. (b) Rate of disintegration $\frac{dN}{dt} = 10^{17}\,s^{-1}$

Half life $T_{1/2} = 1445$ year

$= 1445 \times 365 \times 24 \times 60 \times 60 = 4.55 \times 10^{10}\ sec$

Now decay constant

$\lambda = \frac{0.693}{T_{1/2}} = \frac{0.693}{4.55 \times 10^{10}} = 1.5 \times 10^{-11}$ per sec

The rate of disintegration

$\frac{dN}{dt} = \lambda \times N_0 \Rightarrow 10^{17} = 1.5 \times 10^{-11} \times N_0$

$\Rightarrow N_0 = 6.6 \times 10^{27}.$

54. (b) $P = \frac{nE}{t} \Rightarrow 300 \times 10^6 = \frac{n \times 170 \times 10^6 \times 1.6 \times 10^{-19}}{t}$

$\therefore$ Number of atoms per sec $\frac{n}{t} = 1.102 \times 10^{19}$

Number of atoms per hour = $1.02 \times 10^{19} \times 3600$

$= 3.97 \times 10^{22}.$

55. (a) According to kinetic interpretation of temperature

$K.E. = \left(\frac{1}{2}mv^2\right) = \frac{3}{2}kT.$

$\Rightarrow 10.2 \times 1.6 \times 10^{-19} = \frac{3}{2} \times (1.38 \times 10^{-23})T$

$\Rightarrow T = 7.9 \times 10^{4} K.$

56. (a) R_0 = Initial activity = 1 micro curie = $3.7 \times 10^4\ dps$

r = Activity in 1 cm^3 of blood at t = 5 *hrs*

$= \frac{296}{60}\,dps = 4.93\,dps$

R = Activity of whole blood at time t = 5 *hr,*

Total volume should be $V = \frac{R}{r} = \frac{R_0 e^{-\lambda t}}{r}$

$= \frac{3.7 \times 10^4 \times 0.7927}{4.93} = 5.94 \times 10^3\ cm^3 = 5.94$ *Litre.*

57. (b) Let ground state energy (in *eV*) be E_1

Then from the given condition

$E_{2n} - E_1 = 204\,eV$ or $\frac{E_1}{4n^2} - E_1 = 204\,eV$

$\Rightarrow E_1\left(\frac{1}{4n^2} - 1\right) = 204\,eV$ .....(i)

and $E_{2n} - E_n = 40.8\,eV$

$\Rightarrow \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8\,eV$ .....(ii)

From equation (i) and (ii), $\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$

58. (b) Here $\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{1/3}$

where n = Number of half lives $= \frac{1}{3}$

$\Rightarrow \frac{N}{N_0} = \frac{1}{1.26} \Rightarrow \frac{N_U}{N_{Pb} + N_U} = \frac{1}{1.26}$

$\Rightarrow N_{Pb} = 0.26\,N_U \Rightarrow \frac{N_{Pb}}{N_U} = 0.26$

59. (b) For K_α X-ray line

$$\frac{1}{\lambda_\alpha} = R(Z-1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}(Z-1)^2$$

On putting the given values

$$\frac{1}{0.76\times10^{-10}} = \frac{3}{4}\times1.09\times10^7(Z-1)^2$$

$$\Rightarrow (Z-1)^2 \approx 1600 \Rightarrow Z-1 = 40 \Rightarrow Z = 41$$

60. (a) Maximum energy is liberated for transition $E_n \to 1$ and minimum energy for $E_n \to E_{n-1}$

Hence $\frac{E_1}{n^2} - E_1 = 52.224\, eV$ ......(i)

and $\frac{E_1}{n^2} - \frac{E_1}{(n-1)^2} = 1.224\, eV$ .....(ii)

Solving equations (i) and (ii) we get

$E_1 = -54.4\, eV$ and $n = 5$

Now $E_1 = -\frac{13.6\, Z^2}{1^2} = -54.4\, eV$. Hence $Z = 2$

61. (a) Activity of substance that has 2000 disintegration/sec

$$= \frac{2000}{3.7\times10^{10}} = 0.054\times10^{-6} ci = 0.054\, \mu ci$$

The number of radioactive nuclei having activity A

$$N = \frac{A}{\lambda} = \frac{2000\times T_{1/2}}{\log_e 2}$$

$$= \frac{2000\times138.6\times24\times3600}{0.693} = 3.45\times10^{10}$$

62. (a) Maximum number of nuclei will be present when rate of decay = rate of formation $\Rightarrow \lambda N = \alpha \Rightarrow N = \frac{\alpha}{\lambda}$

63. (b) $r \propto A^{1/3} \Rightarrow \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{3}{5} = \left(\frac{27}{A}\right)^{1/3} \Rightarrow \frac{27}{125} = \frac{27}{A} \Rightarrow A = 125$$

Number of nuclei in atom $X = A - 52 = 125 - 52 = 73$.

64. (c) 1 week ≈ 7 days $\simeq$ $7\times24 hrs \simeq 14$ half lives

Number of atoms left $= \frac{No}{(2)^{14}}$, Activity = $N\lambda$

$\therefore$ Activity left is $\frac{1}{(2)^{14}}$ times the initial

$$\Rightarrow \frac{1}{(2)^{14}}\times1 \text{ curie} = \frac{1}{16384}\times1 \text{ curie} \cong 61\times10^{-6} \text{ curie}$$

$\approx 60\mu$ *curie*.

65. (a) $m_0c^2 = 0.54\, MeV$ and K.E. = $mc^2 - m_0c^2$

Also $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1-(0.8)^2}} = \frac{m_0}{0.6}$

$$\therefore E = mc^2 = \frac{m_0}{0.6}c^2 = \frac{m_0c}{0.6} = \frac{0.5\, H}{0.6} = 0.9\, MeV$$

$\therefore$ K.E.= (0.9 – 0.54) = 0.36 *MeV*.

Graphical Questions

1. (a) B.E. per nucleon is maximum for Fe^{56}. For further detail refer theory.

2. (a) $\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = 2\pi c\bar{\nu} \Rightarrow \omega \propto \bar{\nu}$.

3. (c)

4. (d) The total number of atoms neither remains constant (as in option (a) nor can ever increase (as in option (b) and (c)). They will continuously decrease with time. Therefore option (d) is correct.

5. (c) $N = N_0e^{-\lambda t} \Rightarrow \frac{dN}{dt} = -N_0\lambda e^{-\lambda t}$

i.e. Rate of decay $\left(\frac{dN}{dt}\right)$ varies exponentially with time (t).

6. (d) Rate $R = -\frac{dN}{dt} = \lambda\, N_0e^{-\lambda t} = \lambda N \Rightarrow \frac{R}{N} = \lambda$ (constant)

i.e. graph between $\frac{R}{N}$ and t, be a straight line parallel to the time axis.

7. (b) Read time for 50 count rate, it gives half life period of 3 *hrs*, one small square gives 600 counts (10 × 60). The number of small squares between graph and time axis are approx 24

Hence count rate = $24\times600 = 14400$

8. (b) Number of atoms undecayed $N = N_0e^{-\lambda t}$

Number of atoms decayed $= N_0 - N = N_0(1-e^{-\lambda t})$

$\Rightarrow$ Decayed fraction $f = \frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$

i.e. fraction will rise up to 1, following exponential path as shown in graph (B).

9. (c) Energy is released in a process when total Binding energy (B.E.) of the nucleus is increased or we can say when total *B.E.* of products is more than the reactants. By calculation we can see that only in case of option (c), this happens.

Given $W \to 2Y$

B.E. of reactants = 120 × 75 = 900 *MeV*

and *B.E.* of products = $2\times(60\times85) = 1020\, MeV$

i.e. B.E. of products > *B.E.* of reactants.

10. (d) $N = N_0e^{-\lambda t}$ and $A = A_0e^{-\lambda t} = \lambda N_0e^{-\lambda t}$

$\therefore N_{decayed} = N_0 - N = N_0 - N_0 e^{\lambda t} \Rightarrow N_{decayed} = N_0 - \frac{A}{\lambda}$

This is equation of straight line with negative slope.

11. (d) Radius of n^{th} orbit $r_n \propto n^2$, graph between r_n and n is a parabola. Also, $\frac{r_n}{r_1} = \left(\frac{n}{1}\right)^2 \Rightarrow \log_e\left(\frac{r_n}{r_1}\right) = 2\log_e(n)$

Comparing this equation with $y = mx + c$,

Graph between $\log_e\left(\frac{r_n}{r_1}\right)$ and $\log_e(n)$ will be a straight line, passing from origin.

Similarly it can be proved that graph between $\log_e\left(\frac{f_n}{f_1}\right)$ and $\log_e n$ is not a straight line.

12. (d) By using $N = N_0 e^{-\lambda t}$ and $\frac{dN}{dt} = -\lambda N$.

It shows that N decreases exponentially with time.

13. (b) Activity $= -\frac{dN}{dt} = \lambda N = \lambda N_0 e^{-\lambda t}$

i.e., graph between activity and t, be exponential having negative slope.

14. (d) Activity $A = \lambda N_0 e^{-\lambda t} \Rightarrow \log_e A = \log_e \lambda N_0 + \log_e e^{-\lambda t}$

$\Rightarrow \log_e A = \log_e C - \lambda t$ (Take $\lambda N_0 = C$)

$\Rightarrow \log_e A = -\lambda t + \log_e C$

This is the equation of a straight line having negative slope (= $-\lambda$) and positive intercept on $\log_e A$ axis.

15. (c) Charge density is uniform inside and then falls rapidly near the surface of the nucleus.

16. (a) $R = R_0 A^{1/3}$; where $R_0 = 1.2 \times 10^{-15} m$.

$\Rightarrow \log_e R = \log_e R_0 + \frac{1}{3}\log_e A$

This is the equation of a straight line with positive slope.

17. (b) $\left|\frac{dN}{dt}\right| = \lambda N \Rightarrow \left|\frac{dN}{dt}\right| \propto N$

18. (c) Number of atom decayed $N' = N_0(1 - e^{-\lambda t})$

N' will increase with time (t) exponentially.

19. (a) $A_n = \pi r_n^2 \Rightarrow \frac{A_n}{A_1} = \left(\frac{r_n}{r_1}\right)^2 = \left(\frac{n}{1}\right)^4$ $(\because r_n \propto n^2)$

Taking $\log_e$ both the side $\log_e \frac{A_n}{A_1} = 4\log_e(n)$

Comparing it with $y = mx + c$, graph (4) is correct.

Assertion and Reason

1. (c) In fusion, lighter nuclei are used so, fusion is not possible with ^{35}Cl. Also binding energy of ^{35}Cl is not too small.

2. (a) $^{90}_{38}Sr$ decays to $^{90}_{39}Y$ by the emission of $\beta -$ rays. Sr gets absorbed in bones along with calcium.

Reason is also true. $^{90}Sr \xrightarrow{\beta} {}^{90}Y$ which emits $\beta -$ rays of very high energy. Sr does not emit $\gamma -$ rays. The damage is by the $\beta -$ rays only.

3. (b) Neutron is about 0.1 more massive than proton. But the unique thing about the neutron is that while it is heavy, it has no charge (it is neutral). This lack of charge gives it the ability to penetrate matter without interacting as quickly as the beta particles or alpha particles.

4. (b) Bohr postulated that electrons in stationary orbits around the nucleus do not radiate.

This is the one of Bohr's postulate. According to this the moving electrons radiate only when they go from one orbit to the next lower orbit.

5. (c) Nuclear stability depends upon the ratio of neutron to proton. If the n/p ratio is more than the critical value, then a neutron gets converted into a proton forming a β^- particle in the process. $n \to p + e^-$

The β^- particle (e^-) is emitted from the nucleus in some radioactive transformation. So electrons do not exist in the nucleus but they result in some nuclear transformation.

6. (a) ${}_ZX^A \to 2({}_2He^4) + 2({}_{-1}e^0) + 2\gamma + {}_{Z-2}X^{A-8}$

7. (a) Experimentally, it is found that the average radius of a nucleus is given by

$R = R_0 A^{1/3}$ where $R_0 = 1.1 \times 10^{-15} m = 1.1\, fm$

and $A =$ mass number

8. (b)

9. (b) Rutherford confirmed the repulsive force on α-particle due to nucleus varies with distance according to inverse square law and that the positive charges are concentrated at the centre and not distributed throughout the atom.

10. (a) In α-particle scattering experiment, Rutherford found a small number of α-particles which were scattered back through an angle approaching to $180°$. This is possible only if the positive charges are concentrated at the centre or nucleus of the atom.

11. (e) According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence they will be losing their energy continuously and the orbital radius will go on decreasing and form spiral and finally the electron will fall on the nucleus.

12. (c) According to postulates of Bohr's atom model, the electron revolve round the nucleus in fixed orbit of definite radii. As long as the electron is in a certain orbits it does not radiate any energy.

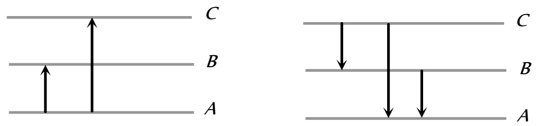
13. (b) Maximum number of photon is given by all the transitions possible $= {}^4C_2 = 6$

Minimum number of transition = 1,

that is directly jump from 4 to 1.

14. (b) When the atom gets appropriate energy from outside, then this electron rises to some higher energy level. Now it can return either directly to the lower energy level or come to the lowest energy level after passing through other lower energy lends, hence all possible transitions take place in the source and many lines are seen in the spectrum.

15. (d) Emission transitions can take place between any higher energy level and any energy level below it while absorption transitions start from the lowest energy level only and may end at any higher energy level. Hence number of absorptions transitions between two given energy levels is always less than the number of emission transitions between same two levels.



Absorption   Emission

16. (a) We knows that an electron is very light particle as compared to an α-particle. Hence electron cannot scatter the α-particle at large angles, according to law of conservation of momentum. On the other hand, mass of nucleus is comparable with the mass of α-particle, hence only the nucleus of atom is responsible for scattering of α-particles.

17. (c) All those elements which are heavier than lead are radioactive. This is because in the nuclei of heavy atoms, besides the nuclear attractive forces, repulsive forces between the protons are also effective and these forces reduce the stability of the nucleus. Hence, the nuclei of heavier elements are being converted into lighter and lighter elements by emission of radioactive radiation. When they are converted into lead, the emission is stopped because the nucleus of lead is stable (or lead is most stable elements in radioactive series).

18. (d) The penetrating power is maximum in case of gamma rays because gamma rays are an electromagnetic radiation of very small wavelength.

19. (b) β-particles, being emitted with very high speed compared to α-particles, pass very little time near the atoms of the medium. So the probability of the atoms being ionised is comparatively less. But due to this reason, their loss of energy is very slow and they can penetrate the medium through a sufficient depth.

20. (b) β-particles are emitted with very high velocity (up to 0.99 c). So, according to Einstein's theory of relatively, the mass of a β-particle is much higher compared to is' its rest mass (m_0). The velocity of electrons obtained by other means is very small compared to c (Velocity of light). So its mass remains nearly m_0. But β-particle and electron both are similar particles.

21. (c) Radioactivity $= -\dfrac{dN}{dt} = \lambda N = \dfrac{0.693N}{T}$

$$= \frac{0.693 \times 10^8}{50} = \frac{0.693 \times 1.2 \times 10^8}{60} = 0.693 \times 2 \times 10^6.$$

Radioactivity is proportional to $1/T_{1/2}$, and not to $T_{1/2}$.

22. (c) Fragments produced in the fission of U^{235} are radioactive. When uranium undergoes fission, barium and krypton are not the only products. Over 100 different isotopes of more than 20 different elements have been detected among fission products. All of these atoms are, however, in the middle of the periodic table, with atomic numbers ranging from 34 to 58. Because the neutron-proton ratio needed for stability in this range is much smaller than that of the original uranium nucleus, the residual nuclei called fission fragments, always have too many neutrons for stability. A few free neutrons are liberated during fission and the fission fragments undergo a series of beta decays (each of which increases Z by one and decreases N by one) until a stable nucleus is reached. During decay of the fission fragments, an average of 15 MeV of additional energy is liberated.

23. (b) Electron capture occurs more often than positron emission in heavy elements. This is because if position emission is energetically allowed, electron capture is necessarily allowed, but the reverse is not true *i.e.* when electron capture is energetically allowed, positron emission is not necessarily allowed.

24. (e) The whole mass of the atom is concentrated at nucleus and $M_{nucleus}$ < (Sum of the masses of nucleous) because, when nucleous combines, some energy is wasted.

Atomic and Nuclear Physics

SET Self Evaluation Test - 26

1. In Bohr model of hydrogen atom, the force on the electron depends on the principal quantum number as

(a) $F \propto 1/n^3$ (b) $F \propto 1/n^4$

(c) $F \propto 1/n^5$ (d) Does not depend on n

2. A nucleus $_Z^AX$ emits 9α-particles and $5p$ particle. The ratio of total protons and neutrons in the final nucleus is

(a) $\frac{Z-13}{(A-Z-23)}$ (b) $\frac{(Z-18)}{(A-36)}$

(c) $\frac{(Z-13)}{(A-36)}$ (d) $\frac{(Z-13)}{(A-Z-13)}$

3. If $t_{1/2}$ is the half life of a substance then $t_{3/4}$ is the time in which substance

(a) Decays $\frac{3}{4}th$ (b) Remains $\frac{3}{4}th$

(c) Decays $\frac{1}{2}$ (d) Remains $\frac{1}{2}$

4. The energy level diagram for an hydrogen like atom is shown in the figure. The radius of its first Bohr orbit is

(a) 0.265 Å (b) 0.53 Å

(c) 0.132 Å (d) None of these

5. How much work must be done to pull apart the electron and the proton that make up the Hydrogen atom, if the atom is initially in the state with $n = 2$

(a) $13.6 \times 1.6 \times 10^{-19}\, J$ (b) $3.4 \times 1.6 \times 10^{-19}\, J$

(c) $1.51 \times 1.6 \times 10^{-19}\, J$ (d) 0

6. The nuclide ^{131}I is radioactive, with a half-life of 8.04 days. At noon on January 1, the activity of a certain sample is 60089. The activity at noon on January 24 will be

(a) 75 *Bq* (b) Less than 75 *Bq*

(c) More than 75 *Bq* (d) 150 *Bq*

7. U^{238} decays into Th^{234} by the emission of an $\alpha-$particle. There follows a chain of further radioactive decays, either by $\alpha-$decay or by β- decay. Eventually a stable nuclide is reached and after that, no further radioactive decay is possible. Which of the following stable nuclides is the and product of the U^{238} radioactive decay chain

(a) Pb^{206} (b) Pb^{207}

(c) Pb^{208} (d) Pb^{209}

8. If the mass of a radioactive sample is doubled, the activity of the sample and the disintegration constant of the sample are respectively

(a) Increases, remains the same

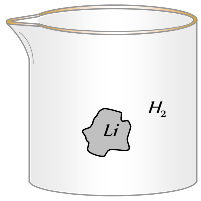
(b) Decreases, increases

(c) Decreases, remains same

(d) Increases, decreases

9. When a sample of solid lithium is placed in a flask of hydrogen gas then following reaction happened

$_1^1H + {}_3Li^7 \rightarrow {}_2He^4 + {}_2He^4$



This statement is

(a) True

(b) False

(c) May be true at a particular pressure

(d) None of these

10. Consider an initially pure *M gm* sample of ^AX, an isotope that has a half life of T hour, what is it's initial decay rate (N_A= Avogrado No.)

(a) $\frac{M\,N_A}{T}$ (b) $\frac{0.693\,M\,N_A}{T}$

(c) $\frac{0.693\,M\,N_A}{AT}$ (d) $\frac{2.303\,M\,N_A}{AT}$

11. At a given instant there are 25% undecayed radioactive nuclei in a same. After 10 *sec* the number of undecayed nuclei reduces to 6.25%, the mean life of the nuclei is

(a) 14.43 *sec* (b) 7.21 *sec*

(c) 5 *sec* (d) 10 *sec*

12. Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of nucleus to that of Helium nucleus is $14^{1/3}$. The atomic number of nucleus will be

(a) 25 (b) 26

(c) 56 (d) 30

13. The ratio of ionization energy of Bohr's hydrogen atom and Bohr's hydrogen like lithium atom is

(a) 1 : 1 (b) 1 : 3

(c) 1 : 9 (d) None of these

14. What is the angular momentum of an electron in Bohr's hydrogen atom whose energy is – 0.544 eV.

(a) $\frac{h}{\pi}$ (b) $\frac{2h}{\pi}$

(c) $\frac{5h}{2\pi}$ (d) $\frac{7h}{2\pi}$

15. Consider a hypothetical annihilation of a stationary electron with a stationary positron. What is the wavelength of resulting radiation.

(a) $\frac{h}{2m_0c}$ (b) $\frac{h}{m_0c}$

(c) $\frac{2h}{m_0c}$ (d) $\frac{h}{m_0c^2}$

(h = Plank's constant, c = speed of light, m_o = rest mass)

16. Nuclear reactions are given as

(i) □ $(n, p)_{15}P^{32}$ □ $(p, \alpha)_8O^{16}$ (iii) $_7$□^{14} (p) $_6C^{14}$

missing particle or nuclide (in box □) in these reactions are respectively

(a) S, F, $_0n^1$ (b) F, S, $_0n^1$

(c) Be, F, $_0n^1$ (d) None of these

17. In a sample of hydrogen like atoms all of which are in ground state, a photon beam containing photons of various energies is passed. In absorption spectrum, five dark lines, are observed. The number of bright lines in the emission spectrum will be (assume that all transitions takes place).

(a) 5 (b) 10

(c) 15 (d) None of these

18. A hydrogen atom emits a photon corresponding to an electron transition from n = 5 to n = 1. The recoil speed of hydrogen atom is almost (mass of proton ≈ 1.6×10^{-27} kg).

(a) 10 ms (b) 2×10^{-2} ms

(c) 4 ms (d) 8×10^{-2} ms

19. Number of nuclei of a radioactive substance at time t = 0 are 1000 and 900 at time t = 2 s. Then number of nuclei at time t = 4 s will be

(a) 800 (b) 810

(c) 790 (d) 700

20. The ratio between total acceleration of the electron in singly ionized helium atom and hydrogen atom (both in ground state) is

(a) 1 (b) 8

(c) 4 (d) 16

21. If the series limit of Lymen series for Hydrogen atom is equal to the series limit of Balmer series for a hydrogen like atom, then atomic number o this hydrogen like atom will be

(a) 1 (b) 2

(c) 3 (d) 4

22. Which sample contains greater number of nuclei :

a 5.00- μCi sample of ^{240}Pu (half-life 6560y) or a 4.45-μCi sample of ^{243}Am (half-life 7370 y)

(a) ^{240}Pu (b) ^{243}Am

(c) Equal in both (d) None of these

23. The fission of ^{235}U can be triggered by the absorption of a slow neutrons by a nucleus. Similarly a slow proton can also be used. This statement is

(a) Correct (b) Wrong

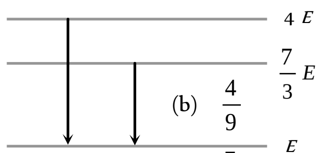
(c) Information is insufficient (d) None of these

24. The radioactivity of a given sample of whisky due to tritium (half life 12.3 years) was found to be only 3% of that measured in a recently purchased bottle marked "7 years old". The sample must have been prepared about

(a) 220 years back (b) 300 years back

(c) 400 years back (d) 70 years back

25. The following diagram indicates the energy levels of a certain atom when the system moves from $4E$ level to E. A photon of wavelength λ_1 is emitted. The wavelength of photon produced during it's transition from $\frac{7}{3}E$ level to E is λ_2. The ratio $\frac{\lambda_1}{\lambda_2}$ will be



(a) $\frac{9}{4}$ (b) $\frac{4}{9}$

(c) $\frac{3}{2}$ (d) $\frac{7}{3}$

Answers and Solutions

(SET -26)

1. (b) $F \propto \frac{v^2}{r}$ also $v \propto \frac{1}{n}$ and $r \propto n^2 \Rightarrow F \propto \frac{1}{n^4}$

2. (a) $_ZX^A \xrightarrow{9\alpha,} {}_{Z-18}X^{A-36} \xrightarrow{5\beta} {}_{Z-13}X^{A-36}$

Number of protons = (Z = 13)

Number of neutrons = (A – 36) – (Z – 13) = (A – Z – 23)

$\therefore \frac{P}{N} = \frac{(Z-13)}{(A-Z-23)}$

3. (a) You must remember that $t_{1/2}$ is time in which substance decays half. Hence in $t_{3/4}$ time substance decays $\frac{3}{4}th$.

4. (a) We know that $E_n = -13.6\frac{Z^2}{n^2}eV$ and $r_n = 0.53\frac{n^2}{Z}(\text{Å})$

Here for n =1, E_1 = – 54.4 eV

Therefore $-54.4 = -13.6\frac{Z^2}{1^1} \Rightarrow Z = 2$

Hence radius of first Bohr orbit $r = \frac{0.53(1)^2}{2} = 0.265\,\text{Å}$

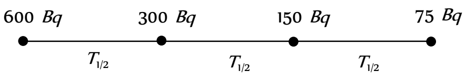
5. (b) The electrostatic $P.E.$ is zero when the electron and proton are far apart from each other. Work done in pulling electron and proton far away from each other

$$W = E_f - E_i = 0 - E_i = -\left(-\frac{13.6}{n^2}eV\right)$$

$$\Rightarrow W = \frac{13.6}{(2)^2}\times 1.6\times 10^{-19}\,J = 3.4 \times 1.6 \times 10^{-19} J.$$

6. (c) Number of days from January 1st to January 24th = 23 days.

Number of half lives $n = \frac{23}{8.04} = 2.86(<3)$



In three half lives activity becomes 75 Bq, but the given number of half lives are lesser than 3 so activity becomes greater than 75 Bq.

7. (a) (4n+2) series starts from U^{238} and it's stable end product is Pb^{206}.

8. (a) Activity depends upon mass, but λ doesn't change.

9. (b) The given reaction is a nuclear reaction, which can take place only if a proton (a hydrogen nucleus) comes into contact with a lithium nucleus. If the hydrogen is in the atomic from, the interaction between it's electron cloud and the electron cloud of a lithium atom keeps the two nuclei from getting close to each other. Even if isolated protons are used, they must be fired at the Li atom with enough kinetic energy to over come the electric repulsion between the proton and Li atom.

10. (c) $N = N_0 e^{-\lambda t} \Rightarrow \left|\frac{dN}{dt}\right| = N_0 \lambda e^{-\lambda t}$

Initially at t = 0, $\left|\frac{dN}{dt}\right|_{t=0} = N_0\lambda$

where N_0 = Initial number of undecayed atoms

$$= \frac{\text{Mass of the sample}}{\text{Mass of a single atom of X}} = \frac{M}{A/N_A} = \frac{MN_A}{A}$$

$$\therefore \left|\frac{dN}{dt}\right|_{t=0} = \frac{MN_A\lambda}{A} = \frac{0.693\,MN_A}{AT}$$

11. (b) In 10 sec, number of nuclei has been reduced to one fourth (25% to 6.25%).

Therefore it's half life is $T_{1/2}$ = 5 sec.

$\therefore$ Mean life $T = \frac{T_{1/2}}{0.693} = \frac{5}{0.693}$ = 7.21 sec.

12. (b) By using $R = R_0\,A^{1/3} \Rightarrow \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$

$$\Rightarrow \frac{R}{R_{He}} = \left(\frac{A}{4}\right)^{1/3} \Rightarrow (14)^{1/3} = \left(\frac{A}{4}\right)^{1/3}$$

$\Rightarrow$ A = 56 so Z = 56 – 30 = 26.

13. (c) Energy of an electron in ground state of an atom (Bohr's hydrogen like atom) is given as

$E = -13.6\,Z^2 eV$ (Z = atomic number of the atom)

$\Rightarrow E_{ionisation}$ = 13.6 Z

$$\Rightarrow \frac{(E_{ion})_H}{(E_{ion})_{Li}} = \left(\frac{Z_H}{Z_{Li}}\right)^2 = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$$

14. (c) By using $E = -\frac{13.6}{n^2}eV$ (for H_2 atom)

$\Rightarrow$ – 0.544 $= -\frac{13.6}{n^2} \Rightarrow n^2 = 25 \Rightarrow n = 5$

$\therefore$ Angular momentum = $n\frac{h}{2\pi} = \frac{5h}{2\pi}$.

15. (b) From conservation of momentum, two identical photons must travel in opposite directions with equal magnitude of momentum and energy $\frac{hc}{\lambda}$

from conservation of energy $\frac{hc}{\lambda} + \frac{hc}{\lambda} = m_0c^2 + m_0c^2$

$$\Rightarrow \lambda = \frac{h}{m_0 c}.$$

16. (a) (i) ${}_{16}S^{32} + {}_0n^1 \rightarrow {}_{15}p^{32} + {}_1H^1$

(ii) ${}_9F^{19} + {}_1H^1 \rightarrow {}_2He^4 + {}_8O^{16}$

(iii) ${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$

17. (c) Number of lines in absorption spectrum = (n–1)

$\Rightarrow$ 5 = n – 1 $\Rightarrow$ n = 6

$\therefore$ Number of bright lines in the emission spectrum

$$= \frac{n(n-1)}{2} = \frac{6(6-1)}{2} = 15.$$

18. (c) The Hydrogen atom before the transition was at rest. Therefore from conservation of momentum.

$$p_{H-\text{atom}} = p_{\text{photon}} = \frac{E_{\text{radiated}}}{c} = \frac{13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)eV}{c}$$

$$1.6\times 10^{-27}\times v = \frac{13.6\left(\frac{1}{1^2} - \frac{1}{5^2}\right)\times 1.6\times 10^{-19}}{3\times 10^8}$$

$\Rightarrow$ v = 4.352 m/s ≈ 4 m/sec.

19. (b) In 2 *sec* only 90% nuclei are left behind. Thus in next two second 90% of 900 or 810 nuclei will be left.

20. (b) Acceleration $a \propto \frac{v^2}{r}$

where $v \propto \frac{Z}{n}$ and $r \propto \frac{n^2}{Z} \Rightarrow a \propto \frac{Z^3}{n^4}$

Since both are in ground state *i.e.*, $n = 1$

so $a \propto Z \Rightarrow \frac{a_{He^+}}{a_H} = \left(\frac{Z_{He^+}}{Z_H}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$.

21. (b) By using $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For Hydrogen atom $\frac{1}{(\lambda_{\min})_H} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] = R$

$(4E - E) = \frac{hc}{\lambda_1} \Rightarrow \lambda_1 = \frac{hc}{3E}$ ...... (i)

Transition from $\frac{7}{3}E$ to E

$\left(\frac{7}{3}E - E\right) = \frac{hc}{\lambda_2} \Rightarrow \lambda_2 = \frac{3hc}{4E}$ ...... (i)

From equation (i) and (ii) $\frac{\lambda_1}{\lambda_2} = \frac{4}{9}$

***

$\Rightarrow (\lambda_{\min})_H = \frac{1}{R}$ .....(i)

For hydrogen like atom $\left(\frac{1}{\lambda_{\min}}\right)_{\text{atom}} = RZ^2\left(\frac{1}{2^2} - \frac{1}{\infty}\right)$

$\Rightarrow (\lambda_{\min})_{\text{atom}} = \frac{4}{RZ^2}$ ....(ii)

From equation (i) and (ii) $\frac{1}{R} = \frac{4}{RZ^2} \Rightarrow Z = 2$.

22. (c) The activity $\left(-\frac{dN}{dt}\right) = \lambda N \Rightarrow N = \left(-\frac{dN}{dt}\right)\left(\frac{T_{1/2}}{\log_e 2}\right)$

Taking the ratio of this expression for ^{240}Pu to this same expression for ^{243}Am,

$$\frac{N_{Pu}}{N_{Am}} = \frac{\left(-\frac{dN_{Pu}}{dt}\right)(T_{1/2})_{Pu}}{\left(-\frac{dN_{Am}}{dt}\right)(T_{1/2})_{Am}} = \frac{(5\mu ci)\times(6560y)}{(4.45\mu ci)\times(7370y)} = 1$$

i.e. the two samples contains equal number of nuclei.

23. (b) Because the neutron has no electric charge, it experience no electric repulsion from a U nucleus. Hence a slow moving neutron can approach and enter a U nucleus, thereby providing the excitation needed to trigger fission. By contrast a slow moving proton feels a strong repulsion from a U nucleus. It never get's close to the nucleus, so it cannot trigger fission.

24. (d) After one half life period, the activity of Tritium becomes 50%.

After 2 half life period 25%

After 3 half life period 12.5%

After 4 half life period 6.25%

After 5 half life period 3.12% ≈ 3%

It is 5 × 12.5 years + 7 years *i.e.* approximately 70 years only .

25. (b) Transition from $4E$ to E

Chapter 27
Electronics

Semiconductor electronics

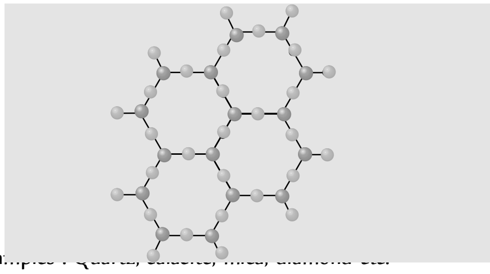
Solids

It is a state of matter which has a definite shape and a definite volume. The characteristic properties of the solid depends upon the nature of forces acting between their constituent particles (*i.e.* ions, atoms or molecules). Solids are divided into two categories.

Crystalline solids

(1) These solids have definite external geometrical form.

(2) Ions, atoms or molecules of these solid are arranged in a definite fashion in all it's three dimensions.



(3) Examples : Quartz, calcite, mica, diamond etc.

(4) They have well defined facets or faces.

(5) They are ordered at short range as well as at long range.

(6) They are anisotropic, *i.e.* the physical properties like elastic modulii, thermal conductivity, electrical conductivity, refractive index have different values in different direction.

(7) They have sharp melting point.

(8) Bond strengths are identical throughout the solid.

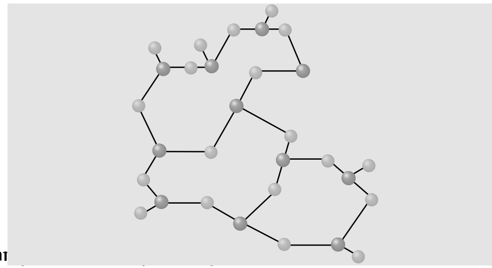
(9) These are considered as true solids.

(10) An important property of crystals is their symmetry.

Amorphous or glassy solids

(1) These solids have no definite external geometrical form.

(2) Ions, atoms or molecules of these solids are not arranged in a definite fashion.



(3) Exa

(4) They do not possess definite facets or faces.

(5) These have short range order, and there is no long range order.

(6) They are isotropic.

(7) They do not have a sharp melting point.

(8) Bond strengths vary.

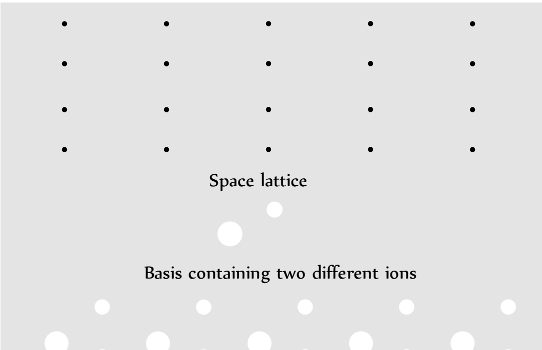
(9) These are considered as pseudo-solids or super cooled liquids.

(10) Amorphous solids do not have any symmetry.

Terms Related with Crystal Structure

(1) **Crystal lattice :** It is a geometrical arrangement of points in space where if atoms or molecules of a solid are placed, we obtain an actual crystal structure of the solid.

(2) **Basis :** The atoms or molecules attached with every lattice point in a crystal structure is called the basis of crystal structure.



(3) **Unit cell :** Is defined as that volume of the solid from which the entire crystal structure can be constructed by the translational repetition in three dimensions. The length of three sides of a unit cell (3*D*) are called primitives or lattice constant they are denoted by *a, b, c*

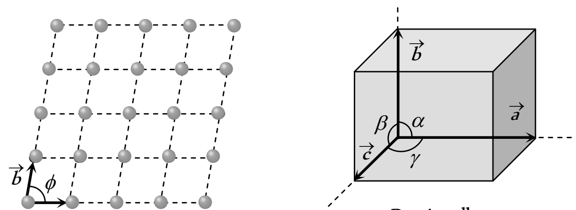


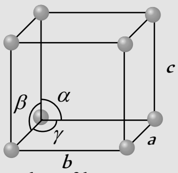
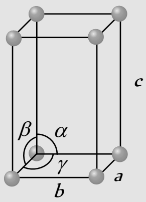
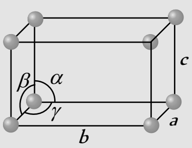
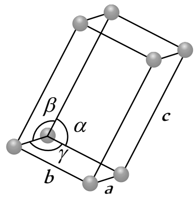
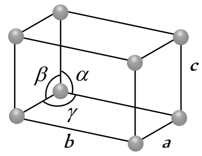
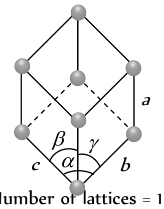
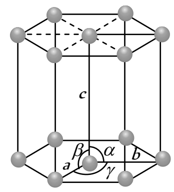
Fig. 27.1

(4) **Primitive cell :** A primitive cell is a minimum volume unit cell or the simple unit cell with particles only at the corners is a primitive unit cell and other types of unit cells are called non-primitive unit cells. There is only one lattice point per primitive cell.

(5) **Crystallographic axis :** The lines drawn parallel to the lines of intersection of the faces of the unit cell are called crystallographic axis.

All the crystals on the basis of the shape of their unit cells, have been divided into seven crystal systems as shown in the following table.

Table 27.1 : Different crystal systems

System	Lattice constants	Angle between lattice constants	Examples
Cubic  Number of lattices = 3	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$	Diamond, *NaCl, Li, Ag, Cu,* NH_4Cl, *Pb etc.*
Tetragonal  Number of lattices = 2	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	White tin, $NiSO_4$ *etc.*
Orthorhombic  Number of lattices = 4	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$	$HgCl_2$, KNO_3, gallium *etc.*
Monoclinic  Number of lattices = 2	$a \neq b \neq c$	$\alpha = \gamma = 90^\circ$ and $\beta \neq 90^\circ$	$KclO_3$, $FeSO_4$ *etc.*
Triclinic  Number of lattices = 1	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$	$K_2Cr_2O_7$, $CuSO_4$ *etc.*
Rhombo-hedral or Trigonal  Number of lattices = 1	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$	Calcite, *As, Sb, Bi etc.*
Hexagonal  Number of lattices = 1	$a = b \neq c$	$\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$	*Zn, Cd, Ni etc.*

Different Types of Symmetry in Cubic Lattices

(1) **Centre of symmetry :** An imaginary point within the crystal such that any line drawn through it intersects the surface of the crystal at equal distances in both directions.

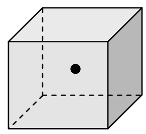
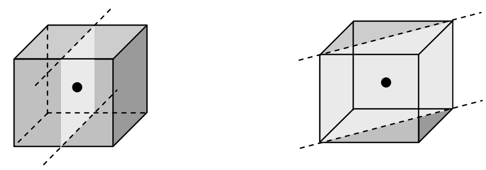


Fig. 27.2

(2) **Plane of symmetry :** It is an imaginary plane which passes through the centre of a crystal and divides it into two equal portions such that one part is exactly the mirror image of the other.



(A) Rectangular plane of symmetry

(B) Diagonal plane of symmetry

Fig. 27.3

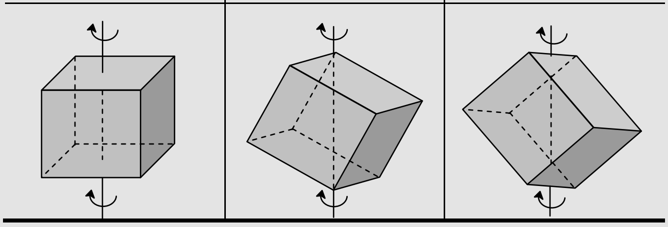
A cubical crystal possesses six diagonal plane of symmetry and three rectangular plane of symmetry.

(3) **Axis of symmetry** : It is an imaginary straight line about which, if the crystal is rotated, it will present the same appearance more than once during the complete revolution.

In general, if the same appearance of a crystal is repeated on rotating through an angle $\frac{360^o}{n}$, around an imaginary axis, the axis is called an *n*-fold axis.

Table 27.2 : A cubical crystal possesses in all 13 axis of symmetry

Axis of four-fold symmetry = 3 (Because of six faces)	Axis of three-fold symmetry = 4 (Because of eight corners)	Axis of two-fold symmetry = 6 (Because of twelve edges)



(4) **Elements of symmetry :** The total number of planes, axes and centre of symmetry possessed by a crystal are termed as elements of symmetry. A cubic crystal possesses a total of 23 elements of symmetry.

Planes of symmetry $=(3+6)=9$,

Axes of symmetry $=(3+4+6)=13$,

Centre of symmetry = 1.

Total number of symmetry elements = 23

More About Cubic Crystals

(1) **Different lattice in cubic crystals :** There are three lattice in the cubic system.

(i) The simple cubic (*sc*) lattice.

(ii) The body-centered cubic (*bcc*).

(iii) The face-centered cubic (*fcc*).

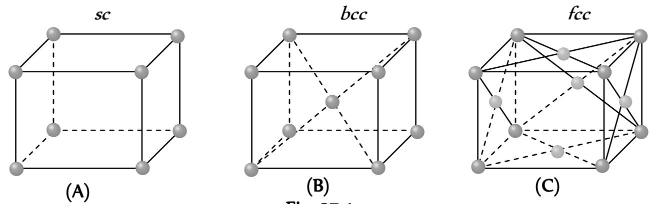


Fig. 27.4

(2) **Atomic radius :** The half of the distance between two atoms in contact is defined as atomic radius.

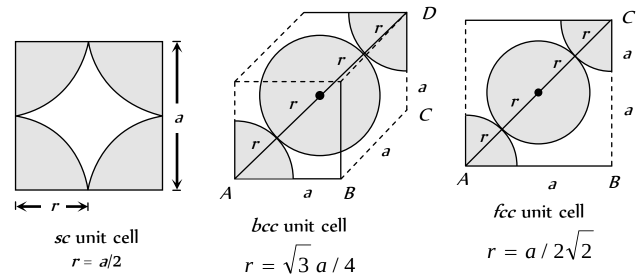


Fig. 27.5

(3) **Atoms per unit cell :** An atom located at the corner of a unit cell of a lattice is shared equally by eight other unit cells in the three dimensional lattice. Therefore, each unit cell has 1/8 share of an atom at its each corner. Similarly, a face of the unit cell is common to the two unit cells in the lattice. Therefore, each unit cell has 1/2 share of an atom at its each face. The atom located at the centre of the unit cell belongs completely to the unit cell.

Let N_c, N_b and N_f be the number of atoms at the corners, centre and face of the unit cell respectively. Therefore the number of atoms per unit cell is given by $N = N_b + \frac{N_f}{2} + \frac{N_c}{8}$

(i) In *sc* lattice : $N_b = 0,\ N_f = 0,\ N_c = 8$ so $N = 1$

(ii) In *bcc* lattice : $N_b = 1,\ N_f = 0,\ N_c = 8$ so $N = 2$

(iii) In *fcc* lattice : $N_b = 0,\ N_f = 6,\ N_c = 8$ so $N = 4$

(4) **Co-ordination number :** It is defined as the number of nearest neighbours that an atom has in a unit cell. It depends upon structure.

(i) Simple cubic structure : Each atom has two neighbours along *X*-axis, two along *Y*-axis and two along *Z*-axis so co-ordination number = 6.

(ii) Face-centred cubic structure: Every corner atom has four neighbours in each of the three planes *XY*, *YZ*, and *ZX* so co-ordination number = 12

(iii) Body-centred cubic structure: The atom of the body of the cell has eight neighbours at eight corner of the unit cell so co-ordination number = 8.

(5) **Atomic packing fraction (or packing factor or relative packing density)**

The atomic packing fraction indicates how close the atoms are packed together in the given crystal structure or the ratio of the volume occupied by atoms in a unit cell in a crystal and the volume of unit cell is defined as APF.

(i) **For *sc* crystal :** Volume occupied by the atom in the unit cell $= \frac{4}{3}\pi r^3 = \frac{\pi a^3}{6}$. Volume of the unit cell $= a^3$

Thus P.F. $= \frac{\pi a^3/6}{a^3} = \frac{\pi}{6} = 0.52 = 52\%$

(ii) **For *bcc* :** P.F. $= \frac{\sqrt{3}\pi}{8} = 68\%$

(iii) **For *fcc* :** P.F. $= \frac{\pi}{3\sqrt{2}} = 74\%$

(6) **Density of unit cell :** Density of unit cell $= \frac{\text{Mass of the unit cell}}{\text{Volume of the unit cell}} = \frac{nA}{NV} = \frac{nA}{Na^3}$

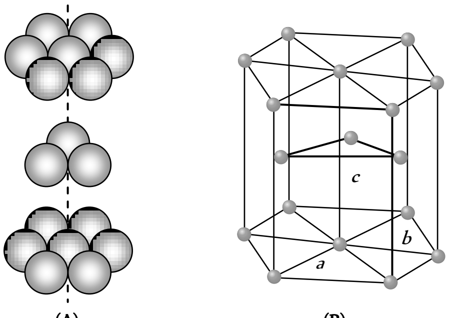
where n = Number of atoms in unit cell (For *sc* lattice n = 1, for *bcc* lattice n = 2, for *fcc* lattice n = 4), A = atomic weight, N = Avogadro's number, V = Volume of the unit cell.

(7) **Bond length :** The distance between two nearest atoms in a unit cell of a crystal is defined as bond length.

(i) In a *sc* lattice : Bond length = a (ii) In a *bcc* lattice : Bond length $= \frac{\sqrt{3}a}{2}$ (iii) In a *fcc* lattice : Bond length $= \frac{a}{\sqrt{2}}$

Hexagonal Close Packed (HCP) Structure

The HCP structure also maximizes the packing fraction



(A) Fig. 27.6 (B)

(1) $a = b \neq c$

(2) Number of atoms per unit cell = 6

(3) The volume of the hexagonal cell = $3\sqrt{2}\,a^3$

(4) The packing fraction $= \frac{\pi\sqrt{2}}{6}$

(5) Coordination number = 12

(6) Magnesium is a special example of HCP lattice structure.

Bonding Forces in Crystals

The properties of a solid are mainly determined by the type of bonding that exists between the atoms. According to bonding in crystals they are classified into following types.

(1) **Ionic crystal :** This type of bonding is formed due to transfer of electrons between atoms and consequent attraction between them.

(i) In *NaCl* crystal, the electron of *Na* atom is transferred to chlorine atom. In this way *Na* atom changes in to *Na* ion and *Cl* atom changes into *Cl* ion.

(ii) Cause of binding is electrostatic force between positive and negative ion.

(iii) These crystal are usually hard, brittle and possesses high melting and boiling point.

(iv) These are bad conductor of electricity.

(v) Common example are *NaCl, CsCl, LiF etc.*

(2) **Covalent crystal :** Covalent bonding is formed by sharing of electrons of opposite spins between two atoms

(i) The conductivity of these solids rise with rise in temperature.

(ii) These crystal posses high melting point.

(iii) Bonding between H_2, Cl_2 molecules *Ge*, *Si*, Quartz, diamond *etc*. are common example of covalent bonding

(3) **Metallic bonds :** This type of bonding is formed due to attraction of valence (free) electrons with the positive ion cores

(i) Their conductivity decreases with rise of temperature.

(ii) When visible light falls on a metallic crystal, the electrons of atom absorb visible light, so they are opaque to visible light. However some orbital electrons absorb energy and reach in excited state. They then return to their normal states, remitting light of same frequency.

Common examples are *Na, Li, K, Cs, Au, Hg etc*.

(4) **Vander waal's crystal :** These crystal consists of neutral atoms or molecules bonded together in solid phase by weak, short range attractive forces called vander Waal's forces.

(i) This bonding is weakest and occurs in solid CO_2, methane, paraffin, ice, etc.

(ii) They are normally insulator, they are soft, easily compressible and posses low melting point.

(5) **Hydrogen bonding :** Hydrogen bonding is due to permanent dipole interaction.

(i) This bond is stronger than vander Waal's bond but much weaker than ionic and covalent bond.

(ii) They possesses low melting point.

(iii) Common examples are H_2O, *HF etc*.

Single, Poly and Liquid Crystals

(1) **Single crystal :** The crystals in which the periodicity of the pattern extends throughout the piece of the crystal are known as single crystals. Single crystals have anisotropic behaviour *i.e.* their physical properties (like mechanical strength, refractive index, thermal and electrical conductivity) are different along different directions. The small sized single crystals are called mono-crystals.

(2) **Poly-crystals :** A poly-crystal is the aggregate of the monocrystals whose well developed faces are joined together so that it has isotropic properties. Ceramics are the important illustrations of the poly-crystalline solids.

(3) **Liquid crystals :** The organic crystalline solid which on heating, to a certain temperature range becomes fluid like but its molecules remain oriented in a particular directions, showing that they retain their anisotropic properties, is called liquid crystal. These crystals are used in a liquid crystal displays (L.C.D.) which are commonly used in electronic watches, clocks and micro-calculators *etc*.

Energy Bands

This theory is based on the Pauli exclusion principle.

In isolated atom the valence electrons can exist only in one of the allowed orbitals each of a sharply defined energy called energy levels. But when two atoms are brought nearer to each other, there are alterations in energy levels and they spread in the form of bands.

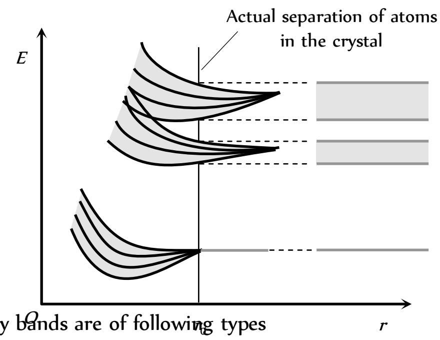


Fig. 27.7 Origin of energy bands in a solid

Energy bands are of following types

(1) **Valence band :** The energy band formed by a series of energy levels containing valence electrons is known as valence band. At 0 *K*, the electrons fills the energy levels in valence band starting from lowest one.

(i) This band is always filled with electrons.

(ii) This is the band of maximum energy.

(iii) Electrons are not capable of gaining energy from external electric field.

(iv) No flow of current due to electrons present in this band.

(v) The highest energy level which can be occupied by an electron in valence band at 0 *K* is called fermi level.

(2) **Conduction band :** The higher energy level band is called the conduction band.

(i) It is also called empty band of minimum energy.

(ii) This band is partially filled by the electrons.

(iii) In this band the electrons can gain energy from external electric field.

(iv) The electrons in the conduction band are called the free electrons. They are able to move any where within the volume of the solid.

(v) Current flows due to such electrons.

(3) **Forbidden energy gap (ΔE) :** Energy gap between conduction band and valence band $\Delta E_g = (C.B.)_{\min} - (V.B.)_{\max}$

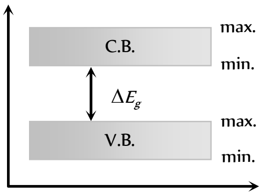


Fig. 27.8

(i) No free electron is present in forbidden energy gap.

(ii) Width of forbidden energy gap depends upon the nature of substance.

(iii) As temperature increases (↑), forbidden energy gap decreases (↓) very slightly.

Table 27.3 : Types of solid

Properties	Conductors	Insulators	Semiconductors
Electrical conductivity	10^2 to 10^8 ℧$/m$	10^{-8} ℧$/m$	10^{-5} to 10^0 ℧$/m$
Resistivity	10^{-2} to 10^{-8} Ω-m (negligible)	10^8 Ω-m	10^5 to 10^0 Ω-m
Band structure	C.B. V.B.	C.B. ΔE_g (large) V.B.	C.B. ΔE_g (small) V.B.
Energy gap (E_g)	Zero or very small	Very large; for diamond it is 6 *eV*	*Ge* → 0.7 *eV* *Si* → 1.1 *eV* *GaAs* →1.3 *eV* GaF_2 → 2.8 *eV*
Current carriers	Free electrons	––	Free electrons and holes
Condition of V.B. and C.B. at ordinary temperature	V.B. and C.B. are completely filled or C.B. is some what empty	V.B. – completely filled C.B. – completely unfilled	V.B. – somewhat empty C.B. – somewhat filled
Temperature co-efficient of resistance	Positive	Zero	Negative
Effect of temperature on conductivity	Decreases	—	Increases
Effect of temperature on resistance	Increases	—	Decreases
Examples	*Cu, Ag, Au, Na, Pt, Hg* etc.	Wood, plastic, mica, diamond, glass etc.	*Ge, Si, Ga, As* etc.
Electron density	$10^{29}/m^3$	—	*Ge* ~ 10^{19} $/m^3$ *Si* ~ 10^{16} $/m^3$

Holes in Semiconductors

(1) When an electron is removed from a covalent bond, it leaves a vacancy behind. An electron from a neighbouring atom can move into this vacancy, leaving the neighbour with a vacancy. In this way the vacancy formed is called hole (or cotter), and can travel through the material and serve as an additional current carriers.

(2) A hole is considered as a seat of positive charge, having magnitude of charge equal to that of an electron.

(3) Holes acts as virtual charge, although there is no physical charge on it.

(4) Effective mass of hole is more than electron.

(5) Mobility of hole is less than electron.

Intrinsic Semiconductors

(1) A pure semiconductor is called intrinsic semiconductor. It has thermally generated current carriers

(2) They have four electrons in the outermost orbit of atom and atoms are held together by covalent bond

(3) Free electrons and holes both are charge carriers and n_e (in C.B.) $= n_h$ (in V.B.)

(4) The drift velocity of electrons (v_e) is greater than that of holes (v_h)

(5) For them fermi energy level lies at the centre of the C.B. and V.B.

(6) In pure semiconductor, impurity must be less than 1 in 10^8 parts of semiconductor.

(7) In intrinsic semiconductor

$n_e^{(o)} = n_h^{(o)} = n_i$; where $n_e^{(o)} =$ Electron density in conduction band, $n_h^{(o)} =$ Hole density in V.B., $n_i =$ Density of intrinsic carriers.

(8) The fraction of electrons of valance band present in conduction band is given by $f \propto e^{-E_g/kT}$; where E_f = Fermi energy or k = Boltzmann's constant and T = Absolute temperature

(9) Because of less number of charge carriers at room temperature, intrinsic semiconductors have low conductivity so they have no practical use.

(10) Number of electrons reaching from valence band to conduction band $n = AT^{3/2}e^{-E_g/2kT}$

Extrinsic Semiconductor

(1) An impure semiconductor is called extrinsic semiconductor

(2) When pure semiconductor material is mixed with small amounts of certain specific impurities with valency different from that of the parent material, the number of mobile electrons/holes drastically changes. The process of addition of impurity is called doping.

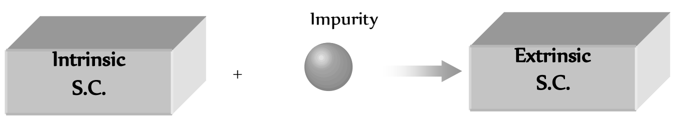


Fig. 27.9

(3) **Pentavalent impurities :** The elements whose atom has five valance electrons are called pentavalent impurities e.g. *As, P, Sb etc.* These impurities are also called donor impurities because they donate extra free electron.

(4) **Trivalent impurities :** The elements whose each atom has three valance electrons are called trivalent impurities e.g. *In, Ga, Al, B, etc.* These impurities are also called acceptor impurities as they accept electron.

(5) The compounds of trivalent and pentavalent elements also behaves like semiconductors *e.g. GaAs, InSb, In P, GaP etc.*

(6) The number of atoms of impurity element is about 1 in 10^8 atoms of the semiconductor.

(7) In extrinsic semiconductors $n_e \neq n_h$

(8) In extrinsic semiconductors fermi level shifts towards valence or conduction energy bands.

(9) Their conductivity is high and they are used for practical purposes.

(10) In a doped extrinsic semiconductor, the number density of e^- of the conduction band (n) and the number density of holes in the valence band (n) differs from that in a pure semiconductor. If n_i is the number density of electron in conduction band or the number density of holes in valence band in a pure semiconductor then $n_e n_h = n_i^2$ (mass action law)

(11) Extrinsic semiconductors are of two types

(i) *N*-type semiconductor (ii) *P*-type semiconductor

N-Type Semiconductor

These are obtained by adding a small amount of pentavalent impurity to a pure sample of semiconductor (*Ge*).

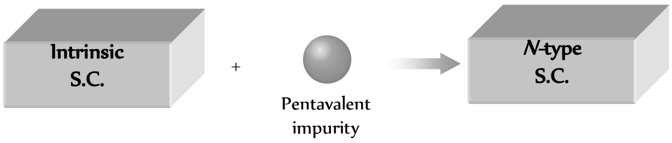


Fig. 27.10

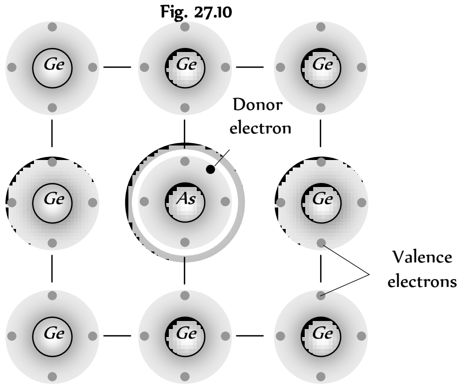


Fig. 27.11

(1) Majority charge carriers – electrons

Minority charge carriers – holes

(2) $n_e >> n_h$; $i_e >> i_h$

(3) Conductivity $\sigma \approx n_e \mu_e e$

(4) *N*-type semiconductor is electrically neutral (not negatively charged)

(5) Impurity is called Donar impurity because one impurity atom generate one electron.

(6) Donor energy level lies just below the conduction band.

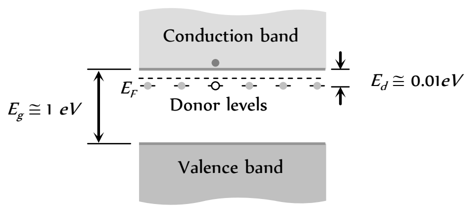
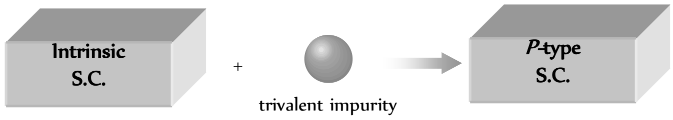


Fig. 27.12

P-Type Semiconductor

These are obtained by adding a small amount of trivalent impurity to a pure sample of semiconductor (*Ge*).



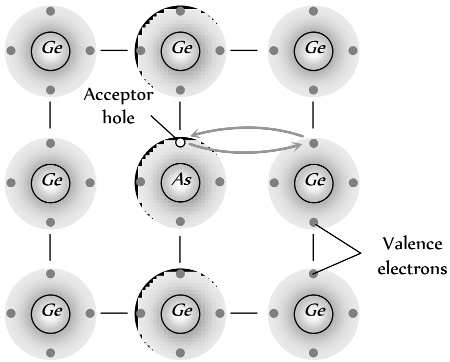


Fig. 27.13

(1) Majority charge carriers – holes

Minority charge carriers – electrons

(2) $n_h >> n_e$; $i_h >> i_e$

(3) Conductivity $\sigma \approx n_h \mu_h e$

(4) *P*-type semiconductor is also electrically neutral (not positively charged)

(5) Impurity is called Acceptor impurity.

(6) Acceptor energy level lies just above the valence band.

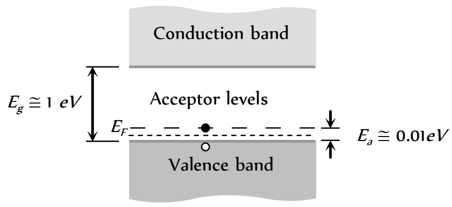


Fig. 27.14

Density of Charge Carriers

Due to thermal collisions, an electron can take up or release energy. Thus, occasionally a valence electron takes up energy and the bond is broken. The electron goes to the conduction band and a hole is created. And occasionally, an electron from the conduction band loses some energy, comes to the valence band and fills up a hole. Thus, new electron-hole pairs are formed as well as old electron-hole disappear. A steady-state situation is reached and the number of electron-hole pairs takes a nearly constant value. For silicon at room temperature (300 *K*), the number of these pairs is about 7×10^{15} *m*. For germanium, this number is about 6×10^{19} /*m*.

Table 27. 4 : Densities of charge carriers

Material	Type	Density of conduction electrons (m^{-3})	Density of holes (m^{-3})
Copper	Conductor	9×10^{28}	0
Silicon	Intrinsic semiconductor	7×10^{15}	7×10^{15}
Silicon doped with phosphorus (1 part in 10^6)	*N*-type semiconductor	5×10^{22}	1 $\times 10^9$

Silicon doped with aluminium (1 part in 10^6	*P*-type semiconductor	1×10^9	5×10^{22}

Conductivity of Semiconductor

(1) In intrinsic semiconductors $n_e = n_h$. Both electron and holes contributes in current conduction.

(2) When some potential difference is applied across a piece of intrinsic semiconductor current flows in it due to both electron and holes *i.e.* $i = i_e + i_h \Rightarrow i = eA[n_e v_e + n_h v_h]$

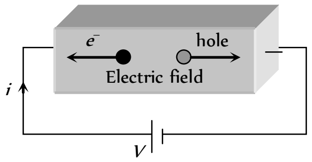


Fig. 27.15

(3) As we know $\sigma = \frac{J}{E} = \frac{i}{AE}$. Hence conductivity of semiconductor

$\sigma = e[n_e \mu_e + n_h \mu_h]$; where v_e = drift velocity of electron, v_h = drift velocity of holes, E = Applied electric field $\mu_e = \frac{v_e}{E}$ = mobility of electron and $\mu_h = \frac{v_h}{E}$ = mobility of holes

(4) Motion of electrons in the conduction band and of holes the valence band under the action of electric field is shown below

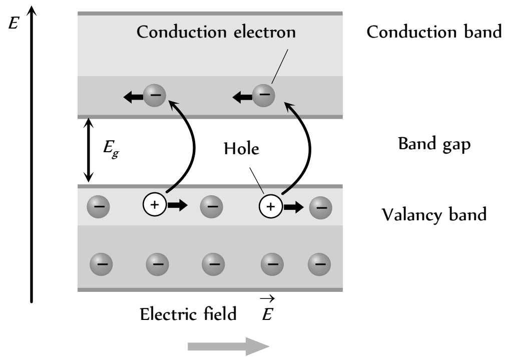


Fig. 27.16

(5) At absolute zero temperature (0 *K*) conduction band of semiconductor is completely empty *i.e.* σ = 0. Hence the semiconductor behaves as an insulator.

P-N Junction Diode

When a *P*-type semiconductor is suitably joined to an *N*-type semiconductor, then resulting arrangement is called *P-N* junction or *P-N* junction diode

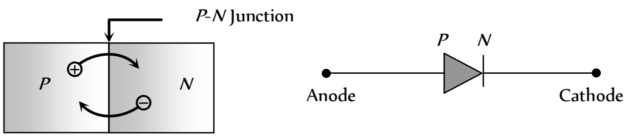


Fig. 27.17

(1) **Depletion region :** On account of difference in concentration of charge carrier in the two sections of *P-N* junction, the electrons from *N*-region diffuse through the junction into *P*-region and the hole from *P* region diffuse into *N*-region.

Due to diffusion, neutrality of both *N* and *P*-type semiconductor is disturbed, a layer of negative charged ions appear near the junction in the *P*-crystal and a layer of positive ions appears near the junction in *N*-crystal. This layer is called depletion layer

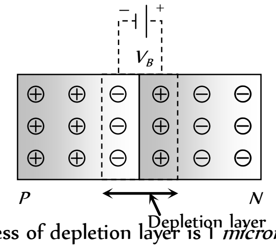


Fig. 27.18

(i) The thickness of depletion layer is 1 *micron* = 10^{-6} *m*.

(ii) Width of depletion layer $\propto \frac{1}{\text{Dopping}}$

(iii) Depletion is directly proportional to temperature.

(iv) The *P-N* junction diode is equivalent to capacitor in which the depletion layer acts as a dielectric.

(2) **Potential barrier :** The potential difference created across the *P-N* junction due to the diffusion of electron and holes is called potential barrier.

For *Ge* $V_B = 0.3V$ and for silicon $V_B = 0.7V$

On the average the potential barrier in *P-N* junction is ~ 0.5 *V* and the width of depletion region ~ 10^{-6} *m*.

So the barrier electric field $E = \frac{V}{d} = \frac{0.5}{10^{-6}} = 5 \times 10^5 \ V/m$

(3) **Some important graphs**

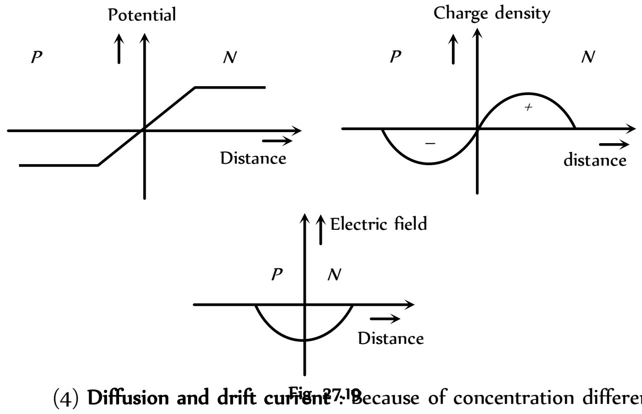


Fig. 27.19

(4) **Diffusion and drift current :** Because of concentration difference holes/electron try to diffuse from their side to other side. Only those holes/electrons crosses the junction, which have high kinetic energy. This diffusion results in an electric current from the *P*-side to the *N*-side known as diffusion current (i_{df})

As electron hole pair (because of thermal collisions) are continuously created in the depletion region. There is a regular flow of electrons towards the *N*-side and of holes towards the *P*-side. This makes a current from the *N*-side to the *P*-side. This current is called the drift current (i_{dr}).

Biasing

It means the way of connecting emf source to *P-N* junction diode. It is of following two types

(1) **Forward biasing :** Positive terminal of the battery is connected to the *P*-crystal and negative terminal of the battery is connected to *N*-crystal

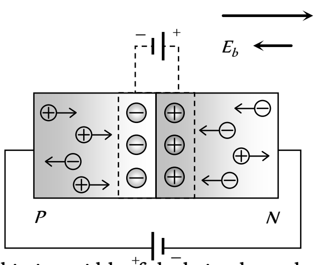


Fig. 27.20

(i) In forward biasing width of depletion layer decreases

(ii) In forward biasing resistance offered $R_{forward} \approx 10\Omega - 25\Omega$

(iii) Forward bias opposes the potential barrier and for $V > V_0$ a forward current is set up across the junction.

(iv) The current is given by $i = i_s(e^{eV/kT} - 1)$; where

$i_s =$ Saturation current, In the exponent $e = 1.6 \times 10^{-19}$ *C*,

k = Boltzmann's constant

(v) Cut-in (Knee) voltage : The voltage at which the current starts to increase rapidly. For *Ge* it is 0.3 *V* and for *Si* it is 0.7 *V*.

(vi) *df* – diffusion

dr – drift

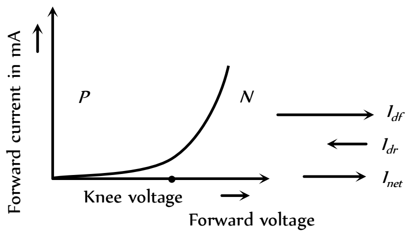


Fig. 27.21

(2) **Reverse biasing :** Positive terminal of the battery is connected to the *N*-crystal and negative terminal of the battery is connected to *P*-crystal

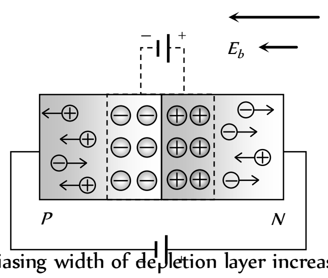


Fig. 27.22

(i) In reverse biasing width of depletion layer increases

(ii) In reverse biasing resistance offered $R_{Reverse} \approx 10\Omega$

(iii) Reverse bias supports the potential barrier and no current flows across the junction due to the diffusion of the majority carriers.

(A very small reverse currents may exist in the circuit due to the drifting of minority carriers across the junction)

(iv) Break down voltage : Reverse voltage at which break down of semiconductor occurs. For *Ge* it is 25 *V* and for *Si* it is 35 *V*.

(v)

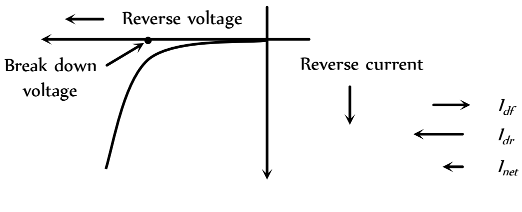


Fig. 27.23

Reverse Breakdown

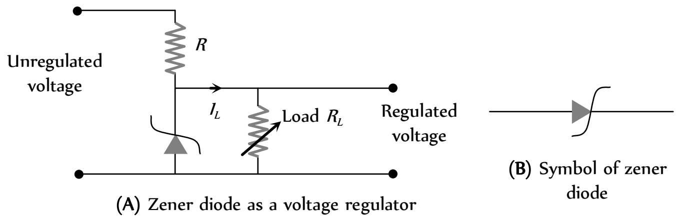
If the reverse biased voltage is too high, then breakdown of *P-N* junction diode occurs. It is of following two types

(1) **Zener breakdown :** When reverse bias is increased the electric field across the junction also increases. At some stage the electric field becomes so high that it breaks the covalent bonds creating electron, hole pairs. Thus a large number of carriers are generated. This causes a large current to flow. This mechanism is known as **Zener breakdown.**

(2) **Avalanche breakdown :** At high reverse voltage, due to high electric field, the minority charge carriers, while crossing the junction acquires very high velocities. These by collision breaks down the covalent bonds, generating more carriers. A chain reaction is established, giving rise to high current. This mechanism is called **avalanche breakdown.**

Special Purpose Diodes

(1) **Zener diode :** It is a highly doped *p-n* junction which is not damaged by high reverse current. It can operate continuously, without being damaged in the region of reverse background voltage. In the forward bias, the zener diode acts as ordinary diode. It can be used as voltage regulator



(A) Zener diode as a voltage regulator (B) Symbol of zener diode

Fig. 27.24

(2) **Light emitting diode (LED :** Specially designed diodes, which give out light radiations when forward biases. LED'S are made of *GaAsp*, *Gap etc.*

These are forward biased *P-N*-junctions which emits spontaneous radiation.

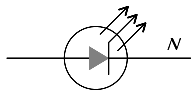


Fig. 27.25

(3) **Photo diode:** Photodiode is a special type of photo-detector. Suppose an optical photons of frequency ν is incident on a semiconductor, such that its energy is greater than the band gap of the semiconductor (*i.e.* $h\nu > E_g$) This photon will excite an electron from the valence band to the conduction band leaving a vacancy or hole in the valence band.

Which obviously increase the conductivity of the semiconductor. Therefore, by measuring the change in the conductance (or resistance) of the semiconductor, one can measure the intensity of the optical signal.

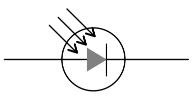


Fig. 27.26

(4) **Solar cells :** It is based on the photovoltic effect. One of the semiconductor region is made so thin that the light incident on it reaches the *P-N*-junction and gets absorbed. It converts solar energy into electrical energy.

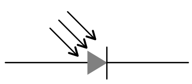


Fig. 27.27

P-N Junction Diode as a Rectifier

Rectifier is a circuit which converts *ac* to unidirectional pulsating output. In other words it converts *ac* to *dc*. It is of following two types

(1) **Half wave rectifier :** When the *P-N* junction diode rectifies half of the *ac* wave, it is called half wave rectifier

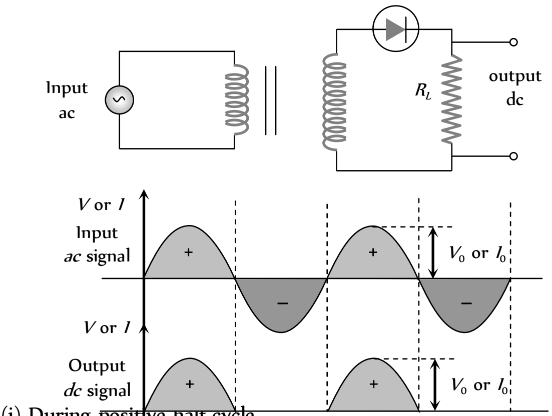


Fig. 27.28

(i) During positive half cycle

Diode ⟶ forward biased

Output signal ⟶ obtained

(ii) During negative half cycle

Diode ⟶ reverse biased

Output signal ⟶ not obtained

(iii) Output voltage is obtained across the load resistance R_L. It is not constant but pulsating (mixture of *ac* and *dc*) in nature .

(iv) Average output in one cycle

$$I_{dc} = \frac{I_0}{\pi} \text{ and } V_{dc} = \frac{V_0}{\pi};\ I_0 = \frac{V_0}{r_f + R_L}$$

(r_f = forward biased resistance)

(v) r.m.s. output : $I_{rms} = \frac{I_0}{2}, V_{rms} = \frac{V_0}{2}$

(vi) The ratio of the effective alternating component of the output voltage or current to the *dc* component is known as ripple factor.

$$r = \frac{I_{ac}}{I_{dc}} = \left[\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1\right]^{1/2} = 1.21$$

(vii) Peak inverse voltage (PIV) : The maximum reverse biased voltage that can be applied before commoncement of Zener region is called the PIV. When diode is not conducting PIV across it = V_0

(viii) Efficiency : It is given by $\%\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{40.6}{1 + \frac{r_f}{R_L}}$

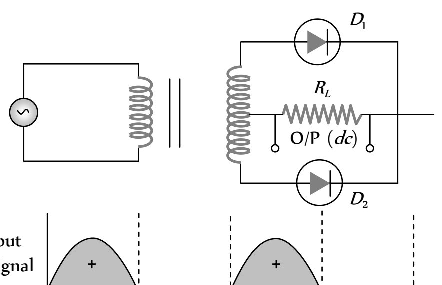
If $R_L >> r_f$ then η = 40.6%

If $R_L = r_f$ then η = 20.3%

(ix) Form factor = $\frac{I_{rms}}{I_{dc}} = \frac{\pi}{2} = 1.57$

(x) The ripple frequency (ω) for half wave rectifier is same as that of *ac*.

(2) **Full wave rectifier :** It rectifies both halves of *ac* input signal.



(i) During positive half cycle

Diode : D_1 ⟶ forward biased

D_2 ⟶ reverse biased

Output signal ⟶ obtained due to D_1 only

(ii) During negative half cycle

Diode : D_1 ⟶ reverse biased

D_2 ⟶ forward biased

Output signal ⟶ obtained due to D_2 only

(iii) Fluctuating *dc* ⟶ Filter ⟶ constant *dc*.

(iv) Output voltage is obtained across the load resistance R_L. It is not constant but pulsating in nature.

(v) Average output : $V_{av} = \frac{2V_0}{\pi}, I_{av} = \frac{2I_0}{\pi}$

(vi) *r.m.s.* output : $V_{rms} = \frac{V_0}{\sqrt{2}}, I_{rms} = \frac{I_0}{\sqrt{2}}$

(vii) Ripple factor : r = 0.48 = 48%

(viii) Ripple frequency : The ripple frequency of full wave rectifier = 2 × (Frequency of input *ac*)

(ix) Peak inverse voltage (PIV) : It's value is $2V_0$

(x) Efficiency : $\eta_{\%} = \frac{81.2}{1 + \frac{r_f}{R_L}}$ for $r_f << R_L$, $\eta = 81.2\%$

(3) **Full wave bridge rectifier :** Four diodes D_1, D_2, D_3 and D_4 are used in the circuit.

During positive half cycle D_1 and D_3 are forward biased and D_2 and D_4 are reverse biased

During negative half cycle D_2 and D_4 are forward biased and D_1 and D_3 are reverse biased

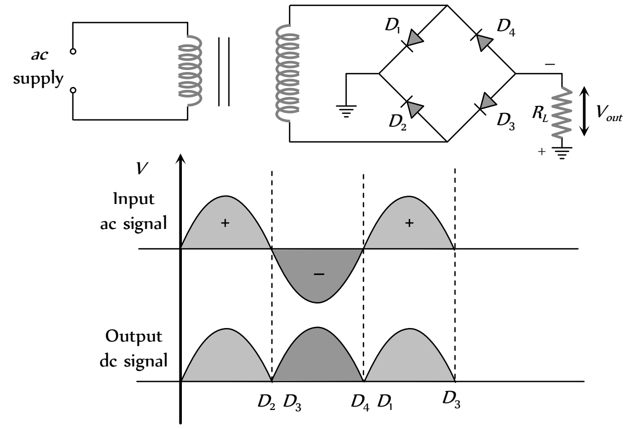


Fig. 27.30

Transistor

(1) The name of this electronic device is derived from it's fundamental action transfer resistor.

(2) Transistor does not need any heater or hot filament, transistor is small in size and light in weight.

(3) Transistor in general is known as bipolar junction transistor.

(4) Transistor is a current operated device.

(5) It consists of three main regions

(i) **Emitter (*E*) :** It provides majority charge carriers by which current flows in the transistor. Therefore the emitter semiconductor is heavily doped.

(ii) **Base (*B*) :** The based region is lightly doped and thin.

(iii) **Collector (*C*) :** The size of collector region is larger than the two other regions.

(6) Junction transistor are of two types :

(i) *NPN* transistor : It is formed by sandwiching a thin layer of *P*-type semiconductor between two *N*-type semiconductors

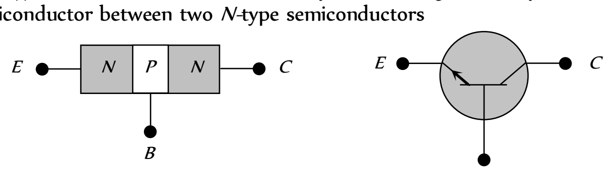


Fig. 27.31

In *NPN* transistor electrons are majority charge carriers and flow from emitter to base.

(ii) *PNP* transistor : It is formed by sandwiching a thin layer of *N*-type semiconductor between two *P*-type semiconductor

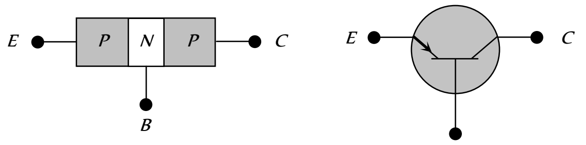


Fig. 27.32

In *PNP* transistor holes are majority charge carriers and flow from emitter to base.

In the symbols of both *NPN* and *PNP* transistor, arrow indicates the direction of conventional current.

Working of Transistor

(1) There are four possible ways of biasing the two *P-N* junctions (emitter junction and collector junction) of transistor.

(i) Active mode : Also known as linear mode operation.

(ii) Saturation mode : Maximum collector current flows and transistor acts as a closed switch from collector to emitter terminals.

(iii) Cut-off mode : Denotes operation like an open switch where only leakage current flows.

(iv) Inverse mode : The emitter and collector are inter changed.

Table 27.5 : Different modes of operation of a transistor

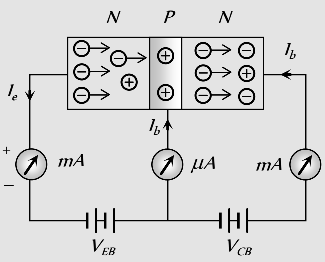
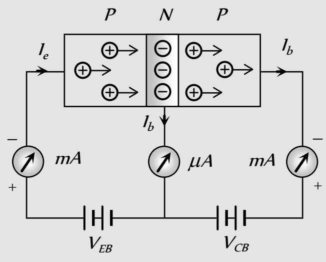
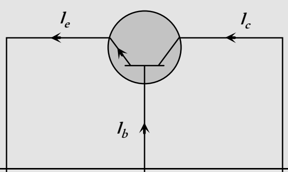
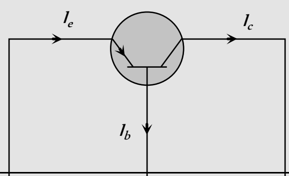
Operating mode	Emitter base bias	Collector base bias
Active	Forward	Reverse
Saturation	forward	Forward
Cut off	Reverse	Reverse
Inverse	Reverse	Forward

(2) A transistor is mostly used in the active region of operation *i.e.* emitter base junction is forward biased and collector base junction is reverse biased.

(3) From the operation of junction transistor it is found that when the current in emitter circuit changes. There is corresponding change in collector current.

(4) In each state of the transistor there is an input port and an output port. In general each electrical quantity (*V* or *I*) obtained at the output is controlled by the input.

Table 27.6 : Circuit diagram of *PNP*/*NPN* transistor

NPN – transistor	*PNP* – transistor
	
	
5% emitter electron combine with the holes in the base region resulting in small base current. Remaining 95% electrons enter the collector region.	5% emitter holes combine with the electrons in the base region resulting in small base current. Remaining 95% holes enter the collector region.
$I_e > I_c$, and $I_e = I_b + I_c$	$I_e > I_c$, and $I_e = I_b + I_c$

Transistor Configurations

A transistor can be connected in a circuit in the following three different configurations.

Common base (CB), Common emitter (CE) and Common collector (CC) configuration.

(1) **CB configurations :** Base is common to both emitter and collector .

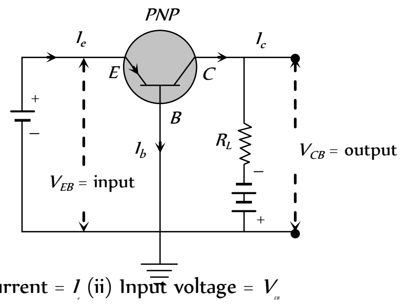


Fig. 27.33

(i) Input current = I_e (ii) Input voltage = V_{eb}

(iii) Output voltage = V_{cb} (iv) Output current = I_c

With small increase in emitter-base voltage V_{eb}, the emitter current I_e increases rapidly due to small input resistance.

(v) **Input characteristics :** If V_{cb} = constant, curve between I_e and V_{eb} is known as input characteristics. It is also known as emitter characteristics

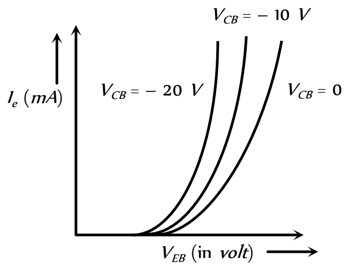


Fig. 27.34

Input characteristics of *NPN* transistor are also similar to the above figure but I_e and V_{eb} both are negative and V_{cb} is positive.

Dynamic input resistance of a transistor is given by

$$R_i = \left(\frac{\Delta V_{EB}}{\Delta I_e}\right)_{V_{CB} = \text{constant}} \quad \{R_i \text{ is of the order of } 100\ \Omega\}$$

(vi) **Output characteristics :** Taking the emitter current i_e constant, the curve drawn between I_c and V_{cb} are known as output characteristics of *CB* configuration.

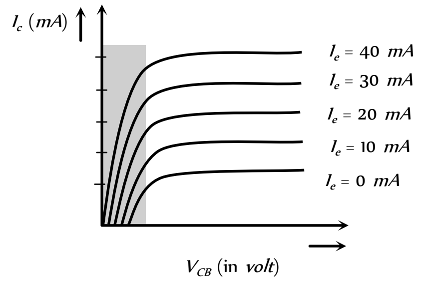


Fig. 27.35

Dynamic output resistance $R_o = \left(\frac{\Delta V_{CB}}{\Delta i_C}\right)_{i_e = \text{constant}}$

(2) **CE configurations :** Emitter is common to both base and collector.

The graphs between voltages and currents when emitter of a transistor is common to input and output circuits are known as CE characteristics of a transistor.

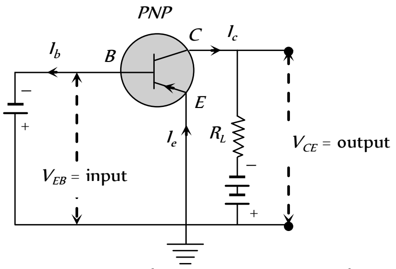


Fig. 27.36

Input characteristics : Input characteristic curve is drawn between base current I_b and emitter base voltage V_{eb}, at constant collector emitter voltage V_{ce}.

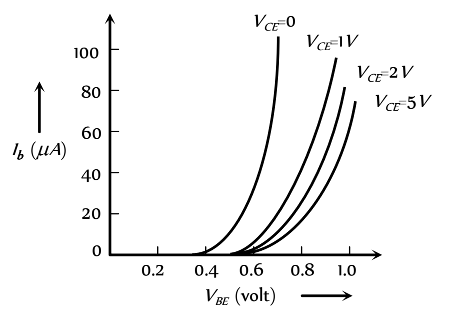


Fig. 27.37

Dynamic input resistance $R_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE} \to \text{constant}}$

Output characteristics : Variation of collector current I_c with V_{ce} can be noticed for V_{ce} between 0 to 1 *V* only. The value of V_{ce} up to which the I_c changes with V_{ce} is called knee voltage. The transistor are operated in the region above knee voltage.

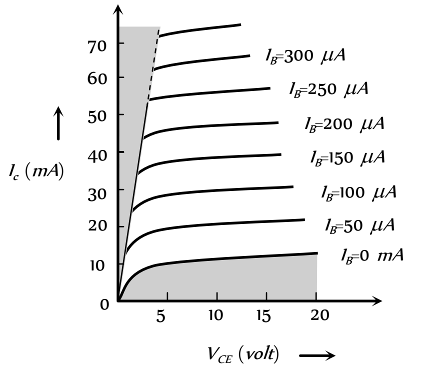


Fig. 27.38

Dynamic output resistance $R_0 = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B \to \text{constant}}$

Field-Effect Transistor

The low input impedance of the junction transistor is a handicap in certain applications. In addition, it is difficult to incorporate large numbers of them in an integrated circuit and they consume relatively large amounts of power. The field-effect transistor (FET) lacks these disadvantages and is widely used today although slower in operation than junction transistors.

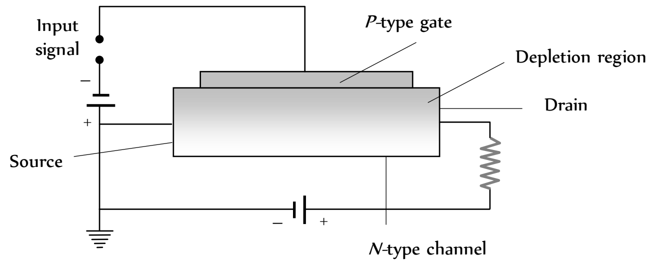


Fig. 27.39

An *n*-channel FET consists of a block of *N*-type material with contacts at each end together with a strip of *P*-type material on one side that is called the gate. When connected as shown, electrons move from the source terminal to the drain terminal through the *N*-type channel. the *PN* junction is given a reverse bias, and as a result both the *N* and *P* materials near the junction are depleted on charge carriers. The higher the reverse potential on the gate, the larger the depleted region in the channel and the fewer the electrons available to carry the current. Thus the gate voltage controls the channel current. Very little current passes through the gate circuit owing to the reverse bias, and the result is an extremely high input impedance. FET is uni-polar.

Transistor as an Amplifier

A device which increases the amplitude of the input signal is called amplifier.

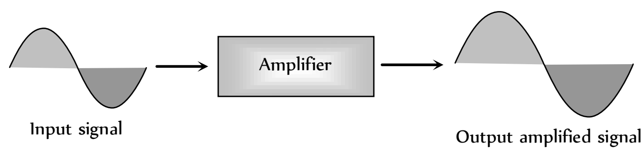


Fig. 27.40

The transistor can be used as an amplifier in the following three configuration

(i) CB amplifier (ii) CE amplifier (iii) CC amplifier

(1) ***NPN* transistor as CB amplifier**

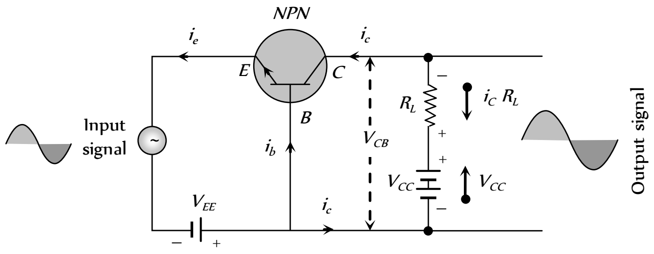


Fig. 27.41

(i) $i_e = i_b + i_C$; i_b = 5% of i_e and i_c = 95% of i_e

(ii) $V_{CB} < V_{CC}$

(iii) Net collector voltage $V_{CB} = V_{CC} - i_C R_L$

When the input signal (signal to be amplified) is fed to the emitter base circuit, it will change the emitter voltage and hence emitter current. This in turn will change the collector current (i). This will vary the collector voltage V_{CB}. This variation of V_{CB} will appear as an amplified output.

(iv) Input and output signals are in same phase

(2) ***NPN* transistor as *CE* amplifier**

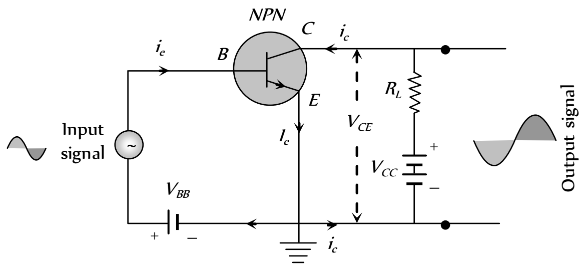


Fig. 27.42

(i) $i_e = i_b + i_C$; i_b = 5% of i_e and i_c = 95% of i_e

(ii) $V_{CC} > V_{BB}$

(iii) Net collector voltage $V_{CE} = V_{CC} - i_C R_L$

(iv) Input and output signals are 180° out of phase.

Different Gains in CE/CB Amplifiers

(1) **Transistor as CB amplifier**

(i) *ac* current gain $\alpha_{ac} = \dfrac{\text{Small change in collector current } (\Delta i_c)}{\text{Small change in collector current } (\Delta i_e)}$

V_{CB} (constant)

(ii) *dc* current gain $\alpha_{dc} (\text{or} \alpha) = \dfrac{\text{Collector current} (i_c)}{\text{Emitter current } (i_e)}$

valve of α_{dc} lies between 0.95 to 0.99

(iii) Voltage gain $A_v = \dfrac{\text{Change in output voltage} (\Delta V_o)}{\text{Change in input voltage} (\Delta V_i)}$

$\Rightarrow A_v = \alpha_{ac} \times$ Resistance gain

(iv) $\text{Power gain} = \dfrac{\text{Change in output power} (\Delta P_o)}{\text{Change in input power} (\Delta P_c)}$

$\Rightarrow \text{Power gain} = \alpha_{ac}^2 \times \text{Resistance gain}$

(2) **Transistor as CE amplifier**

(i) *ac* current gain $\beta_{ac} = \left(\dfrac{\Delta i_c}{\Delta i_b}\right)$ V_{CE} = constant

(ii) *dc* current gain $\beta_{dc} = \dfrac{i_c}{i_b}$

(iii) Voltage gain : $A_v = \dfrac{\Delta V_o}{\Delta V_i} = \beta_{ac} \times \text{Resistance gain}$

(iv) $\text{Power gain} = \dfrac{\Delta P_o}{\Delta P_i} = \beta_{ac}^2 \times \text{Resistance gain}$

(v) Trans conductance (g_m) : The ratio of the change in collector current to the change in emitter base voltage is called trans conductance. *i.e.* $g_m = \dfrac{\Delta i_c}{\Delta V_{EB}}$. Also $g_m = \dfrac{A_V}{R_L}$; R_L = Load resistance

(3) **Relation between α and β** : $\beta = \dfrac{\alpha}{1-\alpha}$ or $\alpha = \dfrac{\beta}{1+\beta}$

Transistor as an Oscillator

(1) It is defined as a circuit which generates an *ac* output signal without any externally applied input signal.

Audio frequency oscillators generates signals of frequencies ranging from a few *Hz* to 20 *kHz* and radio frequency oscillators have a range from few *kHz* to *MHz*.

(2) In an oscillator the frequency, waveform, and magnitude of *ac* power generated is controlled by circuit itself.

(3) An oscillator may be considered as amplifier which provides it's own input signal.

(4) The essential of a transistor oscillator are

(i) **Tank circuit :** Parallel combination of *L* and *C*. This network resonates at a frequency $\nu_0 = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$.

(ii) **Amplifier :** It receives *dc* power from the battery and converts into *ac* power.

The amplifier increases the strength of oscillations.

(iii) **Feed back circuit :** This circuit supplies a part of the collector energy to the tank circuit.

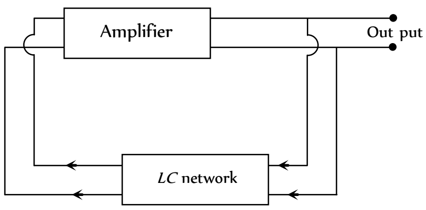


Fig. 27.43

(5) A basic common-emitter *NPN* oscillator is shown in the figure.

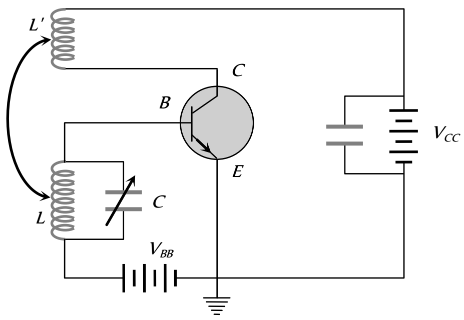


Fig. 27.44

A tank circuit (L-C circuit) is connected in the base-emitter circuit, in which the capacitance C is kept variable. By changing C oscillations of a desired frequency can be obtained. An inductance coil L' connected in the collector-emitter circuit is coupled to coil L.

On completion of the circuit electrical oscillations are developed in the tank circuit. The circuit amplifies these oscillations. A part of the amplifies signal in the collector circuit is fed back in the base circuit by the coupling between L and L'. Due to this feed back amplitude of oscillation builds up till power dissipation in the oscillatory circuit becomes equal to power fed-back. In this state the amplitude of oscillations becomes constant.

The oscillations can be transferred to an external circuit by mutual induction in a coil connected in that circuit.

(6) **Need for positive feedback :** The oscillations are damped due to the presence of some inherent electrical resistance in the circuit. Consequently, the amplitude of oscillations decreases rapidly and the oscillations ultimately stop. Such oscillations are of little practical importance. In order to obtain oscillations of constant amplitude, we make an arrangement for regenerative or positive feedback from the output circuit to the input circuit so that the losses in the circuit can be compensated.

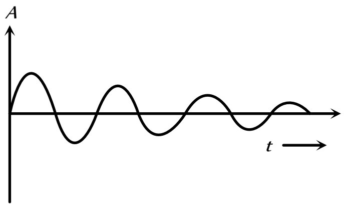


Fig. 27.45

Table 27.7: Comparison between CB, CE and CC amplifier

Characteristic	Amplifier		
	CB	CE	CC
Input resistance (R_i)	≈ 50 to 200 Ω low	≈ 1 to 2 $k\Omega$ medium	≈ 150 – 800 $k\Omega$ high
Output resistance (R_o)	≈ 1 – 2 $k\Omega$ high	≈ 50 $k\Omega$ medium	≈ $k\Omega$ low
Current gain	0.8 – 0.9 low	20 – 200 high	20 – 200 high
Voltage gain	Medium	High	Low
Power gain	Medium	High	Low
Phase difference between input and output voltages	Zero	180°	Zero
Used as amplifier for	current	Power	Voltage

Digital Electronics

Decimal and Binary Number System

(1) **Decimal number system :** In a decimal number system, we have ten digits *i.e.* 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.

A decimal number system has a base of ten (10)

e.g. 1971 = 1000 + 900 + 70 + 1

$= 1 \times 10^3 + 9 \times 10^2 + 7 \times 10^1 + 1 \times 10^0$

MSD LSD

LSD = Least significant digit

MSD = Most significant digit

(2) **Binary number system :** A number system which has only two digits *i.e.* 0 (Low) and 1 (High) is known as binary system. The base of binary number system is 2.

(i) Each digit in binary system is known as a bit and a group of bits is known as a byte.

(ii) The electrical circuit which operates only in these two state *i.e.* 1 (On or High) and 0 (*i.e.* Off or Low) are known as digital circuits.

Table 27. 8 : Different names for the digital signals

State Code	1	0
Name for the State	On	Off
	Up	Down
	Close	Open
	Excited	Unexcited
	True	False
	Pulse	No pulse
	High	Low
	Yes	No

(3) **Decimal to binary conversion**

(i) Divide the given decimal number by 2 and the successive quotients by 2 till the quotient becomes zero.

(ii) The sequence of remainders obtained during divisions gives the binary equivalent of decimal number.

(iii) the most significant digit (or bit) of the binary number so obtained is the last remainder and the least significant digit (or bit) is the first remainder obtained during the division.

***For Example* :** Binary equivalence of 61

2	61	Remainder
2	30	1 LSD
2	15	0

2	7	1
2	3	1
2	1	1
	0	1 MSD

$\Rightarrow (61)_{10} = (111101)_2$

(4) **Binary to decimal conversion :** The least significant digit in the binary number is the coefficient of 2 with power zero. As we move towards the left side of LSD, the power of 2 goes on increasing.

***For Example* :** $(11111100101)_2 = 1\times2^{10} + 1\times2^9 + 1\times2^8 + 1\times2^7 + 1\times2^6 + 1\times2^5 + 0\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 1\times2^0 = 2021$

Voltage Signal

(1) **Analogue voltage signal :** The signal which represents the continuous variation of voltage with time is known as analogue voltage signal

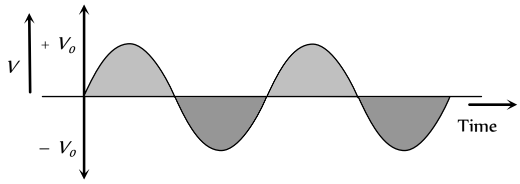


Fig. 27.46

(2) **Digital voltage signal :** The signal which has only two values. *i.e.* either a constant high value of voltage or zero value is called digital voltage signal

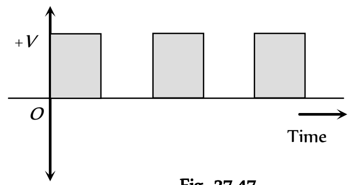


Fig. 27.47

Boolean Algebra

(1) In Boolean algebra only two states of variables (0 and 1) are allowed.

(2) The variables (A, B, C ....) of Boolean Algebra are subjected to three operations.

(i) **OR Operation :** Represented by (+) sign

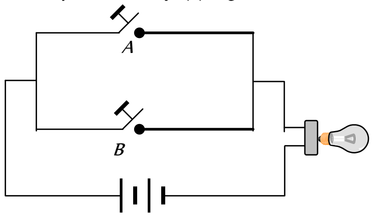


Fig. 27.48

Boolean expression $Y = A + B$

When switch *A* or *B* is closed – Bulb glows

(ii) **AND Operation :** Represented by (·) sign

Boolean expression $Y = A \cdot B$

When switches *A* and *B* both are closed – Bulb glows

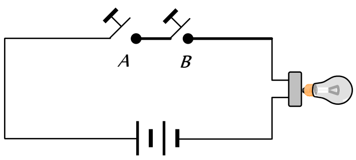
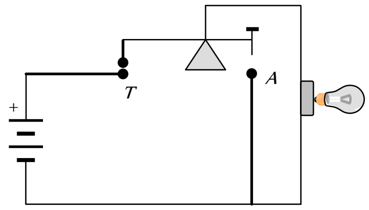


Fig. 27.49

(iii) **NOT Operation :** Represented by bar over the variables

Boolean expression $Y = \overline{A}$



A OFF → Lamp ON
A ON → Contact at *T* is broken
→ Lamp OFF

Fig. 27.50

(3) **Basic Boolean postulates and laws**

(i) Boolean Postulates : $0 + A = A$, $1 \cdot A = A$,

$1 + A = 1$, $0 \cdot A = 0$,

$A + \overline{A} = 1$

(ii) Identity law : $A + A = A$, $A \cdot A = A$

(iii) Negation law : $\overline{\overline{A}} = A$

(iv) Commutative law : $A + B = B + A$, $A \cdot B = B \cdot A$

(v) Associative law : $(A+B) + C = A + (B+C)$,

$(A \cdot B) \cdot C = A \cdot (B \cdot C)$

(vi) Distributive law : $A \cdot (B+C) = A \cdot B + A \cdot C$

$(A + B) \cdot (A + C) = A + BC$

(vii) Absorption laws : $A + A \cdot B = A$, $A \cdot (A + B) = A$

$\overline{A} \cdot (A + B) = \overline{A} \cdot B$

(viii) Boolean identities : $A + \overline{A}B = A + B$, $A(\overline{A} + B) = AB$,

$A + BC = (A + B)(A + C)$, $(\overline{A} + B) \cdot (A + C) = \overline{A}C + AB$

(ix) **De Morgan's theorem** : It states that the complement of the whole sum is equal to the product of individual complements and vice versa *i.e.* $\overline{A+B} = \overline{A} \cdot \overline{B}$ and $\overline{A \cdot B} = \overline{A} + \overline{B}$

Logic Gates and Truth Table

(1) **Logic gate :** The digital circuit that can be analysed with the help of Boolean algebra is called logic gate or logic circuit. A logic gate has two or more inputs but only one output.

There are primarily three logic gates namely the OR gate, the AND gate and the NOT gate.

(2) **Truth table :** The operation of a logic gate or circuit can be represented in a table which contains all possible inputs and their corresponding outputs is called the truth table. To write the truth table we use binary digits 1 and 0.

The 'OR' Gate

(1) It has two inputs (A and B) and only one output (*Y*)

(2) Boolean expression is $Y = A + B$ and is read as "*Y* equals *A* **OR** *B*"

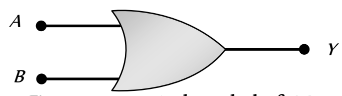
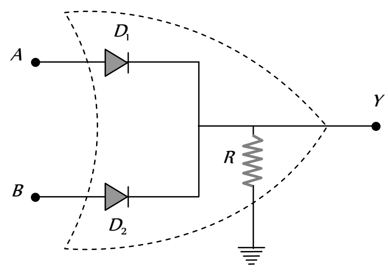


Fig. 27.51 : Logical symbol of OR gate

(3) **Realization of OR gate**



(i) $A = 0,\ B = 0$

Both diodes D_1 and D_2 do not conduct and hence $Y = 0$

(ii) $A = 0,\ B = 1$

D_1 = Does not conducts, D_2 = Conducts, hence $Y = 1$

(iii) $A = 1,\ B = 0$

D_1 = Conducts, D_2 = Does not conduct, hence $Y = 1$

(iv) $A = 1,\ B = 1$

Both D_1 and D_2 conducts, hence $Y = 1$

(4) **Truth table for 'OR' gate**

A	*B*	*Y = A + B*
0	0	0
0	1	1
1	0	1
1	1	1

The 'AND' Gate

(1) It has two inputs (A and B) and only one output (*Y*)

(2) Boolean expression is $Y = A \cdot B$ is read as " *Y* equals *A* AND *B*"

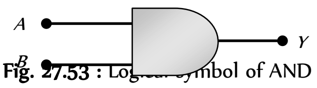


Fig. 27.53 : Logical symbol of AND gate

(3) **Realization of AND gate**

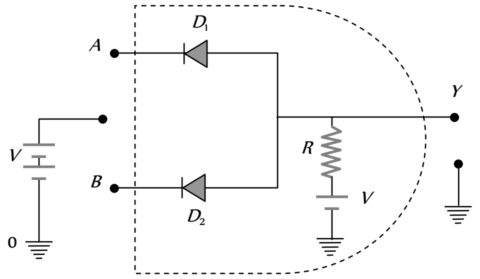


Fig. 27.54

(i) $A = 0,\ B = 0$

The voltage supply through *R* is forward biasing diodes D_1 and D_2 (offers low resistance) the voltage *V* would drop across *R*

The output voltage at *Y* = the voltage across diode = 0

(ii) $A = 0,\ B = 1$

D_1 = conducts, D_2 = Not Conducts

the out voltage at *Y* = The voltage across the diode (D) =0

(iii) $A = 1,\ B = 0$

D_1 = Conducts, D_2 = Not conducts

the out voltage at *Y* = The voltage across the diode (D_1) =0

iv) $A = 1,\ B = 1$

None of the diode conducts

the out voltage at *Y* = Battery voltage =1

(4) **Truth table for 'AND' gate**

A	*B*	*Y = A . B*
0	0	0
0	1	0
1	0	0
1	1	1

The 'NOT' Gate

(1) It has only one input and only one output.

(2) Boolean expression is $Y = \overline{A}$ and is read as "*y* equals not *A*"

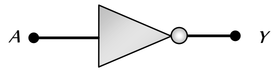


Fig 27.55 : Logical symbol of NOT gate

(3) **Realization of NOT gate :** The transistor is so biased that the collector voltage $V_{cc} = V$ (Voltage corresponding to 1 state)

The resistors R and R_1 are so chosen that if the input is low *i.e.* *O*, the transistor is in the cut off and hence the voltage appearing at the output will be the same as applied *V*. Hence $Y = V$ (or state 1)

If the input is high, the transistor current is in saturation and the net voltage at the output *Y* is 0 (in state 0)

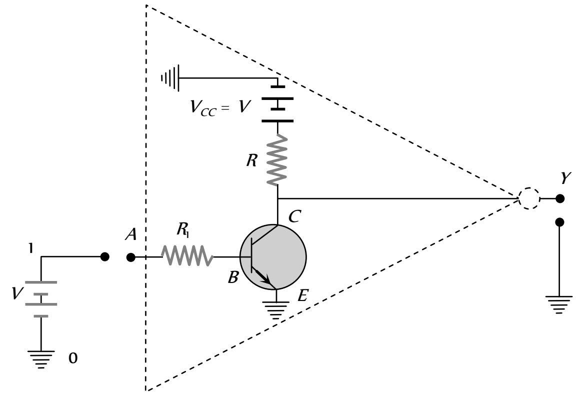


Fig. 27.56

(4) **Truth table for NOT gate :**

A	$Y = \overline{A}$
0	1
1	0

Combination of Logic Gates

(1) **The 'NAND' gate :** From 'AND' and 'NOT' gate

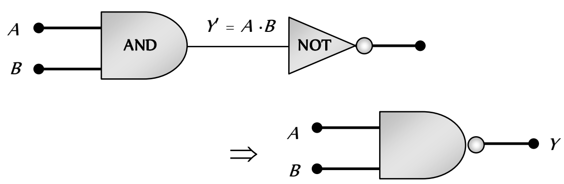


Fig. 27.57

Boolean expression and truth table : $Y = \overline{A \cdot B}$

A	B	$Y' = A \cdot B$	Y
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

(2) **The 'NOR' gate :** From 'OR' and 'NOT' gate

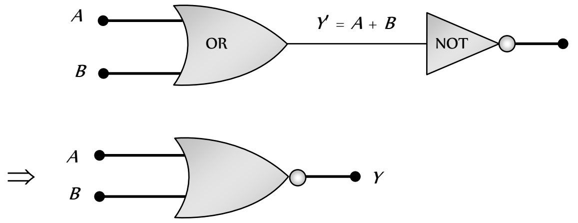


Fig. 27.58

Boolean expression and truth table : $Y = \overline{A + B}$

A	B	$Y' = A + B$	Y
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

(3) **The 'XOR' gate :** From 'NOT', 'AND' and 'OR' gate. Known as exclusive OR gate.

or

The logic gate which gives high output (*i.e.*, 1) if either input A or input B but not both are high (*i.e.* 1) is called exclusive OR gate or the XOR gate.

It may be noted that if both the inputs of the XOR gate are high, then the output is low (*i.e.*, 0).

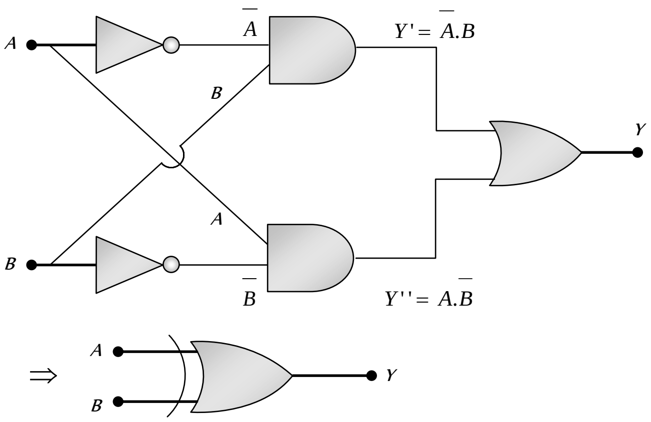


Fig. 27.59

Boolean expression and truth table : $Y = A \oplus B = \overline{A}B + A\overline{B}$

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

(4) **The exclusive nor (XNOR) gate**

XOR + NOT ⟶ XNOR

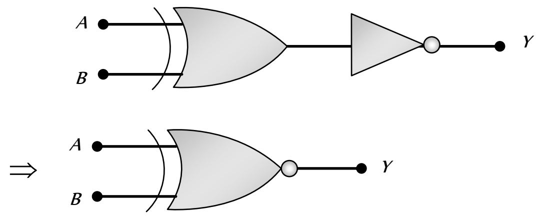


Fig. 27.60

Boolean expression : $Y = A \odot B = \overline{A}\,\overline{B} + AB$

Logic Gates Using 'NAND' Gate

The NAND gate is the building block of the digital electronics. All the logic gates like the OR, the AND and the NOT can be constructed from the NAND gates.

(1) **Construction of the 'NOT' gate from the 'NAND' gate**

(i) When both the inputs (A and B) of the NAND gate are joined together then it works as the NOT gate.

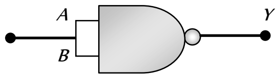


Fig. 27.61

(ii) Truth table and logic symbol

Input	Output
$A = B$	Y
0	1
1	0

(2) **Construction of the 'AND' gate from the 'NAND' gate**

(i) When the output of the NAND gate is given to the input of the NOT gate (made from the NAND gate), then the resultant logic gate works as the AND gate

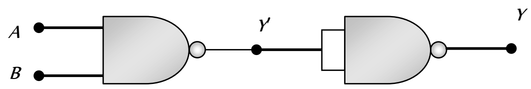


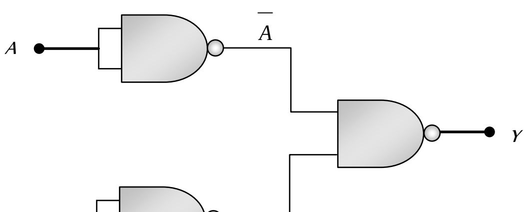
Fig. 27.62

(ii) Truth table and logic symbol

A	B	Y'	Y
0	0	1	0
0	1	1	0
1	0	1	0
1	1	0	1

(3) **Construction of the 'OR' gate by the 'NAND' gate**

(i) When the outputs of two NOT gates (obtained from the NAND gate) is given to the inputs of the NAND gate, the resultant logic gate works as the OR gate



(ii) Truth table and logic symbol

A	B	$\overline{A}$	$\overline{B}$	Y
0	0	1	1	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	1

Valve Electronics

Electron Emission from Metal

(1) Free electron in metal experiences a barrier on surface due to attractive Coulombian force.

(2) When kinetic energy of electron becomes greater than barrier potential energy (or binding energy E_b) then electron can come out of the surface of metal.

(3) **Fermi energy (E_f) :** Is the maximum possible energy possessed by free electron in metal at $0K$ temperature

(i) In this energy level, probability of finding electron is 50%.

(ii) This is a reference level and it is different for different metals.

(4) **Threshold energy (or work function W_0) :** Is the minimum energy required to take out an electron from the surface of metal. Also $W_0 = E_b - E_f$

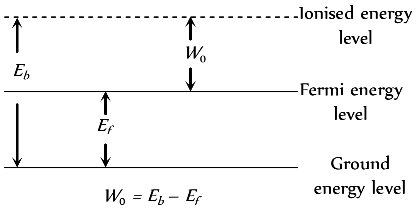


Fig. 27.64

Work function for different materials

$(W_0)_{\text{Pure tungsten}} = 4.5\ eV$

$(W_0)_{\text{Thoriated tungsten}} = 2.6\ eV$

$(W_0)_{\text{Oxide coated tungsten}} = 1\ eV$

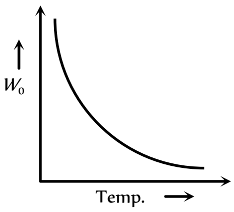


Fig. 27.65

(5) Four processes of electron emission from a metal are

(i) Thermionic emission

(ii) Photoelectric emission

(iii) Field emission

(iv) Secondary emission

Thermionic Emission

(1) The phenomenon of ejection of electrons from a metal surface by the application of heat is called thermionic emission and emitted electrons are called thermions and current flowing is called thermion current.

(2) Thermions have different velocities.

(3) This was discovered by Edison

(4) Richardson – Dushman equation for current density (*i.e.* electric current emitted per unit area of metal surface) is given as

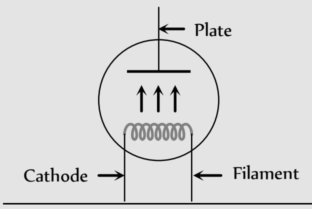
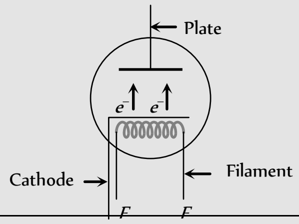
$$J = AT^2 e^{-W_0/kT} = AT^2 e^{-\frac{qV}{kT}} = AT^2 e^{-\frac{11600\ V}{T}}$$

where A = emission constant = 12×10^4 *amp/ m-K*, k = Boltzmann's constant, T = Absolute temp and W_0 = work function.

(5) The number of thermions emitted per second per unit area (J) depends upon following :

(i) $J \propto T^2$ (ii) $J \propto e^{-W_0}$

Table 27.9: Types of thermionic emitters

Directly heated emitter	Indirectly heated emitter
	
Cathode is directly heated by passing current.	Cathode is indirectly heated.
Thermionic current is less.	Thermionic current is more.
Energy consumption and life is small.	Energy consumption and life is more.

Vacuum Tubes and Thermionic Valves

(1) Those tubes in which electrons flows in vacuum are called vacuum tubes.

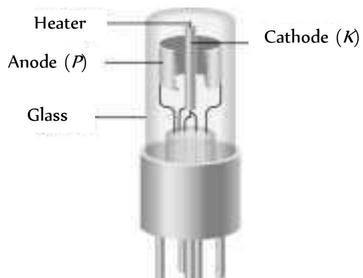
(2) These are also called valves because current flow in them is unidirectional.

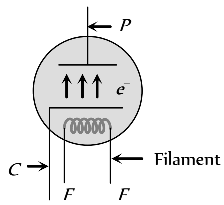
(3) Vacuum in vacuum tubes prevents the emission of secondary electrons and burning of heated filament (which will happen if we use air in place of vacuum)

(4) Every vacuum tube necessarily contains two electrodes out of which one is always electron emitter (cathode) and another one is electron collector (anode or plate).

(5) Depending upon the number of electrodes used the vacuum tubes are named as diode, triode, tetrode, pentode.... respectively, if the number of electrodes used are 2, 3, 4, 5..... respectively.

Diode Valve





(1) **Inventor :** Fleming

(2) **Principle :** Thermionic emission

(3) **Number of electrodes :** Two

(4) **Working :** When plate potential (V_p) is positive, plate current (i_p) flows in the circuit (because some emitted electrons reaches to plate). If $+V_p$ increases i_p also increases and finally becomes maximum (saturation).

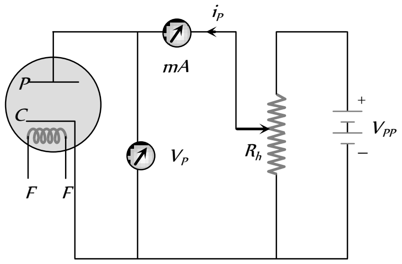


Fig. 27.67

(5) **Space charge :** If V_p is zero or negative, then electrons collect around the plate as a cloud which is called space charge. space charge decreases the emission of electrons from the cathode.

Characteristic Curves of a Diode

A graph represents the variation of i_p with V_p at a given filament current (i_f) is known as characteristic curve.

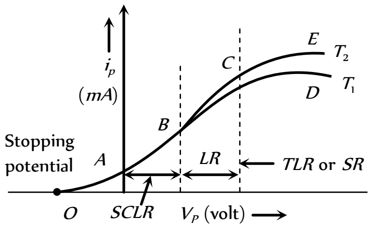


Fig. 27.68

The curve is not linear hence diode valve is a non-ohmic device.

(1) **Space charge limited region (SCLR)** : In this region current is space charge limited current.

Also $i_p \propto V_p^{3/2} \Rightarrow i_p = kV_p^{3/2}$; where k is a constant depending on metal as well as on the shape and area of the cathode. This is called child's law.

(2) **Linear region (LR) :** In this region $i_p \propto V_p$

(3) **Saturated region (SR) or temperature limited region (TLR) :** In this part, the current is independent of potential difference applied between the cathode and anode.

$i_p \neq f(V_p)$, $i_p = f$ (Temperature)

The saturation current follows Richardson Dushman equation *i.e.* $i = AST^2 e^{-\phi_0/kT}$; Here

A = Emission constant = $\dfrac{4\pi\, mek^2}{h^3} amp/m^2 - k^2$

S = Area of emitter in m^2 ; T = Absolute temperature in K

ϕ_0 =Work function of metal in Joule; k =Boltzmann constant

The small increase in i_p after saturation stage due to field emission is known as Shottkey effect.

(4) **Diode resistance**

(i) Static plate resistance or dc plate resistance : $R_p = \dfrac{V_p}{i_p}$.

(ii) Dynamic or ac plate resistance : If at constant filament current, a small change ΔV_p in the plate potential produces a small change Δi_p in the plate current, then the ratio $\Delta V_p / \Delta i_p$ is called the dynamic resistance, or the 'plate resistance' of the diode $r_p = \dfrac{\Delta V_p}{\Delta i_p}$.

(iii) In SCLR : $r_p < R_p$, (iv) In TLR : $R_p < r_p$ and $r_p = \infty$.

(5) **Uses of diode valve**

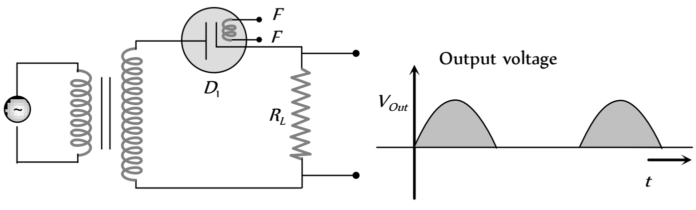
(i) As a rectifier (ii) As a detector

(iii) As a transmitter (iv) As a modulator

Diode Valve as a Rectifier

Rectifier is a device which converts ac into dc

(1) **Half wave rectifier :** The circuit of half wave rectifier is shown below. In the first half cycle of *ac* input the diode conducts and in the second half cycle it does not conducts. Thus half of the input cycle appear as output.



(A) Half wave rectifier (B) Output signal

Fig. 27.69

(i) Output voltage is not constant but pulsating in nature.

(ii) It is a mixture of *ac* and *dc.*

(iii) The *dc* values of the half wave output are given by

$$V_{d.c.} = \frac{V_0}{\pi} \text{ and } i_{d.c.} = \frac{i_0}{\pi}$$

(iv) The *r.m.s.* values of the half wave output are given by

$$V_{rms} = \frac{V_0}{2} \text{ and } i_{rms} = \frac{i_0}{2}$$

(v) The ratio of the effective alternating component to the direct component of the output voltage or current is called ripple factor

$$r = \frac{i_{a.c.}}{i_{d.c.}} = \sqrt{\left(\frac{i_{rms}}{i_{d.c.}}\right)^2 - 1} = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1} = 1.21 = 121\%.$$

(vi) Efficiency of half wave rectifier is given by

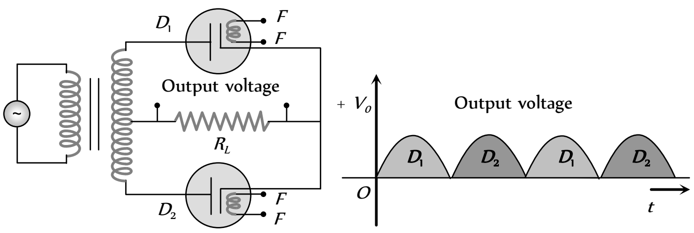
$$\eta = \frac{P_{d.c.}}{P_{a.c.}} \times 100\% = \frac{40.6}{1+\frac{r_p}{R_L}}\%$$

The maximum efficiency (for $R_L >> r_p$) = 40.6%

(vii) Form factor $= \frac{i_{rms}}{i_{d.c.}} = \frac{V_{rms}}{V_{d.c.}} = \frac{\pi}{2} = 1.57$

(viii) Ripple frequency = Frequency of input ac = ω

(2) **Full wave rectifier :** It consist of two diodes D_1 and D_2. They conducts alternately during positive and negative half cycle of input *ac* and a unidirectional (or *dc*) current flows in output



(A) Full wave rectifier (B) Output signal

Fig. 27.70

(i) The average or *dc* output values are

$$V_{d.c.} = \frac{2V_0}{\pi} \text{ and } i_{d.c.} = \frac{2i_0}{\pi}$$

(ii) It is a mixture of *ac* and *dc*

(iii) The *r.m.s.* values of the half wave output are given by

$$V_{rms} = \frac{V_0}{\sqrt{2}} \text{ and } i_{rms} = \frac{i_0}{\sqrt{2}}$$

(iv) Ripple factor $r = \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1} = 0.48 = 48\%$.

(v) Efficiency of half wave rectifier is given by

$$\eta = \frac{P_{d.c.}}{P_{a.c.}} \times 100\% = \frac{81.2}{1+\frac{r_p}{R_L}}\%$$

The maximum efficiency (for $R_L >> r_p$) = 81.2%

(vii) Form factor $= \frac{i_{rms}}{i_{d.c.}} = \frac{V_{rms}}{V_{d.c.}} = \frac{\pi}{2\sqrt{2}} = 1.11$

(viii) Ripple frequency = Double of frequency of input ac = 2ω

Filter Circuit

Filter circuits smooth out the fluctuations in amplitude of ac ripple of the output voltage obtained from a rectifier.

(i) Filter circuit consists of capacitors or/ and choke coils.

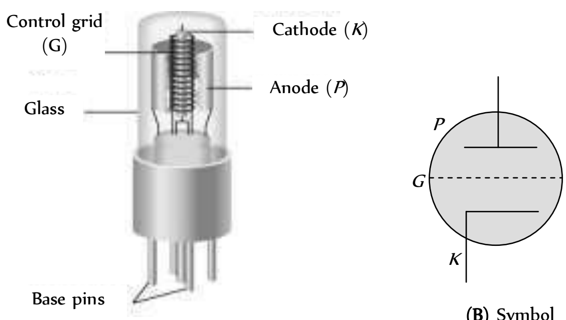
(ii) A capacitor offers a high resistance to low frequency ac ripple (infinite resistance to dc) and a low resistance to high frequency ac ripple. Therefore, it is always used as a shunt to the load.

(iii) A choke coil offers high resistance to high frequency ac, and almost zero resistance to dc. It is used in series.

(iv) π - Filter is best for ripple control.

(v) For voltage regulation choke input filter (*L*-filter) is best.

Triode Valve



(A) Triode valve (B) Symbol

Fig. 27.71

(1) **Inventor :** Dr. Lee De Forest

(2) **Principle :** Thermionic emission

(3) **Number of electrodes :** It consists of three electrodes.

(i) Filament (*F*) : It emits electron on heating.

(ii) Plate or anode (*P*) : It collect the electrons.

(iii) Control grid : It is a third electrode, also known as control grid, which controls the electrons going from cathode to plate. As a result grid controls the plate current. It is kept near the cathode with low negative potential.

When grid is given positive potential then plate current increases but in this case triode cannot be used for amplifier and therefore grid is normally not given positive potential.

When grid is given negative potential then plate current decreases but in this case grid controls plate current most effectively.

(4) **Working :** Plate of triode valve is always kept at positive potential *w.r.t.* cathode. The potential of plate is more than that of grid.

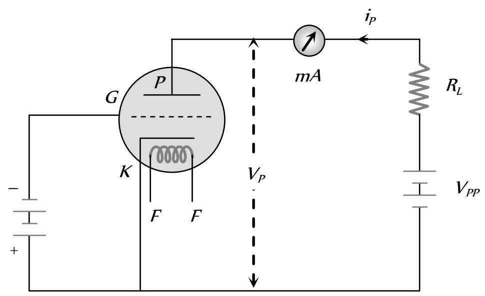


Fig. 27.72

The variation of plate potential affects the plate current as follows $i_p = k\left(V_G + \frac{V_p}{\mu}\right)^{3/2}$; where μ = Amplification factor of triode valve, k = Constant of triode valve.

The valve of V_G for which the plate current becomes zero is known as the cut off voltage. For a given V_p, it is given by $V_G = -\frac{V_p}{\mu}$.

Characteristics of Triode

The triode characteristics can be obtained under two sets of condition as

Static characteristics and dynamic characteristics

(1) **Static characteristics :** Graphical representation of V_p or V_G and i_p without any load

(i) **Static plate characteristic curve :** Graphical representation of i_p and V_p at constant V_g.

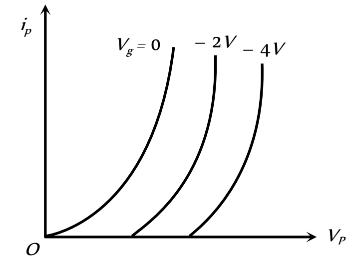


Fig. 27.73

(ii) **Static mutual characteristics curve :** Graphical representation of i_p and V_g when V_p is kept constant

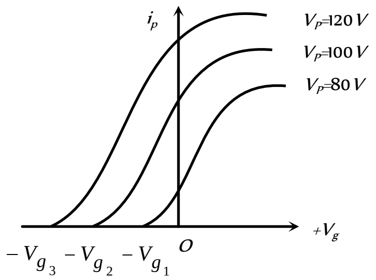


Fig. 27.74

(iii) **Constant current characteristic curve :** Graphical representation between V_p and V_g when i_p is constant.

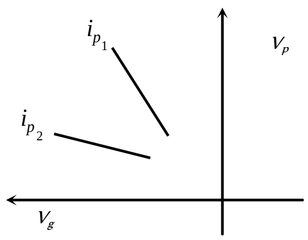


Fig. 27.75

(2) **Dynamic characteristics :** The curve plotted between i_p, V_p and V_g when the triode contains load in the plate circuit are called dynamics characteristics of diode.

(i) **Load line :** Voltage drop iR_L across load R_L which decreases the plate potential will be less then the supply voltage.

Plate voltage $V_p = V_{pp} - iR_L \Rightarrow i_p = -\frac{1}{R_L}V_p + \frac{V_{pp}}{R_L}$

This equation represents a straight line on the static plate characteristics, joining the points (V_{pp} , 0) on plate voltage axis and $(0, V_{pp}/R_L)$ on plate current axis. This line known as load line.

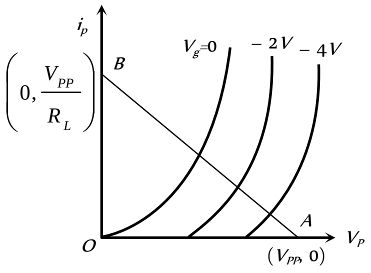


Fig. 27.76

(a) Points at which load line cuts the plate characteristic curves are called operating points.

(b) The slope of load line $AB = \frac{di_p}{dV_p} = -\frac{1}{R_L}$

(c) In graph, $OA = V_{pp}$ = intercept of load line on V_p axis and $OB = V_{pp}/R_L$ = intercept of load line on i_p axis.

(d) Static plate characteristic + load line

→ Dynamic plate characteristic

Static mutual characteristic + load line

→ Dynamic mutual characteristic

Constants of Triode Valve

(1) **Plate or dynamic resistance (r_p)**

(i) The slope of plate characteristic curve is equal to $\frac{1}{\text{plate resistance}}$

or It is the ratio of small change in plate voltage to the change in plate current produced by it, the grid voltage remaining constant. That is, $r_p = \frac{\Delta V_p}{\Delta i_p}, V_G = \text{constant}$.

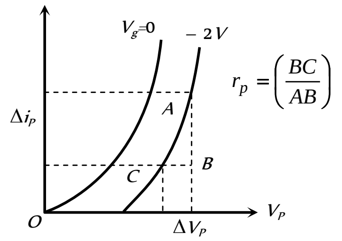


Fig. 27.77

(ii) It is expressed in kilo ohms ($k\Omega$). Typically, it ranges from $8k\Omega$ to $40k\Omega$. The r_p can be determined from plate characteristics. It represents the reciprocal of the slope of the plate characteristic curve.

(iii) If the distance between plate and cathode is increased the r_p increases. The value of r_p is infinity in the state of cut off bias or saturation state.

(2) **Mutual conductance (or *trans* conductance) (g_m)**

(i) It is defined as the ratio of small change in plate current (Δi_p) to the corresponding small change in grid potential (ΔV_g) when plate potential V_p is kept constant *i.e.* $g_m = \left(\frac{\Delta i_p}{\Delta V_g}\right)_{V_p \text{ is constant}}$

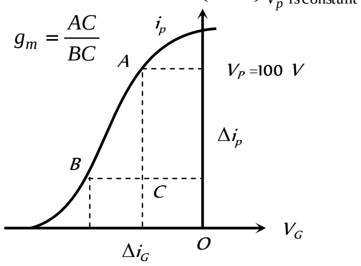


Fig. 27.78

(ii) The value of g_m is equal to the slope of mutual characteristics of triode.

(iii) The value of g_m depends upon the separation between grid and cathode. The smaller is this separation, the larger is the value of g_m and vice versa.

(iv) In the saturation state, the value of $\Delta i_p = 0$, $g_m = 0$

(3) **Amplification factor (μ) :** It is defined as the ratio of change in plate potential (ΔV_p) to produce certain change in plate current (Δi_p) to the change in grid potential (ΔV_g) for the same change in plate current (Δi_p) *i.e.* $\mu = -\left(\frac{\Delta V_p}{\Delta V_g}\right)_{\Delta I_p = \text{a constant}}$; negative sign indicates that V_p and V_g are in opposite phase.

(i) Amplification factor depends upon the distance between plate and cathode (d_{pk}), plate and grid (d_{pg}) and grid and cathode(d_{gk}).

i.e. $\mu \propto d_{pg} \propto d_{pk} \propto \frac{1}{d_{gk}}$

(ii) The value of μ is greater than one.

(iii) Amplification factor is unitless and dimensionless.

(4) **Relation between triode constants :** The triode constants are not independent of each other. They are related by the relation $\mu = r_p \times g_m$

The r_p and g_m depends on i_p in the following manner

$r_p \propto i_p^{-1/3}$, $g_m \propto i_p^{1/3}$, μ does not depend on i_p.

Above three constants may be determined from any one set of characteristic curves.

$r_p = \frac{V_{P1} - V_{P2}}{I_{PA} - I_{PB}}$,

$g_m = \frac{I_{PA} - I_{PB}}{V_{G1} - V_{G2}}$,

$\mu = -\frac{V_{P1} - V_{P2}}{V_{G2} - V_{G1}}$

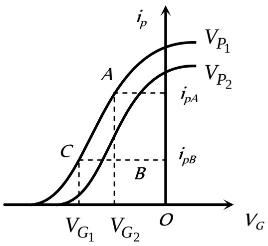


Fig. 27.79

Triode as an Amplifiers

Amplifier is a device by which the amplitude of variation of *ac* signal voltage / current/ power can be increased

(1) The signal to be amplified (V_i) is applied in the grid circuit and amplified output is obtained from the plate circuit

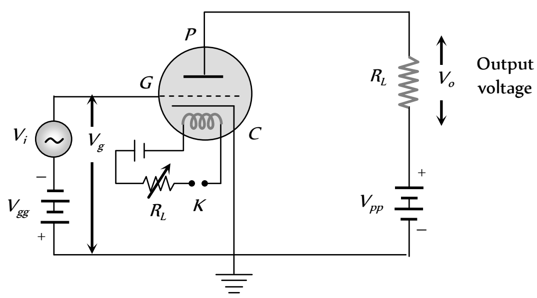


Fig. 27.80

(2) The voltage at grid is the sum of signal V_i and grid bias V_{gg}.

$V_g = V_{gg} + V_i$

(3) Small change in grid voltage results in a large change in plate current so results in a large change in voltage across R_L $(V_0 = i_p R_L \Rightarrow \Delta V_0 = \Delta i_p R_L)$

(4) The linear portion of the mutual characteristic with maximum slope is chosen for amplification without distortion.

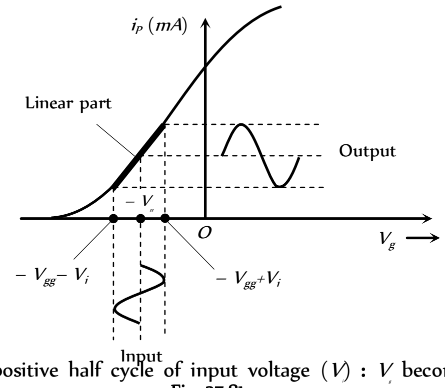


Fig. 27.81

(i) For the positive half cycle of input voltage (V_i) : V_g becomes less negative, so i_p increases

(ii) For the negative half cycle of input voltage (V_i) : V_g becomes more negative, so i_p decreases

(iii) The phase difference between the output signal and input signal is 180° (or π)

(5) **Voltage amplification**

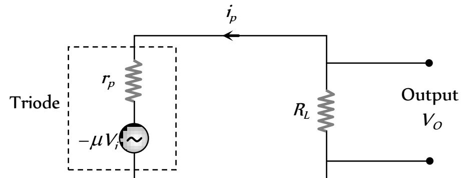


Fig. 27. 82 : Equivalent circuit of triode amplifier

Current through the load resistance is given by $i_p = -\frac{\mu V_i}{r_p + R_L}$

$\Rightarrow V_0 = i_p R_L = \frac{-\mu V_i R_L}{r_p + R_L}$ $\Rightarrow$ Voltage gain $= \frac{V_0}{V_i} = -\frac{\mu R_L}{r_p + R_L}$

Numerically $A = \frac{\mu R_L}{r_p + R_L} = \frac{\mu}{1 + \frac{r_p}{R_L}}$

(i) If $R_L = \infty \Rightarrow A$ will be maximum and $A_{max} = \mu$

(Practically $A < \mu$)

(ii) If $r_p = R_L \Rightarrow A = \frac{\mu}{2}$

(iii) Power at load resistance $P = i_p V_0 = i_p^2 R_L$

Condition for maximum power $R_L = r_p$

$\therefore P_{max} = \left(\frac{\mu V_i}{R_L + R_L}\right)^2 \times R_L = \frac{\mu^2 V_i^2}{4 R_L}$

Tips & Tricks

✍ The most efficient packing of atoms in cubic lattice structure occurs for *fcc*.

- The lattice for $NaCl$ crystal is *fcc*.
- The space lattice of diamond is *fcc*. (The diamond structure may be viewed as two *fcc* structures displaced from each other by one quarter of a body diagonal).
- Carbon, silicon, germanium, tin can crystallize in the diamond structure.
- At room temperature $\sigma_{Ge} > \sigma_{Si}$
- $(n_i)_{Ge} \simeq 2.4 \times 10^{19} / m^3$ and $(n_i)_{Si} \simeq 1.5 \times 10^{16} / m^3$
- In a transistor circuit the reverse bias is high as compared to the forward bias. So that it may exert a large attractive force on the charge carriers to enter the collector region.
- *Ge* is more sensitive to heat since it's forbidden energy gap is smaller than that of silicon. Electrons from the valence band of *Ge* requires less energy to move from the valence band to conduction band.
- Both *N*-type as well as *P*-type semiconductor are neutral.
- Semiconductor devices are current control devices.
- The semiconductor devices are temperature sensitive devices.
- The electric field setup across the potential barrier is of the order of 3×10^5 *V/m* for *Ge* and 7×10^5 *V/m* for *Si*.
- An ideal junction diode when forward biased offers zero resistance. Voltage drop across such a junction diode is zero. In reverse biased diode offers infinite resistance and voltage drop across it is equal to voltage applied.
- A *P-N* junction diode can be considered to be equivalent to a capacitor with *P* and *N* regions acting as the plates of the capacitors and depletion layer as the dielectric medium.
- The mobility of electron is two-three times the mobility of holes. Therefore NPN devices are fast and hence preferred.
- If $E_g \simeq 0\, eV$, the material is good conductor or metal and if $E_g \simeq 1\, eV$, the material is a semiconductor. If $E_g \simeq 6\, eV$ then the material is an insulator.
- A *P-N* junction or diode acts like a valve or voltage controlled switch. When forward biased, it acts like ON switch. When reverse biased, it acts like an OFF switch.
- The current due to minority carriers in the junction diode is independent of the applied voltage. It only depends upon the temperature of the diode.
- Voltage obtained from a diode rectifier is a mixture of alternating and direct voltage.
- Cross sectional area of base is very large as compared to emitter. Cross sectional area of collector is less than base but greater than emitter.
- C.C (common collector) amplifier is called power amplifier or current booster or emitter follower.
- Devices like tunnel diode, tetrode and thyrisisters have negative resistance.
- Transistor provides good power amplification when they are use in CE configuration.
- **MOSFETS :** In a MOSFET, a type of three-terminal transistor, a potential applied to the gate terminal *G* controls the internal flow of electrons from the source terminal *S* to the drain terminal *D*. Commonly, a MOSFET is operated only in its ON (conducting) or OFF (not conducting condition. Installed by the thousands and millions on silicon wafers (chips) to form integrated circuits, MOSFETs form the basis for computer hardware.
- When a *PN* junction is forward biased, it can emit light, hence can serve as a light-emitting diode (LED). The wavelength of the emitted light is $\lambda = \frac{c}{f} = \frac{hc}{E_g}$
- The fermi energy of a given material is the energy of a quantum state that has the probability 0.5 of being occupied by an electron.
- Number of conduction electrons per unit volume

$$= \frac{(\text{Material's density})}{(\text{Molar mass } M)/N_A}$$

(N_A = Avogadro's number = 6.02×10^{23} */mol*)

- The occupancy probability $P(E)$: Electrical conduction of a metal depends on the probability that if an energy level is available at energy E, is it actually occupied by an electron.

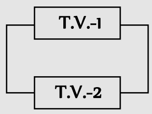
the expression for occupancy probability $P(E)$ is given by

Fermi-Dirac statistics $P(E) = \frac{1}{\exp\left(\frac{E - E_F}{kT}\right) + 1}$; E_F=Fermi energy

- A good emitter should have low work function, high melting point, high working temperature, high electrical and mechanical strength.
- When triode amplifier are in series, total voltage gain

$A = A_1 A_2 A_3$ ....

- When two triode valve are in parallel



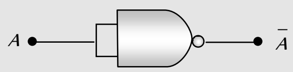
Total plate resistance $\frac{1}{r_p} = \frac{1}{r_{p_1}} + \frac{1}{r_{p_2}}$

Total mutual conductance $G_m = g_{m_1} + g_{m_2}$

Total amplification factor $\mu = G_m R_p$

Voltage amplification $A = \frac{\mu R_L}{r_p + R_L}$

- **NOR** gate is a universal gate because it can be used to perform the basic logic function, AND, OR and NOT.
- Output in Ex-OR gate is '1' only when inputs are different.
- If both inputs of NAND gate are shorted then it will become 'NOT gate



NOT gate

Ordinary Thinking

Objective Questions

Solids and Crystals

1. The nature of binding for a crystal with alternate and evenly spaced positive and negative ions is [CBSE PMT 2000]
   (a) Covalent (b) Metallic
   (c) Dipolar (d) Ionic
2. For a crystal system, $a = b = c$, $\alpha = \beta = \gamma \neq 90^{\circ}$, the system is [BHU 2000]
   (a) Tetragonal system (b) Cubic system
   (c) Orthorhombic system (d) Rhombohedral system
3. Biaxial crystal among the following is [Pb. CET 1998]
   (a) Calcite (b) Quartz
   (c) Selenite (d) Tourmaline
4. The temperature coefficient of resistance of a conductor is [AFMC 1998]
   (a) Positive always (b) Negative always
   (c) Zero (d) Infinite
5. Potassium has a *bcc* structure with nearest neighbour distance 4.525 $\AA$. Its molecular weight is 39. Its density in kg/m is [DCE 1997]
   (a) 900 (b) 494
   (c) 602 (d) 802
6. The expected energy of the electrons at absolute zero is called [RPET 1996]
   (a) Fermi energy (b) Emission energy
   (c) Work function (d) Potential energy
7. In a triclinic crystal system [EAMCET (Med.) 1995]
   (a) $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma$ (b) $a = b = c$, $\alpha \neq \beta \neq \gamma$
   (c) $a \neq b \neq c$, $\alpha \neq \beta = \gamma$ (d) $a = b \neq c$, $\alpha = \beta = \gamma$
8. Metallic solids are always opaque because [AFMC 1994]
   (a) Solids effect the incident light
   (b) Incident light is readily absorbed by the free electron in a metal
   (c) Incident light is scattered by solid molecules
   (d) Energy band traps the incident light
9. In which of the following ionic bond is present [EAMCET (Med.) 1994]
   (a) $NaCl$ (b) Ar
   (c) Si (d) Ge
10. Which of the following materials is non crystalline [CBSE PMT 1993]
   (a) Copper (b) Sodium chloride
   (c) Wood (d) Diamond

11. The coordination number of Cu is [AMU 1992]

(a) 1 (b) 6

(c) 8 (d) 12

12. Which one of the following is the weakest kind of bonding in solids [CBSE PMT 1992; KCET 1992]

(a) Ionic (b) Metallic

(c) Vander Waals (d) Covalent

13. In a crystal, the atoms are located at the position of [AMU 1985]

(a) Maximum potential energy

(b) Minimum potential energy

(c) Zero potential energy

(d) Infinite potential energy

14. Crystal structure of $NaCl$ is [NCERT 1982]

(a) Fcc (b) Bcc

(c) Both of the above (d) None of the above

15. What is the coordination number of sodium ions in the case of sodium chloride structure [CBSE PMT 1988]

(a) 6 (b) 8

(c) 4 (d) 12

16. The distance between the body centred atom and a corner atom in sodium (a = 4.225 $\mathring{A}$) is [CBSE PMT 1995]

(a) 3.66 $\mathring{A}$ (b) 3.17 $\mathring{A}$

(c) 2.99 $\mathring{A}$ (d) 2.54 $\mathring{A}$

17. A solid that transmits light in visible region and has a very low melting point possesses [J & K CET 2001]

(a) Metallic bonding (b) Ionic bonding

(c) Covalent bonding (d) Vander Waal's bonding

18. Atomic radius of *fcc* is [J & K CET 2001]

(a) $\frac{a}{2}$ (b) $\frac{a}{2\sqrt{2}}$

(c) $\frac{\sqrt{3}}{4}a$ (d) $\frac{\sqrt{3}}{2}a$

19. A solid reflects incident light and it's electrical conductivity decreases with temperature. The binding in this solids

(a) Ionic (b) Covalent

(c) Metallic (d) Molecular

20. The laptop PC's modern electronic watches and calculators use the following for display

(a) Single crystal (b) Poly crystal

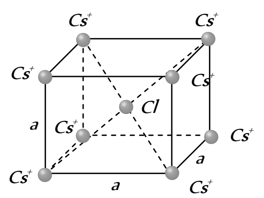
(c) Liquid crystal (d) Semiconductors

21. The nearest distance between two atoms in case of a bcc lattice is equal to [J & K CET 2004]

(a) $a\frac{\sqrt{2}}{3}$ (b) $a\frac{\sqrt{3}}{2}$

(c) $q\sqrt{3}$ (d) $\frac{a}{\sqrt{2}}$

22. What is the net force on a *Cl* placed at the centre of the *bcc* structure of *CsCl* [DCE 2003; AIIMS 2004]



(a) Zero (b) ke^2/a^2

(c) ke^2a^2 (d) Data is incomplete

23. Sodium has body centred packing. If the distance between two nearest atoms is 3.7 Å, then its lattice parameter is [Pb. PET 2002]

(a) 4.8 Å (b) 4.3 Å

(c) 3.9 Å (d) 3.3 Å

24. Which of the following is an amorphous solid [AIIMS 2005; J & K CET 2004]

(a) Glass (b) Diamond

(c) Salt (d) Sugar

25. Copper has face centered cubic (*fcc*) lattice with interatomic spacing equal to 2.54Å. The value of the lattice constant for this lattice is

(a) 1.27 Å (b) 5.08 Å

(c) 2.54 Å (d) 3.59 Å

26. In good conductors of electricity, the type of bonding that exists is

(a) Ionic (b) Vander Waals

(c) Covalent (d) Metallic

27. Bonding in a germanium crystal (semi- conductor) is [CPMT 1986; KCET 1992; EAMCET (Med.) 1995; MP PET/PMT 2004]

(a) Metallic (b) Ionic

(c) Vander Waal's type (d) Covalent

28. The ionic bond is absent in [J & K CET 2005]

(a) *NaCl* (b) *CsCl*

(c) *LiF* (d) H_2O

Semiconductors

1. The majority charge carriers in *P*-type semiconductor are [MP PMT 1999; CBSE PMT 1999; MP PET 1991; MP PET/PMT 1998; MH CET 2003]

(a) Electrons (b) Protons

(c) Holes (d) Neutrons

2. A *P*-type semiconductor can be obtained by adding [NCERT 1979; BIT 1988; MP PMT 1987; 90]

(a) Arsenic to pure silicon

(b) Gallium to pure silicon

(c) Antimony to pure germanium

(d) Phosphorous to pure germanium

3. The valence of an impurity added to germanium crystal in order to convert it into a *P*-type semi conductor is [MP PMT 1989; CPMT 1987]

(a) 6 (b) 5

(c) 4 (d) 3

4. In a semiconductor, the concentration of electrons is $8\times10^{14}/cm^3$ and that of the holes is $5\times10^{12}cm^3$. The semiconductor is [MP PMT 1997; RPET 1999; Kerala PET 2002]

(a) *P*-type (b) *N*-type

(c) Intrinsic (d) *PNP*-type

5. In *P*-type semiconductor, there is [MP PMT 1989]

(a) An excess of one electron

(b) Absence of one electron

(c) A missing atom

(d) A donar level

6. The valence of the impurity atom that is to be added to germanium crystal so as to make it a *N*-type semiconductor, is

[MNR 1993; MP PET 1994; CBSE PMT 1999; AIIMS 2000]

(a) 6 (b) 5

(c) 4 (d) 3

7. Silicon is a semiconductor. If a small amount of *As* is added to it, then its electrical conductivity [MP PMT 1996]

(a) Decreases (b) Increases

(c) Remains unchanged (d) Becomes zero

8. When the electrical conductivity of a semi- conductor is due to the breaking of its covalent bonds, then the semiconductor is said to be

[AIIMS 1997; KCET (Engg.) 2002]

(a) Donar (b) Acceptor

(c) Intrinsic (d) Extrinsic

9. A piece of copper and the other of germanium are cooled from the room temperature to 80 K, then which of the following would be a correct statement

[IIT-JEE 1988; Bihar CEE 1992; CBSE PMT 1993; MP PET 1997; RPET 1999; AIEEE 2004]

(a) Resistance of each increases

(b) Resistance of each decreases

(c) Resistance of copper increases while that of germanium decreases

(d) Resistance of copper decreases while that of germanium increases

10. To obtain *P*-type Si semiconductor, we need to dope pure Si with [IIT-JEE 1988; MP PET 1997, 93; Pb. PMT 2001, 02; UPSEAT 2004]

(a) Aluminium (b) Phosphorous

(c) Oxygen (d) Germanium

11. Electrical conductivity of a semiconductor

[MP PMT 1993, 2000; RPET 1996]

(a) Decreases with the rise in its temperature

(b) Increases with the rise in its temperature

(c) Does not change with the rise in its temperature

(d) First increases and then decreases with the rise in its temperature

12. Three semi-conductors are arranged in the increasing order of their energy gap as follows. The correct arrangement is

[MP PMT 1993]

(a) Tellurium, germanium, silicon

(b) Tellurium, silicon, germanium

(c) Silicon, germanium, tellurium

(d) Silicon, tellurium, germanium

13. When a semiconductor is heated, its resistance

[KCET 1992; MP PMT 1994; MP PET 1992, 2002; RPMT 2001; DCE 2001]

(a) Decreases (b) Increases

(c) Remains unchanged (d) Nothing is definite

14. In an insulator, the forbidden energy gap between the valence band and conduction band is of the order of

[DPMT 1988; EAMCET (Engg.) 1995; MP PET 1996]

(a) $1\,MeV$ (b) $0.1\,MeV$

(c) $1\,eV$ (d) $5\,eV$

15. A *N*-type semiconductor is [AFMC 1988; RPMT 1999]

(a) Negatively charged (b) Positively charged

(c) Neutral (d) None of these

16. The energy band gap of Si is

[MP PET 1994, 2002; BHU 1995; RPMT 2000]

(a) $0.70\,eV$

(b) 1.1 *eV*

(c) Between $0.70\,eV$ to $1.1\,eV$

(d) 5 *eV*

17. The forbidden energy band gap in conductors, semiconductors and insulators are EG_1, EG_2 and EG_3 respectively. The relation among them is

[MP PMT 1994; RPMT 1997]

(a) $EG_1 = EG_2 = EG_3$ (b) $EG_1 < EG_2 < EG_3$

(c) $EG_1 > EG_2 > EG_3$ (d) $EG_1 < EG_2 > EG_3$

18. Which statement is correct [MP PMT 1994]

(a) *N*-type germanium is negatively charged and *P*-type germanium is positively charged

(b) Both *N*-type and *P*-type germanium are neutral

(c) *N*-type germanium is positively charged and *P*-type germanium is negatively charged

(d) Both *N*-type and *P*-type germanium are negatively charged

19. When *Ge* crystals are doped with phosphorus atom, then it becomes [AFMC 1995; Orissa PMT 2004]

(a) Insulator (b) *P*-type

(c) *N*-type (d) Superconductor

20. Let n_P and n_e be the number of holes and conduction electrons respectively in a semiconductor. Then

[MP PET 1995]

(a) $n_P > n_e$ in an intrinsic semiconductor

(b) $n_P = n_e$ in an extrinsic semiconductor

(c) $n_P = n_e$ in an intrinsic semiconductor

(d) $n_e > n_P$ in an intrinsic semiconductor

21. Wires P and Q have the same resistance at ordinary (room) temperature. When heated, resistance of P increases and that of Q decreases. We conclude that [MP PMT 1995; MP PET 2001]

(a) P and Q are conductors of different materials
(b) P is N-type semiconductor and Q is P-type semiconductor
(c) P is semiconductor and Q is conductor
(d) P is conductor and Q is semiconductor

22. The impurity atoms which are mixed with pure silicon to make a P-type semiconductor are those of [MP PMT 1995]

(a) Phosphorus (b) Boron
(c) Antimony (d) Copper

23. Holes are charge carriers in [IIT-JEE 1996]

(a) Intrinsic semiconductors (b) Ionic solids
(c) P-type semiconductors (d) Metals

24. In extrinsic P and N-type, semiconductor materials, the ratio of the impurity atoms to the pure semiconductor atoms is about

(a) 1 (b) 10^{-1}
(c) 10^{-4} (d) 10^{-7}

25. A hole in a P-type semiconductor is [MP PET 1996]

(a) An excess electron (b) A missing electron
(c) A missing atom (d) A donor level

26. The forbidden gap in the energy bands of germanium at room temperature is about [MP PMT/PET 1998]

(a) $1.1eV$ (b) $0.1eV$
(c) $0.67eV$ (d) $6.7eV$

27. In P-type semiconductor the majority and minority charge carriers are respectively

[EAMCET 1994; MP PMT/PET 1998; MH CET 2000]

(a) Protons and electrons (b) Electrons and protons
(c) Electrons and holes (d) Holes and electrons

28. At zero Kelvin a piece of germanium [MP PET 1999]

(a) Becomes semiconductor
(b) Becomes good conductor
(c) Becomes bad conductor
(d) Has maximum conductivity

29. Electronic configuration of germanium is 2, 8, 18 and 4. To make it extrinsic semiconductor small quantity of antimony is added

(a) The material obtained will be N-type germanium in which electrons and holes are equal in number
(b) The material obtained will be P-type germanium
(c) The material obtained will be N-type germanium which has more electrons than holes at room temperature
(d) The material obtained will be N-type germanium which has less electrons than holes at room temperature

30. A semiconductor is cooled from T_1K to T_2K. Its resistance

[MP PET 1999]

(a) Will decrease
(b) Will increase
(c) Will first decrease and then increase
(d) Will not change

31. If N_P and N_e be the numbers of holes and conduction electrons in an extrinsic semiconductor, then

[MP PMT 1999; AMU 2001]

(a) $N_P > N_e$
(b) $N_P = N_e$
(c) $N_P < N_e$
(d) $N_P > N_e$ or $N_P < N_e$ depending on the nature of impurity

32. In intrinsic semiconductor at room temperature, number of electrons and holes are

[EAMCET (Engg.) 1995; JIPMER 2001, 02]

(a) Equal (b) Zero
(c) Unequal (d) Infinite

33. (USS 133) Indium impurity in germanium makes

[EAMCET (Engg.) 1995]

[MP PET 2003]

(a) N-type (b) P-type
(c) Insulator (d) Intrinsic

34. Fermi level of energy of an intrinsic semiconductor lies

[EAMCET (Med.) 1995]

(a) In the middle of forbidden gap
(b) Below the middle of forbidden gap
(c) Above the middle of forbidden gap
(d) Outside the forbidden gap

35. In a semiconductor the separation between conduction band and valence band is of the order of

[EAMCET (Med.) 1995; AIIMS 2000]

(a) $100\,eV$ (b) $10\,eV$
(c) $1eV$ (d) 0 eV

36. The intrinsic semiconductor becomes an insulator at

[EAMCET (Med.) 1995; KCET (Engg./Med.) 1999; MP PET 2000; CBSE PMT 2001]

(a) $0°C$ (b) $-100°C$
(c) $300\,K$ (d) $0\,K$

37. The addition of antimony atoms to a sample of intrinsic germanium transforms it to a material which is

[AMU 1995]

[MP PET 1999]

(a) Superconductor (b) An insulator
(c) N-type semiconductor (d) P-type semiconductor

38. Resistance of semiconductor at $0°K$ is [RPET 1997]

(a) Zero (b) Infinite
(c) Large (d) Small

39. In a good conductor the energy gap between the conduction band and the valence band is

[KCET 1993; EMCET (Med.) 1994]

(a) Infinite (b) Wide
(c) Narrow (d) Zero

40. The impurity atom added to germanium to make it N-type semiconductor is [KCET 1993; KCET (Engg./Med.) 2000]

(a) Arsenic (b) Iridium
(c) Aluminium (d) Iodine

41. When *N*-type of semiconductor is heated [CBSE PMT 1993; DPMT 2000]
(a) Number of electrons increases while that of holes decreases
(b) Number of holes increases while that of electrons decreases
(c) Number of electrons and holes remains same
(d) Number of electrons and holes increases equally

42. To obtain a *P*-type germanium semiconductor, it must be doped with [CBSE PMT 1997; Pb. PET 2000]
(a) Arsenic (b) Antimony
(c) Indium (d) Phosphorus

43. The temperature coefficient of resistance of a semiconductor [AFMC 1998, MNR 1998]
(a) Is always positive
(b) Is always negative
(c) Is zero
(d) May be positive or negative or zero

44. *P*-type semiconductor is formed when [RPET 1999]
A. *As* impurity is mixed in *Si*
B. *Al* impurity is mixed in *Si*
C. *B* impurity is mixed in *Ge*
D. *P* impurity is mixed in *Ge*
(a) A and C (b) A and D
(c) B and C (d) B and D

45. In case of a semiconductor, which of the following statement is wrong [Pb. PMT 1999]
(a) Doping increases conductivity
(b) Temperature coefficient of resistance is negative
(c) Resisitivity is in between that of a conductor and insulator
(d) At absolute zero temperature, it behaves like a conductor

46. Energy bands in solids are a consequence of [DCE 1999, 2000; AIEEE 2004]
(a) Ohm's Law
(b) Pauli's exclusion principle
(c) Bohr's theory
(d) Heisenberg's uncertainty principle

47. In a *P*-type semiconductor [AIIMS 1997; Orissa JEE 2002; MP PET 2003]
(a) Current is mainly carried by holes
(b) Current is mainly carried by electrons
(c) The material is always positively charged
(d) Doping is done by pentavalent material

48. At ordinary temperatures, the electrical conductivity of semi conductors in $mho/meter$ is in the range [MP PET 2003]
(a) 10^{-3} to 10^{-4} (b) 10^{6} to 10^{9}
(c) 10^{-6} to 10^{-10} (d) 10^{-10} to 10^{-16}

49. When the temperature of silicon sample is increased from $27°C$ to $100°C$, the conductivity of silicon will be [RPMT 1999]
(a) Increased (b) Decreased
(c) Remain same (d) Zero

50. In a *P*-type semiconductor, germanium is doped with [AFMC 1999]
(a) Boron (b) Gallium
(c) Aluminium (d) All of these

51. In *N*-type semiconductors, majority charge carriers are [AIIMS 1999]
(a) Holes (b) Protons
(c) Neutrons (d) Electrons

52. Semiconductor is damaged by the strong current due to [MH CET 2000]
(a) Lack of free electron (b) Excess of electrons
(c) Excess of proton (d) None of these

53. GaAs is [RPMT 2000]
(a) Element semiconductor
(b) Alloy semiconductor
(c) Bad conductor
(d) Metallic semiconductor

54. If n_e and n_h are the number of electrons and holes in a semiconductor heavily doped with phosphorus, then [MP PMT 2000]
(a) $n_e >> n_h$ (b) $n_e << n_h$
(c) $n_e \le n_h$ (d) $n_e = n_h$

55. An *N*-type and *P*-type silicon can be obtained by doping pure silicon with [EAMCET (Med.) 2000]
(a) Arsenic and Phosphorous (b) Indium and Aluminium
(c) Phosphorous and Indium (d) Aluminium and Boron

56. *N*-type semiconductors will be obtained, when germanium is doped with [AIIMS 2000]
(a) Phosphorus (b) Aluminium
(c) Arsenic (d) Both (a) or (c)

57. The state of the energy gained by valance electrons when the temperature is raised or when electric field is applied is called as
(a) Valance band (b) Conduction band
(c) Forbidden band (d) None of these

58. To obtain electrons as majority charge carriers in a semiconductor, the impurity mixed is [MP PET 2000]
(a) Monovalent (b) Divalent
(c) Trivalent (d) Pentavalent

59. For germanium crystal, the forbidden energy gap in joules is [MP PET 2000]
(a) 1.12×10^{-19} (b) 1.76×10^{-19}
(c) 1.6×10^{-19} (d) Zero

60. A pure semiconductor behaves slightly as a conductor at [MH CET (Med.) 2001; BHU 2000; AFMC 2001]
(a) Room temperature (b) Low temperature

(c) High temperature (d) Both (b) and (c)

61. Which is the correct relation for forbidden energy gap in conductor, semi conductor and insulator

[RPMT 2001; AIEEE 2002]

(a) $\Delta Eg_{c} > \Delta Eg_{sc} > \Delta Eg_{\text{insulator}}$

(b) $\Delta Eg_{\text{insulator}} > \Delta Eg_{sc} > \Delta Eg_{\text{conductor}}$

(c) $\Delta Eg_{\text{conductor}} > \Delta Eg_{\text{insulator}} > \Delta Eg_{sc}$

(d) $\Delta Eg_{sc} > \Delta Eg_{\text{conductor}} > \Delta Eg_{\text{insulator}}$

62. The band gap in Germanium and silicon in *eV* respectively is

(a) 0.7, 1.1 (b) 1.1, 0.7

(c) 1.1, 0 (d) 0, 1.1

63. *P*-type semiconductors are made by adding impurity element

(a) *As* (b) *P*

(c) *B* (d) *Bi*

64. At room temperature, a *P*-type semiconductor has

[Kerala PMT 2002]

(a) Large number of holes and few electrons

(b) Large number of free electrons and few holes

(c) Equal number of free electrons and holes

(d) No electrons or holes

65. In intrinsic semiconductor at room temperature, number of electrons and holes are [JIPMER 2001, 02; MP PMT 2002]

(a) Unequal (b) Equal

(c) Infinite (d) Zero

66. The valence band and conduction band of a solid overlap at low temperature, the solid may be

[Orissa JEE 2002; BCECE 2004]

(a) A metal (b) A semiconductor

(c) An insulator (d) None of these

67. Which impurity is doped in *Si* to form *N*-type semi-conductor? [CBSE PMT 1996; AIEEE 2002]

(a) *Al* (b) *B*

(c) *As* (d) None of these

68. In a semiconductor [AIEEE 2002; AIIMS 2002]

(a) There are no free electrons at any temperature

(b) The number of free electrons is more than that in a conductor

(c) There are no free electrons at 0 *K*

(d) None of these

69. The energy band gap is maximum in [AIEEE 2002]

(a) Metals (b) Superconductors

(c) Insulators (d) Semiconductors

70. The process of adding impurities to the pure semiconductor is called [MH CET 2002]

(a) Drouping (b) Drooping

(c) Doping (d) None of these

71. When phosphorus and antimony are mixed in zermaniun, then

(a) *P*-type semiconductor is formed

(b) *N*-type semiconductor is formed

(c) Both (a) and (b)

(d) None of these

72. To a germanium sample, traces of gallium are added as an impurity. The resultant sample would behave like

[AIIMS 2003]

(a) A conductor

(b) A *P*-type semiconductor

(c) An *N*-type semiconductor

(d) An insulator [MP PMT 2001]

73. For non-conductors, the energy gap is

[EAMCET (Engg.) 1995; MP PET 1996; RPET 2003]

(a) 6 *eV* [MP PMT 2001] (b) 1.1 *eV*

(c) 0.8 *eV* (d) 0.3 *eV*

74. Donor type impurity is found in [RPET 2003]

(a) Trivalent elements (b) Pentavalent elements

(c) In both the above (d) None of these

75. The difference in the variation of resistance with temperature in a metal and a semiconductor arises essentially due to the difference in the [AIEEE 2003]

(a) Variation of scattering mechanism with temperature

(b) Crystal structure

(c) Variation of the number of charge carriers with temperature

(d) Type of bon

76. The charge on a hole is equal to the charge of

[MP PMT 2004]

(a) Zero (b) Proton

(c) Neutron (d) Electron

77. When germanium is doped with phosphorus, the doped material has

(a) Excess positive charge

(b) Excess negative charge

(c) More negative current carriers

(d) More positive current carriers

78. A *Ge* specimen is doped with *Al*. The concentration of acceptor atoms is ~10^{21} *atoms*/m^3. Given that the intrinsic concentration of electron hole pairs is $\sim 10^{19}/m^3$, the concentration of electrons in the specimen is [AIIMS 2004]

(a) $10^{17}/m^3$ (b) $10^{15}/m^3$

(c) $10^{4}/m^3$ (d) $10^{2}/m^3$

79. Which of the following has negative temperature coefficient of resistance [AFMC 2004]

(a) Copper (b) Aluminium

(c) Iron (d) Germanium

80. In semiconductors at a room temperature [CPMT 2003] [CBSE PMT 2004]

(a) The valence band is partially empty and the conduction band is partially filled

(b) The valence band is completely filled and the conduction band is partially filled

(c) The valence band is completely filled

(d) The conduction band is completely empty

81. Regarding a semiconductor which one of the following is wrong

(a) There are no free electrons at room temperature

(b) There are no free electrons at 0 K

(c) The number of free electrons increases with rise of temperature

(d) The charge carriers are electrons and holes

82. Which of the following statements is true for an *N*-type semi-conductor **[CPMT 2004]**

(a) The donor level lies closely below the bottom of the conduction band

(b) The donor level lies closely above the top of the valence band

(c) The donor level lies at the halfway mark of the forbidden energy gap

(d) None of above

83. Choose the correct statement **[DCE 2004]**

(a) When we heat a semiconductor its resistance increases

(b) When we heat a semiconductor its resistance decreases

(c) When we cool a semiconductor to 0 K then it becomes super conductor

(d) Resistance of a semiconductor is independent of temperature

84. In a *P*-type semi-conductor, germanium is dopped with **[MH CET 2003]**

(a) Gallium (b) Boron

(c) Aluminium (d) All of these

85. A piece of semiconductor is connected in series in an electric circuit. On increasing the temperature, the current in the circuit will

(a) Decrease (b) Remain unchanged

(c) Increase (d) Stop flowing

86. Intrinsic semiconductor is electrically neutral. Extrinsic semiconductor having large number of current carriers would be

(a) Positively charged

(b) Negatively charged

(c) Positively charged or negatively charged depending upon the type of impurity that has been added

(d) Electrically neutral

87. If n and v be the number of electrons and drift velocity in a semiconductor. When the temperature is increased **[Pb. CET 2000]**

(a) n increases and v decreases

(b) n decreases and v increases

(c) Both n and v increases

(d) Both n and v decreases

88. In extrinsic semiconductors **[EAMCET (Engg.) 1999]**

(a) The conduction band and valence band overlap

(b) The gap between conduction band and valence band is more than 16 eV

(c) The gap between conduction band and valence band is near about 1 eV

(d) The gap between conduction band and valence band will be 100 eV and more **[CPMT 2004]**

89. Resistivity of a semiconductor depends on **[MP PMT 1999]**

(a) Shape of semiconductor

(b) Atomic nature of semiconductor

(c) Length of semiconductor

(d) Shape and atomic nature of semiconductor

90. Electric current is due to drift of electrons in **[CPMT 1996]**

(a) Metallic conductors

(b) Semi-conductors

(c) Both (a) and (b)

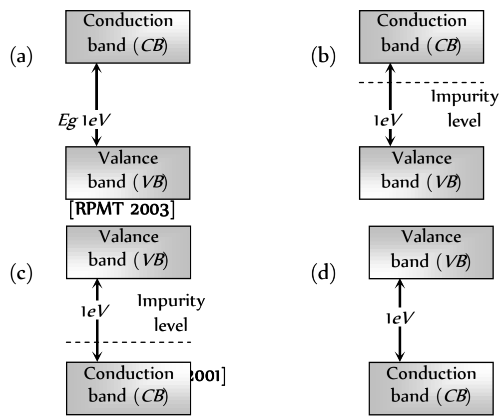
(d) None of these

91. The energy gap of silicon is 1.14 eV. The maximum wavelength at which silicon will begin absorbing energy is **[MP PMT 1993]**

(a) 10888 $\AA$ (b) 1088.8 $\AA$

(c) 108.88 $\AA$ (d) 10.888 $\AA$

92. Which of the following energy band diagram shows the *N*-type semiconductor **[RPET 1986]**



93. The mobility of free electron is greater than that of free holes because

(a) The carry negative charge

(b) They are light

(c) They mutually collide less

(d) They require low energy to continue their motion

94. The relation between the number of free electrons in semiconductors (n) and its temperature (T) is

(a) $n \propto T^2$ (b) $n \propto T$

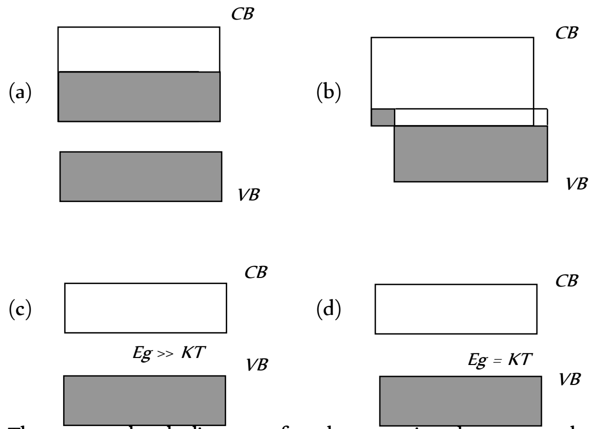
(c) $n \propto \sqrt{T}$ (d) $n \propto T^{3/2}$

95. The electron mobility in *N*-type germanium is 3900 $cm^2/v\text{-}s$ and its conductivity is 6.24 *mho/cm*, then impurity concentration will be if the effect of cotters is negligible

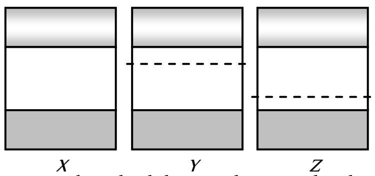
(a) $10^{15}\ cm^3$ (b) $10^{13}\ /cm^3$

(c) $10^{12}\ /cm^3$ (d) $10^{16}\ /cm^3$

96. Which of the energy band diagrams shown in the figure corresponds to that of a semiconductor [Orissa JEE 2003]



97. The energy band diagrams for three semiconductor samples of silicon are as shown. We can then assert that [Haryana CEE 1996]



(a) Sample *X* is undoped while samples *Y* and *Z* have been doped with a third group and a fifth group impurity respectively
(b) Sample *X* is undoped while both samples *Y* and *Z* have been doped with a fifth group impurity
(c) Sample *X* has been doped with equal amounts of third and fifth group impurities while samples *Y* and *Z* are undoped
(d) Sample *X* is undoped while samples *Y* and *Z* have been doped with a fifth group and a third group impurity respectively

98. Carbon, silicon and Germanium atoms have four valence electrons each. Their valence and conduction band are separated by energy band gaps represented by $(E_g)_C$. $(E_g)_{Si}$ and $(E_g)_{Ge}$ respectively. Which one of the following relationship is true in their case

(a) $(E_g)_C > (E_g)_{Si}$ (b) $(E_g)_C = (E_g)_{Si}$

(c) $(E_g)_C < (E_g)_{Ge}$ (d) $(E_g)_C < (E_g)_{Si}$

99. A semiconductor dopped with a donor impurity is [AFMC 2005]

(a) *P*-type (b) *N*-type

(c) *NPN* type (d) *PNP* type

100. In a semiconducting material the mobilities of electrons and holes are μ_e and μ_h respectively. Which of the following is true

(a) $\mu_e > \mu_h$ (b) $\mu_e < \mu_h$

(c) $\mu_e = \mu_h$ (d) $\mu_e < 0; \mu_h > 0$

101. Doping of intrinsic semiconductor is done [Orissa JEE 2005]

(a) To neutralize charge carriers
(b) To increase the concentration of majority charge carriers
(c) To make it neutral before disposal
(d) To carry out further purification

Semiconductor Diode

1. In the forward bias arrangement of a *PN*-junction diode [MP PMT 1994, 96, 99]

(a) The *N*-end is connected to the positive terminal of the battery
(b) The *P*-end is connected to the positive terminal of the battery
(c) The direction of current is from *N*-end to *P*-end in the diode
(d) The *P*-end is connected to the negative terminal of battery

2. In a *PN*-junction diode [MP PET 1993]

(a) The current in the reverse biased condition is generally very small
(b) The current in the reverse biased condition is small but the forward biased current is independent of the bias voltage
(c) The reverse biased current is strongly dependent on the applied bias voltage
(d) The forward biased current is very small in comparison to reverse biased current

3. The cut-in voltage for silicon diode is approximately

(a) 0.2 V (b) 0.6 V

(c) 1.1 V (d) 1.4 V

4. The electrical circuit used to get smooth dc output from a rectifier circuit is called [KCET 2003]

(a) Oscillator (b) Filter

(c) Amplifier (d) Logic gates

5. *PN*-junction diode works as a insulator, if connected [CPMT 1987]

(a) To A.C. (b) In forward bias

(c) In reverse bias (d) None of these

6. The reverse biasing in a *PN* junction diode [MP PMT 1991; EAMCET 1994; CBSE PMT 2003]

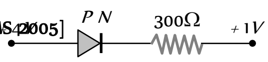
(a) Decreases the potential barrier
(b) Increases the potential barrier
(c) Increases the number of minority charge carriers
(d) Increases the number of majority charge carriers

[CBSE PMT 2005]

7. The electrical resistance of depletion layer is large because

(a) It has no charge carriers
(b) It has a large number of charge carriers
(c) It contains electrons as charge carriers
(d) It has holes as charge carriers

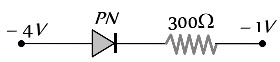
8. In the circuit given below, the value of the current is [AIIMS 2005]



(a) 0 *amp* (b) 10^{-2} *amp*

(c) 10^{2} *amp* (d) 10^{-3} *amp*

9. What is the current in the circuit shown below [AFMC 2000; RPMT 2001]



(a) 0 *amp* (b) 10^{-2} *amp*

(c) 1 *amp* (d) 0.10 *amp*

10. If the forward voltage in a semiconductor diode is doubled, the width of the depletion layer will [MP PMT 1996]

(a) Become half (b) Become one-fourth

(c) Remain unchanged (d) Become double

11. The *PN* junction diode is used as [CPMT 1972; AFMC 1997; CBSE PMT 1999; AIIMS 1999; RPMT 2000; MP PMT 04]

(a) An amplifier (b) A rectifier

(c) An oscillator (d) A modulator

12. When a *PN* junction diode is reverse biased

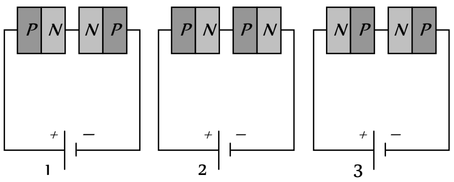
(a) Electrons and holes are attracted towards each other and move towards the depletion region

(b) Electrons and holes move away from the junction depletion region

(c) Height of the potential barrier decreases

(d) No change in the current takes place

13. Two *PN*-junctions can be connected in series by three different methods as shown in the figure. If the potential difference in the junctions is the same, then the correct connections will be



(a) In the circuit (1) and (2) (b) In the circuit (2) and (3)

(c) In the circuit (1) and (3) (d) Only in the circuit (1)

14. A *PN*- junction has a thickness of the order of [BIT 1990]

(a) $1\,cm$ (b) $1\,mm$

(c) $10^{-6}\,m$ (d) $10^{-12}\,cm$

15. In the depletion region of an unbiased *P-N* junction diode there are [KCET 1999; CBSE PMT 1999; RPMT 2001; MP PMT 1994, 2003]

(a) Only electrons

(b) Only holes

(c) Both electrons and holes

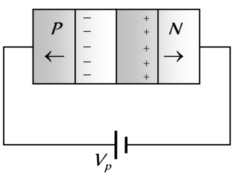
(d) Only fixed ions

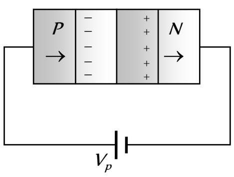
16. On increasing the reverse bias to a large value in a *PN*-junction diode, current [MP PMT 1994; BHU 2002]

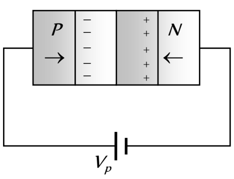
(a) Increases slowly (b) Remains fixed

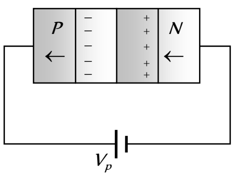
(c) Suddenly increases (d) Decreases slowly

17. In the case of forward biasing of *PN*-junction, which one of the following figures correctly depicts the direction of flow of carriers

(a) 

(b) 

(c) 

(d) 

18. Which of the following statements concerning the depletion zone of an unbiased *PN* junction is (are) true [IIT-JEE 1995]

(a) The width of the zone is independent of the densities of the dopants (impurities)

(b) The width of the zone is dependent on the densities of the dopants

(c) The electric field in the zone is produced by the ionized dopant atoms

(d) The electric field in the zone is provided by the electrons in the conduction band and the holes in the valence band

19. A semiconductor device is connected in a series circuit with a battery and a resistance. A current is found to pass through the circuit. If the polarity of the battery is reversed, the current drops almost to zero. The device may be [MP PET 1995; CBSE PMT 1998]

(a) A *P*-type semiconductor (b) An *N*-type semiconductor

(c) A *PN*-junction [IIT-JEE 1989] (d) An intrinsic semiconductor

20. The approximate ratio of resistances in the forward and reverse bias of the *PN*-junction diode is [MP PET 2000; MP PMT 1999, 2002, 03; Pb. PMT 2003]

(a) $10^2:1$ (b) $10^{-2}:1$

(c) $1:10^{-4}$ (d) $1:10^4$

21. In a junction diode, the holes are due to [CBSE PMT 1999; Pb. PMT 2003]

(a) Protons (b) Neutrons

(c) Extra electrons (d) Missing of electrons

22. In forward bias, the width of potential barrier in a *P-N* junction diode [EAMCET (Engg.) 1995; CBSE PMT 1999 RPMT 1997, 2002, 03]

(a) Increases

(b) Decreases

(c) Remains constant

(d) First increases then decreases

23. The cause of the potential barrier in a *P-N* diode is [CBSE PMT 1998; RPMT 2001]

(a) Depletion of positive charges near the junction

(b) Concentration of positive charges near the junction

(c) Depletion of negative charges near the junction

(d) Concentration of positive and negative charges near the junction

24. In a *PN*[CBSE PMT 1995] junction diode not connected to any circuit [IIT-JEE 1998]

(a) The potential is the same everywhere

(b) The *P*-type is a higher potential than the *N*-type side

(c) There is an electric field at the junction directed from the *N*-type side to the *P*- type side

(d) There is an electric field at the junction directed from the *P*-type side to the *N*-type side

25. Which of the following statements is not true [IIT-JEE 1997 Re-Exam]

(a) The resistance of intrinsic semiconductors decrease with increase of temperature

(b) Doping pure Si with trivalent impurities give *P*-type semiconductors

(c) The majority carriers in *N*-type semiconductors are holes

(d) A *PN*-junction can act as a semiconductor diode

26. The dominant mechanisms for motion of charge carriers in forward and reverse biased silicon *P-N* junctions are [IIT-JEE 1997 Cancelled; RPMT 2000; AIIMS 2000]

(a) Drift in forward bias, diffusion in reverse bias

(b) Diffusion in forward bias, drift in reverse bias

(c) Diffusion in both forward and reverse bias

(d) Drift in both forward and reverse bias

27. In *P-N* junction, avalanche current flows in circuit when biasing is

(a) Forward (b) Reverse

(c) Zero (d) Excess

28. The depletion layer in the *P-N* junction region is caused by [CBSE PMT 1994]

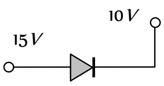
(a) Drift of holes

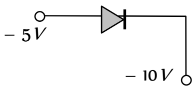
(b) Diffusion of charge carriers

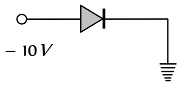
(c) Migration of impurity ions

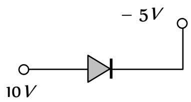
(d) Drift of electrons

29. Which one is reverse-biased [DCE 1999]

(a) 

(b) 

(c) 

(d) 

30. In a *P-N* junction diode if *P* region is heavily doped than *n* region then the depletion layer is [RPMT 1999]

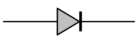
(a) Greater in *P* region

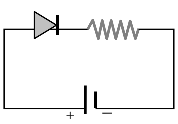
(b) Greater in *N* region

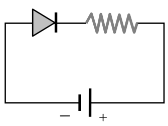
(c) Equal in both region

(d) No depletion layer is formed in this case

31. Which one is in forward bias [RPMT 2000]

(a) 

(b) 

(c) 

(d) None of these

32. The reason of current flow in *P-N* junction in forward bias is [RPMT 2000]

(a) Drifting of charge carriers

(b) Minority charge carriers

(c) Diffusion of charge carriers

(d) All of these

33. The resistance of a reverse biased *P-N* junction diode is about

(a) 1 *ohm* (b) 10^2 *ohm*

(c) 10^3 *ohm* (d) 10^6 *ohm*

34. Consider the following statements *A* and *B* and identify the correct choice of the given answers

A: The width of the depletion layer in a *P-N* junction diode increases in forwards bias

B: In an intrinsic semiconductor the fermi energy level is exactly in the middle of the forbidden gap [EAMCET (Engg.) 2000]

(a) *A* is true and *B* is false (b) Both *A* and *B* are false

(c) *A* is false and *B* is true (d) Both *A* and *B* are true

[RPET 1997]

35. In comparison to a half wave rectifier, the full wave rectifier gives lower [AFMC 2001]

(a) Efficiency (b) Average *dc*

(c) Average output voltage (d) None of these

36. Avalanche breakdown is due to [RPMT 2001]

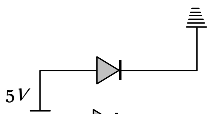
(a) Collision of minority charge carrier

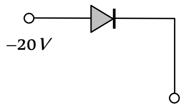
(b) Increase in depletion layer thickness

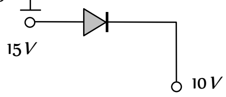
(c) Decrease in depletion layer thickness

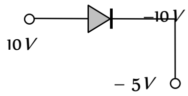
(d) None of these

37. Which is reverse biased diode [DCE 2001]

(a) 

(b) 

(c) 

(d) 

38. Zener breakdown in a semi-conductor diode occurs when [UPSEAT 2002]

(a) Forward current exceeds certain value

(b) Reverse bias exceeds certain value

(c) Forward bias exceeds certain value

(d) Potential barrier is reduced to zero

39. When forward bias is applied to a *P-N* junction, then what happens to the potential barrier V_B, and the width of charge depleted region *x* [UPSEAT 2002, 03; Roorkee 1999; RPET 2003; AIEEE 2004]

(a) V_B increases, *x* decreases

(b) V_B decreases, *x* increases

(c) V_B increases, *x* increases

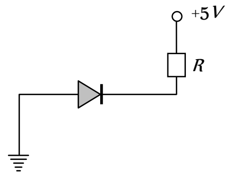
(d) V_B decreases, *x* decreases

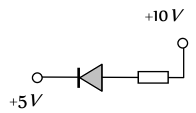
40. The potential barrier, in the depletion layer, is due to [EAMCET (Engg.) 1998; Pb. PMT 1999; Pb. PET 2001; AIIMS 2002]

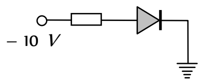
(a) Ions (b) Holes

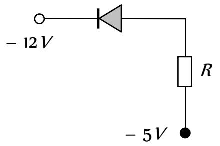
(c) Electrons (d) Both (b) and (c)

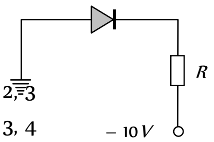
41. In the given figure, which of the diodes are forward biased ? [Kerala PET 2002]

1.


2.


3.


4.


5.


(a) 1, 2, 3 (b) 2, 4, 5

(c) 1, 3, 4 (d) 2, 3, 4

42. Function of rectifier is [AFMC 2002, 04]

(a) To convert *ac* into *dc* (b) To convert *dc* into *ac*

(c) Both (a) and (b) (d) None of these

43. When the *P* end of *P*-*N* junction is connected to the negative terminal of the battery and the *N* end to the positive terminal of the battery, then the *P*-*N* junction behaves like

(a) A conductor (b) An insulator

(c) A super-conductor (d) A semi-conductor

44. If the two ends *P* and *N* of a *P*-*N* diode junction are joined by a wire [MP PMT 2002]

(a) There will not be a steady current in the circuit

(b) There will be a steady current from *N* side to *P* side

(c) There will be a steady current from *P* side to *N* side

(d) There may not be a current depending upon the resistance of the connecting wire

45. A potential barrier of 0.50 *V* exists across a *P*-*N* junction. If the depletion region is 5.0×10^{-7} *m* wide, the intensity of the electric field in this region is [UPSEAT 2002]

(a) 1.0×10^{6} *V/m* (b) 1.0×10^{5} *V/m*

(c) 2.0×10^{5} *V/m* (d) 2.0×10^{6} *V/m*

46. If no external voltage is applied across *P*-*N* junction, there would be

(a) No electric field across the junction

(b) An electric field pointing from *N*-type to *P*-type side across the junction

(c) An electric field pointing from *P*-type to *N*-type side across the junction

(d) A temporary electric field during formation of *P*-*N* junction that would subsequently disappear

47. In a *PN*-junction [CBSE PMT 2002]

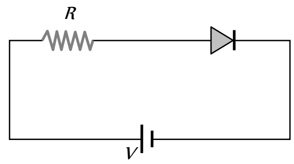
(a) *P* and *N* both are at same potential

(b) High potential at *N* side and low potential at *P* side

(c) High potential at *P* side and low potential at *N* side

(d) Low potential at *N* side and zero potential at *P* side

48. For the given circuit of *PN*-junction diode, which of the following statement is correct [CBSE PMT 2002]



(a) In forward biasing the voltage across *R* is *V*

(b) In forward biasing the voltage across *R* is 2*V*

(c) In reverse biasing the voltage across *R* is *V*

(d) In reverse biasing the voltage across *R* is 2*V*

49. On adjusting the *P*-*N* junction diode in forward biased [RPET 2003]

(a) Depletion layer increases (b) Resistance increases

(c) Both decreases (d) None of these

50. In the middle of the depletion layer of a reverse-biased *PN* junction, the [AIEEE 2003]

(a) Potential is zero (b) Electric field is zero

(c) Potential is maximum (d) Electric field is maximum

51. Barrier potential of a *P*-*N* junction diode does not depend on

(a) Temperature (b) Forward bias

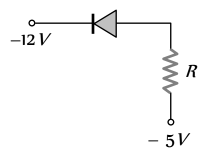
(c) Doping density [MP PET 2002] (d) Diode design

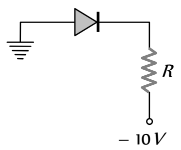
52. A crystal diode is a [MP PET 2004]

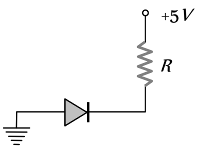
(a) Non-linear device (b) Amplifying device

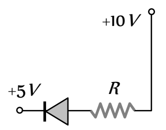
(c) Linear device (d) Fluctuating device

53. Of the diodes shown in the following diagrams, which one is reverse biased [CBSE PMT 2004]

(a)


(b)


(c)


(d)


[Orissa JEE 2002]

54. In a *PN* junction photo cell, the value of photo-electromotive force produced by monochromatic light is proportional to [CBSE PMT 2004]

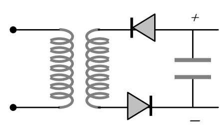
(a) The voltage applied at the *PN* junction

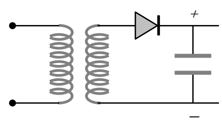
(b) The barrier voltage at the *PN* junction

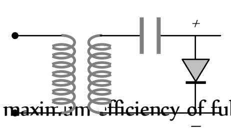
(c) The intensity of the light falling on the cell

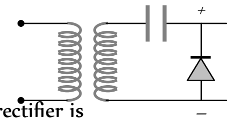
(d) The frequency of the light falling on the cell

55. Which is the correct diagram of a half-wave rectifier [Orissa PMT 2004]

(a)


(b)


(c) 

(d) 

56. The maximum efficiency of full wave rectifier is [J & K CET 2004]

(a) 100% (b) 25.20%

(c) 40.2% (d) 81.2%

57. Serious draw back of the semiconductor device is [Pb. PMT 2004]

(a) They cannot be used with high voltage

(b) They pollute the environment

(c) They are costly

(d) They do not last for long time

58. Select the correct statement [RPMT 2003]

(a) In a full wave rectifier, two diodes work alternately

(b) In a full wave rectifier, two diodes work simultaneously

(c) The efficiency of full wave and half wave rectifiers is same

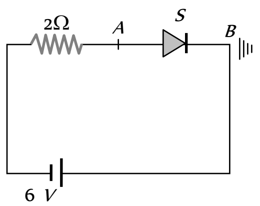
(d) The full wave rectifier is bi-directional.

59. In order to forward bias a *PN* junction, the negative terminal of battery is connected to [RPMT 2003]

(a) *P*–side (b) Either *P*–side or *N*–side

(c) *N*–side (d) None of these

60. The diode shown in the circuit is a silicon diode. The potential difference between the points *A* and *B* will be [RPMT 2002]



(a) 6 V

(b) 0.6 V

(c) 0.7 V

(d) 0 V

61. Zener breakdown takes place if [RPMT 2000]

(a) Doped impurity is low (b) Doped impurity is high

(c) Less impurity in *N*-part (d) Less impurity in *P*-type

62. Consider the following statements *A* and *B* and identify the correct choice of the given answers

(A) A zener diode is always connected in reverse bias

(B) The potential barrier of a *PN* junction lies between 0.1 to 0.3 V approximately [EAMCET 2000]

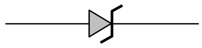
(a) *A* and *B* are correct

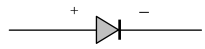
(b) *A* and *B* are wrong

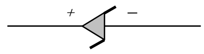
(c) *A* is correct but *B* is wrong

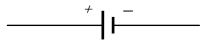
(d) *A* is wrong but *B* is correct

63. The correct symbol for zener diode is [RPMT 2000]

(a) 

(b) 

(c) 

(d) 

64. Which one of the following statements is not correct [SCRA 2000]

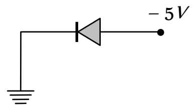
(a) A diode does not obey Ohm's law

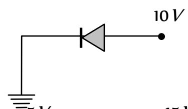
(b) A *PN* junction diode symbol shows an arrow identifying the direction of current (forward) flow

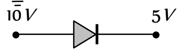
(c) An ideal diode is an open switch

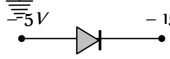
(d) An ideal diode is an ideal one way conductor

65. Which of the following semi-conductor diodes is reverse biased

(a) 

(b) 

(c) 

(d) 

66. No bias is applied to a *P-N* junction, then the current [RPMT 1999]

(a) Is zero because the number of charge carriers flowing on both sides is same

(b) Is zero because the charge carriers do not move

(c) Is non-zero

(d) None of these

67. Zener diode is used as [CBSE PMT 1999]

(a) Half wave rectifier (b) Full wave rectifier

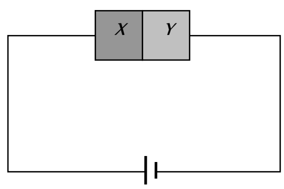
(c) ac voltage stabilizer (d) dc voltage stabilizer

68. The width of forbidden gap in silicon crystal is 1.1 eV. When the crystal is converted in to a *N*-type semiconductor the distance of Fermi level from conduction band is [EAMCET (Med.) 1999]

(a) Greater than 0.55 eV (b) Equal to 0.55 eV

(c) Lesser than 0.55 eV (d) Equal to 1.1 eV

69. A semiconductor *X* is made by doping a germanium crystal with arsenic (Z = 33). A second semiconductor *Y* is made by doping germanium with indium (Z = 49). The two are joined end to end and connected to a battery as shown. Which of the following statements is correct [Orissa JEE 1998]



(a) *X* is *P*-type, *Y* is *N*-type and the junction is forward biased

(b) *X* is *N*-type, *Y* is *P*-type and the junction is forward biased

(c) *X* is *P*-type, *Y* is *N*-type and the junction is reverse biased

(d) *X* is *N*-type, *Y* is *P*-type and the junction is reverse biased

70. In *P-N* junction, the barrier potential offers resistance to [AMU 1995, 96]

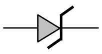
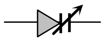
(a) Free electrons in *N* region and holes in *P* region

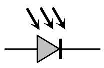
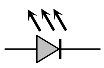
(b) Free electrons in *P* region and holes in *N* region

(c) Only free electrons in *N* region

(d) Only holes in *P* region

71. Symbolic representation of photodiode is [RPMT 1995]

(a)  (b) 

(c)  (d) 

72. To make a *PN* junction conducting [IIT-JEE 1994]

(a) The value of forward bias should be more than the barrier potential

(b) The value of forward bias should be less than the barrier potential

(c) The value of reverse bias should be more than the barrier potential

(d) The value of reverse bias should be less than the barrier potential

73. Which is the wrong statement in following sentences? A device in which *P* and *N*-type semiconductors are used is more useful then a vacuum type because [MP PET 1992]

(a) Power is not necessary to heat the filament

(b) It is more stable

(c) Very less heat is produced in it

(d) Its efficiency is high due to a high voltage across the junction

74. The depletion layer in silicon diode is 1 μm wide and the knee potential is 0.6 *V*, then the electric field in the depletion layer will be

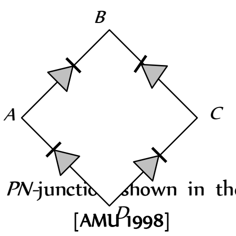
(a) Zero

(b) 0.6 Vm^{-1}

(c) 6×10^{4} V/m

(d) 6×10^{5} V/m

75. In the diagram, the input is across the terminals *A* and *C* and the output is across the terminals *B* and *D*, then the output is



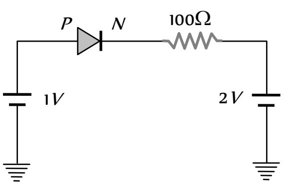
(a) Zero

(b) Same as input

(c) Full wave rectifier

(d) Half wave rectifier

76. The current through an ideal *PN*-junction shown in the following circuit diagram will be [AMU 1998]



(a) Zero

(b) 1 *mA*

(c) 10 *mA*

(d) 30 *mA*

77. If a full wave rectifier circuit is operating from 50 *Hz* mains, the fundamental frequency in the ripple will be

[UPSEAT 2000; CBSE PMT 2003; AIEEE 2005]

(a) 50 *Hz* (b) 70.7 *Hz*

(c) 100 *Hz* (d) 25 *Hz*

78. In a full wave rectifiers, input *ac* current has a frequency 'ν'. The output frequency of current is [BHU 2005]

(a) $\nu/2$ (b) ν

(c) 2ν (d) None of these

79. A diode having potential difference 0.5 *V* across its junction which does not depend on current, is connected in series with resistance of 20 Ω across source. If 0.1 *A* passes through resistance then what is the voltage of the source

[DCE 2005]

(a) 1.5 *V* (b) 2.0 *V*

(c) 2.5 *V* (d) 5 *V*

Junction Transistor

1. When *NPN* transistor is used as an amplifier

[AIEEE 2004]

(a) Electrons move from base to collector

(b) Holes move from emitter to base

(c) Electrons move from collector to base

(d) Holes move from base to emitter

2. The phase difference between input and output voltages of a CE circuit is [MP PET 2004]

(a) 0° (b) 90°

(c) 180° (d) 270°

3. An oscillator is nothing but an amplifier with

[MP PET 2004]

(a) Positive feed back (b) Large gain

(c) No feedback (d) Negative feedback

4. The emitter-base junction of a transistor is ...... biased while the collector-base junction is .... biased

[CBSE PMT 1994] [KCET 2004]

(a) Reverse, forward (b) Reverse, reverse

(c) Forward, forward (d) Forward, reverse

5. In an *NPN* transistor the collector current is 24 *mA*. If 80% of electrons reach collector its base current in *mA* is

[Kerala PMT 2004]

(a) 36 (b) 26

(c) 16 (d) 6

6. A *NPN* transistor conducts when [CPMT 2003]

(a) Both collector and emitter are positive with respect to the base

(b) Collector is positive and emitter is negative with respect to the base

(c) Collector is positive and emitter is at same potential as the base

(d) Both collector and emitter are negative with respect to the base

7. In the case of constants α and β of a transistor [CET 2003]

(a) $\alpha = \beta$ (b) $\beta < 1 \quad \alpha > 1$

(c) $\alpha\beta = 1$ (d) $\beta > 1 \quad \alpha < 1$

8. Which of the following is true [DPMT 2002]

(a) Common base transistor is commonly used because current gain is maximum

(b) Common emitter is commonly used because current gain is maximum

(c) Common collector is commonly used because current gain is maximum

(d) Common emitter is the least used transistor

9. If α = 0.98 and current through emitter i_e = 20 *mA*, the value of β is [DPMT 2002]

(a) 4.9 (b) 49

(c) 96 (d) 9.6

10. For a common base configuration of *PNP* transistor $\frac{I_C}{I_E} = 0.98$ then maximum current gain in common emitter configuration will be [CBSE PMT 2002]

(a) 12 (b) 24

(c) 6 (d) 5

11. In a *PNP* transistor working as a common-base amplifier, current gain is 0.96 and emitter current is 7.2 *mA*. The base current is [AFMC 2002, Pb. PET 2002]

(a) 0.4 *mA* (b) 0.2 *mA*

(c) 0.29 *mA* (d) 0.35 *mA*

12. If l_1, l_2, l_3 are the lengths of the emitter, base and collector of a transistor then [KCET 2002]

(a) $l_1 = l_2 = l_3$ (b) $l_3 < l_2 > l_1$

(c) $l_3 < l_1 < l_2$ (d) $l_3 > l_1 > l_2$

13. In an *NPN* transistor circuit, the collector current is 10 *mA*. If 90% of the electrons emitted reach the collector, the emitter current (i_E) and base current (i_B) are given by [KCET 2001]

(a) $i_E = -1$ *mA*, $i_B = 9$ *mA*

(b) $i_E = 9$ *mA*, $i_B = -1$ *mA*

(c) $i_E = 1$ *mA*, $i_B = 11$ *mA*

(d) $i_E = 11$ *mA*, $i_B = 1$ *mA*

14. In a common emitter transistor, the current gain is 80. What is the change in collector current, when the change in base current is 250 μA [CBSE PMT 2000]

(a) 80×250 μA (b) $(250 - 80)$ μA

(c) $(250 + 80)$ μA (d) 250/80 μA

15. Least doped region in a transistor [KCET 2000]

(a) Either emitter or collector

(b) Base

(c) Emitter

(d) Collector

16. The transistors provide good power amplification when they are used in [AMU 1999]

(a) Common collector configuration

(b) Common emitter configuration

(c) Common base configuration

(d) None of these

17. The transfer ratio of a transistor is 50. The input resistance of the transistor when used in the common-emitter configuration is 1 $K\Omega$. The peak value for an A.C input voltage of 0.01 *V* peak is

(a) 100 μA (b) 0.01 *mA*

(c) 0.25 *mA* (d) 500 μA

18. For a transistor the parameter β = 99. The value of the parameter α is [Pb CET 1998]

(a) 0.9 (b) 0.99

(c) 1 (d) 9

19. A transistor is used in common emitter mode as an amplifier. Then

(a) The base-emitter junction is forward biased

(b) The base-emitter junction is reverse biased

(c) The input signal is connected in series with the voltage applied to the base-emitter junction

(d) The input signal is connected in series with the voltage applied to bias the base collector junction

20. In a *PNP* transistor the base is the *N*-region. Its width relative to the *P*-region is [DCE 1997]

(a) Smaller (b) Larger

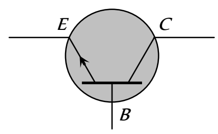
(c) Same (d) Not related

21. A common emitter amplifier is designed with *NPN* transistor (α = 0.99). The input impedance is 1 $K\Omega$ and load is 10 $K\Omega$. The voltage gain will be [CPMT 1996]

(a) 9.9 (b) 99

(c) 990 (d) 9900

22. The symbol given in figure represents [AMU 1995, 96]



(a) *NPN* transistor

(b) *PNP* transistor

(c) Forward biased *PN* junction diode

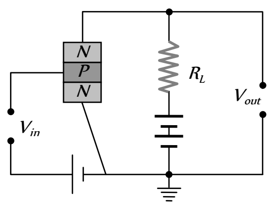
(d) Reverse biased *NP* junction diode

23. The most commonly used material for making transistor is [MNR 1995]

(a) Copper (b) Silicon

(c) Ebonite (d) Silver

24. An *NPN*-transistor circuit is arranged as shown in figure. It is [BHU 1994]



(a) A common base amplifier circuit

(b) A common emitter amplifier circuit

(c) A common collector amplifier circuit

(d) Neither of the above

25. The part of a transistor which is heavily doped to produce a large number of majority carriers, is [CBSE PMT 1993]

(a) Base (b) Emitter

(c) Collector (d) None of these

26. For a transistor, the current amplification factor is 0.8. The transistor is connected in common emitter configuration. The change in the collector current when the base current changes by 6 *mA* is [Haryana CET 1991]

(a) 6 *mA* (b) 4.8 *mA*

(c) 24 *mA* (d) 8 *mA*

27. In a common base amplifier circuit, calculate the change in base current if that in the emitter current is 2 *mA* and $\alpha = 0.98$ [BHU 1995]

(a) 0.04 *mA* (b) 1.96 *mA*

(c) 0.98 *mA* (d) 2 *mA*

28. In case of *NPN*-transistors the collector current is always less than the emitter current because [AIIMS 1983]

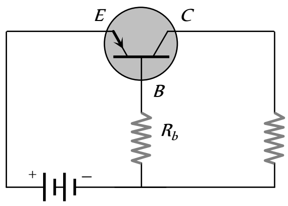
(a) Collector side is reverse biased and emitter side is forward biased

(b) After electrons are lost in the base and only remaining ones reach the collector

(c) Collector side is forward biased and emitter side is reverse biased

(d) Collector being reverse biased attracts less electrons

29. In a transistor circuit shown here the base current is 35 μA. The value of the resistor R_b is



(a) 123.5 $k\Omega$

(b) 257 $k\Omega$

(c) 380.05 $k\Omega$

(d) None of these

30. In a transistor, a change of 8.0 *mA* in the emitter current produces a change of 7.8 *mA* in the collector current. What change in the base current is necessary to produce the same change in the collector current

(a) 50 μA (b) 100 μA

(c) 150 μA (d) 200 μA

31. In a transistor configuration β-parameter is [Orissa PMT 2004]

(a) $\frac{l_b}{l_c}$ (b) $\frac{l_c}{l_b}$

(c) $\frac{l_c}{l_a}$ (d) $\frac{l_a}{l_c}$

32. Which of these is unipolar transistor [Pb PMT 2004]

(a) Point contact transistor (b) Field effect transistor

(c) *PNP* transistor (d) None of these

33. For a transistor, in a common emitter arrangement, the alternating current gain β is given by [DPMT 2004]

(a) $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_C}$ (b) $\beta = \left(\frac{\Delta I_B}{\Delta I_C}\right)_{V_C}$

(c) $\beta = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_C}$ (d) $\beta = \left(\frac{\Delta I_E}{\Delta I_C}\right)_{V_C}$

34. The relation between α and β parameters of current gains for a transistors is given by [Pb. PET 2000]

(a) $\alpha = \frac{\beta}{1-\beta}$ (b) $\alpha = \frac{\beta}{1+\beta}$

(c) $\alpha = \frac{1-\beta}{\beta}$ (d) $\alpha = \frac{1+\beta}{\beta}$

35. When *NPN* transistor is used as an amplifier [DCE 2002]

(a) Electrons move from base to emitter

(b) Electrons move from emitter to base

(c) Electrons moves from base to emitter

(d) Holes moves from base to emitter

36. In the *CB* mode of a transistor, when the collector voltage is changed by 0.5 *volt*. The collector current changes by 0.05 *mA*. The output resistance will be [Pb. PMT 2003]

(a) 10 $k\Omega$ (b) 20 $k\Omega$

(c) 5 $k\Omega$ (d) 2.5 $k\Omega$

37. Which of the following is used to produce radio waves of constant amplitude [DCE 2004]

(a) Oscillator (b) FET

(c) Rectifier (d) Amplifier

38. While a collector to emitter voltage is constant in a transistor, the collector current changes by 8.2 *mA* when the emitter current changes by 8.3 *mA*. The value of forward current ratio h_{fe} is

(a) 82 (b) 83

(c) 8.2 (d) 8.3

39. Consider an *NPN* transistor amplifier in common-emitter configuration. The current gain of the transistor is 100. If the collector current changes by 1 *mA,* what will be the change in emitter current [AIIMS 2005]

(a) 1.1 *mA* (b) 1.01 *mA*

(c) 0.01 *mA* (d) 10 *mA*

40. In a common base amplifier the phase difference between the input signal voltage and the output voltage is [CBSE PMT 1990; AIEEE 2005]

(a) 0 (b) $\pi / 4$

(c) $\pi / 2$ (d) π

41. In *NPN* transistor the collector current is 10 *mA*. If 90% of electrons emitted reach the collector, then [Kerala PMT 2005]

(a) Emitter current will be 9 *mA*
(b) Emitter current will be 11.1 *mA*
(c) Base current will be 0.1 *mA*
(d) Base current will be 0.01 *mA*

42. *NPN* transistor are preferred to *PNP* transistor because they have [J & K CET 2005]

(a) Low cost
(b) Low dissipation energy
(c) Capability of handing large power
(d) Electrons having high mobility than holes

43. In a transistor in CE configuration, the ratio of power gain to voltage gain is [J & K CET 2005]

(a) α (b) β / α
(c) $\beta\alpha$ (d) β

44. In the study of transistor as an amplifier, if $\alpha = I_c / I_e$ and $\beta = I_c / I_b$, where I_c, I_b and I_e are the collector, base and emitter currents, then

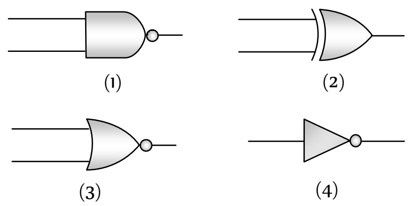
[CBSE PMT 2000; KCET 2000; Orissa JEE 2005]

(a) $\beta = \dfrac{1-\alpha}{\alpha}$ (b) $\beta = \dfrac{\alpha}{1-\alpha}$

(c) $\beta = \dfrac{\alpha}{1+\alpha}$ (d) $\beta = \dfrac{1+\alpha}{\alpha}$

Digital Electronics

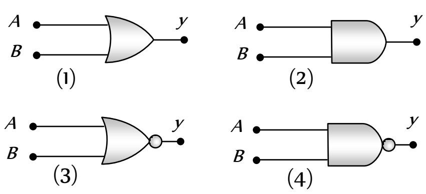
1. Given below are symbols for some logic gates



The XOR gate and NOR gate respectively are [AFMC 1994]

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

2. Given below are four logic gate symbol (figure). Those for OR, NOR and NAND are respectively [NSEP 1994]



(a) 1, 4, 3 (b) 4, 1, 2
(c) 1, 3, 4 (d) 4, 2, 1

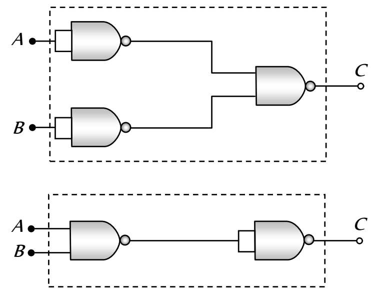
3. The following truth table corresponds to the logic gate

[BHU 1994; CPMT 2000; J & K CET 2004]

A	0	0	1	1
B	0	1	0	1
X	0	1	1	1

(a) NAND (b) OR
(c) AND (d) XOR

4. The combination of 'NAND' gates shown here under (figure) are equivalent to [Haryana CEET 1996]



(a) An OR gate and an AND gate respectively
(b) An AND gate and a NOT gate respectively
(c) An AND gate and an OR gate respectively
(d) An OR gate and a NOT gate respectively.

5. A truth table is given below. Which of the following has this type of truth table [CBSE PMT 1996; UPSEAT 2002]

A	0	1	0	1
B	0	0	1	1
y	1	0	0	0

(a) XOR gate (b) NOR gate
(c) AND gate (d) OR gate

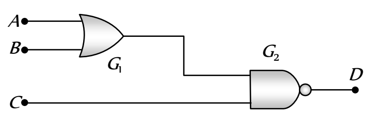
6. The truth table shown in figure is for [Pb. CET 1998]

A	0	0	1	1
B	0	1	0	1
Y	1	0	0	1

(a) XOR (b) AND
(c) XNOR (d) OR

7. For the given combination of gates, if the logic states of inputs *A*, *B*, *C* are as follows *A* = *B* = *C* = 0 and *A* = *B* = 1, *C* = 0 then the logic states of output *D* are

(a) 0, 0
(b) 0, 1
(c) 1, 0
(d) 1, 1



8. Boolean algebra is essentially based on [AIIMS 1999]

(a) Truth (b) Logic
(c) Symbol (d) Numbers

9. The logic behind 'NOR' gate is that it gives

[CPMT 1999, AFMC 1999]

(a) High output when both the inputs are low
(b) Low output when both the inputs are low
(c) High output when both the inputs are high

(d) None of these

10. A logic gate is an electronic circuit which **[BHU 2000]**

(a) Makes logic decisions

(b) Allows electrons flow only in one direction

(c) Works binary algebra

(d) Alternates between 0 and 1 values

11. A gate has the following truth table **[CBSE PMT 2000]**

P	1	1	0	0
Q	1	0	1	0
R	1	0	0	0

The gate is

(a) NOR (b) OR

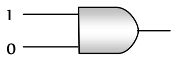
(c) NAND (d) AND

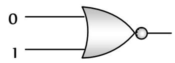
12. How many NAND gates are used to form an AND gate **[MP PET 2004]**

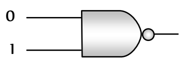
(a) 1 (b) 2

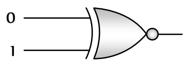
(c) 3 (d) 4

13. Which of the following gates will have an output of 1 **[CBSE PMT 1998]**

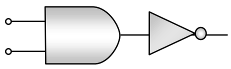
(a) 

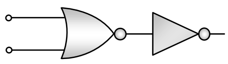
(b) 

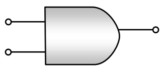
(c) 

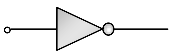
(d) 

14. Which represents NAND gate **[DCE 2002]**

(a) 

(b) 

(c) 

(d) 

15. The given truth table is of **[AMU 1998; J & K CET 2002]**

A	*X*
0	1
1	0

(a) OR gate (b) AND gate

(c) NOT gate (d) None of above

16. What will be the input of *A* and *B* for the Boolean expression $\overline{(A+B)}\cdot\overline{(A\cdot B)}=1$ **[TNPCEE 2002]**

(a) 0, 0 (b) 0, 1

(c) 1, 0 (d) 1, 1

17. If *A* and *B* are two inputs in AND gate, then AND gate has an output of 1 when the values of *A* and *B* are **[TNPCEE 2002]**

(a) $A = 0,\ B = 0$ (b) $A = 1,\ B = 1$

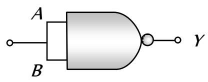
(c) $A = 1,\ B = 0$ (d) $A = 0,\ B = 1$

18. The Boolean equation of NOR gate is **[Haryana CET 2002]**

(a) $C = A + B$ (b) $C = \overline{A+B}$

(c) $C = A\cdot B$ (d) $C = \overline{A\cdot B}$

19. This symbol represents **[CBSE PMT 1996]**



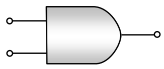
(a) NOT gate

(b) OR gate

(c) AND gate

(d) NOR gate

20. Which logic gate is represented by following diagram **[DCE 2001]**

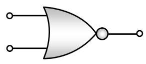


(a) AND

(b) OR

(c) NOR

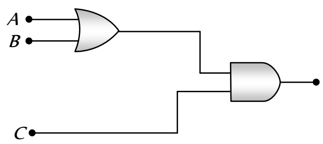
(d) XOR

21. Symbol  represents **[Kerala PMT 2001]**

(a) NAND gate (b) NOR gate

(c) NOT gate (d) XNOR gate

22. To get an output 1 from the circuit shown in the figure, the input must be **[UPSEAT 2002]**



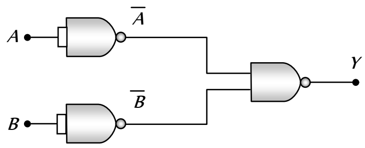
(a) $A=0,\ B=1,\ C=0$

(b) $A=1,\ B=0,\ C=0$

(c) $A=1,\ B=0,\ C=1$

(d) $A=1,\ B=1,\ C=0$

23. The combination of the gates shown in the figure below produces



(a) NOR gate

(b) OR gate

(c) AND gate

(d) XOR gate

24. The output of a NAND gate is 0 **[UPSEAT 2004]**

(a) If both inputs are 0

(b) If one input is 0 and the other input is 1

(c) If both inputs are 1

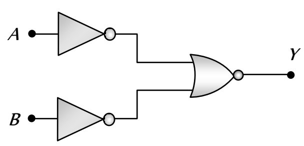
(d) Either if both inputs are 1 or if one of the inputs is 1 and the other 0

25. A gate in which all the inputs must be low to get a high output is called **[UPSEAT 2004]**

(a) A NAND gate (b) An inverter

(c) A NOR gate (d) An AND gate

26. Which logic gate is represented by the following combination of logic gates **[AIIMS 2004]**



(a) OR (b) NAND

(c) AND (d) NOR

27. The output of OR gate is 1 [CBSE PMT 2004]

(a) If both inputs are zero

(b) If either or both inputs are 1

(c) Only if both input are 1

(d) If either input is zero

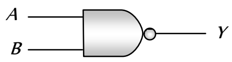
28. Which gates is represented by this figure [DCE 2003]

(a) NAND gate

(b) AND gate

(c) NOT gate

(d) OR gate



29. Sum of the two binary numbers $(1000010)_2$ and $(11011)_2$ is

(a) $(111101)_2$ (b) $(111111)_2$

(c) $(101111)_2$ (d) $(111001)_2$

30. The truth-table given below is for which gate

[CBSE PMT 1994, 98 2002; DPMT 2002; BCECE 2005]

A	0	0	1	1
B	0	1	0	1
C	1	1	1	0

(a) XOR (b) OR

(c) AND (d) NAND

31. Which of the following logic gate is an universal gate

[AIIMS 2005]

(a) OR (b) NOT

(c) AND (d) NOR

Valve Electronics (Diode and Triode)

1. Thermionic emission from a heated filament varies with its temperature *T* as

[CBSE PMT 1990; RPMT 2000; CPMT 2002]

(a) T^{-1} (b) T

(c) T^2 (d) $T^{3/2}$

2. Number of secondary electrons emitted per number of primary electrons depends on [RPET 2000]

(a) Material of target

(b) Frequency of primary electrons

(c) Intensity

(d) None of the above

3. Due to S.C.R in vacuum tube [RPET 2000]

(a) $I_p \rightarrow$ Decrease (b) $I_p -$ Increase

(c) $V_p =$ Increase (d) $V_g =$ Increase

4. In diode, when there is saturation current, the plate resistance (r_p) is [AIIMS 1997; Haryana PMT 2000]

(a) Zero (b) Infinite

(c) Some finite quantity (d) Data is insufficient

5. The grid voltage of any triode valve is changed from –1 volt to – 3 *volt* and the mutual conductance is 3×10^{-4} *mho*. The change in plate circuit current will be [MNR 1999]

(a) 0.8 *mA* (b) 0.6 *mA*

(c) 0.4 *mA* (d) 1 *mA*

6. In a triode, $g_m = 2 \times 10^{-3} ohm^{-1}; \mu = 42$, resistance load, $R = 50$ kilo ohm. The voltage amplification obtained from this triode will be [MNR 1999]

(a) 30.42 (b) 29.57

(c) 28.18 (d) 27.15

7. In an amplifier the load resistance R_L is equal to the plate resistance (r_p). The voltage amplification is equal to [DCE 2004]

[CPMT 1995]

(a) μ (b) 2μ

(c) $\mu / 2$ (d) $\mu / 4$

8. For a given plate-voltage, the plate current in a triode is maximum when the potential of

[IIT-JEE 1985; CPMT 1995; AFMC 1999]

(a) The grid is positive and plate is negative

(b) The grid is positive and plate is positive

(c) The grid is zero and plate is positive

(d) The grid is negative and plate is positive

9. If $R_p = 7K\Omega, g_m = 2.5$ *millimho*, then on increasing plate voltage by $50V$, how much the grid voltage is changed so that plate current remains the same [RPET 1996]

(a) – 2.86 *V* (b) – 4 *V*

(c) + 4 *V* (d) + 2 *V*

10. The amplification factor of a triode is 20 and trans-conductance is 3 *milli mho* and load resistance $3 \times 10^4 \Omega$, then the voltage gain is

(a) 16.36 (b) 28

(c) 78 (d) 108

11. In a triode amplifier, $\mu = 25, r_p = 40$ kilo ohm and load resistance $R_L = 10$ kilo ohm. If the input signal voltage is 0.5 volt, then output signal voltage will be [RPMT 1995]

(a) 1.25 *volt* (b) 5 *volt*

(c) 2.5 *volt* (d) 10 *volt*

12. The amplification factor of a triode is 20. If the grid potential is reduced by 0.2 *volt* then to keep the plate current constant its plate voltage is to be increased by

[RPMT 1993, 95]

(a) 10 *volt* (b) 4 *volt*

(c) 40 *volt* (d) 100 *volt*

13. For a triode $r_p = 10$ *kilo ohm* and $g_m = 3$ *milli mho*. If the load resistance is double of plate resistance, then the value of voltage gain will be [RPMT 1994]

(a) 10 (b) 20

(c) 15 (d) 30

14. The amplification produced by a triode is due to the action of

(a) Filament (b) Cathode

(c) Grid (d) Plate

15. In an experiment, the saturation in the plate current in a diode is observed at 240 *V*. But a student still wants to increase the plate current. It can be done, if [MNR 1994]

(a) The plate voltage is increased further

(b) The plate voltage is decreased

(c) The filament current is decreased

(d) The filament current is increased

16. In a triode amplifier, the value of maximum gain is equal to

[MP PMT 1992]

(a) Half the amplification factor

(b) Amplification factor

(c) Twice the amplification factor

(d) Infinity

17. For a given triode $\mu = 20$. The load resistance is 1.5 times the anode resistance. The maximum gain will be

[CPMT 1992]

(a) 16 (b) 12

(c) 10 (d) None of the above

18. The voltage gain of a triode depends upon [CPMT 1992]

(a) Filament voltage (b) Plate voltage

(c) Plate resistance (d) Plate current

19. In a triode valve [MP PET 1992]

(a) If the grid voltage is zero then plate current will be zero

(b) If the temperature of filament is doubled, then the thermionic current will also be doubled

(c) If the temperature of filament is doubled, then the thermionic current will nearly be four times [RPMT 1996]

(d) At a definite grid voltage the plate current varies with plate voltage according to Ohm's law

20. The amplification factor of a triode valve is 15. If the grid voltage is changed by 0.3 *volt* the change in plate voltage in order to keep the plate current constant (in volt) is

[CPMT 1990]

(a) 0.02 (b) 0.002

(c) 4.5 (d) 5.0

21. The slope of plate characteristic of a vacuum tube diode for certain operating point on the curve is $10^{-3} \frac{mA}{V}$. The plate resistance of the diode and its nature respectively

[MP PMT 1990]

(a) 100 kilo-ohms static (b) 1000 *kilo-ohms* static

(c) 1000 *kilo-ohms* dynamic (d) 100 *kilo-ohms* dynamic

22. A triode has a mutual conductance of $2 \times 10^{-3} mho$ and an amplification factor of 50. The anode is connected through a resistance of 25×10^3 *ohms* to a 250 *volts* supply. The voltage gain of this amplifier is [MP PMT 1989]

(a) 50 (b) 25

(c) 100 [AFMC 1994] (d) 12.5

23. 14×10^{15} electrons reach the anode per second. If the power consumed is 448 *milliwatts*, then the plate (anode) voltage is

(a) 150 *V* (b) 200 *V*

(c) $14 \times 448V$ (d) 448/14 *V*

24. In the circuit of a triode valve, there is no change in the plate current, when the plate potential is increased from 200 *volt* to 220 *volt* and the grid potential is decreased from – 0.5 *volt* to –1.3 *volt*. The amplification factor of this valve is

[MP PMT 1989]

(a) 15 (b) 20

(c) 25 (d) 35

25. If the amplification factor of a triode (μ) is 22 and its plate resistance is 6600 *ohm*, then the mutual conductance of this valve is mho is [MP PMT 1989]

(a) $\frac{1}{300}$ (b) 25×10^{-2}

(c) 2.5×10^{-2} (d) 0.25×10^{-2}

26. For a triode, at $V_g = -1$ *volt*, the following observations were taken $V_p = 75V, I_p = 2mA$, $V_p = 100V, I_p = 4mA$. The value of plate resistance will be [MP PMT 1989]

(a) 25 $k\Omega$ (b) 20.8 $k\Omega$

(c) 12.5 $k\Omega$ (d) 100 $k\Omega$

27. The triode constant is out of the following **[RPMT 1989]**

(a) Plate resistance (b) Amplification factor

(c) Mutual conductance (d) All the above

28. The unit of mutual conductance of a triode valve is **[MP PMT 1988]**

(a) Siemen (b) *Ohm*

(c) *Ohm metre* (d) *Joule Coulomb*

29. With a change of load resistance of a triode, used as an amplifier, from 50 *kilo ohms* to 100 *kilo ohms*, its voltage amplification changes from 25 to 30. Plate resistance of the triode is

(a) 25 $k\Omega$ (b) 75 $k\Omega$

(c) 7.5 $k\Omega$ (d) 2.5 $k\Omega$

30. Select the correct statements from the following **[IIT-JEE 1984]**

(a) A diode can be used as a rectifier

(b) A triode cannot be used as a rectifier

(c) The current in a diode is always proportional to the applied voltage

(d) The linear portion of the I–V characteristic of a triode is used for amplification without distortion

31. The introduction of a grid in a triode valve affects plate current by

(a) Making the thermionic emission easier at low temperature

(b) Releasing more electrons from the plate

(c) By increasing plate voltage

(d) By neutralising space charge

32. Before the saturation state of a diode at the plate voltages of 400 V and 200 V respectively the currents are i and i respectively. The ratio i/i will be

(a) $\sqrt{2}/4$ (b) $2\sqrt{2}$

(c) 2 (d) 1/2

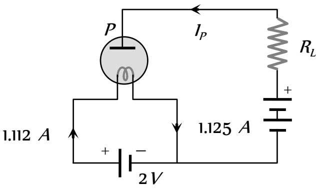
33. The value of plate current in the given circuit diagram will be

(a) 3 mA

(b) 8 mA

(c) 13 mA

(d) 18 mA



34. Coating of strontium oxide on Tungsten cathode in a valve is good for thermionic emission because **[RPMT 1998]**

(a) Work function decreases

(b) Work function increases

(c) Conductivity of cathode increases

(d) Cathode can be heated to high temperature

35. Correct relation for triode is **[RPMT 2000]**

(a) $\mu = g_m \times r_p$ (b) $\mu = \frac{g_m}{r_p}$

(c) $\mu = 2g_m \times r_p$ (d) None of these

36. Following is the relation between current and charge $I = AT^2 e^{qt/V_L}$ then value of V will be **[RPMT 2000]**

(a) $\frac{V}{kT}$ (b) $\frac{kV}{T}$

(c) $\frac{kT}{V}$ (d) $\frac{VT}{k}$

37. Which one is correct relation for thermionic emission **[RPMT 2000]**

(a) $J = AT^{1/2} e^{-\phi/kT}$ (b) $J = AT^2 e^{-\phi/kT}$

(c) $J = AT^{3/2} e^{-\phi/kT}$ (d) $J = AT^2 e^{-\phi/2kT}$

[MP PET 1986]

38. When plate voltage in diode valve is increased from 100 *volt* to 150 *volt* then plate current increases from 7.5 mA to 12 mA. The dynamic plastic resistance will be **[RPMT 2000]**

(a) 10 $k\Omega$ (b) 11 $k\Omega$

(c) 15 $k\Omega$ (d) 11.1 $k\Omega$

39. In a diode valve, the state of saturation can be obtained easily by

(a) High plate voltage and high filament current

(b) Low filament current and high plate voltage

(c) Low plate voltage and high cathode temperature

(d) High filament current and high plate voltage

40. Plate resistance of two triode valves is 2 $K\Omega$ and 4 $K\Omega$, amplification factor of each of the valves is 40. The ratio of voltage amplification, when used with 4 $K\Omega$ load resistance, will be **[CPMT 1975, 90]**

(a) 10 (b) $\frac{4}{3}$

(c) $\frac{3}{4}$ (d) $\frac{16}{3}$

41. Diode is used as a/an **[AIIMS 1999]**

(a) Oscillator (b) Amplifier

(c) Rectifier (d) Modulator

42. The electrical circuits used to get smooth d.c. output from a rectifier circuit is called **[KCET 2000]**

(a) Filter (b) Amplifier

(c) Full wave rectifier (d) Oscillator

43. Which of the following does not vary with plate or grid voltages

(a) g (b) R

(c) μ (d) Each of them varies

44. The grid in a triode valve is used **[UPSEAT 2000]**

(a) To increases the thermionic emission

(b) To control the plate to cathode current

(c) To reduce the inter-electrode capacity

(d) To keep cathode at constant potential

45. In a triode valve the amplification factor is 20 and mutual conductance is 10 *mho*. The plate resistance is **[UPSEAT 2000]**

(a) 2 × 10 Ω (b) 4 × 10 Ω

(c) 2 × 10· Ω (d) 2 × 10· Ω

46. The thermionic emission of electron is due to [UPSEAT 2000]

(a) Electromagnetic field (b) Electrostatic field

(c) High temperature (d) Photoelectric effect

47. The amplification factor of a triode is 50. If the grid potential is decreased by 0.20 *V*, what increase in plate potential will keep the plate current unchanged [RPMT 1999]

(a) 5 *V* (b) 10 *V*

(c) 0.2 *V* (d) 50 *V*

48. The slope of plate characteristic of a vacuum diode is $2 \times 10^{-2}\, mA / V$. The plate resistance of diode will be [RPMT 1999]

(a) 50 Ω (b) 50 *k*Ω

(c) 500 *k*Ω (d) 500 *k*Ω

49. The transconductance of a triode amplifier is 2.5 *mili mho* having plate resistance of 20 *k*Ω, amplification 10. Find the load resistance

(a) 5 *k*Ω (b) 25 *k*Ω

(c) 20 *k*Ω (d) 50 *k*Ω

50. The amplification factor of a triode is 18 and its plate resistance is 8 × 10Ω. A load resistance of 10Ω is connected in the plate circuit. The voltage gain will be [RPMT 2002]

(a) 30 (b) 20

(c) 10 (d) 1

51. The ripple factor in a half wave rectifier is [RPMT 2002]

(a) 1.21 (b) 0.48

(c) 0.6 (d) None of these

52. The correct relation for a triode is [RPET 2000, 02]

(a) $g_m = \left.\frac{\Delta I_p}{\Delta V_p}\right|_{V_g = constt.}$ (b) $g_m = \left.\frac{\Delta I_p}{\Delta V_g}\right|_{V_p = constt.}$

(c) Both (d) None of these

53. In a diode valve the cathode temperature must be (ϕ = work function) [RPET 2002]

(a) High and ϕ should be high

(b) High and ϕ should be low

(c) Low and ϕ should be high

(d) Low and ϕ should be high

54. The plate resistance of a triode is 2.5 × 10· Ω and mutual conductance is 2 × 10· *mho*. What will be the value of amplification factor [RPET 2002]

(a) 50 (b) 1.25 × 10·

(c) 75 (d) 2.25 × 10·

55. Plate voltage of a triode is increased from 200 *V* to 225 *V*. To maintain the plate current, change in grid voltage from 5 *V* to 5.75 *V* is needed. The amplification factor is [RPET 2002]

(a) 40 (b) 45

(c) 33.3 (d) 25

56. The current in a triode at anode potential 100 *V* and grid potential – 1.2 *V* is 7.5 *mA*. If grid potential is changed to – 2.2 *V*, the current becomes 5.5 *mA*. the value of trans conductance (g) will be

(a) 2 *mili mho* (b) 3 *mili mho*

(c) 4 *mili mho* (d) 0.2 *mili mho*

57. Select the correct statement [RPMT 2003]

(a) In a full wave rectifier, two diodes work alternately

(b) In a full wave rectifier, two diodes work simultaneously

(c) The efficiency of full wave and half wave rectifiers is same

(d) The full wave rectifier is bi-directional

58. The amplification factor of a triode is 20. Its plate resistance is 10 kilo ohms. Mutual conductance is [MNR 1992; Orissa JEE 2005]

(a) 2×10^{5} *mho* (b) 2×10^{4} *mho*

(c) 500 *mho* (d) 2×10^{-3} *mho*

[RPMT 2001]

Critical Thinking

Objective Questions

1. A silicon speciman is made into a *P*-type semi-conductor by dopping, on an average, one Indium atom per 5×10^7 silicon atoms. If the number density of atoms in the silicon specimen is 5×10^{28} atoms $/m^3$ then the number of acceptor atoms in silicon per cubic centimetre will be [MP PMT 1993, 2003]

(a) $2.5\times10^{30}\,atoms/cm^3$ (b) $1.0\times10^{13}\,atoms/cm^3$

(c) $1.0\times10^{15}\,atoms/cm^3$ (d) $2.5\times10^{36}\,atoms/cm^3$

2. The probability of electrons to be found in the conduction band of an intrinsic semiconductor at a finite temperature [IIT-JEE 1995; DPMT 2004]

(a) Decreases exponentially with increasing band gap

(b) Increases exponentially with increasing band gap

(c) Decreases with increasing temperature

(d) Is independent of the temperature and the band gap

3. The typical ionisation energy of a donor in silicon is [IIT-JEE 1992]

(a) $10.0\,eV$ (b) $1.0\,eV$

(c) $0.1\,eV$ (d) $0.001\,eV$

4. In *PN*-junction diode the reverse saturation current is 10^{-5} *amp* at $27°C$. The forward current for a voltage of $0.2 volt$ is

(a) $2037.6\times10^{-3}amp$ (b) $203.76\times10^{-3}amp$

(c) $20.376\times10^{-3}amp$ (d) $2.0376\times10^{3}amp$

$[\exp(7.62) = 2038.6, K = 1.4\times10^{-23}\,J/K]$

5. When a potential difference is applied across, the current passing through [IIT-JEE 1999]

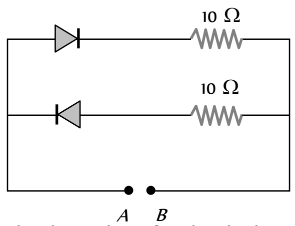
(a) An insulator at $0K$ is zero

(b) A semiconductor at $0K$ is zero

(c) A metal at $0K$ is finite

(d) A *P-N* diode at $300K$ is finite, if it is reverse biased

6. A 2 *V* battery is connected across the points *A* and *B* as shown in the figure given below. Assuming that the resistance of each diode is zero in forward bias and infinity in reverse bias, the current supplied by the battery when its positive terminal is connected to *A* is [UPSEAT 2002]



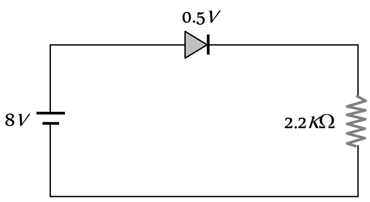
(a) 0.2 *A*

(b) 0.4 *A*

(c) Zero

(d) 0.1 *A*

7. In the circuit, if the forward voltage drop for the diode is 0.5 *V*, the current will be [UPSEAT 2003]



(a) 3.4 *mA*

(b) 2 *mA*

(c) 2.5 *mA*

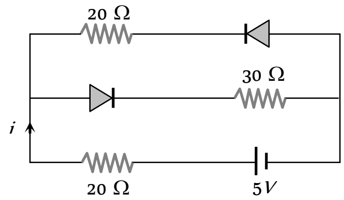
(d) 3 *mA*

8. A *P*-type semiconductor has acceptor levels 57 *meV* above the valence band. The maximum wavelength of light required to create a hole is (Planck's constant $h = 6.6\times10^{-34}$ *J-s*)

(a) 57 Å (b) 57×10^{-3} Å

(c) 217100 Å (d) 11.61×10^{-33} Å

9. Current in the circuit will be [CBSE PMT 2001]



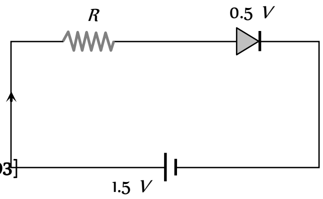
(a) $\frac{5}{40}A$

(b) $\frac{5}{50}A$

(c) $\frac{5}{10}A$

(d) $\frac{5}{20}A$

10. The diode used in the circuit shown in the figure has a constant voltage drop of 0.5 *V* at all currents and a maximum power rating of 100 *milliwatts*. What should be the value of the resistor *R*, connected in series with the diode for obtaining maximum current [CBSE PMT



(a) 1.5 Ω

(b) 5 Ω

(c) 6.67 Ω

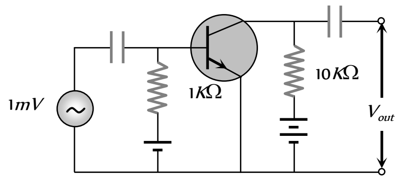
(d) 200 Ω [MP PMT 1993]

11. For a transistor amplifier in common emitter configuration for load impedance of 1 *k*Ω (h_{fe} = 50 and h_{oe} = 25 *μA/V*) the current gain is

(a) – 5.2 (b) – 15.7

(c) – 24.8 (d) – 48.78

12. In the following common emitter configuration an *NPN* transistor with current gain β = 100 is used. The output voltage of the amplifier will be [AIIMS 2003]



(a) 10 *mV*

(b) 0.1 *V*

(c) 1.0 *V*

(d) 10 *V*

13. In semiconductor the concentrations of electrons and holes are 8 × 10-/*m* and 5 × 10-/*m* respectively. If the mobilities of electrons and hole are 2.3 *m*/*volt-sec* and 0.01 *m*/*volt-sec* respectively, then semiconductor is

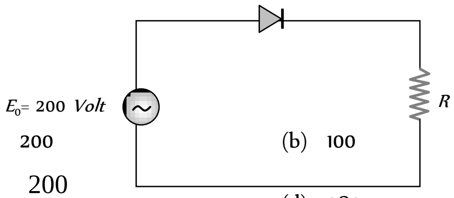
(a) *N*-type and its resistivity is 0.34 *ohm-metre*

(b) *P*-type and its resistivity is 0.034 *ohm-metre*

(c) *N*-type and its resistivity is 0.034 *ohm-metre*

(d) *P*-type and its resistivity is 3.40 *ohm-metre*

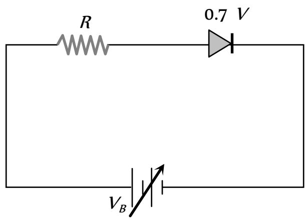
14. A sinusoidal voltage of peak value 200 *volt* is connected to a diode and resistor *R* in the circuit shown so that half wave rectification occurs. If the forward resistance of the diode is negligible compared to *R* the *rms* voltage (in *volt*) across *R* is approximately



(a) 200 (b) 100

(c) $\frac{200}{\sqrt{2}}$ (d) 280

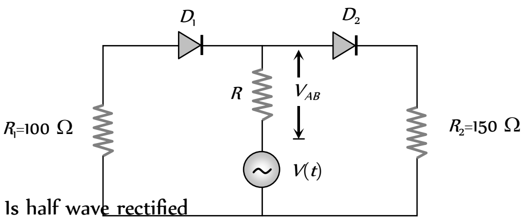
15. The junction diode in the following circuit requires a minimum current of 1 *mA* to be above the knee point (0.7 *V*) of its I-V characteristic curve. The voltage across the diode is independent of current above the knee point. If V_B = 5 *V*, then the maximum value of *R* so that the voltage is above the knee point, will be



(a) 4.3 $k\Omega$ (b) 860 $k\Omega$

(c) 4.3 Ω (d) 860 Ω

16. In the circuit given below, *V*(*t*) is the sinusoidal voltage source, voltage drop $V_{AB}(t)$ across the resistance *R* is [IIT 1993]



(a) Is half wave rectified

(b) Is full wave rectified

(c) Has the same peak value in the positive and negative half cycles

(d) Has different peak values during positive and negative half cycle

17. The peak voltage in the output of a half-wave diode rectifier fed with a sinusoidal signal without filter is 10 *V*. The dc component of the output voltage is [CBSE PMT 2004]

(a) $10/\sqrt{2}\ V$ (b) $10/\pi\ V$

(c) 10 *V* (d) $20/\pi\ V$

18. A transistor is used as an amplifier in *CB* mode with a load resistance of 5 $k\,\Omega$ the current gain of amplifier is 0.98 and the input resistance is 70 Ω, the voltage gain and power gain respectively are [Pb. PET 2003]

(a) 70, 68.6 (b) 80, 75.6

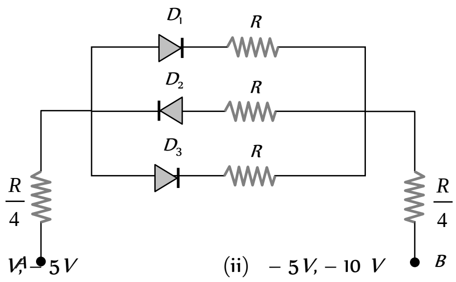
(c) 60, 66.6 (d) 90, 96.6

19. The Bohr radius of the fifth electron of phosphorus (atomic number = 15) acting as dopant in silicon (relative dielectric constant = 12) is

(a) 10.6 Å (b) 0.53 Å

(c) 21.2 Å (d) None of these

20. In the following circuits *PN*-junction diodes D_1, D_2 and D_3 are ideal for the following potential of *A* and *B*, the correct increasing order of resistance between *A* and *B* will be



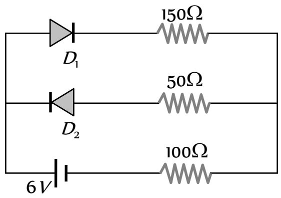
(i) – 10 *V*, – 5 *V* (ii) – 5 *V*, – 10 *V*

(iii) – 4 *V*, – 12 *V*

(a) (i) < (ii) < (iii) (b) (iii) < (ii) < (i)

(c) (ii) = (iii) < (i) (d) (i) = (iii) < (ii)

21. The circuit shown in following figure contains two diode D_1 and D_2 each with a forward resistance of 50 *ohms* and with infinite backward resistance. If the battery voltage is 6 *V*, the current through the 100 *ohm* resistance (in *amperes*) is [IIT-JEE 1997]



(a) Zero (b) 0.02

(c) 0.03 (d) 0.036

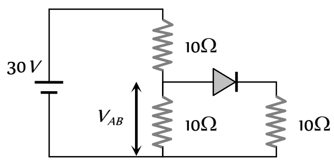
22. Find V_{AB} [RPMT 2000]

(a) 10 *V*

(b) 20 *V*

(c) 30 *V*

(d) None of these



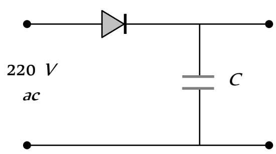
23. A diode is connected to 220 *V* (*rms*) *ac* in series with a capacitor as shown in figure. The voltage across the capacitor is

(a) 220 *V*

(b) 110 *V*

(c) 311.1 *V*

(d) $\frac{220}{\sqrt{2}}\ V$



24. A potential difference of 2 *V* is applied between the opposite faces of a *Ge* crystal plate of area 1 *cm* and thickness 0.5 *mm*. If the concentration of electrons in *Ge* is $2 \times 10^{-}/m$ and mobilities of electrons and holes are $0.36\frac{m^2}{volt-\sec}$ and $0.14\frac{m^2}{volt-\sec}$ respectively, then the current flowing through the plate will be

(a) 0.25 A (b) 0.45 A

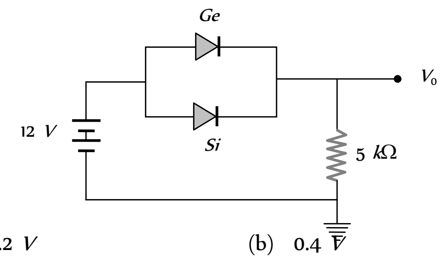
(c) 0.56 A (d) 0.64 A

25. The contribution in the total current flowing through a semiconductor due to electrons and holes are $\frac{3}{4}$ and $\frac{1}{4}$ respectively. If the drift velocity of electrons is $\frac{5}{2}$ times that of holes at this temperature, then the ratio of concentration of electrons and holes is

(a) 6 : 5 (b) 5 : 6

(c) 3 : 2 (d) 2 : 3

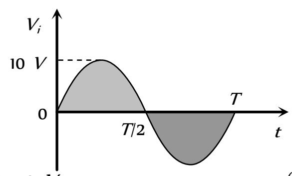
26. *Ge* and *Si* diodes conduct at 0.3 V and 0.7 V respectively. In the following figure if *Ge* diode connection are reversed, the valve of V_0 changes by [Based on Roorkee 2000]

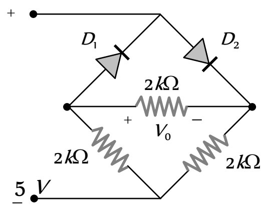


(a) 0.2 V (b) 0.4 V

(c) 0.6 V (d) 0.8 V

27. In the circuit shown in figure the maximum output voltage V_0 is

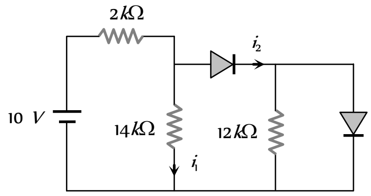




(a) 0 V (b) 5 V

(c) 10 V (d) $\frac{5}{\sqrt{2}}V$

28. In the following circuit find I_1 and I_2



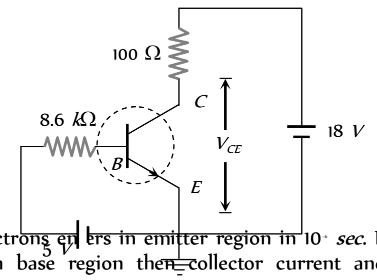
(a) 0, 0

(b) 5 mA, 5 mA

(c) 5 mA, 0

(d) 0, 5 mA

29. For the transistor circuit shown below, if β = 100, voltage drop between emitter and base is 0.7 V then value of V_{ce} will be



(a) 10 V

(b) 5 V

(c) 13 V

(d) 0 V

30. In *NPN* transistor, 10^{10} electrons enters in emitter region in 10^{-6} *sec*. If 2% electrons are lost in base region then collector current and current amplification factor (β) respectively are

(a) 1.57 mA, 49 (b) 1.92 mA, 70

(c) 2 mA, 25 (d) 2.25 mA, 100

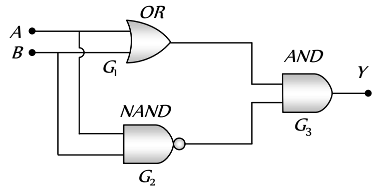
31. The following configuration of gate is equivalent to [AMU 1999]

(a) NAND

(b) XOR

(c) OR

(d) None of these



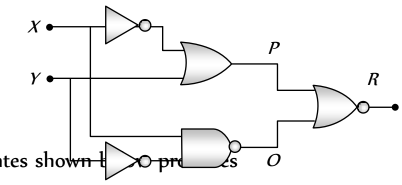
32. Figure gives a system of logic gates. From the study of truth table it can be found that to produce a high output (1) at R, we must have

(a) X = 0, Y = 1

(b) X = 1, Y = 1

(c) X = 1, Y = 0

(d) X = 0, Y = 0



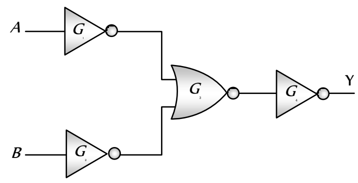
33. The combination of gates shown below produces

(a) AND gate

(b) XOR gate

(c) NOR gate

(d) NAND gate



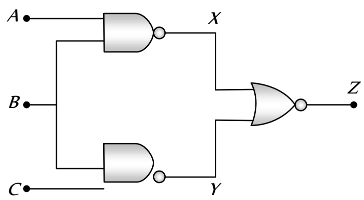
34. The shows two NAND gates followed by a NOR gate. The system is equivalent to the following logic gate

(a) OR

(b) AND

(c) NAND

(d) None of these



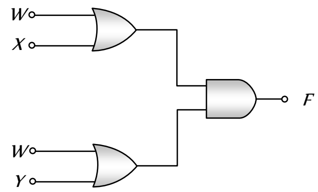
35. The diagram of a logic circuit is given below. The output F of the circuit is represented by

(a) $W.(X+Y)$

(b) $W\cdot(X\cdot Y)$

(c) $W+(X\cdot Y)$

(d) $W+(X+Y)$



36. The plate current i_p in a triode valve is given $i_p = K(V_p + \mu V_g)^{3/2}$ where i_p is in milliampere and V_p and V_g are in *volt*. If r_p = 10^4 *ohm*, and $g_m = 5\times10^{-3} mho$, then for $i_p = 8\,mA$ and $V_p = 300\,volt$, what is the value of K and grid cut off voltage [Roorkee 1992]

(a) – 6V, $(30)^{3/2}$ (b) $-6V,(1/30)^{3/2}$

(c) + 6V, $(30)^{3/2}$ (d) + 6V, $(1/30)^{3/2}$

37. The linear portions of the characteristic curves of a triode valve give the following readings [Roorkee 1985]

V_g (*volt*)	0	– 2	– 4	– 6

$I_p(mA)$ for $V_p = 150$ *volts*	15	12.5	10	7.5
$I_p(mA)$ for $V_p = 120$ *volts*	10	7.5	5	2.5

The plate resistance is

(a) 2000 *ohms* (b) 4000 *ohms*

(c) 8000 *ohms* (d) 6000 *ohms*

38. The relation between dynamic plate resistance (r_p) of a vacuum diode and plate current in the space charge limited region, is

(a) $r_p \propto I_p$ (b) $r_p \propto I_p^{3/2}$

(c) $r_p \propto \frac{1}{I_p}$ (d) $r_p \propto \frac{1}{(I_p)^{1/3}}$

39. The relation between I_p and V_p for a triode is

$$I_p = (0.125V_p - 7.5)mA$$

Keeping the grid potential constant at 1*V*, the value of r_p will be

(a) 8 $k\Omega$ (b) 4 $k\Omega$

(c) 2 $k\Omega$ (d) 8 $k\Omega$

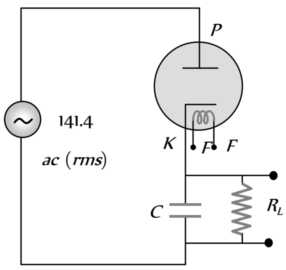
40. An alternating voltage of 141.4 *V* (*rms*) is applied to a vacuum diode as shown in the figure. The maximum potential difference across the condenser will be

(a) 100 *V*

(b) 200 *V*

(c) $100\sqrt{2}V$

(d) $200\sqrt{2}V$



41. A metallic surface with work function of 2 *eV*, on heating to a temperature of 800 *K* gives an emission current of 1 *mA*. If another metallic surface having the same surface area, same emission constant but work function 4 *eV* is heated to a temperature of 1600 *K*, then the emission current will be

(a) 1 *mA* (b) 2 *mA*

(c) 4 *mA* (d) None of these

42. A change of 0.8 *mA* in the anode current of a triode occurs when the anode potential is changed by 10 *V*. If μ = 8 for the triode, then what change in the grid voltage would be required to produce a change of 4 *mA* in the anode current

(a) 6.25 *V* (b) 0.16 *V*

(c) 15.2 *V* (d) None of these

43. The plate current in a triode is given by

$$I_p = 0.004\,(V_p + 10V_g)^{3/2} mA$$

where I_p, V_p and V_g are the values of plate current, plate voltage and grid voltage, respectively. What are the triode parameters μ, r_p and g_m for the operating point at $V_p = 120\,volt$ and $V_g = -2\,volt$?

(a) 10, 16.7 $k\Omega$, 0.6 *m mho* (b) 15, 16.7 $k\Omega$, 0.06 *m mho*

(c) 20, 6 $k\Omega$, 16.7 *m mho* (d) None of these

44. A triode whose mutual conductance is 2.5 *m A/volt* and anode resistance is 20 *kilo ohm*, is used as an amplifier whose amplification is 10. The resistance connected in plate circuit will be [MP PET 1989; RPMT 1998]

(a) 1 $k\Omega$ (b) 5 $k\Omega$

(c) 10 $k\Omega$ (d) 20 $k\Omega$

45. In the grid circuit of a triode a signal $E = 2\sqrt{2}\cos\omega t$ is applied. If μ = 14 and r_p =10 $k\Omega$ then root mean square current flowing through $R_L = 12\,k\Omega$ will be

(a) 1.27 *mA* (b) 10 *mA*

(c) 1.5 *mA* (d) 12.4 *mA*

46. For a triode μ = 64 and g_m =1600 μ *mho*. It is used as an amplifier and an input signal of 1 *V* (*rms*) is applied. The signal power in the load of 40 $k\Omega$ will be

(a) 23.5 *mW* (b) 48.7 *mW*

(c) 25.6 *mW* (d) None of these

47. Amplification factor of a triode is 10. When the plate potential is 200 *volt* and grid potential is – 4 *volt*, then the plate current of 4 *mA* is observed. If plate potential is changed to 160 *volt* and grid potential is kept at – 7 *volt*, then the plate current will be

(a) 1.69 *mA* (b) 3.95 *mA*

(c) 2.87 (d) 7.02 *mA*

48. On applying a potential of – 1 *volt* at the grid of a triode, the following relation between plate voltage V_p (*volt*) and plate current $I_p(\text{in}\,mA)$ is found

$$I_p = 0.125\,V_p - 7.5$$

If on applying – 3 *volt* potential at grid and 300 *V* potential at plate, the plate current is found to be 5 *mA*, then amplification factor of the triode is

(a) 100 (b) 50

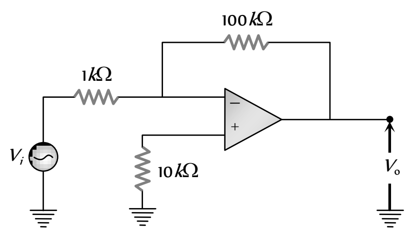
(c) 30 (d) 20

49. The slopes of anode and mutual characteristics of a triode are 0.02 *mA V* and 1 *mA V* respectively. What is the amplification factor of the valve [MP PMT 1990]

(a) 5 (b) 50

(c) 500 (d) 0.5

50. The voltage gain of the following amplifier is [AIIMS 2005]



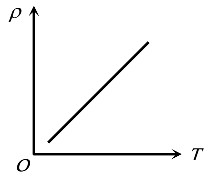
(a) 10 (b) 100

(c) 1000 (d) 9.9

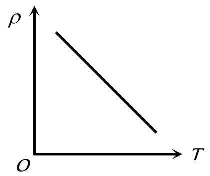
Graphical Questions

1. The temperature (T) dependence of resistivity (ρ) of a semiconductor is represented by **[AIIMS 2004]**

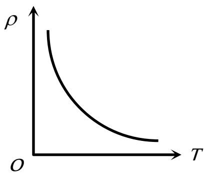
(a)



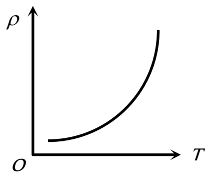
(b)



(c)

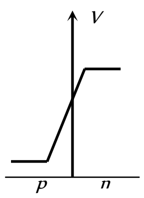


(d)

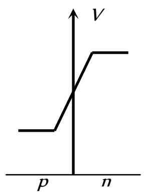


2. In a forward biased *PN*-junction diode, the potential barrier in the depletion region is of the form ... **[KCET 2004]**

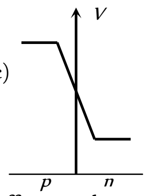
(a)



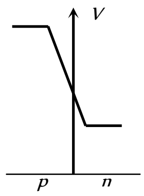
(b)



(c)



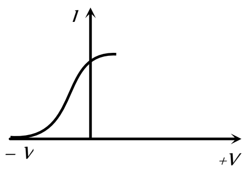
(d)



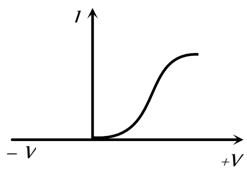
3. Different voltages are applied across a *P-N* junction and the currents are measured for each value. Which of the following graphs is obtained between voltage and current

[MP PET 1996; UPSEAT 2002]

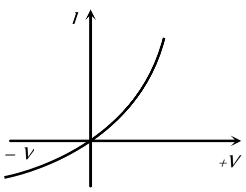
(a)



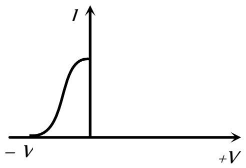
(b)



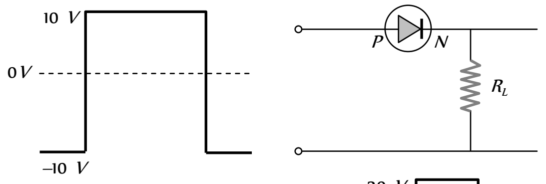
(c)

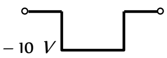


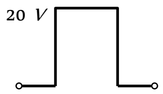
(d)

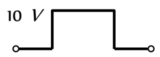


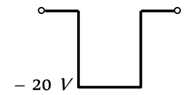
4. If the following input signal is sent through a *PN*-junction diode, then the output signal across R_L will be



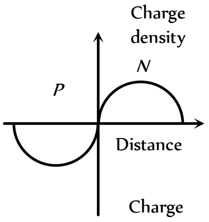
(a) 

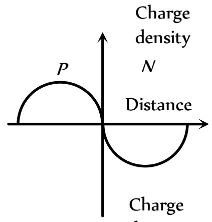
(b) 

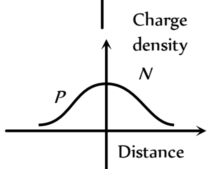
(c) 

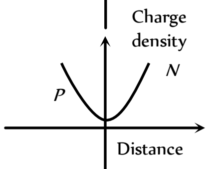
(d) 

5. The curve between charge density and distance near *P-N* junction will be

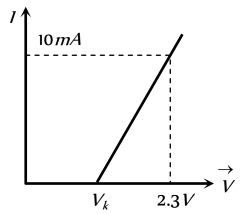
(a) 

(b) 

(c) 

(d) 

6. The resistance of a germanium junction diode whose $V - I$ is shown in figure is $(V_k = 0.3V)$



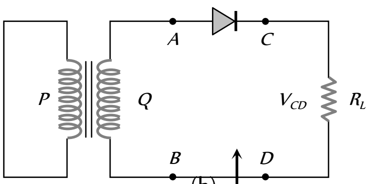
(a) 5 $k\Omega$

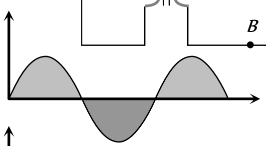
(b) 0.2 $k\Omega$

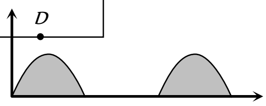
(c) 2.3 $k\Omega$

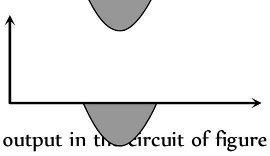
(d) $\left(\frac{10}{2.3}\right) k\Omega$

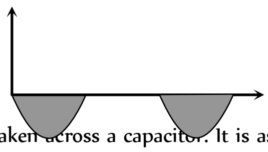
7. In the half-wave rectifier circuit shown. Which one of the following wave forms is true for V_{CD}, the output across *C* and *D*?



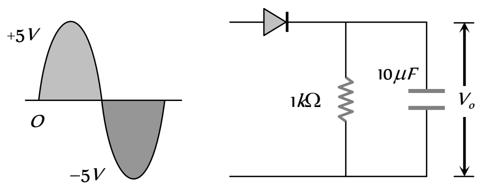
(a) 

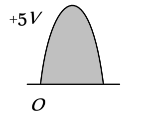
(b) 

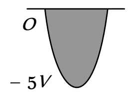
(c) 

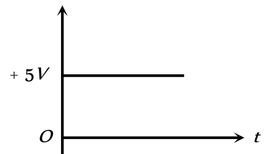
(d) 

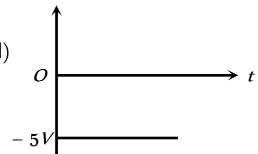
8. The output in the circuit of figure is taken across a capacitor. It is as shown in figure



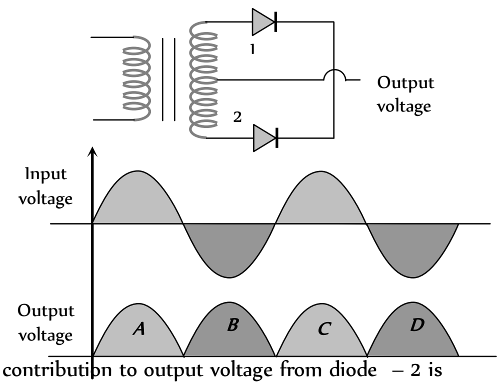
(a) 

(b) 

(c) 

(d) 

9. A full wave rectifier circuit along with the input and output voltages is shown in the figure



The contribution to output voltage from diode – 2 is

[MP PMT 2001]

(a) *A, C* (b) *B, D*

(c) *B, C* (d) *A, D*

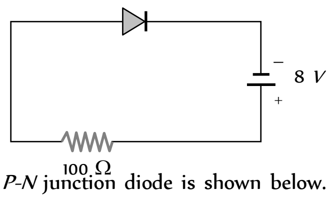
10. A source voltage of 8*V* drives the diode in fig. through a current-limiting resistor of 100 *ohm*. Then the magnitude of the slope load line on the *V-I* characteristics of the diode is

(a) 0.01

(b) 100

(c) 0.08

(d) 12.5



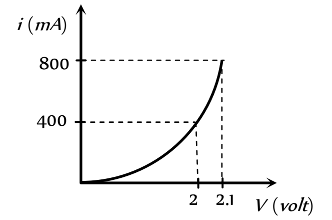
11. The *i-V* characteristic of a *P-N* junction diode is shown below. The approximate dynamic resistance of the *P-N* junction when a forward bias of 2*volt* is applied

(a) 1 Ω

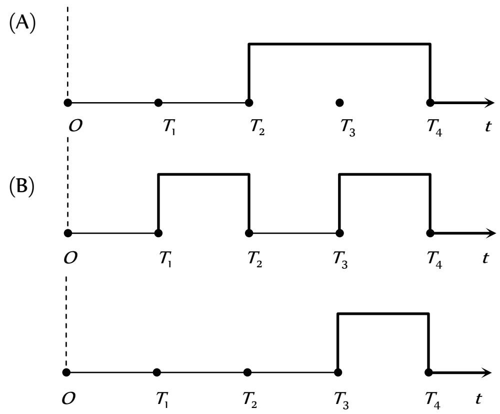
(b) 0.25 Ω

(c) 0.5 Ω

(d) 5 Ω



12. The given figure shows the wave forms for two inputs *A* and *B* and that for the output *Y* of a logic circuit. The logic circuit is

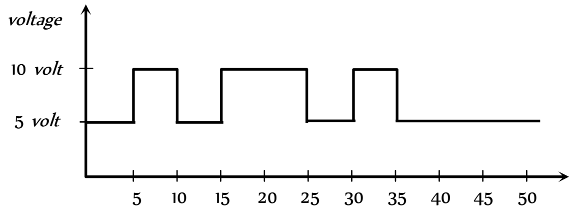


(Y)

(a) An AND gate (b) An OR gate

(c) A NAND gate (d) An NOT gate

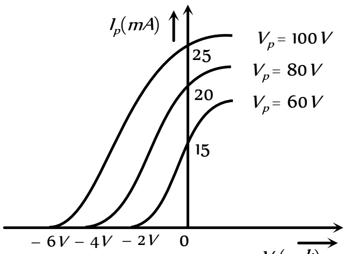
13. In a negative logic the following wave form corresponds to the



(a) 0000000000 000

(c) 111111111 (d) 1010010111

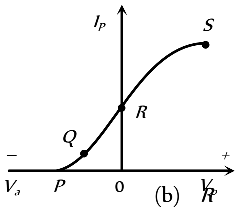
14. The variation of anode current in a triode corresponding to a change in grid potential at three different values of the plate potential is shown in the diagram. The mutual conductance of the triode is



(a) 2.5 $m\ mho$ (b) 5.0 $m\ mho$

(c) 7.5 $m\ mho$ (d) 10.0 $m\ mho$

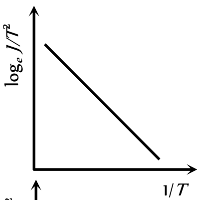
15. The point representing the cut off grid voltage on the mutual characteristic of triode is

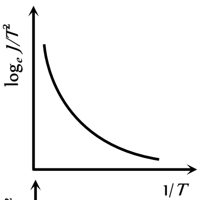


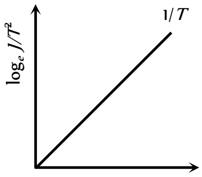
(a) S (b) R

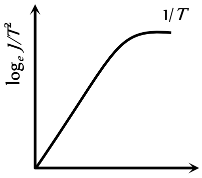
(c) O (d) P

16. For a thermionic emitter (metallic) if J represents the current density and T is its absolute temperature then the correct curve between $\log_e \frac{J}{T^2}$ and $\frac{1}{T}$ is

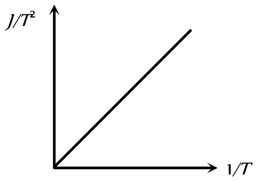
(a)


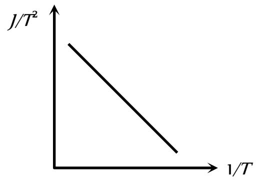
(b)


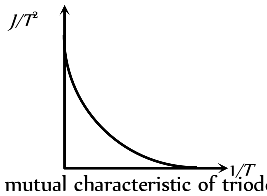
(c)


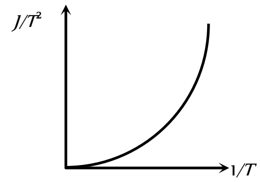
(d)


17. If the thermionic current density is J and emitter temperature is T then the curve between $\frac{J}{T^2}$ and $\frac{1}{T}$ will be

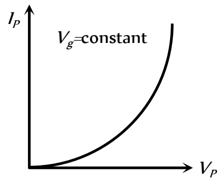
(a)


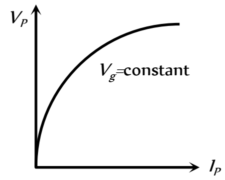
(b)


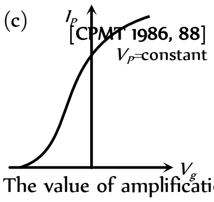
(c)


(d)


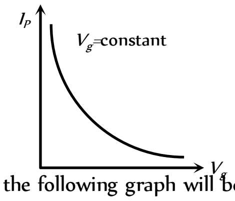
18. The mutual characteristic of triode is

(a)


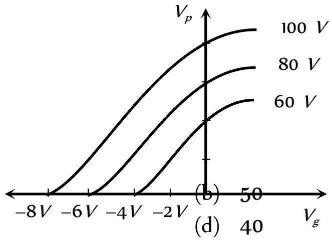
(b)


(c)


[CPMT 1986, 88]

(d)


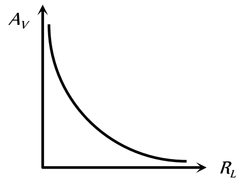
19. The value of amplification factor from the following graph will be

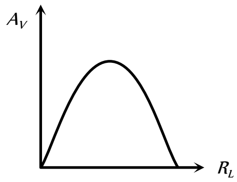


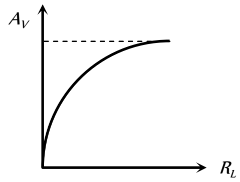
(a) 10 (b) 50

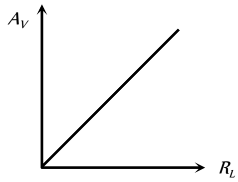
(c) 25 (d) 40

20. The correct curve between voltage gain (A_v) and load resistance (R_L) is

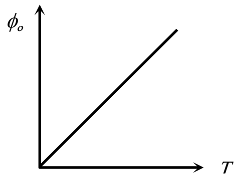
(a)


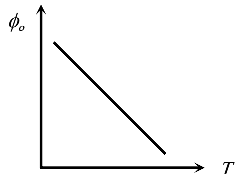
(b)


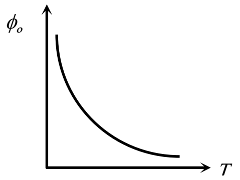
(c)


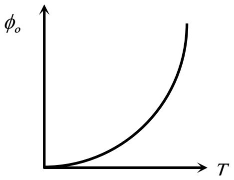
(d)


21. The curve between the work function of a metal (ϕ_o) and its temperature (T) will be

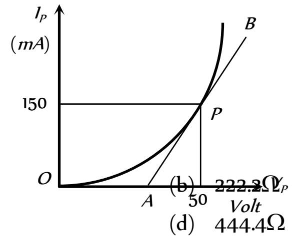
(a)


(b)


(c)


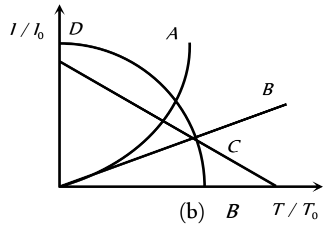
(d)


22. The plate characteristic curve of a diode in space charge limited region is as shown in the figure. The slope of curve at point *P* is 5.0 *mA*/*V*. The static plate resistance of diode will be



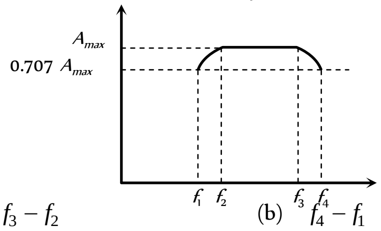
(a) 111.1Ω (b) 222.2Ω
(c) 333.3Ω (d) 444.4Ω

23. The ratio of thermionic currents (I/I_0) for a metal when the temperature is slowly increased T_0 to T as shown in figure. (*I* and I_0 are currents at *T* and respectively). Then which one is correct?



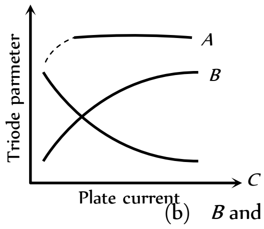
(a) *A* (b) *B*
(c) *C* (d) *D*

24. The frequency response curve of *RC* coupled amplifier is shown in figure. The band width of the amplifier will be



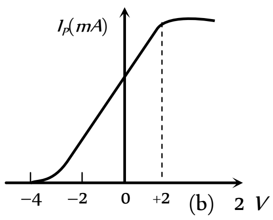
(a) $f_3 - f_2$ (b) $f_4 - f_1$
(c) $\frac{f_4 - f_2}{2}$ (d) $f_3 - f_1$

25. The figure represents variation of triode parameter (μ or r_p or g_m) with the plate current. The correct variation of μ and r_p are given, respectively by the curves



(a) *A* and *B* (b) *B* and *C*
(c) *A* and *C* (d) None of the above

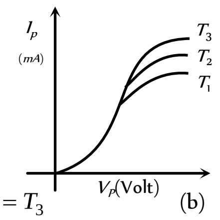
26. The mutual characteristic curves of a triode are as shown in figure. The cut off voltage for the triode is



(a) 0 *V* (b) 2 *V*
(c) – 4 *V* (d) 6 *V*

27. For the diode, the characteristic curves are given at different temperature. The relation between the temperatures is

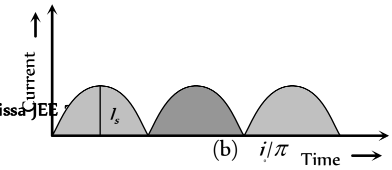
[RPET 1990]



(a) $T_1 = T_2 = T_3$ (b) $T_1 < T_2 < T_3$
(c) $T_1 > T_2 > T_3$ (d) None of the above

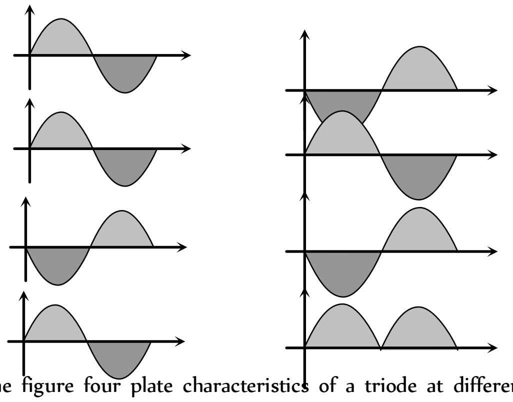
28. The output current versus time curve of a rectifier is shown in the figure. The average value of the output current in this case is

[Orissa JEE]



(a) 0 (b) i_0/π
(c) $2i_0/\pi$ (d) i_0

29. Which of the following figures correctly shows the phase relation between the input signal and the output signal of triode amplifier



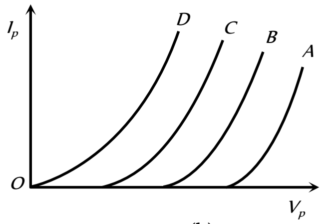
(a)

(b)

(c)

(d)

30. In the figure four plate characteristics of a triode at different grid voltage are shown. The difference between successive grid voltage is 1 *V*. Which curve will have maximum grid voltage and what is its value?



(a) *A*, V_g = + 4 *V* (b) *B*, V_g = + 4 *V*
(c) *A*, V_g = 0 (d) *D*, V_g = 0

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1.	Assertion	:	The logic gate NOT can be built using diode.
	Reason	:	The output voltage and the input voltage of the diode have 180° phase difference. [AIIMS 2005]
2.	Assertion	:	The number of electrons in a *P*-type silicon semiconductor is less than the number of electrons in a pure silicon semiconductor at room temperature.
	Reason	:	It is due to law of mass action. [AIIMS 2005]
3.	Assertion	:	In a common emitter transistor amplifier the input current is much less than the output current.
	Reason	:	The common emitter transistor amplifier has very high input impedance. [AIIMS 2005]
4.	Assertion	:	A transistor amplifier in common emitter configuration has a low input impedence.
	Reason	:	The base to emitter region is forward biased. [AIIMS 2004]
5.	Assertion	:	The resistivity of a semiconductor increases with temperature.
	Reason	:	The atoms of a semiconductor vibrate with larger amplitude at higher temperature there by increasing it's resistivity. [AIIMS 2003]
6.	Assertion	:	If the temperature of a semiconductor is increased then it's resistance decreases.
	Reason	:	The energy gap between conduction band and valence band is very small [AIIMS 1997]
7.	Assertion	:	The temperature coefficient of resistance is positive for metals and negative for *P-type* semiconductor.
	Reason	:	The effective charge carriers in metals are negatively charged whereas in *P*-type semiconductor they are positively charged. [AIIMS 1996]
8.	Assertion	:	Electron has higher mobility than hole in a semiconductor.
	Reason	:	Mass of electron is less than the mass of hole.
9.	Assertion	:	An *N*-type semiconductor has a large number of electrons but still it is electrically neutral.
	Reason	:	An *N*-type semiconductor is obtained by doping an intrinsic semiconductor with a pentavalent impurity.
10.	Assertion	:	The crystalline solids have a sharp melting point.
	Reason	:	All the bonds between the atoms or molecules of a crystalline solids are equally strong, that they get broken at the same temperature.
11.	Assertion	:	Silicon is preferred over germanium for making semiconductor devices.
	Reason	:	The energy gap for germanium is more than the energy gap of silicon.
12.	Assertion	:	We can measure the potential barrier of a *PN* junction by putting a sensitive voltmeter across its terminals.
	Reason	:	The current through the *PN* junction is not same in forward and reversed bias.
13.	Assertion	:	Semiconductors do not Obey's Ohm's law.
	Reason	:	Current is determined by the rate of flow of charge carriers.

14. Assertion : Two P-N junction diodes placed back to back, will work as a NPN transistor.

Reason : The P-region of two PN junction diodes back to back will form the base of NPN transistor.

15. Assertion : In transistor common emitter mode as an amplifier is preferred over common base mode.

Reason : In common emitter mode the input signal is connected in series with the voltage applied to the base emitter function.

16. Assertion : The dominant mechanism for motion of charge carriers in forward and reverse biased silicon P-N junction are drift in both forward and reverse bias.

Reason : In reverse biasing, no current flow through the junction.

17. Assertion : A transistor is a voltage-operating device.

Reason : Base current is greater than the collector current.

18. Assertion : NAND or NOR gates are called digital building blocks.

Reason : The repeated use of NAND (or NOR) gates can produce all the basic or complicated gates.

19. Assertion : At 0 K Germanium is a superconductor.

Reason : At 0 K Germanium offers zero resistance.

20. Assertion : Base in a transistor is made very thin as compared to collector and emitter regions.

Reason : Due to thin base power gain and voltage gain is obtained by a transistor.

21. Assertion : The current gain in common base circuit is always less than one.

Reason : At constant collector voltage the change in collector current is more than the change in emitter current.

22. Assertion : V-i characteristic of P-N junction diode is same as that of any other conductor.

Reason : P-N junction diode behave as conductor at room temperature.

23. Assertion : Zener diode works on a principle of breakdown voltage.

Reason : Current increases suddenly after breakdown voltage.

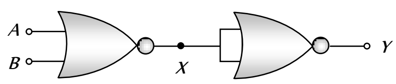
24. Assertion : NOT gate is also called inverter circuit.

Reason : NOT gate inverts the input order.

25. Assertion : In vacuum tubes (valves), vacuum is necessary for the movement of electrons between electrodes otherwise electrons collide with air particle and loses their energy.

Reason : In semiconductors devices, external heating or vacuum is not required.

26. Assertion : The following circuit represents 'OR' gate



Reason : For the above circuit $Y = \overline{X} = \overline{\overline{A+B}} = A+B$

27. Assertion : A P-N photodiode is made from a semiconductor for which E_g = 2.8 eV. This photo diode will not detect the wavelength of 6000 nm.

Reason : A PN photodiode detect wavelength λ if $\frac{hc}{\lambda} > E_g$.

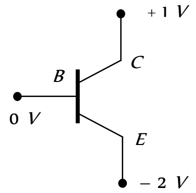
28. Assertion : 29 is the equivalent decimal number of binary number 11101.

Reason : $(11101)_2 = (1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0)_{10}$

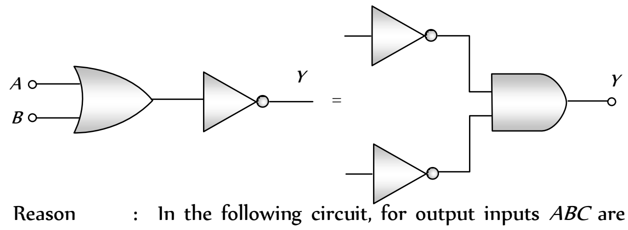
$= (16 + 8 + 4 + 0 + 1)_{10} = (29)_{10}$

29. Assertion : When PN-junction is forward biased then motion of charge carriers at junction is due to diffusion. In reverse biasing. The cause of motion of charge is drifting.

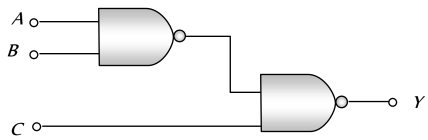
Reason : In the following circuit emitter is reverse biased and collector is forward biased.



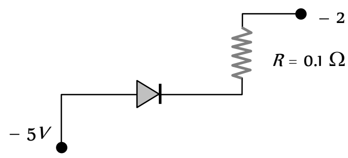
30. Assertion : De-morgan's theorem $\overline{A+B} = \overline{A} \cdot \overline{B}$ may be explained by the following circuit



Reason : In the following circuit, for output inputs ABC are 101



31. Assertion : In the following circuit the potential drop across the resistance is zero.



Reason : The given resistance has low value.

Answers

Solids and Crystals

1	d	2	d	3	d	4	a	5	a
6	a	7	a	8	b	9	a	10	c
11	d	12	c	13	b	14	a	15	a
16	a	17	d	18	b	19	c	20	c
21	b	22	a	23	b	24	a	25	d
26	d	27	d	28	d				

Semiconductors

1	c	2	b	3	d	4	b	5	b
6	b	7	b	8	c	9	d	10	a
11	b	12	a	13	a	14	d	15	c
16	b	17	b	18	b	19	c	20	c
21	d	22	b	23	ac	24	d	25	b
26	c	27	d	28	c	29	c	30	b
31	d	32	a	33	b	34	a	35	c
36	d	37	c	38	b	39	d	40	a
41	d	42	c	43	b	44	c	45	d
46	b	47	a	48	b	49	a	50	d
51	d	52	b	53	b	54	a	55	c
56	d	57	b	58	d	59	a	60	a
61	b	62	a	63	c	64	a	65	b
66	a	67	c	68	c	69	c	70	c
71	b	72	b	73	a	74	b	75	c
76	b	77	c	78	a	79	d	80	a
81	a	82	a	83	b	84	d	85	c
86	d	87	a	88	c	89	b	90	c
91	a	92	b	93	d	94	d	95	d
96	d	97	d	98	a	99	b	100	a
101	b								

Semiconductor Diode

1	b	2	a	3	b	4	b	5	c
6	b	7	a	8	b	9	a	10	a
11	b	12	b	13	b	14	c	15	d
16	c	17	c	18	bc	19	c	20	d
21	d	22	b	23	d	24	c	25	c
26	b	27	b	28	b	29	c	30	b
31	b	32	c	33	d	34	c	35	d
36	a	37	b	38	b	39	d	40	a
41	b	42	a	43	b	44	a	45	a
46	b	47	b	48	a	49	c	50	d
51	d	52	a	53	c	54	c	55	b
56	d	57	a	58	a	59	c	60	a
61	b	62	c	63	a	64	c	65	a
66	b	67	c	68	c	69	d	70	a
71	c	72	a	73	d	74	d	75	c
76	a	77	c	78	c	79	c		

Junction Transistor

1	a	2	c	3	a	4	d	5	d
6	b	7	d	8	b	9	b	10	b
11	c	12	d	13	d	14	a	15	b
16	b	17	d	18	b	19	ac	20	a
21	c	22	a	23	b	24	b	25	b
26	c	27	a	28	b	29	b	30	d
31	b	32	b	33	a	34	b	35	b
36	a	37	a	38	a	39	b	40	a
41	b	42	d	43	d	44	b		

Digital Electronics

1	b	2	c	3	b	4	a	5	b
6	c	7	d	8	b	9	a	10	a
11	d	12	b	13	c	14	a	15	c
16	a	17	b	18	b	19	a	20	a
21	b	22	c	23	b	24	c	25	b
26	c	27	b	28	a	29	a	30	d
31	d								

Valve Electronics

1	c	2	c	3	a	4	b	5	b
6	b	7	c	8	b	9	a	10	a
11	c	12	b	13	b	14	c	15	d
16	b	17	b	18	c	19	c	20	c
21	b	22	b	23	b	24	c	25	a
26	c	27	d	28	a	29	a	30	ad
31	d	32	c	33	c	34	a	35	a
36	c	37	b	38	d	39	b	40	c
41	c	42	b	43	d	44	b	45	c
46	c	47	b	48	b	49	a	50	c
51	a	52	b	53	b	54	a	55	c
56	a	57	a	58	d				

Critical Thinking Questions

1	c	2	a	3	c	4	c	5	abd
6	a	7	a	8	c	9	b	10	b
11	d	12	c	13	a	14	b	15	a
16	d	17	b	18	a	19	a	20	c
21	b	22	a	23	d	24	d	25	a
26	b	27	b	28	d	29	c	30	a
31	b	32	c	33	d	34	b	35	c
36	b	37	d	38	d	39	d	40	b
41	c	42	a	43	a	44	b	45	a
46	c	47	a	48	a	49	b	50	b

Graphical Questions

1	c	2	b	3	c	4	c	5	a

6	b	7	b	8	c	9	b	10	a
11	b	12	a	13	d	14	a	15	d
16	a	17	c	18	c	19	a	20	c
21	c	22	c	23	a	24	b	25	c
26	c	27	b	28	c	29	a	30	d

Assertion and Reason

1	d	2	a	3	c	4	a	5	d
6	a	7	b	8	a	9	b	10	a
11	c	12	e	13	e	14	d	15	b
16	d	17	d	18	a	19	d	20	a
21	c	22	d	23	a	24	a	25	b
26	a	27	a	28	a	29	b	30	c
31	b								

Answers and Solutions

Solids and Crystals

1. (d) Ionic bonds cone into being when atoms that have low ionization energies, and hence lose electrons rapidly, interact with other atoms that and to acquire excess electrons. The former atoms give up electrons to the latter and they there upon become positive and negative ions respectively.

2. (d) For tetragonal, cubic and orthorhombic system $\alpha = \beta = \gamma = 90°$.

3. (d) Tourmaline crystal is biaxial.

4. (a) The temperature co-efficient of resistance of conductor is positive.

5. (a) Density $\rho = \frac{nA}{N(a)^3}$

where $n = 2$ for bcc structure , $A = 39 \times 10^{-3}$ kg,

$N = 6.02 \times 10^{23}$, $a = \frac{2}{\sqrt{3}}d = \frac{2}{\sqrt{3}} \times (4.525 \times 10^{-10})m$

(d = nearest neighbour distance = distance between centres of two neighbouring atoms $= \frac{a}{\sqrt{2}}$)

On putting the values we get $\rho = 907$

6. (a) The highest energy level which an electron can occupy in the valence band at 0 K, is called Fermi energy level.

7. (a) In a triclinic crystal $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90°$

8. (b) Metallic solids are opaque because incident light is absorbed by the free electrons in a metal.

9. (a) In ionic bonding electrons are transferred from one type of atoms to the other type creating positive and negative ions. For example in $NaCl$, Na loses one electrons and Cl gains one so that Na and Cl ions have a stable shell structure.

10. (c) Wood is non-crystalline.

11. (d) Cu has fcc structure, for fcc structure co-ordination number = 12

12. (c) Vander Waal force is weak dipole-dipole interaction.

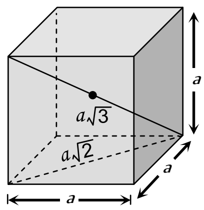
13. (b)

14. (a) The sodium chloride crystal structure has a fcc lattice with one chloride ion at each lattice point and one sodium ion half a cube length above it.

15. (a) In $NaCl$ crystal Na ion is surrounded by $6\,Cl^-$ ion, therefore coordination number of Na is 6.

16. (a) Sodium has bcc structure. The distance between body centre and a corner $= \frac{\sqrt{3}\,a}{2}$

$= \frac{\sqrt{3} \times 4.225}{2} = 3.66\ \mathring{A}$

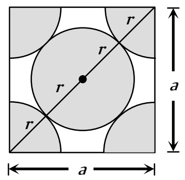


17. (d)

18. (b) For the fcc structure

$4r = (a^2 + a^2)^{1/2} = a\sqrt{2}$

$\Rightarrow r = \frac{a\sqrt{2}}{4} = \frac{a}{2\sqrt{2}}$



19. (c) Metals reflects incident light by the vibrations of free electrons under the influence of electric field of incident wave. The conductivity of metals decreases with increase of temperature due to increase in random motion of free electrons. The bonding is therefore metallic.

20. (c)

21. (b) The nearest distance between two atoms in a bcc lattice = 2 (atomic radius) $= 2 \times \left(\frac{\sqrt{3}\,a}{4}\right) = \frac{\sqrt{3}a}{2}$

22. (a) The net force on electron placed at the centre of bcc structure is zero. (By the principle of superposition of couloumb forces)

23. (b) For bcc packing, distance between two nearest atoms

$d = 2r = 2\left(\frac{\sqrt{3}\,a}{4}\right)$

$\Rightarrow$ Lattice constant $a = \frac{2d}{\sqrt{3}} = \frac{2 \times 3.7}{\sqrt{3}} = 4.3\mathring{A}$

24. (a)

25. (d) $\sqrt{2}\,a = 4r \Rightarrow a = \frac{4r}{\sqrt{2}} = \sqrt{2}(2r) = \sqrt{2} \times 2.54 = 3.59\ \mathring{A}$

26. (d)

27. (d) Covalent bonding exists in semi-conductor.

28. (d) In H_2O covalent bonding is present.

Semiconductors

1. (c) In P-type semiconductors, holes are the majority charge carriers

2. (b) Ga has a valancy of 3.

3. (d) Ge + Trivalent impurity → P-type semiconductor

4. (b) Since $n_e > n_h$; the semiconductor is N-type.

5. (b) Absence of one electron, creates the positive charge of magnitude equal to that of electronic charge.

6. (b) [Ge] + [Pantavalent impurity] → [N - type semiconductor]

7. (b) Impurity increases the conductivity.

8. (c) [Intrinsic semiconductor] → Conductivity is due to the breaking of covalent bond

[Extrisnsic semiconductor] → Conductivity is due to the breaking of covalent bond and excess of charge carriers due to impurity.

9. (d) Resistance of conductors (*Cu*) decreases with decrease in temperature while that of semi-conductors (*Ge*) increases with decrease in temperature.

10. (a) Aluminum is trivalent impurity.

11. (b) With temperature rise conductivity of semiconductors increases.

12. (a)

13. (a) Similar to Q. 11

14. (d) In insulators, the forbidden energy gap is largest and it is of the order of 6 *eV*.

15. (c) *N*-type semiconductors are neutral because neutral atoms are added during doping.

16. (b)

17. (b) In insulators, the forbidden energy gap is very large, in case of semiconductor it is moderate and in conductors the energy gap is zero.

18. (b) Similar to Q. 15.

19. (c) Phosphorus is pentavalent.

20. (c) In intrinsic semiconductors, the creation or liberation of one free electron by the thermal energy has created one hole. Thus in intrinsic semiconductors $n = n$

21. (d) Conductor has positive temperature coefficient of resistance but semiconductor has negative temperature coefficient of resistance.

22. (b) Boron is trivalent.

23. (a, c) In intrinsic semiconductors, electrons and holes both are charge carriers. In *P*-type semiconductors (Extrinsic semiconductors) holes are majority charge carriers.

24. (d)

25. (b)

26. (c) $\Delta E_{g(Germanium)} = 0.67\ eV$

27. (d) In *P*-type semiconductors, holes are majority charge carrier and electrons are minority charge carriers.

28. (c) At zero Kelvin, there is no thermal agitation and therefore no electrons from valence band are able to shift to conduction band.

29. (c) Antimony is a fifth group impurity and is therefore a donor of electrons.

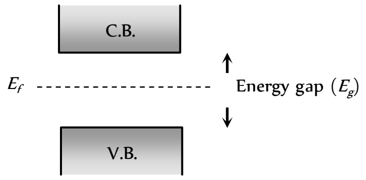
30. (b) Resistance of semiconductor $\propto \frac{1}{\text{Temperature}}$

31. (d) [Extrinsic S.C.] → $P - \text{Type}\,(n_p >> n_e)$; → $N - \text{Type}\,(n_e >> n_p)$

32. (a) At room temperature the number of electrons and holes are equal in the intrinsic semiconductor.

33. (b) Indium is trivalent, hence on doping with it, the intrinsic semiconductor becomes *P*-type semiconductor.

34. (a)



35. (c) In semiconductors, Forbidden energy gap is of the order of 1 *eV*.

36. (d) At 0*K* temperature semiconductor behaves as an insulator, because at very low temperature electrons cannot jump from the valence band to conduction band.

37. (c) Antimony is pentavalent.

38. (b) At 0*K* semiconductor behaves as insulator so it's resistance is infinite.

39. (d) The conduction and valence bands in the conductors merge into each other.

40. (a) For *N*-type semiconductor, the impurity should be pentavalent.

41. (d) When a free electron is produced, simultaneously a hole is also produced.

42. (c) For $P -$ type semiconductor the doping impurity should be trivalent.

43. (b) The temperature co-efficient of resistance of a semiconductor is always negative.

44. (c) The resistance of semiconductor decreases with the increase in temperature.

45. (d) At absolute zero temperature, semiconductor.

46. (b) Formation of energy bands in solids are due to Pauli's exclusion principle.

47. (a) In *P*-type semiconductors, holes are majority charge carriers.

48. (b)

49. (a) Conductivity of semiconductors increases with rise in temperature.

50. (d) All are trivalent in nature.

51. (d) In *N*-type semiconductors, electrons are majority charge corners.

52. (b) When a strong current passes through the semiconductor it heats up the crystal and covalent bond are broken. Hence because of excess number of free electrons it behaves like a conductor.

53. (b)

54. (a) Phosphorus is a pentavalent impurity so $n > n$.

55. (c) Phosphorus is pentavalent while Indium is trivalent.

56. (d) Phosphorus and Arsenic both are pentavalent.

57. (b)

58. (d)

59. (a) For *Ge*, $E_g = 0.7\,eV = 0.7 \times 1.6 \times 10^{-19}\,J = 1.12 \times 10^{-19}\,J$

60. (a) At room temperature some covalent bond breaks and semiconductor behaves slightly as a conductor.

61. (b)

62. (a)

63. (c) Because boron is a trivalent impurity.

64. (a) In P-type semi conductor, holes are majority charge carriers.

65. (b) In intrinsic semiconductors, at room temperature $n_e = n_h$.

66. (a) In conductors valence band and conduction band overlaps.

67. (c) Because As is pentavalent impurity.

68. (c) At 0 K semiconductor behaves as an insulator.

69. (c)

70. (c)

71. (b) Antimony and phosphorous both are pentavalent.

72. (b) Gallium is trivalent impurity.

73. (a)

74. (b) One atom of pentavalent impurity, donates one electron.

75. (c)

76. (b) The charge on hole is positive.

77. (c) Phosphorus is pentavalent impurity.

78. (a) $n_i^2 = n_h n_e \Rightarrow (10^{19})^2 = 10^{21} \times n_e \Rightarrow n_e = 10^{17} / m^3$.

79. (d) Temperature co-efficient of semiconductor is negative.

80. (a) Copper, Aluminum, Iron are conductors, while Ge is semiconductor.

81. (a) At room temperature, few bonds breaks and electron hole pair generates inside the semiconductor.

82. (a)

83. (b) With rise in temperature, conductivity of semiconductor increases while resistance decreases.

84. (d) Gallium, boron and aluminum are trivalent.

85. (c) Because with rise in temperature, resistance of semiconductor decreases, hence overall resistance of the circuit increases, which in turn increases the current in the circuit.

86. (d) Extrinsic semiconductor (N-type or P-type) are neutral.

87. (a) Because $v_d = \dfrac{i}{(n_e)eA}$

88. (c)

89. (b) Resistivity is the intrinsic property, it doesn't depend upon length and shape of the semiconductors.

90. (c)

91. (a) $\lambda_{max} = \dfrac{hc}{E} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{1.14 \times 1.6 \times 10^{-19}} = 10888 Å$

92. (b) In N-type semiconductor impurity energy level lies just below the conduction band.

93. (d)

94. (d)

95. (d) $\sigma = e n_e \mu_e$

$$\Rightarrow n_e = \frac{\sigma}{e\mu_e} = \frac{6.24}{1.6 \times 10^{-19 \times 3900}} = 10^{16} / cm^3$$

96. (d) In semiconductors, the forbidden energy gap between the valence band and conduction band is very small, almost equal to kT. Moreover, valence band is completely filled where as conduction band is empty.

97. (d) In sample x no impurity level seen, so it is undoped. In sample y impurity energy level lies below the conduction bond so it is doped with fifth group impurity.

In sample z, impurity energy level lies above the valence band so it is doped with third group impurity.

98. (a) Forbidden energy gap for carbon is greater than that of silicon.

99. (b)

100. (a) Because electrons needed less energy to move.

101. (b)

Semiconductor Diode

1. (b)

2. (a) In forward biased *PN*-junction, external voltage decreases the potential barrier, so current is maximum. While in reversed biased *PN*-junction, external voltage increases the potential barrier, so the current is very small.

3. (b)

4. (b) Filter circuits are used to get smooth *dc* π -filter is the best filter.

5. (c) In reverse bias no current flows.

6. (b) In reverse biasing, width of depletion layer increases.

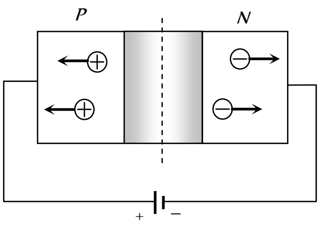
7. (a) Depletion layer consist of mainly stationary ions.

8. (b) Current flow is possible and $i = \frac{V}{R} = \frac{(4-1)}{300} = 10^{-2} A$

9. (a) The potential of *P*-side is more negative that of *N*-side, hence diode is in reverse biasing. In reverse biasing it acts as open circuit, hence no current flows.

10. (a)

11. (b) It is used to convert *ac* into *dc* (rectifier)



12. (b)

13. (b) Because in case (1) N is connected with N. This is not a series combination of transistor.

14. (c)

15. (d)

16. (c) After a large reverse voltage is *PN*-junction diode, a huge current flows in the reverse direction suddenly. This is called Breakdown of *PN*-junction diode.

17. (c) In forward biasing both positive and negative charge carriers move towards the junction.

18. (b,c)

19. (c) When polarity of the battery is reversed, the *P-N* junction becomes reverse biased so no current flows.

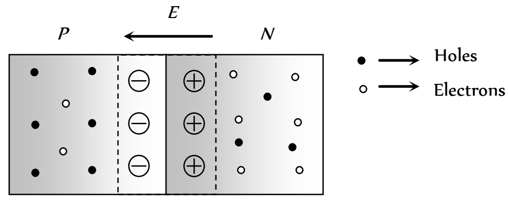
20. (d) Resistance in forward biasing $R_{fr} \approx 10\,\Omega$ and resistance in reverse biasing $R_{Rw} \approx 10^5 \Omega \Rightarrow \frac{R_{fr}}{R_{Rw}} = \frac{1}{10^4}$

21. (d)

22. (b) In forward biasing width of depletion layer decreases.

23. (d)

24. (c) At junction a potential barrier/depletion layer is formed, with *N*-side at higher potential and *P*-side at lower potential. Therefore there is an electric field at the junction directed from the *N*-side to *P*-side



25. (c) In *N*-type semiconductor majority charge carriers are electrons.

26. (b) In forward biasing the diffusion current increases and drift current remains constant so not current is due to the diffusion.

In reverse biasing diffusion becomes more difficult so net current (very small) is due to the drift.

27. (b) At a particular reverse voltage in *PN*-junction, a huge current flows in reverse direction known as avalanche current.

28. (b) Due to the large concentration of electrons in *N*-side and holes in *P*-side, they diffuses from their own side to other side. Hence depletion region produces.

29. (c) Only in option (c), *P*-side is more negative as compared to *N*-side.

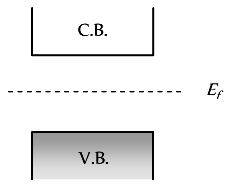
30. (b) Depletion layer is more in less doped side.

31. (b) In forward biasing *P*-side is connected with positive terminal and *N*-side with negative terminal of the battery

32. (c) In forward biasing of *PN*-junction diode, current mainly flows due to the diffusion of majority charge carriers.

33. (d)

34. (c) In forward biasing of *PN* junction diode width of depletion layer decreases. In intrinsic semiconductor fermi energy level is exactly in the middle of the forbidden gap



35. (d)

36. (a) At high reverse voltage, the minority charge carriers, acquires very high velocities. These by collision break down the covalent bonds, generating more carriers. This mechanism is called Avalanche breakdown.

37. (b) Because *P*-side is more negative as compared to *N*-side.

38. (b) When reverse bias is increased, the electric field at the junction also increases. At some stage the electric field breaks the covalent bond, thus the large number of charge carriers are generated. This is called Zener breakdown.

39. (d) In forward biasing both V and x decreases.

40. (a)

41. (b) In figure 2,4 and 5. *P*-crystals are more positive as compared to *N*-crystals.

42. (a) *ac* → Rectifier → *dc*

43. (b) In this condition $P-N$ junction is reverse biased.

44. (a)

45. (a) $E = \frac{V}{d} = \frac{0.5}{5 \times 10^{-7}} = 10^6\ V/m$.

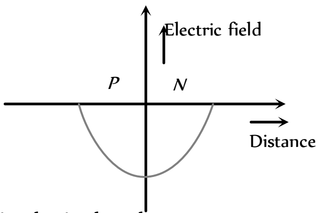
46. (b) Across the $P-N$ junction, a barrier potential is developed whose direction is from N region to P region.

47. (b)

48. (a) In forward biasing, resistance of PN junction diode is zero, so whole voltage appears across the resistance.

49. (c)

50. (d) The electric field strength versus distance curve across the *P-N* junction is as follows



51. (d)

52. (a) It doesn't Obey's ohms law.

53. (c) Because *N*-side is more positive as compared to *P*-side.

54. (c) When a light (wavelength sufficient to break the covalent bond) falls on the junction, new hole electron pairs are created. No. of produced electron hole pair deponed upon no. of photons. So photo emf or current proportional to intensity of light.

55. (b)

56. (d) For full wave rectifier $\eta = \dfrac{81.2}{1+\dfrac{r_f}{R_L}}$

$\Rightarrow n_{max} = 81.2\%$ $(r_f << R_L)$

57. (a)

58. (a)

59. (c) In reverse biasing negative terminal of the battery is connected to *N*-side.

60. (a) In the given condition diode is in reverse biasing so it acts as open circuit. Hence potential difference between *A* and *B* is 6 *V*

61. (b) Zener breakdown can occur in heavily doped diodes. In lightly doped diodes the necessary voltage is higher, and avalanche multiplication is then the chief process involved.

62. (c)

63. (a)

64. (c) Diode acts as open switch only when it is reverse biased

65. (a) Because *P*-side is more negative than *N*-side.

66. (b) In unbiased condition of *PN*-junction, depletion region is generated which stops the movement of charge carriers.

67. (c) For a wide range of values of load resistance, the current in the zener diode may change but the voltage across it remains unaffected. Thus the output voltage across the zener diode is a regulated voltage.

68. (c)

69. (d) Arsenic has five valence electrons, so it a donor impurity. Hence *X* becomes *N*-type semiconductor. Indium has only three outer electrons, so it is an acceptor impurity. Hence *Y* becomes *P*-type semiconductor. Also *N* (*i.e. X*) is connected to positive terminal of battery and *P*(*i.e. Y*) is connected to negative terminal of battery so *PN*-junction is reverse biased.

70. (a)

71. (c) In photodiode, it is illuminated by light radiations, which in turn produces electric current.

72. (a)

73. (d)

74. (d) By using $E = \dfrac{V}{d} = \dfrac{0.6}{10^{-6}} = 6\times10^5\ V/m$

75. (c) The given circuit is full wave rectifier.

76. (a) The diode is in reverse biasing so current through it is zero.

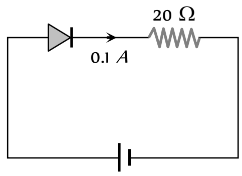
77. (c) In full wave rectifier, the fundamental frequency in ripple is twice that of input frequency.

78. (c)

79. (c) $V' = V + IR$

$= 0.5 + 0.1 \times 20$

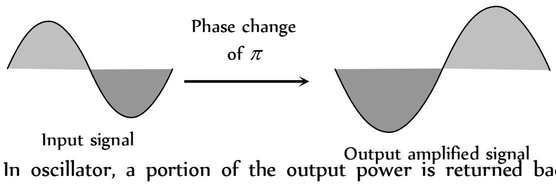
$= 2.5\ V$



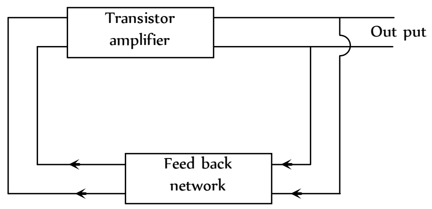
Junction Transistor

1. (a) When *NPN* transistor is used as an amplifier, majority charge carrier electrons of *N*-type emitter move from emitter to base and than base to collector.

2. (c)



3. (a) In oscillator, a portion of the output power is returned back (feed back) to the input in phase with the starting power. This process is termed as positive feedback.

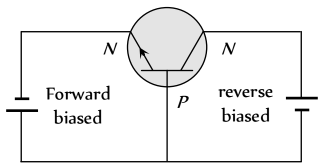


4. (d) The emitter base junction is forward biased while collector base junction is reversed biased.

5. (d) Given $i_c = \dfrac{80}{100}\times i_e \Rightarrow 24 = \dfrac{80}{100}\times i_e \Rightarrow i_e = 30\,mA$

By using $i_e = i_b + i_c \Rightarrow i_b = 30 - 24 = 6\ mA$.

6. (b)



7. (d) α is the ratio of collector current and emitter current while β is the ratio of collector current and base current.

8. (b)

9. (b) $\beta = \dfrac{\alpha}{1-\alpha} = \dfrac{0.98}{1-0.98} = 49.$

10. (b) $\beta = \dfrac{\alpha}{1-\alpha} = \dfrac{0.96}{1-0.96} = 24.$

11. (c) $\alpha = \frac{i_c}{i_e}$ =0.96 and i_e = 7.2 mA

$\Rightarrow i_c = 0.96 \times i_e$ = 0.96 × 7.2 = 6.91 mA

$\therefore i_e = i_c + i_b \Rightarrow$ 7.2 = 6.91 + $i_b \Rightarrow i_b$ = 0.29 mA.

12. (d)

13. (d) $i_C = \frac{90}{100} \times i_E \Rightarrow$ 10 = 0.9 × i_e = 11mA

Also $i_E = i_B + i_C \Rightarrow i_B = 11 - 10 = 1mA$.

14. (a) Current gain $\beta = \frac{\Delta i_c}{\Delta i_b} \Rightarrow \Delta i_c = \beta \times \Delta i_b$ = 80 × 250 μA.

15. (b) In transistor, base is least doped.

16. (b)

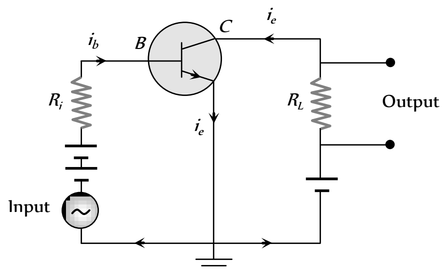
17. (d) β = 50, R_i = 1000 Ω, V_i = 0.01V

$$\beta = \frac{i_c}{i_b} \text{ and } i_b = \frac{V_i}{R_i} = \frac{0.01}{10^3} = 10^{-5} A$$

Hence $i_c = 50 \times 10^{-5} A = 500\, \mu A$.

18. (b) $\alpha = \frac{\beta}{1+\beta} = \frac{99}{1+99} = 0.99$.

19. (a,c) The circuit of a CE amplifier is as shown below.



This has been shown a NPN transistor. Therefore base emitter are forward, biased and input signal is connected between base and emitter.

20. (a) The base is always thin

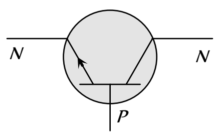
21. (c) Voltage gain = β × Resistance gain

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{(1-0.99)} = 99$$

Resistance gain $= \frac{10 \times 10^3}{10^3} = 10$

$\Rightarrow$ Voltage gain = 99 × 10 = 990.

22. (a) The arrow head in the transistor symbol always shows the direction of hole flow in the emitter region.



23. (b)

24. (b) Because emitter (N) is common to both, base (P) and collector (N).

25. (b) Emitter is heavily doped.

26. (c) α = 0.8 $\Rightarrow \beta = \frac{0.8}{(1-0.8)}$ =4

Also $\beta = \frac{\Delta i_c}{\Delta i_b} \Rightarrow \Delta i_c = \beta \times \Delta i_b$ = 4 × 6 = 24mA.

27. (a) $\Delta i_c = \alpha\, \Delta i_e = 0.98 \times 2 = 1.96\, mA$

$\therefore \quad \Delta i_b = \Delta i_e - \Delta i_c = 2 - 1.96 = 0.04\, mA$.

28. (b) $i_e = i_b + i_c \Rightarrow i_c = i_e - i_b$

29. (b) $V_b = i_b R_b \Rightarrow R_b = \frac{9}{35 \times 10^{-6}}$ =257 $k\Omega$.

30. (d) $\Delta i_e = \Delta i_c + \Delta i_b$

$\Rightarrow$ 8 = 7.8 + $\Delta i_b \Rightarrow \Delta i_b$ =0.2mA = 200 μA.

31. (b) $\beta = \frac{i_c}{i_b}$

32. (b) FET is unipolar.

33. (a)

34. (b) $i_e = i_b + i_c \Rightarrow \frac{i_e}{i_c} = \frac{i_b}{i_c} + 1 \Rightarrow \frac{1}{\alpha} = \frac{1}{\beta} + 1 \Rightarrow \alpha = \frac{\beta}{(1+\beta)}$.

35. (b) In NPN transistor when emitter-base is forward biased, electrons move from emitter to base.

36. (a) Here $\Delta V_c = 0.5\, V$, Δi_c =0.05mA = 0.05 × 10^{-3}A

Output resistance is given by

$$R_{out} = \frac{\Delta V_c}{\Delta i_c} = \frac{0.5}{0.05 \times 10^{-3}} = 10^4 \Omega = 10 k\Omega.$$

37. (a) Oscillator can produce radio waves of constant amplitude.

38. (a) $h_{fe} = \left(\frac{\Delta i_c}{\Delta i_b}\right)_{V_{ce}} = \frac{8.2}{8.3 - 8.2} = 82$

39. (b) Current gain $\beta = \frac{\Delta i_c}{\Delta i_b} \Rightarrow \Delta i_b = \frac{1 \times 10^{-3}}{100} = 10^{-5} A$ =0.01mA.

By using $\Delta i_e = \Delta i_b + \Delta i_c \Rightarrow \Delta i_e$ = 1.01 + 1 = 1.01mA.

40. (a) In CB amplifier Input and output voltage signal are in same phase.

41. (b)

42. (d)

43. (d) For CE configuration voltage gain $= \beta \times R_L / R_i$

Power gain $= \beta^2 \times R_L / R_i \Rightarrow \frac{\text{Power gain}}{\text{Voltage gain}} = \beta$

44. (b) As we know $i_E = i_C + i_B$

$$\Rightarrow \frac{i_e}{i_c} = 1 + \frac{i_b}{i_c} \Rightarrow \frac{1}{\alpha} = 1 + \frac{1}{\beta} \Rightarrow \beta = \frac{\alpha}{1-\alpha}.$$

Digital Electronics

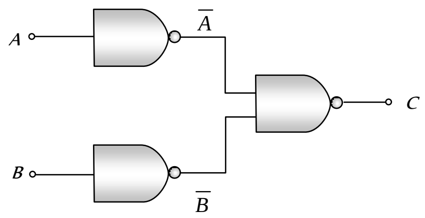
1. (b)

2. (c)

3. (b) For 'OR' gate $X = A + B$

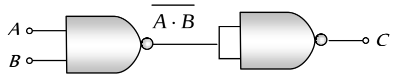
i.e. $0+0=0$, $0+1=1$, $1+0=1$, $1+1=1$

4. (a)



$C=\overline{\bar A.\bar B}=\overline{\bar A}+\overline{\bar B}=A+B$ (De morgan's theorem)

Hence output C is equivalent to OR gate.



$C=\overline{\overline{AB}.\overline{AB}}=\overline{\overline{AB}}+\overline{\overline{AB}}=AB+AB=AB$

In this case output C is equivalent to AND gate.

5. (b) In 'NOR' gate $Y=\overline{A+B}$

i.e. $\overline{0+0}=\bar 0=1$, $\overline{1+0}=\bar 1=0$

$\overline{0+1}=\bar 1=0$, $\overline{1+1}=\bar 1=0$

6. (c) For 'XNOR' gate $Y=\bar A\,\bar B+AB$

i.e. $\bar 0.\bar 0+0.0=1.1+0.0=1+0=1$

$\bar 0.\bar 1+0.1=1.0+0.1=0+0=0$

$\bar 1.\bar 0+1.0=0.1+1.0=0+0=0$

$\bar 1.\bar 1+1.1=0.0+1.1=0+1=1$

7. (d) The output D for the given combination

$D=\overline{(A+B).C}=\overline{(A+B)}+\bar C$

If $A=B=C=0$ then $D=\overline{(0+0)}+\bar 0=\bar 0+\bar 0=1+1=1$

If $A=B=1, C=0$ then $D=\overline{(1+1)}+\bar 0=\bar 1+\bar 0=0+1=1$

8. (b)

9. (a) The Boolean expression for 'NOR' gate is $Y=\overline{A+B}$

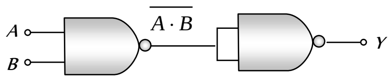
i.e. if $A=B=0$ (Low), $Y=\overline{0+0}=\bar 0=1$ (High)

10. (a)

11. (d) The Boolean expression for 'AND' gate is $R=P.Q$

$\Rightarrow 1.1=1,\ 1.0=0,\ 0.1=0,\ 0.0=0$

12. (b) Two 'NAND' gates are required as follows



$Y=\overline{\overline{AB}.\overline{AB}}=AB$

13. (c) For 'NAND' gate (option c), output $=\overline{0.1}=\bar 0=1$

14. (a) AND + NOT $\rightarrow$ NAND

15. (c) For 'NOT' gate $X=\bar A$

16. (a) The given Boolean expression can be written as

$Y=\overline{(A+B)}.\overline{(A.B)}=(\bar A.\bar B).(\bar A+\bar B)=(\bar A\,\bar A).\bar B+\bar A(\bar B.\bar B)$

$=\bar A.\bar B+\bar A\,\bar B=\bar A\,\bar B$

A	B	Y
0	0	1
1	0	0
0	1	0
1	1	0

17. (b) For 'AND' gate, if output is 1 then both inputs must be 1.

18. (b)

19. (a)

20. (a) The given symbol is of 'AND' gate.

21. (b) It is the symbol of 'NOR' gate.

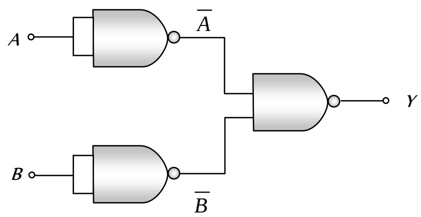
22. (c) The Boolean expression for the given combination is output $Y=(A+B).C$

The truth table is

A	B	C	Y =(A+B).C
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Hence $A=1$, $B=0$, $C=1$

23. (b)



$Y=\overline{\bar A.\bar B}=\bar{\bar A}+\bar{\bar B}=A+B$

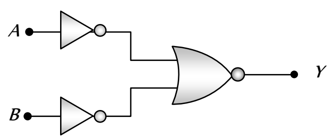
This output equation is equivalent to OR gate.

24. (c) If inputs are A and B then output for NAND gate is $Y=\overline{AB}$

$\Rightarrow$ If $A=B=1$, $Y=\overline{1.1}=\bar 1=0$

25. (b)

26. (c)



$Y=\overline{\bar A+\bar B}$

According to De morgan's theorem

$Y=\overline{\bar A+\bar B}=\bar{\bar A}.\bar{\bar B}=A.B$

This is the output equation of 'AND' gate.

27. (b) The output of OR gate is $Y = A + B$.

28. (a) The given symbol is of NAND gate.

29. (a) $(100010)_2 = 2^5 \times 1 + 2^4 \times 0 + 2^3 \times 0 + 2^2 \times 0 +$

$2^1 \times 1 + 2^0 \times 0 = 32 + 0 + 0 + 0 + 2 + 0 = (34)_{10}$

and $(11011)_2 = 2^4 \times 1 + 2^3 \times 1 + 2^2 \times 0 + 2^1 \times 1 + 2^0 \times 1$

$= 16 + 8 + 0 + 2 + 1 = (27)_{10}$

$\therefore$ Sum $(100010)_2 + (11011)_2 = (34)_{10} + (27)_{10} = (61)_{10}$

Now

2	61	Remainder
2	30	1 LSD
2	15	0
2	7	1
2	3	1
2	1	1
	0	1 MSD

$\therefore$ Required sum (in binary system)

$(100010)_2 + (11011)_2 = (111101)_2$

30. (d) For 'NAND' gate $C = \overline{A.B}$

i.e. $\overline{0.0} = \overline{0} = 1$, $\overline{0.1} = \overline{0} = 1$

$\overline{1.0} = \overline{0} = 1$, $\overline{1.1} = \overline{1} = 0$

31. (d) 'NOR' gates are considered as universal gates, because all the gates like AND, OR, NOT can be obtained by using only NOR gates.

Valve Electronics (Diode and Triode)

1. (c) According to Richardson-Dushman equation, number of thermions emitted per sec per unit area $J = AT^2 e^{-W_0/kT} \Rightarrow J \propto T^2$

2. (c) Intensity $\propto$ Number of electrons

3. (a) In SCR (Space charge region) electrons collect around the plate, this cloud decreases the emission of electrons from the cathode, hence plate current decreases.

4. (b)

5. (b) By using $g_m = \frac{\Delta i_p}{\Delta v_g} \Rightarrow 3 \times 10^{-4} = \frac{\Delta i_p}{-1-(-3)}$

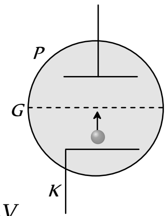
$\Rightarrow \Delta i_p = 6 \times 10^{-4} A = 0.6\, mA$

6. (b) Voltage gain $A_v = \frac{\mu}{1 + \frac{r_p}{R_L}}$ and $\mu = r_p \times g_m$

$\Rightarrow r_p = \frac{42}{2 \times 10^{-3}} = 21000\,\Omega \Rightarrow A_v = \frac{42}{1 + \frac{21000}{50 \times 10^3}} = 29.57$

7. (c) Voltage gain $A_v = \frac{\mu}{1 + \frac{r_p}{R_L}}$, for $r_p = R_L \Rightarrow A_v = \frac{\mu}{2}$

8. (b) When grid is given positive potential more electrons will cross the grid to reach the positive plate *P*. Hence current increases.



9. (a) By using $\mu = -\frac{\Delta V_p}{\Delta V_g} = r_p \times g_m$

$\Rightarrow 7 \times 10^3 \times 2.5 \times 10^{-3} = -\frac{50}{\Delta V_g} \Rightarrow \Delta V_g = -2.86\, V$.

10. (a) Using voltage gain $A_v = \frac{\mu}{1 + \frac{r_p}{R_L}}$ also $\mu = r_p \times g_m$

$\Rightarrow r_p = \frac{\mu}{g_m} = \frac{20}{3 \times 10^{-3}}$

$\therefore A_v = \frac{20}{1 + \frac{20}{3 \times 10^{-3} \times 3 \times 10^4}} = \frac{180}{11} = 16.36.$

11. (c) Voltage gain $= \frac{V_{out}}{V_{in}} = \frac{\mu}{1 + \frac{r_p}{R_L}} \Rightarrow \frac{V_{out}}{0.5} = \frac{25}{1 + \frac{40 \times 10^3}{10 \times 10^3}}$

$\Rightarrow V_{out} = 2.5\, V$.

12. (b) $\mu = -\frac{\Delta V_p}{\Delta V_G} \Rightarrow \Delta V_p = -\mu \Delta V_G = -20 \times (-0.2) = 4\, V$.

13. (b) Voltage gain $A_V = \frac{\mu}{1 + \frac{r_p}{R_L}}$ and $\mu = r_p \times g_m$

$\Rightarrow \mu = 10 \times 10^3 \times 3 \times 10^{-3} = 30$

$\therefore A_v = \frac{\mu}{1 + \frac{r_p}{2r_p}} = \frac{2}{3}\mu = \frac{2}{3} \times 30 = 20.$

14. (c)

15. (d) After saturation plate current can be increased by increasing the temperature of filament. It can be done by increasing the filament current.

16. (b) The maximum voltage gain $(A)_{max} = \mu$

(Which is obtained when $R_L = \infty$).

17. (b) Voltage gain $A_v = \frac{\mu}{1 + \frac{r_p}{R_L}}$

$\because R_L = 1.5\, r_p \Rightarrow A_v = \frac{\mu}{1 + \frac{r_p}{1.5\, r_p}} = \frac{3}{5}\mu = \frac{3}{5} \times 20 = 12$.

18. (c)

19. (c)

20. (c) $\mu = \frac{\Delta V_p}{\Delta V_g} \Rightarrow \Delta V_p = \mu \Delta V_g = 15 \times 0.3 = 4.5$ *volt.*

21. (b) Plate resistance $=\dfrac{1}{\text{slope}}=\dfrac{1}{10^{-3}\times10^{-3}}=10^6\Omega$

$= 1000\ k\Omega$ (static).

22. (b) Using $A_v=\dfrac{\mu}{1+\dfrac{r_p}{R_L}}$ and $\mu=r_p\times g_m$

$\Rightarrow r_p=\dfrac{\mu}{g_m}=\dfrac{50}{2\times10^{-3}}=25\times10^3\Omega$

$\therefore A_v=\dfrac{50}{1+\dfrac{25\times10^3}{25\times10^3}}=25.$

23. (b) $P=Vi\Rightarrow V=\dfrac{P}{i}=\dfrac{448\times10^{-3}}{14\times10^{15}\times1.6\times10^{-19}}=200V$

24. (c) $\mu=\dfrac{(V_{p_1}-V_{p_2})}{(V_{G_1}-V_{G_2})}=\dfrac{(200-220)}{(0.5-1.3)}=25.$

25. (a) $\mu=r_p\times g_m\Rightarrow g_m=\dfrac{\mu}{r_p}=\dfrac{22}{6600}=\dfrac{1}{300}.$

26. (c) $r_p=\dfrac{V_{p_1}-V_{p_2}}{I_{p_1}-I_{p_2}}=\dfrac{75-100}{(2-4)\times10^{-3}}=12.5\times10^3\Omega=12.5k\Omega.$

27. (d)

28. (a)

29. (a) Voltage amplification $A_v=\dfrac{\mu}{1+\dfrac{r_p}{R_L}}$

$\Rightarrow\ 25=\dfrac{\mu}{1+\dfrac{r_p}{50\times10^3}}$ ......(i)

and $30=\dfrac{\mu}{1+\dfrac{r_p}{100\times10^3}}$ ......(ii)

an solving equation (i) and (ii), $r_p=25k\Omega.$

30. (a, d)

31. (d)

32. (c) Before saturation region, linear region comes. In linear region $i_p\propto V_p$

$\Rightarrow\dfrac{i_1}{i_2}=\dfrac{V_{p_1}}{V_{p_2}}=\dfrac{400}{200}=\dfrac{2}{1}.$

33. (c) $i_p = 1.125 - 1.112 = 0.013A = 13\ mA.$

34. (a)

35. (a)

36. (c) Comparing the given equation with standard equation

$i=AT^2e^{qV/kT}\Rightarrow V_L=\dfrac{kT}{V}.$

37. (b)

38. (d) $r_p=\dfrac{\Delta V_p}{\Delta i_p}=\dfrac{150-100}{(12-7.5)\times10^{-3}}=\dfrac{50}{4.5}\times10^3=11.1k\Omega.$

39. (b)

40. (c) Voltage amplification $A_v=\dfrac{\mu}{1+\dfrac{r_p}{R_L}}=\dfrac{\mu R_L}{R_L+r_p}$

$\Rightarrow\dfrac{A_1}{A_2}=\dfrac{2+4}{4+4}=\dfrac{3}{4}.$

41. (c) A diode is used as a rectifier to convert *ac* in to *dc*.

42. (b) Fluctuating *dc* → Filter circuit → smooth *dc*.

43. (d)

44. (b)

45. (c) $\mu=r_p\times g_m\Rightarrow r_p=\dfrac{20}{10^{-3}}=2\times10^4\Omega.$

46. (c)

47. (b) $\mu=-\dfrac{\Delta V_p}{\Delta V_g}$

$\Rightarrow\Delta V_p=-\mu\times\Delta V_g=-50(-0.20)=10\,V.$

48. (b) $r_p=\dfrac{1}{\text{slope}}=\dfrac{1}{2\times10^{-2}\times10^{-3}}=50k\Omega.$

49. (a) Voltage amplification $A_v=\dfrac{\mu}{1+\dfrac{r_p}{R_L}}=\dfrac{r_p\times g_m\times R_L}{R_L+r_p}$

$\Rightarrow10=\dfrac{20\times10^3\times2.5\times10^{-3}\times R_L}{(R_L+20\times10^3)}\Rightarrow R_L=5k\Omega.$

50. (c) Voltage gain $A_v=\dfrac{\mu}{1+\dfrac{r_p}{R_L}}=\dfrac{18}{1+\dfrac{8\times10^3}{10^4}}=10.$

51. (a) Ripple factor $r=\sqrt{\left(\dfrac{I_{rms}}{I_{dc}}\right)^2-1}=\sqrt{\dfrac{(I_0/2)^2}{(I_0/\pi)^2}-1}=1.21.$

52. (b)

53. (b)

54. (a) $\mu=r_p\times g_m=2.5\times10^4\times2\times10^{-3}=50.$

55. (c) $\mu=\left(\dfrac{\Delta V_p}{\Delta V_g}\right)_{i_p=\text{constant}}=\dfrac{(225-200)}{(5.75-5)}=33.3$

56. (a) $g_m=\left(\dfrac{\Delta I_p}{\Delta V_g}\right)_{V_p=\text{constant}}=\dfrac{(7.5-5.5)}{-1.2-(-2.2)}=2m\,mho$

57. (a)

58. (d) Using $\mu=r_p\times g_m\Rightarrow g_m=\dfrac{20}{10\times10^3}=2\times10^{-3}.$

Critical Thinking Questions

1. (c) Number density of atoms in silicon specimen $= 5\times10^{28}$ *atom/m*^{3} $= 5\times10^{22}$ *atom/cm*^{3}

Since one atom of indium is doped in 5×10^7 *Si* atom. So number of indium atoms doped per *cm*^{3} of silicon.

$$n=\frac{5\times10^{22}}{5\times10^7}=1\times10^{15}\ atom/cm^3.$$

2. (a) The probability of electrons to be found in the conduction band of an intrinsic semiconductor

$P(E)=\dfrac{1}{1+e^{\frac{(E-E_F)}{kT}}}$; where k = Boltzmann's constant

Hence, at a finite temperature, the probability decreases exponentially with increasing band gap.

3. (c) When donor impurity (+5 valence) added to a pure silicon (+4 valence), the +5 valence donor atom sits in the place of + 4 valence silicon atom. So it has a net additional + 1 electronic charge. The four valence electron form covalent bond and get fixed in the lattice. The fifth electron (with net – 1 electronic charge) can be approximated to revolve around + 1 additional charge. The situation is like the hydrogen atom for which energy is given by $E=-\dfrac{13.6}{n^2}eV$. For the case of hydrogen, the permittivity was taken as ε_0. However, if the medium has a permittivity ε_r relative to ε_0, then $E=-\dfrac{13.6}{\varepsilon_r^2 n^2}eV$

For *Si*, ε_r = 12 and for n = 1, $E \simeq 0.1\,eV$

4. (c) The forward current

$$i=i_s(e^{eV/kT}-1)=10^{-5}\left[e^{\frac{1.6\times10^{-19}\times0.2}{1.4\times10^{-23}\times300}}-1\right]$$

$$=10^{-5}[2038.6-1]=20.376\times10^{-3}A$$

5. (a,b,d) At 0 *K*, a semiconductor becomes a perfect insulator. Therefore at 0 *K*, if some potential difference is applied across an insulator or a semiconductor, current is zero. But a conductor will become a superconductor at 0 *K*. Therefore, current will be infinite. In reverse biasing at 300 *K* through a *P-N* junction diode, a small finite current flows due to minority charge carriers.

6. (a) Since diode in upper branch is forward biased and in lower branch is reversed biased. So current through circuit $i=\dfrac{V}{R+r_d}$; here r_d = diode resistance in forward biasing = 0

$\Rightarrow\ i=\dfrac{V}{R}=\dfrac{2}{10}=0.2A$.

7. (a) The voltage drop across resistance = 8 – 0.5 = 7.5 *V*

$\therefore$ Current $i=\dfrac{7.5}{2.2\times10^3}=3.4\,mA$

8. (c) $E=\dfrac{hc}{\lambda}\Rightarrow\lambda=\dfrac{hc}{E}=\dfrac{6.6\times10^{-34}\times3\times10^{8}}{57\times10^{-3}\times1.6\times10^{-19}}$ =217100Å.

9. (b) The diode in lower branch is forward biased and diode in upper branch is reverse biased

$\therefore\quad i=\dfrac{5}{20+30}=\dfrac{5}{50}A$.

10. (b) The current through circuit $i=\dfrac{P}{V}=\dfrac{100\times10^{-3}}{0.5}=0.2A$

$\therefore$ voltage drop across resistance = 1.5 – 0.5 = 1 *V*

$\Rightarrow R=\dfrac{1}{0.2}=5\,\Omega$.

11. (d) In common emitter configuration current gain

$A_i=\dfrac{-h_{fe}}{1+h_{oe}R_L}=\dfrac{-50}{1+25\times10^{-6}\times10^{3}}$ = – 48.78.

12. (c) Voltage gain $=\dfrac{\text{Output voltage}}{\text{Input voltage}}$

$\Rightarrow V_{out} = V_{in}\times$ Voltage gain

$\Rightarrow V_{out} = V_{in}\times$ Current gain × Resistance gain

$= V_{in}\times\beta\times\dfrac{R_L}{R_{BE}} = 10^{-3}\times100\times\dfrac{10}{1}=1V.$

13. (a) $n_e=8\times10^{18}/m^3,\ n_h=5\times10^{18}/m^3$

$\mu_e=2.3\dfrac{m^2}{volt-\sec},\ \mu_h=0.01\dfrac{m^2}{volt-\sec}$

$\because n_e>n_h$ so semiconductor is *N*-type

Also conductivity $\sigma=\dfrac{1}{\text{Resistivity}(\rho)}=e(n_e\mu_e+n_h\mu_h)$

$\Rightarrow\dfrac{1}{\rho}=1.6\times10^{-19}[8\times10^{18}\times2.3+5\times10^{18}\times0.01]$

$\Rightarrow\rho$ = 0.34 Ω-*m*.

14. (b) $V_{rms}=\dfrac{V_0}{2}=\dfrac{200}{2}=100V$

15. (a) At knee point voltage across the diode is 0.7 *V*.

Hence voltage across resistance *R* is 5 – 0.7 = 4.3 *V*.

$\Rightarrow$ using $V = iR \Rightarrow 4.3 = 1\times10^{-3}\times R\Rightarrow R$ = 4.3 *k*Ω.

16. (d) In positive half cycle one diode is in forward biasing and other is in reverse biasing while in negative half cycle their polarity reverses, and direction of current is opposite through *R* for positive and negative half cycles so out put is not rectified.

Since R_1 and R_2 are different hence the peaks during positive half and negative half of the input signal will be different.

17. (b) In half wave rectifier $V_{dc}=\dfrac{V_0}{\pi}=\dfrac{10}{\pi}$

18. (a) In common base mode α = 0.98, *R* = 5 *k*Ω, R_{in} = 70Ω

$\therefore$ voltage gain $A_v=\alpha\times\dfrac{R}{R_{in}}=0.98\times\dfrac{5\times10^3}{70}=70$

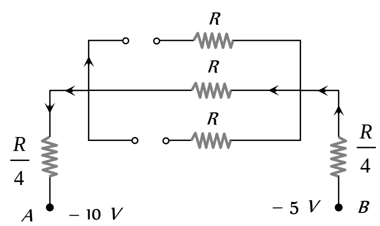
Power gain = Current gain × Voltage gain

= 0.98 × 70 = 68.6

19. (a) $r_n=\varepsilon_r\left(\dfrac{n^2}{Z}\right)a_o=12\times\dfrac{(5^2)}{15}\times0.53$ = 10.6 Å.

20. (c) (i) V_A = –10 *V* and V_B = –5 *V*

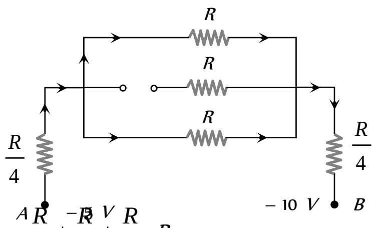
Diodes D_1 and D_3 are reveres biased and D_2 is forward biased.



$$\Rightarrow R_{AB} = R + \frac{R}{4} + \frac{R}{4} = \frac{3}{2}R.$$

(ii) When $V_A = -5V$ and $V_B = -10V$

Diodes D_2 is reverse biased D_1 and D_3 are forward biased



$$\Rightarrow R_{AB} = \frac{R}{4} + \frac{R}{2} + \frac{R}{4} = R.$$

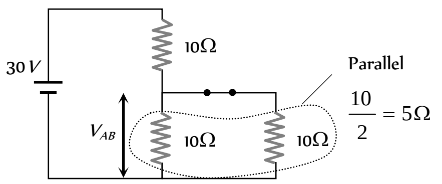
(iii) In this case equivalent resistance between A and B is also R.

Hence (ii) = (iii) < (i).

21. (b) According to the given polarity, diode D_1 is forward biased while D_2 is reverse biased. Hence current will pass through D_1 only.

So current $i = \frac{6}{(150+50+100)} = 0.02\ A$

22. (a) Diode is in forwards biasing hence the circuit can be redrawn as follows



$$V_{AB} = \frac{30}{(10+5)} \times 5 = 10\ V$$

23. (d) The diode D will conduct for positive half cycle of *a.c.* supply because this is forward biased. For negative half cycle of *a.c.* supply, this is reverse biased and does not conduct. So out put would be half wave rectified and for half wave rectified out put

$$V_{rms} = \frac{V_0}{2} = \frac{200\sqrt{2}}{2} = \frac{200}{\sqrt{2}}$$

24. (d) $\sigma = ne(\mu_e + \mu_h) = 2\times10^{19} \times 1.6\times10^{-19}(0.36+0.14)$

$= 1.6\,(\Omega\text{-}m)^{-1}$

$$R = \rho\frac{l}{A} = \frac{l}{\sigma A} = \frac{0.5\times10^{-3}}{1.6\times10^{-4}} = \frac{25}{8}\Omega$$

$$\therefore\ i = \frac{V}{R} = \frac{2}{25/8} = \frac{16}{25}A = 0.64\ A$$

25. (a) As we know current density $J = nqv$

$\Rightarrow J_e = n_e q v_e$ and $J_h = n_h q v_h$

$$\Rightarrow \frac{J_e}{J_h} = \frac{n_e}{n_h} \times \frac{v_e}{v_h} \Rightarrow \frac{3/4}{1/4} = \frac{n_e}{n_h} \times \frac{5}{20} \Rightarrow \frac{n_e}{n_h} = \frac{6}{5}$$

26. (b) Consider the case when *Ge* and *Si* diodes are connected as show in the given figure.

Equivalent voltage drop across the combination *Ge* and *Si* diode = 0.3 V

$\Rightarrow$ Current $i = \frac{12-0.3}{5\,k\Omega} = 2.34\ mA$

$\therefore$ Out put voltage $V_0 = Ri = 5\ k\Omega \times 2.34\ mA = 11.7\ V$

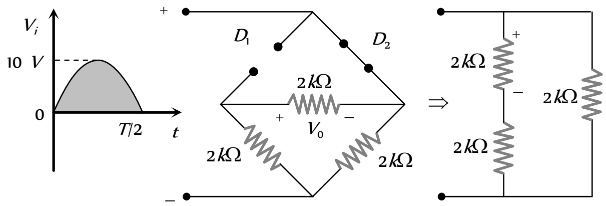
Now consider the case when diode connection are reversed. In this case voltage drop across the diode's combination = 0.7 V

$\Rightarrow$ Current $i = \frac{12-0.7}{5\,k\Omega} = 2.26\ mA$

$\therefore\ V_0 = iR = 2.26\,mA \times 5\,k\Omega = 11.3\ V$

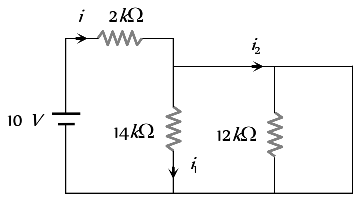
Hence charge in the value of V_0 = 11.7 –11.3 = 0.4 V

27. (b) For the positive half cycle of input the resulting network is shown below



$\Rightarrow (V_0)_{max} = \frac{1}{2}(V_i)_{max} = \frac{1}{2}\times 10 = 5\ V.$

28. (d) The equivalent circuit can be redrawn as follows



From figure it is clear that current drawn from the battery

$i = i_2 = \frac{10}{2} = 5mA$ and $i_1 = 0.$

29. (c) $i_b = \frac{5-0.7}{8.6} = 0.5\ mA \Rightarrow I_c = \beta I_b = 100\times0.5\ mA$

By using $V_{CE} = V_{CC} - I_c R_L = 18 - 50\times10^{-3}\times100 = 13V$

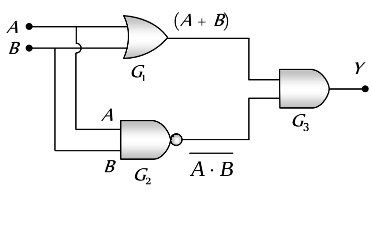
30. (a) $I_e = 10^{10}\times1.6\times10^{-19}\times\frac{1}{10^{-6}} = 1.6\ mA \quad \left(\because I = \frac{Q}{t}\right)$

Since 2% electrons are absorbed by base, hence 98% electrons reaches the collector *i.e.* α = 0.98

$\Rightarrow I_c = \alpha I_e = 0.98\times1.6 = 1.568\ mA \approx 1.57\ mA$

Also current amplification factor $\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{0.02} = 49$

31. (b)



$Y = (A+B).\overline{AB}$

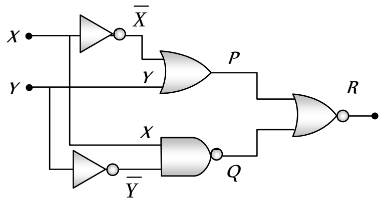
The given output equation can also be written as

$Y = (A+B).(\overline{A}+\overline{B})$ (De morgan's theorem)

$= A\overline{A} + A\overline{B} + B\overline{A} + B\overline{B} = 0 + A\overline{B} + \overline{A}B + 0 = \overline{A}B + A\overline{B}$

This is the expression for XOR gate.

32. (c)

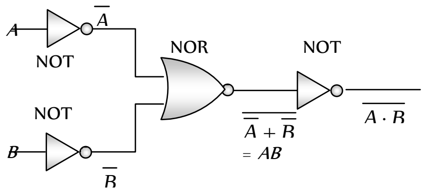


The truth table can be written as

X	Y	$\overline{X}$	$\overline{Y}$	$P = \overline{X} + Y$	$Q = \overline{X.\overline{Y}}$	$R = \overline{P+Q}$
0	1	1	0	1	1	0
1	1	0	0	1	1	0
1	0	0	1	0	0	1
0	0	1	1	1	1	0

Hence $X = 1$, $Y = 0$ gives output $R = 1$

33. (d)



Hence option (d) is correct.

34. (b) The truth table of the circuit is given

A	B	C	$X = \overline{AB}$	$Y = \overline{BC}$	$Z = \overline{X+Y}$
0	0	0	1	1	0
1	0	0	1	1	0
0	0	1	1	1	0
1	0	1	1	1	0
0	1	0	1	1	0
1	1	0	0	1	0
0	1	1	1	0	0
1	1	1	0	0	1

Output Z of single three input gate is that of AND gate.

35. (c) Output of upper OR gate = $W + X$

Output of lower OR gate = $W + Y$

Net output $F = (W + X)(W + Y)$

$= WW + WY + XW + XY$ (Since $WW = W$)

$= W(1 + Y) + XW + XY$ (Since $1 + Y = 1$)

$= W + XW + XY = W(1 + X) + XY = W + XY$

36. (b) $\mu = r_p\, g_m = 50$

From $i_p = KV_p^{3/2} \Rightarrow \dfrac{\Delta V_p}{\Delta i_p} = r_p = \dfrac{2i_p^{-1/3}}{3K^{2/3}}$

$\Rightarrow g_m = \dfrac{\mu}{r_p} = \dfrac{3\mu K^{2/3} i_p^{1/3}}{2} = \dfrac{3}{2}\mu K^{2/3}\left[K^{1/3}(V_p + \mu V_g)^{1/2}\right]$

$= \dfrac{3}{2}\mu K(V_p + \mu V_g)^{1/2} = 75\, K\,(i_p/K)^{1/3}$

Because i_p was in mA, g_m is substituted as 5 $m℧$

$\Rightarrow 5 = 75K^{2/3} i_p^{1/3} = 75\, K^{2/3}(8)^{1/3} \Rightarrow K = \left(\dfrac{1}{30}\right)^{3/2}$

Cut off grid voltage $V_G = -\dfrac{V_p}{\mu} = -\dfrac{300}{50} = -6V$

37. (d) $g_m = \left(\dfrac{\Delta i_p}{\Delta V_g}\right)_{V_p = \text{constant}} = \dfrac{(15-10)\times 10^{-3}}{0-(-4)} = 1.25 \times 10^{-3}\Omega$

$\mu = \left(\dfrac{\Delta V_p}{\Delta V_g}\right)_{I_p = \text{constant}} = \dfrac{150-120}{0-(-4)} = 7.5$

$\therefore\ r_p = \dfrac{\mu}{g_m} = \dfrac{7.5}{1.25\times 10^{-3}} = 6000\ ohms$

38. (d) The dynamic plate resistance is $r_p = \dfrac{\Delta V_p}{\Delta i_p}$

Now for a vacuum diode $i_p = KV_p^{3/2} \Rightarrow V_p = \left(\dfrac{i_p}{K}\right)^{2/3}$

$\Rightarrow \dfrac{\Delta V_p}{\Delta i_p} = \dfrac{2}{3\,K^{2/3}}\, i_p^{\left(\frac{2}{3}-1\right)}$

$\Rightarrow r_p = (\text{constant}) I_p^{-1/3} \Rightarrow r_p \propto \dfrac{1}{I_p^{1/3}}$

39. (d) $i_p = [0.125\, V_p - 7.5]\times 10^{-3}\ amp$

Differentiating this equation $w.r.t.$ V_p

$\dfrac{\Delta i_p}{\Delta V_p} = 0.125\times 10^{-3}$ or $\dfrac{1}{r_p} = 0.125 \times 10^{-3} \Rightarrow r_p = 8\ k\Omega$

40. (b) $V_{peak} = \sqrt{2}\ \ V_{rms} = \sqrt{2}\times 141.4 = 200\ V$

41. (c) The emission current $i = AT^2 Se^{-\phi/kT}$

For the two surfaces $A_1 = A_2$, $S_1 = S_2$, $T_1 = 800\ K$, $T_2 = 1600\, K, \phi_1 / T_1 = \phi_2 / T_2$

Therefore, $\dfrac{i_2}{i_1} = \left(\dfrac{T_2}{T_1}\right)^2 = (2)^2 = 4 \Rightarrow i_2 = 4i_1 = 4\ mA.$

42. (a) The first data gives value of plate resistance $r_p = \dfrac{\Delta V_p}{\Delta i_p} = \dfrac{10}{0.8\times 10^{-3}} = \dfrac{10^5}{8}\Omega$

Also $g_m = \dfrac{\Delta i_p}{\Delta V_g}$ and $g_m = \dfrac{\mu}{r_p}$

$$\Rightarrow \Delta V_g = \frac{\Delta i_p \times r_p}{\mu} = \frac{4\times10^{-3}\times10^5/8}{8} = 6.25\ V$$

43. (a) $I_p = 0.004\,(V_p + 10V_g)^{3/2}$

$$\Rightarrow \frac{\Delta I_p}{\Delta V_g} = 0.004\left[\frac{3}{2}(V_p+10V_g)^{1/2}\times 10\right]$$

$$\Rightarrow g_m = 0.004\times\frac{3}{2}(120+10\times -2)^{1/2}\times 10$$

$$\Rightarrow g_m = 6\times10^{-4}\,mho = 0.6\,m\,mho$$

Comparing the given equation of I_p with standard equation $I_p = K(V_p+\mu V_g)^{3/2}$ we get $\mu = 10$

Also from $\mu = r_p \times g_m \Rightarrow r_p = \frac{\mu}{g_m} = \frac{10}{0.6\times10^{-3}}$

$$\Rightarrow r_p = 16.67\times10^3\Omega = 16.67\,k\Omega.$$

44. (b) $\mu = r_P \times g_m = 20\times2.5 = 50$

From $A = \frac{\mu R_L}{r_P + R_L} \Rightarrow r_P + R_L = \frac{\mu R_L}{A} = \frac{50R_L}{10} = 5R_L$

$$\Rightarrow 4R_L = r_p \Rightarrow R_L = \frac{r_p}{4} = \frac{20}{4} = 5k\Omega$$

45. (a) $A = \frac{\mu R_L}{r_p + R_L} = \frac{14\times12}{10+12} = \frac{84}{11}$. Peak value of output signal

$$V_0 = \frac{84}{11}\times2\sqrt{2}V \Rightarrow V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{84\times2}{11}V$$

$\Rightarrow$ *r.m.s.* value of current through the load

$$= \frac{84\times2}{11\times12\times10^3}A = 1.27\,mA$$

46. (c) $r_p = \frac{\mu}{g_m} = \frac{64}{1600\times10^{-6}} = 4\times10^4\Omega$

Voltage gain $A_v = \frac{\mu}{1+\frac{r_p}{R_L}} = \frac{64}{1+\frac{4\times10^4}{40\times10^3}} = 32$

$\therefore$ Output signal voltage

$$V_0 = A_v \times V_i = 32\times1 = 32\,V(r.m.s.)$$

Signal power in load $= \frac{V_0^2}{R_L} = \frac{(32)^2}{40\times10^3} = 25.6\,mW$

47. (a) $i_p = k(V_p+\mu V_g)^{3/2}mA$

$\Rightarrow 4 = k(200 - 10\times4)^{3/2} = k\times(160)^{3/2}$ ....(i)

and $i_p = k(160-10\times7)^{3/2} = k\times(90)^{3/2}$ ....(ii)

From equation (i) and (ii) we get

$$i_p = 4\times\left(\frac{90}{160}\right)^{3/2} = 4\times\left(\frac{3}{4}\right)^3 = 1.69\,mA$$

48. (a) At $V_g = -3V, V_p = 300\ V$ and $I_p = 5mA$

At $V_g = -1V$, for constant plate current *i.e.* $I_p = 5mA$

From $I_p = 0.125\,V_p - 7.5$

$$\Rightarrow 5 = 0.125V_p - 7.5 \Rightarrow V_p = 100V$$

$\therefore$ change in plate voltage $\Delta V_p = 300 - 100 = 200V$

Change in grid voltage $\Delta V_g = -1-(-3) = 2V$

So, $\mu = \frac{\Delta V_p}{\Delta V_g} = \frac{200}{2} = 100$

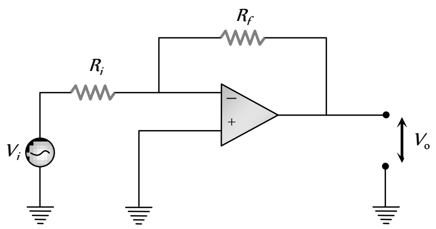
49. (b) The slope of anode characteristic curve $= \frac{1}{r_p}$

$$\Rightarrow r_p = \frac{1}{0.02\,mA/V} = 50\frac{V}{mA} = 50\times10^3\frac{V}{A}$$

The slope of mutual characteristic curve = g_m = 1×10^{-3} *A/V*.

$\therefore \mu = r_p\times g_m = 50\times10^3\times10^{-3} = 50$.

50. (b) Voltage gain $A = \frac{V_o}{V_i} = \frac{R_f}{R_i} = \frac{100\,k\Omega}{1\,k\Omega} = 100$.



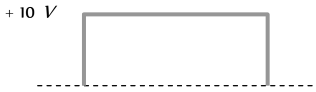
Graphical Questions

1. (c) With rise in temperature, resistivity of semiconductors decreases exponentially.

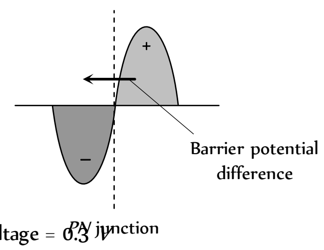
2. (b) Potential across the *PN* junction varies symmetrically linear, having *P* side negative and *N* side positive.

3. (c) *PN* junction has low resistance in one direction of potential difference $+V$, so a large current flows (forward biasing). It has a high resistance in the opposite potential difference direction $-V$, so a very small current flows (Reverse biasing).

4. (c) When input voltage is − 10 *V*, the diode is reverse biased and no output is obtained. On the other hand, when input is +10 *V*, the diode is forward biased and output is obtained which is +10 *V*. Therefore the output is of the form as show in the following figure.



5. (a) In the depletion layer of *PN* junction, stationary, positive ions exists in the *N*-side and stationary negative ions exists in the *P* side.



6. (b) V_k = knee voltage = 0.3 *V*

$\therefore$ Resistance $= \frac{\Delta V}{\Delta i} = \frac{(2.3-0.3)}{(10-0)\times10^{-3}} = 200\Omega = 0.2k\Omega$

7. (b) Half wave rectifier, rectifies only the half cycle of input ac signal and it blocks the other half.

8. (c) As *RC* time constant of the capacitor is quite large ($\tau = RC = 10 \times 10^3 \times 10 \times 10^{-6} = 0.1\,sec$), if will not discharge appreciably. Hence voltage remains nearly constant.

9. (b) In the positive half cycle of input *ac* signal diode D_1 is forward biased and D_2 is reverse biased so in the output voltage signal, *A* and *C* are due to D_1. In negative half cycle of Input *ac* signal D_2 conducts, hence output signals *B* and *D* are due to D_2.

10. (a) If *i* is the current in the diode and *V* is voltage drop across it, then for given figure voltage equation is

$$i \times 100 + V = 8 \Rightarrow i = -\frac{1}{100}V + \frac{8}{100} \Rightarrow i = -(0.01)V + 0.08$$

Thus the slope of *i-V* graph $= \frac{1}{R_L} = 0.01$

11. (b) The current at 2 *V* is 400 *mA* and at 2.1 *V* it is 800 *mA*. The dynamic resistance in this region

$$R = \frac{\Delta V}{\Delta i} = \frac{(2.1 - 2)}{(800 - 400) \times 10^{-3}} = \frac{1}{4} = 0.25\Omega$$

12. (a) From the given waveforms, the following truth table can be made

Time interval	Inputs		Output
	A	*B*	*Y*
$0 \to T_1$	0	0	0
$T_1 \to T_2$	0	1	0
$T_2 \to T_3$	1	0	0
$T_3 \to T_4$	1	1	1

This truth table is equivalent to 'AND' gate.

13. (d) 5 *volt* is low signal (0) and 10 *volt* is high signal (1) and taking 5 *μ-sec* as 1 unit. In a negative logic, low signal (0) gives high output (1) and high signal (1) gives low output (0). The output is therefore 1010010111.

14. (a) $g_m = \frac{\Delta i_p}{\Delta V_g} = \frac{(20 - 15) \times 10^{-3}}{(4 - 2)} = 2.5\,millimho$

15. (d) The cut off grid voltage is that negative grid bias corresponding to which the plate current becomes zero. At point *P*, $i_p = 0$

16. (a) According to Richardson-Dushman equation $J = AT^2 e^{-b/T}$

Taking log of this equation $\log_e \frac{J}{T^2} = \log_e A - \frac{b}{T}$

i.e. graph between $\log_e \frac{J}{T^2}$ and $\frac{1}{T}$ will be a straight line having negative slope and positive intercept ($\log_e A$) on $\log_e \frac{J}{T^2}$ axis.

17. (c) $J = AT^2 e^{-b/T} \Rightarrow \frac{J}{T^2} \propto e^{-b/T}$

i.e. $\frac{J}{T^2}$ will vary exponentially with $\frac{1}{T}$, having negative slope.

18. (c) This is the graph between i_p and V_p and i_p becomes zero at certain negative potential.

19. (a) $\mu = -\left(\frac{\Delta V_p}{\Delta V_g}\right)_{\Delta i_p = \text{const.}} = \frac{-(80 - 60)}{[-6 - (-4)]} = \frac{20}{2} = 10$

20. (c) According to $|A_v| = \frac{\mu}{1 + \frac{r_p}{R_L}}$

as R_L increases A_v also increases. When R_L becomes too high then A_v = maximum = μ

Hence only option (*c*) is correct.

21. (c) With rise in temperature, work function decreases (non-linearly).

22. (c) $R_p = \frac{V_p}{i_p} = \frac{50}{150 \times 10^{-3}} = 333.3\,\Omega$

23. (a) $i \propto T^2 \Rightarrow \frac{i}{i_0} = \left(\frac{T}{T_0}\right)^2$

This is the equation of a parabola.

24. (b) The band width is defined as the frequency band in which the amplifier gain remains above $\frac{1}{\sqrt{2}} = 0.707$ of the mid frequency gain (A_{max}). The low frequency f_1 at which the gain falls to $\frac{1}{\sqrt{2}}$ *i.e.* 0-.707 times it's mid frequency value is called lower cut off frequency and the high frequency f_4 at which the gain falls to $\frac{1}{\sqrt{2}}$ *i.e.* 0.707 times of it's mid frequency is known as higher cut off frequency so band width = $f_4 - f_1$.

25. (c) r_p varies with i_p according to relation $r_p \propto i_p^{-1/3}$ *i.e.* when i_p increases, r_p decreases, hence graph *C* represents the variation of r_p.

μ doesn't depends upon i_p, hence graph *A* is correct.

26. (c) From the graph it is clear that of for $V_g = -4V, i_p = 0,$ so cut off voltage is – 4 *volt*.

27. (b) As temperature increases saturation current also increases.

28. (c)

29. (a) Output signal voltage has phase difference of 180° with respect to input.

30. (d) Grid is maintained between 0 *volt* to certain negative voltage.

Assertion and Reason

1. (d) In diode the output is in same phase with the input therefore it cannot be used to built NOT gate.

2. (a) According to law of mass action, $n_i^2 = n_e n_h$. In intrinsic semiconductors $n_i = n_e = n_h$ and for *P*-type semiconductor n_e would be less than n_i, since n_h is necessarily more than n_i.

3. (c) In common emitter transistor amplifier current gain $\beta > 1,$ so output current > Input current, hence assertion is correct.

Also, input circuit has low resistance due to forward biasing to emitter base junction, hence reason is false.

4. (a) Input impedance of common emitter configuration

$$= \left.\frac{\Delta V_{BE}}{\Delta i_B}\right|_{V_{CE} = \text{constant}}$$

where ΔV_{BE} = voltage across base and emitter (base emitter region is forward biased)

Δi_B = base current which is order of few microampere.

Thus input impedance of common emitter is low.

5. (d) Resistivity of semiconductors decreases with temperature. The atoms of a semiconductor vibrate with larger amplitudes at higher temperatures there by increasing it's conductivity not resistivity.

6. (a) In semiconductors the energy gap between conduction band and valence band is small ($\approx$ 1 *eV*). Due to temperature rise, electron in the valence band gained thermal energy and may jump across the small energy gap, goes in to the conduction band. Thus conductivity increases and hence resistance decreases.

7. (b)

8. (a) The ratio of the velocity to the applied field is called the mobility. Since electron is lighter than holes, they move faster in applied field than holes.

9. (b)

Intrinsic semiconductor	+	Pentalvalent impurity	→	*N*-type semiconductor
(Neutral)		(Neutral)		(Neutral)

10. (a) At a particular temperature all the bonds of crystalline solids breaks and show sharp melting point.

11. (c) The energy gap for germanium is less $(0.72 eV)$ than the energy gap of silicon $(1.1 eV)$. Therefore, silicon is preferred over germanium for making semiconductor devices.

12. (e) We cannot measure the potential barrier of a *PN*-junction by connecting a sensitive voltmeter across its terminals because in the depletion region, there are no free electrons and holes and in the absence of forward biasing, *PN*- junction offers infinite resistance.

13. (e) The assertion is not true. In fact, semiconductor Obeys Ohm's law for low values of electric field (~ 10^6 *V/m*). Above this, the current becomes almost independent of electric field.

14. (d) Two *PN*-junctions placed back to back cannot work as *NPN* transistor because in transistor the width and concentration of doping of *P*-semiconductor is less as compared to width doping of *N*-type semiconductor type.

15. (b) Common emitter is prepared over common base because all the current, voltage and power gain of common emitter amplifier is much more than the gains of common base amplifier.

16. (d) In *PN*-junction, the diffusion of majority carriers takes place when junction is forward biased and drifting of minority carriers takes place across the function, when reverse biased. The reverse bias opposes the majority carriers but makes the minority carriers to cross the *PN*-junction. Thus the small current in μA flows during reverse bias.

17. (d) A transistor is a current operating device because the action of transistor is controlled by the charge carriers (electrons or holes). Base current is very much lesser than the collector current.

18. (a) These gates are called digital building blocks because using these gates only (either NAND or NOR) we can compile all other gates also (like OR, AND, NOT, XOR).

19. (d) At 0*K*, Germanium offers infinite resistance, and it behaves as an insulator.

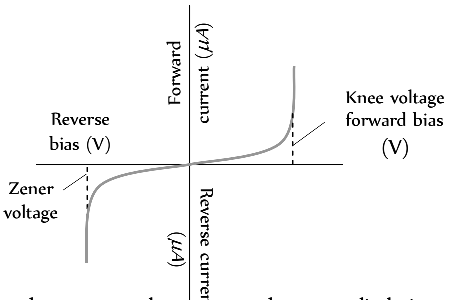
20. (a) In a transistor, the base is made extremely thin to reduce the combinations of holes and electrons. Under this condition, most of the holes (or electrons) arriving from the emitter diffuses across the base and reach the collector. Hence, the collector current, is almost equal to the emitter current, the base current being comparatively much smaller. This is the main reason that power gain and voltage gain are obtained by a transistor. If the base region was made quite thick, then majority of carriers from emitter will combine with the carriers in the base and only small number of carriers will reach the collector, so there would be little collector current and the purpose of transistor would be defeated.

21. (c) The current gain in common base circuit $\alpha = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_C}$

The change in collector current is always less than the change in emitter current.

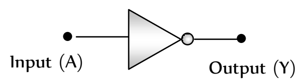
$\Delta I_C < \Delta I_E$. Therefore, $\alpha < 1$.

22. (d) The *V-i* characteristic of *PN*- diode depends whether the junction is forward biased or reverse biased. This can be showed by graph between voltage and current.



23. (a) When the reverse voltage across the zener diode is equal to or more than the breakdown voltage, the reverse current increases sharply.

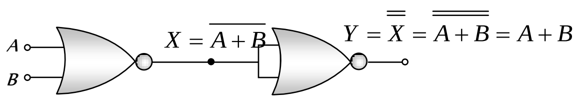
24. (a)



If A = 0, Y = 1 and A = 1, Y = 0.

25. (b) In vacuum tubes, vacuum is necessary and the working of semiconductor devices is independent of heating or vacuum.

26. (a)



This is the Boolean expression for 'OR' gate.

27. (a) For detection of a particular wavelength (λ) by a *PN* photo diode, energy of incident light > $E_g \Rightarrow \frac{hc}{E_g} > \lambda$

For $E_g = 2.8\, eV, \frac{hc}{E_g} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.8 \times 1.6 \times 10^{-19}} = 441.9\, nm$

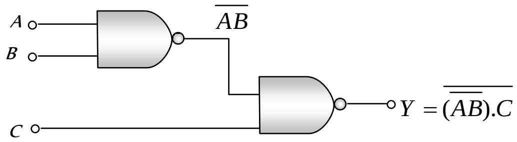
i.e. $\frac{hc}{E_g} < 6000\, nm$, so diode will not detect the wavelength of 6000Å.

28. (a)

29. (b) In forward biasing of *PN* junction current flows due to diffusion of majority charge carriers. While in reverse biasing current flows due to drifting of minority charge carriers.

The circuit given in the reason is a *PNP* transistor having emitter is more negative *w.r.t.* base so it is reverse biased and collector is more positive *w.r.t.* base so it is forward biased.

30. (c) Assertion is true but reason is false



If $A = 1$, $B = 0$, $C = 1$ then $Y = 0$

31. (b) Both assertion and reason are true but potential difference across the resistance is zero, because diode is in reverse biasing hence no current flows.

Electronics

SET Self Evaluation Test - 27

1. In a pure silicon ($n_i = 10^{16}/m^3$) crystal at 300 *K*, 10^{21} atoms of phosphorus are added per cubic meter. The new hole concentration will be

(a) 10^{21} per m^3 (b) 10^{19} per m^3

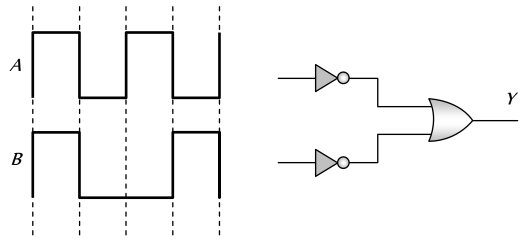
(c) 10^{11} per m^3 (d) 10^{5} per m^3

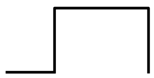
2. In the Boolean algebra $\overline{(\overline{A}\cdot\overline{B})}\cdot A$ equals to

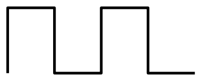
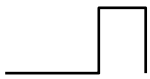
(a) $\overline{A+B}$ (b) A

(c) $\overline{A\cdot B}$ (d) $A + B$

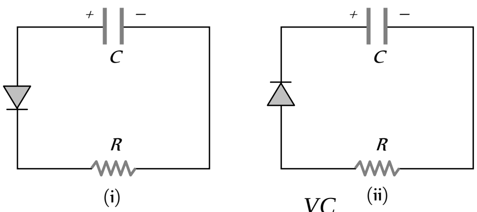
3. In a given circuit as shown the two input waveform *A* and *B* are applied simultaneously. The resultant waveform *Y* is



(a)  (b) 

(c)  (d) 

4. Two identical capacitors *A* and *B* are charged to the same potential *V* and are connected in two circuits at $t = 0$, as shown in figure. The charge on the capacitors at time $t = CR$ are respectively



(a) *VC*, *VC* (b) $\frac{VC}{e}$, *VC*

(c) *VC*, $\frac{VC}{e}$ (d) $\frac{VC}{e}, \frac{VC}{e}$

5. In transistor, forward bias is always smaller than the reverse bias. The correct reason is

(a) To avoid excessive heating of transistor

(b) To maintain a constant base current

(c) To produce large voltage gain

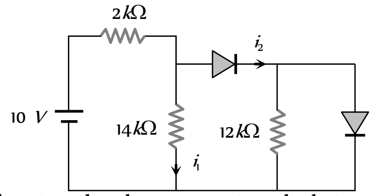
(d) None of these

6. In *NPN* transistor, if doping in base region is increased then collector current

(a) Increases (b) Decreases

(c) Remain same (d) None of these

7. In the following circuit I_1 and I_2 are respectively



(a) 0, 0

(b) 5 *mA*, 5 *mA*

(c) 5 *mA*, 0

(d) 0, 5 *mA*

8. In space charge limited region, the plate current in a diode is 10 *mA* for plate voltage 150 *V*. If the plate voltage is increased to 600 *V*, then the plate current will be

(a) 10 *mA* (b) 40 *mA*

(c) 80 *mA* (d) 160 *mA*

9. A triode has a plate resistance of 10 *k*Ω and amplification factor 24. If the input signal voltage is 0.4 *V* (*r.m.s.*), and the load resistance is 10 *k ohm*, then, the output voltage (*r.m.s.*) is

(a) 4.8 *V* (b) 9.6 *V*

(c) 12.0 *V* (d) None of these

10. Pure sodium (*Na*) is a good conductor of electricity because the 3*s* and 3*p* atomic bands overlap to form a partially filled conduction band. By contrast the ionic sodium chloride (*NaCl*) crystal is

(a) Insulator (b) Conductor

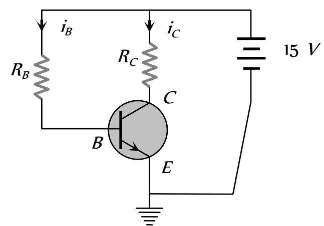
(c) Semiconductor (d) None of these

11. Would there be any advantage to adding *n*-type or *p*-type impurities to copper

(a) Yes (b) No

(c) May be (d) Information is insufficient

12. In the following common emitter circuit if $\beta = 100$, $V_{CE} = 7V$, V_{BE} = Negligible $R_C = 2\ k\Omega$ then $I_B = ?$



(a) 0.01 *mA*

(b) 0.04 *mA*

(c) 0.02 *mA*

(d) 0.03 *mA*

13. When a battery is connected to a *P*-type semiconductor with a metallic wire, the current in the semiconductor (predominantly), inside the metallic wire and that inside the battery respectively due to

(a) Holes, electrons, ions (b) Holes, ions, electrons

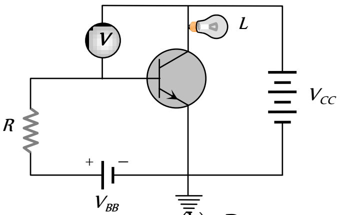
(c) Electrons, ions, holes (d) Ions, electrons, holes

14. Is the ionisation energy of an isolated free atom different from the ionisation energy E_g for the atoms in a crystalline lattice

(a) Yes (b) No

(c) May be (d) None of these

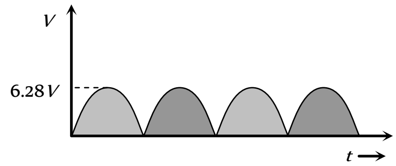
15. In the following circuit, a voltmeter V is connected across a lamp L. What change would occur in voltmeter reading if the resistance R is reduced in value



(a) Increases (b) Decreases

(c) Remains same (d) None of these

16. For given electric voltage signal dc value is



(a) 6.28 V (b) 3.14 V

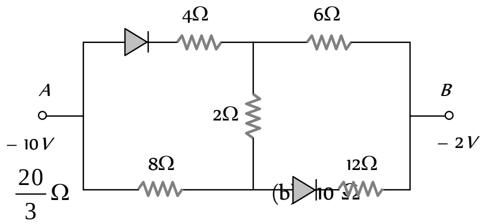
(c) 4 V (d) 0 V

17. When a silicon PN junction is in forward biased condition with series resistance, it has knee voltage of 0.6 V. Current flow in it is 5 mA, when PN junction is connected with 2.6 V battery, the value of series resistance is

(a) 100 Ω (b) 200 Ω

(c) 400 Ω (d) 500 Ω

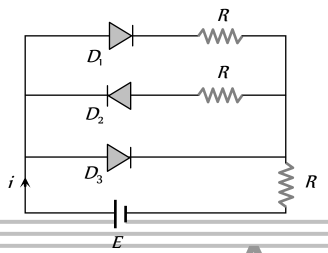
18. In the following circuit the equivalent resistance between A and B is



(a) $\frac{20}{3}\Omega$ (b) 10 Ω

(c) 16 Ω (d) 20 Ω

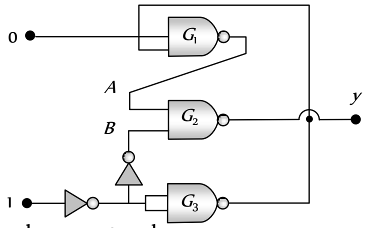
19. In the following circuit of PN junction diodes D_1, D_2 and D_3 are ideal then i is



(a) E/R (b) $E/2R$

(c) $2E/3R$ (d) Zero

20. In circuit in following fig. the value of Y is



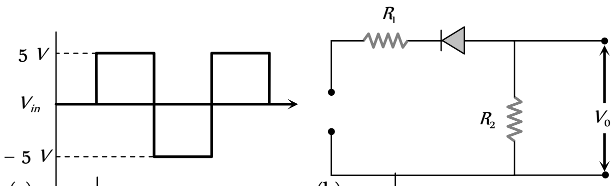
(a) 0

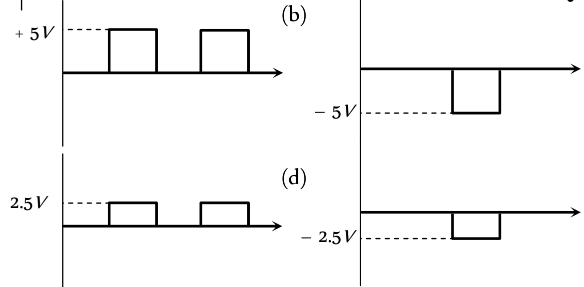
(b) 1

(c) Fluctuates between 0 and 1

(d) Indeterminate as the circuit can't be realised

21. A waveform shown when applied to the following circuit will produce which of the following output waveform. Assuming ideal diode configuration and $R_1 = R_2$





22. In a triode, cathode, grid and plate are at 0, – 2 and 80 V respectively. The electrons is emitted from the cathode with energy 3 eV. The energy of the electron reaching the plate is

(a) 77 eV (b) 85 eV

(c) 81 eV (d) 83 eV

23. The energy gap of silicon is 1.5 eV. At what wavelength the silicon will stop to absorb the photon

(a) 8250 Å (b) 7250 Å

(c) 6875.5 Å (d) 5000 Å

AS Answers and Solutions

(SET -27)

1. (c) By using mass action law $n_i^2 = n_e n_h$

$$\Rightarrow n_h = \frac{n_i^2}{n_e} = \frac{(10^{16})^2}{10^{21}} = 10^{11}\ per\ m^3$$

2. (b) $(\overline{\overline{A} \cdot \overline{B}}) \cdot A = (\overline{\overline{A}} + \overline{\overline{B}}) \cdot A = (A + B) \cdot A$

$= A \cdot A + AB = A + AB = A(1 + B) = A$

3. (a) (1 = high, 0 = low)

Input to A is in the sequence, 1,0,1,0.

Input to B is in the sequence, 1, 0, 0, 1.

Sequence is inverted by NOT gate.

Thus inputs to OR gate becomes 0, 1, 0, 1 and output of OR gate becomes 0, 1, 1, 1

Since for OR gate 0 + 1 = 1. Hence choice (a) is correct.

4. (b) Time $t = CR$ is known as time constant. It is time in which charge on the capacitor decreases to $\frac{1}{e}$ times of it's initial charge (steady state charge).

In figure (i) PN junction diode is in forward bias, so current will flow the circuit *i.e.*, charge on the capacitor decrease and in time t it becomes $Q = \frac{1}{e}(Q_o)$; where $Q_o = CV$

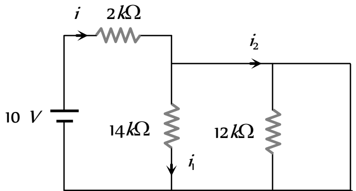
$\Rightarrow Q = \frac{CV}{e}$

In figure (ii) P-N junction diode is in reverse bias, so no current will flow through the circuit hence change on capacitor will not decay and it remains same *i.e.* CV after time t.

5. (a) If forward bias is made large, the majority charge carriers would move from the emitter to the collector through the base with high velocity. This would give rise to excessive heat causing damage to transistor.

6. (b) Number of holes in base region increases hence recombination of electron and hole are also increases in this region. As result base current increases which in turn decreases the collector current.

7. (d) Equivalent circuit can be redrawn as follows



$i = \frac{10}{2} = 5\,mA = i_2$

$i_1 = 0$

8. (c) In space charge limited region, the plate current is given by Child's law $i_p = KV_p^{3/2}$

Thus, $\frac{i_{p_2}}{i_{p_1}} = \left(\frac{V_{p_2}}{V_{p_1}}\right)^{3/2} = \left(\frac{600}{150}\right)^{3/2} = (4)^{3/2} = 8$

or $i_{p_2} = i_{p_1} \times 8 = 10 \times 8\ mA = 80\ mA$.

9. (a) Use $V_0 = AV_s$

Now $A = \frac{24 \times 10k}{10k + 10k} = \frac{24 \times 10}{20} = 12$

Therefore, $V_0 = 12 \times 0.4 = 4.8\,volt(r.m.s.)$

10. (a) In sodium chloride the Na^+ and Cl^- ions both have noble gas electron configuration corresponding to completely filled bands. Since the bands do not overlap, there must be a gap between the filled bands and the empty bands above them, so $NaCl$ is an insulator.

11. (b) Pure Cu is already an excellent conductor, since it has a partially filled conduction band, furthermore, Cu forms a metallic crystal as opposed to the covalent crystals of silicon or germanium, so the scheme of using an impurity to donate or accept an electron does not work for copper. In fact adding impurities to copper decreases the conductivity because an impurity tends to scatter electrons, impeding the flow of current.

12. (b) $V = V_{CE} + I_C R_L$

$\Rightarrow 15 = 7 + I_c \times 2 \times 10^3 \Rightarrow i_c = 4\ mA$

$\because\ \beta = \frac{i_C}{i_B} \Rightarrow i_B = \frac{4}{100} = 0.04\,mA$

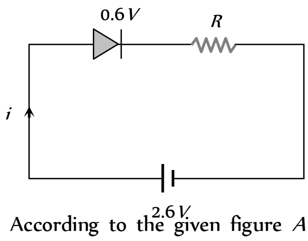
13. (a) Charge carriers inside the P-type semiconductor are holes (mainly). Inside the conductor charge carriers are electrons and for cell ions are the charge carriers.

14. (a) The ionisation energy of an isolated atom is different from it's value in crystalline lattice, because in the latter case each bound electron is influenced by many atoms in the periodic crystalline lattice.

15. (a) Here the emitter base junction of N-P-N transistor is forward biased with battery V_{BB} through resistance R. When the value of R is reduced, then the emitter current i_e will increase. As a result the collector current will also increase. ($i_c = i_e - i_b$). Due to increase in i_c, the potential difference across L increases and hence the reading of voltmeter will increases.

16. (c) $V_{dc} = V_{ac} = \frac{2V_0}{\pi} = \frac{2 \times 6.28}{3.14} = 4V.$

17. (c)

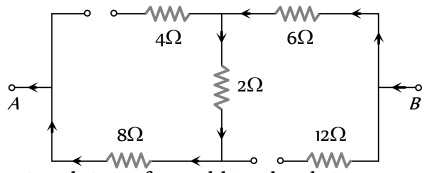


$R = \frac{(2.6 - 0.6)}{5 \times 10^{-3}} = 400\ \Omega.$

18. (c) According to the given figure A is at lower potential *w.r.t.* B. Hence both diodes are in reverse biasing, so equivalent, circuit can be redrawn as follows.

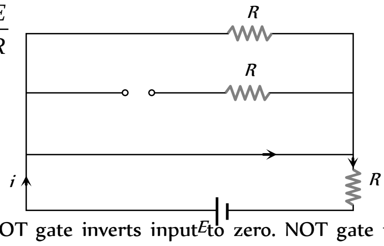
$\Rightarrow$ Equivalent resistance between A and B

$R = 8 + 2 + 6 = 16\ \Omega.$



19. (a) Diodes D_1 and D_3 are forward biased and D_2 is reverse biased so the circuit can be redrawn as follows.

$\Rightarrow i = \frac{E}{R}$



20. (a) Lower NOT gate inverts input to zero. NOT gate from NAND gate inverts this output to 1 upper NAND gate converts this input 1 and input 0 to 1.

Thus $A = 1$ and $B = 1$ become inputs of NAND gate giving final output as zero. Choice A is correct.

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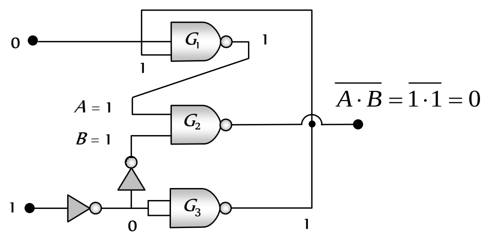
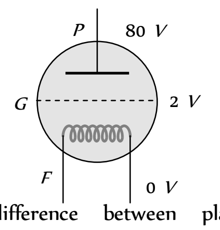


21. (d) The *P-N* junction will conduct only when it is forward biased *i.e.* when $-5V$ is fed to it, so it will conduct only for 3rd quarter part of signal shown and when it conducts potential drop 5 *volt* will be across both the resistors, so output voltage across R is 2.5 *V*.

$\therefore V_0 = -2.5\ V$

22. (d) There is a loss of kinetic energy of 2 *eV* from filament to grid. The energy of the electron after passing through the grid will be 3 – 2 = 1 *eV*



The potential difference between plate and grid is $80-(-2)=82V$. The electron will gain energy 82 *eV* from the grid to the plate. The energy of electron reaching the plate = 1 + 82 = 83 *eV*

23. (a) $\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.5\times1.6\times10^{-19}} = 8.25\times10^{-7}m = 8250Å$

The photon having wavelength equal to 8250Å or more than this will not able to overcome the energy gap of silicon.

Chapter 28
Communication

The term communication refers to the transmitting, receiving and processing of information by electronic means.

Basic Communication System

A basic communication system consists of an information source, a transmitter, a link and a receiver.

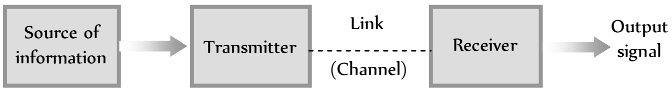


Fig. 28.1

(1) **Information :** The idea/message that is to be conveyed is information. The message may be individual one or a set of messages. The message may be a symbol, code, group of words or any pre decided unit.

(2) **Transmitter :** In radio transmission, the transmitter consists of a transducer, modulator, amplifier and transmitting anteena.

Transducer : Converts sound signals into electric signal.

Modulator : Mixing of audio electric signal with high frequency radio wave.

Amplifier : Boosting the power of modulated signal.

Anteena : Signal is radiated in the space with the aid of an anteena.

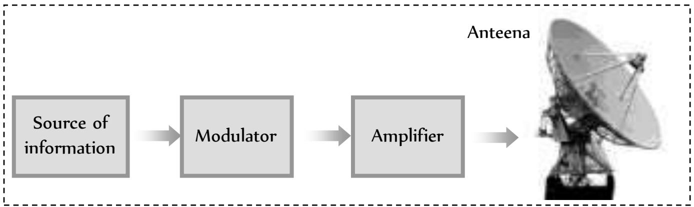


Fig. 28.2 : Transmitter

(3) **Communication channel :** The function of communication channel is to carry the modulated signal from transmitter to receiver. The communication channel is also called transmission medium or link.

The term channel refers to the frequency range allocated to a particular service or transmission.

Table 28.1 : Different channels

Type of communication	Channels or links
Radio communication	Free space
Telephony and Telegraphy communication	Transmission line
Optical communication	Optical fibre

(4) **Receiver :** The receiver consists of

Pickup anteena : To pick the signal

Demodulator : To separate out the audio signal from the modulated signal

Amplifier : To boost up the weak audio signal

Transducer : To convert back audio signal in the form of electrical pulses into sound waves.

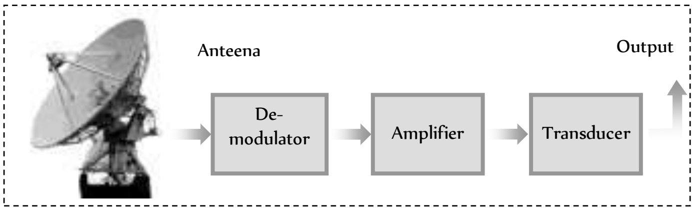


Fig. 28.3 : Receiver

Types of Communication System

Communication systems can be classified according to the nature of information or mode of transmission or types of transmission channel.

(1) **According to the nature of information source**

(i) Speech transmission

(ii) Picture transmission

(iii) **Facsimile transmission (FAX) :** This involves exact reproduction of a document or picture which are static.

(2) **According to the mode of transmission**

(i) **Analog communication :** The communication system, which make use of analog signals are called analog communication system.

Table 28.2 : Few analog communication system

System	Specification
Telegraphy	Message in the form of codes are sent.
Television broadcast	Both sound as well as pictures are sent.
Telephony	It sends voice signal from one place to another by means of wire.
Radar	It means radio detection and ranging. It is used for determining the distance and direction of objects using microwave.
Teleprinting	Message can be typed and telegraphed to distant receivers

(ii) **Digital communication :** In this system digital signals are used.

Table 28.3 : Few digital communication system

System	Specification
Facsimile transmission (FAX)	This involves exact reproduction of a document or picture which are static
Mobile phone	Such telephones are also called cellular phones, because they operate within a network of radio cells.
E-mail	the message sent via a computer network are called e-mail
Tele conferencing	It is a system in which persons sitting at coloured television screens. See and talk to each other via a computer communication network.
Communication satellite	Used to relay radio and television programmers.
Global positioning system (GPS)	It is a navigation system based on a network of earth orbiting satellites. The users can find their positions within an accuracy of 100 *m* by receiving.

(3) **According to the transmission channel**

(i) Line communication (ii) Space communication

(4) **According to the type of modulation**

(i) Amplitude modulation (AM)

(ii) Frequency modulation (FM)

(iii) Phase modulation (PM)

(iv) Pulse amplitude modulation (PAM)

(v) Pulse time modulation (PTM)

(vi) Pulse code modulation (PCM)

Analog and Digital Signals

In communication system, a signal means a time varying electrical signal containing informations.

(1) **Analog signals :** It is a continuous wave form which changes smoothly over time.

(i) Such signals can be easily generated from the source of information by using an appropriate transducer *e.g.* pressure variations in the sound waves can be converted into corresponding current or voltage pulses with the help of a microphone.

(ii) A simple analog signal is represented by a sine wave

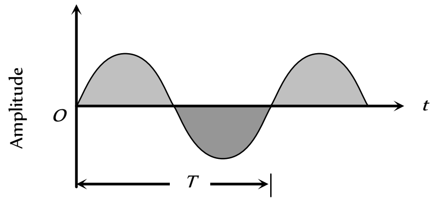


Fig. 28.4

(iii) The frequency of analog signals associated with speed or music varies over a range between 20 *Hz* to 20 *KHz*.

(iv) The range over which the frequencies of a signal vary is called band width.

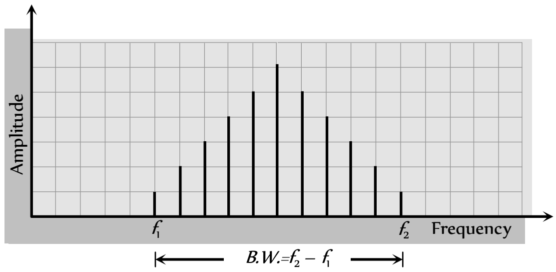


Fig. 28.5

(v) The term base band designates the band of frequencies representing the signal supplied by the source of information.

(vi) A signal consist of two or more waves of different frequencies is known as a complex analog signal.

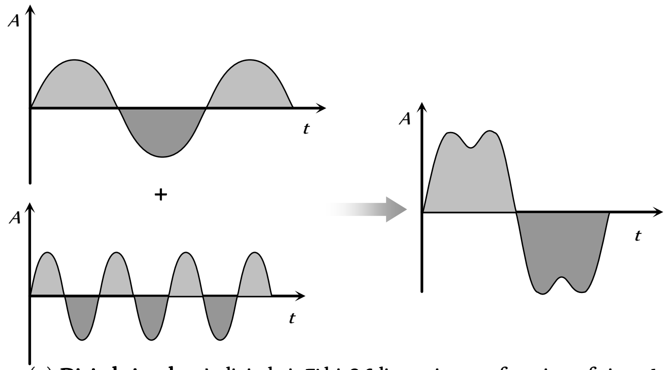


Fig. 28.6

(2) **Digital signals :** A digital signal is a discontinuous function of time. It has only two voltage level *i.e.* either low (0) or high (1).

Either of 0 and 1 is known as bit. A group of bit is called byte.

A byte comprising of 2 bits can give on the four code combination *i.e.* 00, 01, 10 and 11.

The number of code combination increase with number of bits in a byte is given by $N = 2^x$, where x = number of bits in a byte.

The number of binary digits (bits) per second, which describe a digital signal is called it's bit rate. Bit rate is expressed in bits per second (bps).

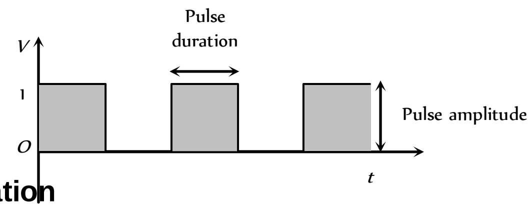


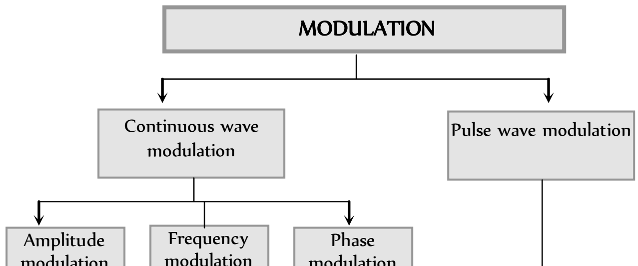
Fig. 28.7

Modulation

(1) Digital and analog signals to be transmitted are usually of low frequency and hence cannot be transmitted as such.

(2) These signals require some carrier to be transported. These carriers are known as carrier waves or high frequency signals.

(3) The process of placement of a low frequency (LF) signal over the high frequency (HF) signal is known as modulation.



(4) **Need for modulation :** The sound wave (20 *Hz* to 20 *KHz*) cannot be transmitted directly from one place to another for the following reasons.

(i) **Height of anteena :** For efficient radiation and reception , the height of transmitting and receiving antennas should be comparable to a quarter of wavelength of the frequency used. For 15 *KHz* it is 5000 *m* (too large) and for 1 *MHz* it is 75 *m*.

The energy radiated from an anteena is practically zero, when the frequency of the signal to be transmitted is below 15 *Hz*.

(ii) **Detecting signals :** All audible signals are in the range of 20 *Hz* to 20 *KHz* so the signals from all sources remains heavily mixed up in air. It will be very difficult to differentiate or detect the broadcast signal at the receiving station.

Thus modulation is necessary for a low frequency signal. When it is to be sent to a distant place so that the information may not die out in the way it self as well as for the proper identification of a signal and to keep the height of anteena small also

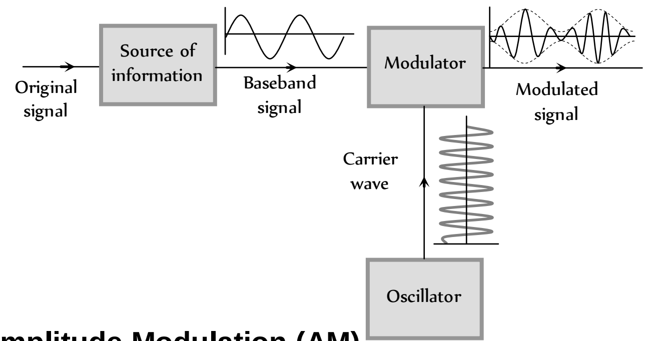


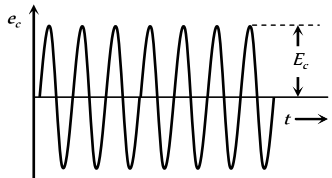
Fig. 28.9

Amplitude Modulation (AM)

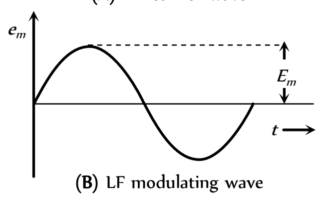
The process of changing the amplitude of a carrier wave in accordance with the amplitude of the audio frequency (AF) signal is known as amplitude modulation (AM).

In AM frequency of the carrier wave remains unchanged.

The amplitude of modulated wave is varied in accordance with the amplitude of modulating wave.



(A) HF carrier wave



(B) LF modulating wave

(1) **Modulation index :** The ratio of change of amplitude of carrier wave to the amplitude of original carrier wave is called the modulation factor or degree of modulation or modulation index (*m*).

$$m_a = \frac{\text{Change in amplitude of carrier wave}}{\text{Amplitude of original carrier wave}} = \frac{kE_m}{E_c}$$

where k = A factor which determines the maximum change in the amplitude for a given amplitude E_m of the modulating signal. If k = 1 then $m_a = \frac{E_m}{E_c} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$

If a carrier wave is modulated by several sine waves the total modulated index m_t is given by $m_t = \sqrt{m_1^2 + m_2^2 + m_3^2 + ...}$

(2) **Voltage equation for AM wave :** Suppose voltage equations for carrier wave and modulating wave are $e_c = E_c \cos \omega_c t$ and $e_m = E_m \sin \omega_m t = mE_c \sin \omega_m t$

where e_c = Instantaneous voltage of carrier wave, E_c = Amplitude of carrier wave, $\omega_c = 2\pi f_c =$ Angular velocity at carrier frequency f_c, $e_m =$ Instantaneous voltage of modulating, $E_m =$ Amplitude of modulating wave, $\omega_m = 2\pi f_m =$ Angular velocity of modulating frequency f_m

Voltage equation for AM wave is

$$e = E \sin \omega_c t = (E_c + e_m) \sin \omega_c t = (E_c + e_m \sin \omega_m t) \sin \omega_c t$$

$$= E_c \sin \omega_c t + \frac{m_a E_c}{2} \cos(\omega_c - \omega_m)t - \frac{m_a E_c}{2} \cos(\omega_c + \omega_m)t$$

The above AM wave indicated that the AM wave is equivalent to summation of three sinusoidal wave, one having amplitude E_c and the other two having amplitude $\frac{m_a E_c}{2}$.

(3) **Side band frequencies and band width in AM wave**

(i) **Side band frequencies :** The AM wave contains three frequencies $f_c, (f_c + f_m)$ and $(f_c - f_m)$, f_c is called carrier frequency, $(f_c + f_m)$ and $(f_c - f_m)$ are called side band frequencies.

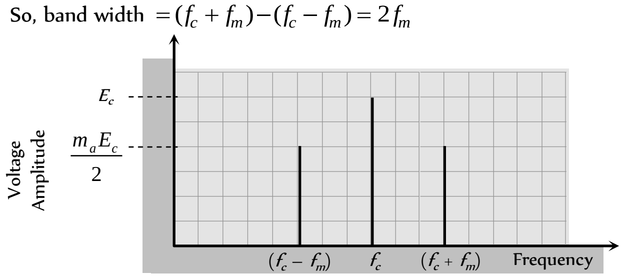
$(f_c + f_m)$: Upper side band (USB) frequency

$(f_c - f_m)$: Lower side band (LSB) frequency

Side band frequencies are generally close to the carrier frequency.

(ii) **Band width :** The two side bands lie on either side of the carrier frequency at equal frequency interval f_m.

So, band width $= (f_c + f_m) - (f_c - f_m) = 2f_m$



(4) **Power in AM waves** : Power dissipated in any circuit $P = \frac{V_{rms}^2}{R}$.

Hence (i) carrier power $P_c = \frac{\left(\frac{E_c}{\sqrt{2}}\right)^2}{R} = \frac{E_c^2}{2R}$

(ii) Total power of side bands $P_{sb} = \frac{\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2}{R} + \frac{\left(\frac{m_a E_c}{2\sqrt{2}}\right)^2}{R} = \frac{m_a^2 E_c^2}{4R}$

(iii) Total power of AM wave $P_{Total} = P_c + P_{sb} = \frac{E_c^2}{2R}\left(1 + \frac{m_a^2}{2}\right)$

(iv) $\frac{P_t}{P_c} = \left(1 + \frac{m_a^2}{2}\right)$ and $\frac{P_{sb}}{P_t} = \frac{m_a^2/2}{\left(1 + \frac{m_a^2}{2}\right)}$

(v) Maximum power in the AM (without distortion) will occur when $m_a = 1$ *i.e.* $P_t = 1.5P = 3P_{sb}$

(vi) If I_c = Unmodulated current and I_t = total or modulated current $\Rightarrow$ $\frac{P_t}{P_c} = \frac{I_t^2}{I_c^2} \Rightarrow \frac{I_t}{I_c} = \sqrt{\left(1 + \frac{m_a^2}{2}\right)}$

(5) **Limitation of amplitude modulation**

(i) Noisy reception (ii) Low efficiency

(iii) Small operating range (iv) Poor audio quality

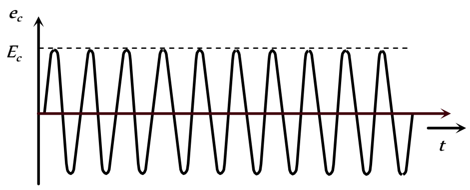
Frequency Modulation (FM)

The process of changing the frequency of a carrier wave in accordance with the audio frequency signal is known as frequency modulation

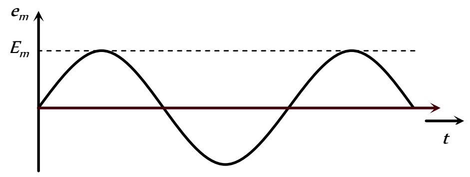
(1) Audio quality of AM transmission is poor. There are need to eliminate amplitude sensitive noise. This is possible if we eliminate amplitude variation. (*i.e.* a need to keep the amplitude of the carrier constant). This is precisely what we do in FM.

(2) In FM the overall amplitude of FM wave remains constant at all times.

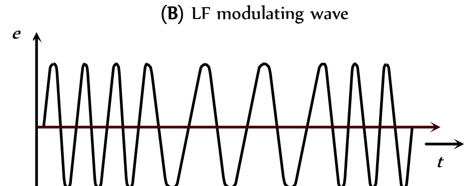
(3) In FM, the total transmitted power remains constant.



(A) HF carrier wave



(B) LF modulating wave



(4) **Frequency deviation :** The maximum change in frequency from mean value (ν) is known as frequency deviation. This is also the change or shift either above or below the frequency ν_c and is called as frequency deviation.

$$\therefore \quad \delta = (f_{\max} - f_c) = f_c - f_{\min} = k_f . \frac{E_m}{2\pi}$$

k_f = Constant of proportionality. It determines the maximum variation in frequency of the modulated wave for a given modulating signal.

(5) **Carrier swing (CS) :** The total variation in frequency from the lowest to the highest is called the carrier swing

i.e. $CS = 2 \times \Delta f$

(6) **Frequency modulation index (*m*) :** The ratio of maximum frequency deviation to the modulating frequency is called modulation index.

$$m_f = \frac{\delta}{f_m} = \frac{f_{\max} - f_c}{f_m} = \frac{f_c - f_{\min}}{f_m} = \frac{k_f E_m}{f_m}$$

(7) **Frequency spectrum :** FM side band modulated signal consist of infinite number of side bands whose frequencies are

$$(f_c \pm f_m), (f_c \pm 2f_m), (f_c \pm 3f_m) ....$$

The number of side bands depends on the modulation index m_f

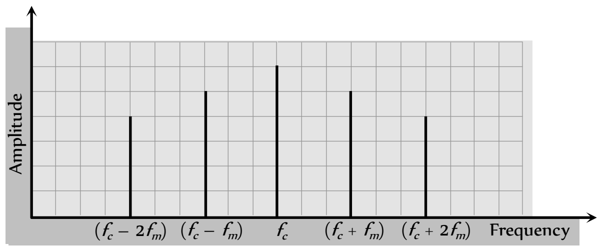


Fig. 28.13

In FM signal, the information (audio signal) is contained in the side bands. Since the side bands are separated from each other by the frequency of modulating signal f_m so

Band width $= 2n \times f_m$; where n = number of significant side band pairs

(8) **Deviation ratio :** The ratio of maximum permitted frequency deviation to the maximum permitted audio frequency is known as deviation ratio. Thus, deviation ratio $= \frac{(\Delta f)_{\max}}{(f_m)_{\max}}$

(9) **Percent modulation :** The ratio of actual frequency deviation to the maximum allowed frequency deviation is defined as percent modulation. Thus, percent modulation, $m = \frac{(\Delta f)_{\text{actual}}}{(\Delta f)_{\max}}$

Table 28.4 : Range of frequency allotted for FM radio/TV broadcast

Type of broadcast	Frequency band
FM radio	88 to 108 *MHz*
UHF TV	47 to 230 *MHz*
UHF TV	470 to 960 *MHz*

Pulse Modulation

Here the carrier wave is in the form of pulses.

(1) **Pulse amplitude modulation (PAM) :** The amplitude of the pulse varies in accordance with the modulating signal.

(2) **Pulse width modulation (PWM) :** The pulse duration varies in accordance with the modulating signal.

(3) **Pulse position modulation (PPM) :** In PPM, the position of the pulses of the carrier wave train is varied in accordance with the instantaneous value of the modulating signal.

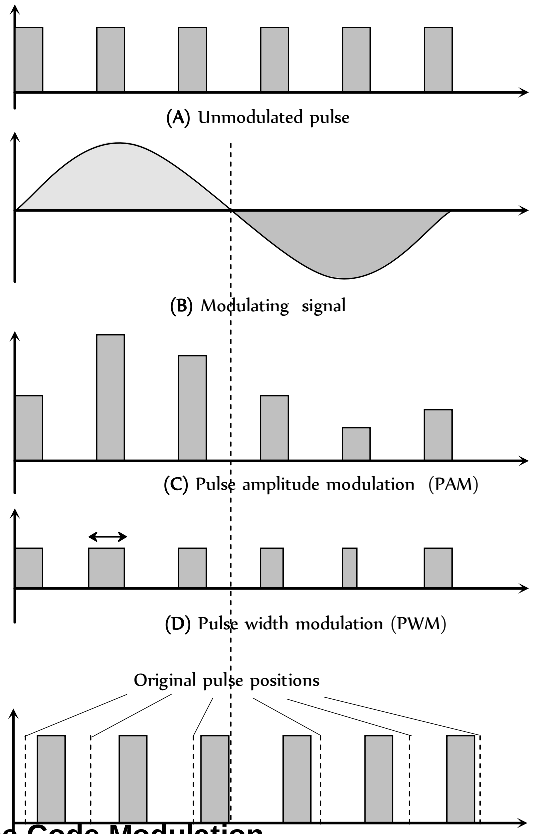


Fig. 28.14

Pulse Code Modulation

The pulse amplitude, pulse width and pulse position modulations are not completely digital.

A completely digital modulation is obtained by pulse code modulation (PCM).

An analog signal is pulse code modulated by following three operation.

(1) **Sampling :** It is the process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal.

The number of samples taken per second is called sampling rate.

(2) **Quantisation :** The process of dividing the maximum amplitude of the analog voltage signal into a fixed number of levels is called quantisation.

e.g. amplitude 5 *V* of the analog voltage signal divides into six. Quantisation level viz 0, 1, 2, 3, 4, 5.

Pulses having amplitude between – 0.5 *V* to 0.5 *V* are approximated (quantised) to a value 0 *V*, amplitude between 0.5 *V* to 1.5 *V* are approximated to a value of 1 *V* and so on.

(3) **Coding :** The process of digitising the quantised pulses according to some code is called coding.

Table 28.5 : Coding

Quantisation level	0	1	2	3	4	5	6	7
Binary code	000	001	010	011	100	101	110	111

For example consider that voltage amplitude of an analog signal varies between 0 and 7 *V*.

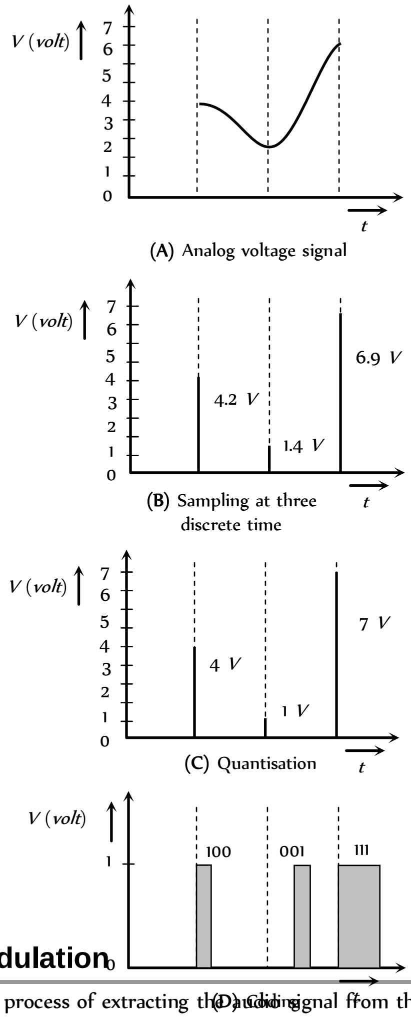


Fig. 28.15

Demodulation

The process of extracting the audio signal from the modulated wave is known as demodulation or detection.

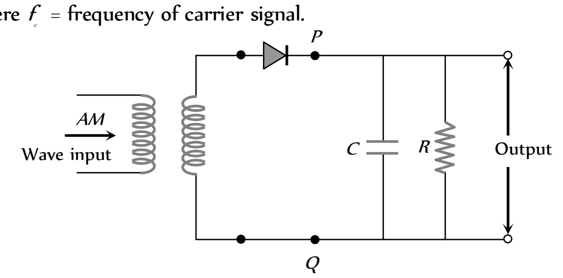
The wireless signals consist of radio frequency (high frequency) carrier wave modulated by audio frequency (low frequency). The diaphragm of a telephone receiver or a loud speaker cannot vibrate with high frequency. So it is necessary to separate the audio frequencies from the radio frequency carrier wave.

Simple demodulator circuit : A diode can be used to detect or demodulate an amplitude modulated (AM) wave. A diode basically acts as a rectifier *i.e.* it reduces the modulated carrier wave into positive envelope only.

The AM wave input is shown in figure. It appears at the output of the diode across *PQ* as a rectified wave (since a diode conducts only in the positive half cycle). This rectified wave after passing through the *RC* network does not contain the radio frequency carrier component. Instead, it has only the envelope of the modulated wave.

In the actual circuit the value of RC is chosen such that $\frac{1}{f_c} << RC$;

where f_c = frequency of carrier signal.



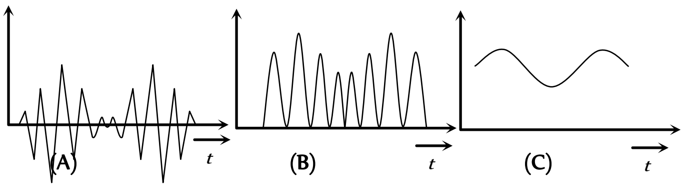


Fig. 28.16

Data Transmission and Retrieval

The term data is applied to a representation of facts, concepts or instructions suitable for communication, interpretation or processing by human beings or by automatic means. Data in most cases consists of pulse type of signals.

The pulse code modulated (PCM) signal is a series of 1's and 0's. The following three modulation techniques are used to transmit a PCM signal.

(1) **Amplitude shift keying (ASK) :** Two different amplitudes of the carrier represent the two binary values of the PCM signal. This method is also known as on-off keying (OOK)

1 : Presence of carrier of same constant amplitude.

0 : Carrier of zero amplitude.

(2) **Frequency shift keying (FSK) :** The binary values of the PCM signal are represented by two frequencies.

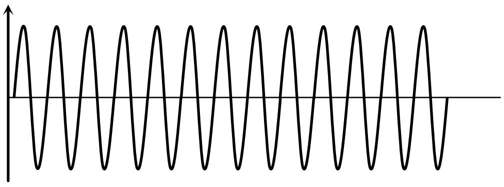
1 : Increase in frequency

0 : Frequency unaffected

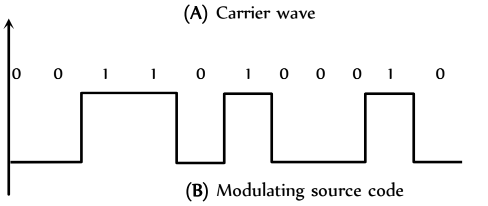
(3) **Phase shift keying (PSK) :** The phase of the carrier wave is changed in accordance with modulating data signal.

1 : Phase changed by π

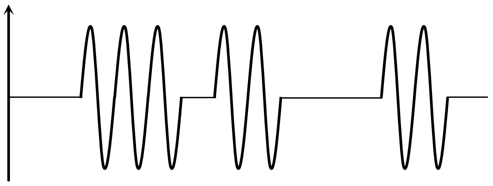
0 : Phase remains unchanged.



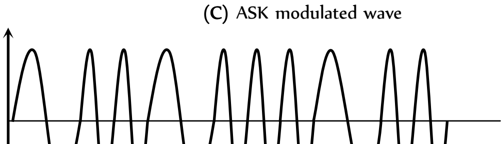
(A) Carrier wave



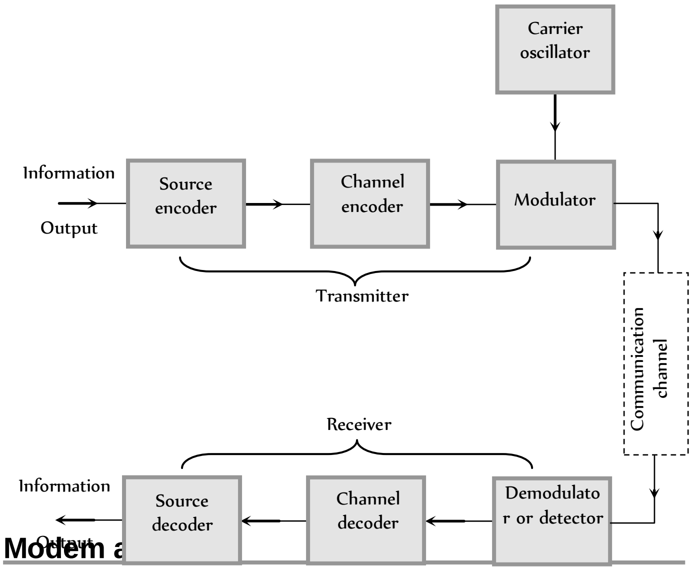
(B) Modulating source code



(C) ASK modulated wave



The analog signal is sampled by the sampler. The sampled pulses are then quantised. The encoder codes the quantised pulses according to the binary codes. After modulating the PCM signal (by ASK, FSK or PSK method) the modulated signal is, then transmitted into free space in the form of bits.



Modem a

Fig. 28.18

(1) **Modem :** Modems are used to interface two digital sources/receivers.

(i) Word modem has been obtained from the words modulator and demodulator. As the name implies both the functions (modulation) and demodulation) are included in a signal unit.

(ii) Modems are placed at both ends of the communication circuit as shown.

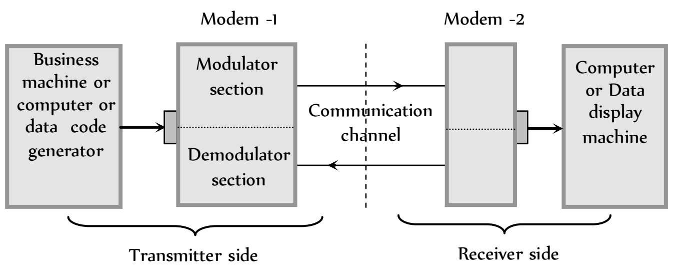


Fig. 28.19

(iii) The modem at the transmitting station changes the digital output from a computer (or any other business machine) to a from (analog signal) which can be easily sent via a communication channel (Telephone line *etc.*). While the receiving modem reverses the process.

(iv) There are three modes of operation of a modem.

(a) Simplex mode : In this mode data is transmitted in only one direction.

(b) Half duplex : In this mode data is transmitted between the transmitter and the receiver in both direction, but only in one direction at a time.

(c) Full duplex : In this mode, the data are transmitted between the transmitter and receiver in both directions at the same time.

Table 28.6 : Modem data transmission speed

Types	Speed in bits per sec and (bps)
Low speed modem	600 bps
Medium speed modem	600 to 2400 bps
High speed modem	2400 to 10,800 bps

(2) **Fax (Facsimile transmission) :** The electronic reproduction of a document at a distance place is known as facsimile transmission (FAX).

The original written document is converted into transmittable codes at the sending end. These codes are converted back into a copy of the original document at the receiving end.

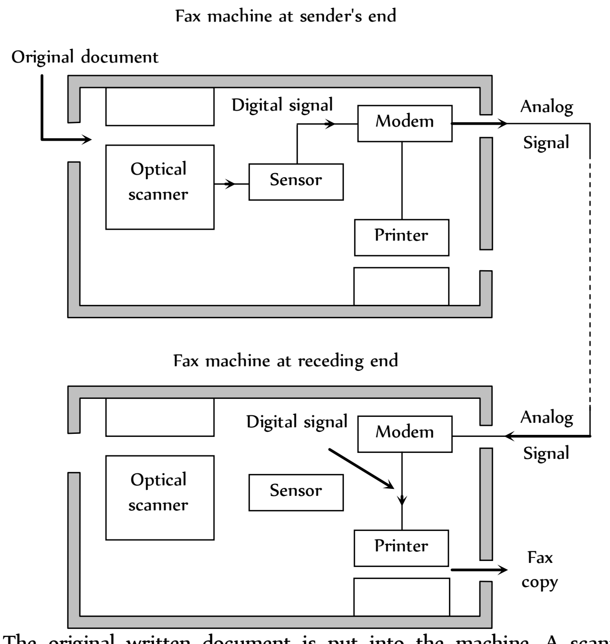


Fig. 28.20

The original written document is put into the machine. A scanner scans the whole document.

The scanned written document is then moved on a glass plate. A beam of light from a given source is projected through the glass and is reflected from the surface of the document.

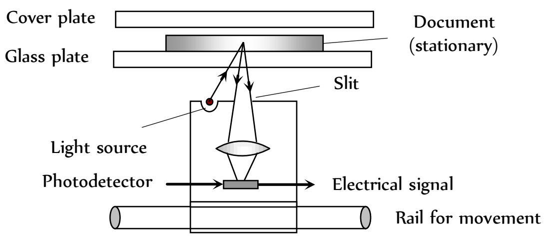


Fig. 28.21

The reflected light is focussed on a device known as photo detector which converts the optical signals (carrying the information regarding the patterns/writings/signatures *etc.*) in to electrical signals.

These electrical signals are then modulated and transmitted on to the telephone lines to the receiving end.

Space Communication

The communication process utilising the physical space around the earth is termed as space communication.

Electromagnetic waves which are used in Radio, Television and other communication system are radio waves and microwaves.

The radio waves emitted from a transmitter anteena can reach the receiver antenna by the following mode of operation.

+ Ground wave propagation

+ Sky wave propagation.

+ Space wave propagation.

(1) **Ground wave propagation**

(i) In ground wave propagation, radio waves travel along the surface of the earth (following the curvature of earth).

(ii) These waves induce currents in the ground as they propagate due to which some energy is lost.

(iii) The decrease in the value of energy (*i.e.* attenuation) increases with the increase in the frequency of radiowave.

(iv) As the ground wave propagates over the earth, it tilts over more and more due to diffraction. (This is another cause of attenuation of ground wave). After covering some distance, the wave just lie down which means it's death.

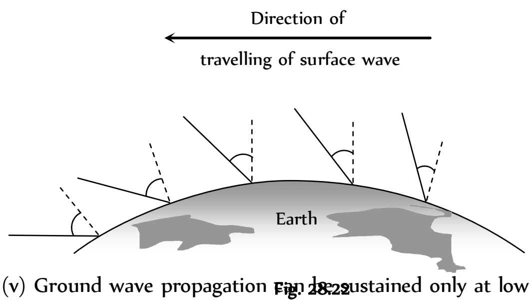


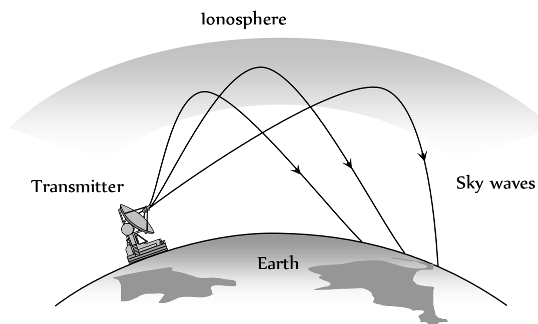
Fig. 28.22

(v) Ground wave propagation can be sustained only at low frequencies (~ 500 *kHz* to 1500 *kHz*) or for radio broadcast at long wavelengths.

(2) **Sky wave propagation**

(i) These are the waves which are reflected back to the earth by ionosphere.

Ionosphere is a layer of atmosphere having charged particles, ions and electrons and extended above 80 *km* – 300 *km* from the earth's surface.



(ii) These are the radio waves of frequency range 2 *MHz* to 30 *MHz*.

(iii) Sky waves are used for very long distance radio communication at medium and high frequencies (*i.e.* at medium waves and short waves).

(iv) The sky waves being electromagnetic in nature, changes the dielectric constant and refractive index of the ionosphere. The effective refractive index of the ionosphere is

$$n_{eff} = n_0\left[1-\frac{Ne^2}{\varepsilon_0 m\omega^2}\right]^{1/2} = n_0\left[1-\frac{80.5N}{f^2}\right]^{1/2}$$

where n_0 = refractive index of free space, N = electron density of ionosphere, ε_0 = dielectric constant of free space, e = charge on electron, m = mass of electron ω = angular frequency of EM wave.

(v) As we go deep into the ionosphere, N increases so n_{eff} decreases. The refractions or bending of the beam will continue and finally it reflects back.

(vi) **Critical frequency (f_c) :** It is defined as the highest frequency of radio wave, which gets reflected to earth by the ionosphere after having been sent straight to it.

If maximum electron density of the ionosphere is N_{max} per m^3, then $f_c \approx 9(N_{max})^{1/2}$. Above f_c a wave will penetrate the ionosphere and is not reflected by it.

(vii) **Maximum usable frequency (MUF) :** It is the highest frequency of radio waves which when sent at some angle of incidence θ, towards the ionosphere, get reflected and return to the earth. $MUF = \frac{f_c}{\cos\theta}$

(viii) **Skip distance :** It is the smallest distance from a transmitter along the earth's surface at which a sky wave of a fixed frequency but more than f_c is sent back to the earth.

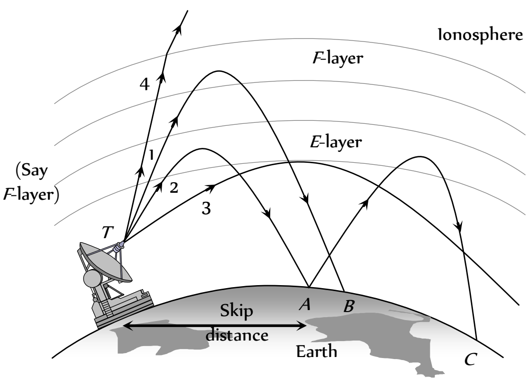


Fig. 28.24

(ix) **Fading :** It is defined as the fluctuation in the strength of a signal at a receiver due to interference of two waves.

Fading is more at high frequencies. It results into errors in data transmission and retrieval.

Space Wave Propagation

The space waves are the radio waves of very high frequency (30 *MHz* to 300 *MHz*) ultra high frequency (300 *MHz* to 3000 *MHz*) and microwave (more than 3000 *MHz*). At such high frequencies, the sky wave as well as ground wave propagation both fails.

These waves can be transmitted from transmitting to receiving antenna either directly or after reflection from the ground or in troposphere, the wave propagation is called space wave propagation.

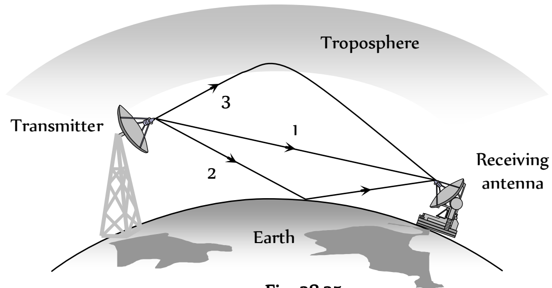


Fig. 28.25

The space wave propagation is also called as line of sight propagation. The line of sight distance is the distance between transmitting antenna and receiving antenna at which they can see each other.

Space wave propagation can be utilised for transmitting high frequency TV and FM signals.

(1) **Television signal propagation :** Frequency range for propagation is 80 *MHz* to 200 *MHz*

Height of transmitting antenna : $h = \frac{d^2}{2R}$ (d = distance covered by the signal, R = Radius of the Earth)

Area covered : $A = \pi d = 2\pi Rh$

Population cover : Population density × Area covered

(2) **Microwave communication :** Microwave communication systems are used for long distance communication. Since at microwave frequencies, electromagnetic waves cannot bend across the obstacles, such as the top of the buildings, mountains *etc.*, it is therefore necessary that microwave transmission is in line-of-sight.

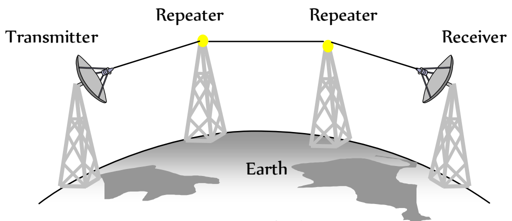


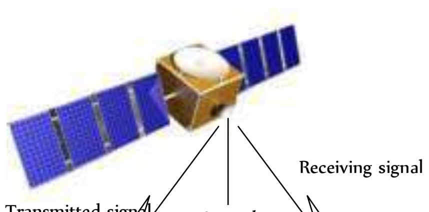
Fig. 28.26

Due to curvature in the surface of earth, the range of microwave transmission is very small (≈ 50 *km*). The range of microwave transmission is also limited by the fact that signals gets weaker and weaker as it propagates. However, these problems are overcome by using repeaters (A repeater is basically an amplifier, which amplifies the attenuated signal and then retransmits it.) at intervals between the transmitter and the receiver. Due to this, the cost of transmission of signal between the two stations increases.

The problems faced in a microwave communication system are solved to a large extent by using a geostationary satellite as a communication satellite.

Satellite Communication

(1) Satellite communication is like the line-of-sight microwave transmission. In this case, a beam of modulated microwave is projected towards the satellite.



(2) Satellite communication is mainly done through geostationary satellites (for steady reliable transmission and reception)

(3) A geostationary satellite has the same time period of revolution of earth (*i.e.* 24 *hrs.*). It appears stationary *w.r.t.* earth. It locates at the height of 36000 *km* above the earth's surface (well above the ionosphere).

(4) A communication satellite is a spacecraft placed in an orbit around the earth which carriers a transmitting and receiving equipment called radio transponder. It amplifies the microwave signals emitted by the transmitter from the surface of earth and send then to the receiving station on earth.

(5) The transmitted signal is UP-LINKED and received by the satellite station which DOWN-LINKS it with the ground station through it's transmitter.

The up-link and down-link frequencies are kept different (both frequencies being in the regions of UHF/microwave).

(6) A single satellite cannot cover the entire surface of the earth. At least three geo-stationary satellites are required which are 120° apart from each other to have the communication link over the entire globe of earth.

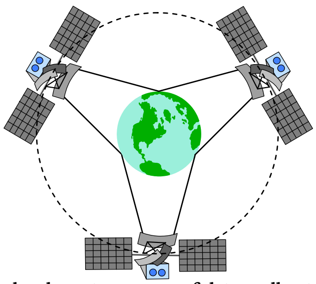


Fig. 28.28

(7) Satellite technology is very useful in collecting information about various factors of the atmosphere which governs the weather and climatic conditions.

The satellite communication can be used for establishing mobile communication with great use the communication satellites are now being used in Global Positioning System (GPS). The ordinary users can find their positions within an accuracy of 100 *m*.

There are two types of satellites used for long distance transmission.

(i) Passive satellite : It act as reflector only for the signals transmitted from earth. Moon the natural satellite of earth is a passive satellite.

(ii) Active satellite : It carries all the equipment used for receiving signals sent from the earth, processing them and then re-transmitting them to the earth. Now a days active satellites are in use.

(8) The Indian communication satellites INSAT-2B and INSAT-2C are positioned in such away in the outer space that they are accessible from any place in India.

Remote Sensing

Remote sensing is the technique to obtain information about an object (in respect of it's size, colour nature, location, temperature *etc.*) by observing it from a distance and without coming to actual contact with it.

(1) There are two types of remote sensing instruments : active and passive. Active instruments provide their own energy to illuminate the object of interest, as radar does. They send an energy pulse to the object and then receive and process the pulse reflected from the object. Passive instruments sense only radiations emitted by the object or solar radiation reflected from the object.

(2) The remote sensing is done through a satellite. The satellite used in remote sensing should move in an orbit around the earth in such away that it always passes over the particular area of the earth at the same local time.

The orbit of such a satellite is known as sun-synchronous orbit. A remote sensing orbit can be circular polar orbit or in highly inclined elliptical orbit.

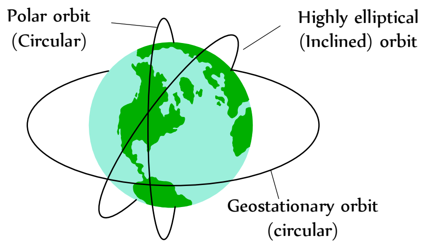


Fig. 28.29

(3) A remote sensing satellite takes, photographs of a particular region which nearly the same illumination every time it passes through that region.

(4) The most useful remote sensing technology is that it makes possible the repetitive surveys of vast areas in a very short time, even if the areas are inaccessible.

(5) Space based remote sensing is a new technology. It has high potential for applications in nearly all aspects of resource management.

(6) The Indian remote sensing satellites are IRS-1A, JRS-1B, and IRS-1C.

(7) **Some applications of remote sensing includes**

(i) Meteorology : (development of weather systems and weather for casting).

(ii) Climatology : Monitoring climatic changes.

(iii) Oceanography : (Sea surface temperatures, mapping of sea-ice and oil pollution monitoring).

(iv) Archaeology, geological surveys.

(v) Water resource surveys,

(vi) Urban land use surveys.

(vii) Agriculture and forestry and natural disaster.

(viii) In the field of spying to detect movements of enemy army an their positions.

(ix) It is used to locate the place where under ground nuclear explosion has carried out.

Line Communication

Line communication means interconnection of two points that are at some distance from each other with the help of wires for exchange of information *e.g.* interconnection between a transmitter and receiver or a transmitter and anteena or an anteena and receiver.

Two Wire Transmission Line

The most commonly used two wire lines are : Parallel wire, twisted pair wires and co-axial cable.

(1) **Parallel wire line :** In a two wire transmission line, two metallic wires are arranged parallel to each other inside a protective insulation coating.

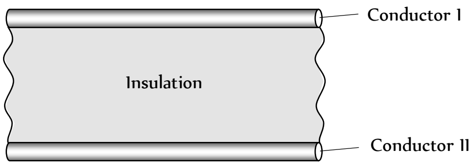


Fig. 28.30

(i) The wires may be hard or flexible depending on the power to be handled.

(ii) It is commonly used to connect an anteena with TV receiver.

(iii) Such wires can suffer from interferences and losses.

(2) **Twisted pair wire :** It consists of two insulated copper wires twisted around each other at regular intervals to minimize electrical interference.

(i) Twisted pair wires are used to connect telephone systems. It works well up to a distance of about 10 *cm*. They cannot transmit signals over very large distances.

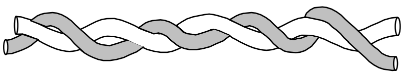


Fig. 28.31

(ii) They can be used for transmitting both, the analog and digital signals.

(iii) They are easy to install and cost effective.

(3) **Coaxial wire lines :** It consist of a central copper wire (which transmits the signals) surrounded by a PVC insulation over which a sleeve of copper mesh (outer conductor) is placed. The outer conductor is normally connected to ground and thus it provides an electrical shield to the signals carried by the central conductor. The outer conductor is externally covered with a polymer jacket for protection.

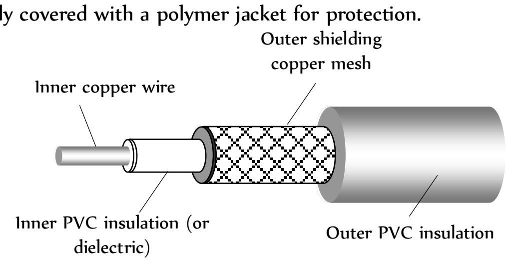


Fig. 28.32

(i) Co-axial line wires can be used for microwaves and ultra high frequency waves.

(ii) The communication through co-axial lines is more efficient than through a twisted pair wire lines.

(iii) Co-axial cables can be gas filled also. To reduce flash over between the conductor handling high power, N_2-gas is used in the cable.

Impedance of Line

Each portion of the transmission line can be considered as a small inductor, resistor and capacitor as shown.

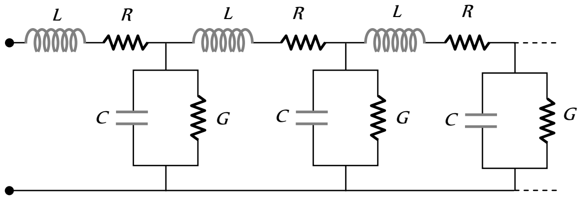


Fig. 28.33

(1) Such inductors, resistors and capacitors are distributed throughout the transmission line.

As a result each length of transmission line has a characteristic impedance.

(2) In case of co-axial cable, the dielectric can be represented by a shunt resistance *G*.

(3) When co-axial cable is used to transmit a radio frequency signal, X_L and X_C are large as compared to *R* and *G* respectively. Hence *R* and *G* can be neglected.

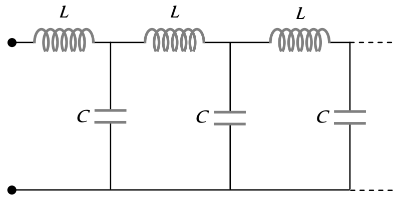


Fig. 28.34

(4) In co-axial cable, *R* is zero, so no loss of energy and hence no attenuation of frequency signal occurs when transmitted along it. That's why co-axial cables are specially used in cable TV network.

(5) **Characteristic impedance (Z_0) :** It is defined as the impedance measured at the input of a line of infinite length.

For parallel line $Z_0 = \frac{276}{\sqrt{k}} \log \frac{2s}{d}$

d = Diameter of each wire

s = Separation between the two wires

k = Dielectric constant of the insulating medium

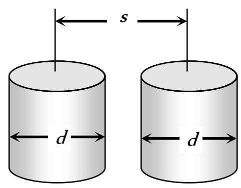


Fig. 28.35

For co-axial line wire $Z_0 = \frac{138}{\sqrt{k}} \log \frac{D}{d}$

d = Diameter of inner conductor

D = Diameter of outer conductor

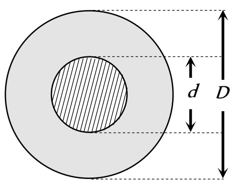


Fig. 28.36

At radio frequency $Z_0 = \sqrt{\frac{L}{C}}$

the usual range of characteristic impedance for parallel wire lines is 150Ω to 600 Ω and for co-axial wire it is 40 Ω to 150 Ω.

(6) **Velocity factor of a line** (*v. f.*) **:** It is the ratio of reduction of speed of light in the dielectric of the cable

$$v.f. = \frac{v}{c} = \frac{\text{Speed of light in medium}}{\text{Speed of light in vacuum}} = \frac{1}{\sqrt{K}}$$

For a line *v.f.* is generally of the order of 0.6 to 0.9.

Telephone Links

(1) Telephone is the most common means of communication. Now a days, the telephone system is required to converse from earth to another heavenly bodies like moon *etc.*

(2) A telephone link can be established with the help of co-axial cables, ground waves, sky waves, microwaves or optical fibre cables.

(3) Simultaneous transmission of a number of messages over a single channel without their interfering with one another is called multiplexing. Two types of multiplexing techniques are in use :

(i) Frequency division multiplexing uses analog modulation of message signals.

(ii) Time division multiplexing makes use of pulse modulation of message signals.

(4) Twisted pair wire lines provide a band width of 2 *MHz*, while co-axial cable provides a band width of 20 *MHz*. For further increase in band width, we use

(i) microwave link

(ii) communication satellite link.

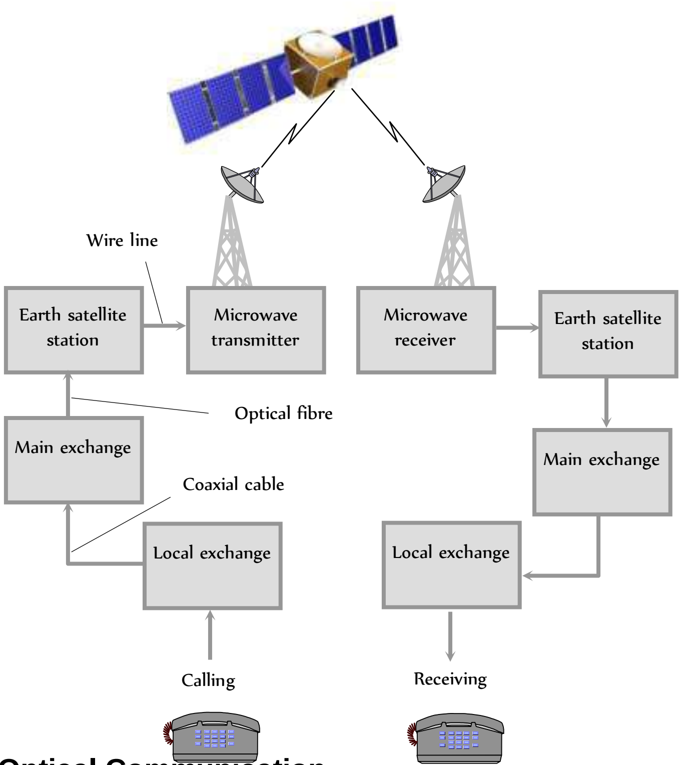


Fig. 28.37

Optical Communication

(1) The use of optical carrier waves for transmission of information from one place to another is called optical communication.

(2) The useful optical frequency range is 10^{12} *Hz* to 10^{16} *Hz* which is very high as compared to radio and microwave frequencies (10^{6} *Hz* – 10^{11} *Hz*).

(3) The information carrying capacity ∝ bandwidth ∝ frequency of carrier wave. So optical communication is better than others. (because of high frequency).

(4) Basic setup of optical communication shown below

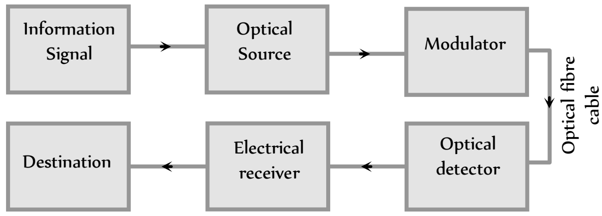


Fig. 28.38

(5) Light emitting diodes (LED) and diode lasers are preferred for optical source. LED's are used for small distance transmission while diode laser is used for very large distance transmission.

(6) In order to transmit information signal via an optical communication system, it is necessary to modulate light with the information signal.

(7) The optical signal reaching the receiving end has to be detected by a detector which converts light into electrical signals, So that the transmitted information may be decoded. Semiconductor based photo-electors are used

Optical Fibre

The optical fibres are used to transmit light signals from one place to another without any practical loss in the intensity of light signal.

(1) **Design :** Optical fibre is made of a thin glass core (diameter 10 to 100 μm) surrounded by a glass coating called cladding are protected by a jacket of plastic.

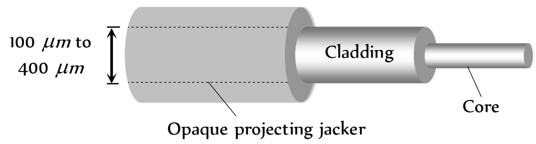


Fig. 28.39

(2) **Principle :** It works on the principle of total internal reflection.

(3) **Action :** The refractive index of the glass used for making core (μ_1 ≈ 1.7) is a little more than the refractive index of the glass (μ_2 ≈ 1.5) used for making the cladding *i.e.* $\mu_1 > \mu_2$.

The core dimension is so small (≈ 10 μm) that the light entering will almost essentially be having incident angle (θ) more than the critical angle (θ) and will suffer total internal reflection at the core. Cladding boundary such successive total reflections at opposite boundaries will confine the light to the core as shown in figure.

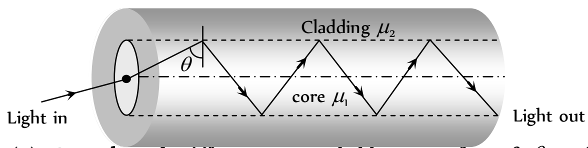


Fig. 28.40

(4) **Critical angle (θ) :** At core-cladding interface if $\theta = \theta_c$ then

$$\cos\theta_c = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1} \Rightarrow \theta_c = \cos^{-1}\left(\frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_1}\right)$$

(5) **Acceptance angle (θ) :** The value of maximum angle of incidence with the axis of fibre in air for which all the incident light is totally reflected is known as acceptance angle.

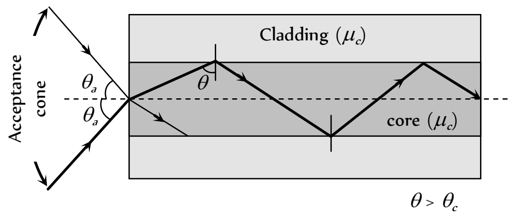


Fig. 28.41

If θ_a = Acceptance angle then μ_1 = refractive index of core, μ_2 = refractive index of cladding.

$$\sin\theta_a = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0} \Rightarrow \theta_a = \sin^{-1}\sqrt{\mu_1^2 - \mu_2^2} \quad \text{(for air } \mu_0 = 1\text{)}$$

(6) **Numerical aperture :** Light gathering capability of a fibre is related to numerical aperture. This is defined as the sine of acceptance angle *i.e.*

$$NA = \sin i = \sqrt{\mu_1^2 - \mu_2^2}$$

The numerical aperture can also be given in terms of relative core-cladding index difference (Δ), where $\Delta = \frac{\mu_1^2 - \mu_2^2}{2\mu_1^2}$

Thus, $NA = \sqrt{\mu_1^2 - \mu_2^2} = \mu_1\sqrt{2\Delta}$

(7) **Fibre attenuation :** In practice a very small part of light energy is lost from an optical fibre. This reduction in energy of the light is called attenuation and is described by $I = I_0 e^{-\alpha x}$

where I_0 = Intensity of light when it enters the fibre

I = Intensity of light at a distance x along the fibre

α = Absorption co-efficient or attenuation co-efficient

Also attenuation (in *dB*) $= 10 \log_{10} \frac{I}{I_0}$

(8) **Types of optical fibre**

(i) **Monomode optical fibre :** It has a very narrow core of diameter about 5μm or less, cladding is relatively big.

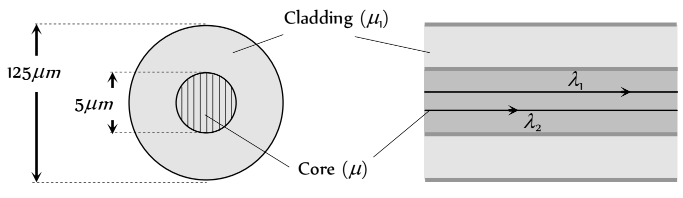


Fig. 28.42

(ii) **Multimode optical fibre :** It is again of two types

(a) Step index multimode fibre :

The diameter of the core is about 50 μm.

Core has constant R.I μ_1 from it's centre to boundary.

The refractive index then changes to a lower value of μ_2 which remains constant through the cladding.

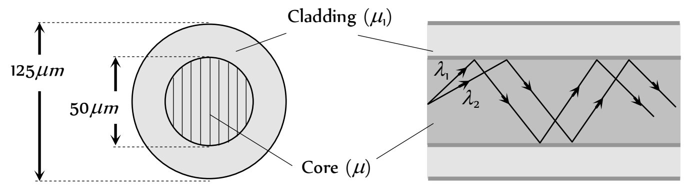


Fig. 28.43

Since refractive index of a material depend on the wavelength of light. The wavelength fellow diff. paths.

The overall time difference between two wavelengths reaches the other end is of the order of 33 × 10^{-9} *sec/cm* length of the fibre.

(iii) **Graded index multimode fibre :** Refractive index decreases smoothly from it's centre to the outer surface of the fibre (cladding). There is no notieable boundary between core and cladding.

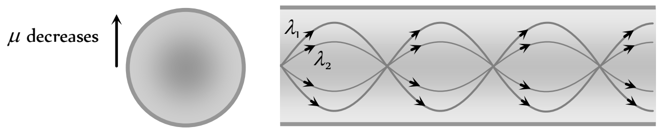


Fig. 28.44

Advantages of Optical Fibres Over Wires

(1) Lower cost in the long run.

(2) Low loss of signal typically less than 0.3 *dB/km*), so repeater-less transmission over long distances is possible.

(3) Large data-carrying capacity (thousands of times greater, reaching speeds of up to 1.6 *Tb/s* in field deployed systems and up to 10 *Tb/s* in lab systems).

(4) No electromagnetic radiation; difficult to eavesdrop.

(5) High electrical resistance, so safe to use near high-voltage equipment or between areas with different earth potentials.

(6) Low weight.

(7) Signals contain very little power.

(8) No cross talk between cables.

(9) No sparks (*e.g.* in automobile applications)

(10) Difficult to place a tap or listening device on the line, providing better physical network security.

Laser

Laser is a process by which we get a beam which is coherent, highly monochromatic and almost perfectly parallel. Such a beam is also called laser.

Coherent : Because all the photons in the light beam, emitted by different atoms, at different instant are in phase.

Monochromatic :	Because, the spread $\Delta\lambda$ in wavelength is very small, of the order of 10^{-6} *nm*.
Perfectly parallel :	Because, a laser beam can be sent to a far off place and returns back without any practical loss of intensity.

The term LASER stands for **L**ight **A**mplification by **S**timulated **E**mission **R**adiation.

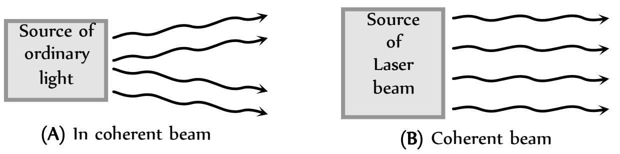


Fig. 28.45

Concepts Related to Production of LASER

(1) **Stimulated absorption :** Consider an atom which has an allowed state at energy E_1 and another allowed state at a higher energy E_2. Suppose the atom is in the lower energy state E_1. If a photon of light having energy $E_2 - E_1$ is incident on this atom, the atom may absorb the photon and jump to the higher energy state E_2. This process is called stimulated absorption of light photon. The incident photon has stimulated the atom to absorb the energy.

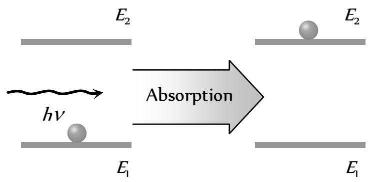


Fig. 28.46

(2) **Spontaneous emission :** If an atom is present in the higher energy state, it tends to return to the lower energy state within a time of 10^{-8} *sec* by emitting a photon of energy $h\nu = E_2 - E_1$. We call this process spontaneous emission. Spontaneous because the event was not triggered by any outside influence.

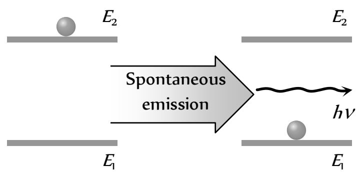


Fig. 28.47

(3) **Stimulated emission :** Suppose a photon of energy $h\nu = E_2 - E_1$ interacts with an atom that is already in the excited state E_2.

The incident photon may stimulate the atom to emit a photon, the energy, phase, and direction of travel of this second photon are exactly the same as those of the incident photon. That is the quantum state of the stimulated photon is identical to that of the incident photon. This process is called stimulated emission.

If these two photons then interact with two more excited state atoms, two more photons are produced, and soon. Therefore, the stimulation process leads to photon amplification.

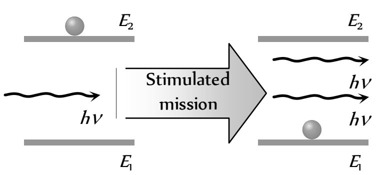


Fig. 28.48

(4) **Population inversion :** Usually the number of atoms in the lower energy state is more than the number of atoms in the excited state. To emit photons which are coherent (*i.e.* in phase), the number of atoms in the higher state must be greater than the number of atoms in the lower energy state. In other words, population of atoms in the higher energy state must be larger than the population of atoms in the lower energy state. The process of making the population of atoms in the higher energy state more than that of lower energy state is known as population inversion.

The method used to invert the population of atoms is known as pumping.

(5) **Metastable states :** A metastable state is one, which has a mean life time of the order of 10^{-3} *s* or more *i.e.* much larger than 10^{-8} *s*, the life time of a higher energy state. Some atomic systems, such as chromium, neon, *etc* possess metastable states. The atom of such an atomic system, when in higher energy state, does not come down to lower energy state directly. It first returns to metastable state and then after a finite lapse of time of the order of 10^{-3} *s*, returns to the lower energy state. Since such atom stays in metastable state for a sufficiently long time, the population inversion can sustain in such atomic system.

A system in which population inversion is achieved is called the active system.

Principle of Laser

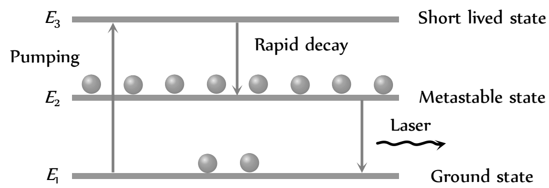


Fig. 28.49

Atoms from the ground state E_1 are 'pumped' up to an excited state E_3. From E_3 the atom decay rapidly to state of energy E_2. For lasing (lasing means laser action) to occur, this state must be metastable. If conditions are right, state E_2 can then become more heavily populated than state E_1, thus providing the needed population inversion.

When photon of energy $h\nu = E_2 - E_1$ is incident on one of the atoms present in the metastable state, the atom will drop to lower energy state E_1, emitting a photon of same energy as that of the incident photon, which is in phase with it and is emitted in the same direction. The two photons, then interact with two more atoms present in metastable state and so on. This process is called amplification of light.

For smooth process two conditions are necessary

(1) The metastable state should all the time have larger number of atoms than the number of atoms in lower energy state.

(It is achieved by pumping)

(2) The photons emitted due to stimulated emission should stimulate other atoms to multiply the photons inside the system.

(It is achieved by two mirrors are fixed at the ends of the system containing lasing material. The mirrors reflect the photons back and forth to keep them inside the region for a long time.)

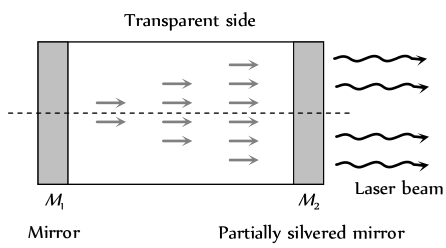


Fig. 28.50

Helium-Neon Laser

This laser contains a mixture of helium (≈ 90%) and neon (≈ 10%) at low pressure in a cylindrical tube with mirrors at each end. The energy level diagram in figure shows the important energy levels for the helium and neon atoms. A large electric field is established in the tube by electrodes connected to a high-voltage power supply, Electrons from ionized atoms are accelerated by the field and collide with atoms.

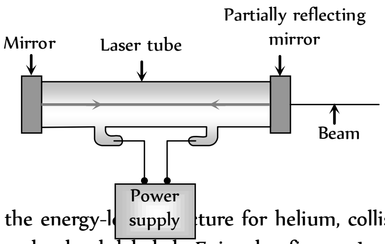


Fig. 28.51

Because of the energy-l[illegible]ture for helium, collisions often excite helium atoms to the level labeled E_3 in the figure. In a process called collision transfer, energy is transferred from excited helium atoms to neon atoms during collisions, thus producing a population of neon atoms in the E_2 level. The transition from level E_2 to E_1 in neon is forbidden, but the transition out of the E_1 level is allowed. This means that the population of atoms in the E_2 level builds up, and that of the E_1 level is rapidly depleted.

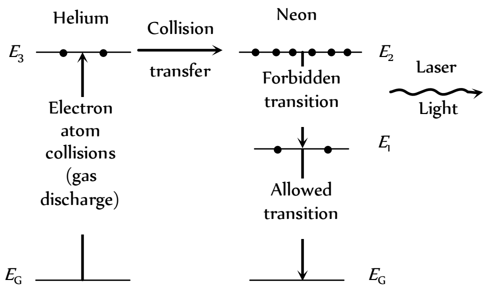


Fig. 28.52

Stimulated emission from E_2 to E_1 predominates and laser light is generated.

The mirrors at each end of the tube encourage emissions along the tube axis by reflecting the light back and forth inside the tube. One of the mirrors is slightly leaky, transmitting about 1 percent of the incident light. This transmitted light forms the laser beam which we find so useful.

Tips & Tricks

✍ Parallel wire lines are never used for transmission of microwaves. This is because at the frequency of microwaves, separation between the two wires approaches half a wavelength ($\lambda/2$). Therefore radiation loss of energy becomes maximum.

✍ Number of channel accommodated for

$$\text{Transmission} = \frac{\text{Total band width of channel}}{\text{Band width needed per channel}}$$

✍ Bit rate = Sampling rate × no. of bits per sample.

✍ Modulation factor determines the strength and quality of the transmitted signal.

✍ A Hertz antenna is a straight conductor of length equal to half the wavelength of radio signals to be transmitted or received. A Marconi antenna is a straight conductor of length $l = \lambda/4$

✍ In a digital signal, information is carried by the pattern of pulses and not by the shape of pulses.

✍ Sampling converts an analog signal into digital. For example when an analog signal is sampled at interval of 125 μ*-sec* the number of samples taken per second $= \dfrac{1}{125 \times 10^{-6}} = 8000.$

✍ AGC stands for automatic gain control. It is used in receive.

✍ Sputinik-I launched by Russia in 1957 was the first active satellite.

✍ First communication satellite was put in an orbit by USA in 1958.

✍ The first India experimental satellite *i.e.* Apple was launched on June 19, 1981.

✍ The national information cenre at Delhi has linked computers at all head quarters through INSAT 2B.

✍ First communication satellite was put in an orbit by USA in 1958.

✍ Just as $\sqrt{\dfrac{Z}{Y}}$ represents characteristic impedance (Z) of a transmission line, $\sqrt{ZY}$ represents propagation constant of the line.

✍ Glass-core and glass cladding (often called SCS fire *i.e.* silica clad silica fibre) have the best propagation characteristics.

✍ The dish type antenna's used for satellite communication are generally of cassegrain type

✍ Ground waves propagate along the surface of the earth. These are vertically polarised to prevent short circuiting of the electric field at a distance d is given by $E = \dfrac{120\,\pi h_t I}{\lambda d}$ and signal received by an antenna of height h_r is given by $V\,(\text{volts}) = \dfrac{120\pi h_t h_r I}{\lambda d}$

✍ Receivers may be of two types, tuned radio frequency (TRF) receivers and superheterodyne receivers. Super heterodyne receivers use local oscillators and intermediate frequency amplifiers before the signal is detected. In this way the reception becomes free of signal frequency but depends only on intermediate frequency which is fixed.

✍ A rectifier with peak detection is used in the AM wave detection and FM detection is achieved by an *LC* circuit tuned at off resonant frequency.

✍ APDs (Avalanche photodiodes) are best suited for detection in fiber optic communication.

✍ **MASER** is microwave amplification by stimulated emission of radiation. It is used as a microwave amplifier or oscillator. The principle of MASER is identical to that of LASER. Only frequency range is $\leq 10^{11}$ *Hz* in masers.

✍ In frequency modulation m_f (frequency modulation index) is inversely proportional to modulating frequency f_m. While in PM it does not vary with modulating frequency. Moreover, FM is more noise immune.

✍ AM with single side band suppressed carrier is better as it contains maximum modulating power.

Ordinary Thinking

Objective Questions

Communication

1. In short wave communication waves of which of the following frequencies will be reflected back by the ionospheric layer, having electron density 10^{11} per *m*

[AIIMS 2003]

(a) 2 *MHz* (b) 10 *MHz*

(c) 12 *MHz* (d) 18 *MHz*

2. In an amplitude modulated wave for audio frequency of 500 *cycle/second*, the appropriate carrier frequency will be

[AMU 1996]

(a) 50 *cycles/sec* (b) 100 *cycles/sec*

(c) 500 *cycles/sec* (d) 50,000 *cycles/sec*

3. AM is used for broadcasting because

(a) It is more noise immune than other modulation systems

(b) It requires less transmitting power compared with other systems

(c) Its use avoids receiver complexity

(d) No other modulation system can provide the necessary bandwidth faithful transmission

4. Range of frequencies allotted for commercial FM radio broadcast is

(a) 88 to 108 *MHz* (b) 88 to 108 *kHz*

(c) 8 to 88 *MHz* (d) 88 to 108 *GHz*

5. The velocity factor of a transmission line *x*. If dielectric constant of the medium is 2.6, the value of *x* is

[AFMC 1995]

(a) 0.26 (b) 0.62

(c) 2.6 (d) 6.2

6. The process of superimposing signal frequency (*i.e.* audio wave) on the carrier wave is known as [AIIMS 1987]

(a) Transmission (b) Reception

(c) Modulation (d) Detection

7. Long distance short-wave radio broadcasting uses

[AFMC 1996]

(a) Ground wave (b) Ionospheric wave

(c) Direct wave (d) Sky wave

8. A step index fibre has a relative refractive index of 0.88%. What is the critical angle at the corecladding interface

[Manipal 2003]

(a) 60° (b) 75°

(c) 45° (d) None of these

9. The characteristic impedance of a coaxial cable is of the order of

(a) 50 Ω (b) 200 Ω

(c) 270 Ω (d) None of these

10. In which frequency range, space waves are normally propagated

(a) HF (b) VHF

(c) UHF (d) SHF

11. If μ_1 and μ_2 are the refractive indices of the materials of core and cladding of an optical fibre, then the loss of light due to its leakage can be minimised by having [BVP 2003]

(a) $\mu_1 > \mu_2$ (b) $\mu_1 < \mu_2$

(c) $\mu_1 = \mu_2$ (d) None of these

12. Through which mode of propagation, the radio waves can be sent from one place to another [JIPMER 2003]

(a) Ground wave propagation

(b) Sky wave propagation

(c) Space wave propagation

(d) All of them

13. A laser beam of pulse power 10^{12} *watt* is focussed on an object are 10^{-4} *cm*. The energy flux in *watt*/ *cm* at the point of focus is

(a) 10^{20} (b) 10^{16}

(c) 10^{8} (d) 10^{4}

14. The carrier frequency generated by a tank circuit containing 1 *nF* capacitor and 10 μH inductor is [AFMC 2003]

(a) 1592 *Hz* (b) 1592 *MHz*

(c) 1592 *kHz* (d) 159.2 *Hz*

15. Broadcasting antennas are generally [AFMC 2003]

(a) Omnidirectional type (b) Vertical type

(c) Horizontal type (d) None of these

16. For television broadcasting, the frequency employed is normally

(a) 30-300 *MHz* (b) 30-300 *GHz*

(c) 30-300 *KHz* (d) 30-300 *Hz*

17. The radio waves of frequency 300 *MHz* to 3000 *MHz* belong to [MNR 1997]

(a) High frequency band

(b) Very high frequency band

(c) Ultra high frequency band

(d) Super high frequency band

18. An antenna behaves as resonant circuit only when its length is

(a) $\frac{\lambda}{2}$

(b) $\frac{\lambda}{4}$

(c) λ

(d) $\frac{\lambda}{2}$ or integral multiple of $\frac{\lambda}{2}$

19. Maximum useable frequency (MUF) in *F*-region layer is *x*, when the critical frequency is 60 *MHz* and the angle of incidence is 70°. Then *x* is [Himachal PMT 2003]

(a) 150 *MHz* (b) 170 *MHz*

(c) 175 *MHz* (d) 190 *MHz*

20. The electromagnetic waves of frequency 2 *MHz* to 30 *MHz* are [CPMT 2003]

(a) In ground wave propagation

(b) In sky wave propagation

(c) In microwave propagation

(d) In satellite communication

21. A laser is a coherent source because it contains

[JIPMER 2003] [EAMCET 2002]

(a) Many wavelengths

(b) Uncoordinated wave of a particular wavelength

(c) Coordinated wave of many wavelengths

(d) Coordinated waves of a particular wavelength

22. The attenuation in optical fibre is mainly due to [AFMC 2003]

(a) Absorption

(b) Scattering

(c) Neither absorption nor scattering

(d) Both (a) and (b)

23. The maximum distance upto which TV transmission from a TV tower of height h can be received is proportional to [AIIMS 2003]

(a) $h^{1/2}$ (b) h

(c) $h^{3/2}$ (d) h^2

24. A laser beam is used for carrying out surgery because it [AIIMS 2003]

(a) Is highly monochromatic (b) Is highly coherent

(c) Is highly directional (d) Can be sharply focussed

25. Laser beams are used to measure long distances because [DCE 2002, 03]

(a) They are monochromatic

(b) They are highly polarised

(c) They are coherent

(d) They have high degree of parallelism

26. An oscillator is producing FM waves of frequency 2 *kHz* with a variation of 10 *kHz*. What is the modulating index [DCE 2004]

(a) 0.20 (b) 5.0

(c) 0.67 (d) 1.5

27. The maximum peak to peak voltage of an AM wire is 24 *mV* and the minimum peak to peak voltage is 8 *mV*. The modulation factor is

(a) 10% (b) 20%

(c) 25% (d) 50%

28. Sinusoidal carrier voltage of frequency 1.5 *MHz* and amplitude 50 *V* is amplitude modulated by sinusoidal voltage of frequency 10 *kHz* producing 50% modulation. The lower and upper side-band frequencies in *kHz* are

(a) 1490, 1510 (b) 1510, 1490

(c) $\frac{1}{1490}, \frac{1}{1510}$ (d) $\frac{1}{1510}, \frac{1}{1490}$

29. What is the modulation index of an over modulated wave

(a) 1 (b) Zero

(c) < 1 (d) > 1

30. Basically, the product modulator is

(a) An amplifier (b) A mixer

(c) A frequency separator (d) A phase separator

31. If f_a and f_f represent the carrier wave frequencies for amplitude and frequency modulations respectively, then

(a) $f_a > f_f$ (b) $f_a < f_f$

(c) $f_a \approx f_f$ (d) $f_a \geq f_f$

32. Which of the following is the disadvantage of FM over AM

(a) Larger band width requirement

(b) Larger noise

(c) Higher modulation power

(d) Low efficiency

33. If a number of sine waves with modulation indices n_1, n_2, n_3 .... modulate a carrier wave, then total modulation index (n) of the wave is

(a) $n_1 + n_2 .... + 2(n_1 + n_2.....)$

(b) $\sqrt{n_1 - n_2 + n_3..........}$

(c) $\sqrt{n_1^2 + n_2^2 + n_3^2.........}$

(d) None of these

34. An AM wave has 1800 *watt* of total power content, For 100% modulation the carrier should have power content equal to

(a) 1000 *watt* (b) 1200 *watt*

(c) 1500 *watt* (d) 1600 *watt*

35. The frequency of a FM transmitter without signal input is called

(a) Lower side band frequency

(b) Upper side band frequency

(c) Resting frequency

(d) None of these

36. What type of modulation is employed in India for radio transmission

(a) Amplitude modulation (b) Frequency modulation

(c) Pulse modulation (d) None of these

37. When the modulating frequency is doubled, the modulation index is halved and the modulating voltage remains constant, the modulation system is

(a) Amplitude modulation (b) Phase modulation

(c) Frequency modulation (d) All of the above

38. An antenna is a device

(a) That converts electromagnetic energy into radio frequency signal

(b) That converts radio frequency signal into electromagnetic energy

(c) That converts guided electromagnetic waves into free space electromagnetic waves and vice-versa

(d) None of these

39. While tuning in a certain broadcast station with a receiver, we are actually

(a) Varying the local oscillator frequency

(b) Varying the frequency of the radio signal to be picked up

(c) Tuning the antenna

(d) None of these

40. Indicate which one of the following system is digital

(a) Pulse position modulation

(b) Pulse code modulation

(c) Pulse width modulation

(d) Pulse amplitude modulation

41. In a communication system, noise is most likely to affect the signal

(a) At the transmitter

(b) In the channel or in the transmission line

(c) In the information source

(d) At the receiver

42. The waves used in telecommunication are

(a) IR (b) UV

(c) Microwave (d) Cosmic rays

43. In an FM system a 7 *kHz* signal modulates 108 *MHz* carrier so that frequency deviation is 50 *kHz*. The carrier swing is

(a) 7.143 (b) 8

(c) 0.71 (d) 350

44. Consider telecommunication through optical fibres. Which of the following statements is not true [AIEEE 2003]

(a) Optical fibres may have homogeneous core with a suitable cladding

(b) Optical fibres can be of graded refractive index

(c) Optical fibres are subject to electromagnetic interference from outside

(d) Optical fibres have extremely low transmission loss

45. The phenomenon by which light travels in an optical fibres is

(a) Reflection (b) Refraction

(c) Total internal reflection (d) Transmission

46. Television signals on earth cannot be received at distances greater than 100 *km* from the transmission station. The reason behind this is that [DCE 1995]

(a) The receiver antenna is unable to detect the signal at a distance greater than 100 *km*

(b) The TV programme consists of both audio and video signals

(c) The TV signals are less powerful than radio signals

(d) The surface of earth is curved like a sphere

47. Advantage of optical fibre [DCE 2005]

(a) High bandwidth and EM interference

(b) Low bandwidth and EM interference

(c) High band width, low transmission capacity and no EM interference

(d) High bandwidth, high data transmission capacity and no EM interference

48. In frequency modulation [Kerala PMT 2005]

(a) The amplitude of modulated wave varies as frequency of carrier wave

(b) The frequency of modulated wave varies as amplitude of modulating wave

(c) The amplitude of modulated wave varies as amplitude of carrier wave

(d) The frequency of modulated wave varies as frequency of modulating wave

(e) The frequency of modulated wave varies as frequency of carrier wave

49. Audio signal cannot be transmitted because

[Kerala PMT 2005]

(a) The signal has more noise

(b) The signal cannot be amplified for distance communication

(c) The transmitting antenna length is very small to design

(d) The transmitting antenna length is very large and impracticable

(e) The signal is not a radio signal

50. In which of the following remote sensing technique is not used

(a) Forest density (b) Pollution

(c) Wetland mapping (d) Medical treatment

51. For sky wave propagation of a 10 *MHz* signal, what should be the minimum electron density in ionosphere

[AIIMS 2005]

(a) $\sim 1.2 \times 10^{12}\ m^{-3}$ (b) $\sim 10^{6}\ m^{-3}$

(c) $\sim 10^{14}\ m^{-3}$ (d) $\sim 10^{22}\ m^{-3}$

52. What should be the maximum acceptance angle at the aircore interface of an optical fibre if n_1 and n_2 are the refractive indices of the core and the cladding, respectively

[AIIMS 2005]

(a) $\sin^{-1}(n_2/n_1)$ (b) $\sin^{-1}\sqrt{n_1^2 - n_2^2}$

(c) $\left[\tan^{-1}\frac{n_2}{n_1}\right]$ (d) $\left[\tan^{-1}\frac{n_1}{n_2}\right]$

[DCE 2001]

Critical Thinking

Objective Questions

1. A sky wave with a frequency 55 *MHz* is incident on *D*-region of earth's atmosphere at 45°. The angle of refraction is (electron density for *D*-region is 400 $electron/cm^3$)

[Haryana PMT 2003]

(a) 60° (b) 45°

(c) 30° (d) 15°

2. In a diode AM-detector, the output circuit consist of $R = 1k\Omega$ and $C = 10\ pF$. A carrier signal of 100 *kHz* is to be detected. Is it good

(a) Yes

(b) No

(c) Information is not sufficient

(d) None of these

3. Consider an optical communication system operating at $\lambda \sim 800\ nm$. Suppose, only 1% of the optical source frequency is the available channel bandwidth for optical communication. How many channels can be accommodated for transmitting audio signals requiring a bandwidth of 8 *kHz*

(a) 4.8×10^{8} (b) 48

(c) 6.2×10^{8} (d) 4.8×10^{5}

4. A photodetector is made from a semiconductor $In_{0.53}Ga_{0.47}As$ with $E_g = 0.73\ eV$. What is the maximum wavelength, which it can detect

(a) 1000 *nm* (b) 1703 *nm*

(c) 500 *nm* (d) 173 *nm*

5. A transmitter supplies 9 kW to the aerial when unmodulated. The power radiated when modulated to 40% is

(a) 5 kW (b) 9.72 kW

(c) 10 kW (d) 12 kW

6. The antenna current of an AM transmitter is 8 A when only carrier is sent but increases to 8.96 A when the carrier is sinusoidally modulated. The percentage modulation is

(a) 50% (b) 60%

(c) 65% (d) 71%

7. The total power content of an AM wave is 1500 W. For 100% modulation, the power transmitted by the carrier is

(a) 500 W (b) 700 W

(c) 750 W (d) 1000 W

8. The total power content of an AM wave is 900 W. For 100% modulation, the power transmitted by each side band is

(a) 50 W (b) 100 W

(c) 150 W (d) 200 W

9. The modulation index of an FM carrier having a carrier swing of 200 kHz and a modulating signal 10 kHz is

(a) 5 (b) 10

(c) 20 (d) 25

10. A 500 Hz modulating voltage fed into an FM generator produces a frequency deviation of 2.25 kHz. If amplitude of the voltage is kept constant but frequency is raised to 6 kHz then the new deviation will be

(a) 4.5 kHz (b) 54 kHz

(c) 27 kHz (d) 15 kHz

11. The audio signal used to modulate 60 sin $(2\pi \times 10^6\ t)$ is $15 \sin 300\pi t$. The depth of modulation is

(a) 50% (b) 40%

(c) 25% (d) 15%

12. The bit rate for a signal, which has a sampling rate of 8 kHz and where 16 quantisation levels have been used is

(a) 32000 *bits/sec* (b) 16000 *bits/sec*

(c) 64000 *bits/sec* (d) 72000 *bits/sec*

13. An amplitude modulated wave is modulated to 50%. What is the saving in power if carrier as well as one of the side bands are suppressed

(a) 70% (b) 65.4%

(c) 94.4% (d) 25.5%

14. In AM, the centpercent modulation is achieved when

(a) Carrier amplitude = signal amplitude

(b) Carrier amplitude ≠ signal amplitude

(c) Carrier frequency = signal frequency

(d) Carrier frequency ≠ signal frequency

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : Diode lasers are used as optical sources in optical communication.

Reason : Diode lasers consume less energy. [AIIMS 2005]

2. Assertion : Television signals are received through sky-wave propagation.

Reason : The ionosphere reflects electromagnetic waves of frequencies greater than a certain critical frequency. [AIIMS 2005]

3. Assertion : In high latitude one sees colourful curtains of light hanging down from high altitudes.

Reason : The high energy charged particles from the sun are deflected to polar regions by the magnetic field of the earth. [AIIMS 2003]

4. Assertion : Short wave bands are used for transmission of radio waves to a large distance.

Reason : Short waves are reflected by ionosphere [AIIMS 1994]

5. Assertion : The electrical conductivity of earth's atmosphere decreases with altitude.

Reason : The high energy particles (*i.e.* γ-rays and cosmic rays) coming from outer space and entering our earth's atmosphere cause ionisation of the atoms of the gases present there and the pressure of gases decreases with increase in altitude.

6. Assertion : The electromagnetic waves of shorter wavelength can travel longer distances on earth's surface than those of longer wavelengths.

Reason : Shorter the wavelength, the larger is the velocity of wave propagation.

7. Assertion : The surface wave propagation is used for medium wave band and for television broadcasting.

Reason : The surface waves travel directly from transmitting antenna to receiver antenna through atmosphere.

8. Assertion : The television broadcasting becomes weaker with increasing distance.

Reason : The power transmitted from TV transmitter varies inversely as the distance of the receiver

9. Assertion : Microwave propagation is better than the sky wave propagation.

Reason : Microwaves have frequencies 100 to 300 GHz, which have very good directional properties.

10. Assertion : Satellite is an ideal platform for remote sensing.

Reason : Satellite in polar orbit can provide global coverage or continuous coverage of the fixed area in geostationary configuration.

11. Assertion : Fax is a modulating and demodulating device.

Reason : It is necessary for exact reproduction of a document.

12. Assertion : A dish antenna is highly directional.

Reason : This is because a dipole antenna is omni directional.

Answers

Communication

1	a	2	d	3	c	4	a	5	b
6	c	7	c	8	d	9	c	10	c
11	a	12	d	13	b	14	c	15	b
16	a	17	c	18	d	19	c	20	b
21	d	22	d	23	a	24	d	25	d
26	b	27	d	28	a	29	d	30	b
31	b	32	a	33	c	34	b	35	c
36	a	37	c	38	c	39	a	40	b
41	b	42	c	43	a	44	c	45	c
46	d	47	d	48	b	49	d	50	d
51	a	52	b						

Critical Thinking Questions

1	b	2	b	3	a	4	b	5	b
6	d	7	d	8	c	9	b	10	b
11	c	12	a	13	c	14	a		

Assertion and Reason

1	b	2	d	3	a	4	a	5	e
6	c	7	a	8	c	9	a	10	a
11	e	12	b						

Answers and Solutions

Communication

1. (a) By using $f_c \approx 9(N_{\max})^{1/2} \Rightarrow f_c \approx 2\ MHz$

2. (d) Carrier frequency > audio frequency

3. (c)

4. (a) A maximum frequency deviation of 75 *kHz* is permitted for commercial FM broadcast stations in the 88 to 108 *MHz VHF* band.

5. (b) $v.f. = \frac{1}{\sqrt{k}} = \frac{1}{\sqrt{2.6}} = 0.62$

6. (c) Carrier + signal → modulation.

7. (c)

8. (d) Here $\frac{n_1 - n_2}{n_1} = \frac{0.88}{100} \Rightarrow \frac{n_2}{n_1} = 0.9912$

   ∴ Critical angle $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}(0.9912) = 84°24'$

9. (c)

10. (c)

11. (a)

12. (d) Radio waves can be transmitted from one place to another as grand wave or sky wave or space wave propagation.

13. (b) The energy flux $\phi = \frac{\text{Pulsepower}}{\text{Area}} = \frac{10^{12}}{10^{-4}} = 10^{16}\ \frac{W}{cm^2}$

14. (c) $\nu = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{10 \times 10^{-6} \times 1 \times 10^{-9}}}$ = 1592 *kHz*

15. (b)

16. (a) VHF (Very High Frequency) band having frequency range 30 *MHz* to 300 *MHz* is typically used for TV and radar transmission.

17. (c)

18. (d)

19. (c) $MUF = \frac{f_c}{\cos\theta} = \frac{60}{\cos 70°} = 175\ MHz$

20. (b)

21. (d)

22. (d) A very small part of light energy is lost from an optical fibre due to absorption or due to light leaving the fibre as a result of scattering of light sideways by impurities in the glass fibre.

23. (a) $d = \sqrt{2hR} \Rightarrow d \propto h^{1/2}$

24. (d) Surgery needs sharply focused beam of light and laser can be sharply focused.

25. (d) Laser beams are perfectly parallel. So that they are very narrow and can travel a long distance without spreading. This is the feature of laser while they are monochromatic and coherent these are characteristics only.

26. (b) The formula for modulating index is given by

$$m_f = \frac{\delta}{v_m} = \frac{\text{Frequency variation}}{\text{Modulatingfrequency}} = \frac{10 \times 10^3}{2 \times 10^3} = 5$$

27. (d) Here, $V_{\max} = \frac{24}{2} = 12\,mV$ and $V_{\min} = \frac{8}{2} = 2\,mV$

   Now, $m = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} = \frac{12-4}{12+4} = \frac{8}{16} = \frac{1}{2} = 0.5 = 50\%$

28. (a) Here, $f_c = 1.5\,MHz = 1500\,kHz,\ f_m == 10\,kHz$

   ∴ Low side band frequency

   $= f_c - f_m = 1500\,kHz - 10\,kHz = 1490\,kHz$

   Upper side band frequency

   $= f_c + f_m = 1500\,kHz + 10\,kHz = 1510\,kHz$

29. (d) When $m_a > 1$ then carrier is said to be over modulated.

30. (b) It mix weak signals with carrier signals.

31. (b)

32. (a) Frequency modulation requires much wider channel (7 to 15 times) as compared to AM.

33. (c)

34. (b) $P_t = P_c\left(1 + \frac{m_a^2}{2}\right)$; Here $m_a = 1$

$$\Rightarrow 1800 = P_c\left(1 + \frac{(1)^2}{2}\right) \Rightarrow P_c = 1200W$$

35. (c)

36. (a)

37. (c)

38. (c) An antenna is a metallic structure used to radiate or receive EM waves.

39. (a)

40. (b) Pulse code modulation is a digital system.

41. (b)

42. (c) In telecommunication, microwaves are used.

43. (a) Carrier swing $= \frac{\text{Frequency deviation}}{\text{Modulating frequency}} = \frac{50}{7} = 7.143$

44. (c) Optical fibres are not subjected to electromagnetic interference from outside.

45. (c) In optical fibre, light travels inside it, due to total internal reflection.

46. (d)

47. (d) Few advantages of optical fibres are that the number of signals carried by optical fibres is much more than that carried by the *Cu* wire or radio waves. Optical fibres are practically free from electromagnetic interference and problem of cross talks whereas ordinary cables and microwave links suffer a lot from it.

48. (b) The process of changing the frequency of a carrier wave (modulated wave) in accordance with the audio frequency signal (modulating wave) is known as frequency modulation (FM).

49. (d) Following are the problems which are faced while transmitting audio signals directly.

(i) These signals are relatively of short range.

(ii) If every body started transmitting these low frequency signals directly, mutual interference will render all of them ineffective.

(iii) Size of antenna required for their efficient radiation would be larger *i.e.* about 75 *km*.

50. (d) Remote sensing is the technique to collect information about an object in respect of its size, colour, nature, location, temperature *etc.* without physically touching it. There are some areas or location which are inaccessible. So to explore these areas or locations, a technique known as remote sensing is used. Remote sensing is done through a satellite.

51. (a) The critical frequency of a sky wave for reflection from a layer of atmosphere is given by $f_c = 9(N_{max})^{1/2}$

$\Rightarrow 10 \times 10^6 = 9(N_{max})^{1/2}$

$\Rightarrow N_{max} = \left(\frac{10 \times 10^6}{9}\right)^2 \simeq 1.2 \times 10^{12} m^{-3}$

52. (b) Core of acceptance angle $\theta = \sin^{-1}\sqrt{n_1^2 - n_2^2}$

Critical Thinking Questions

1. (b) $n_{eff} = n_0\sqrt{1 - \left(\frac{80.5\,N}{\nu^2}\right)} = 1\sqrt{1 - \frac{80.5 \times (400 \times 10^6)}{(55 \times 10^6)^2}} \approx 1$

Also $n_{eff} = \frac{\sin i}{\sin r} \Rightarrow \sin r = \sin i \Rightarrow r = i = 45°$

2. (b) For demodulation $\frac{1}{f_c} << RC$

$\frac{1}{f_c} = \frac{1}{100 \times 10^3} = 10^{-5}\,s$

$RC = 10^3 \times 10 \times 10^{-12}\,s = 10^{-8}\,s$

We see that $\frac{1}{f_c}$ here is not less than *RC* as required by the above condition. Hence, this is not good.

3. (a) Optical source frequency $f = \frac{c}{\lambda}$

$= 3 \times 10^8/(800 \times 10^{-9}) = 3.8 \times 10^{14}\,Hz$

Bandwidth of channel (1% of above) $= 3.8 \times 10^{12}\,Hz$

Number of channels =(Total bandwidth of channel)/(Bandwidth needed per channel)

(a) Number of channels for audio signal

$= (3.8 \times 10^{12})/(8 \times 10^3) \sim 4.8 \times 10^8$

4. (b) Limiting value of $h\nu$ is E_g, such that $h\nu = \frac{hc}{\lambda} = E_g$

or $\lambda = \frac{hc}{E_g} = \frac{6.63 \times 10^{-34}\,J\text{-}s \times 3 \times 10^8\,ms^{-1}}{0.73 \times 1.6 \times 10^{-19}\,J}$

$= 1703\,nm$

5. (b) $P_t = P_c\left[1 + \frac{m^2}{2}\right] = 9\left[1 + \frac{(0.4)^2}{2}\right]$

$= 9\left[1 + \frac{0.16}{2}\right]$ $(\because m = 40\% = 0.4)$

$= 9\,(1.08) = 9.72\,kW$

6. (d) We know that $\left(\frac{I_t}{I_c}\right)^2 = 1 + \frac{m^2}{2}$

Here, $I_t = 8.96A$ and $I_c = 8A$

$\therefore \left(\frac{8.96}{8}\right)^2 = 1 + \frac{m^2}{2}$ or $1.254 = 1 + \frac{m^2}{2}$

or $\frac{m^2}{2} = 0.254$ or $m^2 = 0.508$

or $m = 0.71 = 71\%$

7. (d) $\frac{P_t}{P_c} = 1 + \frac{m^2}{2}$ or $P_c = P_t\left[\frac{2}{2 + m^2}\right]$

$\therefore P_c = 1500\left[\frac{2}{2+1}\right]$ $\because m = 100\% = 1$

$= 1000\,W$

8. (c) $P_c = P_t\left[\frac{2}{2 + m^2}\right] = 900\left[\frac{2}{2+1}\right] = 600W$

Now, $P_{LSB} = \frac{m^2}{4} \times P_c = \frac{1}{4} \times 600 = 150\,W$

9. (b) CS = 2 × Δf or $\Delta f = CS/2$

$\therefore \Delta f = \frac{200}{2} = 100\,kHz$

Now $m_f = \frac{\Delta f}{f_m} = \frac{100}{10} = 10$

10. (b) $m_f = \frac{\delta}{f_m} = \frac{2250}{500} = 4.5$

$\therefore$ New deviation $= 2(m_f\, f_m) = 2 \times 4.5 \times 6 = 54\, kHz$.

11. (c) $m_a = \frac{E_m}{E_c} = \frac{15}{60} \times 100 = 25\%$

12. (a) If n is the number of bits per sample, then number of quantisation level = 2·

Since the number of quantisation level is 16

$\Rightarrow$ 2· = 16 $\Rightarrow n = 4$

$\therefore$ bit rate = sampling rate × no. of bits per sample

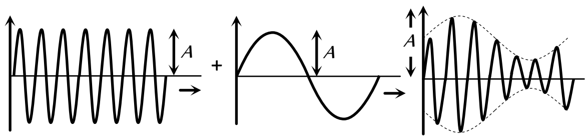
= 8000 × 4 = 32,000 *bits/sec*.

13. (c) $P_{sb} = P_c\left(\frac{m_a}{2}\right)^2 = P_c\frac{(0.5)^2}{4} = 0.0625\, P_c$

Also $P = P_c\left(1 + \frac{m_a^2}{2}\right) = P_c\left(1 + \frac{(0.5)^2}{2}\right) = 1.125 P_c$

$\therefore$ % saving $= \frac{(1.125P_c - 0.0625P_c)}{1.125P_c} \times 100 = 94.4\%$.

14. (a) When signal amplitude is equal to the carrier amplitude, the amplitude of carrier wave varies between $2A$ and zero.



$$m_a = \frac{\text{Amplitude charge of carrier}}{\text{Amplitude of normal carrier}} = \frac{2A - A}{A} \times 100 = 100\%$$

Assertion and Reason

1. (b) In optical communication, diode laser is used to generate analog signals or digital pulses for transmission or digital pulses for transmission trough optical fibres. The advantage of diode lasers are their small size and low power input.

2. (d) TV signals (frequency greater than 30 *MHz*) cannot be propagated through sky wave propagation.

Above critical frequency, an electromagnetic wave penetratates the ionosphere and is not reflected by it.

3. (a) Microwave communication is preferred over optical communication because microwaves provide large number of channels and wider band width compared to optical signals as information carrying capacity is directly proportional to band width. So, wider the band width, greater the information carrying capacity.

4. (a) Having the range of wavelength from 30 *km* to 30 *cm* are known as short wave. These waves are used for radio transmission and for general communication purpose to a longer distance from ionosphere. Ionosphere is the outermost region of atmosphere extending from height of 80 *km* to 400 *km* approximately, above the surface of earth. Therefore, both the assertion and reason are true and reason is the correct explanation of assertion.

5. (e) The electrical conductivity of earth's atmosphere increases with height so assertion is false.

When high energy particles enters in earth's atmosphere. They ionises the gases present in atmosphere. Also as we go up, the air thins out gradually and air pressure decreases.

6. (c) The electromagnetic waves of shorter wavelength do not suffer much diffraction from the obstacles of earth's atmosphere so they can travel long distance.

Also, shorter the wavelength, shorter is the velocity of wave propagation.

7. (a) Both assertion and reason are true and reason is the correct explanation of assertion. (For more detail, refer theory).

8. (c) As the distance increases, TV signals becomes weaker. So assertion is true. The power transmitted from TV transmitter is inversely proportional to the square of the distance of the receiver. That's why reason is false.

9. (a) Microwaves have got good directional properties. Due to it, the microwaves can be directed as beam signals in a particular direction, much better than radio waves, because microwaves do not bend around the corners of any obstacle coming in their way.

10. (a) The remote sensing is done through a satellite. A remote sensing satellite files in a polar orbit at an altitude of 918 *km*, around the earth, in such away that it passes over a given location on the earth at the same local time.

11. (e) The electronic reproduction of a document at a distance plane is known as FAX modulation and demodulation is done by modem.

12. (b) A dish antenna is a directional antenna because it can transmit or sec.

Communication

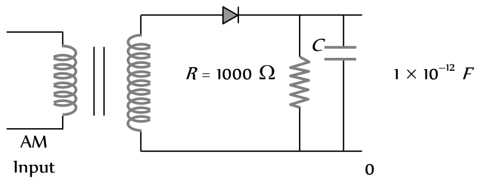
SET Self Evaluation Test - 28

1. A ground receiver station is receiving a signal at (i) 5 *MHz* and transmitted from a ground transmitter at a height of 300 *m*, located at a distance of 100 *km* from the receiver station. The signal is coming via. Radius of earth = 6.4×10^6 *m*. N_{max} of isosphere = 10^{12} m^3

(a) Space wave (b) Sky wave propagation

(c) Satellite transponder (d) All of these

2. In the given detector circuit, the suitable value of carrier frequency is



(a) $<< 10^9$ *Hz* (b) $<< 10^5$ *Hz*

(c) $>> 10^9$ *Hz* (d) None of these

3. The impedance of coaxial cable, when its inductance is 0.40 μH and capacitance is 1×10^{-11} *F*, can be

(a) $2 \times 10^2\ \Omega$ (b) $100\ \Omega$

(c) $3 \times 10^3\ \Omega$ (d) $3 \times 10^{-2}\ \Omega$

4. A wave is represented as

$$e = 10 \sin(10^8 t + 6 \sin 1250t)$$

then the modulating index is

(a) 10 (b) 1250

(c) 10^8 (d) 6

5. An optical fibre communication system works on a wavelength of 1.3 μm. The number of subscribers it can feed if a channel requires 20 *kHz* are

(a) 2.3×10^{10} (b) 1.15×10^{10}

(c) 1×10^5 (d) None of these

6. In an FM system a 7 *kHz* signal modulates 108 *MHz* carrier so that frequency deviation is 50 *kHz*. The carrier swing is

(a) 7.143 (b) 8

(c) 0.71 (d) 350

7. In a radio receiver, the short wave and medium wave stations are tuned by using the same capacitor but coils of different inductance L_s and L_m respectively then

(a) $L_s > L_m$ (b) $L_s < L_m$

(c) $L_s = L_m$ (d) None of these

8. The electron density of E, F_1, F_2 layers of ionosphere is 2×10^{11}, 5×10^{11} and 8×10^{11} m^3 respectively. What is the ratio of critical frequency for reflection of radiowaves

(a) 2 : 4 : 3 (b) 4 : 3 : 2

(c) 2 : 3 : 4 (d) 3 : 2 : 4

9. A carrier is simultaneously modulated by two sine waves with modulation indices of 0.4 and 0.3. The resultant modulation index will be

(a) 1.0 (b) 0.7

(c) 0.5 (d) 0.35

10. Mean optical power launched into an 8 *km* fibre is 120 μW and mean output power is 4 μW, then the overall attenuation is (Given log 30 = 1.477)

(a) 14.77 *dB* (b) 16.77 *dB*

(c) 3.01 *dB* (d) None of these

11. A antenna current of an AM broadcast transmitter modulated by 50% is 11 *A*. The carrier current is

(a) 10.35 *A* (b) 9.25 *A*

(c) 10 *A* (d) 5.5 *A*

12. Because of tilting which waves finally disappear

(a) Microwaves (b) Surface waves

(c) Sky waves (d) Space waves

13. A transmitter transmits a power of 10 *kW* when modulation is 50%. Power of carrier wave is

(a) 5 *kW* (b) 8.89 *kW*

(c) 14 *kW* (d) 5.7 *kW*

14. A telephone link operating at a central frequency of 10 *GHz* is established. If 1% of this is available then how many telephone channel can be simultaneously given when each telephone covering a band width of 5 *kHz*

(a) 2×10^4 (b) 2×10^6

(c) 5×10^4 (d) 5×10^6

AS Answers and Solutions

(SET -28)

1. (b) Maximum distance covered by space wave communication $\sqrt{2Rh} = 62\,km$

Critical frequency = $f_c = 9(N_{\max})^{1/2} \simeq 9\ MHz$

5 MHz < f_c sky wave propagation (ionospheric propagation)

2. (a) Using $\frac{1}{f_{carrier}} << RC$

We get time constant, $RC = 1000 \times 10^{-12} = 10^{-9}\,s$

Now $\nu = \frac{1}{T} = \frac{1}{10^{-9}} = 10^{9}\,Hz$

Thus the value of carrier frequency should be much less than $10^{9}\,Hz$, say 100 kHz.

3. (a) Using $Z = \sqrt{\frac{L}{C}}$ we get $Z = \sqrt{\frac{0.40 \times 10^{-6}}{10^{-11}}} = 2 \times 10^{2}\,\Omega$

4. (d) Comparing with standard equation.

5. (b) Optical source frequency $f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{1.3 \times 10^{-6}} = 2.3 \times 10^{14}\,Hz$

$\therefore$ Number of channels or subscribers $= \frac{2.3 \times 10^{14}}{20 \times 10^{3}}$

= 1.15 × 10^{10}

6. (a) Carrier swing $= \frac{\text{Frequency deviation}}{\text{Modulatingfrequency}} = \frac{50}{7} = 7.143$

7. (b) As $\nu = \frac{c}{\lambda} \Rightarrow \nu_m = \frac{c}{\lambda_m}$ and $\nu_s = \frac{c}{\lambda_s}$

$\because \lambda_m > \lambda_s \Rightarrow \nu_m < \nu_s$

Also $\nu_m = \frac{1}{2\pi\sqrt{L_m C}}$ and $\nu_s = \frac{1}{2\pi\sqrt{L_s C}}$

$\Rightarrow \frac{\nu_m}{\nu_s} = \sqrt{\frac{L_s}{L_m}} \Rightarrow L_s < L_m.$

8. (c) $f_c \propto (N)^{1/2} \Rightarrow (f_c)_E : (f_c)_{F_1} : (f_c)_{F_2}$

$= (2 \times 10^{11})^{1/2} : (5 \times 10^{11})^{1/2} : (8 \times 10^{11})^{1/2}$ = 2 : 3 : 4

9. (c) $m = \sqrt{m_1^2 + m_2^2} = \sqrt{(0.16) + (0.09)} = 0.5$

10. (a) Attenuation $= 10\log\frac{120}{4} = 10\log 30$

$= 10 \times 1.4771 = 14.77\,dB.$

11. (a) $I_{Carrier} = \frac{I_{rms}}{\sqrt{1 + \frac{m_a^2}{2}}} = \frac{11}{\sqrt{1 + \frac{(0.5)^2}{2}}} = 10.35\,A$

12. (b)

13. (b) $P_c = \frac{P}{\left(1 + \frac{m_a^2}{2}\right)} = \frac{10000}{\left(1 + \frac{(0.5)^2}{2}\right)} = \frac{10000}{1.125} = 8.89\,kW$

14. (a) 1% of 10 GHz = $10 \times 10^{9} \times \frac{1}{100} = 10^{8}\,Hz$

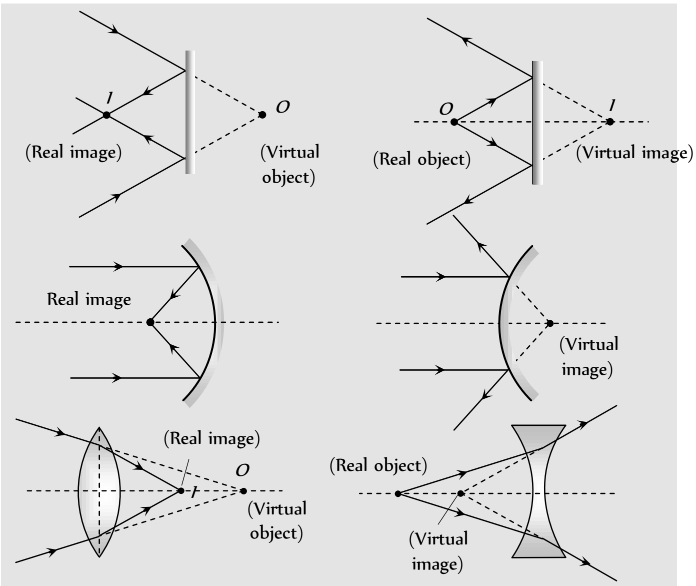
Number of channels $= \frac{10^{8}}{5 \times 10^{3}} = 2 \times 10^{4}$

***

Chapter 29
Ray Optics

Real and Virtual Images

If light rays, after reflection or refraction, actually meets at a point then real image is formed and if they appears to meet virtual image is formed.



Reflection of Light

When a ray of light after incidenting on a boundary separating two media comes back into the same media, then this phenomenon, is called reflection of light.

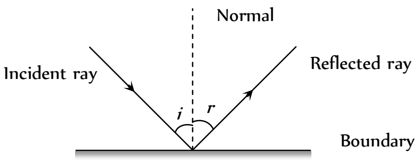


Fig. 29.1

(1) $\angle i = \angle r$

(2) After reflection, velocity, wave length and frequency of light remains same but intensity decreases.

(3) There is a phase change of π if reflection takes place from denser medium.

Reflection From a Plane Surface (Plane Mirror)

The image formed by a plane mirror is virtual, erect, laterally inverted, equal in size that of the object and at a distance equal to the distance of the object in front of the mirror.

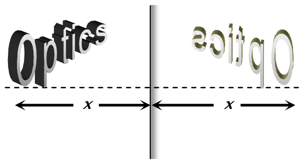
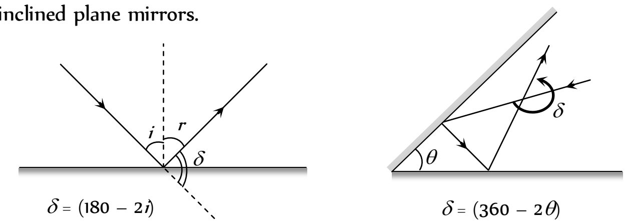


Fig. 29.2

(1) Deviation produced by a plane mirror and by two inclined plane mirrors.



$\delta = (180 - 2i)$
(A) Single Reflection

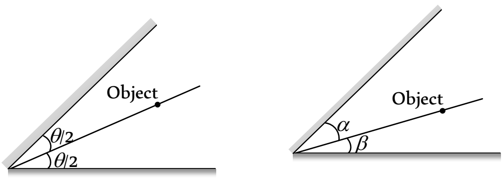
$\delta = (360 - 2\theta)$
(B) Double Reflection

Fig. 29.3

(2) **Images by two inclined plane mirrors :** When two plane mirrors are inclined to each other at an angle θ, then number of images (n) formed of an object which is kept between them.

(i) $n = \left(\frac{360^o}{\theta} - 1\right)$; If $\frac{360^o}{\theta}$ = even integer

(ii) If $\frac{360^o}{\theta}$ = odd integer then there are two possibilities



(A) Object is placed symmetrically

(B) Object is placed asymmetrically

Fig. 29.4

$$n = \left(\frac{360}{\theta} - 1\right) \qquad n = \frac{360}{\theta}$$

(3) **Other important informations**

(i) When the object moves with speed u towards (or away) from the plane mirror then image also moves towards (or away) with speed u. But relative speed of image *w.r.t.* object is $2u$.

(ii) When mirror moves towards the stationary object with speed u, the image will move with speed $2u$ in same direction as that of mirror.

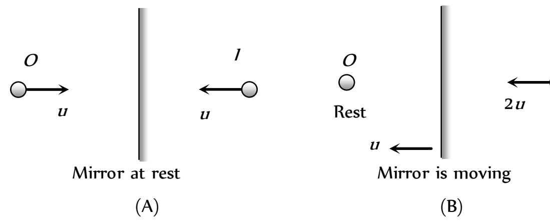


Fig. 29.5

(iii) A man of height h requires a mirror of length at least equal to $h/2$, to see his own complete image.

(iv) To see complete wall behind himself a person requires a plane mirror of at least one third the height of wall. It should be noted that person is standing in the middle of the room.

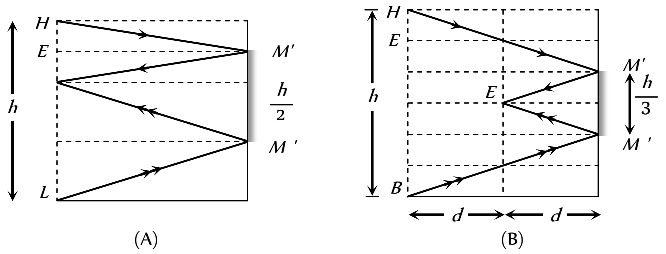


Fig. 29.6

Curved Mirror

It is a part of a transparent hollow sphere whose one surface is polished.

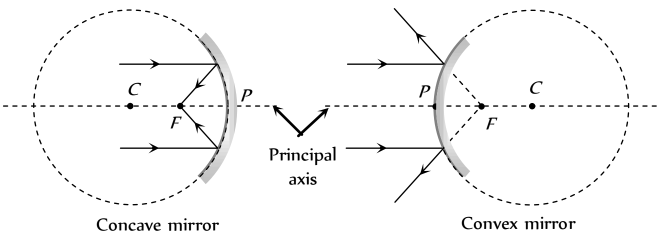


Fig. 29.7

Concave mirror converges the light rays and used as a shaving mirror, In search light, in cinema projector, in telescope, by E.N.T. specialists etc.

Convex mirror diverges the light rays and used in road lamps, side mirror in vehicles *etc*.

(1) **Terminology**

(i) Pole (P) **:** Mid point of the mirror

(ii) Centre of curvature (C) : Centre of the sphere of which the mirror is a part.

(iii) Radius of curvature (R): Distance between pole and centre of curvature. ($R_{concave} = -ve$, $R_{convex} = +ve$, $R_{plane} = \infty$)

(iv) Principle axis : A line passing through P and C.

(v) Focus (F) : An image point on principle axis for an object at ∞.

(vi) Focal length (f) : Distance between P and F.

(vii) Relation between f and R : $f = \frac{R}{2}$

($f_{concave} = -ve$, $f_{convex} = +ve$, $f_{plane} = \infty$)

(viii) Power : The converging or diverging ability of mirror

(ix) Aperture : Effective diameter of light reflecting area. Intensity of image $\propto$ Area $\propto$ (Aperture)^2

(x) Focal plane : A plane passing from focus and perpendicular to principle axis.

(2) **Sign conventions :**

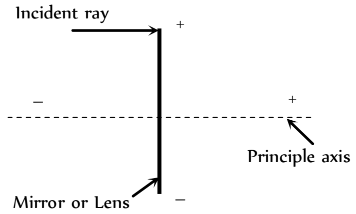


Fig. 29.8

(i) All distances are measured from the pole.

(ii) Distances measured in the direction of incident rays are taken as positive while in the direction opposite of incident rays are taken negative.

(iii) Distances above the principle axis are taken positive and below the principle axis are taken negative.

Table 29.1 : Useful sign

Concave mirror		Convex mirror
Real image ($u \geq f$)	Virtual image ($u < f$)	
Distance of object $u \rightarrow -$	$u \rightarrow -$	$u \rightarrow -$
Distance of image $v \rightarrow -$	$v \rightarrow +$	$v \rightarrow +$
Focal length $f \rightarrow -$	$f \rightarrow -$	$f \rightarrow +$
Height of object $O \rightarrow +$	$O \rightarrow +$	$O \rightarrow +$
Height of image $I \rightarrow -$	$I \rightarrow +$	$I \rightarrow +$
Radius of curvature $R \rightarrow -$	$R \rightarrow -$	$R \rightarrow +$
Magnification $m \rightarrow -$	$m \rightarrow +$	$m \rightarrow +$

Image Formation by Curved Mirrors

Concave mirror : Image formed by concave mirror may be real or virtual, may be inverted or erect, may be smaller, larger or equal in size of object.

(1) When object is placed at infinite (*i.e.* $u = \infty$)

Image

⟶ At F
⟶ Real
⟶ Inverted
⟶ Very small in size
⟶

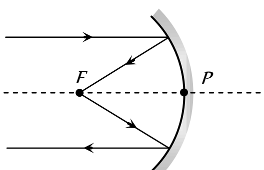


Fig. 29.9

Magnification $m << -1$

(2) When object is placed between infinite and centre of curvature (*i.e.* $u > 2f$)

Image

⟶ Between F and C
⟶ Real
⟶ Inverted
⟶ Small in size
⟶ $m < -1$

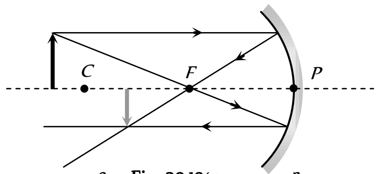


Fig. 29.10

(3) When object is placed at centre of curvature (*i.e.* $u = 2f$)

Image

⟶ At C
⟶ Real
⟶ Inverted
⟶ Equal in size
⟶ $m = -1$

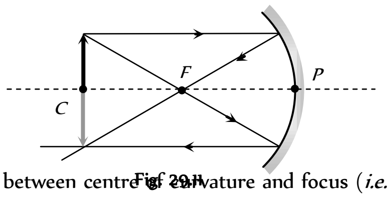


Fig. 29.11

(4) When object is placed between centre of curvature and focus (*i.e.* $f < u < 2f$)

Image

⟶ Between $2f$ and ∞
⟶ Real
⟶ Inverted
⟶ Large in size
⟶ $m > -1$

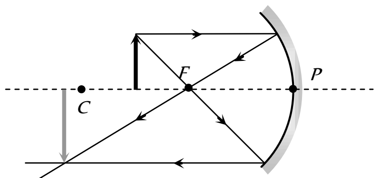


Fig. 29.12

(5) When object is placed at focus (*i.e.* $u = f$)

Image

⟶ At ∞
⟶ Real
⟶ Inverted
⟶ Very large in size
⟶ $m >> -1$

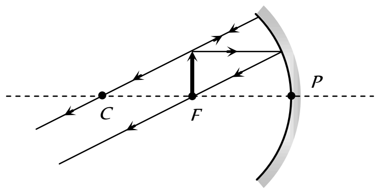


Fig. 29.13

(6) When object is placed between focus and pole (*i.e.* $u < f$)

Image

⟶ Behind the mirror
⟶ Virtual
⟶ Erect
⟶ Large in size
⟶ $m > +1$

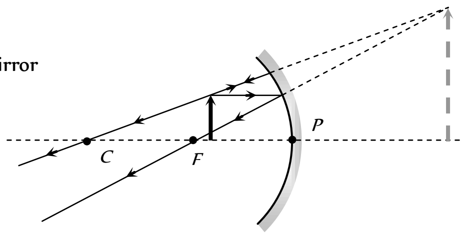


Fig. 29.14

Convex mirror : Image formed by convex mirror is always virtual, erect and smaller in size.

(1) When object is placed at infinite (*i.e.* $u = \infty$)

Image

⟶ At F
⟶ Virtual
⟶ Erect
⟶ Very small in size
⟶ Magnification $m << +1$

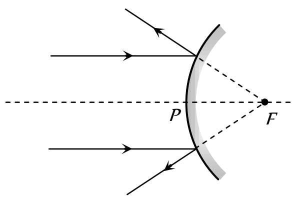


Fig. 29.15

(2) When object is placed any where on the principal axis

Image

⟶ Between P and F
⟶ Virtual
⟶ Erect
⟶ Small in size
⟶ Magnification $m < +1$

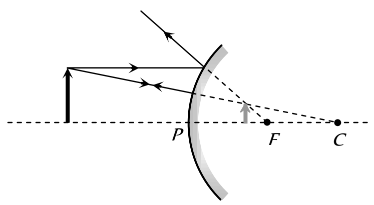


Fig. 29.16

Mirror Formula and Magnification

For a spherical mirror if u = Distance of object from pole, v = distance of image from pole, f = Focal length, R = Radius of curvature, O = Size of object, I = size of image

(1) **Mirror formula :** $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

(2) **Lateral magnification :** When an object is placed perpendicular to the principle axis, then linear magnification is called lateral or transverse magnification.

$$m = \frac{I}{O} = -\frac{v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$$

(* Always use sign convention while solving the problems)

Axial magnification : When object lies along the principle axis then its axial magnification $m = \frac{I}{O} = \frac{-(v_2 - v_1)}{(u_2 - u_1)}$

If object is small; $m = -\frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f-u}\right)^2 = \left(\frac{f-v}{f}\right)^2$

Areal magnification : If a $2D$-object is placed with it's plane perpendicular to principle axis. It's Areal magnification

$$m_s = \frac{\text{Area of image } (A_i)}{\text{Area of object} (A_o)} \Rightarrow m_s = m^2 = \frac{A_i}{A_o}$$

Refraction of Light

The bending of the ray of light passing from one medium to the other medium is called refraction.

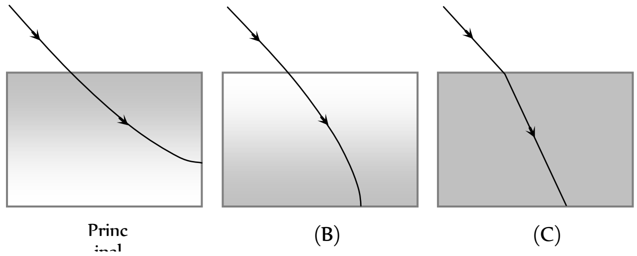


Fig. 29.17

(1) The refraction of light takes place on going from one medium to another because the speed of light is different in the two media.

(2) Greater the difference in the speeds of light in the two media, greater will be the amount of refraction.

(3) A medium in which the speed of light is more is known as optically rarer medium and a medium is which the speed of light is less, is known as optically denser medium.

(4) When a ray of light goes from a rarer medium to a denser medium, it bends towards the normal.

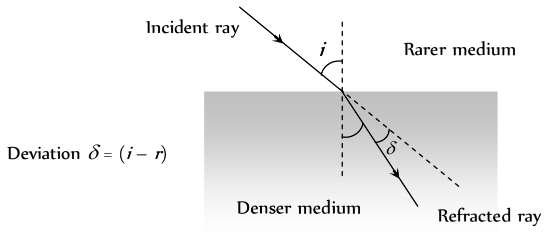


Fig. 29.18

(5) When a ray of light goes from a denser medium to a rarer medium, it bends away from the normal.

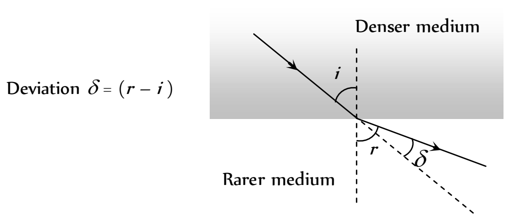


Fig. 29.19

(6) **Snell's law :** The ratio of sine of the angle of incidence to the angle of refraction (r) is a constant called refractive index

i.e. $\frac{\sin i}{\sin r} = \mu$ (a constant). For two media, Snell's law can be written as ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$

$\Rightarrow \mu_1 \times \sin i = \mu_2 \times \sin r$ *i.e.* $\mu \sin\theta =$ constant

Also in vector form : $\hat{\boldsymbol{i}} \times \hat{\boldsymbol{n}} = \mu(\hat{\boldsymbol{r}} \times \hat{\boldsymbol{n}})$

Refractive Index

(1) Refractive index of a medium is that characteristic which decides speed of light in it.

(2) It is a scalar, unit less and dimensionless quantity.

(3) **Absolute refractive index :** When light travels from vacuum to any transparent medium then refractive index of medium *w.r.t.* vacuum is called it's absolute refractive index *i.e.* ${}_{\text{vacuum}}\mu_{\text{medium}} = \frac{c}{v}$

Absolute refractive indices for glass, water and diamond are respectively $\mu_g = \frac{3}{2} = 1.5$, $\mu_w = \frac{4}{3} = 1.33$ and $\mu_D = \frac{12}{5} = 2.4$

(4) **Relative refractive index :** When light travels from medium (1) to medium (2) then refractive index of medium (2) *w.r.t.* medium (1) is called it's relative refractive index *i.e.* ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}$ (where v_1 and v_2 are the speed of light in medium 1 and 2 respectively).

(5) When we say refractive index we mean absolute refractive index.

(6) The minimum value of absolute refractive index is 1. For air it is very near to 1. ($\cong 1.003$)

(7) Cauchy's equation : $\mu = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + ...$

($\lambda_{\text{Red}} > \lambda_{\text{violet}}$ so $\mu_{\text{Red}} < \mu_{\text{violet}}$)

(8) If a light ray travels from medium (1) to medium (2), then

$${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

(9) **Dependence of Refractive index**

(i) Nature of the media of incidence and refraction.

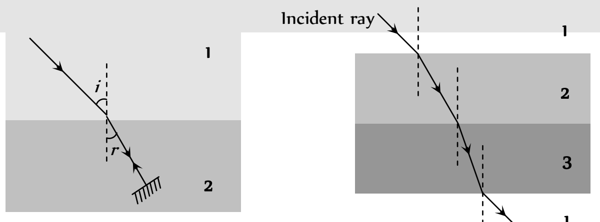
(ii) Colour of light or wavelength of light.

(iii) Temperature of the media : Refractive index decreases with the increase in temperature.

Table 29.2 : Indices of refraction for various substances, Measured with light of vacuum wavelength λ_0 = 589 *nm*

Substance	Refractive index	Substance	Refractive index
Solids at 20°*C*		**Liquids at 20°*C***	
Diamond (*C*)	2.419	Benzene	1.501
Fluorite (CaF_2)	1.434	Carbon disulfide	1.628
Flused quartz (SiO_2)	1.458	Carbon tetrachloride	1.461
Glass, crown	1.52	Ethyl alcohol	1.361
Glass, flint	1.66	Glycerine	1.473
Ice (H_2O) (at 0°*C*)	1.309	Water	1.333
Polystyrene	1.49	**Gases at 0°*C*, 1 *atm***	
Sodium chloride	1.544	Air	1.000293
Zircon	1.923	Carbon dioxide	1.00045

(10) **Reversibility of light and refraction through several media**



(A) ${}_1\mu_2 = \frac{1}{{}_2\mu_1}$

(B) ${}_1\mu_2 \times {}_2\mu_3 \times {}_3\mu_1 = 1$ or ${}_2\mu_3 = \frac{{}_1\mu_3}{{}_1\mu_2}$

Fig. 29.20

Real and Apparent Depth

If object and observer are situated in different medium then due to refraction, object appears to be displaced from it's real position.

(1) **When object is in denser medium and observer is in rarer medium**

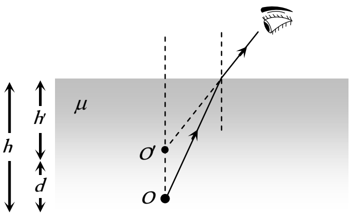


Fig. 29.21

(i) $\mu = \dfrac{\text{Real depth}}{\text{Apparent depth}} = \dfrac{h}{h'}$

(ii) Real depth > Apparent depth

(iii) Shift $d = h - h' = \left(1 - \dfrac{1}{\mu}\right)h$. For water $\mu = \dfrac{4}{3} \Rightarrow d = \dfrac{h}{4}$;

For glass $\mu = \dfrac{3}{2} \Rightarrow d = \dfrac{h}{3}$

(iv) Lateral magnification : consider an object of height x placed vertically in a medium μ such that the lower end (B) is a distance h from the interface and the upper end (A) at a distance ($h - x$) from the interface.

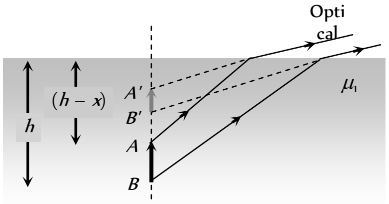


Fig. 29.22

Distance of image of B (*i.e.* B') from the interface = $\dfrac{\mu_2}{\mu_1}h$

Distance of image of A (*i.e.* A') from the interface $= \dfrac{\mu_2}{\mu_1}(h - x)$

Therefore, length of the image $\dfrac{\mu_2}{\mu_1}x$

or, the lateral magnification of the object $m = \dfrac{\mu_2}{\mu_1} = \dfrac{1}{\mu}$

(v) If a beaker contains various immiscible liquids as shown then

Apparent depth of bottom $= \dfrac{d_1}{\mu_1} + \dfrac{d_2}{\mu_2} + \dfrac{d_3}{\mu_3} + ...$

$\mu = \dfrac{d_{AC}}{d_{App.}} = \dfrac{d_1 + d_2 + ...}{\dfrac{d_1}{\mu_1} + \dfrac{d_2}{\mu_2} + ...}$

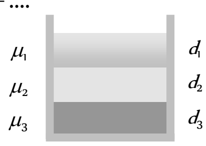
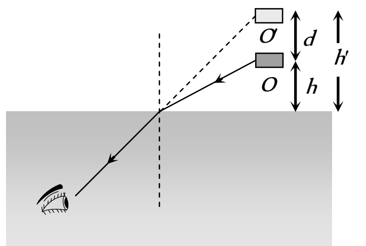


Fig. 29.23

(In case of two liquids if $d_1 = d_2$ than $\mu = \dfrac{2\mu_1\mu_2}{\mu_1 + \mu_2}$)

(2) **Object is in rarer medium and observer is in denser medium**



(i) $\mu = \dfrac{h'}{h}$

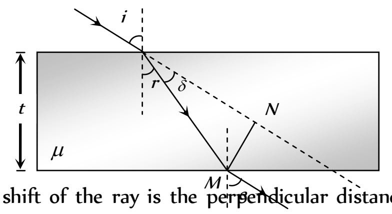
(ii) Real depth < Apparent depth.

(iii) $d = (\mu - 1)h$

(iv) Shift for water $d_w = \dfrac{h}{3}$; Shift for glass $d_g = \dfrac{h}{2}$

Refraction Through a Glass Slab

(1) **Lateral shift :** The refracting surfaces of a glass slab are parallel to each other. When a light ray passes through a glass slab it is refracted twice at the two parallel faces and finally emerges out parallel to it's incident direction *i.e.* the ray undergoes no deviation $\delta = 0$. The angle of emergence (e) is equal to the angle of incidence (i)



The Lateral shift of the ray is the perpendicular distance between the incident and the emergent ray, and it is given by

Fig. 29.25

$MN = t \sec r \sin (i - r)$

(2) **Normal shift :** If a glass slab is placed in the path of a converging or diverging beam of light then point of convergence or point of divergence appears to be shifted as shown

Normal shift

$OO' = x = \left(1 - \dfrac{1}{\mu}\right)t$

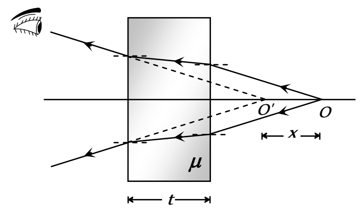


Fig. 29.26

(3) **Optical path :** It is defined as distance travelled by light in vacuum in the same time in which it travels a given path length in a medium.

Time taken by light ray to pass through the medium $= \dfrac{\mu x}{c}$; where x = geometrical path and μx = optical path

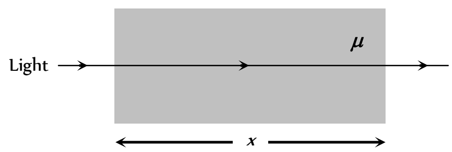
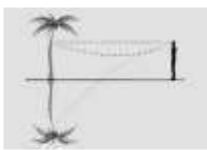


Fig. 29.27

Total Internal Reflection (TIR)

When a ray of light goes from denser to rarer medium it bends away from the normal and as the angle of incidence in denser medium increases, the angle of refraction in rarer medium also increases and at a certain angle, angle of refraction becomes 90°, this angle of incidence is called critical angle (C).

When Angle of incidence exceeds the critical angle than light ray comes back in to the same medium after reflection from interface. This phenomenon is called Total internal reflection (TIR).

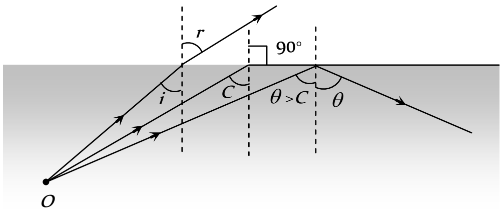


Fig. 29.28

(1) $\mu = \dfrac{1}{\sin C} = \mathbf{cosec}\ C$ where $\mu \rightarrow {}_{\text{Rarer}}\mu_{\text{Denser}}$

(2) **Conditions for TIR**

(i) The ray must travel from denser medium to rarer medium.

(ii) The angle of incidence i must be greater than critical angle C

(3) **Dependence of critical angle**

(i) Colour of light (or wavelength of light) : Critical angle depends upon wavelength as $\lambda \propto \dfrac{1}{\mu} \propto \sin C$

(a) $\lambda_R > \lambda_V \Rightarrow C_R > C_V$

(b) Sin $C = \dfrac{1}{{}_R\mu_D} = \dfrac{\mu_R}{\mu_D} = \dfrac{\lambda_D}{\lambda_R} = \dfrac{v_D}{v_R}$ (for two media)

(ii) Nature of the pair of media : Greater the refractive index lesser will be the critical angle.

(a) For (glass- air) pair $\rightarrow C_{\text{glass}} = 42^o$

(b) For (water-air) pair $\rightarrow C_{\text{water}} = 49^o$

(c) For (diamond-air) pair $\rightarrow C_{\text{diamond}} = 24^o$

(iii) Temperature : With temperature rise refractive index of the material decreases therefore critical angle increases.

Common Examples of TIR

(1) **Looming :** An optical illusion in cold countries

(2) **Mirage :** An optical illusion in deserts


Fig. 29.29

(3) **Brilliance of diamond :** Due to repeated internal reflections diamond sparkles.

(4) **Optical fibre :** Optical fibres consist of many long high quality composite glass/quartz fibres. Each fibre consists of a core and cladding.

(i) The refractive index of the material of the core (μ) is higher than that of the cladding (μ).

(ii) When the light is incident on one end of the fibre at a small angle, the light passes inside, undergoes repeated total internal reflections along the fibre and finally comes out. The angle of incidence is always larger than the critical angle of the core material with respect to its cladding.

(iii) Even if the fibre is bent, the light can easily travel through along the fibre

(iv) A bundle of optical fibres can be used as a 'light pipe' in medical and optical examination. It can also be used for optical signal transmission. Optical fibres have also been used for transmitting and receiving electrical signals which are converted to light by suitable transducers.

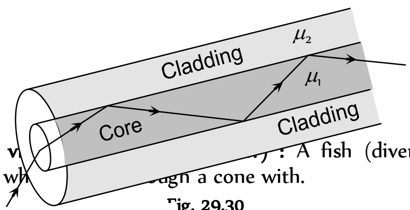


Fig. 29.30

(5) **Field of v**...) : A fish (diver) inside the water can see the wh... ugh a cone with.

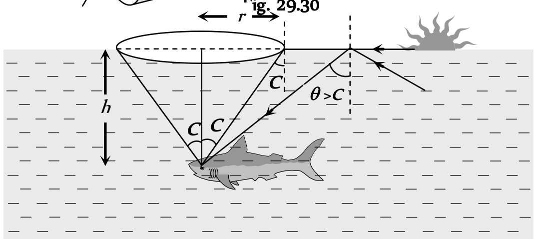


Fig. 29.31

(a) Apex angle $= 2C = 98^o$

(b) Radius of base $r = h \tan C = \dfrac{h}{\sqrt{\mu^2 - 1}}$; for water $r = \dfrac{3h}{\sqrt{7}}$

(c) Area of base $A = \dfrac{\pi h^2}{(\mu^2 - 1)}$; for water $a = \dfrac{9\pi}{7} h^2$

(6) **Porro prism :** A right angled isosceles prism, which is used in periscopes or binoculars. It is used to deviate light rays through 90^o and 180^o and also to erect the image.

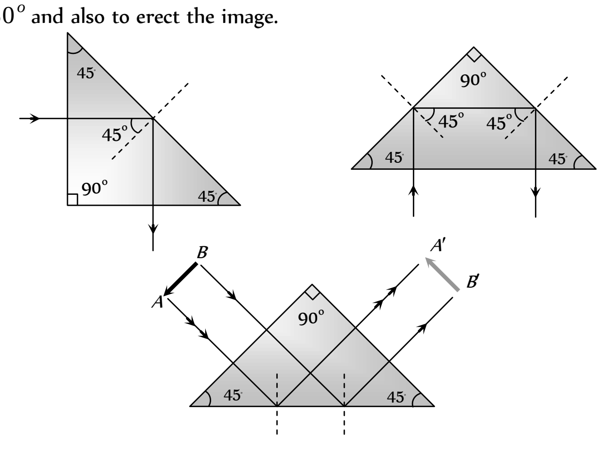


Fig. 29.32

Refraction From Spherical Surface

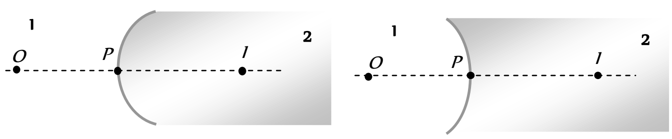


Fig. 29.33

(1) **Refraction formula :** $\dfrac{\mu_2 - \mu_1}{R} = \dfrac{\mu_2}{v} - \dfrac{\mu_1}{u}$

Where μ_1 = Refractive index of the medium from which light rays are coming (from object).

μ_2 = Refractive index of the medium in which light rays are entering.

u = Distance of object, v = Distance of image, R = Radius of curvature

(2) **Lateral magnification :** The lateral magnification m is the ratio of the image height to the object height

or $m = \left(\dfrac{h_i}{h_0}\right) = \left(\dfrac{\mu_1}{\mu_2}\right)\left(\dfrac{v}{u}\right)$

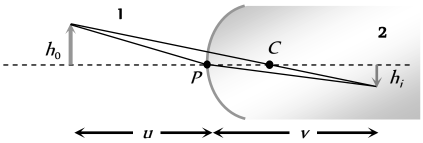


Fig. 29.34

Lens

(1) Lens is a transparent medium bounded by two refracting surfaces, such that at least one surface is curved. Curved surface can be spherical, cylindrical etc.

(2) Lenses are of two basic types convex which are thicker in the middle than at the edges and concave for which the reverse holds.

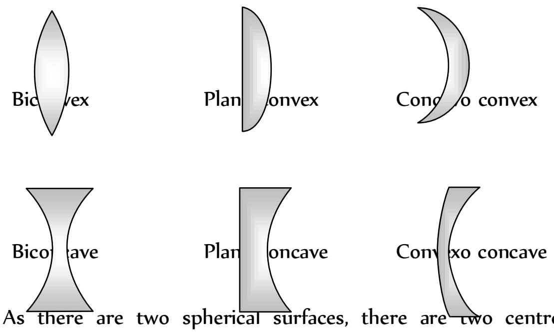


Fig. 29.35

(3) As there are two spherical surfaces, there are two centres of curvature C_1 and C_2 and correspondingly two radii of curvature R_1 and R_2

(4) The line joining C_1 and C_2 is called the principal axis of the lens. The centre of the thin lens which is on the principal axis, is called the optical centre.

(5) A ray passing through optical centre proceeds undeviated through the lens.

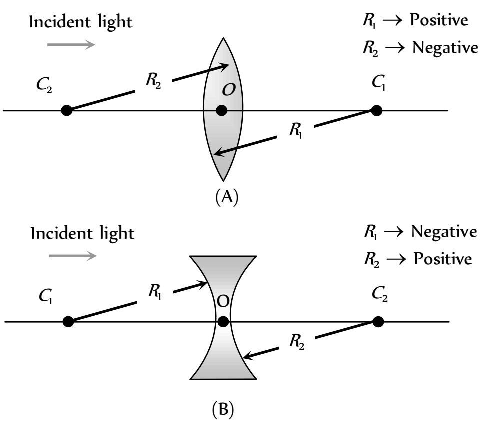


Fig. 29.36

(6) **Principal focus :** We define two principal focus for the lens. We are mainly concerned with the second principal focus (F). Thus wherever we write the focus, it means the second principal focus.

First principal focus : An object point for which image is formed at infinity.

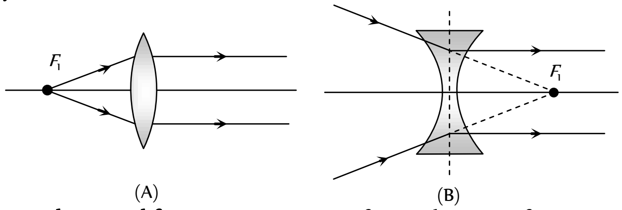


Fig. 29.37

Second principal focus : An image point for an object at infinity.

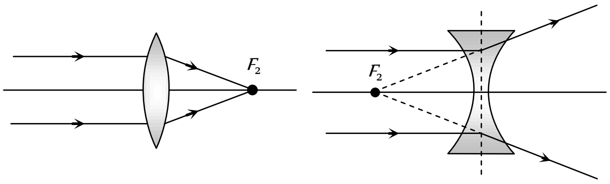


Fig. 29.38

Focal Length, Power and Aperture of Lens

(1) **Focal length (f) :** Distance of second principle focus from optical centre is called focal length

$f_{\text{convex}} \rightarrow$ positive, $f_{\text{concave}} \rightarrow$ negative, $f_{\text{plane}} \rightarrow \infty$

(2) **Aperture :** Effective diameter of light transmitting area is called aperture. $\text{Intensity of image} \propto (\text{Aperture})^2$

(3) **Power of lens (P) :** Means the ability of a lens to deviate the path of the rays passing through it. If the lens converges the rays parallel to the principal axis its power is positive and if it diverges the rays it is negative.

Power of lens $P = \dfrac{1}{f(m)} = \dfrac{100}{f(cm)}$; Unit of power is Diopter (D)

$P_{\text{convex}} \rightarrow$ positive, $P_{\text{concave}} \rightarrow$ negative, $P_{\text{plane}} \rightarrow$ zero.

Rules of Image Formation by Lens

Convex lens : The image formed by convex lens depends on the position of object.

(1) When object is placed at infinite (*i.e.* $u = \infty$)

Image

⟶ At F
⟶ Real
⟶ Inverted
⟶ Very small in size
⟶ Magnification $m << -1$

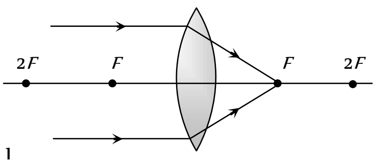


Fig. 29.39

(2) When object is placed between infinite and $2F$ (*i.e.* $u > 2f$)

Image

⟶ Between F and $2F$
⟶ Real
⟶ Inverted
⟶ Very small in size
⟶ Magnification $m < -1$

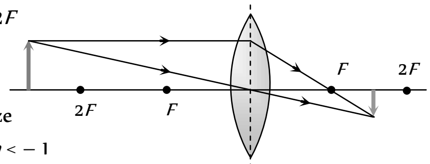


Fig. 29.40

(3) When object is placed at $2F$ (*i.e.* $u = 2f$)

Image

⟶ At $2F$
⟶
⟶
⟶
⟶

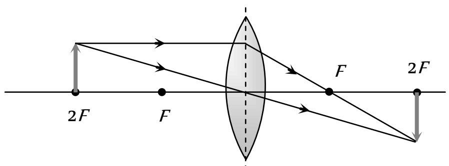


Fig. 29.41

Real

Inverted

Equal in size

Magnification $m = -1$

(4) When object is placed between F and $2F$ (*i.e.* $f < u < 2f$)

Image

- Beyond $2F$
- Real
- Inverted
- Large in size
- Magnification $m > -1$

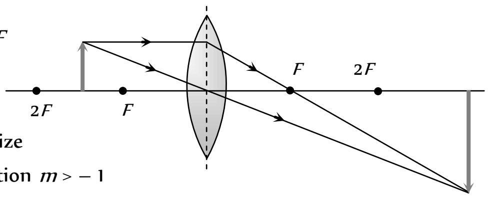


Fig. 29.42

(5) When object is placed at F (*i.e.* $u = f$)

Image

- At ∞
- Real
- Inverted
- Very large in size
- Magnification $m >> -1$

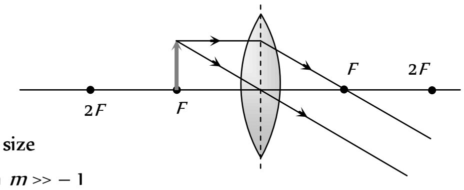


Fig. 29.43

(6) When object is placed between F and optical center (*i.e.* $u < f$)

Image

- Same side as that of object
- Virtual
- Erect
- large in size
- Magnification $m > 1$

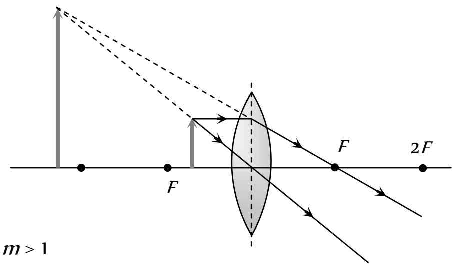


Fig. 29.44

Concave lens : The image formed by a concave lens is always virtual, erect and diminished (like a convex mirror)

(1) When object is placed at ∞

Image

- At F
- Virtual
- Erect
- Point size
- Magnification $m << +1$

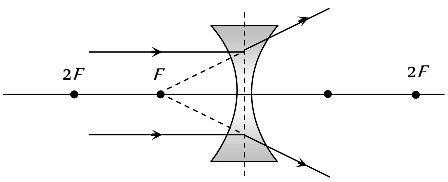


Fig. 29.45

(2) When object is placed any where on the principal axis

Image

- Between optical centre and focus
- Virtual
- Erect
- Smaller in size
- Magnification $m < +1$

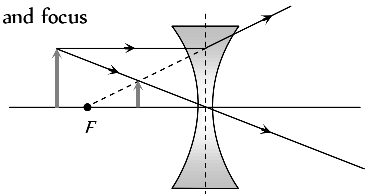


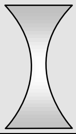
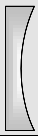
Fig. 29.46

Lens Maker's Formula and Lens Formula

(1) **Lens maker's formula :** If R_1 and R_2 are the radii of curvature of first and second refracting surfaces of a thin lens of focal length f and refractive index μ (*w.r.t.* surrounding medium) then the relation between f, μ, R_1 and R_2 is known as lens maker's formula.

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Table 29.3 : Focal length of different lenses

Lens	Focal length	For $\mu = 1.5$
Biconvex lens $R_1 = R$, $R_2 = -R$ 	$f = \frac{R}{2(\mu - 1)}$	$f = R$
Plano-convex lens $R_1 = \infty$, $R_2 = -R$ 	$f = \frac{R}{(\mu - 1)}$	$f = 2R$
Biconcave $R_1 = -R$, $R_2 = +R$ 	$f = -\frac{R}{2(\mu - 1)}$	$f = -R$
Plano-concave $R_1 = \infty$, $R_2 = R$ 	$f = \frac{-R}{(\mu - 1)}$	$f = -2R$

(2) **Lens formula :** The expression which shows the relation between u, v and f is called lens formula.

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Magnification

The ratio of the size of the image to the size of object is called magnification.

(1) Transverse magnification : $m = \frac{I}{O} = \frac{v}{u} = \frac{f}{f+u} = \frac{f-v}{f}$ (use sign convention while solving the problem)

(2) Longitudinal magnification : $m = \frac{I}{O} = \frac{v_2 - v_1}{u_2 - u_1}$. For very small object $m = \frac{dv}{du} = \left(\frac{v}{u}\right)^2 = \left(\frac{f}{f+u}\right)^2 = \left(\frac{f-v}{f}\right)^2$

(3) Areal magnification : $m_s = \frac{A_i}{A_o} = m^2 = \left(\frac{f}{f+u}\right)^2$,

(A_i = Area of image, A_o = Area of object)

(4) **Relation between object and image speed :** If an object moves with constant speed (V_o) towards a convex lens from infinity to focus, the image will move slower in the beginning and then faster. Also $V_i = \left(\frac{f}{f+u}\right)^2 . V_o$

Newton's Formula

If the distance of object (x) and image (x) are not measured from optical centre, but from first and second principal foci then Newton's formula states $f^2 = x_1 x_2$

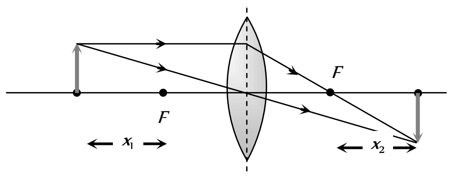


Fig. 29.47

Lens Immersed in a Liquid

If a lens (made of glass) of refractive index μ is immersed in a liquid of refractive index μ_l then its focal length in liquid, f_l is given by

$$\frac{1}{f_l} = ({}_l\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ......(i)$$

If f_a is the focal length of lens in air, then

$$\frac{1}{f_a} = ({}_a\mu_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad ......(ii)$$

$$\Rightarrow \quad \frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)}$$

(1) If $\mu_g > \mu_l$, then f_l and f_a are of same sign and $f_l > f_a$.

That is the nature of lens remains unchanged, but it's focal length increases and hence power of lens decreases.

(2) If $\mu_g = \mu_l$, then $f_l = \infty$. It means lens behaves as a plane glass plate and becomes invisible in the medium.

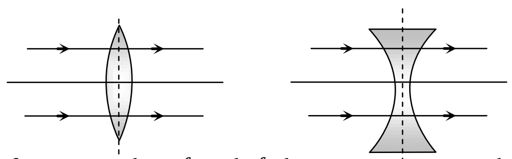


Fig. 29.48

(3) If $\mu_g < \mu_l$, then f_l and f_a have opposite signs and the nature of lens changes *i.e.* a convex lens diverges the light rays and concave lens converges the light rays.

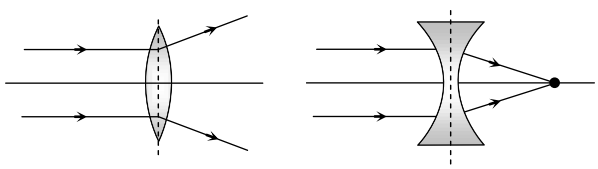


Fig. 29.49

Displacement Method

By this method focal length of convex lens is determined.

Consider an object and a screen placed at a distance D (> $4f$) apart. Let a lens of focal length f be placed between the object and the screen.

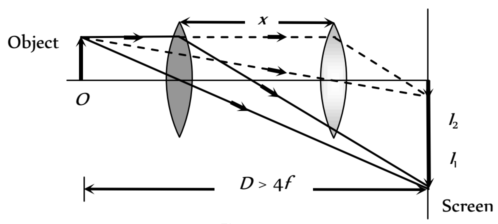


Fig. 29.50

(1) For two different positions of lens two images $(I_1 \text{ and } I_2)$ of an object are formed at the screen.

(2) Focal length of the lens $f = \frac{D^2 - x^2}{4D} = \frac{x}{m_1 - m_2}$

where $m_1 = \frac{I_1}{O}$; $m_2 = \frac{I_2}{O}$ and $m_1 m_2 = 1$.

(3) Size of object $O = \sqrt{I_1 . I_2}$

Cutting of Lens

(1) A symmetric lens is cut along optical axis in two equal parts. Intensity of image formed by each part will be same as that of complete lens. Focal length is double the original for each part.

(2) A symmetric lens is cut along principle axis in two equal parts. Intensity of image formed by each part will be less compared as that of complete lens.(aperture of each part is $\frac{1}{\sqrt{2}}$ times that of complete lens). Focal length remains same for each part.

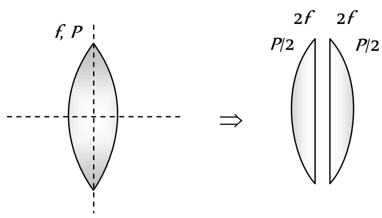


Fig. 29.51

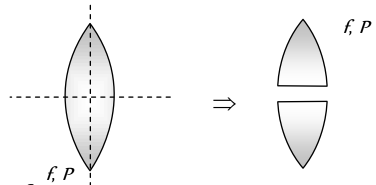


Fig. 29.52

Combination of Lens

(1) For a system of lenses, the net power, net focal length and magnification are given as follows :

$$P = P_1 + P_2 + P_3 ...., \qquad \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ... ,$$

$$m = m_1 \times m_2 \times m_3 \times ....$$

(2) In case when two thin lens are in contact : Combination will behave as a lens, which have more power or lesser focal length.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow F = \frac{f_1 f_2}{f_1 + f_2} \quad \text{and} \quad P = P_1 + P_2$$

(3) If two lens of equal focal length but of opposite nature are in contact then combination will behave as a plane glass plate and $F_{combination} = \infty$

(4) When two lenses are placed co-axially at a distance d from each other then equivalent focal length (F).

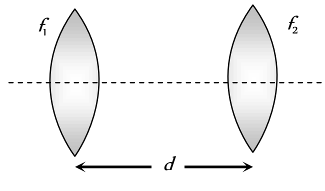


Fig. 29.53

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1 f_2} \text{ and } P=P_1+P_2-dP_1P_2$$

(5) Combination of parts of a lens :

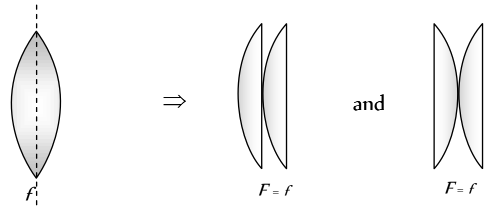


Fig. 29.54

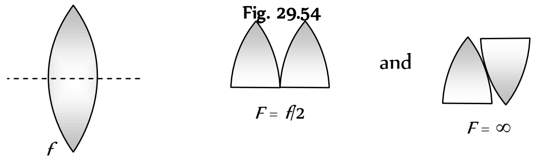


Fig. 29.55

Silvering of Lens

On silvering the surface of the lens it behaves as a mirror. The focal length of the silvered lens is $\frac{1}{F}=\frac{2}{f_l}+\frac{1}{f_m}$

where f_l = focal length of lens from which refraction takes place (twice)

f_m = focal length of mirror from which reflection takes place.

(1) Plano convex is silvered

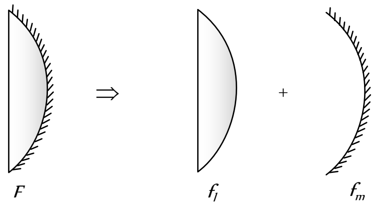


Fig. 29.56

$$f_m=\frac{R}{2},\ f_l=\frac{R}{(\mu-1)} \text{ so } F=\frac{R}{2\mu}$$

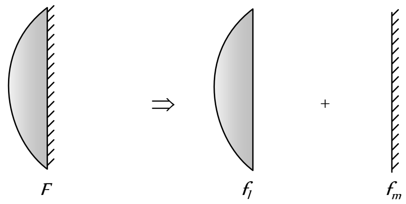


Fig. 29.57

$$f_m=\infty,\ f_l=\frac{R}{(\mu-1)} \text{ so } F=\frac{R}{2(\mu-1)}$$

(ii) Double convex lens is silvered

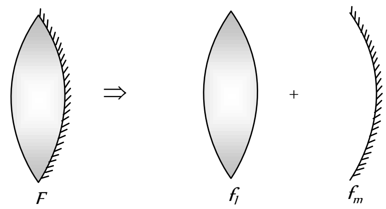


Fig. 29.58

Since $f_l=\frac{R}{2(\mu-1)},\ f_m=\frac{R}{2}$ so $F=\frac{R}{2(2\mu-1)}$

Defects in Lens

(1) **Chromatic aberration :** Image of a white object is coloured and blurred because μ (hence f) of lens is different for different colours. This defect is called chromatic aberration.

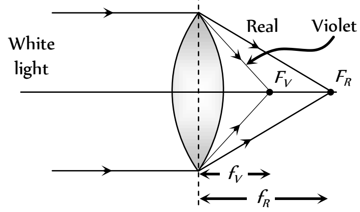


Fig. 29.59

$\mu_V>\mu_R$ so $f_R>f_V$

Mathematically chromatic aberration = $f_R-f_V=\omega f_y$

ω = Dispersive power of lens.

f = Focal length for mean colour $=\sqrt{f_R f_V}$

Removal : To remove this defect *i.e.* for Achromatism we use two or more lenses in contact in place of single lens.

Mathematically condition of Achromatism is : $\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=0$ or $\omega_1 f_2=-\omega_2 f_1$

(2) **Spherical aberration :** Inability of a lens to form the point image of a point object on the axis is called Spherical aberration.

In this defect all the rays passing through a lens are not focussed at a single point and the image of a point object on the axis is blurred.

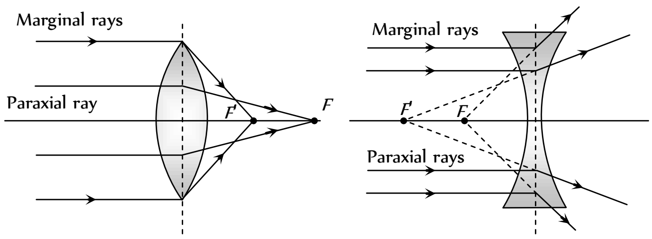


Fig. 29.60

Removal : A simple method to reduce spherical aberration is to use a stop before and infront of the lens. (but this method reduces the intensity of the image as most of the light is cut off). Also by using plano-convex lens, using two lenses separated by distance $d = F - F'$, using crossed lens.

(3) **Coma :** When the point object is placed away from the principle axis and the image is received on a screen perpendicular to the axis, the shape of the image is like a comet. This defect is called Coma.

It refers to spreading of a point object in a plane $\perp$ to principle axis.

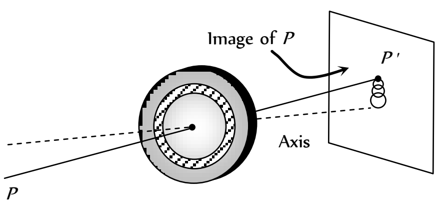


Fig. 29.61

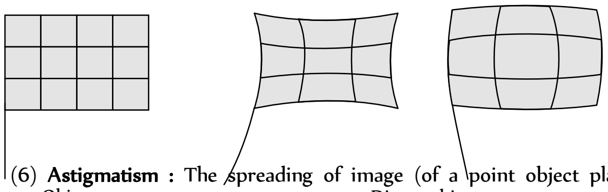
Removal : It can be reduced by properly designing radii of curvature of the lens surfaces. It can also be reduced by appropriate stops placed at appropriate distances from the lens.

(4) **Curvature :** For a point object placed off the axis, the image is spread both along and perpendicular to the principal axis. The best image

is, in general, obtained not on a plane but on a curved surface. This defect is known as Curvature.

Removal : Astigmatism or the curvature may be reduced by using proper stops placed at proper locations along the axis.

(5) **Distortion :** When extended objects are imaged, different portions of the object are in general at different distances from the axis. The magnification is not the same for all portions of the extended object. As a result a line object is not imaged into a line but into a curve.



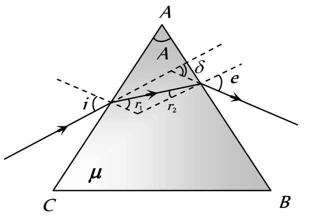
(6) **Astigmatism :** The spreading of image (of a point object placed away from the principal axis) along the principal axis is called Astigmatism.

Fig. 29.62

Prism

Prism is a transparent medium bounded by refracting surfaces, such that the incident surface (on which light ray is incidenting) and emergent surface (from which light rays emerges) are plane and non parallel.

(1) **Refraction through a prism**



i – Angle of incidence,
e – Angle of emergence,
A – Angle of prism or refracting angle of prism,
r_1 and r_2 – Angle of refraction,
δ – Angle of deviation

Fig. 29.63

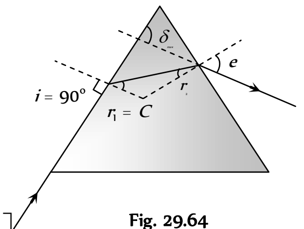
$A = r_1 + r_2$ and $i + e = A + \delta$

For surface AC $\mu = \dfrac{\sin i}{\sin r_1}$; For surface AB $\dfrac{1}{\mu} = \dfrac{\sin r_2}{\sin e}$

(2) **Deviation through a prism :** For thin prism $\delta = (\mu - 1)A$. Also deviation is different for different colour light *e.g.* $\mu_R < \mu_V$ so $\delta_R < \delta_V$.

$\mu_{\text{Flint}} > \mu_{\text{Crown}}$ so $\delta_F > \delta_C$

(i) Maximum deviation : Condition of maximum deviation is $\angle i = 90^o \Rightarrow r_1 = C,\ r_2 = A - C$ and from Snell's law on emergent surface



$$e = \sin^{-1}\left[\frac{\sin(A-C)}{\sin C}\right]$$

$$\delta_{\max} = \frac{\pi}{2} + \sin^{-1}\left[\frac{\sin(A-C)}{\sin C}\right] - A$$

Fig. 29.64

(ii) Minimum deviation : It is observed if $\angle i = \angle e$ and $\angle r_1 = \angle r_2 = r$, deviation produced is minimum.

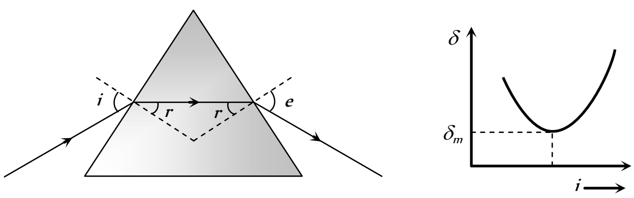


Fig. 29.65

(a) Refracted ray inside the prism is parallel to the base of the prism for equilateral and isosceles prisms.

(b) $r = \dfrac{A}{2}$ and $i = \dfrac{A + \delta_m}{2}$

(c) $\mu = \dfrac{\sin i}{\sin A/2}$ or $\mu = \dfrac{\sin \dfrac{A+\delta_m}{2}}{\sin A/2}$ (Prism formula).

(3) **Condition of no emergence :** For no emergence of light, TIR must takes place at the second surface

For TIR at second surface $r_2 > C$

So $A > r_1 + C$ (From $A = r_1 + r_2$)

As maximum value of $r_1 = C$

So, $A \ge 2C$. for any angle of incidence.

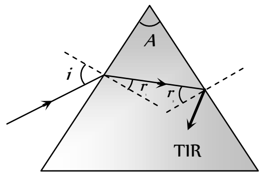


Fig. 29.66

If light ray incident normally on first surface *i.e.* $\angle i = 0°$ it means $\angle r_1 = 0°$. So in this case condition of no emergence from second surface is $A > C$.

$$\Rightarrow \sin A > \sin C \Rightarrow \sin A > \frac{1}{\mu} \Rightarrow \mu > \text{cosec}\, A$$

Dispersion Through a Prism

The splitting of white light into it's constituent colours is called dispersion of light.

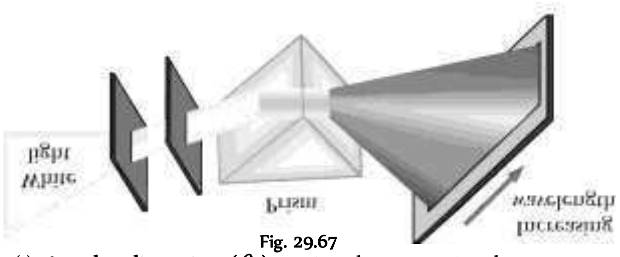


Fig. 29.67

(1) **Angular dispersion (θ) :** Angular separation between extreme colours *i.e.* $\theta = \delta_V - \delta_R = (\mu_V - \mu_R)A$. It depends upon μ and A.

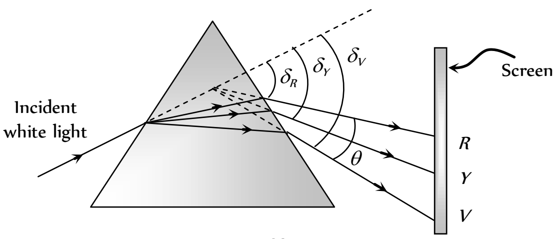


Fig. 29.68

(2) **Dispersive power (ω) :**

$$\omega = \frac{\theta}{\delta_y} = \frac{\mu_V - \mu_R}{\mu_y - 1} \quad \text{where} \left\{\mu_y = \frac{\mu_V + \mu_R}{2}\right\}$$

$\Rightarrow$ It depends only upon the material of the prism *i.e.* μ and it doesn't depends upon angle of prism A

(3) **Combination of prisms :** Two prisms (made of crown and flint material) are combined to get either dispersion only or deviation only.

(i) Dispersion without deviation (chromatic combination)

$$\frac{A'}{A} = -\frac{(\mu_y - 1)}{(\mu'_y - 1)}$$

$$\theta_{net} = \theta\left(1 - \frac{\omega'}{\omega}\right) = (\omega\delta - \omega'\delta')$$

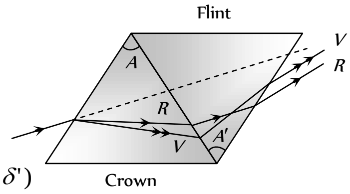


Fig. 29.69

(ii) Deviation without dispersion (Achromatic combination)

$$\frac{A'}{A} = -\frac{(\mu_V - \mu_R)}{(\mu'_V - \mu'_R)}$$

$$\delta_{net} = \delta\left(1 - \frac{\omega}{\omega'}\right)$$

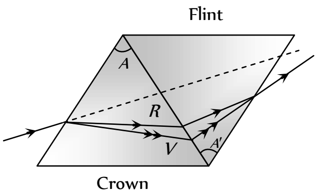


Fig. 29.70

Scattering of Light

Molecules of a medium after absorbing incoming light radiations, emits them in all direction. This phenomenon is called Scattering.

(1) **According to scientist Rayleigh :** Intensity of scattered light $\propto \frac{1}{\lambda^4}$

(2) **Some phenomenon based on scattering :** (i) Sky looks blue due to scattering.

(ii) At the time of sunrise or sunset sun looks reddish.

(iii) Danger signals are made of red colour.

(3) **Elastic scattering :** When the wavelength of radiation remains unchanged, the scattering is called elastic.

(4) **Inelastic scattering (Raman's effect) :** Under specific condition, light can also suffer inelastic scattering from molecules in which it's wavelength changes.

Rainbow

Rainbow is formed due to the dispersion of light suffering refraction and TIR in the droplets present in the atmosphere. Observer should stand with its back towards sun to observe rainbow.

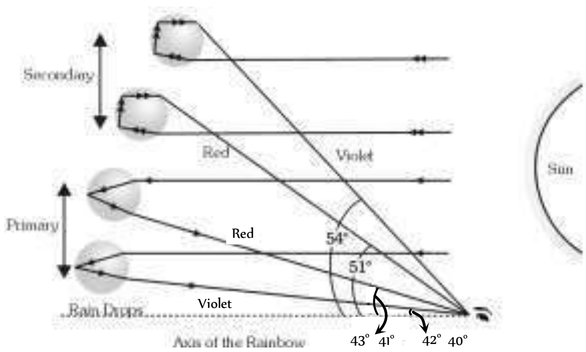


Fig. 29.71

(1) **Primary rainbow :** (i) Two refraction and one TIR. (ii) Innermost arc is violet and outermost is red. (iii) Subtends an angle of 42^o at the eye of the observer. (iv) More bright

(2) **Secondary rainbow :** (i) Two refraction and two TIR. (ii) Innermost arc is red and outermost is violet. (iii) It subtends an angle of 52.5^o at the eye. (iv) Comparatively less bright.

Colours of Objects

Colour is defined as the sensation received by the eye (rod cells of the eye) due to light coming from an object.

(1) **Colours of opaque object :** The colours of opaque bodies are due to selective reflection. *e.g.*

(i) A rose appears red in white light because it reflects red colour and absorbs all remaining colours.

(ii) When yellow light falls on a bunch of flowers, then yellow and white flowers looks yellow. Other flowers looks black.

(2) **Colours of transparent object :** The colours of transperent bodies are due to selective transmission..

(i) A red glass appears red because it absorbs all colours, except red which it transmits.

(ii) When we look on objects through a green glass or green filter then green and white objects will appear green while other black.

(3) **Colour of the sky :** Light of shorter wavelength is scattered much more than the light of longer wavelength. Since blue colour has relatively shorter wavelength, it predominates the sky and hence sky appears bluish.

(4) **Colour of clouds :** Large particles like water droplets and dust do not have this selective scattering power. They scatter all wavelengths alomost equally. Hence clouds appear to the white.

(5) **Colour triangle for spectral colours :** Red, Green and blue are primary colours.

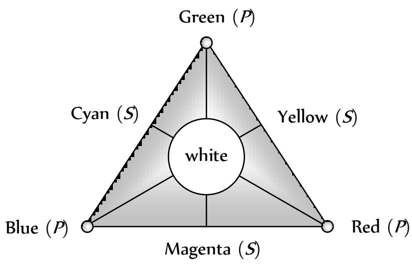


Fig. 29.72

(i) Complementary colours : Green and Magenta, Blue and Yellow, Red and Cyan.

(ii) Combination : Green + Red + Blue = White, Blue + Yellow = White, Red + Cyan = White, Green + Magenta = White

(6) **Colour triangle for pigment and dyes :** Red, Yellow and Blue are the primary colours.

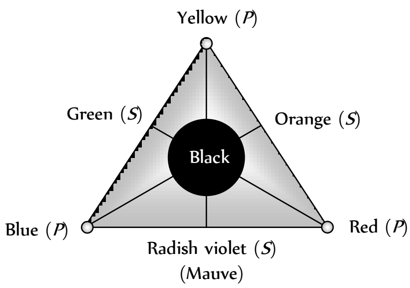


Fig. 29.73

(i) Complementary colours : Yellow and Mauve, Red and Green, Blue and Orange.

(ii) Combination : Yellow + Red + Blue = Black, Blue + Orange = Black, Red + Green = Black, Yellow + Mauve = Black

Spectrum

The ordered arrangements of radiations according to wavelengths or frequencies is called Spectrum. Spectrum can be divided in two parts Emission spectrum and Absorption spectrum.

(1) **Emission spectrum :** When light emitted by a self luminous object is dispersed by a prism to get the spectrum, the spectrum is called emission spectra.

Continuous emission spectrum

(i) It consists of continuously varying wavelengths in a definite wavelength range.

(ii) It is produced by solids, liquids and highly compressed gases heated to high temperature.

(iii) *e.g.* Light from the sun, filament of incandescent bulb, candle flame *etc.*

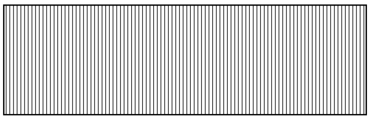


Fig. 29.74

Line emission spectrum

(i) It consist of distinct bright lines.

(ii) It is produced by an excited source in atomic state.

(iii) *e.g.* Spectrum of excited helium, mercury vapours, sodium vapours or atomic hydrogen.

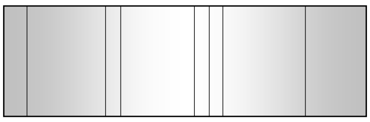


Fig. 29.75

Band emission spectrum

(i) It consist of district bright bands.

(ii) It is produced by an excited source in molecular state.

(iii) *e.g.* Spectra of molecular H_2, CO, NH_3 *etc.*

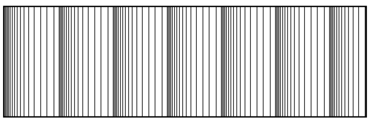


Fig. 29.76

(2) **Absorption spectrum :** When white light passes through a semi-transparent solid, or liquid or gas, it's spectrum contains certain dark lines or bands, such spectrum is called absorption spectrum (of the substance through which light is passed).

(i) Substances in atomic state produces line absorption spectra. Polyatomic substances such as H_2, CO_2 and $KMnO_4$ produces band absorption spectrum.

(ii) Absorption spectra of sodium vapour have two (yellow lines) wavelengths $D_1(5890\ Å)$ and $D_2(5896\ Å)$

(3) **Fraunhoffer's lines :** The central part (photosphere) of the sun is very hot and emits all possible wavelengths of the visible light. However, the outer part (chromosphere) consists of vapours of different elements. When the light emitted from the photosphere passes through the chromosphere, certain wavelengths are absorbed. Hence, in the spectrum of sunlight a large number of dark lines are seen called Fraunhoffer lines.

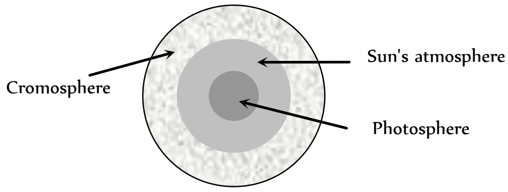


Fig. 29.77

(i) The prominent lines in the yellow part of the visible spectrum were labelled as *D*-lines, those in blue part as *F*-lines and in red part as *C*-line.

(ii) From the study of Fraunhoffer's lines the presence of various elements in the sun's atmosphere can be identified *e.g.* abundance of hydrogen and helium.

(iii) In the event of a solar eclipse, dark lines become bright. This is because of the reason that the presence of an opaque obstacle in between sun and earth cuts the light off from the central region (photo-sphere), while light from corner portion (cromosphere) is still being received. The bright lines appear exactly at the places where dark lines were present.

(4) **Spectrometer :** A spectrometer is used for obtaining pure spectrum of a source in laboratory and calculation of μ of material of prism and μ of a transparent liquid.

It consists of three parts : Collimator which provides a parallel beam of light; Prism Table for holding the prism and Telescope for observing the spectrum and making measurements on it.

The telescope is first set for parallel rays and then collimator is set for parallel rays. When prism is set in minimum deviation position, the spectrum seen is pure spectrum. Angle of prism (*A*) and angle of minimum deviation (δ_m) are measured and μ of material of prism is calculated using prism formula. For μ of a transparent liquid, we take a hollow prism with thin glass sides. Fill it with the liquid and measure (δ_m) and *A* of liquid prism. μ of liquid is calculated using prism formula.

(5) **Direct vision spectroscope :** It is an instrument used to observe pure spectrum. It produces dispersion without deviation with the help of n crown prisms and $(n-1)$ flint prisms alternately arranged in a tabular structure.

For no deviation $n(\mu-1)A=(n-1)\,(\mu'-1)A'$.

Human Eye

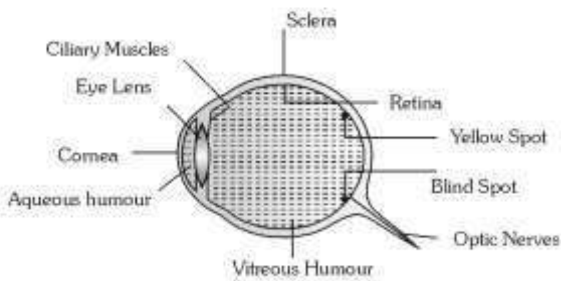


Fig. 29.78

(1) **Eye lens :** Over all behaves as a convex lens of $\mu=1.437$

(2) **Retina :** Real and inverted image of an object, obtained at retina, brain sense it erect.

(3) **Yellow spot :** It is the most sensitive part, the image formed at yellow spot is brightest.

(4) **Blind spot :** Optic nerves goes to brain through blind spot. It is not sensitive for light.

(5) **Ciliary muscles :** Eye lens is fixed between these muscles. It's both radius of curvature can be changed by applying pressure on it through ciliary muscles.

(6) **Power of accomodation :** The ability of eye to see near objects as well as far objects is called power of accomodation.

(7) **Range of vision :** For healthy eye it is 25 *cm* (near point) to ∞ (far point).

A normal eye can see the objects clearly, only if they are at a distance greater than 25 *cm*. This distance is called Least distance of distinct vision and is represented by *D*.

(8) **Persistence of vision :** Is 1/10 *sec. i.e.* if time interval between two consecutive light pulses is lesser than 0.1 *sec.*, eye cannot distinguish them separately.

(9) **Binocular vision :** The seeing with two eyes is called binocular vision.

(10) **Resolving limit :** The minimum angular separation between two objects, so that they are just resolved is called resolving limit. For eye it is $1' = \left(\frac{1}{60}\right)^o$.

Defects in Eye

(1) **Myopia (short sightness) :** A short-sighted eye can see only nearer objects. Distant objects are not seen clearly.

(i) In this defect image is formed before the retina and Far point comes closer.

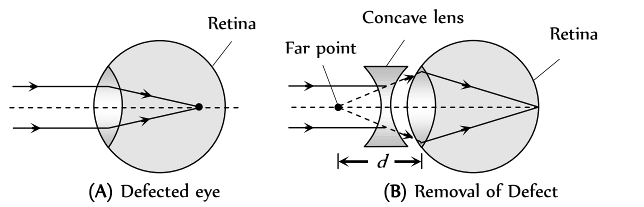


Fig. 29.79

(ii) In this defect focal length or radii of curvature of lens reduced or power of lens increases or distance between eye lens and retina increases.

(iii) This defect can be removed by using a concave lens of suitable focal length.

(iv) If defected far point is at a distance *d* from eye then

Focal length of used lens $f = -d = -$ (defected far point)

(v) A person can see upto distance → *x*, wants to see distance → *y* ($y > x$) so $f = \frac{xy}{x - y}$ or power of the lens $P = \frac{x - y}{xy}$

(2) **Hypermetropia (long sightness) :** A long-sighted eye can see distant objects clearly but nearer object are not clearly visible.

(i) Image formed behind the retina and near point moves away

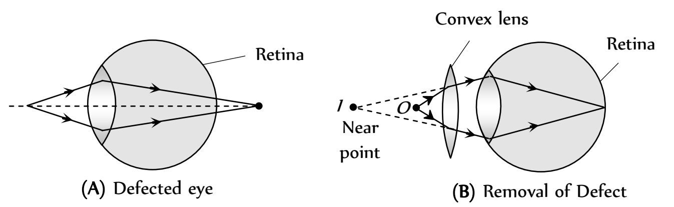


Fig. 29.80

(ii) In this defect focal length or radii of curvature of lens increases or power of lens decreases or distance between eye lens and retina decreases.

(iii) This defect can be removed by using a convex lens.

(iv) If a person cannot see before distance d but wants to see the object placed at distance *D* from eye so $f = \frac{dD}{d - D}$ and power of the lens $P = \frac{d - D}{dD}$

(3) **Presbyopia :** In this defect both near and far objects are not clearly visible. It is an old age disease and it is due to the loosing power of accommodation. It can be removed by using bifocal lens.

(4) **Astigmatism :** In this defect eye cannot see horizontal and vertical lines clearly, simultaneously. It is due to imperfect spherical nature of eye lens. This defect can be removed by using cylindrical lens (Torric lenses).

Lens Camera

(1) In lens camera a converging lens of adjustable aperture is used.

(2) Distance of film from lens is also adjustable.

(3) In photographing an object, the image is first focused on the film by adjusting the distance between lens and film. It is called focusing. After focusing, aperture is set to a specific value and then film is exposed to light for a given time through shutter.

(4) ***f*-number :** The ratio of focal length to the aperture of lens is called *f*-number of the camera.

2, 2.8, 4, 5.6, 8, 11, 22, 32 are the *f*-numbers marked on aperture.

$f\text{-number} = \frac{\text{Focal length}}{\text{Aperture}} \Rightarrow \text{Aperture} \propto \frac{1}{f\text{-number}}$

(5) **Time of exposure :** It is the time for which the shutter opens and light enters the camera to expose film.

(i) If intensity of light is kept fixed then for proper exposure

Time of exposure $(t) \propto \frac{1}{(\text{Aperture})^2}$

(ii) If aperture is kept fixed then for proper exposure

Time of exposure $(t) \propto \frac{1}{[\text{Intensity}(I)]^2}$

$\Rightarrow It = \text{constant} \Rightarrow I_1 t_1 = I_2 t_2$

(iii) Smaller the *f*-number larger will be the aperture and lesser will be the time of exposure and faster will be the camera.

(6) **Depth of focus :** It refers to the range of distance over which the object may lie so as to form a good quality image. Large *f*-number increase the depth of focus.

Microscope

It is an optical instrument used to see very small objects. It's magnifying power is given by

$$m = \frac{\text{Visual angle with instrument}(\beta)}{\text{Visual angle when object is placed at least distance of distinct vision}(\alpha)}$$

(1) **Simple microscope**

(i) It is a single convex lens of lesser focal length.

(ii) Also called magnifying glass or reading lens.

(iii) Magnification's, when final image is formed at *D* and ∞ (*i.e.* m_D and m_∞) $\quad m_D = \left(1+\frac{D}{f}\right)_{\max}$ and $m_\infty = \left(\frac{D}{f}\right)_{\min}$

(iv) If lens is kept at a distance *a* from the eye then $m_D = 1 + \frac{D-a}{f}$ and $m_\infty = \frac{D-a}{f}$

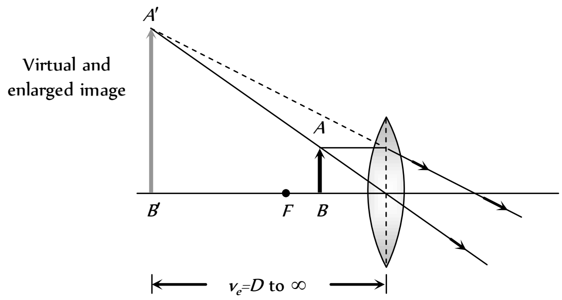


Fig. 29.81

(2) **Compound microscope**

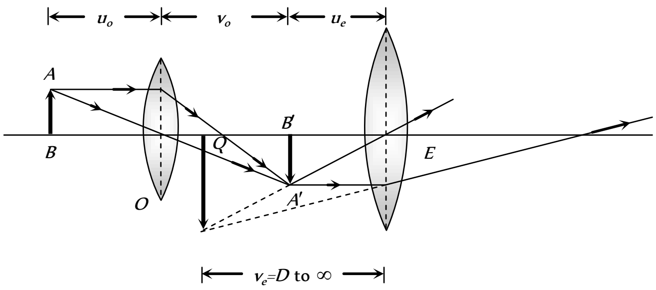


Fig. 29.82

(i) Consist of two converging lenses called objective and eye lens.

(ii) $f_{\text{eye lens}} > f_{\text{objective}}$ and $(\text{diameter})_{\text{eye lens}} > (\text{diameter})_{\text{objective}}$

(iii) Intermediate image is real and enlarged.

(iv) Final image is magnified, virtual and inverted.

(v) u_o = Distance of object from objective (*o*), v_o = Distance of image $(A'B')$ formed by objective from objective, u_e = Distance of $A'B'$ from eye lens, v_e = Distance of final image from eye lens, f_o = Focal length of objective, f_e = Focal length of eye lens.

(vi) **Final image is formed at *D* :** Magnification $m_D = -\frac{v_o}{u_o}\left(1+\frac{D}{f_e}\right)$ and length of the microscope tube (distance between two lenses) is $L_D = v_o + u_e$.

Generally object is placed very near to the principal focus of the objective hence $u_o \cong f_o$. The eye piece is also of small focal length and the image formed by the objective is also very near to the eye piece.

So $v_o \cong L_D$, the length of the tube.

Hence, we can write $m_D = \frac{-L}{f_o}\left(1+\frac{D}{f_e}\right)$

(vii) **Final image is formed at ∞ :** Magnification

$m_\infty = -\frac{v_0}{u_0}\cdot\frac{D}{f_e}$ and length of tube $L_\infty = v_0 + f_e$

In terms of length $m_\infty = \frac{(L_\infty - f_o - f_e)D}{f_o f_e}$

(viii) For large magnification of the compound microscope, both f_o and f_e should be small.

(ix) If the length of the tube of microscope increases, then its magnifying power increases.

(x) The magnifying power of the compound microscope may be expressed as $M = m_o \times m_e$; where m_o is the magnification of the objective and m_e is magnifying power of eye piece.

Astronomical Telescope (Refracting Type)

By astronomical telescope heavenly bodies are seen.

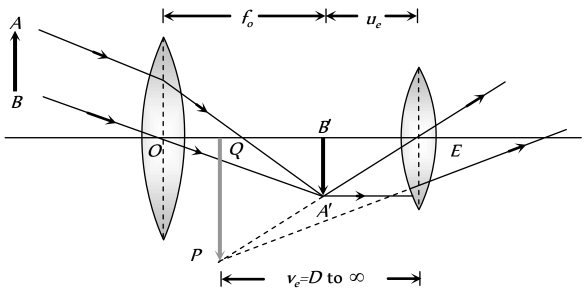


Fig. 29.83

(1) $f_{\text{objective}} > f_{\text{eyelens}}$ and $d_{\text{objective}} > d_{\text{eye lens}}$.

(2) Intermediate image is real, inverted and small.

(3) Final image is virtual, inverted and small.

(4) Magnification : $m_D = -\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ and $m_\infty = -\frac{f_o}{f_e}$

(5) Length : $L_D = f_0 + u_e$ and $L_\infty = f_0 + f_e$

Terrestrial Telescope

It is used to see far off object on the earth.

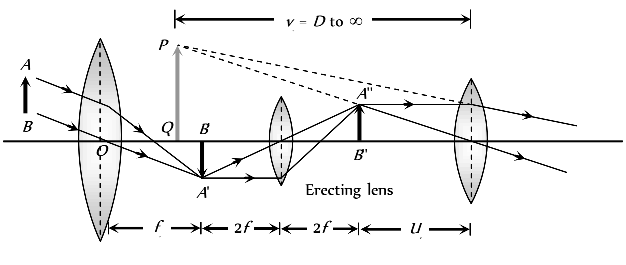


Fig. 29.84

(1) It consists of three converging lens : objective, eye lens and erecting lens.

(2) It's final image is virtual, erect and smaller.

(3) Magnification : $m_D = \frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ and $m_\infty = \frac{f_0}{f_e}$

(4) Length : $L_D = f_0 + 4f + u_e$ and $L_\infty = f_0 + 4f + f_e$

Galilean Telescope

It is also type of terrestrial telescope but of much smaller field of view.

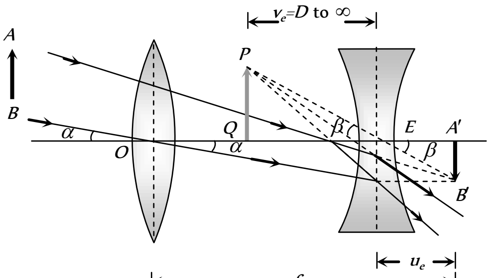


Fig. 29.85

(1) Objective is a converging lens while eye lens is diverging lens.

(2) Magnification : $m_D = \frac{f_0}{f_e}\left(1-\frac{f_e}{D}\right)$ and $m_\infty = \frac{f_0}{f_e}$

(3) Length : $L_D = f_0 - u_e$ and $L_\infty = f_0 - f_e$

Reflecting Telescope

Reflecting telescopes are based upon the same principle except that the formation of images takes place by reflection instead of by refraction.

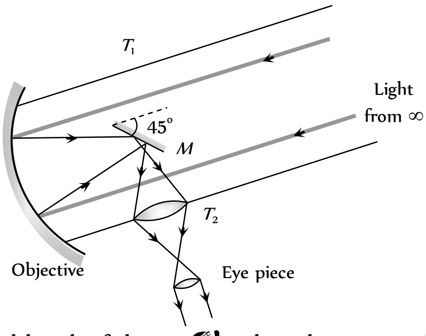


Fig. 29.86

If f_o is focal length of the concave spherical mirror used as objective and f_e the focal length of the eye-piece, the magnifying power of the reflecting telescope is given by $m = \frac{f_o}{f_e}$

Further, if D is diameter of the objective and d, the diameter of the pupil of the eye, then brightness ratio (β) is given by $\beta = \frac{D^2}{d^2}$

Resolving Limit and Resolving Power

(1) **Microscope :** In reference to a microscope, the minimum distance between two lines at which they are just distinct is called Resolving limit (*RL*) and it's reciprocal is called Resolving power (*RP*)

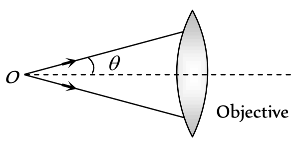


Fig. 29.87

$$R.L. = \frac{\lambda}{2\mu\sin\theta} \text{ and } R.P. = \frac{2\mu\sin\theta}{\lambda} \Rightarrow R.P. \propto \frac{1}{\lambda}$$

λ = Wavelength of light used to illuminate the object,

μ = Refractive index of the medium between object and objective,

θ = Half angle of the cone of light from the point object, $\mu\sin\theta$ = Numerical aperture.

(2) **Telescope :** Smallest angular separations ($d\theta$) between two distant objects, whose images are separated in the telescope is called resolving limit. So resolving limit $d\theta = \frac{1.22\lambda}{a}$

and resolving power $(RP) = \frac{1}{d\theta} = \frac{a}{1.22\lambda} \Rightarrow R.P. \propto \frac{1}{\lambda}$ where a = aperture of objective.

Binocular

If two telescopes are mounted parallel to each other so that an object can be seen by both the eyes simultaneously, the arrangement is called 'binocular'. In a binocular, the length of each tube is reduced by using a set of totally reflecting prisms which provide intense, erect image free from lateral inversion. Through a binocular we get two images of the same object from different angles at same time. Their superposition gives the perception of depth along with length and breadth, *i.e.*, binocular vision gives proper three-dimensional (3*D*) image.

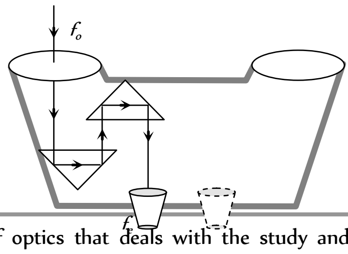


Fig. 29.88

Photometry

The branch of optics that deals with the study and measurement of the light energy is called photometry.

(1) **Radiant flux (*R*) :** The total energy radiated by a source per second is called radiant flux. It's S.I. unit is **Watt (*W*)**.

(2) **Luminous flux (ϕ) :** The total light energy emitted by a source per second is called luminous flux. It represents the total brightness producing capacity of the source. It's S.I. unit is **Lumen (*lm*)**.

(3) **Luminous efficiency (η) :** The Ratio of luminous flux and radiant flux is called luminous efficiency *i.e.* $\eta = \frac{\phi}{R}$.

Table 29.4 : Luminous flux and efficiency

Light source	Flux (lumen)	Efficiency (lumen/watt)
40 W tungsten bulb	465	12
60 W tungsten bulb	835	14
500 W tungsten bulb	9950	20
30 W fluorescent tube	1500	50

(4) **Luminous Intensity (*L*) :** In a given direction it is defined as luminous flux per unit solid angle *i.e.*

$$L = \frac{\phi}{\omega} \rightarrow \frac{\text{Light energy}}{\text{sec} \times \text{solid angle}} \xrightarrow{\text{S.I. unit}} \frac{\text{lumen}}{\text{steradian}} = \text{candela}\,(Cd)$$

The luminous intensity of a point source is given by : $L=\frac{\phi}{4\pi}\Rightarrow$ $\phi=4\pi\times(L)$

(5) **Illuminance or intensity of illumination (*I*) :** The luminous flux incident per unit area of a surface is called illuminance. $I=\frac{\phi}{A}$. It's S.I. unit is $\frac{\text{Lumen}}{m^2}$ or Lux (*lx*) and it's C.G.S. unit is Phot. $1\,\text{Phot}=10^4\,\text{Lux}=\frac{1\,\text{Lumen}}{cm^2}$

(i) Intensity of illumination at a distance *r* from a point source is $I=\frac{\phi}{4\pi r^2}\Rightarrow I\propto\frac{1}{r^2}$.

(ii) Intensity of illumination at a distance *r* from a line source is $I=\frac{\phi}{2\pi rl}\Rightarrow I\propto\frac{1}{r}$

(iii) In case of a parallel beam of light $I\propto r^0$.

(iv) The illuminance represents the luminous flux incident on unit area of the surface, while luminance represents the luminous flux reflected from a unit area of the surface.

(6) **Relation Between Luminous Intensity (*L*) and Illuminance (*I*) :** If S is a unidirectional point source of light of luminous intensity L and there is a surface at a distance r from source, on which light is falling normally.

(i) Illuminance of surface is given by : $I=\frac{L}{r^2}$

(ii) For a given source L = constant so $I\propto\frac{1}{r^2}$; This is called. Inverse square law of illuminance.

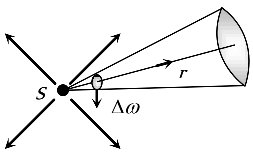


Fig. 29.89

(7) **Lambert's Cosine Law of Illuminance :** In the above discussion if surface is so oriented that light from the source falls, on it obliquely and the central ray of light makes an angle θ with the normal to the surface, then

(i) Illuminance of the surface $I=\frac{L\cos\theta}{r^2}$

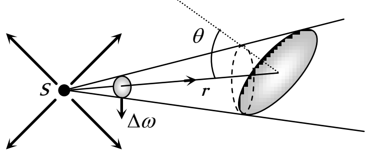


Fig. 29.90

(ii) For a given light source and point of illumination (*i.e.* *L* and *r* = constant) $I\propto\cos\theta$ this is called Lambert's cosine law of illuminance. $\Rightarrow I_{\max}=\frac{L}{r^2}=I_o(\text{at}\,\theta=0^o)$

(iii) For a given source and plane of illuminance (*i.e.* *L* and *h* = constant)

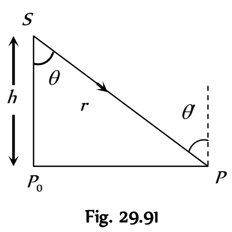


Fig. 29.91

$\cos\theta=\frac{h}{r}$ so $I=\frac{L}{h^2}\cos^3\theta$

or $I=\frac{Lh}{r^3}$ *i.e.* $I\propto\cos^3\theta$ or $I\propto\frac{1}{r^3}$

(8) **Photometer and Principle of Photometry :** A photometer is a device used to compare the illuminance of two sources.

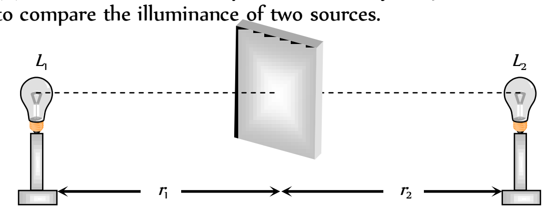


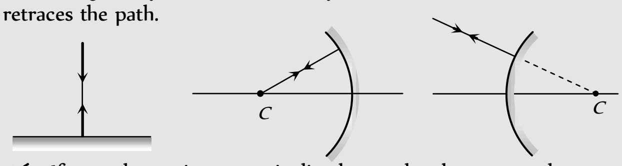
Fig. 29.92

Two sources of luminous intensity L_1, and L_2 are placed at distances r_1 and r_2 from the screen so that their flux are perpendicular to the screen. The distance r_1 and r_2 are adjusted till $I_1=I_2$. So $\frac{L_1}{r_1^2}=\frac{L_2}{r_2^2}\Rightarrow\frac{L_1}{L_2}=\left(\frac{r_1}{r_2}\right)^2$; This is called principle of photometry.

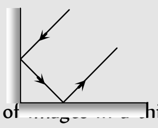
Tips & Tricks

✍ After reflection velocity, wavelength and frequency of light remains same but intensity decreases.

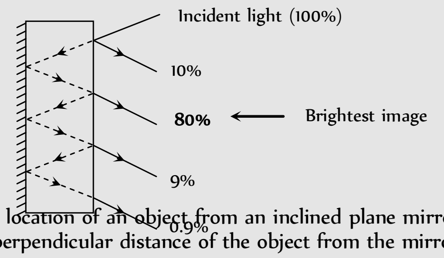
✍ If light ray incident normally on a surface, after reflection it retraces the path.



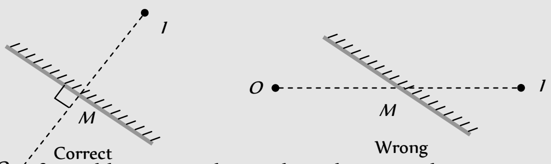
✍ If two plane mirrors are inclined to each other at 90°, the emergent ray is anti-parallel to incident ray, if it suffers one reflection from each. Whatever be the angle to incidence.



✍ We observe number of ... hick plane mirror, out of them only second is brightest.



✍ To find the location of an object from an inclined plane mirror, you have to see the perpendicular distance of the object from the mirror.



✍ Images formed by mirrors do not show chromatic aberration.

✍ In concave mirror, minimum distance between a real object and it's real image is zero. (*i.e.* when *u* = *v* = 2*f*)

✍ If a spherical mirror produces an image '*m*' times the size of the object (m = magnification) then u, v and f are given by the followings

$$u = \left(\frac{m-1}{m}\right)f,\quad v = -(m-1)f \text{ and } f = \left(\frac{m}{m-1}\right)u$$

✍ Focal length of a mirror is independent of material of mirror and medium in which it is placed and wavelength of incident light

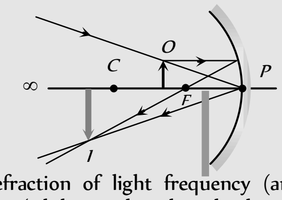
✍ Divergence or Convergence power of a mirror does not change with the change in medium.

✍ If an object is moving at a speed v towards a spherical mirror along it's axis then speed of image away from mirror is

$$v_i = -\left(\frac{f}{u-f}\right)^2 . v_o$$

✍ When object is moved from focus to infinity at constant speed, the image will move faster in the beginning till object moves from f to $2f$, and slower later on, towards the mirror.

✍ As every part of mirror forms a complete image, if a part of the mirror is obstructed, full image will be formed but intensity will be reduced.



✍ In case of refraction of light frequency (and hence colour) and phase do not change (while wavelength and velocity will change).

✍ *In the refraction intensity of incident light decreases as it goes from one medium to another medium.*

✍ A transparent solid is invisible in a liquid of same refractive index (Because of No refraction).

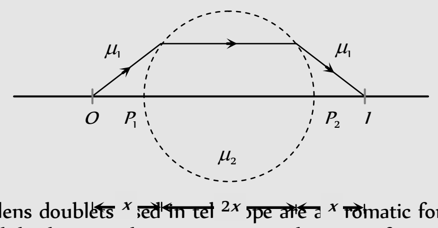
✍ When a glass slab is kept over various coloured letters and seen from the top, the violet colour letters appears closer (Because $\lambda_V < \lambda_R$ so $\mu_V > \mu_R$ and from $\mu = \frac{h}{h'}$ if μ increases then h' decreases i.e. Letter appears to be closer)

✍ Minimum distance between an object and it's real image formed by a convex lens is $4f$.

✍ Component lenses of an achromatic doublet cemented by canada blasam because it is transparent and has a refractive index almost equal to the refractive index of the glass.

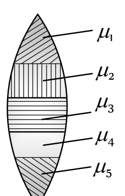
✍ Parabolic mirrors are free from spherical aberration.

✍ If a sphere of radius R made of material of refractive index μ_2 is placed in a medium of refractive index μ_1, then if the object is placed at a distance $\left(\frac{\mu_1}{\mu_2-\mu_1}\right)R$ from the pole, the real image formed is equidistant from the sphere



✍ The lens doublets used in telescope are achromatic for blue and red colours, while these used in camera are achromatic for violet and green colours. The reason for this is that our eye is most sensitive between blue and red colours, while the photographic plates are most sensitive between violet and green colours.

✍ **Composite lens :** If a lens is made of several materials then



Number of images formed = Number of materials used

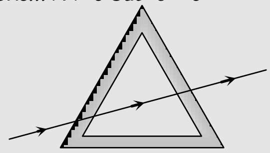
Here no. of images = 5

✍ For the condition of grazing emergence through a prism. Minimum angle of incidence $i_{min} = \sin^{-1}\left[\sqrt{\mu^2-1}\sin A - \cos A\right]$.

✍ If a substance emits spectral lines at high temperature then it absorbs the same lines at low temperature. This is Kirchoff's law.

✍ When a ray of white light passes through a glass prism red light is deviated less than blue light.

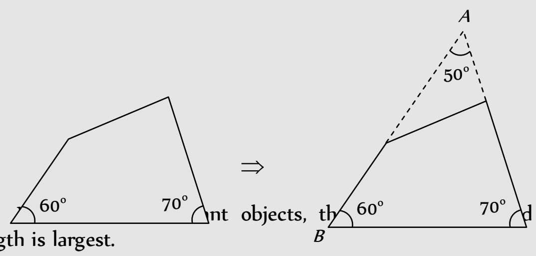
✍ For a hollow prism $A \neq 0$ but $\delta = 0$



✍ If an opaque coloured object or crystal is crushed to fine powder it will appear white (in sun light) as it will lose it's property of selective reflection.

✍ Our eye is most sensitive to that part of the spectrum which lies between the F line (sky green) and the C-line (red) of hydrogen, and the mean refractive index of this part is nearly equal to the refractive index for the D line (yellow) of sodium. Hence for the dispersive power, the following formula is internationally accepted $\omega = \frac{\mu_F - \mu_C}{\mu_D - 1}$

✍ Sometimes a part of prism is given and we keep on thinking whether how should we proceed ? To solve such problems first complete the prism then solve as the problems of prism are solved



✍ ...nt objects, th... d it's focal length is largest.

✍ Minimum separation (d) between objects, so they can just resolved by a telescope is : $d = \frac{r}{R.P.}$

Where r = distance of objects from telescope.

✍ As magnifying power astronomical telescope is negative, the image seen in astronomical telescope is truly inverted, i.e., left is turned right with upside down simultaneously. However, as most of the astronomical objects are symmetrical this inversion does not affect the observations.

✍ If objective and eye lens of a telescope are interchanged, it will not behave as a microscope but object appears very small.

✍ In a telescope, if field and eye lenses are interchanged magnification will change from (f_o/f_e) to (f_e/f_o), *i.e.,* it will change from m to $(1/m)$, i.e., will become $(1/m)$ times of its initial value.

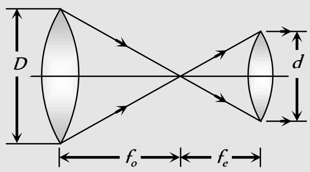
✍ As magnification produced by telescope for normal setting is (f_o/f_e), so to have large magnification, f_o must be as large as practically possible and f_e small. This is why in a telescope, objective is of large focal length while eye piece of small.

✍ In a telescope, aperture of the field lens is made as large as practically possible to increase its resolving power as resolving power of a telescope $\propto (D/\lambda)$. Large aperture of objective also helps in improving the brightness of image by gathering more light from distant object. However, it increases aberrations particularly spherical.

✍ For a telescope with increase in length of the tube, magnification decreases.

✍ In case of a telescope if object and final image are at infinity then :

$m = \frac{f_o}{f_e} = \frac{D}{d}$



✍ If we are given four convex lenses having focal lengths $f_1 > f_2 > f_3 > f_4$. For making a good telescope and microscope. We choose the following lenses respectively.

Telescope $f_1(o), f_4(e)$ Microscope $f_4(o), f_3(e)$

✍ If a parrot is sitting on the objective of a large telescope and we look towards (or take a photograph)of distant astronomical object (say moon) through it, the parrot will not be seen but the intensity of the image will be slightly reduced as the parrot will act as obstruction to light and will reduce the aperture of the objective.

✍ The luminous flux of a source of (1/685) watt emitting monochromatic light of wavelength 5500 Å is called 1 lumen.

✍ While solving the problems of photometry keep in mind.

$R \propto \phi \propto L$ (As $\phi = \eta R = 4\pi L$)

$\Rightarrow \frac{R_1}{R_2} = \frac{\phi_1}{\phi_2} = \frac{L_1}{L_2}$

Ordinary Thinking

Objective Questions

Plane Mirror

1. Two vertical plane mirrors are inclined at an angle of $60°$ with each other. A ray of light travelling horizontally is reflected first from one mirror and then from the other. The resultant deviation is
   (a) $60°$ (b) $120°$
   (c) $180°$ (d) $240°$

2. A plane mirror reflects a pencil of light to form a real image. Then the pencil of light incident on the mirror is [MP PMT 1997; DCE 2001, 03]
   (a) Parallel (b) Convergent
   (c) Divergent (d) None of the above

3. What should be the angle between two plane mirrors so that whatever be the angle of incidence, the incident ray and the reflected ray from the two mirrors be parallel to each other [KCET 1994; SCRA 1994]
   (a) $60°$ (b) $90°$
   (c) $120°$ (d) $175°$

4. A plane mirror reflecting a ray of incident light is rotated through an angle θ about an axis through the point of incidence in the plane of the mirror perpendicular to the plane of incidence, then
   (a) The reflected ray does not rotate
   (b) The reflected ray rotates through an angle θ
   (c) The reflected ray rotates through an angle 2θ
   (d) The incident ray is fixed

5. A plane mirror is approaching you at a speed of $10\,cm/sec$ You can see your image in it. At what speed will your image approach you [CPMT 1974]
   (a) $10 cm/sec$ (b) $5 cm/sec$
   (c) $20 cm/sec$ (d) $15 cm/sec$

6. A light bulb is placed between two plane mirrors inclined at an angle of $60°$. The number of images formed are
   SCRA 1994; AIIMS 1997; RPMT 1999; AIEEE 2002; Orissa JEE 2003; MP PMT 2004; MP PET 2004]
   (a) 6 (b) 2
   (c) 5 (d) 4

7. It is desired to photograph the image of an object placed at a distance of $3m$ from the plane mirror. The camera which is at a distance of $4.5m$ from the mirror should be focussed for a distance of [NCERT 1971]
   (a) $3m$ (b) $4.5m$
   (c) $6m$ (d) $7.5m$

8. A thick plane mirror shows a number of images of the filament of an electric bulb. Of these, the brightest image is the
   (a) First (b) Second
   (c) Fourth (d) Last

9. A man is $180cm$ tall and his eyes are $10cm$ below the top of his head. In order to see his entire height right from toe to head, he uses a plane mirror kept at a distance of $1m$ from him. The minimum length of the plane mirror required is [MP PMT 1993; DPMT 2001]
   (a) $180cm$ (b) $90cm$
   (c) $85cm$ (d) $170cm$

10. A person is in a room whose ceiling and two adjacent walls are mirrors. How many images are formed [AFMC 2002]
    (a) 5 (b) 6
    (c) 7 (d) 8

11. When a plane mirror is placed horizontally on a level ground at a distance of $60m$ from the foot of a tower, the top of the tower and its image in the mirror subtend an angle of $90°$ at the eye. The height of the tower will be [CPMT 1984]
    (a) $30m$ (b) $60m$
    (c) $90m$ (d) $120m$

12. A ray of light incidents on a plane mirror at an angle of $30°$. The deviation produced in the ray is [NCERT 1978; CPMT 1991]
    (a) $30°$ (b) $60°$
    (c) $90°$ (d) $120°$

13. A ray of light is incidenting normally on a plane mirror. The angle of reflection will be [MP PET 2000]

(a) $0°$ (b) $90°$

(c) Will not be reflected (d) None of the above

14. When light wave suffers reflection at the interface from air to glass, the change in phase of the reflected wave is equal to [CPMT 1991; J & KCET 2004]

(a) 0 (b) $\frac{\pi}{2}$

(c) π (d) 2π

15. A ray is reflected in turn by three plain mirrors mutually at right angles to each other. The angle between the incident and the reflected rays is [Roorkee 1995]

(a) $90°$ (b) $60°$

(c) $180°$ (d) None of these

16. Two plane mirrors are at right angles to each other. A man stands between them and combs his hair with his right hand. In how many of the images will he be seen using his right hand [MP PMT 1995; UPSEAT 2001]

(a) None (b) 1

(c) 2 (d) 3

17. When a plane mirror is rotated through an angle θ then the reflected ray turns through the angle 2θ then the size of the image

(a) Is doubled (b) Is halved

(c) Remains the same (d) Becomes infinite

18. A plane mirror produces a magnification of [MP PET/PMT 1997]

(a) -1 (b) $+1$

(c) Zero (d) Between 0 and $+\infty$

19. A plane mirror makes an angle of $30°$ with horizontal. If a vertical ray strikes the mirror, find the angle between mirror and reflected ray [RPET 1997]

(a) $30°$ (b) $45°$

(c) $60°$ (d) $90°$

20. A watch shows time as $3:25$ when seen through a mirror, time appeared will be [RPMT 1997; JIPMER 2001, 02]

(a) $8:35$ (b) $9:35$

(c) $7:35$ (d) $8:25$

21. If an observer is walking away from the plane mirror with $6m/sec$. Then the velocity of the image with respect to observer will be [RPMT 1999]

(a) $6m/sec$ (b) $-6m/sec$

(c) $12m/sec$ (d) $3m/sec$

22. A man runs towards mirror at a speed of $15m/s$. What is the speed of his image [CBSE PMT 2000]

(a) 7.5 m/s (b) 15 m/s

(c) 30 m/s (d) 45 m/s

23. A small object is placed 10 cm infront of a plane mirror. If you stand behind the object 30 cm from the mirror and look at its image, the distance focused for your eye will be [KCET (Engg.) 2001]

(a) 60 cm (b) 20 cm

(c) 40 cm (d) 80 cm

24. An object is at a distance of 0.5 m in front of a plane mirror. Distance between the object and image is [CPMT 2002]

(a) 0.5 m (b) 1 m

(c) 0.25 m (d) 1.5 m

25. A man runs towards a mirror at a speed 15 m/s The speed of the image relative to the man is [Kerala PET 2002]

(a) 15 ms^{-1} (b) 30 ms^{-1}

(c) 35 ms^{-1} (d) 20 ms^{-1}

26. The light reflected by a plane mirror may form a real image [KCET (Engg. & Med.) 2002]

(a) If the rays incident on the mirror are diverging

(b) If the rays incident on the mirror are converging

(c) If the object is placed very close to the mirror

(d) Under no circumstances

27. Two plane mirrors are inclined at an angle of 72^0. The number of images of a point object placed between them will be [KCET (Engg. & Med.)1999;

(a) 2 (b) 3

(c) 4 (d) 5

28. To get three images of a single object, one should have two plane mirrors at an angle of [AIEEE 2003]

(a) 30° (b) 60°

(c) 90° (d) 150°

29. A man of length h requires a mirror, to see his own complete image of length at least equal to [MP PET 2003]

(a) $\frac{h}{4}$ (b) $\frac{h}{3}$

(c) $\frac{h}{2}$ (d) h

30. Two plane mirrors are at $45°$ to each other. If an object is placed between them, then the number of images will be [MP PMT 2003]

(a) 5 (b) 9

(c) 7 (d) 8

31. A man having height 6 m. He observes image of 2 m height erect, then mirror used is [BCECE 2004]

(a) Concave (b) Convex

(c) Plane (d) None of these

32. A light beam is being reflected by using two mirrors, as in a periscope used in submarines. If one of the mirrors rotates by an angle θ, the reflected light will deviate from its original path by the angle [UPSEAT 2004]

(a) 2θ (b) 0^o

(c) θ (d) 4θ

33. Focal length of a plane mirror is [RPMT 2000]

(a) Zero (b) Infinite

(c) Very less (d) Indefinite

34. A ray of light is incident at 50° on the middle of one of the two mirrors arranged at an angle of 60° between them. The ray then touches the second mirror, get reflected back to the first mirror, making an angle of incidence of [MP PET 2005]

(a) 50° (b) 60°

(c) 70° (d) 80°

Spherical Mirror

1. A convex mirror of focal length *f* forms an image which is $\frac{1}{n}$ times the object. The distance of the object from the mirror is

(a) $(n-1)f$ (b) $\left(\frac{n-1}{n}\right)f$

(c) $\left(\frac{n+1}{n}\right)f$ (d) $(n+1)f$

2. A diminished virtual image can be formed only in [MP PMT 2002]

(a) Plane mirror (b) A concave mirror

(c) A convex mirror (d) Concave-parabolic mirror

3. Which of the following could not produce a virtual image

(a) Plane mirror

(b) Convex mirror

(c) Concave mirror

(d) All the above can produce a virtual image

4. An object $5cm$ tall is placed $1m$ from a concave spherical mirror which has a radius of curvature of $20cm$ The size of the image is

(a) $0.11cm$ (b) $0.50cm$

(c) $0.55cm$ (d) $0.60cm$

5. The focal length of a concave mirror is $50cm$. Where an object be placed so that its image is two times and inverted

(a) 75 *cm* (b) 72 *cm*

(c) 63 *cm* (d) 50 *cm*

6. An object of size $7.5cm$ is placed in front of a convex mirror of radius of curvature $25cm$ at a distance of $40cm$. The size of the image should be

(a) $2.3cm$ (b) $1.78cm$

(c) $1cm$ (d) $0.8cm$

7. The field of view is maximum for

(a) Plane mirror (b) Concave mirror

(c) Convex mirror (d) Cylindrical mirror

8. The focal length of a concave mirror is *f* and the distance from the object to the principle focus is *x*. The ratio of the size of the image to the size of the object is [Kerala PET 2005]

(a) $\frac{f+x}{f}$ (b) $\frac{f}{x}$

(c) $\sqrt{\frac{f}{x}}$ (d) $\frac{f^2}{x^2}$

9. Image formed by a convex mirror is [MP PET 1993]

(a) Virtual (b) Real

(c) Enlarged (d) Inverted

10. In a concave mirror experiment, an object is placed at a distance x_1 from the focus and the image is formed at a distance x_2 from the focus. The focal length of the mirror would be

(a) x_1x_2 (b) $\sqrt{x_1x_2}$

(c) $\frac{x_1+x_2}{2}$ (d) $\sqrt{\frac{x_1}{x_2}}$

11. A convex mirror is used to form the image of an object. Then which of the following statements is wrong [CPMT 1973]

(a) The image lies between the pole and the focus

(b) The image is diminished in size

(c) The image is erect

(d) The image is real

12. Given a point source of light, which of the following can produce a parallel beam of light [CPMT 1974; KCET 2005]

(a) Convex mirror

(b) Concave mirror

(c) Concave lens

(d) Two plane mirrors inclined at an angle of $90°$

13. The image formed by a convex mirror of focal length $30cm$ is a quarter of the size of the object. The distance of the object from the mirror is [MP PET 1993]

(a) $30cm$ (b) $90cm$

(c) $120cm$ (d) $60cm$

14. A boy stands straight infront of a mirror at a distance of $30cm$ away from it. He sees his erect image whose height is $\frac{1}{5}th$ of his real height. The mirror he is using is [MP PMT 1993]

(a) Plane mirror (b) Convex mirror

(c) Concave mirror (d) Plano-convex mirror

15. A person sees his virtual image by holding a mirror very close to the face. When he moves the mirror away from his face, the image becomes inverted. What type of mirror he is using

(a) Plane mirror (b) Convex mirror

(c) Concave mirror (d) None of these

16. Which one of the following statements is true

(a) An object situated at the principle focus of a concave lens will have its image formed at infinity

(b) Concave mirror can give diminished virtual image

(c) Given a point source of light, a convex mirror can produce a parallel beam of light

(d) The virtual image formed in a plane mirror can be photographed

17. The relation between the linear magnification m, the object distance u and the focal length f is

(a) $m = \frac{f-u}{f}$ (b) $m = \frac{f}{f-u}$

(c) $m = \frac{f+u}{f}$ (d) $m = \frac{f}{f+u}$

18. While using an electric bulb, the reflection for street lighting should be from

(a) Concave mirror (b) Convex mirror

(c) Cylindrical mirror (d) Parabolic mirror

19. A concave mirror is used to focus the image of a flower on a nearby well $120cm$ from the flower. If a lateral magnification of 16 is desired, the distance of the flower from the mirror should be

(a) $8cm$ (b) $12cm$

(c) $80cm$ (d) $120cm$

20. A virtual image larger than the object can be obtained by [MP PMT 1986]

(a) Concave mirror (b) Convex mirror

(c) Plane mirror (d) Concave lens

21. An object is placed $40cm$ from a concave mirror of focal length $20cm$. The image formed is [MP PET 1986; MP PMT/PET 1998]

(a) Real, inverted and same in size

(b) Real, inverted and smaller

(c) Virtual, erect and larger

(d) Virtual, erect and smaller

22. A virtual image three times the size of the object is obtained with a concave mirror of radius of curvature $36cm$. The distance of the object from the mirror is [MP PET 1986]

(a) $5cm$ (b) $12cm$

(c) $10cm$ (d) $20cm$

23. Radius of curvature of concave mirror is $40cm$ and the size of image is twice as that of object, then the object distance is [AFMC 1995]

(a) $60cm$ (b) $20cm$

(c) $40cm$ (d) $30cm$

24. All of the following statements are correct except [Manipal MEE 1995]

(a) The magnification produced by a convex mirror is always less than one

(b) A virtual, erect, same-sized image can be obtained using a plane mirror

(c) A virtual, erect, magnified image can be formed using a concave mirror

(d) A real, inverted, same-sized image can be formed using a convex mirror

25. If an object is placed $10cm$ infront of a concave mirror of focal length $20cm$, the image will be [MP PMT 1995]

(a) Diminished, upright, virtual

(b) Enlarged, upright, virtual

(c) Diminished, inverted, real

(d) Enlarged, upright, real

26. Which of the following form(s) a virtual and erect image for all positions of the object [IIT-JEE 1996]

(a) Convex lens (b) Concave lens

(c) Convex mirror (d) Concave mirror

27. A convex mirror has a focal length f. A real object is placed at a distance f in front of it from the pole produces an image at [MP PET 1986]

(a) Infinity (b) f

(c) $f/2$ (d) $2f$

28. An object $1cm$ tall is placed $4cm$ infront of a mirror. In order to produce an upright image of $3cm$ height one needs a

(a) Convex mirror of radius of curvature $12cm$

(b) Concave mirror of radius of curvature $12cm$

(c) Concave mirror of radius of curvature $4cm$

(d) Plane mirror of height $12cm$

29. Match List I with List II and select the correct answer using the codes given below the lists : [SCRA 1998]

List I	List II
(Position of the object)	(Magnification)
(I) An object is placed at focus before a convex mirror	(A) Magnification is $-\infty$
(II) An object is placed at centre of curvature before a concave mirror	(B) Magnification is 0.5
(III) An object is placed at focus before a concave mirror	(C) Magnification is $+1$
(IV) An object is placed at centre of curvature before a convex mirror	(D) Magnification is – 1
	(E) Magnification is 0.33

Codes :

(a) I-B, II-D, III-A, IV-E (b) I-A, II-D, III-C, IV-B

(c) I-C, II-B, III-A, IV-E (d) I-B, II-E, III-D, IV-C

30. A concave mirror gives an image three times as large as the object placed at a distance of $20cm$ from it. For the image to be real, the focal length should be [SCRA 1998; JIPMER 2000]

(a) $10cm$ (b) $15cm$

(c) $20cm$ (d) $30cm$

31. The minimum distance between the object and its real image for concave mirror is [RPMT 1999]

(a) f (b) $2f$

(c) $4f$ (d) Zero

32. An object is placed at $20cm$ from a convex mirror of focal length $10\,cm$. The image formed by the mirror is [JIPMER 1999]

(a) Real and at $20\,cm$ from the mirror

(b) Virtual and at $20\,cm$ from the mirror

(c) Virtual and at $20/3\,cm$ from the mirror

(d) Real and at $20/3\,cm$ from the mirror

33. A point object is placed at a distance of $10\,cm$ and its real image is formed at a distance of $20\,cm$ from a concave mirror. If the object is moved by $0.1\,cm$ towards the mirror, the image will shift by about [MP PMT 2000]

(a) $0.4cm$ away from the mirror

(b) $0.4cm$ towards the mirror

(c) $0.8cm$ away from the mirror

(d) $0.8cm$ towards the mirror

34. Under which of the following conditions will a convex mirror of focal length f produce an image that is erect, diminished and virtual [AMU (Engg.) 2001]

(a) Only when $2f > u > f$ (b) Only when $u = f$

(c) Only when $u < f$ (d) Always

35. The focal length of a convex mirror is 20 *cm* its radius of curvature will be [MP PMT 2001]

(a) 10 *cm* (b) 20 *cm*

(c) 30 *cm* (d) 40 *cm*

36. A concave mirror of focal length 15 *cm* forms an image having twice the linear dimensions of the object. The position of the object when the image is virtual will be

(a) 22.5 *cm* (b) 7.5 *cm*

(c) 30 *cm* (d) 45 *cm*

37. A point object is placed at a distance of 30 *cm* from a convex mirror of focal length 30*cm*. The image will form at [JIPMER 2002]

(a) Infinity

(b) Focus

(c) Pole

(d) 15 *cm* behind the mirror

38. An object 2.5 *cm* high is placed at a distance of 10 *cm* from a concave mirror of radius of curvature 30 *cm* The size of the image is [BVP 2003]

(a) 9.2 *cm* (b) 10.5 *cm*

(c) 5.6 *cm* (d) 7.5 *cm*

39. For a real object, which of the following can produced a real image

(a) Plane mirror (b) Concave lens

(c) Convex mirror (d) Concave mirror

40. An object of length 6 *cm* is placed on the principle axis of a concave mirror of focal length f at a distance of $4f$. The length of the image will be [MP PET 2003]

(a) 2 *cm* (b) 12 *cm*

(c) 4 *cm* (d) 1.2 *cm*

41. Convergence of concave mirror can be decreased by dipping in

(a) Water (b) Oil

(c) Both (d) None of these

42. What will be the height of image when an object of 2 *mm* is placed on the axis of a convex mirror at a distance 20 *cm* of radius of curvature 40 *cm* [Orissa PMT 2004]

(a) 20 *mm* (b) 10 *mm*

(c) 6 *mm* (d) 1 *mm*

43. Image formed by a concave mirror of focal length 6 *cm*, is 3 times of the object, then the distance of object from mirror is [RPMT 2000]

(a) – 4 *cm* (b) 8 *cm*

(c) 6 *cm* (d) 12 *cm*

44. A concave mirror of focal length f (in air) is immersed in water ($\mu = 4/3$). The focal length of the mirror in water will be

(a) f (b) $\frac{4}{3}f$

(c) $\frac{3}{4}f$ (d) $\frac{7}{3}f$

Refraction of Light at Plane Surfaces

1. To an observer on the earth the stars appear to twinkle. This can be ascribed to [CPMT 1972, 74; AFMC 1995]

(a) The fact that stars do not emit light continuously

(b) Frequent absorption of star light by their own atmosphere

(c) Frequent absorption of star light by the earth's atmosphere

(d) The refractive index fluctuations in the earth's atmosphere

2. The ratio of the refractive index of red light to blue light in air is

(a) Less than unity

(b) Equal to unity

(c) Greater than unity

(d) Less as well as greater than unity depending upon the experimental arrangement

3. The refractive index of a piece of transparent quartz is the greatest for [MP PET 1985, 94]

(a) Red light (b) Violet light

(c) Green light (d) Yellow light

4. The refractive index of a certain glass is 1.5 for light whose wavelength in vacuum is 6000 Å. The wavelength of this light when it passes through glass is [NCERT 1979; CBSE PMT 1993; MP PET 1985, 89] [Orissa JEE 2003]

(a) 4000 Å (b) 6000 Å

(c) 9000 Å (d) 15000 Å

5. When light travels from one medium to the other of which the refractive index is different, then which of the following will change [MP PMT 1986; AMU 2001; BVP 2003]

(a) Frequency, wavelength and velocity

(b) Frequency and wavelength

(c) Frequency and velocity

(d) Wavelength and velocity

6. A light wave has a frequency of 4×10^{14} Hz and a wavelength of 5×10^{-7} meters in a medium. The refractive index of the medium is [MP PMT 1989]

(a) 1.5 (b) 1.33
(c) 1.0 (d) 0.66

7. How much water should be filled in a container 21 *cm* in height, so that it appears half filled when viewed from the top of the container (given that ${}_a\mu_\omega = 4/3$) [MP PMT 1989]

(a) 8.0 *cm* (b) 10.5 *cm*
(c) 12.0 *cm* (d) None of the above

8. Light of different colours propagates through air

(a) With the velocity of air
(b) With different velocities
(c) With the velocity of sound
(d) Having the equal velocities

9. Monochromatic light is refracted from air into the glass of refractive index μ. The ratio of the wavelength of incident and refracted waves is [JIPMER 2000; MP PMT 1996, 2003]

(a) $1:\mu$ (b) $1:\mu^2$
(c) $\mu:1$ (d) $1:1$

10. A monochromatic beam of light passes from a denser medium into a rarer medium. As a result [CPMT 1972]

(a) Its velocity increases (b) Its velocity decreases
(c) Its frequency decreases (d) Its wavelength decreases

11. Refractive index for a material for infrared light is [CPMT 1984]

(a) Equal to that of ultraviolet light
(b) Less than for ultraviolet light
(c) Equal to that for red colour of light
(d) Greater than that for ultraviolet light

12. The index of refraction of diamond is 2.0, velocity of light in diamond in *cm/second* is approximately [CPMT 1975; MNR 1987; UPSEAT 2000]

(a) 6×10^{10} (b) 3.0×10^{10}
(c) 2×10^{10} (d) 1.5×10^{10}

13. A beam of light propagating in medium *A* with index of refraction *n* (*A*) passes across an interface into medium *B* with index of refraction *n*(*B*). The angle of incidence is greater than the angle of refraction; *v*(*A*) and *v*(*B*) denotes the speed of light in *A* and *B*. Then which of the following is true

(a) $v(A) > v(B)$ and $n(A) > n(B)$
(b) $v(A) > v(B)$ and $n(A) < n(B)$
(c) $v(A) < v(B)$ and $n(A) > n(B)$
(d) $v(A) < v(B)$ and $n(A) < n(B)$

14. A rectangular tank of depth 8 meter is full of water ($\mu = 4/3$), the bottom is seen at the depth [MP PMT 1987]

(a) 6 *m* (b) 8/3 *m*
(c) 8 *cm* (d) 10 *cm*

15. A vessel of depth 2d *cm* is half filled with a liquid of refractive index μ_1 and the upper half with a liquid of refractive index μ_2. The apparent depth of the vessel seen perpendicularly is

(a) $d\left(\frac{\mu_1\mu_2}{\mu_1+\mu_2}\right)$ (b) $d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$
(c) $2d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$ (d) $2d\left(\frac{1}{\mu_1\mu_2}\right)$

16. A beam of light is converging towards a point I on a screen. A plane glass plate whose thickness in the direction of the beam = t, refractive index = μ, is introduced in the path of the beam. The convergence point is shifted by [MNR 1987]

(a) $t\left(1-\frac{1}{\mu}\right)$ away (b) $t\left(1+\frac{1}{\mu}\right)$ away
(c) $t\left(1-\frac{1}{\mu}\right)$ nearer (d) $t\left(1+\frac{1}{\mu}\right)$ nearer

17. Light travels through a glass plate of thickness *t* and having refractive index *n*. If *c* is the velocity of light in vacuum, the time taken by the light to travel this thickness of glass is [NCERT 1976; MP PET 1994; CBSE PMT 1996; KCET 1994; MP PMT 1999, 2001]

(a) $\frac{t}{nc}$ (b) tnc
(c) $\frac{nt}{c}$ (d) $\frac{tc}{n}$

18. When a light wave goes from air into water, the quality that remains unchanged is its [AMU 1995; MNR 1985, 95; KCET 1993; CPMT 1990, 97; MP PET 1991, 2000, 02; UPSEAT 1999, 2000; AFMC 1993, 98, 2003; RPET 1996, 2000, 03; RPMT 1999, 2000; DCE 2001; BHU 2001]

(a) Speed (b) Amplitude
(c) Frequency (d) Wavelength

19. Light takes 8 *min* 20 *sec* to reach from sun on the earth. If the whole atmosphere is filled with water, the light will take the time (${}_a\mu_w = 4/3$)

(a) 8 *min* 20 *sec* (b) 8 *min*
(c) 6 *min* 11 *sec* (d) 11 *min* 6 *sec*

20. The length of the optical path of two media in contact of length d_1 and d_2 of refractive indices μ_1 and μ_2 respectively, is

(a) $\mu_1 d_1 + \mu_2 d_2$ (b) $\mu_1 d_2 + \mu_2 d_1$
(c) $\frac{d_1 d_2}{\mu_1\mu_2}$ (d) $\frac{d_1+d_2}{\mu_1\mu_2}$

21. Immiscible transparent liquids A, B, C, D and E are placed in a rectangular container of glass with the liquids making layers according to their densities. The refractive index of the liquids are shown in the adjoining diagram. The container is illuminated from the side and a small piece of glass having refractive index 1.61 is

gently dropped into the liquid layer. The glass piece as it descends downwards will not be visible in [CPMT 1986]

A	1.51
B	1.53
C	1.61
D	1.52
E	1.65

(a) Liquid *A* and *B* only

(b) Liquid *C* only

(c) Liquid *D* and *E* only

(d) Liquid *A, B, D* and *E*

22. The refractive indices of glass and water *w.r.t.* air are 3/2 and 4/3 respectively. The refractive index of glass *w.r.t.* water will be

[MNR 1990; JIPMER 1997, 2000; MP PET 2000]

(a) 8/9 (b) 9/8

(c) 7/6 (d) None of these

23. If ${}_i\mu_j$ represents refractive index when a light ray goes from medium *i* to medium *j*, then the product ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3$ is equal to [CBSE PMT 1990]

(a) ${}_3\mu_1$ (b) ${}_3\mu_2$

(c) $\frac{1}{{}_1\mu_4}$ (d) ${}_4\mu_2$

24. The wavelength of light diminishes μ times ($\mu = 1.33$ for water) in a medium. A diver from inside water looks at an object whose natural colour is green. He sees the object as

[CPMT 1990; MNR 1998]

(a) Green (b) Blue

(c) Yellow (d) Red

25. Ray optics fails when

(a) The size of the obstacle is 5 *cm*

(b) The size of the obstacle is 3 *cm*

(c) The size of the obstacle is less than the wavelength of light

(d) (a) and (b) both

26. When light travels from air to water and from water to glass, again from glass to CO_2 gas and finally through air. The relation between their refractive indices will be given by

(a) ${}_an_w \times {}_wn_{gl} \times {}_{gl}n_{gas} \times {}_{gas}n_a = 1$

(b) ${}_an_w \times {}_wn_{gl} \times {}_{gas}n_{gl} \times {}_{gl}n_a = 1$

(c) ${}_an_w \times {}_wn_{gl} \times {}_{gl}n_{gas} = 1$

(d) There is no such relation

27. For a colour of light the wavelength for air is 6000 *Å* and in water the wavelength is 4500 *Å*. Then the speed of light in water will be

(a) $5. \times 10^{14}\ m/s$ (b) 2.25×10^{8} *m/s*

(c) 4.0×10^{8} *m/s* (d) Zero

28. A ray of light travelling inside a rectangular glass block of refractive index $\sqrt{2}$ is incident on the glass–air surface at an angle of incidence of 45°. The refractive index of air is 1. Under these conditions the ray [CPMT 1972]

(a) Will emerge into the air without any deviation

(b) Will be reflected back into the glass

(c) Will be absorbed

(d) Will emerge into the air with an angle of refraction equal to 90°

29. If ε_0 and μ_0 are respectively, the electric permittivity and the magnetic permeability of free space, ε and μ the corresponding quantities in a medium, the refractive index of the medium is

[IIT-JEE 1982; MP PET 1995; CBSE PMT 1997]

(a) $\sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$ (b) $\frac{\mu\varepsilon}{\mu_0\varepsilon_0}$

(c) $\sqrt{\frac{\mu_0\varepsilon_0}{\mu\varepsilon}}$ (d) $\sqrt{\frac{\mu\mu_0}{\varepsilon\varepsilon_0}}$

30. A beam of monochromatic blue light of wavelength 4200Å in air travels in water ($\mu = 4/3$). Its wavelength in water will be

(a) 2800 *Å* (b) 5600 *Å*

(c) 3150 *Å* (d) 4000 *Å*

31. If μ_0 be the relative permeability and K_0 the dielectric constant of a medium, its refractive index is given by

[MNR 1995]

(a) $\frac{1}{\sqrt{\mu_0 K_0}}$ (b) $\frac{1}{\mu_0 K_0}$

(c) $\sqrt{\mu_0 K_0}$ (d) $\mu_0 K_0$

32. If the speed of light in vacuum is $C\ m/\sec$, then the velocity of light in a medium of refractive index 1.5

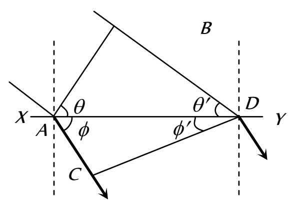
[NCERT 1977; MP PMT 1984; CPMT 2002]

(a) Is 1.5 × *C* (b) Is *C*

(c) Is $\frac{C}{1.5}$ (d) Can have any velocity

33. In the adjoining diagram, a wavefront *AB*, moving in air is incident on a plane glass surface *XY*. Its position *CD* after refraction through a glass slab is shown also along with the normals drawn at *A* and *D*. The refractive index of glass with respect to air ($\mu = 1$) will be equal to

[CPMT 1988; DPMT 1999]



(a) $\frac{\sin\theta}{\sin\theta'}$

(b) $\frac{\sin\theta}{\sin\phi'}$

(c) $\frac{\sin\phi'}{\sin\theta}$

(d) $\frac{AB}{CD}$

34. When light enters from air to water, then its

[MP PMT 1994; MP PET 1996]

(a) Frequency increases and speed decreases

(b) Frequency is same but the wavelength is smaller in water than in air

(c) Frequency is same but the wavelength in water is greater than in air

(d) Frequency decreases and wavelength is smaller in water than in air

35. On a glass plate a light wave is incident at an angle of 60°. If the reflected and the refracted waves are mutually perpendicular, the refractive index of material is

[MP PMT 1994; Haryana CEE 1996; KCET 1994; 2000]

(a) $\frac{\sqrt{3}}{2}$ (b) $\sqrt{3}$

(c) $\frac{3}{2}$ (d) $\frac{1}{\sqrt{3}}$

36. Refractive index of glass is $\frac{3}{2}$ and refractive index of water is $\frac{4}{3}$. If the speed of light in glass is 2.00×10^8 m/s, the speed in water will be **[MP PMT 1994; RPMT 1997]**

(a) 2.67×10^8 *m/s* (b) 2.25×10^8 *m/s*

(c) 1.78×10^8 *m/s* (d) 1.50×10^8 *m/s*

37. Monochromatic light of frequency 5×10^{14} *Hz* travelling in vacuum enters a medium of refractive index 1.5. Its wavelength in the medium is

[MP PET/ PMT 1995; Pb. PET 2003]

(a) 4000 $Å$ (b) 5000 $Å$

(c) 6000 $Å$ (d) 5500 $Å$

38. Light of wavelength is 7200 Å in air. It has a wavelength in glass ($\mu = 1.5$) equal to **[DCE 1999]**

(a) 7200 $Å$ (b) 4800 $Å$

(c) 10800 $Å$ (d) 7201.5 $Å$

39. Which of the following is *not* a correct statement **[MP PET 1997]**

(a) The wavelength of red light is greater than the wavelength of green light

(b) The wavelength of blue light is smaller than the wavelength of orange light

(c) The frequency of green light is greater than the frequency of blue light

(d) The frequency of violet light is greater than the frequency of blue light

40. Which of the following is a *correct* relation **[MP PET 1997]**

(a) ${}_a\mu_r = {}_a\mu_w \times {}_r\mu_\omega$ (b) ${}_a\mu_r \times {}_r\mu_w = {}_w\mu_a$

(c) ${}_a\mu_r \times {}_r\mu_a = 0$ (d) ${}_a\mu_r / {}_w\mu_r = {}_a\mu_w$

41. The time taken by sunlight to cross a 5 *mm* thick glass plate ($\mu = 3/2$) is **[MP PMT/PET 1998; BHU 2005]**

(a) 0.25×10^{-10} *s* (b) 0.167×10^{-7} *s*

(c) 2.5×10^{-10} *s* (d) 1.0×10^{-10} *s*

42. The distance travelled by light in glass (refractive index =1.5) in a nanosecond will be **[MP PET 1999]**

(a) 45 *cm* (b) 40 *cm*

(c) 30 *cm* (d) 20 *cm*

43. When light is refracted from air into glass

[IIT 1980; CBSE PMT 1992; MP PET 1999; MP PMT 1999; RPMT 1997, 2000, 03; MH CET 2004]

(a) Its wavelength and frequency both increase

(b) Its wavelength increases but frequency remains unchanged

(c) Its wavelength decreases but frequency remains unchanged

(d) Its wavelength and frequency both decrease

44. A mark at the bottom of a liquid appears to rise by 0.1 *m*. The depth of the liquid is 1 *m*. The refractive index of the liquid is

(a) 1.33 (b) $\frac{9}{10}$

(c) $\frac{10}{9}$ (b) 1.5

45. A man standing in a swimming pool looks at a stone lying at the bottom. The depth of the swimming pool is *h*. At what distance from the surface of water is the image of the stone formed (Line of vision is normal; Refractive index of water is *n*)

(a) h/n (b) n/h

(c) h (d) hn

46. On heating a liquid, the refractive index generally

[KCET 1994]

(a) Decreases

(b) Increases or decreases depending on the rate of heating

(c) Does not change

(d) Increases

47. If $\hat{i}$ denotes a unit vector along incident light ray, $\hat{r}$ a unit vector along refracted ray into a medium of refractive index μ and $\hat{n}$ unit vector normal to boundary of medium directed towards incident medium, then law of refraction is

[EAMCET (Engg.) 1995]

(a) $\hat{i}\,.\,\hat{n} = \mu(\hat{r}\,.\,\hat{n})$ (b) $\hat{i}\times\hat{n} = \mu(\hat{n}\times\hat{r})$

(c) $\hat{i}\times\hat{n} = \mu(\hat{r}\times\hat{n})$ (d) $\mu(\hat{i}\times\hat{n}) = \hat{r}\times\hat{n}$

48. The bottom of a container filled with liquid appear slightly raised because of **[RPMT 1997]**

(a) Refraction (b) Interference

(c) Diffraction (d) Reflection

49. The speed of light in air is 3×10^8 m/s. What will be its speed in diamond whose refractive index is 2.4

[KCET 1993]

(a) 3×10^8 m/s (b) 332 m/s

(c) 1.25×10^8 *m/s* (d) 7.2×10^8 m/s

50. Time taken by the sunlight to pass through a window of thickness 4 mm whose refractive index is 1.5 is

[CBSE PMT 1993]

(a) 2×10^{-8} *sec* (b) 2×10^{8} *sec*

(c) 2×10^{-11} *sec* (d) 2×10^{11} *sec*

51. Ray optics is valid, when characteristic dimensions are [CBSE PMT 1994; CPMT 2001]

(a) Of the same order as the wavelength of light

(b) Much smaller than the wavelength of light

(c) Of the order of one millimetre

(d) Much larger than the wavelength of light

52. The refractive index of water is 1.33. What will be the speed of light in water [CBSE PMT 1996; KCET 1998]

(a) 3×10^{8} m/s (b) 2.25×10^{8} m/s

(c) 4×10^{8} m/s (d) 1.33×10^{8} *m/s*

53. The time required to pass the light through a glass slab of 2 *mm* thick is ($\mu_{glass}=1.5$) [AFMC 1997; MH CET 2002, 04]

(a) 10^{-5} s (b) 10^{-11} s

(c) 10^{-9} s (d) 10^{-13} s

54. The refractive index of water with respect to air is 4 / 3 and the refractive index of glass with respect to air is 3/2. The refractive index of water with respect to glass is [BHU 1997; JIPMER 2000]

(a) $\frac{9}{8}$ (b) $\frac{8}{9}$

(c) $\frac{1}{2}$ (d) 2

55. Electromagnetic radiation of frequency *n*, wavelength λ, travelling with velocity *v* in air, enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively [CBSE PMT 1997]

(a) $\frac{n}{\mu},\frac{\lambda}{\mu},\frac{v}{\mu}$ (b) $n,\frac{\lambda}{\mu},\frac{v}{\mu}$

(c) $n,\lambda,\frac{v}{\mu}$ (d) $\frac{n}{\mu},\ \frac{\lambda}{\mu},v$

56. What is the time taken (in *seconds*) to cross a glass of thickness 4 *mm* and μ = 3 by light [BHU 1998; Pb. PMT 1999, 2001; MH CET 2000; MP PET 2001]

(a) 4×10^{-11} (b) 2×10^{-11}

(c) 16×10^{-11} (d) 8×10^{-10}

57. A plane glass slab is kept over various coloured letters, the letter which appears least raised is [J & K CET 2004; BHU 1998, 05]

(a) Blue (b) Violet

(c) Green (d) Red

58. A ray of light is incident on the surface of separation of a medium at an angle 45° and is refracted in the medium at an angle 30°. What will be the velocity of light in the medium [AFMC 1998; MH CET (Med.) 1999]

(a) 1.96×10^{8} *m/s* (b) 2.12×10^{8} m/s

(c) 3.18×10^{8} m/s (d) 3.33×18^{8} m/s

59. Absolute refractive indices of glass and water are $\frac{3}{2}$ and $\frac{4}{3}$. The ratio of velocity of light in glass and water will be [UPSEAT 1999]

(a) 4 : 3 (b) 8 : 7

(c) 8 : 9 (d) 3 : 4

60. The ratio of thickness of plates of two transparent mediums *A* and *B* is 6 : 4. If light takes equal time in passing through them, then refractive index of *B* with respect to *A* will be [UPSEAT 1999]

(a) 1.4 (b) 1.5

(c) 1.75 (d) 1.33

61. The refractive index of water and glass with respect to air is 1.3 and 1.5 respectively. Then the refractive index of glass with respect to water is [MH CET (Med.) 1999]

(a) $\frac{2.6}{1.5}$ (b) $\frac{1.5}{2.6}$

(c) $\frac{1.3}{1.5}$ (d) $\frac{1.5}{1.3}$

62. A tank is filled with benzene to a height of 120 *mm*. The apparent depth of a needle lying at a bottom of the tank is measured by a microscope to be 80 *mm*. The refractive index of benzene is

(a) 1.5 (b) 2.5

(c) 3.5 (d) 4.5

63. Each quarter of a vessel of depth *H* is filled with liquids of the refractive indices n_1, n_2, n_3 and n_4 from the bottom respectively. The apparent depth of the vessel when looked normally is

(a) $\frac{H(n_1+n_2+n_3+n_4)}{4}$ (b) $\frac{H\left(\frac{1}{n_1}+\frac{1}{n_2}+\frac{1}{n_3}+\frac{1}{n_4}\right)}{4}$

(c) $\frac{(n_1+n_2+n_3+n_4)}{4H}$ (d) $\frac{H\left(\frac{1}{n_1}+\frac{1}{n_2}+\frac{1}{n_3}+\frac{1}{n_4}\right)}{2}$

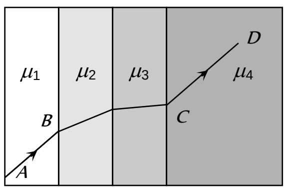
64. A ray of light passes through four transparent media with refractive indices $\mu_1.\mu_2\mu_3$, and μ_4 as shown in the figure. The surfaces of all media are parallel. If the emergent ray *CD* is parallel to the incident ray *AB*, we must have [IIT-JEE (Screening) 2001]

(a) $\mu_1=\mu_2$

(b) $\mu_2=\mu_3$

(c) $\mu_3=\mu_4$

(d) $\mu_4=\mu_1$



65. The reason of seeing the Sun a little before the sunrise is [MP PMT 2001; Orissa JEE 2003]

(a) Reflection of the light (b) Refraction of the light

(c) Scattering of the light (d) Dispersion of the light

66. An under water swimmer is at a depth of 12 *m* below the surface of water. A bird is at a height of 18 *m* from the surface of water, directly above his eyes. For the swimmer the bird appears to be at a distance from the surface of water equal to (Refractive Index of water is 4/3)

[KCET (Engg.) 2001]

(a) 24 *m* (b) 12 *m*

(c) 18 *m* (d) 9 *m*

67. The optical path of a monochromatic light is same if it goes through 4.0 *cm* of glass or 4.5 *cm* of water. If the refractive index of glass is 1.53, the refractive index of the water is

[UPSEAT 2002]

(a) 1.30 (b) 1.36

(c) 1.42 (d) 1.46

68. Which of the following statement is true **[Orissa JEE 2002]**

(a) Velocity of light is constant in all media

(b) Velocity of light in vacuum is maximum

(c) Velocity of light is same in all reference frames

(d) Laws of nature have identical form in all reference frames

69. A ray of light is incident on a transparent glass slab of refractive index 1.62. The reflected and the refracted rays are mutually perpendicular. The angle of incidence is

[MP PET 2002]

(a) 58.3° (b) 50°

(c) 35° (d) 30°

70. A microscope is focussed on a coin lying at the bottom of a beaker. The microscope is now raised up by 1 *cm*. To what depth should the water be poured into the beaker so that coin is again in focus ? (Refractive index of water is $\frac{4}{3}$)

[BHU 2003]

(a) 1 *cm* (b) $\frac{4}{3}$ *cm*

(c) 3 *cm* (d) 4 *cm*

71. Velocity of light in glass whose refractive index with respect to air is 1.5 is 2×10^8 *m/s* and in certain liquid the velocity of light found to be 2.5×10^8 *m/s*. The refractive index of the liquid with respect to air is **[CPMT 1978; MP PET/PMT 1988]**

(a) 0.64 (b) 0.80

(c) 1.20 (d) 1.44

72. Stars are twinkling due to **[CPMT 1997]**

(a) Diffraction (b) Reflection

(c) Refraction (d) Scattering

73. A thin oil layer floats on water. A ray of light making an angle of incidence of 40° shines on oil layer. The angle of refraction of light ray in water is ($\mu_{oil} = 1.45, \mu_{water} = 1.33$)

[MP PMT 1993]

(a) 36 .1° (b) 44.5°

(c) 26. 8° (d) 28.9°

74. An object is immersed in a fluid. In order that the object becomes invisible, it should **[AIIMS 2004]**

(a) Behave as a perfect reflector

(b) Absorb all light falling on it

(c) Have refractive index one

(d) Have refractive index exactly matching with that of the surrounding fluid

75. When light travels from glass to air, the incident angle is θ_1 and the refracted angle is θ_2. The true relation is

[Orissa PMT 2004]

(a) $\theta_1 = \theta_2$ (b) $\theta_1 < \theta_2$

(c) $\theta_1 > \theta_2$ (d) Not predictable

76. Velocity of light in a medium is $1.5 \times 10^8 \, m/s$. Its refractive index will be **[Pb. PET 2000]**

(a) 8 (b) 6

(c) 4 (d) 2

77. The frequency of a light ray is $6 \times 10^{14} \, Hz$. Its frequency when it propagates in a medium of refractive index 1.5, will be

[MP PMT 2000; DPMT 2003; Pb PMT 2003; MH CET 2004]

(a) $1.67 \times 10^{14} \, Hz$ (b) $9.10 \times 10^{14} \, Hz$

(c) $6 \times 10^{14} \, Hz$ (d) $4 \times 10^{14} \, Hz$

78. The refractive indices of water and glass with respect to air are 1.2 and 1.5 respectively. The refractive index of glass with respect to water is **[Pb. PET 2002]**

(a) 0.6 (b) 0.8

(c) 1.25 (d) 1.75

79. The wavelength of sodium light in air is 5890 Å. The velocity of light in air is $3 \times 10^8 \, ms^{-1}$. The wavelength of light in a glass of refractive index 1.6 would be close to

[DCE 2003]

(a) 5890 Å (b) 3681 Å

(c) 9424 Å (d) 15078 Å

80. The mean distance of sun from the earth is $1.5 \times 10^8 \, Km$ (nearly). The time taken by the light to reach earth from the sun is

(a) 0.12 *min* (b) 8.33 *min*

(c) 12.5 *min* (d) 6.25 *min*

81. Refractive index of air is 1.0003. The correct thickness of air column which will have one more wavelength of yellow light (6000 Å) than in the same thickness in vacuum is

[RPMT 1995]

(a) 2 *mm* (b) 2 *cm*

(c) 2 *m* (d) 2 *km*

82. The wavelength of light in air and some other medium are respectively λ_a and λ_m. The refractive index of medium is

[RPMT 2003]

(a) λ_a / λ_m (b) λ_m / λ_a

(c) $\lambda_a \times \lambda_m$ (d) None of these

83. An astronaut in a spaceship see the outer space as

[CPMT 1990, MP PMT 1991; JIPMER 1997]

(a) White (b) Black

(c) Blue (d) Red

84. Speed of light is maximum in

[CPMT 1990; MP PMT 1994; AFMC 1996]

(a) Water (b) Air

(c) Glass (d) Diamond

85. Which one of the following statements is correct

[KCET 1994]

(a) In vacuum, the speed of light depends upon frequency

(b) In vacuum, the speed of light does not depend upon frequency

(c) In vacuum, the speed of light is independent of frequency and wavelength

(d) In vacuum, the speed of light depends upon wavelength

86. If the wavelength of light in vacuum be λ, the wavelength in a medium of refractive index n will be

[UPSEAT 2001; MP PET 2001]

(a) $n\lambda$ (b) $\frac{\lambda}{n}$

(c) $\frac{\lambda}{n^2}$ (d) $n\lambda$

87. In vacuum the speed of light depends upon [MP PMT 2001]

(a) Frequency

(b) Wave length

(c) Velocity of the source of light

(d) None of these

88. A transparent cube of 15 *cm* edge contains a small air bubble. Its apparent depth when viewed through one face is 6 *cm* and when viewed through the opposite face is 4 *cm*. Then the refractive index of the material of the cube is

[CPMT 2004; MP PMT 2005]

(a) 2.0 (b) 2.5

(c) 1.6 (d) 1.5

89. A glass slab of thickness 3 *cm* and refractive index 3/2 is placed on ink mark on a piece of paper. For a person looking at the mark at a distance 5.0 *cm* above it, the distance of the mark will appear to be [Kerala PMT 2005]

(a) 3.0 *cm* (b) 4.0 *cm*

(c) 4.5 *cm* (d) 5.0 *cm*

90. A fish at a depth of 12 *cm* in water is viewed by an observer on the bank of a lake. To what height the image of the fish is raised.

(a) 9 *cm* (b) 12 *cm*

(c) 3.8 *cm* (d) 3 *cm*

Total Internal Reflection

1. A cut diamond sparkles because of its

[NCERT 1974; RPET 1996; AFMC 2005]

(a) Hardness

(b) High refractive index

(c) Emission of light by the diamond

(d) Absorption of light by the diamond

2. A diver in a swimming pool wants to signal his distress to a person lying on the edge of the pool by flashing his water proof flash light

[NCERT 1972]

(a) He must direct the beam vertically upwards

(b) He has to direct the beam horizontally

(c) He has to direct the beam at an angle to the vertical which is slightly less than the critical angle of incidence for total internal reflection

(d) He has to direct the beam at an angle to the vertical which is slightly more than the critical angle of incidence for the total internal reflection

3. Finger prints on a piece of paper may be detected by sprinkling fluorescent powder on the paper and then looking it into

(a) Mercury light (b) Sunlight

(c) Infrared light (d) Ultraviolet light

4. Critical angle of light passing from glass to air is minimum for

(a) Red (b) Green

(c) Yellow (d) Violet

5. The wavelength of light in two liquids '*x*' and '*y*' is 3500 Å and 7000 Å, then the critical angle of x relative to y will be

(a) 60° (b) 45°

(c) 30° (d) 15°

6. A fish is a little away below the surface of a lake. If the critical angle is 49°, then the fish could see things above the water surface within an angular range of θ^o where

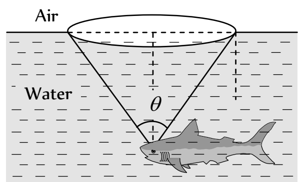
[MP PMT 1986]

(a) $\theta = 49^o$

(b) $\theta = 90^o$

(c) $\theta = 98^o$

(d) $\theta = 24\frac{1^o}{2}$



7. If the critical angle for total internal reflection from a medium to vacuum is 30°, the velocity of light in the medium is

KCET 2000; BCECE 2003; RPMT 2003]

(a) 3×10^8 *m/s* (b) 1.5×10^8 *m/s*

(c) 6×10^8 *m/s* (d) $\sqrt{3}\times10^8$ *m/s*

8. A ray of light is incident at an angle *i* from denser to rare medium. The reflected and the refracted rays are mutually perpendicular. The angle of reflection and the angle of refraction are respectively *r* and *r'*, then the critical angle will be

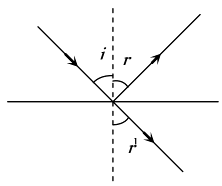
CBSE PMT 1996; MP PMT 1985, 99; Pb. PET 2002]

(a) $\sin^{-1}(\sin r)$

(b) $\sin^{-1}(\tan r')$ [MP PET 2005]

(c) $\sin^{-1}(\tan i)$

(d) $\tan^{-1}(\sin i)$



9. For total internal reflection to take place, the angle of incidence i and the refractive index μ of the medium must satisfy the inequality **[MP PET 1994]**

(a) $\frac{1}{\sin i} < \mu$ (b) $\frac{1}{\sin i} > \mu$

(c) $\sin i < \mu$ (d) $\sin i > \mu$

10. Total internal reflection of light is possible when light enters from

(a) Air to glass (b) Vacuum to air

(c) Air to water (d) Water to air

11. Total internal reflection of a ray of light is possible when the (i_c = critical angle, i = angle of incidence)

[NCERT 1977; MP PMT 1994]

(a) Ray goes from denser medium to rarer medium and $i < i_c$

(b) Ray goes from denser medium to rarer medium and $i > i_c$

(c) Ray goes from rarer medium to denser medium and $i > i_c$

(d) Ray goes from rarer medium to denser medium and $i < i_c$

12. A diver at a depth of 12m in water ($\mu = 4/3$) sees the sky in a cone of semi-vertical angle

[KCET 1999; Pb. PMT 2002; MP PMT 1995, 2003]

(a) $\sin^{-1}(4/3)$ (b) $\tan^{-1}(4/3)$

(c) $\sin^{-1}(3/4)$ (d) 90°

13. Critical angle is that angle of incidence in the denser medium for which the angle of refraction in rarer medium is

[MP PMT 1996]

(a) 0° (b) 57°

(c) 90° (d) 180°

14. The critical angle for diamond (refractive index = 2) is

[MP PET 2003]

(a) About 20° (b) 60°

(c) 45° (d) 30°

15. The reason for shining of air bubble in water is

[MP PET 1997; KCET 1999]

(a) Diffraction of light

(b) Dispersion of light

(c) Scattering of light

(d) Total internal reflection of light

16. With respect to air critical angle in a medium for light of red colour [λ_1] is θ. Other facts remaining same, critical angle for light of yellow colour [λ_2] will be **[MP PET 1999]**

(a) θ (b) More than θ

(c) Less than θ (d) $\frac{\theta\lambda_1}{\lambda_2}$

17. 'Mirage' is a phenomenon due to

[AIIMS 1998; MP PET 2002; AFMC 2003]

(a) Reflection of light

(b) Refraction of light

(c) Total internal reflection of light

(d) Diffraction of light

18. A ray of light travelling in a transparent medium falls on a surface separating the medium from air at an angle of incidence of 45°. The ray undergoes total internal reflection. If n is the refractive index of the medium with respect to air, select the possible value (s) of n from the following

[IIT-JEE 1998]

[CPMT 1973; MP PMT 1994]

(a) 1.3 (b) 1.4

(c) 1.5 (d) 1.6

19. When a ray of light emerges from a block of glass, the critical angle is **[KCET 1994]**

(a) Equal to the angle of reflection

(b) The angle between the refracted ray and the normal

(c) The angle of incidence for which the refracted ray travels along the glass-air boundary

(d) The angle of incidence

20. The phenomenon utilised in an optical fibre is

[KCET 1994; AMU 1995; CBSE PMT 2001; DCE 1999, 2000, 01, 02; AIEEE 2002]

(a) Refraction (b) Interference

(c) Polarization (d) Total internal reflection

21. The refractive index of water is 4 / 3 and that of glass is 5/3. What will be the critical angle for the ray of light entering water from the glass **[RPMT 1996]**

(a) $\sin^{-1}\frac{4}{5}$ (b) $\sin^{-1}\frac{5}{4}$

(c) $\sin^{-1}\frac{1}{2}$ (d) $\sin^{-1}\frac{2}{1}$

22. Total internal reflection is possible when light rays travel

[RPMT 1999]

(a) Air to water (b) Air to glass

(c) Glass to water (d) Water to glass

23. The velocity of light in a medium is half its velocity in air. If ray of light emerges from such a medium into air, the angle of incidence, at which it will be totally internally reflected, is

[Roorkee 1999]

(a) 15° (b 30°

(c) 45° (d) 60°

24. A ray of light propagates from glass (refractive index = 3/2) to water (refractive index = 4/3). The value of the critical angle **[JIPMER 1999; UPSEAT 20**

(a) $\sin^{-1}(1/2)$ (b) $\sin^{-1}\left(\frac{\sqrt{8}}{9}\right)$

(c) $\sin^{-1}(8/9)$ (d) $\sin^{-1}(5/7)$

25. Relation between critical angles of water and glass is

[CBSE PMT 2000; Pb. PET 2000; CPMT 2001]

(a) $C_w > C_g$ (b) $C_w < C_g$

(c) $C_w = C_g$ (d) $C_w = C_g = 0$

26. If critical angle for a material to air is 30°, the refractive index of the material will be **[MP PET 2001]**

(a) 1.0 (b) 1.5

(c) 2.0 (d) 2.5

27. The refractive index of water is 1.33. The direction in which a man under water should look to see the setting sun is

[MP PET 1991; Kerala PET 2002; Pb. PET 2003]

(a) 49° to the horizontal (b) 90° with the vertical
(c) 49° to the vertical (d) Along the horizontal

28. Optical fibres are related with [AFMC 2002]

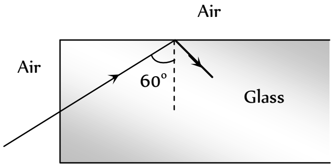
(a) Communication (b) Light
(c) Computer (d) None of these

29. Brilliance of diamond is due to [AIIMS 2002; MP PMT 2003]

(a) Shape (b) Cutting
(c) Reflection (d) Total internal reflection

30. A light ray from air is incident (as shown in figure) at one end of a glass fiber (refractive index $\mu = 1.5$) making an incidence angle of 60° on the lateral surface, so that it undergoes a total internal reflection. How much time would it take to traverse the straight fiber of length 1 *km* [Orissa JEE 2002]

(a) 3.33 μ *sec*
(b) 6.67 μ *sec*
(c) 5.77 μ *sec*
(d) 3.85 μ *sec*



31. Light wave enters from medium 1 to medium 2. Its velocity in 2nd medium is double from 1st. For total internal reflection the angle of incidence must be greater than [CPMT 2002]

(a) 30° (b) 60°
(c) 45° (d) 90°

32. Consider telecommunication through optical fibres. Which of the following statements is not true [AIEEE 2003]

(a) Optical fibres may have homogeneous core with a suitable cladding
(b) Optical fibres can be of graded refractive index
(c) Optical fibres are subject to electromagnetic interference from outside
(d) Optical fibres have extremely low transmission loss

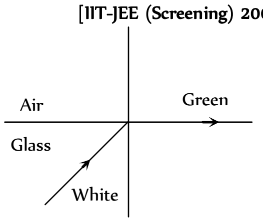
33. The critical angle for a medium is 60^o. The refractive index of the medium is [MP PMT 2004]

(a) $\frac{2}{\sqrt{3}}$ (b) $\frac{\sqrt{2}}{3}$
(c) $\sqrt{3}$ (d) $\frac{\sqrt{3}}{2}$

34. Glass has refractive index μ with respect to air and the critical angle for a ray of light going from glass to air is θ. If a ray of light is incident from air on the glass with angle of incidence θ, the corresponding angle of refraction is [MP PMT 2004]

(a) $\sin^{-1}\left(\frac{1}{\sqrt{\mu}}\right)$ (b) 90^o
(c) $\sin^{-1}\left(\frac{1}{\mu^2}\right)$ (d) $\sin^{-1}\left(\frac{1}{\mu}\right)$

35. White light is incident on the interface of glass and air as shown in the figure. If green light is just totally internally reflected then the emerging ray in air contains [IIT-JEE (Screening) 2004]



(a) Yellow, orange, red
(b) Violet, indigo, blue
(c) All colours
(d) All colours except green

36. Material *A* has critical angle i_A, and material *B* has critical angle $i_B (i_B > i_A)$. Then which of the following is true

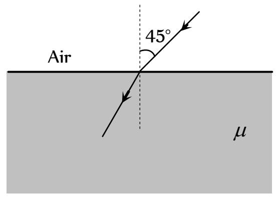
(i) Light can be totally internally reflected when it passes from *B* to *A*
(ii) Light can be totally internally reflected when it passes from *A* to *B*
(iii) Critical angle for total internal reflection is $i_B - i_A$
(iv) Critical angle between *A* and *B* is $\sin^{-1}\left(\frac{\sin i_A}{\sin i_B}\right)$

[UPSEAT 2004]

(a) (i) and (iii) (b) (i) and (iv)
(c) (ii) and (iii) (d) (ii) and (iv)

37. In the figure shown, for an angle of incidence 45^o, at the top surface, what is the minimum refractive index needed for total internal reflection at vertical face [DCE 2002]

(a) $\frac{\sqrt{2}+1}{2}$
(b $\sqrt{\frac{3}{2}}$
(c) $\sqrt{\frac{1}{2}}$
(d) $\sqrt{2}+1$



38. Critical angle for light going from medium (i) to (ii) is θ. The speed of light in medium (i) is *v* then speed in medium (ii) is [DCE 2002]

(a) $v(1-\cos\theta)$ (b $v/\sin\theta$
(c) $v/\cos\theta$ (d) $v(1-\sin\theta)$

39. If light travels a distance *x* in t_1 *sec* in air and 10 *x* distance in t_2 *sec* in a medium, the critical angle of the medium will be

(a) $\tan^{-1}\left(\frac{t_1}{t_2}\right)$ (b) $\sin^{-1}\left(\frac{t_1}{t_2}\right)$
(c) $\sin^{-1}\left(\frac{10t_1}{t_2}\right)$ (d) $\tan^{-1}\left(\frac{10t_1}{t_2}\right)$

40. The critical angle of a medium with respect to air is 45^o. The refractive index of medium is [MH CET 2003]

(a) 1.41 (b) 1.2
(c) 1.5 (d) 2

41. An endoscope is employed by a physician to view the internal parts of a body organ. It is based on the principle of [AIIMS 2004]

(a) Refraction (b) Reflection
(c) Total internal reflection (d) Dispersion

42. A normally incident ray reflected at an angle of 90^o. The value of critical angle is [RPMT 1996]

(a) 45^o (b 90^o

(c) 65^o (d) 43.2^o

43. The phenomena of total internal reflection is seen when angle of incidence is [RPMT 2001]

(a) 90^o (b Greater than critical angle

(c) Equal to critical angle (d) 0^o

44. A fish looking up through the water sees the outside world contained in a circular horizon. If the refractive index of water is $\frac{4}{3}$ and the fish is 12 *cm* below the surface, the radius of this circle in *cm* is

[NCERT 1980; KCET 2002; AIEEE 2005; CPMT 2005]

(a) $36\sqrt{5}$ (b) $4\sqrt{5}$

(c) $36\sqrt{7}$ (d) $36/\sqrt{7}$

45. A point source of light is placed 4 *m* below the surface of water of refractive index 5 / 3. The minimum diameter of a disc which should be placed over the source on the surface of water to cut–off all light coming out of water is

[CBSE PMT 1994; JIPMER 2001, 02]

(a) 2 *m* (b 6 *m*

(c) 4 *m* (d) 3 *m*

46. A fist looking from within water sees the outside world through a circular horizon. If the fish $\sqrt{7}$ *cm* below the surface of water, what will be the radius of the circular horizon

(a) 3.0 *cm* (b) 4.0 *cm*

(c) 4.5 *cm* (d) 5.0 *cm*

Refraction at Curved Surface

1. The radius of curvature for a convex lens is 40 *cm*, for each surface. Its refractive index is 1.5. The focal length will be

[MP PMT 1989]

(a) 40 *cm* (b) 20 *cm*

(c) 80 *cm* (d) 30 *cm*

2. A convex lens of focal length f is placed somewhere in between an object and a screen. The distance between the object and the screen is x. If the numerical value of the magnification produced by the lens is m, , then the focal length of the lens is

(a) $\frac{mx}{(m+1)^2}$ (b) $\frac{mx}{(m-1)^2}$

(c) $\frac{(m+1)^2}{m}x$ (d) $\frac{(m-1)^2}{m}x$

3. A thin lens focal length f_1 and its aperture has diameter *d*. It forms an image of intensity *I*. Now the central part of the aperture upto diameter $\frac{d}{2}$ is blocked by an opaque paper. The focal length and image intensity will change to

[CPMT 1989; MP PET 1997; KCET 1998]

(a) $\frac{f}{2}$ and $\frac{I}{2}$ (b) f and $\frac{I}{4}$

(c) $\frac{3f}{4}$ and $\frac{I}{2}$ (d) f and $\frac{3I}{4}$

4. A lens of power + 2 diopters is placed in contact with a lens of power – 1 diopter. The combination will behave like

(a) A convergent lens of focal length 50 *cm*

(b) A divergent lens of focal length 100 *cm*

(c) A convergent lens of focal length 100 *cm*

(d) A convergent lens of focal length 200 *cm*

5. A convex lens of focal length 40 cm is in contact with a concave lens of focal length 25 cm. The power of combination is

[IIT-JEE 1982; AFMC 1997; CBSE PMT 2000; RPMT 2003]

(a) – 1.5 *D* (b) – 6.5 *D*

(c) + 6.5 *D* (d) + 6.67 *D*

6. Two lenses are placed in contact with each other and the focal length of combination is 80 *cm*. If the focal length of one is 20 *cm*, then the power of the other will be

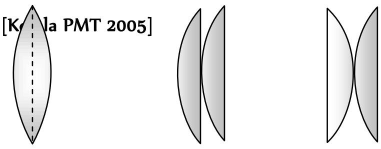
[NCERT 1981]

(a) 1.66 *D* (b) 4.00 *D*

(c) –1.00 *D* (d) – 3.75 *D*

7. Two similar plano-convex lenses are combined together in three different ways as shown in the adjoining figure. The ratio of the focal lengths in three cases will be

[Kerala PMT 2005]



(a) 2 : 2 : 1 (b 1 : 1 : 1

(c) 1 : 2 : 2 (d) 2 : 1 : 1

8. Two lenses of power +12 and – 2 diopters are placed in contact. What will the focal length of combination

[MP PET 1990; MNR 1987;

MH CET (Med.) 2001; UPSEAT 2000; Pb. PMT 2003]

(a) 10 *cm* (b) 12.5 *cm*

(c) 16.6 *cm* (d) 8.33 *cm*

9. A concave and convex lens have the same focal length of 20 cm and are put into contact to form a lens combination. The combination is used to view an object of 5 *cm* length kept at 20 cm from the lens combination. As compared to the object, the image will be

(a) Magnified and inverted

(b) Reduced and erect

(c) Of the same size as the object and erect

(d) Of the same size as the object but inverted

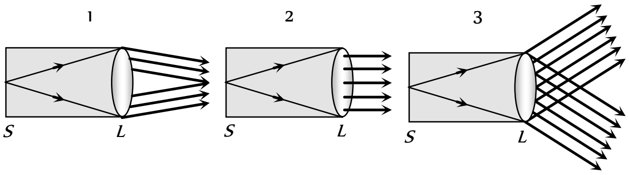
10. If in a plano-convex lens, the radius of curvature of the convex surface is 10 *cm* and the focal length of the lens is 30 *cm*, then the refractive index of the material of lens will be

[CPMT 1986; MNR 1988; MP PMT 2002; UPSEAT 2000]

(a) 1.5 (b) 1.66

(c) 1.33 (d) 3

11. The slit of a collimator is illuminated by a source as shown in the adjoining figures. The distance between the slit *S* and the collimating lens *L* is equal to the focal length of the lens. The correct direction of the emergent beam will be as shown in figure



(a) 1 (b) 3

(c) 2 (d) None of the figures

12. A converging lens is used to form an image on a screen. When upper half of the lens is covered by an opaque screen

[IIT-JEE 1986; SCRA 1994; MP PET 1996; MP PMT 2004; BHU 1998, 05]

(a) Half the image will disappear

(b) Complete image will be formed of same intensity

(c) Half image will be formed of same intensity

(d) Complete image will be formed of decreased intensity

13. A thin convex lens of focal length 10 *cm* is placed in contact with a concave lens of same material and of same focal length. The focal length of combination will be

[CPMT 1972; 1988]

(a) Zero (b) Infinity

(c) 10 *cm* (d) 20 *cm*

14. A convex lens of focal length 84 *cm* is in contact with a concave lens of focal length 12 *cm*. The power of combination (in diopters) is

(a) 25/24 (b) 25/18

(c) – 50/7 (d) + 50/7

15. A convex lens makes a real image 4 *cm* long on a screen. When the lens is shifted to a new position without disturbing the object, we again get a real image on the screen which is 16 *cm* tall. The length of the object must be [MP PET 1991]

(a) 1/4 *cm* (b) 8 *cm*

(c) 12 *cm* (d) 20 *cm*

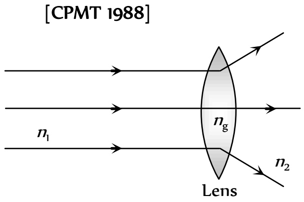
16. A glass convex lens $(\mu_g = 1.5)$ has a focal length of $8\,cm$ when placed in air. What would be the focal length of the lens when it is immersed in water ($\mu_w = 1.33$)

[BHU 1994; MP PMT 1996]

(a) 2 *m* (b) 4 *cm*

(c) 16 *cm* (d) 32 *cm*

17. The ray diagram could be correct [CPMT 1988]



(a) If $n_1 = n_2 = n_g$

(b) If $n_1 = n_2$ and $n_1 < n_g$

(c) If $n_1 = n_2$ and $n_1 > n_g$

(d) Under no circumstances

18. A thin convex lens of refractive index 1.5 has a focal length of 15 *cm* in air. When the lens is placed in liquid of refractive index 4/3 , its focal length will be

[CPMT 1974, 77; MP PMT 1992]

(a) 15 *cm* (b) 10 *cm*

(c) 30 *cm* (d) 60 *cm*

19. A glass lens is placed in a medium in which it is found to behave like a glass plate. Refractive index of the medium will be

(a) Greater than the refractive index of glass

(b) Smaller than the refractive index of glass

(c) Equal to refractive index of glass [CPMT 1986]

(d) No case will be possible from above

20. If I_1 and I_2 be the size of the images respectively for the two positions of lens in the displacement method, then the size of the object is given by [CPMT 1988]

(a) I_1 / I_2 (b) $I_1 \times I_2$

(c) $\sqrt{I_1 \times I_2}$ (d) $\sqrt{I_1 / I_2}$

21. A convex lens of crown glass (n =1.525) will behave as a divergent lens if immersed in [CPMT 1984]

(a) Water (n =1.33)

(b) In a medium of n = 1.525

(c) Carbon disulphide n =1.66

(d) It cannot act as a divergent lens

22. A divergent lens will produce [CPMT 1984]

(a) Always a virtual image

(b) Always real image

(c) Sometimes real and sometimes virtual

(d) None of the above

23. The minimum distance between an object and its real image formed by a convex lens is [CPMT 1973; JIPMER 1997]

(a) 1.5 f (b) 2 f

(c) 2.5 f (d) 4 f

[MP PET 1991]

24. An object is placed at a distance of 20 *cm* from a convex lens of focal length 10 *cm*. The image is formed on the other side of the lens at a distance [CPMT 1971; RPET 2003]

(a) 20 *cm* (b) 10 *cm*

(c) 40 *cm* (d) 30 *cm*

25. Two thin lenses, one of focal length + 60 *cm* and the other of focal length – 20 *cm* are put in contact. The combined focal length is [CPMT 1973, 8

(a) + 15 *cm* (b) – 15 *cm*

(c) + 30 *cm* (d) –30 *cm*

26. A double convex lens of focal length 20 *cm* is made of glass of refractive index 3 / 2. When placed completely in water $({}_a\mu_w = 4/3)$, its focal length will be

[CBSE PMT 1990; MP PMT/PET 1998]

(a) 80 *cm* (b) 15 *cm*

(c) 17.7 *cm* (d) 22.5 *cm*

27. Two thin lenses of focal lengths 20 *cm* and 25 *cm* are placed in contact convex. The effective power of the combination is

[CBSE PMT 1990; RPMT 2001]

(a) 45 *dioptres* (b) 9 *dioptres*

(c) 1/9 *dioptre* (d) 6 *dioptres*

28. An object is placed at a distance of $f/2$ from a convex lens. The image will be [CPMT 1974, 89]

(a) At one of the foci, virtual and double its size

(b) At $3f/2$, real and inverted

(c) At $2f$, virtual and erect

(d) None of these

29. A double convex thin lens made of glass (refractive index μ = 1.5) has both radii of curvature of magnitude 20 *cm*. Incident light rays parallel to the axis of the lens will converge at a distance L such that [MNR 1991; MP PET 1996; UPSEAT 2000; Pb PET 2004]

(a) L = 20 *cm* (b) L = 10 *cm*

(c) L = 40 *cm* (d) L = 20 / 3 *cm*

30. A lens behaves as a converging lens in air and a diverging lens in water. The refractive index of the material is [CPMT 1991; NCERT 1979; BHU 2005]

(a) Equal to unity (b) Equal to 1.33

(c) Between unity and 1.33 (d) Greater than 1.33

31. A biconvex lens forms a real image of an object placed perpendicular to its principal axis. Suppose the radii of curvature of the lens tend to infinity. Then the image would [MP PET 1994]

(a) Disappear

(b) Remain as real image still

(c) Be virtual and of the same size as the object

(d) Suffer from aberrations

32. The radius of curvature of convex surface of a thin plano-convex lens is 15 *cm* and refractive index of its material is 1.6. The power of the lens will be [MP PMT 1994]

(a) $+1\,D$ (b) $-2\,D$

(c) $+3\,D$ (d) $+4\,D$

33. Focal length of a convex lens will be maximum for [MP PMT 1994]

(a) Blue light (b) Yellow light

(c) Green light (d) Red light

34. A lens is placed between a source of light and a wall. It forms images of area A_1 and A_2 on the wall for its two different positions. The area of the source or light is [CBSE PMT 1995]

(a) $\frac{A_1 + A_2}{2}$ (b) $\left[\frac{1}{A_1} + \frac{1}{A_2}\right]^{-1}$

(c) $\sqrt{A_1 A_2}$ (d) $\left[\frac{\sqrt{A_1} + \sqrt{A_2}}{2}\right]^2$

35. Two lenses of power $6D$ and $-2D$ are combined to form a single lens. The focal length of this lens will be [MP PET 2003]

(a) $\frac{3}{2}\,m$ (b $\frac{1}{4}\,m$

(c) $4\,m$ (d) $\frac{1}{8}\,m$

36. A combination of two thin lenses with focal lengths f_1 and f_2 respectively forms an image of distant object at distance 60 *cm* when lenses are in contact. The position of this image shifts by 30 *cm* towards the combination when two lenses are separated by 10 *cm*. The corresponding values of f_1 and f_2 are

(a) $30\ cm, -60\ cm$ (b) $20\ cm, -30\ cm$

(c) $15\ cm, -20\ cm$ (d) $12\ cm, -15\ cm$

37. An achromatic combination of lenses is formed by joining [BHU 1995; Pb. PMT 2000, 04]

(a) 2 convex lenses

(b) 2 concave lenses

(c) 1 convex lens and 1 concave lens

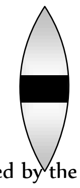
(d) Convex lens and plane mirror

38. A plano convex lens $(f = 20cm)$ is silvered at plane surface. Now f will be [BHU 1995; DPMT 2001; MP PMT 2005]

(a) 20 *cm* (b) 40 *cm*

(c) 30 cm (d) 10 *cm*

39. If the central portion of a convex lens is wrapped in black paper as shown in the figure [Manipal MEE 1995; KCET 2001]



(a) No image will be formed by the remaining portion of the lens

(b) The full image will be formed but it will be less bright

(c) The central portion of the image will be missing

(d) There will be two images each produced by one of the exposed portions of the lens

40. A diminished image of an object is to be obtained on a screen 1.0 *m* from it. This can be achieved by appropriately placing

(a) A convex mirror of suitable focal length

(b) A concave mirror of suitable focal length

(c) A concave lens of suitable focal length

(d) A convex lens of suitable focal length less than 0.25 *m*

41. The focal length of convex lens is 30 *cm* and the size of image is quarter of the object, then the object distance is [AFMC 1995]

(a) 150 *cm* (b) 60 *cm*

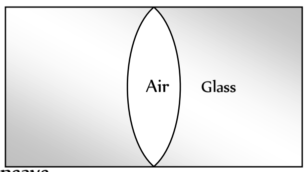
(c) 30 *cm* (d) 40 *cm*

42. A convex lens forms a real image of a point object placed on its principal axis. If the upper half of the lens is painted black, the image will [MP PET 1995]

(a) Be shifted downwards (b) Be shifted upwards

(c) Not be shifted (d) Shift on the principal axis

43. In the figure, an air lens of radii of curvature 10 *cm* (R_1 = R_2 = 10 *cm*) is cut in a cylinder of glass $(\mu = 1.5)$. The focal length and the nature of the lens is [MP PET 1995; Pb. PET 2000]



(a) 15 *cm*, concave

(b) 15 *cm*, convex

(c) ∞, neither concave nor convex

(d) 0, concave

44. A lens (focal length 50 *cm*) forms the image of a distant object which subtends an angle of 1 *milliradian* at the lens. What is the size of the image [MP PMT 1995]

(a) 5 *mm* (b) 1 *mm*

(c) 0.5 *mm* [AIIMS 1995] (d) 0.1 *mm*

45. A convex lens of focal length 12 *cm* is made of glass of $\mu = \frac{3}{2}$. What will be its focal length when immersed in liquid of $\mu = \frac{5}{4}$

(a) 6 *cm* (b) 12 *cm*

(c) 24 *cm* (d) 30 *cm*

46. Two thin lenses of focal lengths f_1 and f_2 are in contact and coaxial. The combination is equivalent to a single lens of power [MP PET 1996, 98; MP PMT 1998; DCE 2000; UP SEAT 2005]

(a) $f_1 + f_2$ (b) $\frac{f_1 f_2}{f_1 + f_2}$

(c) $\frac{1}{2}(f_1 + f_2)$ (d) $\frac{f_1 + f_2}{f_1 f_2}$

47. A plano convex lens is made of glass of refractive index 1.5. The radius of curvature of its convex surface is *R*. Its focal length is

(a) *R*/ 2 (b) *R*

(c) 2*R* (d) 1.5 *R*

48. Two lenses have focal lengths f_1 and f_2 and their dispersive powers are ω_1 and ω_2 respectively. They will together form an achromatic combination if

(a) $\omega_1 f_1 = \omega_2 f_2$ (b) $\omega_1 f_2 + \omega_2 f_1 = 0$

(c) $\omega_1 + f_1 = \omega_2 + f_2$ (d) $\omega_1 - f_1 = \omega_2 - f_2$

49. The dispersive powers of glasses of lenses used in an achromatic pair are in the ratio 5 : 3. If the focal length of the concave lens is 15 *cm*, then the nature and focal length of the other lens would be

(a) Convex, 9 *cm* (b) Concave, 9 *cm*

(c) Convex, 25 *cm* (d) Concave, 25 *cm*

50. A thin double convex lens has radii of curvature each of magnitude 40 *cm* and is made of glass with refractive index 1.65. Its focal length is nearly [MP PMT 1997]

(a) 20 *cm* (b) 31 *cm*

(c) 35 *cm* (d) 50 *cm*

51. The plane surface of a plano-convex lens of focal length *f* is silvered. It will behave as [MP PMT/PET 1998]

(a) Plane mirror

(b) Convex mirror of focal length 2 *f*

(c) Concave mirror of focal length $f/2$

(d) None of the above

52. An equiconvex lens of glass of focal length 0.1 metre is cut along a plane perpendicular to principle axis into two equal parts. The ratio of focal length of new lenses formed is [MP PET 1999; DPMT 2000]

(a) 1 : 1 (b) 1 : 2

(c) 2 : 1 (d) $2 : \frac{1}{2}$

53. A lens of refractive index n is put in a liquid of refractive index n' of focal length of lens in air is f, its focal length in liquid will be

(a) $-\frac{fn'(n-1)}{n'-n}$ (b) $-\frac{f(n'-n)}{n'(n-1)}$

(c) $-\frac{n'(n-1)}{f(n'-n)}$ (d) $\frac{fn'n}{n-n'}$

54. An object of height 1.5 *cm* is placed on the axis of a convex lens of focal length 25 *cm*. A real image is formed at a distance of 75 *cm* from the lens. The size of the image will be

(a) 4.5 *cm* (b) 3.0 *cm*

(c) 0.75 *cm* (d) 0.5 *cm*

55. A symmetric double convex lens is cut in two equal parts by a plane perpendicular to the principal axis. If the power of the original lens was 4 *D*, the power of a cut lens will be [MP PMT 1999]

(a) 2 *D* (b) 3 *D*

(c) 4 *D* (d) 5 *D*

56. A plane convex lens is made of refractive index 1.6. The radius of curvature of the curved surface is 60 *cm*. The focal length of the lens is [CBSE PMT 1999; Pb. PMT 1999; BHU 2001; Very Similar to BHU 2003]

(a) 50 [RPET 2003] (b) 100 *cm*

(c) 200 *cm* (d) 400 *cm*

57. A concave lens of glass, refractive index 1.5, has both surfaces of same radius of curvature *R*. On immersion in a medium of refractive index 1.75, it will behave as a [IIT-JEE 1999]

(a) Convergent lens of focal length 3.5 *R*

(b) Convergent lens of focal length 3.0 *R*

(c) Divergent lens of focal length 3.5 *R*

(d) Divergent lens of focal length 3.0 *R*

58. A convex lens of focal length 0.5 *m* and concave lens of focal length 1 *m* are combined. The power of the resulting lens will be

(a) 1 *D* [MP PET 1997] (b) – 1 *D*

(c) 0.5 *D* (d) – 0.5 *D*

59. A double convex lens is made of glass of refractive index 1.5. If its focal length is 30 cm, then radius of curvature of each of its curved surface is [Bihar CEET 1995]

(a) 10 *cm* (b) 15 *cm*

(c) 18 *cm* (d) None of these

60. A thin lens made of glass of refractive index 1.5 has a front surface + 11 *D* power and back surface – 6 *D*. If this lens is submerged in a liquid of refractive index 1.6, the resulting power of the lens is

(a) – 0.5 *D* (b) + 0.5 *D*

(c) – 0.625 *D* (d) + 0.625 *D*

61. An object is placed first at infinity and then at 20 *cm* from the object side focal plane of the convex lens. The two images thus formed are 5 *cm* apart. The focal length of the lens is

(a) 5 *cm* (b 10 *cm*

(c) 15 *cm* (d) 20 *cm*

62. The distance between an object and the screen is 100 *cm*. A lens produces an image on the screen when placed at either of the positions 40 *cm* apart. The power of the lens is [SCRA 1994]

(a) ≈ 3 *dioptres* (b) ≈ 5 *dioptres*

(c) ≈ 7 *diopters* (d) ≈ 9 *diopters*

63. The image distance of an object placed 10 *cm* in front of a thin lens of focal length + 5 *cm* is [MP PET 1999] [SCRA 1994]

(a) 6.5 *cm* (b) 8.0 *cm*

(c) 9.5 *cm* (d) 10.0 *cm*

64. A achromatic combination is made with a lens of focal length f and dispersive power ω with a lens having dispersive power of 2ω. The focal length of second will be [RPET 1997]

(a) 2 *f* [MP PET 1999] (b) $f/2$

(c) $-f/2$ (d) – 2 *f*

65. A biconvex lens with equal radii curvature has refractive index 1.6 and focal length 10 *cm*. Its radius of curvature will be

(a) 20 *cm* (b) 16 *cm*
(c) 10 *cm* (d) 12 *cm*

66. A convex lens [RPMT 1997]

(a) Converges light rays
(b) Diverges light rays
(c) Form real images always
(d) Always forms virtual images

67. The focal length of a combination of lenses formed with lenses having powers of + 2.50 *D* and – 3.75 *D* will be [RPMT 1997]

(a) – 20 *cm* (b) – 40 *cm*
(c) – 60 *cm* (d) – 80 *cm*

68. Focal length of a converging lens in air is *R*. If it is dipped in water of refractive index 1.33, then its focal length will be around (Refractive index of lens material is 1.5) [RPMT 1997; EAMCET (Med.) 1995]

(a) R (b) $2R$
(c) $4R$ (d) $R/2$

69. Focal length of a convex lens of refractive index 1.5 is 2 *cm*. Focal length of lens when immersed in a liquid of refractive index of 1.25 will be [CBSE PMT 1993]

(a) 10 *cm* (b) 2.5 *cm*
(c) 5 *cm* (d) 7.5 *cm*

70. The focal length of a convex lens depends upon [AFMC 1994]

(a) Frequency of the light ray
(b) Wavelength of the light ray
(c) Both (a) and (b)
(d) None of these

71. If a convex lens of focal length 80 *cm* and a concave lens of focal length 50 *cm* are combined together, what will be their resulting power [CBSE PMT 1996; AFMC 2002]

(a) + 6.5*D* (b) – 6.5 *D*
(c) + 7.5 *D* (d) – 0.75 *D*

72. f_v and f_r are the focal lengths of a convex lens for violet and red light respectively and F_v and F_r are the focal lengths of a concave lens for violet and red light respectively, then

(a) $f_v < f_r$ and $F_v > F_r$ (b $f_v < f_R$ and $F_v < F_r$
(c) $f_c > f_r$ and $F_v > F_r$ (d) $f_v > f_r$ and $F_v < F_r$

73. If a lens is cut into two pieces perpendicular to the principal axis and only one part is used, the intensity of the image [CPMT 1996]

(a) Remains same (b) $\frac{1}{2}$ times
(c) 2 times (d) Infinite

74. A convex lens of focal length f produces an image $\frac{1}{n}$ times than that of the size of the object. The distance of the object from the lens is [BHU 1997; JIPMER 2001, 02]

(a) nf [MP PET 2003] (b) $\frac{f}{n}$
(c) $(n+1)f$ (d) $(n-1)f$

75. Two thin lenses whose powers are +2*D* and –4*D* respectively combine, then the power of combination is [AFMC 1998; CPMT 1996; Very Similar to BHU 2004]

(a) – 2*D* (b) + 2*D*
(c) – 4*D* (d) + 4*D*

76. A substance is behaving as convex lens in air and concave in water, then its refractive index is [BHU 1998]

(a) Smaller than air
(b) Greater than both air and water
(c) Greater than air but less than water
(d) Almost equal to water

77. A concave lens of focal length 20 *cm* placed in contact with a plane mirror acts as a [SCRA 1998]

(a) Convex mirror of focal length 10 *cm*
(b) Concave mirror of focal length 40 *cm*
(c) Concave mirror of focal length 60 *cm*
(d) Concave mirror of focal length 10 *cm*

78. A convex lens is used to form real image of an object on a screen. It is observed that even when the positions of the object and that screen are fixed there are two positions of the lens to form real images. If the heights of the images are 4 *cm* and 9 *cm* respectively, the height of the object is [AMU (Med.) 1999]

(a) 2.25 *cm* (b 6.00 *cm*
(c) 6.50 *cm* (d) 36.00 *cm*

79. A convex lens of power + 6*D* is placed in contact with a concave lens of power – 4*D*. What is the nature and focal length of the combination [AMU (Engg.) 1999]

(a) Concave, 25 *cm* (b) Convex, 50 *cm*
(c) Concave, 20 *cm* (d) Convex, 100 *cm*

80. A double convex lens of glass of μ = 1.5 has radius of curvature of each of its surface is 0.2 *m*. The power of the lens is [CBSE PMT 1996]

(a) + 10 *dioptres* (b) – 10 *dioptres*
(c) – 5 *dioptres* (d) +5 *dioptres*

81. A lens of focal power 0.5 *D* is [JIPMER 1999]

(a) A convex lens of focal length 0.5 *m*
(b) A concave lens of focal length 0.5 *m*
(c) A convex lens of focal length 2 *m*
(d) A concave lens of focal length 2 *m*

82. A lens which has focal length of 4 *cm* and refractive index of 1.4 is immersed in a liquid of refractive index 1.6, then the focal length will be [RPMT 1999]

(a) – 12.8 *cm* (b) 32 *cm*
(c) 12.8 *cm* (d) – 32 *cm*

83. A convex lens has 9 *cm* focal length and a concave lens has – 18 *cm* focal length. The focal length of the combination in contact will be

(a) 9 *cm* (b) – 18 *cm*

(c) – 9 *cm* (d) 18 *cm*

84. A double convex thin lens made of glass of refractive index 1.6 has radii of curvature 15 *cm* each. The focal length of this lens when immersed in a liquid of refractive index 1.63 is

(a) – 407 *cm* (b) 250 *cm*

(c) 125 *cm* (d) 25 *cm*

85. A lens of power + 2 *diopters* is placed in contact with a lens of power – 1 *diopoter*. The combination will behave like

[UPSEAT 2000]

(a) A divergent lens of focal length 50 *cm*

(b) A convergent lens of focal length 50 *cm*

(c) A convergent lens of focal length 100 *cm*

(d) A divergent lens of focal length 100 *cm*

86. Chromatic aberration of lens can be corrected by

[AFMC 2000]

(a) Reducing its aperature

(b) Proper polishing of its two surfaces

(c) Suitably combining it with another lens

(d) Providing different suitable curvature to its two surfaces

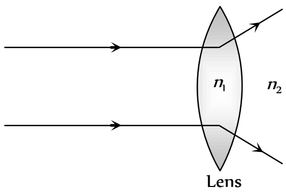
87. The relation between n_1 and n_2, if behaviour of light rays is as shown in figure is [KCET 2000]

(a) $n_1 >> n_2$

(b $n_2 > n_1$

(c) $n_1 > n_2$

(d) $n_1 = n_2$



88. A candle placed 25 *cm* from a lens, forms an image on a screen placed 75 *cm* on the other end of the lens. The focal length and type of the lens should be [KCET 2000]

(a) + 18.75 *cm* and convex lens

(b) – 18.75 *cm* and concave lens

(c) + 20.25 *cm* and convex lens

(d) – 20.25 *cm* and concave lens

89. We combined a convex lens of focal length f_1 and concave lens of focal lengths f_2 and their combined focal length was *F*. The combination of these lenses will behave like a concave lens, if

(a) $f_1 > f_2$ (b) $f_1 < f_2$

(c) $f_1 = f_2$ (d) $f_1 \leq f_2$

90. In a plano-convex lens the radius of curvature of the convex lens is 10 *cm*. If the plane side is polished, then the focal length will be (Refractive index = 1.5)

[CBSE PMT 2000; BHU 2004]

(a) 10.5 *cm* (b 10 *cm*

(c) 5.5 *cm* (d) 5 *cm*

91. The focal length of a convex lens is 10 *cm* and its refractive index is 1.5. If the radius of curvature of one surface is 7.5 *cm*, the radius of curvature of the second surface will be [RPMT 1999]

[MP PMT 2000]

(a) 7.5 *cm* (b) 15.0 *cm*

(c) 75 *cm* (d) 5.0 *cm*

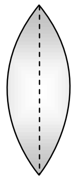
92. A convex lens has a focal length *f*. It is cut into two parts along the dotted line as shown in the figure. The focal length of each part will be [UPSEAT 2000; Pb. PET 2004] [MP PET 2000]

(a) $\frac{f}{2}$

(b) f

(c) $\frac{3}{2}f$

(d) $2f$



93. An object has image thrice of its original size when kept at 8 *cm* and 16 *cm* from a convex lens. Focal length of the lens is

(a) 8 *cm*

(b) 16 *cm*

(c) Between 8 *cm* and 16 *cm*

(d) Less than 8 *cm*

94. The combination of a convex lens (f = 18 *cm*) and a thin concave lens (f = 9 *cm*) is [AMU (Engg.) 2001]

(a) A concave lens (f = 18 *cm*)

(b) A convex lens (f = 18 *cm*)

(c) A convex lens (f = 6 *cm*)

(d) A concave lens (f = 6 *cm*)

95. A convex lens forms a real image of an object for its two different positions on a screen. If height of the image in both the cases be 8 *cm* and 2 *cm*, then height of the object is

[KCET 2000, 01]

(a) 16 *cm* (b) 8 *cm*

(c) 4 *cm* (d) 2 *cm*

96. A convex lens of focal length 25 *cm* and a concave lens of focal length 10 *cm* are joined together. The power of the combination will be [MP PMT 2001]

(a) – 16 *D* (b) + 16 *D*

(c) – 6 *D* (d) + 6 *D*

97. The unit of focal power of a lens is [KCET 2001]

(a) Watt (b) Horse power

(c) Dioptre (d) Lux

98. A thin lens made of glass of refractive index μ = 1.5 has a focal length equal to 12 *cm* in air. It is now immersed in water $\left(\mu = \frac{4}{3}\right)$. Its new focal length is [UPSEAT 2002] [KCET 2000]

(a) 48 *cm* (b) 36 *cm*

(c) 24 *cm* (d) 12 *cm*

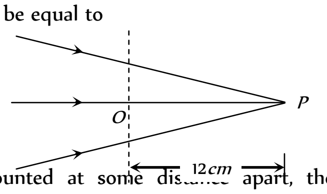
99. Figure given below shows a beam of light converging at point *P*. When a convex lens of focal length 16 *cm* is introduced in the path of the beam at a place *O* shown by dotted line such that *OP* becomes the axis of the lens, the beam converges at a distance *x* from the lens. The value *x* will be equal to

(a) 12 *cm*

(b) 24 *cm*

(c) 36 *cm*

(d) 48 *cm*



100. If two + 5 *D* lenses are mounted at some distance apart, the equivalent power will always be negative if the distance is

[UPSEAT 2002]

(a) Greater than 40 *cm* (b) Equal to 40 *cm*

(c) Equal to 10 *cm* (d) Less than 10 *cm*

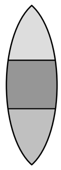
101. A convex lens produces a real image *m* times the size of the object. What will be the distance of the object from the lens

[JIPMER 2002]

(a) $\left(\frac{m+1}{m}\right)f$ (b) $(m-1)f$

(c) $\left(\frac{m-1}{m}\right)f$ (d) $\frac{m+1}{f}$

102. A convex lens is made up of three different materials as shown in the figure. For a point object placed on its axis, the number of images formed are [KCET 2002]



(a) 1

(b) 5

(c) 4

(d) 3

103. An object is placed 12 *cm* to the left of a converging lens of focal length 8 *cm*. Another converging lens of 6 *cm* focal length is placed at a distance of 30 *cm* to the right of the first lens. The second lens will produce [KCET 2002]

(a) No image (b) A virtual enlarged image

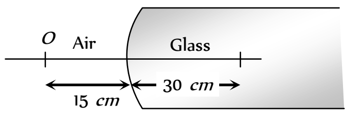
(c) A real enlarged image (d) A real smaller image

104. If convex lens of focal length 80*cm* and a concave lens of focal length 50 *cm* are combined together, what will be their resulting power [AFMC 2002]

(a) + 6.5 *D* (b) – 6.5 *D*

(c) + 7.5 *D* (d) – 0.75 *D*

105. A point object *O* is placed in front of a glass rod having spherical end of radius of curvature 30 *cm*. The image would be formed at



(a) 30 *cm* left

(b) Infinity

(c) 1 *cm* to the right

(d) 18 *cm* to the left

106. The focal length of lens of refractive index 1.5 in air is 30 *cm*. When it is immersed in a liquid of refractive index $\frac{4}{3}$, then its focal length in liquid will be [BHU 2002]

(a) 30 *cm* (b) 60 *cm*

(c) 120 *cm* (d) 240 *cm*

107. Two thin lenses of focal lengths f and f are in contact. The focal length of this combination is [MP PET 2002]

(a) $\frac{f_1 f_2}{f_1 - f_2}$ (b) $\frac{f_1 f_2}{f_1 + f_2}$

(c) $\frac{2 f_1 f_2}{f_1 - f_2}$ (d) $\frac{2 f_1 f_2}{f_1 + f_2}$

108. A convex lens is dipped in a liquid whose refractive index is equal to the refractive index of the lens. Then its focal length will

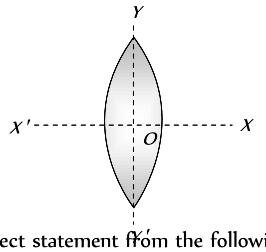
(a) Become infinite

(b) Become small, but non–zero

(c) Remain unchanged

(d) Become zero

109. An equiconvex lens is cut into two halves along (i) *XOX*′ and (ii) *YOY*′ as shown in the figure. Let f, f', f'' be the focal lengths of the complete lens, of each half in case (i), and of each half in case (ii), respectively



Choose the correct statement from the following

[CBSE PMT 2003]

(a) $f' = 2f, f'' = f$ (b) $f' = f, f'' = f$

(c) $f' = 2f, f'' = 2f$ (d) $f' = f, f'' = 2f$

110. The sun makes 0.5° angle on earth surface. Its image is made by convex lens of 50 *cm* focal length. The diameter of the image will be [CPMT 2003]

(a) 5 *mm* (b) 4.36 *mm*

(c) 7 *mm* (d) None of these

111. The chromatic Aberration in lenses becomes due to

[CPMT 2003]

(a) Disimilarity of main axis of rays

(b) Disimilarity of radii of curvature

(c) Variation of focal length of lenses with wavelength

(d) None of these

112. If aperture of lens is halved then image will be [AFMC 2003]

[Orissa JEE 2002]

(a) No effect on size

(b) Intensity of image decreases

(c) Both (a) and (b)

(d) None of these

113. When the convergent nature of a convex lens will be less as compared with air [AFMC 2003]

(a) In water (b) In oil

(c) In both (a) and (b) (d) None of these

114. An achromatic combination of lenses produces

[KCET 1993; JIPMER 1997]

(a) Coloured images

(b) Highly enlarged image

(c) Images in black and white

(d) Images unaffected by variation of refractive index with wavelength

115. In a parallel beam of white light is incident on a converging lens, the colour which is brought to focus nearest to the lens is

(a) Violet (b) Red

(c) The mean colour (d) All the colours together

116. A magnifying glass is to be used at the fixed object distance of 1 *inch*. If it is to produce an erect image magnified 5 *times* its focal length should be [MP PMT 1990]

(a) 0.2 *inch* (b) 0.8 *inch*
(c) 1.25 *inch* (d) 5 *inch*

117. A film projector magnifies a 100 *cm* film strip on a screen. If the linear magnification is 4, the area of magnified film on the screen is CPMT 1977, 91; MP PET 1985, 89; RPMT 2001; BCEC 2005]

(a) 1600 *cm* (b) 400 *cm*
(c) 800 *cm* (d) 200 *cm*

118. An object placed 10 *cm* in front of a lens has an image 20 *cm* behind the lens. What is the power of the lens (in *dioptres*) [MP PMT 1995]

(a) 1.5 (b) 3.0
(c) – 15.0 (d) + 15.0

119. A beam of parallel rays is brought to a focus by a plano-convex lens. A thin concave lens of the same focal length is joined to the first lens. The effect of this is [KCET 2004]

(a) The focal point shifts away from the lens by a small distance
(b) The focus remains undisturbed
(c) The focus shifts to infinity
(d) The focal point shifts towards the lens by a small distance

120. A thin plano-convex lens acts like a concave mirror of focal length 0.2 *m* when silvered from its plane surface. The refractive index of the material of the lens is 1.5. The radius of curvature of the convex surface of the lens will be [KCET 2004]

(a) 0.4 *m* (b 0.2 *m*
(c) 0.1 *m* (d) 0.75 *m*

121. A point object is placed at the center of a glass sphere of radius 6 *cm* and refractive index 1.5. The distance of the virtual image from the surface of the sphere is [IIT-JEE (Screening) 2004]

(a) 2 *cm* (b) 4 *cm*
(c) 6 *cm* (d) 12 *cm*

122. In order to obtain a real image of magnification 2 using a converging lens of focal length 20 *cm*, where should an object be placed [AFMC 2004]

(a) 50 *cm* (b) 30 *cm*
(c) – 50 *cm* (d) – 30 *cm*

123. A plano-convex lens of refractive index 1.5 and radius of curvature 30 *cm* is silvered at the curved surface. Now this lens has been used to form the image of an object. At what distance from this lens an object be placed in order to have a real image of the size of the object [AIEEE 2004]

(a) 20 *cm* (b) 30 *cm*
(c) 60 *cm* (d) 80 *cm*

124. A double convex lens $(R_1 = R_2 = 10\,cm)$ $(\mu = 1.5)$ having focal length equal to the focal length of a concave mirror. The radius of curvature of the concave mirror is [Orssia PMT 2004]

(a) 10 *cm* (b 20 *cm*
(c) 40 *cm* (d) 15 *cm*

125. At what distance from a convex lens of focal length 30 *cm*, an object should be placed so that the size of the image be 1/2 of the object

(a) 30 *cm* (b) 60 *cm*
(c) 15 *cm* (d) 90 *cm*

126. A plano-convex lens is made of refractive index of 1.6. The radius of curvature of the curved surface is 60 *cm*. The focal length of the lens is [NCERT 1980; Pb. PET 2000]

(a) 400 *cm* (b) 200 *cm*
(c) 100 *cm* (d) 50 *cm*

127. The radius of the convex surface of plano-convex lens is 20 *cm* and the refractive index of the material of the lens is 1.5. The focal length of the lens is [CPMT 2004]

(a) 30 *cm* (b) 50 *cm*
(c) 20 *cm* (d) 40 *cm*

128. A combination of two thin convex lenses of focal length 0.3 *m* and 0.1 *m* will have minimum spherical and chromatic aberrations if the distance between them is [UPSEE 2004]

(a) 0.1 *m* (b 0.2 *m*
(c) 0.3 *m* (d) 0.4 *m*

129. A bi-convex lens made of glass (refractive index 1.5) is put in a liquid of refractive index 1.7. Its focal length will [UPSEAT 2004]

(a) Decrease and change sign
(b Increase and change sign
(c) Decrease and remain of the same sign
(d) Increase and remain of the same sign

130. Spherical aberration in a lens [UPSEAT 2004]

(a) Is minimum when most of the deviation is at the first surface
(b) Is minimum when most of the deviation is at the second surface
(c) Is minimum when the total deviation is equally distributed over the two surface
(d) Does not depend on the above consideration

131. The focal lengths of convex lens for red and blue light are 100 *cm* and 96.8 *cm* respectively. The dispersive power of material of lens is [Pb. PET 2003]

(a) 0.325 (b 0.0325
(c) 0.98 (d) 0.968

132. The power of an achromatic convergent lens of two lenses is + 2*D*. The power of convex lens is + 5*D*. The ratio of dispersive power of convex and concave lens will be [Pb. PET 2003]

(a) 5 : 3 (b 3 : 5
(c) 2 : 5 (d) 5 : 2

133. The focal lengths for violet, green and red light rays are f_V, f_G and f_R respectively. Which of the following is the true relationship [BHU 2004; CBS

(a) $f_R < f_G < f_V$ (b $f_V < f_G < f_R$
(c) $f_G < f_R < f_V$ (d) $f_G < f_V < f_R$

134. Two lenses of power + 12 and – 2 diopters are placed in contact. The combined focal length of the combination will be

(a) 8.33 *cm* (b) 1.66 *cm*

(c) 12.5 *cm* (d) 10 *cm*

135. When light rays from the sun fall on a convex lens along a direction parallel to its axis [MP PMT 2004]

(a) Focal length for all colours is the same

(b Focal length for violet colour is the shortest

(c) Focal length for yellow colour is the longest

(d) Focal length for red colour is the shortest

136. A convex lens is in contact with concave lens. The magnitude of the ratio of their focal length is 2/3. Their equivalent focal length is 30 *cm*. What are their individual focal lengths

(a) – 75, 50 (b) – 10, 15

(c) 75, 50 (d) – 15, 10

137. A thin glass (refractive index 1.5) lens has optical power of $-5D$ in air. It's optical power in a liquid medium with refractive index 1.6 will be [AIEEE 2005]

(a) 25 *D* (b) – 25 *D*

(c) 1 *D* (d) None of these

138. The plane faces of two identical plano-convex lenses each having focal length of 40 *cm* are pressed against each other to form a usual convex lens. The distance from this lens, at which an object must be placed to obtain a real, inverted image with magnification one is [NCERT 1980; CPMT 1981; MP PMT 1999; UPSEAT 1999]

(a) 80 *cm* (b 40 *cm*

(c) 20 *cm* (d) 162 *cm*

139. If two lenses of +5 diopters are mounted at some distance apart, the equivalent power will always be negative if the distance is

(a) Greater than 40 *cm* (b) Equal to 40 *cm*

(c) Equal to 10 *cm* (d) Less than 10 *cm*

140. A concave lens and a convex lens have same focal length of 20 *cm* and both put in contact this combination is used to view an object 5 *cm* long kept at 20 *cm* from the lens combination. As compared to object the image will be [CPMT 2005]

(a) Magnified and inverted

(b Reduced and erect

(c) Of the same size and erect

(d) Of the same size and inverted

141. The focal length of the field lens (which is an achromatic combination of two lenses) of telescope is 90 *cm*. The dispersive powers of the two lenses in the combination are 0.024 and 0.036. The focal lengths of two lenses are [CPMT 2005]

(a) 30 *cm* and 60 *cm* (b 30 *cm* and – 45 *cm*

(c) 45 *cm* and 90 *cm* (d) 15 *cm* and 45 *cm*

142. A combination of two thin lenses of the same material with focal lengths f_1 and f_2, arranged on a common axis minimizes chromatic aberration, if the distance between them is

(a) $\frac{(f_1+f_2)}{4}$ (b) $\frac{(f_1+f_2)}{2}$

(c) (f_1+f_2) (d) $2(f_1+f_2)$

143. If the focal length of a double convex lens for red light is f_R, its focal length for the violet light is [EAMCET 2005]

(a) f_R (b) Greater than f_R

(c) Less than f_R (d) $2f_R$

144. A thin equiconvex lens is made of glass of refractive index 1.5 and its focal length is 0.2 *m*, if it acts as a concave lens of 0.5 *m* focal length when dipped in a liquid, the refractive index of the liquid is

(a) $\frac{17}{8}$ (b) $\frac{15}{8}$

(c) $\frac{13}{8}$ (d) $\frac{9}{8}$

145. The dispersive power of the material of lens of focal length 20 *cm* is 0.08. The longitudinal chromatic aberration of the lens is

(a) 0.08 *cm* (b) 0.08/20 *cm*

(c) 1.6 *cm* (d) 0.16 *cm*

[IIT-JEE (Screening) 2005]

Prism Theory & Dispersion of Light

1. Which source is associated with a line emission spectrum [MP PET/PMT 1988; CBSE PMT 1993]

(a) Electric fire (b) Neon street sign

(c) Red traffic light (d) Sun

2. Formula for dispersive power is (where symbols have their usual meanings) [MP PMT/PET 1988]

or

If the refractive indices of crown glass for red, yellow and violet colours are respectively μ_r, μ_y and μ_v, then the dispersive power of this glass would be [MP PMT 1996]

(a) $\frac{\mu_v-\mu_y}{\mu_r-1}$ (b) $\frac{\mu_v-\mu_r}{\mu_y-1}$

(c) $\frac{\mu_v-\mu_r}{\mu_y-\mu_r}$ [BCECE 2005] (d) $\frac{\mu_v-\mu_r}{\mu_y}-1$

3. The critical angle between an equilateral prism and air is 45°. If the incident ray is perpendicular to the refracting surface, then

(a) After deviation it will emerge from the second refracting surface

(b) It is totally reflected on the second surface and emerges out perpendicularly from third surface in air

(c) It is totally reflected from the second and third refracting surfaces and finally emerges out from the first surface

(d) It is totally reflected from all the three sides of prism and never emerges out

4. When white light passes through a glass prism, one gets spectrum on the other side of the prism. In the emergent beam, the ray which is deviating least is or

Deviation by a prism is lowest for [MP PMT 1997]

(a) Violet ray (b) Green ray

(c) Red ray (d) Yellow ray

5. We use flint glass prism to disperse polychromatic light because light of different colours [EAMCET 2005] [MP PET 1993]

(a) Travel with same speed

(b) Travel with same speed but deviate differently due to the shape of the prism

(c) Have different anisotropic properties while travelling through the prism

(d) Travel with different speeds

6. A prism $(\mu = 1.5)$ has the refracting angle of 30°. The deviation of a monochromatic ray incident normally on its one surface will be (sin 48° 36′ = 0.75)

[MP PMT/PET 1988]

(a) 18° 36′ (b) 20° 30′

(c) 18° (d) 22°1′

7. Fraunhofer lines are obtained in

[CPMT 1973; MP PMT 1989; MP PMT 2004]

(a) Solar spectrum

(b) The spectrum obtained from neon lamp

(c) Spectrum from a discharge tube

(d) None of the above

8. When light rays are incident on a prism at an angle of 45°, the minimum deviation is obtained. If refractive index of the material of prism is $\sqrt{2}$, then the angle of prism will be

[MP PMT 1986]

(a) 30° (b) 40°

(c) 50° (d) 60°

9. A spectrum is formed by a prism of dispersive power 'ω'. If the angle of deviation is 'δ', then the angular dispersion is

[MP PMT 1989]

(a) ω / δ (b) δ / ω

(c) $1/\omega\delta$ (d) $\omega\delta$

10. Light from sodium lamp is passed through cold sodium vapours, the spectrum of transmitted light consists of

[MP PET 1989; RPMT 2001]

(a) A line at 5890 Å (b) A line at 5896 Å

(c) Sodium doublet lines (d) No spectral features

11. Angle of minimum deviation for a prism of refractive index 1.5 is equal to the angle of prism. The angle of prism is (cos 41° = 0.75)

(a) 62° (b) 41°

(c) 82° (d) 31°

12. In the formation of primary rainbow, the sunlight rays emerge at minimum deviation from rain-drop after

[MP PET 1989]

(a) One internal reflection and one refraction

(b) One internal reflection and two refractions

(c) Two internal reflections and one refraction

(d) Two internal reflections and two refractions

13. Dispersive power depends upon [RPMT 1997]

(a) The shape of prism (b) Material of prism

(c) Angle of prism (d) Height of the prism

14. When white light passes through the achromatic combination of prisms, then what is observed

[MP PMT 1989]

(a) Only deviation (b) Only dispersion

(c) Deviation and dispersion (d) None of the above

15. The dispersion for a medium of wavelength λ is *D*, then the dispersion for the wavelength 2λ will be

[MP PET 1989]

(a) *D*/8 (b) *D*/4

(c) *D*/2 (d) *D*

16. The refractive index of a prism for a monochromatic wave is $\sqrt{2}$ and its refracting angle is 60°. For minimum deviation, the angle of incidence will be

[MNR 1998; MP PMT 1989, 92, 2002; CPMT 1993, 2004]

(a) 30° (b) 45°

(c) 60° (d) 75°

17. The ratio of angle of minimum deviation of a prism in air and when dipped in water will be ($_a\mu_g = 3/2$ and $_a\mu_w = 4/3$)

(a) 1/8 (b) 1/2

(c) 3/4 (d) 1/4

18. The respective angles of the flint and crown glass prisms are *A*′ and *A*. They are to be used for dispersion without deviation, then the ratio of their angles *A*′ /*A* will be

[MP PMT 1989]

(a) $-\frac{(\mu_y - 1)}{(\mu_y' - 1)}$ (b) $\frac{(\mu_y' - 1)}{(\mu_y - 1)}$

(c) $(\mu_y' - 1)$ (d) $(\mu_y - 1)$

19. The number of wavelengths in the visible spectrum

[MP PMT 1989]

(a) 4000 (b) 6000

(c) 2000 (d) Infinite

20. The black lines in the solar spectrum during solar eclipse can be explained by [MP PMT 1989]

(a) Planck's law (b) Kirchoff's law

(c) Boltzmann's law (d) Solar disturbances

21. The dispersive power is maximum for the material

(a) Flint glass (b) Crown glass

(c) Mixture of both [MP PET/PMT 1988] (d) None of the above

22. A light ray is incident by grazing one of the face of a prism and after refraction ray does not emerge out, what should be the angle of prism while critical angle is *C*

(a) Equal to 2*C* (b) Less than 2*C*

(c) More than 2*C* (d) None of the above

23. A parallel beam of monochromatic light is incident at one surface of a equilateral prism. Angle of incidence is 55° and angle of emergence is 46°. The angle of minimum deviation will be

(a) Less than 41° (b) Equal to 41°

(c) More than 41° (d) None of the above

24. The spectrum of light emitted by a glowing solid is

(a) Continuous spectrum (b) Line spectrum

(c) Band spectrum (d) Absorption spectrum

25. Light rays from a source are incident on a glass prism of index of refraction μ and angle of prism α. At near normal incidence, the angle of deviation of the emerging rays is

[MP PMT 1993]

(a) $(\mu - 2)\alpha$ (b) $(\mu - 1)\alpha$

(c) $(\mu + 1)\alpha$ (d) $(\mu + 2)\alpha$

26. Which of the following element was discovered by study of Fraunhofer lines

(a) Hydrogen (b) Oxygen

(c) Helium (d) Ozone

27. By placing the prism in minimum deviation position, images of the spectrum

(a) Becomes inverted (b) Becomes broader

(c) Becomes distinct (d) Becomes intensive

28. Our eye is most sensitive for which of the following wavelength

(a) 4500 $\mathring{A}$

(b) 5500 $\mathring{A}$

(c) 6500 $\mathring{A}$

(d) Equally sensitive for all wave lengths of visible spectrum

29. Three prisms of crown glass, each have angle of prism 9° and two prisms of flint glass are used to make direct vision spectroscope. What will be the angle of flint glass prisms if μ for flint is 1.60 and μ for crown glass is 1.53

(a) 11.9° (b) 16.0°

(c) 15.3° (d) 9.11°

30. If the refractive indices of crown glass for red, yellow and violet colours are 1.5140, 1.5170 and 1.5318 respectively and for flint glass these are 1.6434, 1.6499 and 1.6852 respectively, then the dispersive powers for crown and flint glass are respectively

(a) 0.034 and 0.064 (b) 0.064 and 0.034

(c) 1.00 and 0.064 (d) 0.034 and 1.0

31. The minimum temperature of a body at which it emits light is

(a) 1200°C (b) 1000°C

(c) 500°C (d) 200°C

32. Band spectrum is obtained when the source emitting light is in the form of **or**

Band spectrum is characteristic of

[CPMT 1988; MP PET 1994; DCE 2004; MP PET 2005]

(a) Atoms (b Molecules

(c) Plasma (d) None of the above

33. Flint glass prism is joined by a crown glass prism to produce dispersion without deviation. The refractive indices of these for mean rays are 1.602 and 1.500 respectively. Angle of prism of flint prism is 10°, then the angle of prism for crown prism will be

(a) 12°2.4' (b) 12°4'

(c) 1.24° (d) 12°

34. The angle of minimum deviation for a prism is 40° and the angle of the prism is 60°. The angle of incidence in this position will be

[EAMCET (Engg.) 1995; MH CET 1999; CPMT 2000]

(a) 30° (b) 60°

(c) 50° (d) 100°

35. In the position of minimum deviation when a ray of yellow light passes through the prism, then its angle of incidence is

[MP PMT 1989; RPMT 1997]

(a) Less than the emergent angle

(b) Greater than the emergent angle

(c) Sum of angle of incidence and emergent angle is 90°

(d) Equal to the emergent angle

36. A circular disc of which 2/3 part is coated with yellow and 1/3 part is with blue. It is rotated about its central axis with high velocity, then it will be seen as

(a) Green (b) Brown

(c) White (d) Violet

37. The fine powder of a coloured glass is seen as

(a) Coloured (b) White

(c) That of the glass colour (d) Black

38. When a white light passes through a hollow prism, then

[MP PMT 1987]

(a) There is no dispersion and no deviation

(b) Dispersion but no deviation

(c) Deviation but no dispersion

(d) There is dispersion and deviation both

39. The light ray is incidence at angle of 60° on a prism of angle 45°. When the light ray falls on the other surface at 90°, the refractive index of the material of prism μ and the angle of deviation δ are given by [MP PET/PMT 1988] [DPMT 2001]

(a) $\mu = \sqrt{2}\, , \delta = 30^o$ (b) $\mu = 1.5\, , \delta = 15^o$

(c) $\mu = \dfrac{\sqrt{3}}{2}, \delta = 30^o$ (d) $\mu = \sqrt{\dfrac{3}{2}}, \delta = 15^o$

40. In dispersion without deviation

(a) The emergent rays of all the colours are parallel to the incident ray

(b) Yellow coloured ray is parallel to the incident ray

(c) Only red coloured ray is parallel to the incident ray

(d) All the rays are parallel, but not parallel to the incident ray

41. Deviation of 5° is observed from a prism whose angle is small and whose refractive index is 1.5. The angle of prism is

[DPMT 2001]

(a) 7.5° (b) 10°

(c) 5° (d) 3.3°

42. The refractive indices of violet and red light are 1.54 and 1.52 respectively. If the angle of prism is 10°, then the angular dispersion is [MP PMT 1990]

(a) 0.02 (b) 0.2

(c) 3.06 (d) 30.6

43. The angle of minimum deviation measured with a prism is 30° and the angle of prism is 60°. The refractive index of prism material is

(a) $\sqrt{2}$ (b) 2

(c) 3/2 (d) 4/3

44. If the refractive indices of a prism for red, yellow and violet colours be 1.61, 1.63 and 1.65 respectively, then the dispersive power of the prism will be

[MP PET 1991; DPMT 1999]

(a) $\frac{1.65-1.62}{1.61-1}$ (b) $\frac{1.62-1.61}{1.65-1}$

(c) $\frac{1.65-1.61}{1.63-1}$ (d) $\frac{1.65-1.63}{1.61-1}$

45. The minimum deviation produced by a hollow prism filled with a certain liquid is found to be 30°. The light ray is also found to be refracted at angle of 30°. The refractive index of the liquid is

(a) $\sqrt{2}$ (b) $\sqrt{3}$

(c) $\sqrt{\frac{3}{2}}$ (d) $\frac{3}{2}$

46. Minimum deviation is observed with a prism having angle of prism *A*, angle of deviation δ, angle of incidence *i* and angle of emergence *e*. We then have generally

[MP PET 1991]

(a) $i > e$ (b) $i < e$

(c) $i = e$ (d) $i = e = \delta$

47. A thin prism P with angle 4° and made from glass of refractive index 1.54 is combined with another thin prism P' made from glass of refractive index 1.72 to produce dispersion without deviation. The angle of prism P' is

[MP PMT 1991, 92; IIT-JEE 1990; MP PET 1995, 99; UPSEAT 2001; RPMT 2004]

(a) 2.6° (b) 3°

(c) 4° (d) 5.33°

48. An achromatic prism is made by combining two prisms $P_1(\mu_v = 1.523, \mu_r = 1.515)$ and $P_2(\mu_v = 1.666, \mu_r = 1.650)$; where μ represents the refractive index. If the angle of the prism P_1 is 10°, then the angle of the prism P_2 will be

[MP PMT 1991]

(a) 5° (b) 7.8°

(c) 10.6° (d) 20°

49. Angle of a prism is 30° and its refractive index is $\sqrt{2}$ and one of the surface is silvered. At what angle of incidence, a ray should be incident on one surface so that after reflection from the silvered surface, it retraces its path

[MP PMT 1991; UPSEAT 2001; CBSE PMT 2004]

(a) 30° (b) 60°

(c) 45° (d) $\sin^{-1}\sqrt{1.5}$

50. For a material, the refractive indices for red, violet and yellow colour light are respectively 1.52, 1.64 and 1.60. The dispersive power of the material is [MP PMT 1991]

(a) 2 (b) 0.45

(c) 0.2 (d) 0.045

51. Band spectrum is produced by [CPMT 1978]

(a) *H* (b) *He*

(c) H_2 (d) *Na*

52. The band spectra (characteristic of molecular species) is due to emission of radiation [CPMT 1982, 90]

(a) Gaseous state (b) Liquid state

(c) Solid state (d) All of three states

53. Line spectrum was first of all theoretically explained by

(a) Swan (b) Fraunhofer

(c) Kirchoff (d) Bohr

54. The spectrum of iodine gas under white light will be

(a) Only violet

(b) Bright lines [MP PET 1991]

(c) Only red lines

(d) Some black bands in continuous spectrum

55. Continuous spectrum is not due to

(a) Hydrogen flame (b) Electric bulb

(c) Kerosene oil lamp flame (d) Candle flame

56. Fraunhofer lines are produced by

(a) The element present in the photosphere of sun

(b) The elements present in the chromosphere of the sun

(c) The vapour of the element present in the chromosphere of the sun

(d) The carbon dioxide present in the atmosphere

57. A medium is said to be dispersive, if [MP PMT 1990]

(a) Light of different wavelengths propagate at different speeds

(b) Light of different wavelengths propagate at same speed but has different frequencies

(c) Light is gradually bent rather than sharply refracted at an interface between the medium and air

(d) Light is never totally internally reflected

58. A ray of light is incident at an angle of 60° on one face of a prism of angle 30°. The ray emerging out of the prism makes an angle of 30° with the incident ray. The emergent ray is

[EAMCET 1990; MP PMT 1990]

(a) Normal to the face through which it emerges

(b) Inclined at 30° to the face through which it emerges

(c) Inclined at 60° to the face through which it emerges

(d) None of these

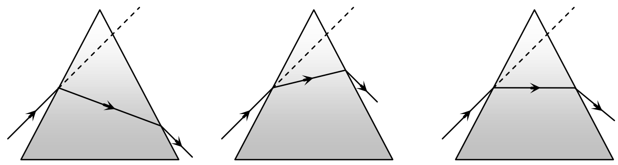
59. In a thin prism of glass (refractive index 1.5), which of the following relations between the angle of minimum deviations δ_m and angle of refraction r will be correct

[MP PMT 1990]

(a) $\delta_m = r$ (b) $\delta_m = 1.5\,r$

(c) $\delta_m = 2r$ (d) $\delta_m = \frac{r}{2}$

60. The figures represent three cases of a ray passing through a prism of angle *A*. The case corresponding to minimum deviation is



(1) (2) (3)

(a) 1 (b) 2

(c) 3 (d) None of these

61. Dispersion can take place for [MP PET 1992]

(a) Transverse waves only but not for longitudinal waves

(b) Longitudinal waves only but not for transverse waves

(c) Both transverse and longitudinal waves

(d) Neither transverse nor longitudinal waves

62. Emission spectrum of CO_2 gas [MP PET 1992]

(a) Is a line spectrum

(b Is a band spectrum

(c) Is a continuous spectrum

(d) Does not fall in the visible region

63. A ray of light passes through an equilateral glass prism in such a manner that the angle of incidence is equal to the angle of emergence and each of these angles is equal to 3/4 of the angle of the prism. The angle of deviation is

[MNR 1988; MP PMT 1999; Roorkee 2000; UPSEAT 2000; MP PET 2005]

(a) 45° (b) 39°

(c) 20° (d) 30°

64. The true statement is

(a) The order of colours in the primary and the secondary rainbows is the same

(b) The intensity of colours in the primary and the secondary rainbows is the same

(c) The intensity of light in the primary rainbow is greater and the order of colours is the same than the secondary rainbow

(d) The intensity of light for different colours in primary rainbow is greater and the order of colours is reverse than the secondary rainbow

65. What will be the colour of sky as seen from the earth, if there were no atmosphere [MP PMT 1992]

(a) Black (b) Blue

(c) Orange (d) Red

66. When light emitted by a white hot solid is passed through a sodium flame, the spectrum of the emergent light will show

[MP PMT 1992]

(a) The D_1 and D_2 bright yellow lines of sodium

(b) Two dark lines in the yellow region

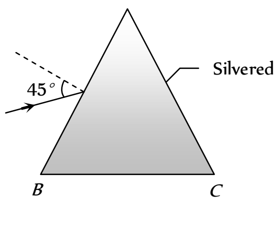
(c) All colours from violet to red

(d) No colours at all

67. A prism ABC of angle 30° has its face AC silvered. A ray of light incident at an angle of 45° at the face AB retraces its path after refraction at face AB and reflection at face AC. The refractive index of the material of the prism is

[MP PMT 1992; EAMCET 2001]

(a) 1.5

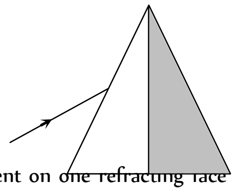


(b) $\frac{3}{\sqrt{2}}$

(c) $\sqrt{2}$

(d) $\frac{4}{3}$

68. A light ray is incident upon a prism in minimum deviation position and suffers a deviation of 34°. If the shaded half of the prism is knocked off, the ray will [MP PMT 1992]



(a) Suffer a deviation of 34°

(b) Suffer a deviation of 68°

(c) Suffer a deviation of 17°

(d) Not come out of the prism

69. A ray of monochromatic light is incident on one refracting face of a prism of angle 75°. It passes through the prism and is incident on the other face at the critical angle. If the refractive index of the material of the prism is $\sqrt{2}$, the angle of incidence on the first face of the prism is

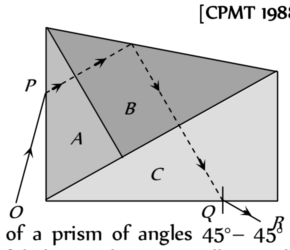
[EAMCET 1983]

(a) 30° (b) 45°

(c) 60° (d) 0°

70. Three glass prisms A, B and C of same refractive index are placed in contact with each other as shown in figure, with no air gap between the prisms. Monochromatic ray of light OP passes through the prism assembly and emerges as QR. The conditions of minimum deviation is satisfied in the prisms

[CPMT 1988]



(a) A and C

(b) B and C

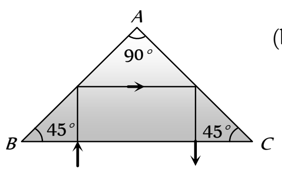
(c) A and B

(d) In all prisms A, B and C

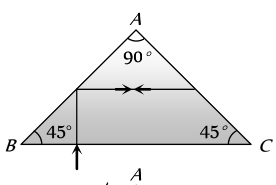
71. The refractive index of a material of a prism of angles 45°– 45° – 90° is 1.5. The path of the ray of light incident normally on the hypotenuse side is shown in

[EAMCET 1985]

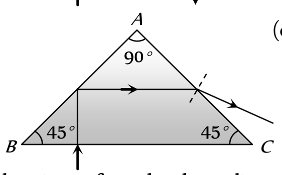
(a)



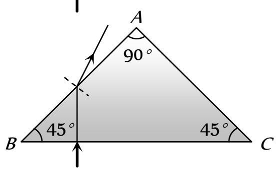
(b)



(c)



(d)



72. At the time of total solar eclipse, the spectrum of solar radiation would be [MP PMT 1990; RPMT 2004]

(a) A large number of dark Fraunhofer lines

(b) A less number of dark Fraunhofer lines

(c) No lines at all

(d) All Fraunhofer lines changed into brilliant colours

73. Angle of deviation (δ) by a prism (refractive index = μ and supposing the angle of prism A to be small) can be given by

(a) $\delta = (\mu - 1)A$ (b) $\delta = (\mu + 1)A$

(c) $\delta = \dfrac{\sin\dfrac{A+\delta}{2}}{\sin\dfrac{A}{2}}$ (d) $\delta = \dfrac{\mu - 1}{\mu + 1}A$

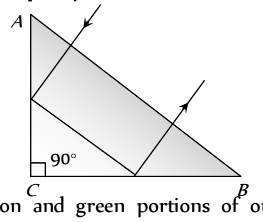
74. Angle of prism is A and its one surface is silvered. Light rays falling at an angle of incidence 2A on first surface return back through the same path after suffering reflection at second silvered surface. Refractive index of the material of prism is

(a) 2 sin A (b) 2 cos A

(c) $\frac{1}{2}\cos A$ (d) $\tan A$

75. A ray of light incident normally on an isosceles right angled prism travels as shown in the figure. The least value of the refractive index of the prism must be

[Manipal MEE 1995; BHU 2003]



(a) $\sqrt{2}$

(b) $\sqrt{3}$

(c) 1.5

(d) 2.0

76. When seen in green light, the saffron and green portions of our National Flag will appear to be [Manipal MEE 1995]

(a) Black

(b) Black and green respectively

(c) Green

(d) Green and yellow respectively

77. At sun rise or sunset, the sun looks more red than at mid-day because [AFMC 1995; Similar to DCE 2003]

(a) The sun is hottest at these times

(b) Of the scattering of light

(c) Of the effects of refraction

(d) Of the effects of diffraction

78. Line spectrum contains information about [MP PET 1995]

(a) The atoms of the prism

(b) The atoms of the source

(c) The molecules of the source

(d) The atoms as well as molecules of the source

79. Missing lines in a continuous spectrum reveal

[MP PET 1995]

(a) Defects of the observing instrument

(b) Absence of some elements in the light source

(c) Presence in the light source of hot vapours of some elements

(d) Presence of cool vapours of some elements around the light source

80. A source emits light of wavelength 4700Å, 5400 Å and 6500 Å. The light passes through red glass before being tested by a spectrometer. Which wavelength is seen in the spectrum

[MP PMT 1995]

(a) 6500 Å (b) 5400 Å

(c) 4700 Å (d) All the above

81. A ray passes through a prism of angle 60° in minimum deviation position and suffers a deviation of 30°. What is the angle of incidence on the prism [MP PMT 1994]

[MP PMT 1995; Pb. PMT 2001; RPMT 2003]

(a) 30° (b) 45°

(c) 60° (d) 90°

82. When light of wavelength λ is incident on an equilateral prism kept in its minimum deviation position, it is found that the angle of deviation equals the angle of the prism itself. The refractive index of the material of the prism for the wavelength λ is, then [AIIMS 1995]

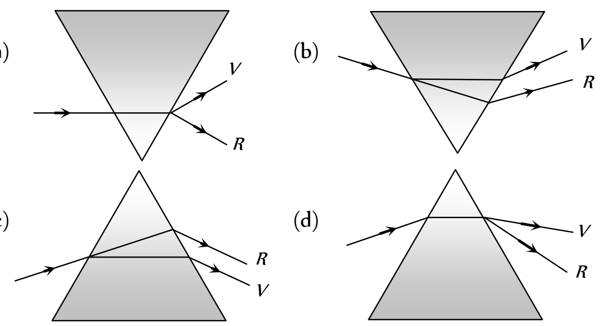
(a) $\sqrt{3}$ (b) $\frac{\sqrt{3}}{2}$

(c) 2 (d) $\sqrt{2}$

83. Which of the following diagrams, shows correctly the dispersion of white light by a prism

[NSEP 1994; MP PET 1996]

(a) (b) (c) (d)



84. A neon sign does not produce

[MP PET 1996; UPSEAT 2004]

(a) Line spectrum

(b) An emission spectrum

(c) An absorption spectrum

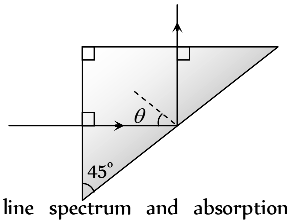
(d) Photons

85. The refractive index of flint glass for blue F line is 1.6333 and red C line is 1.6161. If the refractive index for yellow D line is 1.622, the dispersive power of the glass is

(a) 0.0276 (b) 0.276

(c) 2.76 (d) 0.106

86. A triangular prism of glass is shown in the figure. A ray incident normally to one face is totally reflected, if $\theta = 45^o$. The index of refraction of glass is [AIEEE 2004]



(a) Less than 1.41

(b) Equal to 1.41

(c) Greater than 1.41

(d) None of the above

87. The wavelength of emission line spectrum and absorption line spectrum of a substance are related as

(a) Absorption has larger value

(b) Absorption has smaller value

(c) They are equal

(d) No relation

88. White light is passed through a prism whose angle is 5°. If the refractive indices for rays of red and blue colour are respectively 1.64 and 1.66, the angle of deviation between the two colours will be

(a) 0.1 *degree* (b) 0.2 *degree*

(c) 0.3 *degree* (d) 0.4 *degree*

89. From which source a continuous emission spectrum and a line absorption spectrum are simultaneously obtained [MP PMT 1997]

(a) Bunsen burner flame

(b) The sun

(c) Tube light

(d) Hot filament of an electric bulb

90. A thin prism P_1 with angle 6° and made from glass of refractive index 1.54 is combined with another thin prism P of refractive index 1.72 to produce dispersion without deviation. The angle of prism P_2 will be [MP PMT 1999]

(a) 5° 24′ (b) 4° 30′

(c) 6° (d) 8°

91. If the refractive index of a material of equilateral prism is $\sqrt{3}$, then angle of minimum deviation of the prism is [CBSE PMT 1999; Pb. PMT 2004; MH CET 2004]

(a) 30° (b) 45°

(c) 60° (d) 75°

92. The splitting of white light into several colours on passing through a glass prism is due to [CPMT 1999]

(a) Refraction (b) Reflection

(c) Interference (d) Diffraction

93. A white screen illuminated by green and red light appears to be

(a) Green (b) Red

(c) Yellow (d) White

94. Dark lines on solar spectrum are due to [EAMCET (Engg.) 1995]

(a) Lack of certain elements

(b) Black body radiation

(c) Absorption of certain wavelengths by outer layers

(d) Scattering

95. Line spectra are due to [EAMCET (Med.) 1995]

(a) Hot solids

(b) Atoms in gaseous state

(c) Molecules in gaseous state

(d) Liquid at low temperature

96. The path of a refracted ray of light in a prism is parallel to the base of the prism only when the [SCRA 1994]

(a) Light is of a particular wavelength

(b) Ray is incident normally at one face

(c) Ray undergoes minimum deviation

(d) Prism is made of a particular type of glass

97. For a medium, refractive indices for violet, red and yellow are 1.62, 1.52 and 1.55 respectively, then dispersive power of medium will be [RPET 1997]

(a) 0.65 (b) 0.22

(c) 0.18 [MP PET 1997] (d) 0.02

98. Two lenses having $f_1 : f_2 = 2 : 3$ has combination to make no dispersion. Find the ratio of dispersive power of glasses used

(a) 2 : 3 (b) 3 : 2

(c) 4 : 9 (d) 9 : 4

99. If refractive index of red, violet and yellow lights are 1.42, 1.62 and 1.50 respectively for a medium. Its dispersive power will be

(a) 0.4 (b) 0.3

(c) 0.2 (d) 0.1

100. A ray is incident at an angle of incidence i on one surface of a prism of small angle A and emerges normally from the opposite surface. If the refractive index of the material of the prism is μ , the angle of incidence i is nearly equal to [CBSE PMT 1992]

(a) A / μ (b) $A / 2\mu$

(c) μA (d) $\mu A / 2$

101. Fraunhofer spectrum is a [KCET 1993, 94; RPET 1997; MP PET 1997, 2001; JIPMER 2000; AIIMS 2001]

(a) Line absorption spectrum

(b) Band absorption spectrum

(c) Line emission spectrum

(d) Band emission spectrum

102. The angle of a prism is 60° and its refractive index is $\sqrt{2}$. The angle of minimum deviation suffered by a ray of light in passing through it is [MP PET 2003]

[KCET 1994; RPMT 1997]

(a) About 20° (b) 30°

(c) 60° (d) 45°

103. Colour of the sky is blue due to [CPMT 1996, 99; AFMC 1993; AIIMS 1999; AIEEE 2002; BCECE 2003; BHU 2004]

(a) Scattering of light (b) Total internal reflection

(c) Total emission (d) None of the above

104. Which of the following spectrum have all the frequencies from high to low frequency range [CPMT 1996]

(a) Band spectrum (b) Continuous spectrum

(c) Line spectrum (d) Discontinuous spectrum

105. Stars are not visible in the day time because [JIPMER 1997]

(a) Stars hide behind the sun

(b) Stars do not reflect sun rays during day

(c) Stars vanish during the day

(d) Atmosphere scatters sunlight into a blanket of extreme brightness through which faint stars cannot be visible

106. Which of the following colours suffers maximum deviation in a prism [KCET 1998; DPMT 2000]

(a) Yellow (b) Blue
(c) Green (d) Orange

107. If a thin prism of glass is dipped into water then minimum deviation (with respect to air) of light produced by prism will be left $\left({}_a\mu_g = \frac{3}{2} \text{ and } {}_a\mu_w = \frac{4}{3}\right)$ [UPSEAT 1999]

(a) $\frac{1}{2}$ (b) $\frac{1}{4}$
(c) 2 (d) $\frac{1}{5}$

108. The refractive indices for the light of violet and red colours of any material are 1.66 and 1.64 respectively. If the angle of prism made of this material is 10°, then angular dispersion will be

(a) 0.20° (b) 0.10°
(c) 0.40° (d) 1°

109. The refractive index of the material of the prism for violet colour is 1.69 and that for red is 1.65. If the refractive index for mean colour is 1.66, the dispersive power of the material of the prism

(a) 0.66 (b) 0.06
(c) 0.65 (d) 0.69

110. The deviation caused in red, yellow and violet colours for crown glass prism are 2.84°, 3.28° and 3.72° respectively. The dispersive power of prism material is [KCET (Engg.) 1999]

(a) 0.268 (b) 0.368
(c) 0.468 (d) 0.568

111. Dispersion of light is due to [DCE 1999]

(a) Wavelength (b) Intensity of light
(c) Density of medium (d) None of these

112. A prism of refracting angle 60° is made with a material of refractive index μ. For a certain wavelength of light, the angle of minimum deviation is 30°. For this, wavelength the value of refractive index of the material is [CPMT 1999, MH CET 2000]

(a) 1.231 (b) 1.820
(c) 1.503 (d) 1.414

113. Which of the prism is used to see infrared spectrum of light [RPMT 2000]

(a) Rock Salt (b) Nicol
(c) Flint (d) Crown

114. When white light enters a prism, it gets split into its constituent colours. This is due to [DCE 2000]

(a) High density of prism material
(b) Because μ is different for different λ
(c) Diffraction of light
(d) Velocity changes for different frequencies

115. The dispersive powers of crown and flint glasses are 0.02 and 0.04 respectively. In an achromatic combination of lenses the focal length of flint glass lens is 40 *cm*. The focal length of crown glass lens will be [DCE 2000]

(a) – 20 *cm* (b) + 20 *cm*
(c) – 10 *cm* (d) + 10 *cm*

116. When a ray of light is incident normally on one refracting surface of an equilateral prism (Refractive index of the material of the prism = 1.5 [EAMCET (Med.) 2000]

(a) Emerging ray is deviated by 30°
(b) Emerging ray is deviated by 45°
(c) Emerging ray just grazes the second refracting surface
(d) The ray undergoes total internal reflection at the second refracting surface

117. Consider the following two statements A and B and identify the correct choice in the given answers [EAMCET (Engg.) 2000]

A : Line spectra is due to atoms in gaseous state
B : Band spectra is due to molecules

(a) Both A and B are false
(b) A is true and B is false [UPSEAT 1999]
(c) A is false and B is true
(d) Both A and B are true

118. Under minimum deviation condition in a prism, if a ray is incident at an angle 30°, the angle between the emergent ray and the second refracting surface of the prism is [UPMT 1999] [EAMCET (Engg.) 2000]

(a) 0° (b) 30°
(c) 45° (d) 60°

119. The angle of prism is 5° and its refractive indices for red and violet colours are 1.5 and 1.6 respectively. The angular dispersion produced by the prism is [MP PMT 2000]

(a) 7.75° (b) 5°
(c) 0.5° (d) 0.17°

120. If the refractive angles of two prisms made of crown glass are 10° and 20° respectively, then the ratio of their colour deviation powers will be [KCET 1999; AFMC 2001]

(a) 1 : 1 (b) 2 : 1
(c) 4 : 1 (d) 1 : 2

121. The nature of sun's spectrum is [MP PET 2000; MP PMT 2001]

(a) Continuous spectrum with absorption lines
(b) Line spectrum
(c) The spectrum of the helium atom
(d) Band spectrum

122. A ray of light is incident normally on one of the face of a prism of angle 30° and refractive index $\sqrt{2}$. The angle of deviation will be [KCET 2001]

(a) 26° (b) 0°
(c) 23° (d) 15°

123. For a prism of refractive index 1.732, the angle of minimum deviation is equal to the angle of the prism. The angle of the prism is [CBSE PMT 2001]

(a) 80° (b) 70°

(c) 60° (d) 50°

124. The spectrum obtained from an electric lamp or red hot heater is

(a) Line spectrum (b) Band spectrum

(c) Absorption spectrum (d) Continuous spectrum

125. When a glass prism of refracting angle 60° is immersed in a liquid its angle of minimum deviation is 30°. The critical angle of glass with respect to the liquid medium is [EAMCET 2001]

(a) 42° (b) 45°

(c) 50° (d) 52°

126. Three prisms 1, 2 and 3 have the prism angle $A = 60°$, but their refractive indices are respectively 1.4, 1.5 and 1.6. If $\delta_1, \delta_2, \delta_3$ be their respective angles of deviation then

[MP PMT 2001]

(a) $\delta_3 > \delta_2 > \delta_1$ (b) $\delta_1 > \delta_2 > \delta_3$

(c) $\delta_1 = \delta_2 = \delta_3$ (d) $\delta_2 > \delta_1 > \delta_3$

127. Which one of the following alternative is FALSE for a prism placed in a position of minimum deviation [MP PET 2001]

(a) $i_1 = i_2$ (b) $r_1 = r_2$

(c) $i_1 = r_1$ (d) All of these

128. In the visible region the dispersive powers and the mean angular deviations for crown and flint glass prisms are ω, ω' and d, d' respectively. The condition for getting deviation without dispersion when the two prisms are combined is

[EAMCET 2001]

(a) $\sqrt{\omega d} + \sqrt{\omega' d'} = 0$ (b) $\omega' d + \omega d' = 0$

(c) $\omega d + \omega' d' = 0$ (d) $(\omega d)^2 + (\omega' d')^2 = 0$

129. A ray of light passes through the equilateral prism such that angle of incidence is equal to the angle of emergence if the angle of incidence is 45°. The angle of deviation will be

[Pb. PMT 2002]

(a) 15° (b) 75°

(c) 60° (d) 30°

130. The solar spectrum during a complete solar eclipse is

[Kerala PET 2002]

(a) Continuous (b) Emission line

(c) Dark line (d) Dark band

131. Why sun has elliptical shape on the time when rising and sun setting ? It is due to [AFMC 2002]

(a) Refraction (b) Reflection

(c) Scattering (d) Dispersion

132. In the formation of a rainbow light from the sun on water droplets undergoes [CBSE PMT 2000; Orissa JEE 2002; MP PET 2003; KCET 2004]

(a) Dispersion only

(b) Only total internal reflection

(c) Dispersion and total internal reflection

(d) None of these

[BHU 2001; Pb. PET 2003]

133. The Cauchy's dispersion formula is [AIIMS 2002]

(a) $n = A + B\lambda^{-2} + C\lambda^{-4}$ (b) $n = A + B\lambda^{2} + C\lambda^{-4}$

(c) $n = A + B\lambda^{-2} + C\lambda^{4}$ (d) $n = A + B\lambda^{2} + C\lambda^{4}$

134. A prism of refractive index μ and angle A is placed in the minimum deviation position. If the angle of minimum deviation is A, then the value of A in terms of μ is

[EAMCET 2003]

(a) $\sin^{-1}\left(\frac{\mu}{2}\right)$ (b) $\sin^{-1}\sqrt{\frac{\mu-1}{2}}$

(c) $2\cos^{-1}\left(\frac{\mu}{2}\right)$ (d) $\cos^{-1}\left(\frac{\mu}{2}\right)$

135. A given ray of light suffers minimum deviation in an equilateral prism P. Additional prisms Q and R of identical shape and material are now added to P as shown in the figure. The ray will suffer

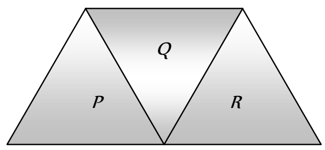
[IIT-JEE (Screening) 2001; KCET 2003]

(a) Greater deviation

(b) Same deviation

(c) No deviation

(d) Total internal reflection



136. In the given figure, what is the angle of prism

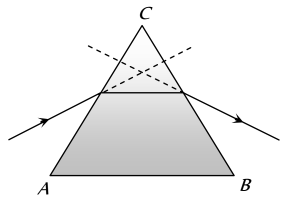
[Orissa JEE 2003]

(a) A

(b) B

(c) C

(d) D



137. A prism of refractive index $\sqrt{2}$ has a refracting angle of 60°. At what angle a ray must be incident on it so that it suffers a minimum deviation [BHU 2003; MP PMT 2005]

(a) 45° (b) 60°

(c) 90° (d) 180°

138. A convex lens, a glass slab, a glass prism and a solid sphere all are made of the same glass, the dispersive power will be

[CPMT 1986]

(a) In the glass slab and prism

(b) In the lens and solid sphere

(c) Only in prism

(d) In all the four

139. A parallel beam of white light falls on a convex lens. Images of blue, yellow and red light are formed on other side of the lens at a distance of 0.20 m, 0.205 m and 0.214 m respectively. The dispersive power of the material of the lens will be

(a) 619/1000 (b) 9/200

(c) 14/205 (d) 5/214

140. The refractive index of the material of the prism for violet colour is 1.69 and that for red is 1.65. If the refractive index for mean colour is 1.66, the dispersive power of the material of the prism [JIPMER 1999]

(a) 0.66 (b 0.06

(c) 0.65 (d) 0.69

141. If the angle of prism is 60^o and the angle of minimum deviation is 40^o, the angle of refraction will be [MP PMT 2004]

(a) 30^o (b) 60^o

(c) 100^o (d) 120^o

142. The refractive index of a particular material is 1.67 for blue light, 1.65 for yellow light and 1.63 for red light. The dispersive power of the material is .... [KCET 2004]

(a) 0.0615 (b) 0.024

(c) 0.031 (d) 1.60

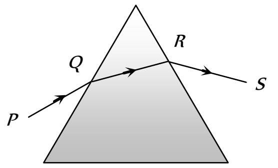
143. A ray of light is incident on an equilateral glass prism placed on a horizontal table. For minimum deviation which of the following is true [IIT-JEE (Screening) 2004]

(a) *PQ* is horizontal

(b) *QR* is horizontal

(c) *RS* is horizontal

(d) Either *PQ* or *RS* is horizontal



144. A beam of light composed of red and green ray is incident obliquely at a point on the face of rectangular glass slab. When coming out on the opposite parallel face, the red and green ray emerge from [CBSE PMT 2004]

(a) Two points propagating in two different directions

(b) Two points propagating in two parallel directions

(c) One point propagating in two different directions

(d) One point propagating in the same directions

145. White light is passed through a prism .... colour shows minimum deviation [Orissa PMT 2004]

(a) Red (b) Violet

(c) Yellow (d) Green

146. A ray of monochromatic light suffers minimum deviation of 38^o while passing through a prism of refracting angle 60^o. Refractive index of the prism material is [Pb. PET 2001]

(a) 1.5 (b) 1.3

(c) 0.8 (d) 2.4

147. A ray incident a 15^o on one refracting surface of a prism of angle 60^o, suffers a deviation of 55^o. What is the angle of emergence [DCE 2002]

(a) 95^o (b) 45^o

(c) 30^o (d) None of these

148. The spectrum obtained from a sodium vapour lamp is an example of [MH CET 2003]

(a) Absorption spectrum (b) Emission spectrum

(c) Continuous spectrum (d) Band spectrum

149. The sky would appear red instead of blue if [DCE 2004]

(a) Atmospheric particles scatter blue light more than red light

(b) Atmospheric particles scatter all colours equally

(c) Atmospheric particles scatter red light more than the blue light

(d) The sun was much hotter

150. Sir C.V. Raman was awarded Nobel Prize for his work connected with which of the following phenomenon of radiation

(a) Scattering (b) Diffraction

(c) Interference (d) Polarisation

151. In absorption spectrum of *Na* the missing wavelength (*s*) are [BCECE 2005]

(a) 589 *nm* (b) 589.6 *nm*

(c) Both (d) None of these

Human Eye and Lens Camera

1. A far sighted man who has lost his spectacles, reads a book by looking through a small hole (3-4 *mm*) in a sheet of paper. The reason will be [CPMT 1977]

(a) Because the hole produces an image of the letters at a longer distance

(b) Because in doing so, the focal length of the eye lens is effectively increased

(c) Because in doing so, the focal length of the eye lens is effectively decreased

(d) None of these

2. For a normal eye, the least distance of distinct vision is [CPMT 1984]

(a) 0.25 *m* (b) 0.50 *m*

(c) 25 *m* (d) Infinite

3. For the myopic eye, the defect is cured by [CPMT 1990; KCET (Engg.) 2000]

(a) Convex lens (b) Concave lens

(c) Cylindrical lens (d) Toric lens

4. Lens used to remove long sightedness (hypermetropia) is

or

A person suffering from hypermetropia requires which type of spectacle lenses [MP PMT 1995]

(a) Concave lens (b) Plano-concave lens

(c) Convexo-concave lens (d) Convex lens

5. Substance on the choroid is

(a) Japan black (b) Nigrim pigment

(c) Carbon black (d) Platinum black

6. Astigmatism (for a human eye) can be removed by using [CPMT 1972; MP PET/PMT 1988; CBSE PMT 1990]

(a) Concave lens (b) Convex lens

(c) Cylindrical lens (d) Prismatic lens

7. Circular part in the centre of retina is called [MP PET/PMT 1988]

(a) Blind spot (b) Yellow spot

(c) Red spot (d) None of the above

8. Image formed on the retina is [CPMT 1983; AFMC 2005]

(a) Real and inverted (b) Virtual and erect

(c) Real and erect (d) Virtual and inverted

9. If there had been one eye of the man, then

(a) Image of the object would have been inverted

(b) Visible region would have decreased

(c) Image would have not been seen three dimensional

(d) (b) and (c) both

10. A person cannot see distinctly at the distance less than one metre. Calculate the power of the lens that he should use to read a book at a distance of 25 *cm* [CPMT 1977; MP PET 1985, 88; MP PMT 1990]

(a) + 3.0 *D* (b) + 0.125 *D*

(c) – 3.0 *D* (d) + 4.0 *D*

11. How should people wearing spectacles work with a microscope

(a) They cannot use the microscope at all

(b) They should keep on wearing their spectacles

(c) They should take off spectacles

(d) (b) and (c) is both way

12. A man who cannot see clearly beyond 5 *m* wants to see stars clearly. He should use a lens of focal length [MP PET/PMT 1988; Pb. PET 2003]

(a) – 100 *m* (b) + 5 *m*

(c) – 5 *m* (d) Very large

13. A man can see only between 75 *cm* and 200 *cm*. The power of lens to correct the near point will be

(a) + 8/3 *D* (b) + 3 *D*

(c) – 3 *D* (d) – 8/3 *D*

14. Image is formed for the short sighted person at [AFMC 1988]

(a) Retina (b) Before retina

(c) Behind the retina (d) Image is not formed at all

15. A man can see the objects upto a distance of one metre from his eyes. For correcting his eye sight so that he can see an object at infinity, he requires a lens whose power is

or

A man can see upto 100 *cm* of the distant object. The power of the lens required to see far objects will be [MP PMT 1993, 2003]

(a) + 0.5 *D* (b) + 1.0 *D*

(c) + 2.0 *D* (d) – 1.0 *D*

16. A man can see the object between 15 *cm* and 30 *cm*. He uses the lens to see the far objects. Then due to the lens used, the near point will be at

(a) $\frac{10}{3}$ *cm* (b) 30 *cm*

(c) 15 *cm* (d) $\frac{100}{3}$ *cm*

17. The far point of a myopia eye is at 40 *cm*. For removing this defect, the power of lens required will be [MP PMT 1987]

(a) 40 *D* (b) – 4 *D*

(c) – 2.5 *D* (d) 0.25 *D*

18. A man suffering from myopia can read a book placed at 10 *cm* distance. For reading the book at a distance of 60 *cm* with relaxed vision, focal length of the lens required will be [MP PMT 1989]

(a) 45 *cm* (b) – 20 *cm*

(c) – 12 *cm* (d) 30 *cm*

19. If the distance of the far point for a myopia patient is doubled, the focal length of the lens required to cure it will become

(a) Half

(b) Double

(c) The same but a convex lens

(d) The same but a concave lens

20. A presbyopic patient has near point as 30 *cm* and far point as 40 *cm*. The dioptric power for the corrective lens for seeing distant objects is

(a) 40 *D* (b) 4 *D*

(c) – 2.5 *D* (d) 0.25 *D*

21. An imaginary line joining the optical centre of the eye lens and the yellow point is called as

(a) Principal axis (b) Vision axis

(c) Neutral axis (d) Optical axis

22. The light when enters the human eye experiences most of the refraction while passing through

(a) Cornea (b) Aqueous humour

(c) Vitrous humour (d) Crystalline lens

23. The impact of an image on the retina remains for

(a) 0.1 *sec* (b) 0.5 *sec*

(c) 10 *sec* (d) 15 *sec*

24. A person is suffering from myopic defect. He is able to see clear objects placed at 15 *cm*. What type and of what focal length of lens he should use to see clearly the object placed 60 *cm* away

(a) Concave lens of 20 *cm* focal length

(b) Convex lens of 20 *cm* focal length

(c) Concave lens of 12 *cm* focal length

(d) Convex lens of 12 *cm* focal length

25. The sensation of vision in the retina is carried to the brain by

(a) Ciliary muscles (b) Blind spot

(c) Cylindrical lens (d) Optic nerve

26. When the power of eye lens increases, the defect of vision is produced. The defect is known as

(a) Shortsightedness (b) Longsightedness

(c) Colourblindness (d) None of the above

27. A man is suffering from colour blindness for green colour. To remove this defect, he should use goggles of

(a) Green colour glasses (b) Red colour glasses

(c) Smoky colour glasses (d) None of the above

28. In human eye the focussing is done by [CPMT 1983]

(a) To and fro movement of eye lens

(b) To and fro movement of the retina

(c) Change in the convexity of the lens surface

(d) Change in the refractive index of the eye fluids

29. A short sighted person can see distinctly only those objects which lie between 10 *cm* and 100 *cm* from him. The power of the spectacle lens required to see a distant object is

[MP PET 1992]

(a) + 0.5 *D* (b) – 1.0 *D*

(c) – 10 *D* (d) + 4.0 *D*

30. A person can see clearly only upto a distance of 25 *cm*. He wants to read a book placed [MP PET 1989] at a distance of 50 *cm*. What kind of lens does he require for his spectacles and what must be its power

(a) Concave, – 1.0 *D* (b) Convex, + 1.5 *D*

(c) Concave, – 2.0 *D* (d) Convex, + 2.0 *D*

31. The human eye has a lens which has a [MP PET 1994]

(a) Soft portion at its centre

(b) Hard surface

(c) Varying refractive index

(d) Constant refractive index

32. A man with defective eyes cannot see distinctly object at the distance more than 60 *cm* from his eyes. The power of the lens to be used will be [MP PMT 1994]

(a) + 60 *D* (b) – 60 *D*

(c) – 1.66 *D* (d) $\frac{1}{1.66}D$

33. A person's near point is 50 *cm* and his far point is 3 *m*. Power of the lenses he requires for

(i) reading and

(ii) for seeing distant stars are [MP PMT 1994]

(a) – 2 *D* and 0.33 *D* (b) 2 *D* and – 0.33 *D*

(c) – 2 *D* and 3 *D* (d) 2 *D* and – 3 *D*

34. A person wears glasses of power – 2.5 *D*. The defect of the eye and the far point of the person without the glasses are respectively [MP PMT 1991]

(a) Farsightedness, 40 *cm* (b) Nearsightedness, 40 *cm*

(c) Astigmatism, 40 *cm* (d) Nearsightedness, 250 *cm*

35. Myopia is due to [AFMC 1996]

(a) Elongation of eye ball

(b) Irregular change in focal length

(c) Shortening of eye ball

(d) Older age

36. A person is suffering from the defect astigmatism. Its main reason is

(a) Distance of the eye lens from retina is increased

(b) Distance of the eye lens from retina is decreased

(c) The cornea is not spherical

(d) Power of accommodation of the eye is decreased

37. A person cannot see objects clearly beyond 2.0 *m*. The power of lens required to correct his vision will be

[MP PMT/PET 1998; JIPMER 2000; KCET 2000; Pb. PET 2001]

(a) + 2.0 *D* (b) – 1.0 *D*

(c) + 1.0 *D* (d) – 0.5 *D*

38. The resolving limit of healthy eye is about

[MP PET 1999; RPMT 1999; AIIMS 2001]

(a) $1'$ or $\left(\frac{1}{60}\right)^{\circ}$ (b) $1''$

(c) 1^{o} (d) $\frac{1}{60}''$

39. When objects at different distances are seen by the eye, which of the following remains constant [MP PMT 1999]

(a) The focal length of the eye lens

(b) The object distance from the eye lens

(c) The radii of curvature of the eye lens

(d) The image distance from the eye lens

40. A person wears glasses of power – 2.0 *D*. The defect of the eye and the far point of the person without the glasses will be

(a) Nearsighted, 50 *cm* (b) Farsighted, 50 *cm*

(c) Nearsighted, 250 *cm* (d) Astigmatism, 50 *cm*

41. An eye specialist prescribes spectacles having a combination of convex lens of focal length 40 *cm* in contact with a concave lens of focal length 25 *cm*. The power of this lens combination in diopters is

[IIT 1997 Cancelled; DPMT 2000]

(a) + 1.5 (b) – 1.5

(c) + 6.67 (d) – 6.67

42. Match the List *I* with the List *II* from the combinations shown

(I)	Presbiopia	(A)	Sphero-cylindrical lens
(II)	Hypermetropia	(B)	Convex lens of proper power may be used close to the eye
(III)	Astigmatism	(C)	Concave lens of suitable focal length
(IV)	Myopia	(D)	Bifocal lens of suitable focal length

(a) I-A; II-C; III-B; IV-D (b) I-B; II-D; III-C; IV-A

(c) I-D; II-B; III-A; IV-C (d) I-D; II-A; III-C; IV-B

43. Near and far points of a human eye are

[EAMCET (Med.) 1995; MP PET 2001; BCECE 2004]

(a) 0 and 25 *cm* (b) 0 and ∞

(c) 25 *cm* and 100 *cm* (d) 25 *cm* and ∞

44. Two parallel pillars are 11 *km* away from an observer. The minimum distance between the pillars so that they can be seen separately will be [RPET 1997; RPMT 2000]

(a) 3.2 *m* (b) 20.8 *m*

(c) 91.5 *m* (d) 183 *m*

45. Retina of eye acts like .... of camera [AFMC 2003]

(a) Shutter (b) Film

(c) Lens (d) None of these

46. The hyper-metropia is a [CBSE PMT 2000]

(a) Short-side defect (b) Long- side defect

(c) Bad vision due to old age (d) None of these

47. Amount of light entering into the camera depends upon

[DCE 2000]

(a) Focal length of the objective lens

(b) Product of focal length and diameter of the objective lens

(c) Distance of the object from camera

(d) Aperture setting of the camera

48. A man cannot see clearly the objects beyond a distance of 20 *cm* from his eyes. To see distant objects clearly he must use which kind of lenses and of what focal length

[MP PMT 2000]

(a) 100 *cm* convex (b) 100 *cm* concave

(c) 20 *cm* convex (d) 20 *cm* concave

49. A person uses spectacles of power +2*D*. He is suffering from

[MP PMT 1999] [MP PET 2000]

(a) Short sightedness or myopia

(b) Long sightedness or hypermetropia

(c) Presbyopia

(d) Astigmatism

50. To remove myopia (short sightedness) a lens of power 0.66 *D* is required. The distant point of the eye is approximately

[MP PMT 2001]

(a) 100 *cm* (b) 150 *cm*

(c) 50 *cm* (d) 25 *cm*

51. A person suffering from [ISM Dhanbad 1994] 'presbyopia' (myopia and hyper metropia both defects) should use [MP PET 2001]

(a) A concave lens

(b) A convex lens

(c) A bifocal lens whose lower portion is convex

(d) A bifocal lens whose upper portion is convex

52. A person who can see things most clearly at a distance of 10 *cm*. Requires spectacles to enable to him to see clearly things at a distance of 30 *cm*. What should be the focal length of the spectacles

[BHU 2003; CPMT 2004; PM PMT 2005]

(a) 15 *cm* (Concave) (b) 15 *cm* (Convex)

(c) 10 *cm* (d) 0

53. Far points of myopic eye is 250 *cm*, then the focal length of the lens to be used will be [DPMT 2002]

(a) – 250 *cm* (b) – 250/9 *cm*

(c) + 250 *cm* (d) + 250/9 *cm*

54. A man can see clearly up to 3 *metres*. Prescribe a lens for his spectacles so that he can see clearly up to 12 *metres*

[DPMT 2002]

(a) – 3/4 *D* (b) 3 *D*

(c) – 1/4 *D* (d) – 4 *D*

55. A satisfactory photographic print is obtained when the exposure time is 10 *sec* at a distance of 2 *m* from a 60 *cd* lamp. The time of exposure required for the same quality print at a distance of 4 *m* from a 120 *cd* lamp is

[Kerala PMT 2002]

(a) 5 *sec* (b) 10 *sec*

(c) 15 *sec* (d) 20 *sec*

56. A person can not see the objects clearly placed at a distance more than 40 *cm*. He is advised to use a lens of power

[DCE 2002; MP PMT 2002, 03]

(a) – 2.5 *D* (b) + 2.5 *D*

(c) – 6.25 *D* (d) + 1.5 *D*

57. A person uses a lens of power + 3*D* to normalise vision. Near point of hypermetropic eye is [CPMT 2002]

(a) 1 *m* (b) 1.66 *m*

(c) 2 *m* (d) 0.66 *m*

58. A defective eye cannot see close objects clearly because their image is formed [MP PET 2003]

(a) On the eye lens
(b) Between eye lens and retina
(c) On the retina
(d) Beyond retina

59. Image formed on retina of eye is proportional to [RPMT 2001]

(a) Size of object (b) Area of object
(c) $\frac{\text{Size of object}}{\text{Size of image}}$ (d) $\frac{\text{size of image}}{\text{size of object}}$

60. A student can distinctly see the object upto a distance 15 *cm*. He wants to see the black board at a distance of 3 *m*. Focal length and power of lens used respectively will be [Pb. PMT 2003]

(a) $-4.8\,cm, -3.3\,D$ (b) $-5.8\,cm, -4.3\,D$
(c) $-7.5\,cm, -6.3\,D$ (d) $-15.8\,cm, -6.3\,D$

61. A camera objective has an aperture diameter *d*. If the aperture is reduced to diameter $d/2$, the exposure time under identical conditions of light should be made [Kerala PMT 2004]

(a) $\sqrt{2}$ fold (b) 2 fold
(c) $2\sqrt{2}$ fold (d) 4 fold

62. The light gathering power of a camera lens depends on [DCE 2003]

(a) Its diameter only
(b) Ratio of focal length and diameter
(c) Product of focal length and diameter
(d) Wavelength of light used

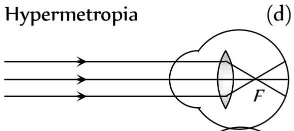
63. The exposure time of a camera lens at the $\frac{f}{2.8}$ setting is $\frac{1}{200}$ second. The correct time of exposure at $\frac{f}{5.6}$ is [DCE 2003]

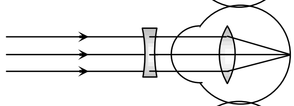
(a) 0.4 *sec* (b) 0.02 *sec*
(c) 0.002 *sec* (d) 0.04 *sec*

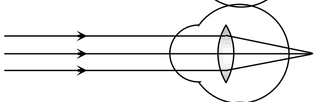
64. Ability of the eye to see objects at all distances is called [AFMC 2005]

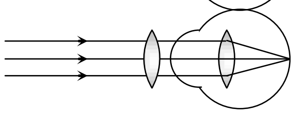
(a) Binocular vision (b) Myopia
(c) Hypermetropia (d) Accommodation

65. [KCET 2005]

1.


2.


3.


4.


Identify the wrong description of the above figures

(a) 1 represents far-sightedness
(b) 2 correction for short sightedness
(c) 3 represents far sightedness
(d) 4 correction for far-sightedness

Microscope and Telescope

1. The focal lengths of the objective and eye-lens of a microscope are 1 *cm* and 5 *cm* respectively. If the magnifying power for the relaxed eye is 45, then the length of the tube is

(a) 30 *cm* (b) 25 *cm*
(c) 15 *cm* (d) 12 *cm*

2. In a compound microscope magnification will be large, if the focal length of the eye piece is [CPMT 1984]

(a) Large (b) Smaller
(c) Equal to that of objective (d) Less than that of objective

3. The focal length of the objective lens of a compound microscope is [CPMT 198

(a) Equal to the focal length of its eye piece
(b) Less than the focal length of eye piece
(c) Greater than the focal length of eye piece
(d) Any of the above three

4. Microscope is an optical instrument which

(a) Enlarges the object
(b) Increases the visual angle formed by the object at the eye
(c) Decreases the visual angle formed by the object at the eye
(d) Brings the object nearer

5. Magnifying power of a simple microscope is (when final image is formed at D = 25 *cm* from eye) [MP PET 1996; BVP 2003]

(a) $\frac{D}{f}$ (b) $1+\frac{D}{f}$
(c) $1+\frac{f}{D}$ (d) $1-\frac{D}{f}$

6. If in compound microscope m_1 and m_2 be the linear magnification of the objective lens and eye lens respectively, then magnifying power of the compound microscope will be [CPMT 1985; KCET 1994]

(a) $m_1 - m_2$ (b) $\sqrt{m_1 + m_2}$
(c) $(m_1 + m_2)/2$ (d) $m_1 \times m_2$

7. For which of the following colour, the magnifying power of a microscope will be maximum

(a) White colour (b) Red colour
(c) Violet colour (d) Yellow colour

8. The length of the compound microscope is 14 *cm*. The magnifying power for relaxed eye is 25. If the focal length of eye lens is 5 *cm*, then the object distance for objective lens will be

(a) 1.8 *cm* (b) 1.5 *cm*
(c) 2.1 *cm* (d) 2.4 *cm*

9. If the focal length of objective and eye lens are 1.2 *cm* and 3 *cm* respectively and the object is put 1.25 *cm* away from the objective lens and the final image is formed at infinity. The magnifying power of the microscope is

(a) 150 (b) 200
(c) 250 (d) 400

10. The focal length of objective and eye lens of a microscope are 4 *cm* and 8 *cm* respectively. If the least distance of distinct vision is 24 *cm* and object distance is 4.5 *cm* from the objective lens, then the magnifying power of the microscope will be

(a) 18 (b) 32

(c) 64 (d) 20

11. When the length of a microscope tube increases, its magnifying power [MNR 1986]

(a) Decreases (b) Increases

(c) Does not change (d) May decrease or increase

12. In a compound microscope, if the objective produces an image I_o and the eye piece produces an image I_e, then [MP PET 1990]

(a) I_o is virtual but I_e is real

(b) I_o is real but I_e is virtual

(c) I_o and I_e are both real

(d) I_o and I_e are both virtual

13. The magnifying power of a simple microscope can be increased, if we use eye-piece of [MP PMT 1986]

(a) Higher focal length (b) Smaller focal length

(c) Higher diameter (d) Smaller diameter

14. An electron microscope is superior to an optical microscope in

(a) Having better resolving power

(b) Being easy to handle

(c) Low cost

(d) Quickness of observation

15. The magnifying power of a microscope with an objective of 5 *mm* focal length is 400. The length of its tube is 20 *cm*. Then the focal length of the eye-piece is [MP PMT 1991]

(a) 200 *cm* (b) 160 *cm*

(c) 2.5 *cm* (d) 0.1 *cm*

16. The maximum magnification that can be obtained with a convex lens of focal length 2.5 *cm* is (the least distance of distinct vision is 25 *cm*) [MP PET 2003]

(a) 10 (b) 0.1

(c) 62.5 (d) 11

17. When the object is self-luminous, the resolving power of a microscope is given by the expression

(a) $\frac{2\mu\sin\theta}{1.22\,\lambda}$ (b) $\frac{\mu\sin\theta}{\lambda}$

(c) $\frac{2\mu\cos\theta}{1.22\,\lambda}$ (d) $\frac{2\mu}{\lambda}$

18. The power of two convex lenses *A* and *B* are 8 *diopters* and 4 *diopters* respectively. If they are to be used as a simple microscope, the magnification of

(a) *B* will be greater than *A*

(b) *A* will be greater than *B*

(c) The information is incomplete

(d) None of the above

19. Finger prints are observed by the use of

(a) Telescope (b) Microscope

(c) Gallilean telescope (d) Concave lens

20. To produce magnified erect image of a far object, we will be required along with a convex lens, is [MNR 1983]

(a) Another convex lens (b) Concave lens

(c) A plane mirror (d) A concave mirror

21. In order to increase the magnifying power of a compound microscope [JIPMER 1986; MP PMT 1997]

(a) The focal lengths of the objective and the eye piece should be small

(b) Objective should have small focal length and the eye piece large

(c) Both should have large focal lengths

(d) The objective should have large focal length and eye piece should have small

22. If the focal length of the objective lens is increased then [MP PMT 1994]

(a) Magnifying power of microscope will increase but that of telescope will decrease

(b) Magnifying power of microscope and telescope both will increase

(c) Magnifying power of microscope and telescope both will decrease

(d) Magnifying power of microscope will decrease but that of telescope will increase

23. The magnification produced by the objective lens and the eye lens of a compound microscope are 25 and 6 respectively. The magnifying power of this microscope is [CPMT 1984] [Manipal MEE 1995; DPMT 2002]

(a) 19 (b) 31

(c) 150 (d) $\sqrt{150}$

24. The focal lengths of the objective and the eye-piece of a compound microscope are 2.0 *cm* and 3.0 *cm* respectively. The distance between the objective and the eye-piece is 15.0 *cm*. The final image formed by the eye-piece is at infinity. The two lenses are thin. The distances in *cm* of the object and the image produced by the objective measured from the objective lens are respectively [IIT 1995]

(a) 2.4 and 12.0 (b) 2.4 and 15.0

(c) 2.3 and 12.0 (d) 2.3 and 3.0

25. Resolving power of a microscope depends upon [MP PET 1995]

(a) The focal length and aperture of the eye lens

(b) The focal lengths of the objective and the eye lens

(c) The apertures of the objective and the eye lens

(d) The wavelength of light illuminating the object

26. The objective lens of a compound microscope produces magnification of 10. In order to get an overall magnification of 100 when image is formed at 25 *cm* from the eye, the focal length of the eye lens should be

(a) 4 *cm* (b) 10 *cm*

(c) $\frac{25}{9}$ *cm* (d) 9 *cm*

27. A person using a lens as a simple microscope sees an

(a) Inverted virtual image

(b) Inverted real magnified image

(c) Upright virtual image

(d) Upright real magnified image

28. Least distance of distinct vision is 25 *cm*. Magnifying power of simple microscope of focal length 5 *cm* is [EAMCET (Engg.) 1995; Pb. PMT 1999]

(a) 1 / 5 (b) 5

(c) 1 / 6 (d) 6

29. The objective of a compound microscope is essentially

[SCRA 1998]

(a) A concave lens of small focal length and small aperture

(b) Convex lens of small focal length and large aperture

(c) Convex lens of large focal length and large aperture

(d) Convex lens of small focal length and small aperture

30. Resolving power of a microscope depends upon [DCE 1999]

(a) Wavelength of light used, directly

(b) Wavelength of light used, inversely

(c) Frequency of light used

(d) Focal length of objective

31. In a compound microscope cross-wires are fixed at the point [EAMCET (Engg.) 2000]

(a) Where the image is formed by the objective

(b) Where the image is formed by the eye-piece

(c) Where the focal point of the objective lies

(d) Where the focal point of the eye-piece lies

32. In a compound microscope, the focal lengths of two lenses are 1.5 *cm* and 6.25 *cm* an object is placed at 2 *cm* form objective and the final image is formed at 25 *cm* from eye lens. The distance between the two lenses is [EAMCET (Med.) 2000]

(a) 6.00 *cm* (b) 7.75 *cm*

(c) 9.25 *cm* (d) 11.00 *cm*

33. The length of the tube of a microscope is 10 *cm*. The focal lengths of the objective and eye lenses are 0.5 *cm* and 1.0 *cm*. The magnifying power of the microscope is about [MP PMT 2000]

(a) 5 (b) 23

(c) 166 (d) 500

34. In a compound microscope, the intermediate image is [IIT-JEE (Screening) 2000; MP PET 2005]

(a) Virtual, erect and magnified

(b) Real, erect and magnified

(c) Real, inverted and magnified

(d) Virtual, erect and reduced

35. The magnifying power of a compound microscope increases when

(a) The focal length of objective lens is increased and that of eye lens is decreased

(b) The focal length of eye lens is increased and that of objective lens is decreased

(c) Focal lengths of both objective and eye-piece are increased

(d) Focal lengths of both objective and eye-piece are decreased

36. If the red light is replaced by blue light illuminating the object in a microscope the resolving power of the microscope

(a) Decreases (b) Increases

(c) Gets halved (d) Remains unchanged

37. The magnifying power of a simple microscope is 6. The focal length of its lens in *metres* will be, if least distance of distinct vision is 25 *cm* [MP PMT 2001]

(a) 0.05 (b) 0.06

(c) 0.25 (d) 0.12

38. Two points separated by a distance of 0.1 *mm* can just be resolved in a microscope when a light of wavelength 6000 Å is used. If the light of wavelength 4800Å is used this limit of resolution becomes

(a) 0.08 *mm* (b) 0.10 *mm*

(c) 0.12 *mm* (d) 0.06 *mm*

39. A compound microscope has two lenses. The magnifying power of one is 5 and the combined magnifying power is 100. The magnifying power of the other lens is [Kerala PMT 2002]

(a) 10 (b) 20

(c) 50 (d) 25

40. The angular magnification of a simple microscope can be increased by increasing [Orissa JEE 2002]

(a) Focal length of lens (b) Size of object

(c) Aperture of lens (d) Power of lens

41. Wavelength of light used in an optical instrument are $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å, then ratio of their respective resolving power (corresponding to λ_1 and λ_2) is [AIEEE 2002]

(a) 16 : 25 (b) 9 : 1

(c) 4 : 5 (d) 5 : 4

42. The separation between two microscopic particles is measured P_A and P_B by two different lights of wavelength 2000 Å and 3000 Å respectively, then [AIEEE 2002]

(a) $P_A > P_B$ (b) $P_A < P_B$

(c) $P_A < 3/2P_B$ (d) $P_A = P_B$

43. The image formed by an objective of a compound microscope is

(a) Virtual and enlarged (b) Virtual and diminished

(c) Real and diminished (d) Real and enlarged

44. An achromatic telescope objective is to be made by combining the lenses of flint and crown glasses. This proper choice is [MP PET 2000]

(a) Convergent of crown and divergent of flint

(b) Divergent of crown and convergent of flint

(c) Both divergent

(d) Both convergent

45. If F_o and F_e are the focal length of the objective and eye-piece respectively of a telescope, then its magnifying power will be [CPMT 1977, 82, 97; SCRA 1994; KCET 1999; Pb. PMT 2000; BHU 2001; DCE 2002; RPMT 2003; BCECE 2003, 04] [DCE 2001]

(a) $F_o + F_e$ (b) $F_o \times F_e$

(c) F_o / F_e (d) $\frac{1}{2}(F_o + F_e)$

46. The magnifying power of a telescope can be increased by [CPMT 1979]

(a) Increasing focal length of the system

(b) Fitting eye piece of high power

(c) Fitting eye piece of low power

(d) Increasing the distance of objects

47. A simple telescope, consisting of an objective of focal length 60 *cm* and a single eye lens of focal length 5 *cm* is focussed on a distant object is such a way that parallel rays comes out from the eye lens. If the object subtends an angle 2° at the objective, the angular width of the image

[CPMT 1979; NCERT 1980; MP PET 1992; JIPMER 1997; UPSEAT 2001]

(a) 10° (b) 24°

(c) 50° (d) $1/6^\circ$

48. The diameter of the objective of the telescope is 0.1 *metre* and wavelength of light is 6000 Å. Its resolving power would be approximately [MP PET 1997]

(a) $7.32\times10^{-6} rad$ (b) $1.36\times10^{6} rad$

(c) $7.32\times10^{-5} rad$ (d) $1.36\times10^{5} rad$

49. A photograph of the moon was taken with telescope. Later on, it was found that a housefly was sitting on the objective lens of the telescope. In photograph

[NCERT 1970; MP PET 1999]

(a) The image of housefly will be reduced

(b) There is a reduction in the intensity of the image

(c) There is an increase in the intensity of the image

(d) The image of the housefly will be enlarged

50. For a telescope to have large resolving power the

[CPMT 1980, 81, 85; MP PET 1994; DCE 2001; AFMC 2005]

(a) Focal length of its objective should be large

(b) Focal length of its eye piece should be large

(c) Focal length of its eye piece should be small

(d) Aperture of its objective should be large

51. An observer looks at a tree of height 15 *m* with a telescope of magnifying power 10. To him, the tree appears

[CPMT 1975]

(a) 10 times taller (b) 15 times taller

(c) 10 times nearer (d) 15 times nearer

52. The focal length of objective and eye lens of a astronomical telescope are respectively 2 *m* and 5 *cm*. Final image is formed at (i) least distance of distinct vision (ii) infinity. The magnifying power in both cases will be [MP PMT/PET 1988]

(a) – 48, – 40 (b) – 40, – 48

(c) – 40, 48 (d) – 48, 40

53. For observing a cricket match, a binocular is preferred to a terrestrial telescope because

(a) The binocular gives the proper three dimensional view

(b) The binocular has shorter length

(c) The telescope does not give erect image

(d) Telescope have chromatic aberrations

54. To increase the magnifying power of telescope (f_o = focal length of the objective and f_e = focal length of the eye lens)

[MP PET/PMT 1988; MP PMT 1992, 94]

(a) f_o should be large and f_e should be small

(b) f_o should be small and f_e should be large

(c) f_o and f_e both should be large

(d) f_o and f_e both should be small

55. Relative difference of focal lengths of objective and eye lens in the microscope and telescope is given as

[MH CET 2001]

(a) It is equal in both (b) It is more in telescope

(c) It is more in microscope (d) It may be more in any one

56. If the telescope is reversed *i.e.* seen from the objective side

(a) Object will appear very small

(b) Object will appear very large

(c) There will be no effect on the image formed by the telescope

(d) Image will be slightly greater than the earlier one

57. The focal length of the objective of a terrestrial telescope is 80 *cm* and it is adjusted for parallel rays, then its magnifying power is 20. If the focal length of erecting lens is 20 *cm*, then full length of telescope will be

(a) 84 *cm* (b) 100 *cm*

(c) 124 *cm* (d) 164 *cm*

58. An astronomical telescope has an angular magnification of magnitude 5 for distant objects. The separation between the objective and the eye piece is 36 *cm* and the final image is formed at infinity. The focal length f_o of the objective and the focal length f_e of the eye piece are

[IIT 1989; MP PET 1995; JIPMER 2000]

(a) f_o = 45 *cm* and f_e = – 9 *cm*

(b) f_o = 7.2 *cm* and f_e = 5 *cm*

(c) f_o = 50 *cm* and f_e = 10 *cm*

(d) f_o = 30 *cm* and f_e = 6 *cm*

59. In an astronomical telescope, the focal lengths of two lenses are 180 *cm* and 6 *cm* respectively. In normal adjustment, the magnifying power will be [MP PET 1990]

(a) 1080 (b) 200

(c) 30 (d) 186

60. The magnifying power of an astronomical telescope for relaxed vision is 16. On adjusting, the distance between the objective and eye lens is 34 *cm*. Then the focal length of objective and eye lens will be respectively [MP PMT 1989]

(a) 17 *cm*, 17 *cm* (b) 20 *cm*, 14 *cm*

(c) 32 *cm*, 2 *cm* (d) 30 *cm*, 4 *cm*

61. In Gallilean telescope, if the powers of an objective and eye lens are respectively +1.25 *D* and – 20 *D*, then for relaxed vision, the length and magnification will be

(a) 21.25 *cm* and 16 (b) 75 *cm* and 20

(c) 75 *cm* and 16 (d) 8.5 *cm* and 21.25

62. The aperture of a telescope is made large, because

[DPMT 1999]

(a) To increase the intensity of image

(b) To decrease the intensity of image

(c) To have greater magnification

(d) To have lesser resolution

63. In Gallilean telescope, the final image formed is

(a) Real, erect and enlarged

(b) Virtual, erect and enlarged

(c) Real, inverted and enlarged

(d) Virtual, inverted and enlarged

64. The magnifying power of a telescope is 9. When it is adjusted for parallel rays, the distance between the objective and the eye-piece is found to be 20 *cm*. The focal length of the two lenses are

(a) 18 *cm*, 2 *cm* (b) 11 *cm*, 9 *cm*

(c) 10 *cm*, 10 *cm* (d) 15 *cm*, 5 *cm*

65. The focal length of the objective and eye piece of a telescope are respectively 60 *cm* and 10 *cm*. The magnitude of the magnifying power when the image is formed at infinity is

(a) 50 (b) 6

(c) 70 (d) 5

66. The magnifying power of an astronomical telescope is 8 and the distance between the two lenses is 54 *cm*. The focal length of eye lens and objective lens will be respectively

[MP PMT 1991; CPMT 1991; Pb. PMT 2001]

(a) 6 *cm* and 48 *cm* (b) 48 *cm* and 6 *cm*

(c) 8 *cm* and 64 *cm* (d) 64 *cm* and 8 *cm*

67. An opera glass (Gallilean telescope) measures 9 *cm* from the objective to the eyepiece. The focal length of the objective is 15 *cm*. Its magnifying power is [DPMT 1988]

(a) 2.5 (b) 2/5

(c) 5/3 (d) 0.4

68. When a telescope is adjusted for parallel light, the distance of the objective from the eye piece is found to be 80 *cm*. The magnifying power of the telescope is 19. The focal lengths of the lenses are

[MP PMT 1992; Very similar to DPMT 2004]

(a) 61 *cm*, 19 *cm* (b) 40 *cm*, 40 *cm*

(c) 76 *cm*, 4 *cm* (d) 50 *cm*, 30 *cm*

69. A reflecting telescope utilizes [CPMT 1983]

(a) A concave mirror (b) A convex mirror

(c) A prism (d) A plano-convex lens

70. The aperture of the objective lens of a telescope is made large so as to [AIEEE 2003; KCET 2003]

(a) Increase the magnifying power of the telescope

(b) Increase the resolving power of the telescope

(c) Make image aberration less

(d) Focus on distant objects

71. On which of the following does the magnifying power of a telescope depends [MP PET 1992]

(a) The focal length of the objective only

(b) The diameter of aperture of the objective only

(c) The focal length of the objective and that of the eye piece

(d) The diameter of aperture of the objective and that of the eye piece

72. Large aperture of telescope are used for

[CPMT 1981; MP PMT 1995; AFMC 2000]

(a) Large image (b) Greater resolution

(c) Reducing lens aberration (d) Ease of manufacture

73. Two convex lenses of focal lengths 0.3 *m* and 0.05 *m* are used to make a telescope. The distance kept between the two is

(a) 0.35 *m* (b) 0.25 *m*

(c) 0.175 *m* (d) 0.15 *m*

74. The diameter of the objective lens of a telescope is 5.0 *m* and wavelength of light is 6000 Å. The limit of resolution of this telescope will be [MP PMT 1994]

(a) 0.03 *sec* (b) 3.03 *sec*

(c) 0.06 *sec* (d) 0.15 *sec*

75. All of the following statements are correct except

[Manipal MEE 1995]

(a) The total length of an astronomical telescope is the sum of the focal lengths of its two lenses

(b) The image formed by the astronomical telescope is always erect because the effect of the combination of the two lenses is divergent [MP PET 1991]

(c) The magnification of an astronomical telescope can be increased by decreasing the focal length of the eye-piece

(d) The magnifying power of the refracting type of astronomical telescope is the ratio of the focal length of the objective to that of the eye-piece

76. A terrestrial telescope is made by introducing an erecting lens of focal length f between the objective and eye piece lenses of an astronomical telescope. This causes the length of the telescope tube to increase by an amount equal to

[KCEE 1996]

(a) f (b) $2f$

(c) $3f$ (d) $4f$

77. The length of an astronomical telescope for normal vision (relaxed eye) (f_o = focal length of objective lens and f_e = focal length of eye lens) is

[EAMCET (Med.) 1995; CPMT 1999; BVP 2003]

(a) $f_o \times f_e$ (b) $\frac{f_o}{f_e}$

(c) $f_o + f_e$ (d) $f_o - f_e$

78. A Gallilean telescope has objective and eye-piece of focal lengths 200 *cm* and 2 *cm* respectively. The magnifying power of the telescope for normal vision is

[MP PMT 1996]

(a) 90 (b) 100

(c) 108 (d) 198

79. In an astronomical telescope, the focal length of the objective lens is 100 *cm* and of eye-piece is 2 *cm*. The magnifying power of the telescope for the normal eye is

[MP PET 1997]

(a) 50 (b) 10

(c) 100 (d) $\frac{1}{50}$

80. When diameter of the aperture of the objective of an astronomical telescope is increased, its [MP PMT 1997]

(a) Magnifying power is increased and resolving power is decreased

(b) Magnifying power and resolving power both are increased

(c) Magnifying power remains the same but resolving power is increased [MNR 1994]

(d) Magnifying power and resolving power both are decreased

81. The focal lengths of the objective and eye lenses of a telescope are respectively 200 *cm* and 5 *cm*. The maximum magnifying power of the telescope will be

[MP PMT/PET 1998; JIPMER 2001, 02]

(a) – 40 (b) – 48

(c) – 60 (d) – 100

82. The minimum magnifying power of a telescope is *M*, If the focal length of its eye lens is halved, the magnifying power will become

(a) *M* / 2 (b) 2 *M*

(c) 3 *M* (d) 4 *M*

83. The astronomical telescope consists of objective and eye-piece. The focal length of the objective is

[AIIMS 1998; BHU 2000]

(a) Equal to that of the eye-piece

(b) Greater than that of the eye-piece

(c) Shorter than that of the eye-piece

(d) Five times shorter than that of the eye-piece

84. Four convergent lenses have focal lengths 100 *cm*, 10 *cm*, 4 *cm* and 0.3 *cm*. For a telescope with maximum possible magnification, we choose the lenses of focal length

[KCET 1994]

(a) 100 *cm*, 0.3 *cm* (b) 10 *cm*, 0.3 *cm*

(c) 10 *cm*, 4 *cm* (d) 100 *cm*, 4 *cm*

85. The focal length of objective and eye-piece of a telescope are 100 *cm* and 5 *cm* respectively. Final image is formed at least distance of distinct vision. The magnification of telescope is

(a) 20 (b) 24

(c) 30 (d) 36

86. A planet is observed by an astronomical refracting telescope having an objective of focal length 16 *m* and an eye-piece of focal length 2 *cm* [IIT-JEE 1992; Roorkee 2000]

(a) The distance between the objective and the eye-piece is 16.02 *m*

(b) The angular magnification of the planet is 800

(c) The image of the planet is inverted

(d) The objective is larger than the eye-piece

87. If tube length of astronomical telescope is 105 *cm* and magnifying power is 20 for normal setting, calculate the focal length of objective

(a) 100 *cm* (b) 10 *cm*

(c) 20 *cm* (d) 25 *cm*

88. The length of a telescope is 36 *cm*. The focal lengths of its lenses can be [Bihar MEE 1995]

(a) 30 *cm*, 6 *cm* (b) – 30 *cm*, – 6 *cm*

(c) 30 *cm*, – 6 *cm* (d) – 30 *cm*, 6 *cm*

89. An astronomical telescope of ten-fold angular magnification has a length of 44 *cm*. The focal length of the objective is

[CBSE PMT 1997]

(a) 4 *cm* (b) 40 *cm*

(c) 44 *cm* (d) 440 *cm*

90. If both the object and image are at infinite distances form a refracting telescope its magnifying power will be equal to

[AMU (Engg.) 1999]

(a) The sum of the focal lengths of the objective and the eyepiece

(b) The difference of the focal lengths of the two lenses

(c) The ratio of the focal length of the objective and eyepiece

(d) The ratio of the focal length of the eyepiece and objective

91. The number of lenses in a terrestrial telescope is

[KCET 1999; MH CET 2003]

(a) Two (b) Three

(c) Four (d) Six

92. The focal lengths of the lenses of an astronomical telescope are 50 *cm* and 5 *cm*. The length of the telescope when the image is formed at the least distance of distinct vision is

[EAMCET (Engg.) 2000]

(a) $45\,cm$ (b) $55\,cm$

(c) $\frac{275}{6}cm$ (d) $\frac{325}{6}cm$

93. The focal lengths of the objective and eye-piece of a telescope are respectively 100 *cm* and 2 *cm*. The moon subtends an angle of 0.5^o at the eye. If it is looked through the telescope, the angle subtended by the moon's image will be

(a) 100^o (b) 50^o

(c) 25^o (d) 10^o

94. The diameter of the objective of a telescope is a, its magnifying power is m and wavelength of light is λ. The resolving power of the telescope is [MP PMT 2000]

(a) $(1.22\lambda)/a$ (b) $(1.22a)/\lambda$

(c) $\lambda m/(1.22a)$ [RPET 1997] (d) $a/(1.22\lambda)$

95. The sun's diameter is $1.4\times10^9\,m$ and its distance from the earth is $10^{11}\,m$. The diameter of its image, formed by a convex lens of focal length $2m$ will be [MP PET 2000]

(a) 0.7 *cm* (b) 1.4 *cm*

(c) 2.8 *cm* (d) Zero (*i.e.* point image)

96. In a terrestrial telescope, the focal length of objective is 90 *cm*, of inverting lens is $5\,cm$ and of eye lens is $6\,cm$. If the final image is at 30 *cm*, then the magnification will be

[DPMT 2001]

(a) 21 (b) 12

(c) 18 [AFMC 1994] (d) 15

97. The resolving power of a telescope depends on

[MP PET 2000, 01; DCE 2003]

(a) Focal length of eye lens

(b) Focal length of objective lens

(c) Length of the telescope

(d) Diameter of the objective lens

98. Four lenses of focal length + 15 *cm*, + 20*cm*, + 150*cm* and + 250 *cm* are available for making an astronomical telescope. To produce the largest magnification, the focal length of the eye-piece should be

[CPMT 2001; AIIMS 2001]

(a) + 15 *cm* (b) + 20 *cm*

(c) +150 *cm* (d) + 250 *cm*

99. In an astronomical telescope, the focal length of objective lens and eye-piece are 150 *cm* and 6 *cm* respectively. In case when final image is formed at least distance of distinct vision. the magnifying power is [KCET 2001]

(a) 20 (b) 30

(c) 60 (d) 15

100. In a laboratory four convex lenses L_1, L_2, L_3 and L_4 of focal lengths 2, 4, 6 and 8 *cm* respectively are available. Two of these lenses form a telescope of length 10 *cm* and magnifying power 4. The objective and eye lenses are

[MP PMT 2001]

(a) L_2, L_3 (b) L_1, L_4

(c) L_3, L_2 (d) L_4, L_1

101. A telescope has an objective of focal length 50 *cm* and an eye piece of focal length 5 *cm*. The least distance of distinct vision is 25 *cm*.

The telescope is focussed for distinct vision on a scale 200 *cm* away. The separation between the objective and the eye-piece is

(a) 75 *cm* (b) 60 *cm*

(c) 71 *cm* (d) 74 *cm*

102. The resolving power of a telescope whose lens has a diameter of 1.22 *m* for a wavelength of 5000 *Å* is [Kerala PMT 2002]

(a) 2×10^5 (b) 2×10^6

(c) 2×10^2 (d) 2×10^4

103. To increase both the resolving power and magnifying power of a telescope [Kerala PET 2002; KCET 2002]

(a) Both the focal length and aperture of the objective has to be increased

(b) The focal length of the objective has to be increased

(c) The aperture of the objective has to be increased

(d) The wavelength of light has to be decreased

104. A Galileo telescope has an objective of focal length $100 cm$ and magnifying power 50. The distance between the two lenses in normal adjustment will be [BHU 2002; Pb. PET 2002]

(a) 96 *cm* (b) 98 *cm*

(c) 102 *cm* (d) 104 *cm*

105. An astronomical telescope has a magnifying power 10. The focal length of eyepiece is 20 *cm*. The focal length of objective is [MP PMT 2002, 03; Pb. PET 2004]

(a) 2 *cm* (b) 200 *cm*

(c) $\frac{1}{2} cm$ (d) $\frac{1}{200} cm$

106. A telescope of diameter 2*m* uses light of wavelength 5000 Å for viewing stars. The minimum angular separation between two stars whose image is just resolved by this telescope is [MP PET 2003]

(a) 4×10^{-4} *rad* (b) 0.25×10^{-6} *rad*

(c) 0.31×10^{-6} *rad* (d) 5.0×10^{-3} *rad*

107. A simple magnifying lens is used in such a way that an image is formed at 25 *cm* away from the eye. In order to have 10 *times* magnification, the focal length of the lens should be

(a) 5 *cm* (b) 2 *cm*

(c) 25 *mm* (d) 0.1 *mm*

108. In a simple microscope, if the final image is located at infinity then its magnifying power is [MP PMT 2004]

(a) $\frac{25}{f}$ (b) $\frac{D}{26}$

(c) $\frac{f}{25}$ (d) $\frac{f}{D+1}$

109. In a compound microscope the objective of f_o and eyepiece of f_e are placed at distance L such that L equals [Kerala PMT 2004]

(a) $f_o + f_e$

(b) $f_o - f_e$

(c) Much greater than f_o or f_e [Kerala PET 2002]

(d) Much less than f_o or f_e

(e) Need not depend either value of focal lengths

110. For a compound microscope, the focal lengths of object lens and eye lens are f_o and f_e respectively, then magnification will be done by microscope when [RPMT 2001]

(a) $f_o = f_e$ (b) $f_o > f_e$

(c) $f_o < f_e$ (d) None of these

111. The angular resolution of a 10 *cm* diameter telescope at a wavelength of 5000 Å is of the order [CBSE PMT 2005]

(a) $10^6 rad$ (b) $10^{-2} rad$

(c) $10^{-4} rad$ (d) $10^{-6} rad$

112. The resolving power of an astronomical telescope is 0.2 seconds. If the central half portion of the objective lens is covered, the resolving power will be [MP PMT 2004]

(a) 0.1 *sec* (b) 0.2 *sec*

(c) 1.0 *sec* (d) 0.6 *sec*

113. An astronomical telescope has objective and eye-piece lens of powers 0.5 *D* and 20 *D* respectively, its magnifying power will be

(a) 8 (b) 20

(c) 30 (d) 40

114. Which of the following is not correct regarding the radio telescope

(a) It can not work at night

(b) It can detect a very faint radio signal

(c) It can be operated even in cloudy weather

(d) It is much cheaper than optical telescope

115. The diameter of objective of a telescope is 1*m*. Its resolving limit for the light of wave length 4538 Å, will be [Pb. PET 2003]

(a) $5.54\times10^{-7} rad$ [MP PET 1990] (b) $2.54\times10^{-4} rad$

(c) $6.54\times10^{-7} rad$ (d) None of these

116. A telescope has an objective lens of focal length 200 *cm* and an eye piece with focal length 2 *cm*. If this telescope is used to see a 50 *meter* tall building at a distance of 2 *km*, what is the height of the image of the building formed by the objective lens

(a) 5 *cm* (b) 10 *cm*

(c) 1 *cm* (d) 2 *cm*

117. Magnification of a compound microscope is 30. Focal length of eye-piece is 5 *cm* and the image is formed at a distance of distinct vision of 25 *cm*. The magnification of the objective lens is

(a) 6 (b) 5

(c) 7.5 (d) 10

118. At Kavalur in India, the astronomers using a telescope whose objective had a diameter of one meter started using a telescope of diameter 2.54 *m*. This resulted in [KCET 2005]

(a) The increase in the resolving power by 2.54 times for the same λ

(b) The increase in the limiting angle by 2.54 times for the same λ

(c) Decrease in resolving power

(d) No effect on the limiting angle

119. A Galileo telescope has an objective of focal length 100 *cm* and magnifying power 50. The distance between the two lenses in normal adjustment will be [BCECE 2005]

(a) 98 *cm* (b) 100 *cm*

(c) 150 *cm* (d) 200 *cm*

120. A compound microscope has an eye piece of focal length 10 *cm* and an objective of focal length 4 *cm*. Calculate the magnification, if an object is kept at a distance of 5 *cm* from the objective so that final image is formed at the least distance vision (20 *cm*)

(a) 12 (b) 11

(c) 10 (d) 13

Photometry

1. If luminous efficiency of a lamp is 2 lumen/watt and its luminous intensity is 42 candela, then power of the lamp is [AFMC 1998]

(a) 62 *W* (b) 76 *W*

(c) 138 *W* (d) 264 *W*

2. An electric bulb illuminates a plane surface. The intensity of illumination on the surface at a point 2*m* away from the bulb is 5×10^{-4} phot (*lumen/cm*). The line joining the bulb to the point makes an angle of 60· with the normal to the surface. The intensity of the bulb in *candela* is [IIT-JEE 1980; CPMT 1991]

(a) $40\sqrt{3}$ (b) 40

(c) 20 (d) 40×10^{-4}

3. In a movie hall, the distance between the projector and the screen is increased by 1% illumination on the screen is [CPMT 1990]

(a) Increased by 1% (b) Decreased by 1%

(c) Increased by 2% (d) Decreased by 2%

4. Correct exposure for a photographic print is 10 *seconds* at a distance of one metre from a point source of 20 *candela*. For an equal fogging of the print placed at a distance of 2 *m* from a 16 *candela* source, the necessary time for exposure is

(a) 100 *sec* (b) 25 *sec*

(c) 50 *sec* (d) 75 *sec*

5. A bulb of 100 *watt* is hanging at a height of one meter above the centre of a circular table of diameter 4 *m*. If the intensity at a point on its rim is I_0, then the intensity at the centre of the table will be [CPMT 1996]

(a) I_0 (b) $2\sqrt{5}I_0$

(c) $2I_0$ (d) $5\sqrt{5}I_0$

6. A movie projector forms an image 3.5*m* long of an object 35 *mm*. Supposing there is negligible absorption of light by aperture then illuminance on slide and screen will be in the ratio of

(a) 100 : 1 (b) 10^4 : 1

(c) 1 : 100 (d) 1 : 10^4

7. A 60 *watt* bulb is hung over the center of a table 4 *m* × 4 *m* at a height of 3 *m*. The ratio of the intensities of illumination at a point on the centre of the edge and on the corner of the table is

(a) $(17/13)^{3/2}$ (b) 2 / 1

(c) 17 / 13 (d) 5 / 4

8. "Lux" is a unit of [Kerala PMT 2001]

(a) Luminous intensity of a source

(b) Illuminance on a surface

(c) Transmission coefficient of a surface

(d) Luminous efficiency of source of light

9. Total flux produced by a source of 1 *cd* is [CPMT 2001] [UP SEAT 2005]

(a) $\frac{1}{4\pi}$ (b) 8π

(c) 4π (d) $\frac{1}{8\pi}$

10. If the luminous intensity of a 100 *W* unidirectional bulb is 100 candela, then total luminous flux emitted from the bulb is

(a) 861 *lumen* (b) 986 *lumen*

(c) 1256 *lumen* (d) 1561 *lumen*

11. The maximum illumination on a screen at a distance of 2 *m* from a lamp is 25 *lux*. The value of total luminous flux emitted by the lamp is [JIMPER 1997]

(a) 1256 *lumen* (b) 1600 *lumen*

(c) 100 *candela* (d) 400 *lumen*

12. A small lamp is hung at a height of 8 feet above the centre of a round table of diameter 16 *feet*. The ratio of intensities of illumination at the centre and at points on the circumference of the table will be [CPMT 1984, 1996]

(a) 1 : 1 (b) 2 : 1

(c) $2\sqrt{2}:1$ (d) 3 : 2

13. Lux is equal to [CPMT 1993]

(a) 1 *lumen/m* (b) 1 *lumen/cm*

(c) 1 *candela/m* (d) 1 *candela/cm*

14. Five *lumen/watt* is the luminous efficiency of a lamp and its luminous intensity is 35 *candela*. The power of the lamp is [CPMT 1992]

(a) 80 *W* (b) 176 *W*

(c) 88 *W* (d) 36 *W*

15. A lamp rated at 100 *cd* hangs over the middle of a round table with diameter 3 *m* at a height of 2 *m*. It is replaced by a lamp of 25 *cd* and the distance to the table is changed so that the illumination at the centre of the table remains as before. The illumination at edge of the table becomes *X* times the original. Then *X* is

(a) $\frac{1}{3}$ (b) $\frac{16}{27}$

(c) $\frac{1}{4}$ (d) $\frac{1}{9}$

16. The distance between a point source of light and a screen which is 60 *cm* is increased to 180 *cm*. The intensity on the screen as compared with the original intensity will be

[CPMT 1982] [CPMT 1888]

(a) (1 / 9) times (b) (1 / 3) times

(c) 3 times (d) 9 times

17. A source of light emits a continuous stream of light energy which falls on a given area. Luminous intensity is defined as [CPMT 1986]

(a) Luminous energy emitted by the source per second

(b) Luminous flux emitted by source per unit solid angle

(c) Luminous flux falling per unit area of a given surface

(d) Luminous flux coming per unit area of an illuminated surface

18. Venus looks brighter than other stars because [MNR 1985]

(a) It has higher density than other stars

(b) It is closer to the earth than other stars

(c) It has no atmosphere

(d) Atomic fission takes place on its surface

19. To prepare a print the time taken is 5 *sec* due to lamp of 60 watt at 0.25 *m* distance. If the distance is increased to 40 *cm* then what is the time taken to prepare the similar print [CPMT 1982]

(a) 3.1 *sec* (b) 1 *sec*

(c) 12.8 *sec* (d) 16 *sec*

20. A lamp is hanging 1 *m* above the centre of a circular table of diameter 1*m*. The ratio of illuminaces at the centre and the edge is

(a) $\frac{1}{2}$ (b) $\left(\frac{5}{4}\right)^{\frac{3}{2}}$

(c) $\frac{4}{3}$ (d) $\frac{4}{5}$

21. Two stars situated at distances of 1 and 10 light years respectively from the earth appear to possess the same brightness. The ratio of their real brightness is [NCERT 1981]

(a) 1 : 10 (b) 10 : 1

(c) 1 : 100 (d) 100 : 1

22. The intensity of direct sunlight on a surface normal to the rays is I_0. What is the intensity of direct sunlight on a surface, whose normal makes an angle of 60° with the rays of the sun

(a) I_0 (b) $I_0\left(\frac{\sqrt{3}}{2}\right)$

(c) $\frac{I_0}{2}$ (d) $2I_0$

23. Inverse square law for illuminance is valid for [CPMT 1978]

(a) Isotropic point source (b) Cylindrical source

(c) Search light (d) All types of sources

24. 1% of light of a source with luminous intensity 50 *candela* is incident on a circular surface of radius 10 *cm*. The average illuminance of surface is

(a) 100 *lux* (b) 200 *lux*

(c) 300 *lux* (d) 400 *lux*

25. Two light sources with equal luminous intensity are lying at a distance of 1.2 *m* from each other. Where should a screen be placed between them such that illuminance on one of its faces is four times that on another face

(a) 0.2 *m* (b) 0.4 *m*

(c) 0.8 *m* (d) 1.6 *m*

26. Two lamps of luminous intensity of 8 *Cd* and 32 *Cd* respectively are lying at a distance of 1.2 *m* from each other. Where should a screen be placed between two lamps such that its two faces are equally illuminated due to two sources

(a) 10 *cm* from 8 *Cd* lamp (b) 10 *cm* from 32*Cd* lamp

(c) 40 *cm* from 8 *Cd* lamp (d) 40 *cm* from 32 *Cd* lamp

27. A lamp is hanging along the axis of a circular table of radius *r*. At what height should the lamp be placed above the table, so that the illuminance at the edge of the table is $\frac{1}{8}$ of that at its center

(a) $\frac{r}{2}$ (b) $\frac{r}{\sqrt{2}}$

(c) $\frac{r}{3}$ (d) $\frac{r}{\sqrt{3}}$

[NCERT 1982]

28. A point source of 100 *candela* is held 5*m* above a sheet of blotting paper which reflects 75% of light incident upon it. The illuminance of blotting paper is

(a) 4 *phot* (b) 4 *lux*

(c) 3 *phot* (d) 3 *lux*

29. A lamp is hanging at a height 40 *cm* from the centre of a table. If its height is increased by 10 *cm* the illuminance on the table will decrease by

(a) 10 % (b) 20%

(c) 27% (d) 36%

30. Which has more luminous efficiency

(a) A 40 *W* bulb (b) A 40 *W* fluorescent tube

(c) Both have same (d) Cannot say

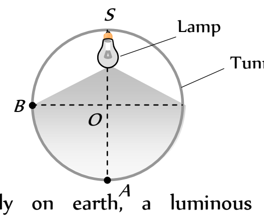
31. An electric lamp is fixed at the ceiling of a circular tunnel as shown is figure. What is the ratio the intensities of light at base *A* and a point *B* on the wall

(a) 1 : 2 [CPMT 1981]

(b) $2 : \sqrt{3}$

(c) $\sqrt{3} : 1$

(d) $1 : \sqrt{2}$



32. When sunlight falls normally on earth, a luminous flux of 1.57×10^5 $lumen/m^2$ is produced on earth. The distance of earth from sun is 1.5×10^8 *Km*. The luminous intensity of sun in candela will be

(a) 3.53×10^{27} (b) 3.53×10^{25}

(c) 3.53×10^{29} (d) 3.53×10^{21}

33. In the above problem, the luminous flux emitted by sun will be

(a) 4.43×10^{25} *lm* (b) 4.43×10^{26} *lm*

(c) 4.43×10^{27} *lm* (d) 4.43×10^{28} *lm*

34. A screen receives 3 *watt* of radiant flux of wavelength 6000 Å. One lumen is equivalent to $1.5\times10^{-3}watt$ of monochromatic light of wavelength 5550 Å. If relative luminosity for 6000 Å is 0.685 while that for 5550 Å is 1.00, then the luminous flux of the source is

(a) $4\times10^{3}lm$ (b) $3\times10^{3}lm$

(c) $2\times10^{3}lm$ (d) $1.37\times10^{3}lm$

35. A point source of 3000 *lumen* is located at the centre of a cube of side length $2m$. The flux through one side is

(a) 500 *lumen* (b) 600 *lumen*

(c) 750 *lumen* (d) 1500 *lumen*

36. Light from a point source falls on a small area placed perpendicular to the incident light. If the area is rotated about the incident light by an angle of 60°, by what fraction will the illuminance change

(a) It will be doubled (b) It will be halved

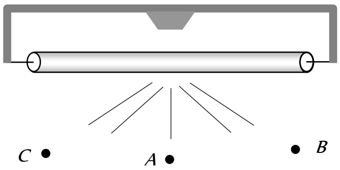
(c) It will not change (d) It will become one-fourth

37. A point source of light moves in a straight line parallel to a plane table. Consider a small portion of the table directly below the line of movement of the source. The illuminance at this portion varies with its distance *r* from the source as

(a) $E \propto \frac{1}{r}$ (b) $E \propto \frac{1}{r^2}$

(c) $E \propto \frac{1}{r^3}$ (d) $E \propto \frac{1}{r^4}$

38. Figure shows a glowing mercury tube. The illuminances at point *A*, *B* and *C* are related as



(a) $B > C > A$

(b) $A > C > B$

(c) $B = C > A$

(d) $B = C < A$

39. The relative luminosity of wavelength 600 *nm* is 0.6. Find the radiant flux of 600 *nm* needed to produce the same brightness sensation as produced by 120 *W* of radiant flux at 555 *nm*

(a) 50 *W* (b) 72 *W*

(c) $120 \times (0.6)^2 W$ (d) 200 *W*

40. Find the luminous intensity of the sun if it produces the same illuminance on the earth as produced by a bulb of 10000 *candela* at a distance 0.3 *m*. The distance between the sun and the earth is $1.5 \times 10^{11} m$

(a) $25 \times 10^{22} cd$ (b) $25 \times 10^{18} cd$

(c) $25 \times 10^{26} cd$ (d) $25 \times 10^{36} cd$

41. A lamp is hanging at a height of 4*m* above a table. The lamp is lowered by 1*m*. The percentage increase in illuminace will be

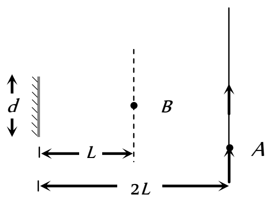
(a) 40 % (b) 64%

(c) 78% (d) 92%

CT Critical Thinking

Objective Questions

1. A point source of light *B* is placed at a distance *L* in front of the centre of a mirror of width *d* hung vertically on a wall. A man walks in front of the mirror along a line parallel to the mirror at a distance 2*L* from it as shown. The greatest distance over which he can see the image of the light source in the mirror is



(a) *d*/2

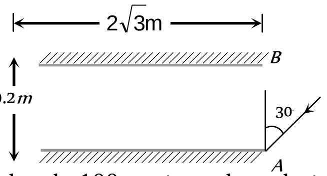
(b) *d*

(c) 2*d*

(d) 3*d*

2. Two plane mirrors. *A* and *B* are aligned parallel to each other, as shown in the figure. A light ray is incident at an angle of $30°$ at a point just inside one end of *A*. The plane of incidence coincides with the plane of the figure. The maximum number of times the ray undergoes reflections (including the first one) before it emerges out is

[IIT-JEE (Screening) 2002]



(a) 28

(b) 30

(c) 32

(d) 34

3. A concave mirror of focal length $100 cm$ is used to obtain the image of the sun which subtends an angle of $30°$. The diameter of the image of the sun will be

(a) $1.74 cm$ (b) $0.87 cm$

(c) $0.435 cm$ (d) $100 cm$

4. A square of side $3 cm$ is placed at a distance of $25 cm$ from a concave mirror of focal length $10 cm$. The centre of the square is at the axis of the mirror and the plane is normal to the axis. The area enclosed by the image of the square is

(a) $4 cm^2$ (b) $6 cm^2$

(c) $16 cm^2$ (d) $36 cm^2$

5. A short linear object of length l lies along the axis of a concave mirror of focal length *f* at a distance u from the pole of the mirror. The size of the image is approximately equal to [IIT-JEE 1988; BHU 2003; CPMT 2

(a) $l\left(\frac{u-f}{f}\right)^{1/2}$ (b) $l\left(\frac{u-f}{f}\right)^2$

(c) $l\left(\frac{f}{u-f}\right)^{1/2}$ (d) $l\left(\frac{f}{u-f}\right)^2$

6. A thin rod of length $f/3$ lies along the axis of a concave mirror of focal length f. One end of its magnified image touches an end of the rod. The length of the image is

[MP PET 1995]

(a) f (b) $\frac{1}{2} f$

(c) $2f$ (d) $\frac{1}{4} f$

7. A ray of light falls on the surface of a spherical glass paper weight making an angle α with the normal and is refracted in the medium at an angle β. The angle of deviation of the emergent ray from the direction of the incident ray

[IIT-JEE (Screening) 2000] [NCERT 1982]

(a) $(\alpha - \beta)$ (b) $2(\alpha - \beta)$

(c) $(\alpha - \beta)/2$ (d) $(\beta - \alpha)$

8. Light enters at an angle of incidence in a transparent rod of refractive index *n*. For what value of the refractive index of the material of the rod the light once entered into it will not leave it through its lateral face whatsoever be the value of angle of incidence

[CBSE PMT 1998]

(a) $n > \sqrt{2}$ (b) $n = 1$

(c) $n = 1.1$ (d) $n = 1.3$

9. A glass hemisphere of radius 0.04 m and *R.I.* of the material 1.6 is placed centrally over a cross mark on a paper (i) with the flat face; (ii) with the curved face in contact with the paper. In each case the cross mark is viewed directly from above. The position of the images will be

[ISM Dhanbad 1994]

(a) (i) 0.04 *m* from the flat face; (ii) 0.025 *m* from the flat face

(b) (i) At the same position of the cross mark; (ii) 0.025 *m* below the flat face

(c) (i) 0.025 *m* from the flat face; (ii) 0.04 *m* from the flat face

(d) For both (i) and (ii) 0.025 *m* from the highest point of the hemisphere

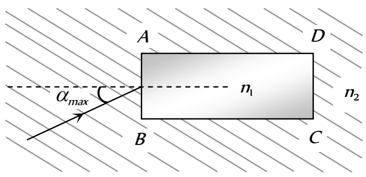
10. One face of a rectangular glass plate 6 *cm* thick is silvered. An object held 8 *cm* in front of the first face, forms an image 12 *cm* behind the silvered face. The refractive index of the glass is

(a) 0.4 (b) 0.8

(c) 1.2 (d) 1.6

11. A rectangular glass slab *ABCD*, of refractive index n_1, is immersed in water of refractive index n_2 $(n_1 > n_2)$. A ray of light in incident at the surface *AB* of the slab as shown. The maximum value of the angle of incidence α_{max}, such that the ray comes out only from the other surface *CD* is given by

[IIT-JEE (Screening) 2000]

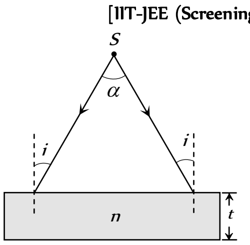


(a) $\sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\frac{n_2}{n_1}\right)\right]$ (b) $\sin^{-1}\left[n_1\cos\left(\sin^{-1}\frac{1}{n_2}\right)\right]$

(c) $\sin^{-1}\left(\frac{n_1}{n_2}\right)$ (d) $\sin^{-1}\left(\frac{n_2}{n_1}\right)$

12. A diverging beam of light from a point source *S* having divergence angle α, falls symmetrically on a glass slab as shown. The angles of incidence of the two extreme rays are equal. If the thickness of the glass slab is *t* and the refractive index *n*, then the divergence angle of the emergent beam is

[IIT-JEE (Screening) 2000]



(a) Zero

(b) α

(c) $\sin^{-1}(1/n)$

(d) $2\sin^{-1}(1/n)$

13. A concave mirror is placed at the bottom of an empty tank with face upwards and axis vertical. When sunlight falls normally on the mirror, it is focussed at distance of 32 *cm* from the mirror. If the tank filled with water $\left(\mu = \frac{4}{3}\right)$ upto a height of 20 *cm*, then the sunlight will now get focussed at

[UPSEAT 2002]

(a) 16 *cm* above water level

(b) 9 *cm* above water level

(c) 24 *cm* below water level

(d) 9 *cm* below water level

14. An air bubble in sphere having 4 *cm* diameter appears 1 *cm* from surface nearest to eye when looked along diameter. If μ = 1.5, the distance of bubble from refracting surface is

[CPMT 2002]

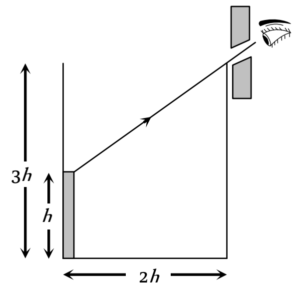
(a) 1.2 *cm* (b) 3.2 *cm*

(c) 2.8 *cm* (d) 1.6 *cm*

15. An observer can see through a pin–hole the top end of a thin rod of height *h*, placed as shown in the figure. The beaker height is 3*h* and its radius *h*. When the beaker is filled with a liquid up to a height 2*h*, he can see the lower end of the rod. Then the refractive index of the liquid is

[CPMT 1999]

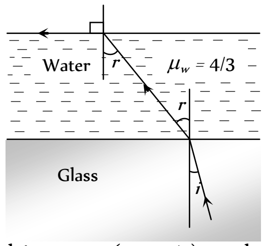
[IIT-JEE (Screening) 2002]



(a) 5/2 (b) $\sqrt{(5/2)}$

(c) $\sqrt{(3/2)}$ (d) 3/2

16. A ray of light is incident at the glass–water interface at an angle *i*, it emerges finally parallel to the surface of water, then the value of μ_g would be **[IIT-JEE (Screening) 2003]**



(a) (4/3) sin *i*

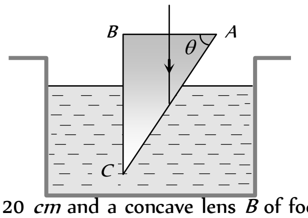
(b) 1/sin *i*

(c) 4/3

(d) 1

17. A glass prism (μ = 1.5) is dipped in water (μ = 4/3) as shown in figure. A light ray is incident normally on the surface *AB*. It reaches the surface BC after totally reflected, if

[IIT JEE 1981; MP PMT 1997]



(a) sin θ ≥ 8/9

(b) 2/3 < sin θ < 8/9

(c) sin θ ≤ 2/3

(d) It is not possible

18. A convex lens *A* of focal length 20 *cm* and a concave lens *B* of focal length 5 *cm* are kept along the same axis with the distance *d* between them. If a parallel beam of light falling on *A* leaves *B* as a parallel beam, then distance *d* in *cm* will be

(a) 25 (b) 15

(c) 30 (d) 50

19. Diameter of a plano–convex lens is 6 *cm* and thickness at the centre is 3 *mm*. If the speed of light in the material of the lens is 2 × 10 *m/sec*, the focal length of the lens is [CPMT 1989]

(a) 15 *cm* (b) 20 *cm*

(c) 30 *cm* (d) 10 *cm*

20. A point object *O* is placed on the principal axis of a convex lens of focal length 20 *cm* at a distance of 40 cm to the left of it. The diameter of the lens is 10 *cm*. If the eye is placed 60 *cm* to the right of the lens at a distance *h* below the principal axis, then the maximum value of *h* to see the image will be

(a) 0 (b) 5 *cm*

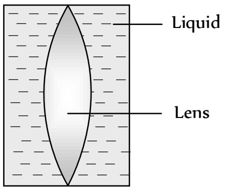
(c) 2.5 *cm* (d) 10 *cm*

21. A luminous object is placed at a distance of 30 *cm* from the convex lens of focal length 20 *cm*. On the other side of the lens, at what distance from the lens a convex mirror of radius of curvature 10 *cm* be placed in order to have an upright image of the object coincident with it [CBSE PMT 1998; JIPMER 2001, 02]

(a) 12 *cm* (b) 30 *cm*

(c) 50 *cm* (d) 60 *cm*

22. Shown in the figure here is a convergent lens placed inside a cell filled with a liquid. The lens has focal length + 20 *cm* when in air and its material has refractive index 1.50. If the liquid has refractive index 1.60, the focal length of the system is [NSEP 1994; DPMT 2000]



(a) + 80 *cm*

(b) – 80 *cm*

(c) – 24 *cm*

(d) –100 *cm*

23. A hollow double concave lens is made of very thin transparent material. It can be filled with air or either of two liquids L_1 and L_2 having refractive indices n_1 and n_2 respectively ($n_2 > n_1 > 1$). The lens will diverge a parallel beam of light if it is filled with

(a) Air and placed in air

(b) Air and immersed in L_1

(c) L_1 and immersed in L_2

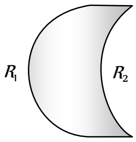
(d) L_2 and immersed in L_1

24. The object distance *u*, the image distance *v* and the magnification *m* in a lens follow certain linear relations. These are

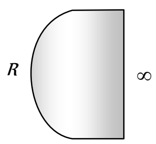
(a) $\frac{1}{u}$ versus $\frac{1}{v}$ (b) *m* versus *u*

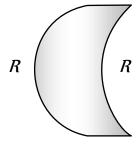
(c) *u* versus *v* (d) *m* versus *v*

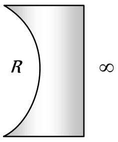
25. Which one of the following spherical lenses does not exhibit dispersion? The radii of curvature of the surfaces of the lenses are as given in the diagrams [IIT-JEE (Screening) 2002]

(a) 

$R_1 \neq R_2$

(b) 

(c) 

(d) 

26. The size of the image of an object, which is at infinity, as formed by a convex lens of focal length 30*cm* is 2 *cm*. If a concave lens of focal length 20 *cm* is placed between the convex lens and the image at a distance of 26 *cm* from the convex lens, calculate the new size of the image [MP PMT 1999] [IIT-JEE (Screening) 2003]

(a) 1.25 *cm* (b) 2.5 *cm*

(c) 1.05 *cm* (d) 2 *cm*

27. An achromatic prism is made by crown glass prism $(A_c = 19^o)$ and flint glass prism $(A_F = 6^o)$. If ${}^C\mu_v = 1.5$ and ${}^F\mu_v = 1.66$, then resultant deviation for red coloured ray will be

(a) 1.04° (b) 5°

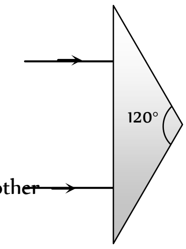
(c) 0.96° (d) 13.5°

28. The refracting angle of prism is *A* and refractive index of material of prism is $\cot\frac{A}{2}$. The angle of minimum deviation is

(a) 180°– 3A (b) 180° + 2A

(c) 90° –A (d) 180° – 2A

29. An isosceles prism of angle 120° has a refractive index of 1.44. Two parallel monochromatic rays enter the prism parallel to each other in air as shown. The rays emerging from the opposite faces



[IIT-JEE (Screening) 2000]

(a) Are parallel to each other

(b) Are diverging

(c) Make an angle $2\sin^{-1}(0.72)$ with each other

(d) Make an angle $2\{\sin^{-1}(0.72) - 30^o\}$ with each other

30. A ray of light is incident on the hypotenuse of a right-angled prism after travelling parallel to the base inside the prism. If μ is the refractive index of the material of the prism, the maximum value of the base angle for which light is totally reflected from the hypotenuse is [Roorkee 2000] [EAMCET 2003]

(a) $\sin^{-1}\left(\frac{1}{\mu}\right)$ (b) $\tan^{-1}\left(\frac{1}{\mu}\right)$

(c) $\sin^{-1}\left(\frac{\mu-1}{\mu}\right)$ (d) $\cos^{-1}\left(\frac{1}{\mu}\right)$

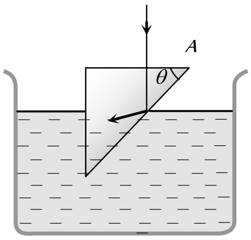
31. The refractive index of the material of the prism and liquid are 1.56 and 1.32 respectively. What will be the value of θ for the following refraction [BHU 2003; CPMT 2004]

(a) $\sin\theta \geq \dfrac{13}{11}$

(b) $\sin\theta \geq \dfrac{11}{13}$

(c) $\sin\theta \geq \dfrac{\sqrt{3}}{2}$

(d) $\sin\theta \geq \dfrac{1}{\sqrt{2}}$



32. A spherical surface of radius of curvature *R* separates air (refractive index 1.0) from glass (refractive index 1.5). The centre of curvature is in the glass. A point object *P* placed in air is found to have a real image *Q* in the glass. The line *PQ* cuts the surface at a point *O*, and PO = OQ. The distance *PO* is equal to

(a) 5 *R* (b) 3 *R*

(c) 2 *R* (d) 1.5 *R*

33. A plano-convex lens when silvered in the plane side behaves like a concave mirror of focal length 30*cm*. However, when silvered on the convex side it behaves like a concave mirror of focal length 10 *cm*. Then the refractive index of its material will be

(a) 3.0 (b) 2.0

(c) 2.5 (d) 1.5

34. A ray of light travels from an optically denser to rarer medium. The critical angle for the two media is *C*. The maximum possible deviation of the ray will be

[KCET (Engg./Med.) 2002]

(a) $\left(\dfrac{\pi}{2} - C\right)$ (b) $2C$

(c) $\pi - 2C$ (d) $\pi - C$

35. An astronaut is looking down on earth's surface from a space shuttle at an altitude of $400\,km$. Assuming that the astronaut's pupil diameter is $5\,mm$ and the wavelength of visible light is $500\,nm$. The astronaut will be able to resolve linear object of the size of about [AIIMS 2003]

(a) 0.5 *m* (b) $5\,m$

(c) 50 *m* (d) 500 *m*

36. The average distance between the earth and moon is 38.6×10^{4} *km*. The minimum separation between the two points on the surface of the moon that can be resolved by a telescope whose objective lens has a diameter of 5 *m* with $\lambda = 6000\,\AA$ is

(a) 5.65 *m* (b) 28.25 *m*

(c) 11.30 *m* (d) 56.51 *m*

37. The distance of the moon from earth is $3.8\times10^{5}\,km$. The eye is most sensitive to light of wavelength 5500 Å. The separation of two points on the moon that can be resolved by a 500 *cm* telescope will be [AMU (Med.) 2002]

(a) 51 *m* (b) 60 *m*

(c) 70 *m* (d) All the above

38. A small source of light is to be suspended directly above the centre of a circular table of radius *R*. What should be the height of the light source above the table so that the intensity of light is maximum at the edges of the table compared to any other height of the source

(a) $\dfrac{R}{2}$ (b) $\dfrac{R}{\sqrt{2}}$

(c) R (d) $\sqrt{2}R$

39. A light source is located at P_1 as shown in the figure. All sides of the polygon are equal. The intensity of illumination at P_2 is I_0. What will be the intensity of illumination at P_3

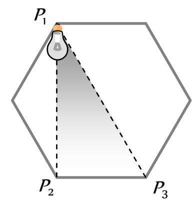
[IIT JEE 1998; DPMT 2000]

(a) $\dfrac{3\sqrt{3}}{8}I_0$

(b) $\dfrac{I_0}{8}$

(c) $\dfrac{3}{8}I_0$

(d) $\dfrac{\sqrt{3}}{8}I_0$



[BHU 1997; UPSEAT 1995]

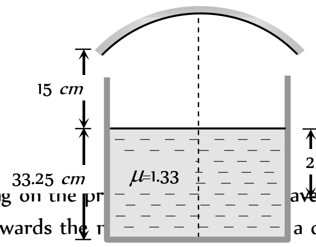
40. A container is filled with water (μ = 1.33) upto a height of 33.25 *cm*. A concave mirror is placed 15 *cm* above the water level and the image of an object placed at the bottom is formed 25 *cm* below the water level. The focal length of the mirror is

(a) 10

(b) 15

(c) 20

(d) 25



41. A point object is moving on the pr... ave mirror of focal length $24cm$ towards th... r... a distance of $60cm$ from the mirror, its velocity is $9cm/sec$. What is the velocity of the image at that instant

[MP PMT 1997]

(a) $5cm/sec$ towards the mirror

(b) $4cm/sec$ towards the mirror

(c) $4cm/sec$ away from the mirror

(d) $9cm/sec$ away from the mirror

[MP PMT 1993]

42. A concave mirror is placed on a horizontal table with its axis directed vertically upwards. Let O be the pole of the mirror and C its centre of curvature. A point object is placed at C. It has a real image, also located at C. If the mirror is now filled with water, the image will be [IIT-JEE 1998]

(a) Real, and will remain at *C*

(b) Real, and located at a point between *C* and ∞

(c) Virtual and located at a point between *C* and *O*

(d) Real, and located at a point between *C* and *O*

43. The diameter of moon is 3.5×10^3 *km* and its distance from the earth is 3.8×10^5 *km*. If it is seen through a telescope whose focal length for objective and eye lens are 4 *m* and 10 *cm* respectively, then the angle subtended by the moon on the eye will be approximately

[NCERT 1982; CPMT 1991]

(a) 15° (b) 20°

(c) 30° (d) 35°

44. The focal length of an objective of a telescope is 3 *metre* and diameter 15 *cm*. Assuming for a normal eye, the diameter of the pupil is 3 *mm* for its complete use, the focal length of eye piece must be [MP PET 1989]

(a) 6 *cm* (b) 6.3 *cm*

(c) 20 *cm* (d) 60 *cm*

45. We wish to see inside an atom. Assuming the atom to have a diameter of 100 *pm*, this means that one must be able to resolved a width of say 10 *p.m.* If an electron microscope is used, the minimum electron energy required is about

[AIIMS 2004]

(a) 1.5 *KeV* (b) 15 *KeV*

(c) 150 *KeV* (d) 1.5 *KeV*

46. A telescope has an objective lens of 10 *cm* diameter and is situated at a distance of one kilometre from two objects. The minimum distance between these two objects, which can be resolved by the telescope, when the mean wavelength of light is 5000 Å, is of the order of [CBSE PMT 2004]

(a) 0.5 *m* (b) 5 *m*

(c) 5 *mm* (d) 5 *cm*

47. Two point white dots are 1*mm* apart on a black paper. They are viewed by eye of pupil diameter 3 *mm*. Approximately, what is the maximum distance at which dots can be resolved by the eye ? [Take wavelength of light = 500 *nm*]

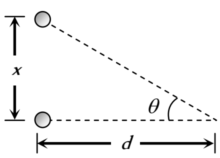
[AIEEE 2005]

(a) 6 *m*

(b) 3 *m*

(c) 5 *m*

(d) 1 *m*



48. A convex lens of focal length 30 *cm* and a concave lens of 10 *cm* focal length are placed so as to have the same axis. If a parallel beam of light falling on convex lens leaves concave lens as a parallel beam, then the distance between two lenses will be

(a) 40 *cm* (b) 30 *cm*

(c) 20 *cm* (d) 10 *cm*

49. A small plane mirror placed at the centre of a spherical screen of radius *R*. A beam of light is falling on the mirror. If the mirror makes *n* revolution. per second, the speed of light on the screen after reflection from the mirror will be

(a) $4\pi nR$ (b) $2\pi nR$

(c) $\frac{nR}{2\pi}$ (d) $\frac{nR}{4\pi}$

50. A room (cubical) is made of mirrors. An insect is moving along the diagonal on the floor such that the velocity of image of insect on two adjacent wall mirrors is 10 *cms*. The velocity of image of insect in ceiling mirror is

(a) 10 *cms* (b) 20 *cms*

(c) $\frac{10}{\sqrt{2}}$ *cms* (d) $10\sqrt{2}$ *cms*

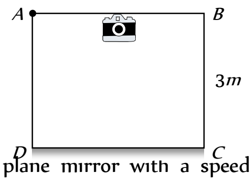
51. Figure shows a cubical room *ABCD* with the wall *CD* as a plane mirror. Each side of the room is 3*m*. We place a camera at the midpoint of the wall *AB*. At what distance should the camera be focussed to photograph an object placed at *A*

(a) 1.5 *m*

(b) 3 *m*

(c) 6 *m*

(d) More than 6 *m*



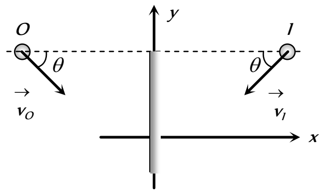
52. If an object moves towards a plane mirror with a speed *v* at an angle θ to the perpendicular to the plane of the mirror, find the relative velocity between the object and the image

(a) v

(b) $2v$

(c) $2v\cos\theta$

(d) $2v\sin\theta$



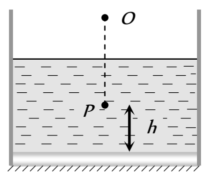
53. A plane mirror is placed at the bottom of the tank containing a liquid of refractive index μ. *P* is a small object at a height *h* above the mirror. An observer *O*-vertically above *P* outside the liquid see *P* and its image in the mirror. The apparent distance between these two will be

(a) $2\mu h$

(b) $\frac{2h}{\mu}$

(c) $\frac{2h}{\mu - 1}$

(d) $h\left(1 + \frac{1}{\mu}\right)$



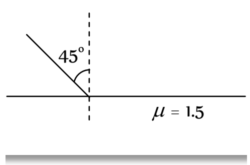
54. One side of a glass slab is silvered as shown. A ray of light is incident on the other side at angle of incidence $i = 45^o$. Refractive index of glass is given as 1.5. The deviation of the ray of light from its initial path when it comes out of the slab is

(a) 90°

(b) 180°

(c) 120°

(d) 45°



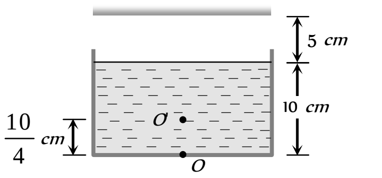
55. Consider the situation shown in figure. Water $\left(\mu_w = \frac{4}{3}\right)$ is filled in a breaker upto a height of 10 *cm*. A plane mirror fixed at a height of 5 *cm* from the surface of water. Distance of image from the mirror after reflection from it of an object *O* at the bottom of the beaker is

(a) 15 *cm*

(b) 12.5 *cm*

(c) 7.5 *cm*

(d) 10 *cm*

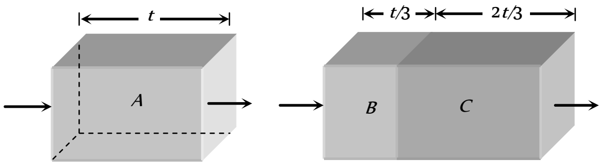


56. A person runs with a speed *u* towards a bicycle moving away from him with speed *v*. The person approaches his image in the mirror fixed at the rear of bicycle with a speed of

(a) $u - v$ (b) $u - 2v$

(c) $2u - v$ (d) $2(u - v)$

57. Two transparent slabs have the same thickness as shown. One is made of material *A* of refractive index 1.5. The other is made of two materials *B* and *C* with thickness in the ratio 1 : 2. The refractive index of *C* is 1.6. If a monochromatic parallel beam passing through the slabs has the same number of waves inside both, the refractive index of *B* is



(a) 1.1 (b) 1.2

(c) 1.3 (d) 1.4

58. An object is placed infront of a convex mirror at a distance of 50 *cm*. A plane mirror is introduced covering the lower half of the convex mirror. If the distance between the object and plane mirror is 30 *cm*, it is found that there is no parallax between the images formed by two mirrors. Radius of curvature of mirror will be

(a) 12.5 *cm* (b) 25 *cm*

(c) $\frac{50}{3}$ *cm* (d) 18 *cm*

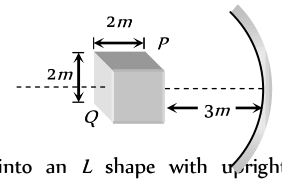
59. A cube of side 2 *m* is placed in front of a concave mirror focal length 1*m* with its face *P* at a distance of 3 *m* and face *Q* at a distance of 5 *m* from the mirror. The distance between the images of face *P* and *Q* and height of images of *P* and *Q* are

(a) 1 *m*, 0.5 *m*, 0.25 *m*

(b) 0.5 *m*, 1 *m*, 0.25 *m*

(c) 0.5 *m*, 0.25 *m*, 1*m*

(d) 0.25 *m*, 1*m*, 0.5 *m*



60. A small piece of wire bent into an *L* shape with upright and horizontal portions of equal lengths, is placed with the horizontal portion along the axis of the concave mirror whose radius of curvature is 10 *cm*. If the bend is 20 *cm* from the pole of the mirror, then the ratio of the lengths of the images of the upright and horizontal portions of the wire is

(a) 1 : 2 (b) 3 : 1

(c) 1 : 3 (d) 2 : 1

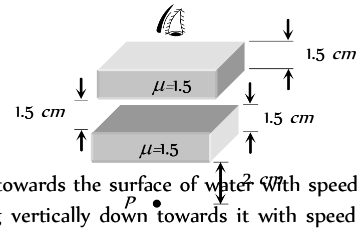
61. The image of point *P* when viewed from top of the slabs will be

(a) 2.0 *cm* above *P*

(b) 1.5 *cm* above *P*

(c) 2.0 *cm* below *P*

(d) 1 *cm* above *P*



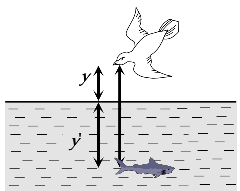
62. A fish rising vertically up towards the surface of water with speed 3 *ms* observes a bird diving vertically down towards it with speed 9 *ms*. The actual velocity of bird is

(a) 4.5 *ms*

(b) 5. *ms*

(c) 3.0 *ms*

(d) 3.4 *ms*



63. A beaker containing liquid is placed on a table, underneath a microscope which can be moved along a vertical scale. The microscope is focussed, through the liquid onto a mark on the table when the reading on the scale is *a*. It is next focussed on the upper surface of the liquid and the reading is *b*. More liquid is added and the observations are repeated, the corresponding readings are *c* and *d*. The refractive index of the liquid is

(a) $\frac{d-b}{d-c-b+a}$ (b) $\frac{b-d}{d-c-b+a}$

(c) $\frac{d-c-b+a}{d-b}$ (d) $\frac{d-b}{a+b-c-d}$

64. Two point light sources are 24 *cm* apart. Where should a convex lens of focal length 9 *cm* be put in between them from one source so that the images of both the sources are formed at the same place

(a) 6 *cm* (b) 9 *cm*

(c) 12 *cm* (d) 15 *cm*

65. There is an equiconvex glass lens with radius of each face as *R* and ${}_a\mu_g = 3/2$ and ${}_a\mu_w = 4/3$. If there is water in object space and air in image space, then the focal length is

(a) 2*R* (b) *R*

(c) 3 *R*/2 (d) R^2

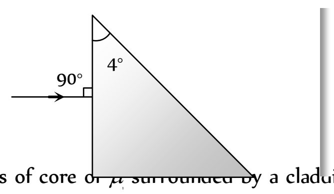
66. A prism having an apex angle 4 and refraction index 1.5 is located in front of a vertical plane mirror as shown in figure. Through what total angle is the ray deviated after reflection from the mirror

(a) 176

(b) 4

(c) 178

(d) 2



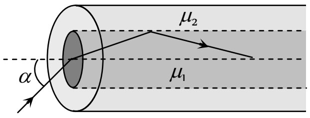
67. An optical fibre consists of core of μ surrounded by a cladding of μ < μ. A beam of light enters from air at an angle α with axis of fibre. The highest α for which ray can be travelled through fibre is

(a) $\cos^{-1}\sqrt{\mu_2^2-\mu_1^2}$

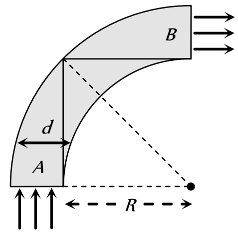
(b) $\sin^{-1}\sqrt{\mu_1^2-\mu_2^2}$

(c) $\tan^{-1}\sqrt{\mu_1^2-\mu_2^2}$

(d) $\sec^{-1}\sqrt{\mu_1^2-\mu_2^2}$



68. A rod of glass (μ = 1.5) and of square cross section is bent into the shape shown in the figure. A parallel beam of light falls on the plane flat surface *A* as shown in the figure. If *d* is the width of a side and *R* is the radius of circular arc then for what maximum value of $\frac{d}{R}$ light entering the glass slab through surface *A* emerges from the glass through *B*



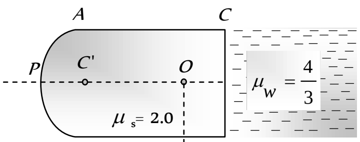
(a) 1.5

(b) 0.5

(c) 1.3

(d) None of these

69. The slab of a material of refractive index 2 shown in figure has curved surface *APB* of radius of curvature 10 *cm* and a plane surface *CD*. On the left of *APB* is air and on the right of *CD* is water with refractive indices as given in figure. An object *O* is placed at a distance of 15 *cm* from pole *P* as shown. The distance of the final image of *O* from *P*, as viewed from the left is



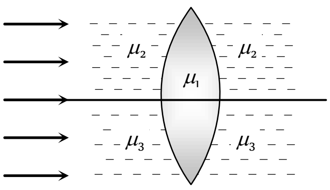
(a) 20 *cm*

(b) 30 *cm*

(c) 40 *cm*

(d) 50 *cm*

70. A double convex lens, lens made of material of refractive index μ_1, is placed inside two liquids of refractive indices μ_2 and μ_3, as shown. $\mu_2 > \mu_1 > \mu_3$. A wide, parallel beam of light is incident on the lens from the left. The lens will give rise to



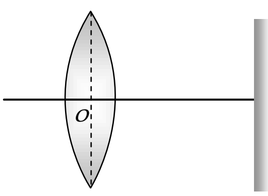
(a) A single convergent beam

(b) Two different convergent beams

(c) Two different divergent beams

(d) A convergent and a divergent beam

71. The distance between a convex lens and a plane mirror is 10 *cm*. The parallel rays incident on the convex lens after reflection from the mirror form image at the optical centre of the lens. Focal length of lens will be



(a) 10 *cm*

(b) 20 *cm*

(c) 30 *cm*

(d) Cannot be determined

72. A compound microscope is used to enlarge an object kept at a distance 0.03*m* from it's objective which consists of several convex lenses in contact and has focal length 0.02*m*. If a lens of focal length 0.1*m* is removed from the objective, then by what distance the eye-piece of the microscope must be moved to refocus the image

(a) 2.5 *cm* (b) 6 *cm*

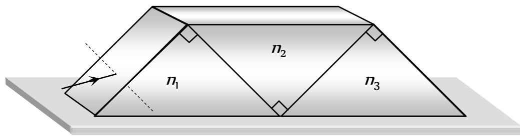
(c) 15 *cm* (d) 9 *cm*

73. If the focal length of the objective lens and the eye lens are 4 *mm* and 25 *mm* respectively in a compound microscope. The length of the tube is 16 *cm*. Find its magnifying power for relaxed eye position

(a) 32.75 (b) 327.5

(c) 0.3275 (d) None of the above

74. Three right angled prisms of refractive indices n_1, n_2 and n_3 are fixed together using an optical glue as shown in figure. If a ray passes through the prisms without suffering any deviation, then



(a) $n_1 = n_2 = n_3$ (b) $n_1 = n_2 \neq n_3$

(c) $1 + n_1 = n_2 + n_3$ (d) $1 + n_2^2 = n_1^2 + n_3^2$

75. In a compound microscope, the focal length of the objective and the eye lens are 2.5 *cm* and 5 *cm* respectively. An object is placed at 3.75 *cm* before the objective and image is formed at the least distance of distinct vision, then the distance between two lenses will be (*i.e.* length of the microscopic tube)

(a) 11.67 *cm* (b) 12.67 *cm*

(c) 13.00 *cm* (d) 12.00 *cm*

76. In a grease spot photometer light from a lamp with dirty chimney is exactly balanced by a point source distance 10 *cm* from the grease spot. On clearing the chimney, the point source is moved 2 *cm* to obtain balance again. The percentage of light absorbed by dirty chimney is nearly

(a) 56% (b) 44%

(c) 36% (d) 64%

77. The separation between the screen and a plane mirror is 2*r*. An isotropic point source of light is placed exactly midway between the mirror and the screen. Assume that mirror reflects 100% of incident light. Then the ratio of illuminances on the screen with and without the mirror is

(a) 10 : 1 (b) 2 : 1

(c) 10 : 9 (d) 9 : 1

78. The separation between the screen and a concave mirror is 2*r*. An isotropic point source of light is placed exactly midway between the mirror and the point source. Mirror has a radius of curvature *r* and reflects 100% of the incident light. Then the ratio of illuminances on the screen with and without the mirror is

(a) 10 : 1 (b) 2 : 1

(c) 10 : 9 (d) 9 : 1

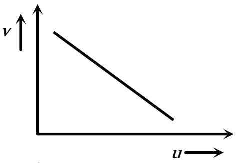
79. The apparent depth of water in cylindrical water tank of diameter 2*R cm* is reducing at the rate of *x cm*/minute when water is being drained out at a constant rate. The amount of water drained in *c.c.* per minute is (n_1 = refractive index of air, n_2 = refractive index of water) **[AIIMS 2005]**

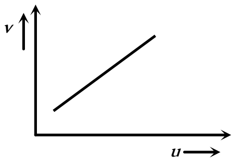
(a) $x \pi R^2 n_1/n_2$ (b) $x \pi R^2 n_2/n_1$

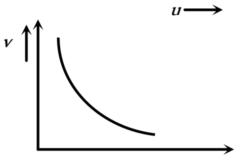
(c) $2 \pi R n_1/n_2$ (d) $\pi R^2 x$

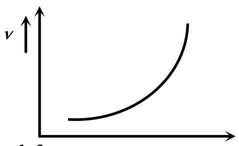
Graphical Questions

1. In an experiment of find the focal length of a concave mirror a graph is drawn between the magnitudes of u and v. The graph looks like [AIIMS 2003]

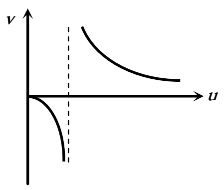
(a) 

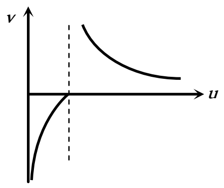
(b) 

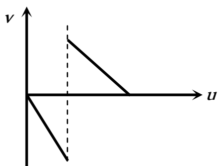
(c) 

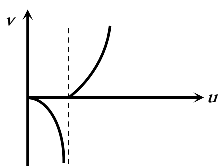
(d) 

2. As the position of an object (u) reflected from a concave mirror is varied, the position of the image (v) also varies. By letting the u changes from 0 to $+\infty$ the graph between v versus u will be

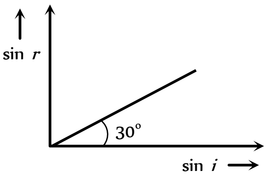
(a) 

(b) 

(c) 

(d) 

3. When light is incident on a medium at angle i and refracted into a second medium at an angle r, the graph of sin i *vs* sin$r$ is as shown in the graph. From this, one can conclude that



(a) Velocity of light in the second medium is 1.73 times the velocity of light in the I medium

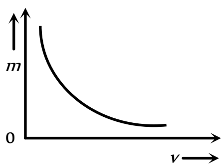
(b) Velocity of light in the I medium is 1.73 times the velocity in the II medium

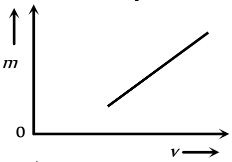
(c) The critical angle for the two media is given by

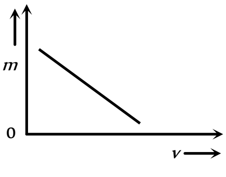
$$\sin i_c = \frac{1}{\sqrt{3}}$$

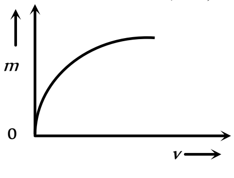
(d) $\sin i_c = \frac{1}{2}$

4. The graph between the lateral magnification (m) produced by a lens and the distance of the image (v) is given by [MP PMT 1994]

(a) 

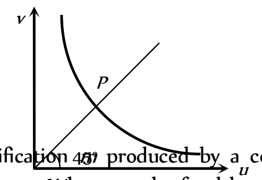
(b) 





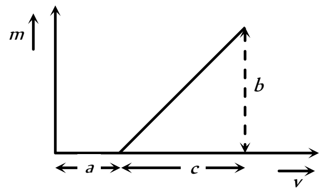
(c) (d)

5. The graph shows variation of v with change in u for a mirror. Points plotted above the point P on the curve are for values of v



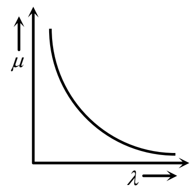
(a) Smaller then f
(b) Smaller then $2f$
(c) Larger then $2f$
(d) Larger than f

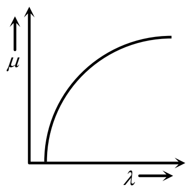
6. The graph shows how the magnification m produced by a convex thin lens varies with image distance v. What was the focal length of the used [DPMT 1995]

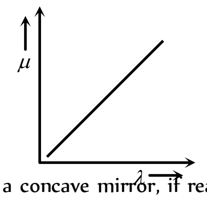


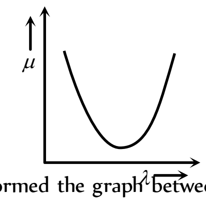
(a) $\frac{b}{c}$
(b) $\frac{b}{ca}$
(c) $\frac{bc}{a}$
(d) $\frac{c}{b}$

7. Which of the following graphs shows appropriate variation of refractive index μ with wavelength λ

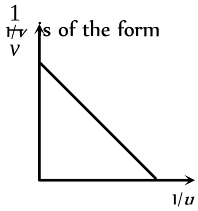
(a) 

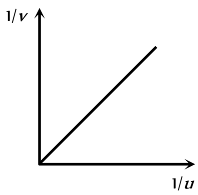
(b) 

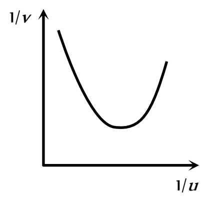
(c) 

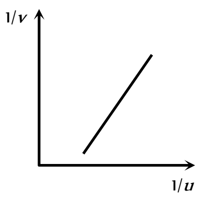
(d) 

8. For a concave mirror, if real image is formed the graph between $\frac{1}{u}$ and $\frac{1}{v}$ is of the form

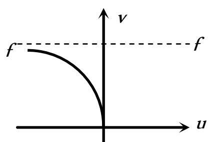
(a) 

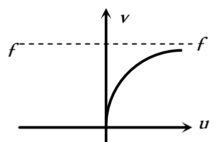
(b) 

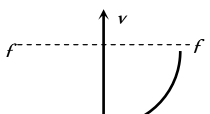
(c) 

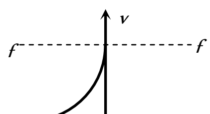
(d) 

9. The graph between u and v for a convex mirror is

(a) 

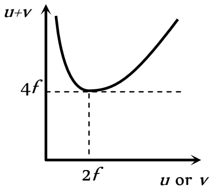
(b) 

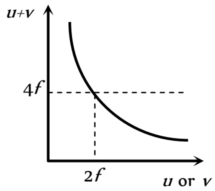


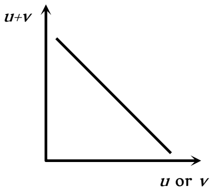


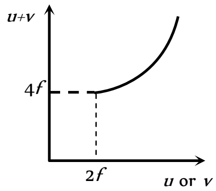
(c) (d)

10. For a convex lens, if real image is formed the graph between $(u + v)$ and u or v is as follows

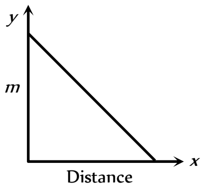
(a)


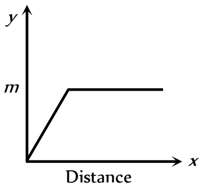
(b)


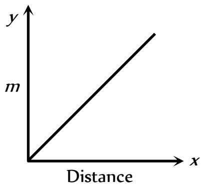
(c)


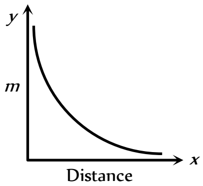
(d)


11. Which of the following graphs is the magnification of a real image against the distance from the focus of a concave mirror

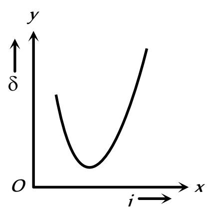
(a)


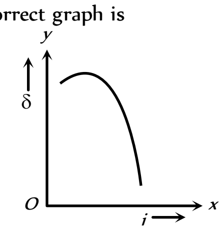
(b)


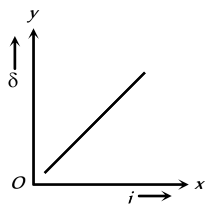
(c)


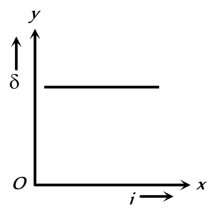
(d)


12. A graph is plotted between angle of deviation (δ) and angle of incidence (i) for a prism. The nearly correct graph is

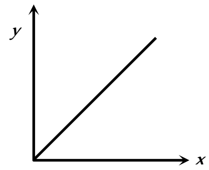
(a)


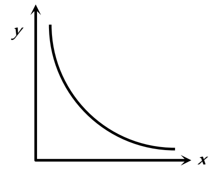
(b)


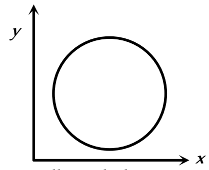
(c)


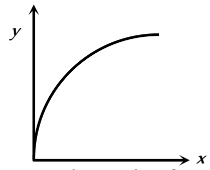
(d)


13. If x is the distance of an object from the focus of a concave mirror and y is the distance of image from the focus, then which of the following graphs is correct between x and y

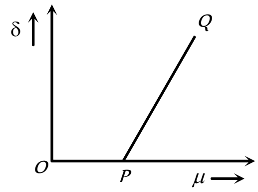
(a)


(b)


(c)


(d)


14. For a small angled prism, angle of prism A, the angle of minimum deviation (δ) varies with the refractive index of the prism as shown in the graph



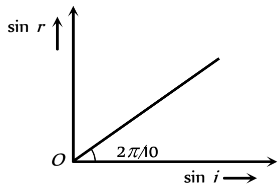
(a) Point P corresponds to $\mu = 1$

(b) Slope of the line $PQ = A/2$

(c) Slope $= A$

(d) None of the above statements is true

15. The graph between sine of angle of refraction (sin r) in medium 2 and sine of angle of incidence (sin i) in medium 1 indicates that (tan 36° $\approx \frac{3}{4}$)



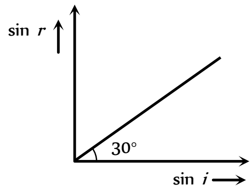
(a) Total internal reflection can take place

(b) Total internal reflection cannot take place

(c) Any of (a) and (b)

(d) Data is incomplete

16. A medium shows relation between i and r as shown. If speed of light in the medium is nc then value of n is



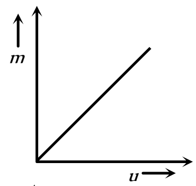
(a) 1.5

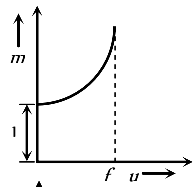
(b) 2

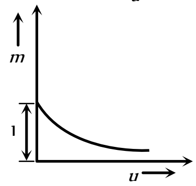
(c) 2

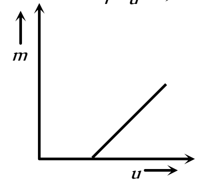
(d) 3

17. For a concave mirror, if virtual image is formed, the graph between m and u is of the form

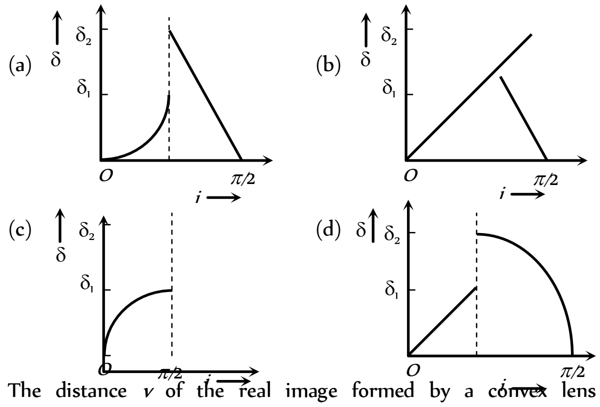
(a)


(b)


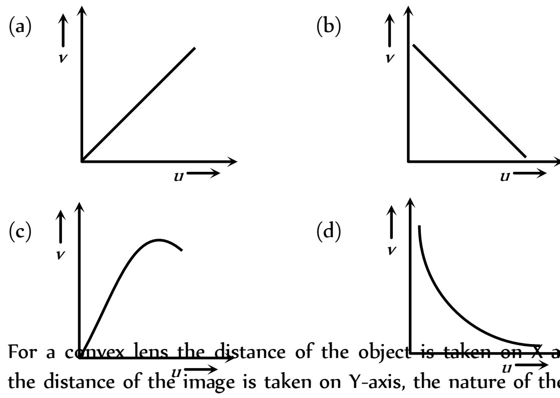
(c)


(d)


18. A ray of light travels from a medium of refractive index μ to air. Its angle of incidence in the medium is i, measured from the normal to the boundary, and its angle of deviation is δ. δ is plotted against i which of the following best represents the resulting curve



19. The distance v of the real image formed by a convex lens is measured for various object distance u. A graph is plotted between v and u, which one of the following graphs is correct



20. For a convex lens the distance of the object is taken on X-axis and the distance of the image is taken on Y-axis, the nature of the graph so obtained is [BVP 2003]

(a) Straight line (b) Circle

(c) Parabola (d) Hyperbola

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : A red object appears dark in the yellow light
   Reason : A red colour is scattered less [AIIMS 2004]

2. Assertion : The stars twinkle while the planets do not.
   Reason : The stars are much bigger in size than the planets.[AIIMS 2003]

3. Assertion : Owls can move freely during night.
   Reason : They have large number of rods on their retina.[AIIMS 2003]

4. Assertion : The air bubble shines in water.
   Reason : Air bubble in water shines due to refraction of light [AIIMS 2002]

5. Assertion : In a movie, ordinarily 24 frames are projected per second from one end to the other of the complete film.
   Reason : The image formed on retina of eye is sustained upto 1/10 second after the removal of stimulus. [AIIMS 2001]

6. Assertion : Blue colour of sky appears due to scattering of blue colour.
   Reason : Blue colour has shortest wave length in visible spectrum. [AIIMS 2001]

7. Assertion : The refractive index of diamond is $\sqrt{6}$ and that of liquid is $\sqrt{3}$. If the light travels from diamond to the liquid, it will totally reflected when the angle of incidence is 30°.
   Reason[BVP 2003] : $\mu = \dfrac{1}{\sin C}$, where μ is the refractive index of diamond with respect to liquid. [AIIMS 2000]

8. Assertion : The setting sun appears to be red.
   Reason : Scattering of light is directly proportional to the wavelength. [AIIMS 2000]

9. Assertion : A double convex lens (μ = 1.5) has focal length 10 *cm*. When the lens is immersed in water (μ = 4/3) its focal length becomes 40 *cm*.
   Reason : $\dfrac{1}{f} = \dfrac{\mu_l - \mu_m}{\mu_m}\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$ [AIIMS 1999]

10. Assertion : Different colours travel with different speed in vacuum.
    Reason : Wavelength of light depends on refractive index of medium. [AIIMS 1998]

11. Assertion : The colour of the green flower seen through red glass appears to be dark.
    Reason : Red glass transmits only red light. [AIIMS 1997]

12. Assertion : The focal length of the mirror is f and distance of the object from the focus is u, the magnification of the mirror is f/u.
    Reason : Magnification $= \dfrac{\text{Size of image}}{\text{Size of object}}$ [AIIMS 1994]

13. Assertion : If a plane glass slab is placed on the letters of different colours all the letters appear to be raised up to the same height.
    Reason : Different colours have different wavelengths.

14. Assertion : The fluorescent tube is considered better than an electric bulb.
    Reason : Efficiency of fluorescent tube is more than the efficiency of electric bulb.

15. Assertion : The polar caps of earth are cold in comparison to equatorial plane.
    Reason : The radiation absorbed by polar caps is less than the radiation absorbed by equatorial plane.

16. Assertion : The illumination of earth's surface from sun is more at noon than in the morning.

Reason : Luminance of a surface refers to brightness of the surface.

17. Assertion : When an object is placed between two plane parallel mirrors, then all the images found are of equal intensity.

Reason : In case of plane parallel mirrors, only two images are possible.

18. Assertion : The mirrors used in search lights are parabolic and not concave spherical.

Reason : In a concave spherical mirror the image formed is always virtual.

19. Assertion : The size of the mirror affect the nature of the image.

Reason : Small mirrors always forms a virtual image.

20. Assertion : Just before setting, the sun may appear to be elliptical. This happens due to refraction.

Reason : Refraction of light ray through the atmosphere may cause different magnification in mutually perpendicular directions.

21. Assertion : Critical angle of light passing from glass to air is minimum for violet colour.

Reason : The wavelength of blue light is greater than the light of other colours.

22. Assertion : We cannot produce a real image by plane or convex mirrors under any circumstances.

Reason : The focal length of a convex mirror is always taken as positive.

23. Assertion : A piece of red glass is heated till it glows in dark. The colour of glowing glass would be orange.

Reason : Red and orange is complementary colours.

24. Assertion : Within a glass slab, a double convex air bubble is formed. This air bubble behaves like a converging lens.

Reason : Refractive index of air is more than the refractive index of glass.

25. Assertion : The images formed by total internal reflections are much brighter than those formed by mirrors or lenses.

Reason : There is no loss of intensity in total internal reflection.

26. Assertion : The focal length of lens does not change when red light is replaced by blue light.

Reason : The focal length of lens does not depends on colour of light used.

27. Assertion : There is no dispersion of light refracted through a rectangular glass slab.

Reason : Dispersion of light is the phenomenon of splitting of a beam of white light into its constituent colours.

28. Assertion : All the materials always have the same colour, whether viewed by reflected light or through transmitted light.

Reason : The colour of material does not depend on nature of light.

29. Assertion : A beam of white light gives a spectrum on passing through a hollow prism.

Reason : Speed of light outside the prism is different from the speed of light inside the prism.

30. Assertion : By increasing the diameter of the objective of telescope, we can increase its range.

Reason : The range of a telescope tells us how far away a star of some standard brightness can be spotted by telescope.

31. Assertion : For the sensitivity of a camera, its aperture should be reduced.

Reason : Smaller the aperture, image focussing is also sharp.

32. Assertion : If objective and eye lenses of a microscope are interchanged then it can work as telescope.

Reason : The objective of telescope has small focal length.

33. Assertion : The illuminance of an image produced by a convex lens is greater in the middle and less towards the edges.

Reason : The middle part of image is formed by undeflected rays while outer part by inclined rays.

34. Assertion : Although the surfaces of a goggle lens are curved, it does not have any power.

Reason : In case of goggles, both the curved surfaces have equal radii of curvature.

35. Assertion : The resolving power of an electron microscope is higher than that of an optical microscope.

Reason : The wavelength of electron is more than the wavelength of visible light.

36. Assertion : If the angles of the base of the prism are equal, then in the position of minimum deviation, the refracted ray will pass parallel to the base of prism.

Reason : In the case of minimum deviation, the angle of incidence is equal to the angle of emergence.

37. Assertion : Dispersion of light occurs because velocity of light in a material depends upon its colour.

Reason : The dispersive power depends only upon the material of the prism, not upon the refracting angle of the prism.

38. Assertion : An empty test tube dipped into water in a beaker appears silver, when viewed from a suitable direction.

Reason : Due to refraction of light, the substance in water appears silvery.

39. Assertion : Spherical aberration occur in lenses of larger aperture.

Reason : The two rays, paraxial and marginal rays focus at different points.

40. Assertion : It is impossible to photograph a virtual image.

Reason : The rays which appear diverging from a virtual image fall on the camera and a real image is captured.

41. Assertion : The speed of light in a rarer medium is greater than that in a denser medium

Reason : One light year equals to 9.5×10^{12} *km*

[AIIMS 1999]

42. Assertion : The frequencies of incident, reflected and refracted beam of monochromatic light incident from one medium to another are same

Reason : The incident, reflected and refracted rays are coplanar [EAMCET (Engg.) 2000]

43. Assertion : The refractive index of a prism depends only on the kind of glass of which it is made of and the colour of light

Reason : The refractive index of a prism depends upon the refracting angle of the prism and the angle of minimum deviation [AIIMS 2000]

44. Assertion : The resolving power of a telescope is more if the diameter of the objective lens is more.

Reason : Objective lens of large diameter collects more light.[AIIMS

45. Assertion : By roughening the surface of a glass sheet its transparency can be reduced.

Reason : Glass sheet with rough surface absorbs more light.[AIIMS

46. Assertion : Diamond glitters brilliantly.

Reason : Diamond does not absorb sunlight.

[AIIMS 2005]

47. Assertion : The cloud in sky generally appear to be whitish.

Reason : Diffraction due to cloud is efficient in equal measure at all wavelengths. [AIIMS 2005]

Answers

Plane Mirror

1	d	2	b	3	b	4	c,d	5	c
6	c	7	d	8	b	9	b	10	c
11	b	12	d	13	a	14	c	15	c
16	b	17	c	18	b	19	c	20	a
21	c	22	b	23	c	24	b	25	b
26	b	27	c	28	c	29	c	30	c
31	b	32	a	33	b	34	c		

Spherical Mirror

1	a	2	c	3	d	4	c	5	a
6	b	7	c	8	b	9	a	10	b
11	d	12	b	13	b	14	b	15	c
16	d	17	b	18	b	19	a	20	a
21	a	22	b	23	d	24	d	25	b
26	bc	27	c	28	b	29	a	30	b
31	d	32	c	33	a	34	d	35	d
36	b	37	d	38	d	39	d	40	a
41	d	42	d	43	a	44	a		

Refraction of Light at Plane Surfaces

1	d	2	a	3	b	4	a	5	d
6	a	7	c	8	d	9	c	10	a
11	b	12	d	13	b	14	a	15	b
16	a	17	c	18	c	19	d	20	a
21	b	22	b	23	c	24	a	25	c
26	a	27	b	28	d	29	a	30	c
31	c	32	c	33	b	34	b	35	b
36	b	37	a	38	b	39	c	40	d
41	a	42	d	43	c	44	c	45	a
46	a	47	c	48	a	49	c	50	c
51	d	52	b	53	b	54	b	55	b
56	a	57	d	58	b	59	c	60	b
61	d	62	a	63	b	64	d	65	b
66	a	67	b	68	b	69	a	70	d
71	c	72	c	73	d	74	d	75	b
76	d	77	c	78	c	79	b	80	b
81	a	82	a	83	b	84	b	85	c
86	b	87	d	88	d	89	b	90	d

Total Internal Reflection

1	b	2	c	3	d	4	d	5	c
6	c	7	b	8	c	9	a	10	d
11	b	12	c	13	c	14	d	15	d
16	c	17	c	18	cd	19	c	20	d
21	a	22	c	23	b	24	c	25	a
26	c	27	c	28	a	29	d	30	d
31	a	32	c	33	a	34	c	35	a
36	d	37	b	38	b	39	c	40	a
41	c	42	b	43	b	44	d	45	B
46	a								

Refraction at Curved Surface

1	a	2	a	3	d	4	c	5	a
6	d	7	b	8	a	9	c	10	c
11	c	12	d	13	b	14	c	15	b
16	d	17	c	18	d	19	c	20	c
21	c	22	a	23	d	24	a	25	d
26	a	27	b	28	a	29	a	30	c
31	c	32	d	33	d	34	c	35	b
36	b	37	c	38	d	39	b	40	d
41	a	42	c	43	a	44	c	45	d
46	d	47	c	48	b	49	a	50	b
51	c	52	a	53	a	54	b	55	a

56	b	57	a	58	a	59	d	60	c
61	b	62	b	63	d	64	d	65	d
66	a	67	d	68	c	69	c	70	b
71	d	72	b	73	a	74	c	75	a
76	c	77	a	78	b	79	b	80	d
81	c	82	a	83	d	84	a	85	c
86	c	87	b	88	a	89	a	90	b
91	b	92	d	93	c	94	a	95	c
96	c	97	c	98	a	99	d	100	a
101	a	102	d	103	c	104	d	105	a
106	c	107	b	108	a	109	d	110	b
111	c	112	c	113	c	114	d	115	a
116	c	117	a	118	d	119	c	120	b
121	c	122	d	123	a	124	b	125	d
126	c	127	d	128	b	129	b	130	c
131	b	132	b	133	b	134	d	135	b
136	d	137	d	138	b	139	a	140	c
141	b	142	b	143	c	144	b	145	c

Prism Theory & Dispersion of Light

1	b	2	b	3	b	4	c	5	c
6	a	7	a	8	d	9	d	10	d
11	c	12	b	13	b	14	a	15	a
16	b	17	d	18	a	19	d	20	b
21	a	22	c	23	a	24	a	25	b
26	c	27	c	28	b	29	a	30	a
31	c	32	b	33	a	34	c	35	d
36	a	37	b	38	a	39	d	40	b
41	b	42	b	43	a	44	c	45	a
46	c	47	b	48	a	49	c	50	c
51	c	52	a	53	d	54	d	55	a
56	c	57	a	58	a	59	a	60	c
61	c	62	b	63	d	64	d	65	a
66	b	67	c	68	c	69	b	70	c
71	a	72	d	73	a	74	b	75	a
76	b	77	b	78	b	79	d	80	a
81	b	82	a	83	b	84	c	85	a
86	c	87	c	88	a	89	b	90	b
91	c	92	a	93	c	94	c	95	b
96	c	97	c	98	a	99	a	100	c
101	a	102	b	103	a	104	b	105	d
106	b	107	b	108	a	109	b	110	a
111	a	112	d	113	a	114	b	115	a
116	d	117	d	118	d	119	c	120	d
121	a	122	d	123	c	124	d	125	b
126	a	127	c	128	c	129	d	130	a

131	a	132	c	133	a	134	c	135	b
136	c	137	a	138	d	139	c	140	b
141	a	142	a	143	b	144	b	145	a
146	a	147	d	148	b	149	c	150	a
151	c								

Human Eye and Lens Camera

1	c	2	a	3	b	4	d	5	b
6	c	7	b	8	a	9	d	10	a
11	c	12	c	13	a	14	b	15	d
16	b	17	c	18	c	19	b	20	c
21	b	22	a	23	a	24	a	25	d
26	a	27	d	28	c	29	b	30	c
31	c	32	c	33	b	34	b	35	a
36	c	37	d	38	a	39	d	40	a
41	b	42	c	43	d	44	a	45	b
46	b	47	d	48	d	49	b	50	b
51	c	52	a	53	a	54	c	55	d
56	a	57	a	58	d	59	a	60	d
61	d	62	a	63	b	64	d	65	a

Microscope and Telescope

1	c	2	b	3	b	4	b	5	b
6	d	7	c	8	a	9	b	10	b
11	a	12	b	13	b	14	a	15	c
16	d	17	a	18	b	19	b	20	b
21	a	22	d	23	c	24	a	25	d
26	c	27	c	28	d	29	d	30	b
31	a	32	d	33	d	34	c	35	d
36	b	37	a	38	a	39	b	40	d
41	d	42	b	43	d	44	a	45	c
46	b	47	b	48	d	49	b	50	d
51	c	52	a	53	a	54	a	55	b
56	a	57	d	58	d	59	c	60	c
61	c	62	a	63	b	64	a	65	b
66	a	67	a	68	c	69	a	70	b
71	c	72	b	73	a	74	a	75	b
76	d	77	c	78	b	79	a	80	c
81	b	82	b	83	b	84	a	85	b
86	abcd	87	a	88	a	89	b	90	c
91	b	92	d	93	c	94	d	95	c
96	c	97	d	98	a	99	b	100	d
101	c	102	b	103	a	104	b	105	b
106	c	107	c	108	a	109	c	110	c
111	d	112	a	113	d	114	a	115	a

116	a	117	b	118	a	119	a	120	a

Photometry

1	d	2	b	3	d	4	c	5	d
6	b	7	a	8	b	9	c	10	c
11	a	12	c	13	c	14	c	15	a
16	a	17	b	18	b	19	c	20	b
21	c	22	c	23	a	24	b	25	bc
26	c	27	d	28	b	29	d	30	b
31	d	32	a	33	d	34	d	35	a
36	c	37	c	38	d	39	d	40	c
41	c								

Critical Thinking Questions

1	d	2	b	3	b	4	a	5	d
6	b	7	b	8	a	9	b	10	c
11	a	12	b	13	b	14	a	15	b
16	b	17	a	18	b	19	c	20	c
21	c	22	d	23	d	24	ad	25	c
26	b	27	d	28	d	29	d	30	d
31	b	32	a	33	d	34	c	35	c
36	d	37	a	38	b	39	a	40	c
41	c	42	d	43	b	44	a	45	b
46	c	47	c	48	c	49	a	50	d
51	d	52	c	53	b	54	a	55	b
56	d	57	c	58	b	59	d	60	b
61	d	62	a	63	a	64	a	65	c
66	c	67	b	68	b	69	b	70	d
71	b	72	d	73	b	74	d	75	a
76	c	77	c	78	b	79	b		

Graphical Questions

1	c	2	a	3	bc	4	c	5	c
6	d	7	a	8	a	9	a	10	a
11	d	12	a	13	b	14	ac	15	b
16	d	17	b	18	a	19	d	20	d

Assertion and Reason

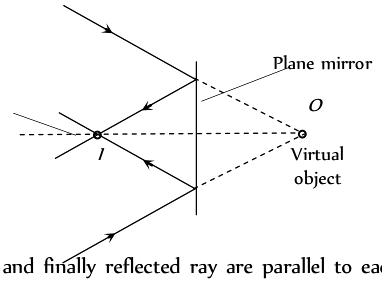
1	b	2	b	3	c	4	c	5	c
6	a	7	e	8	c	9	a	10	e
11	a	12	a	13	e	14	a	15	c
16	b	17	d	18	c	19	d	20	a
21	c	22	e	23	d	24	d	25	a
26	d	27	b	28	d	29	d	30	b
31	c	32	d	33	a	34	a	35	c
36	a	37	b	38	c	39	a	40	e
41	b	42	b	43	c	44	a	45	c
46	b	47	c						

Answers and Solutions

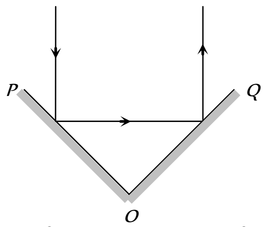
Plane Mirror

1. (d) $\delta = (360 - 2\theta) = (360 - 2 \times 60) = 240^o$

2. (b) When converging beam incident on plane mirror, real image is formed as shown

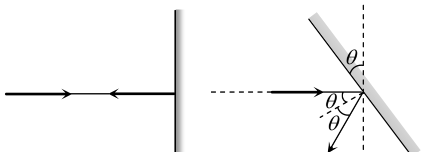


3. (b) Incident ray and finally reflected ray are parallel to each other means $\delta = 180^o$

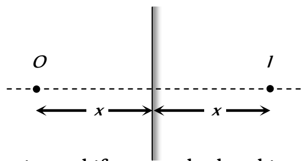


From $\delta = 360 - 2\theta \Rightarrow 180 = 360 - 2\theta \Rightarrow \theta = 90^o$

4. (c, d) By keeping the incident ray is fixed, if plane mirror rotates through an angle θ reflected ray rotates through an angle 2θ.

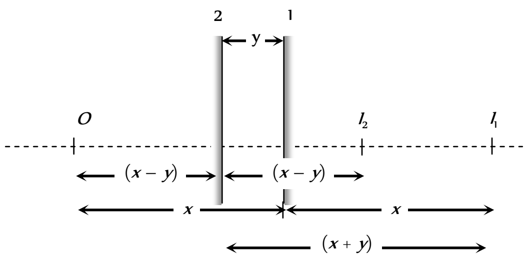


5. (c) Suppose at any instant, plane mirror lies at a distance x from object. Image will be formed behind the mirror at the same distance x.



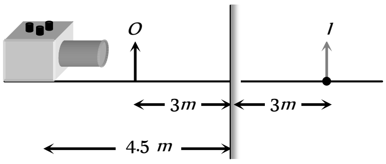
When the mirror shifts towards the object by distance 'y' the image shifts $= x + y - (x - y) = 2y$

So speed of image = 2 × speed of mirror

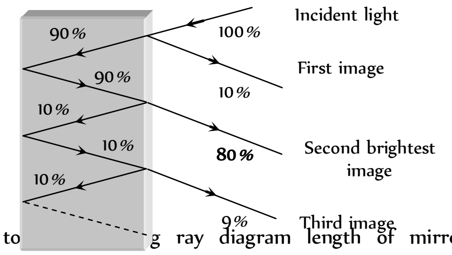


6. (c) Number of images $=\left(\frac{360}{\theta}-1\right)=\left(\frac{360}{60}-1\right)=5$

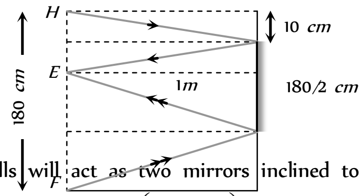
7. (d) F using distance of image = 4.5 m + 3 m = 7.5 m.



8. (b) Several images will be formed but second image will be brightest



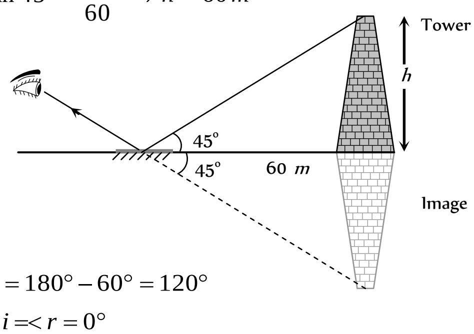
9. (b) According to ray diagram length of mirror $=\frac{1}{2}(10+170)=90\,cm$



10. (c) The walls will act as two mirrors inclined to each other at $90°$ and so will form $\left(\frac{360}{90}-1\right)=4-1$ *i.e.* 3 images of the person. Now these images with person will act as objects for the ceiling mirror and so ceiling mirror will form 4 images further. Therefore total number of images formed $=3+3+1=7$

Note : He can see. 6 images of himself.

11. (b) $\tan 45°=\frac{h}{60}\ \Rightarrow h=60\,m$



12. (d) $\delta=180°-60°=120°$

13. (a) $<i=<r=0°$

14. (c) When light is reflected from denser medium, a phase difference of π always occurs.

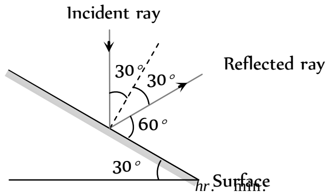
15. (c) Ray after reflection from three mutually perpendicular mirrors becomes anti-parallel.

16. (b) In two images man will see himself using left hand.

17. (c) In plane mirror, size of the image is independent of the angle of incidence.

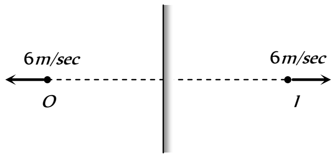
18. (b) Size of image formed by a plane mirror is same as that of the object. Hence its magnification will be 1.

19. (c)



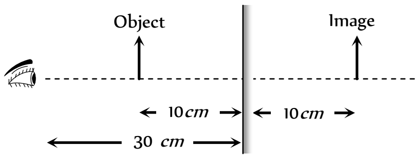
20. (a) Subtract the given time from $11:60$

21. (c) Relative velocity of image $w.r.t.$ object $=6-(-6)=12\,m/\sec$



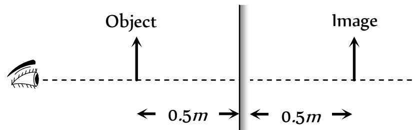
22. (b)

23. (c) See following ray diagram

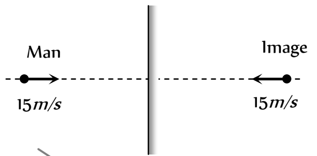


The distance focussed for eye $=30+10=40\,cm$

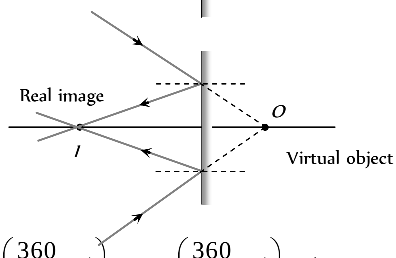
24. (b) Distance between object and image $=0.5+0.5=1\,m$



25. (b) Relative velocity of image $w.r.t.$ man $=15-(-15)=30\ m/s$



26. (b)



27. (c) $n=\left(\frac{360}{\theta}-1\right)\Rightarrow n=\left(\frac{360}{72}-1\right)=4$

28. (c) $n=\left(\frac{360}{\theta}-1\right)\Rightarrow 3=\left(\frac{360}{\theta}-1\right)\Rightarrow \theta=90°$

29. (c)

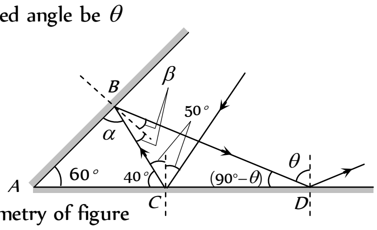
30. (c) $n=\frac{360}{45}-1=7$

31. (b) Diminished, erect image is formed by convex mirror.

32. (a) When a mirror is rotated by an angle θ, the reflected ray deviate from its original path by angle 2θ.

33. (b) $f = \frac{R}{2}$, and $R = \infty$ for plane mirror.

34. (c) Let required angle be θ



From geometry of figure

In Δ ABC; $\alpha = 180° - (60° + 40°) = 80°$

$\Rightarrow \beta = 90° - 80° = 10°$

In Δ ABD; $\angle A = 60°$, $\angle B = (\alpha + 2\beta)$

$= (80 + 2 \times 10) = 100°$ and $\angle D = (90° - \theta)$

$\because \angle A + \angle B + \angle D = 180° \Rightarrow 60° + 100° + (90° - \theta) = 180° \Rightarrow \theta = 70°$

Spherical Mirror

1. (a) $m = +\frac{1}{n} = -\frac{v}{u} \Rightarrow v = -\frac{u}{n}$

By using mirror formula $\frac{1}{f} = \frac{1}{-\frac{u}{n}} + \frac{1}{u} \Rightarrow u = -(n-1)f$

2. (c)

3. (d)

4. (c) $\frac{I}{O} = \frac{f}{(f-u)} \Rightarrow \frac{I}{+5} = \frac{-10}{-10-(-100)} \Rightarrow I = 0.55\ cm$

5. (a) For real image $m = -2$, so by using $m = \frac{f}{f-u}$

$\Rightarrow -2 = \frac{-50}{-50-u} \Rightarrow u = -75\ cm$

6. (b) By using $\frac{I}{O} = \frac{f}{f-u}$

$\Rightarrow \frac{I}{+(7.5)} = \frac{(25/2)}{\left(\frac{25}{2}\right)-(-40)} \Rightarrow I = 1.78\ cm$

7. (c)

8. (b) $\frac{I}{O} = \frac{f}{f-u}$; where $u = f + x$ $\therefore \frac{I}{O} = -\frac{f}{x}$

9. (a) Image formed by convex mirror is virtual for real object placed anywhere.

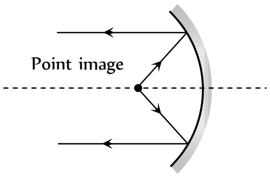
10. (b) Given $u = (f + x_1)$ and $v = (f + x_2)$

The focal length $f = \frac{uv}{u+v} = \frac{(f+x_1)(f+x_2)}{(f+x_1)+(f+x_2)}$

On solving, we get $f^2 = x_1 x_2$ or $f = \sqrt{x_1 x_2}$

11. (d) The image formed by a convex mirror is always virtual.

12. (b) Object should be placed on focus of concave mirror.



13. (b) $m = \frac{f}{(f-u)} \Rightarrow \left(+\frac{1}{4}\right) = \frac{(+30)}{(+30)-u} \Rightarrow u = -90\ cm$

14. (b) Size is $\frac{1}{5}$. It can't be plane and concave mirror, because both conditions are not satisfied in plane or concave mirror. Convex mirror can meet all the requirements.

15. (c) Plane mirror and convex mirror always forms erect images. Image formed by concave mirror may be erect or inverted depending on position of object.

16. (d) Virtual image is seen on the photograph.

17. (b) $\because m = -\frac{v}{u}$ also $\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{u}{f} = \frac{u}{v} + 1$

$\Rightarrow -\frac{u}{v} = 1 - \frac{u}{f} \Rightarrow \frac{-v}{u} = \frac{f}{f-u}$ so $m = \frac{f}{f-u}$.

18. (b) To make the light diverging as much as possible.

19. (a) Let distance $= u$. Now $\frac{v}{u} = 16$ and $v = u + 120$

$\therefore \frac{120+u}{u} = 16 \Rightarrow 15u = 120 \Rightarrow u = 8\ cm$.

20. (a) Virtual image formed is larger in size in case of concave mirror.

21. (a) Real, inverted and same in size because object is at the centre of curvature of the mirror.

22. (b) Image is virtual so $m = +3$. and $f = \frac{R}{2} = 18\ cm$

So from $m = \frac{f}{f-u} \Rightarrow 3 = \frac{(-18)}{(-18)-u} \Rightarrow u = -12\ cm$.

23. (d) $f = \frac{R}{2} = 20\,cm$, $m = 2$ For real image; $m = -2$,

By using $m = \frac{f}{f-u}$, $-2 = \frac{-20}{-20-u} \Rightarrow u = -30\,cm$

For virtual image; $m = +2$

So, $+2 = \frac{-20}{-20-u} \Rightarrow u = -10\,cm$

24. (d) Convex mirror always forms, virtual, erect and smaller image.

25. (b) When object is placed. Between focus and pole, image formed is erect, virtual and enlarged.

26. (b, c) Convex mirror and concave lens form virtual image for all positions of object.

27. (c) Here focal length $= f$ and $u = -f$

On putting these values in $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$\Rightarrow \frac{1}{f} = -\frac{1}{f} + \frac{1}{v} \Rightarrow v = \frac{f}{2}$

28. (b) Erect and enlarged image can produced by concave mirror.

$\frac{I}{O} = \frac{f}{f-u} \Rightarrow \frac{+3}{+1} = \frac{f}{f-(-4)} \Rightarrow f = -6\,cm$

$\Rightarrow R = 2f = -12\,cm$

29. (a)

30. (b) $m = \frac{f}{f-u} \Rightarrow -3 = \frac{f}{f-(-20)} \Rightarrow f = -15\,cm$

31. (d) When object is kept at centre of curvature. It's real image is also formed at centre of curvature.

32. (c) $u = -20\,cm$, $f = +10\,cm$ also $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

$\Rightarrow \frac{1}{+10} = \frac{1}{v} + \frac{1}{(-20)} \Rightarrow v = \frac{20}{3}\ cm$; virtual image.

33. (a) Mirror formula
$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}\Rightarrow\frac{1}{f}=\frac{1}{-20}+\frac{1}{(-10)}\Rightarrow f=\frac{20}{3}\,cm$. If object moves towards the mirror by $0.1\,cm$ then.

$u=(10-0.1)=9.9\,cm$. Hence again from mirror formula

$\frac{1}{-20/3}=\frac{1}{v'}+\frac{1}{-9.9}\Rightarrow v'=20.4\,cm$ i.e. image shifts away from the mirror by $0.4\,cm$.

34. (d) Image formed by convex mirror is always. Erect diminished and virtual.

35. (d) $f=\frac{R}{2}\Rightarrow R=40\,cm$

36. (b) $f=-15\,cm,\ m=+2$ (Positive because image is virtual)

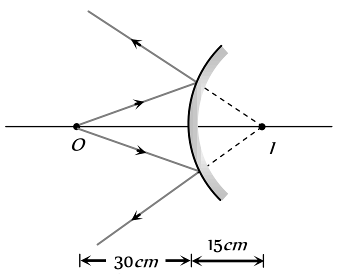
$\because m=-\frac{v}{u}\Rightarrow v=-2u$. By using mirror formula

$\frac{1}{-15}=\frac{1}{(-2u)}+\frac{1}{u}\Rightarrow u=-7.5\,cm$

37. (d) $u=-30\,cm,\ f=+30\,cm$, by using mirror formula

$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}\Rightarrow\frac{1}{+30}=\frac{1}{v}+\frac{1}{(-30)}$

$v=15\,cm$, behind the mirror



38. (d) $R=-30\,cm\Rightarrow f=-15\,cm$

$O=+2.5\,cm,\ u=-10\,cm$

By mirror formula $\frac{1}{-15}=\frac{1}{v}+\frac{1}{(-10)}\Rightarrow v=30\,cm$.

Also $\frac{I}{O}=-\frac{v}{u}\Rightarrow\frac{I}{(+2.5)}=-\frac{30}{(-10)}\Rightarrow I=+7.5\,cm$.

39. (d)

40. (a) $\frac{I}{O}=\frac{f}{f-u}\Rightarrow\frac{I}{+6}=\frac{-f}{-f-(-4f)}\Rightarrow I=-2\,cm$.

41. (d) Convergence (or power) is independent of medium for mirror.

42. (d) $\frac{I}{O}=\frac{f}{f-u}\Rightarrow\frac{I}{2}=\frac{20}{20+20}=\frac{1}{2}\Rightarrow I=1\,mm$

43. (a) $m=\pm 3$ and $f=-6\,cm$

Now $m=\frac{f}{f-u}\Rightarrow\pm 3=\frac{-6}{-6-u}$

For real image $-3=\frac{-6}{-6-u}\Rightarrow u=-8\,cm$

For virtual image $3=\frac{-6}{-6-u}\Rightarrow u=-4\,cm$

44. (a) Focal length of the mirror remains unchanged.

Refraction of Light at Plane Surfaces

1. (d)

2. (a) $\mu_{blue}>\mu_{red}$

3. (b) $\mu\propto\frac{1}{\lambda},\lambda_r>\lambda_v$

4. (a) $\lambda_{medium}=\frac{\lambda_{air}}{\mu}=\frac{6000}{1.5}=4000\,Å$

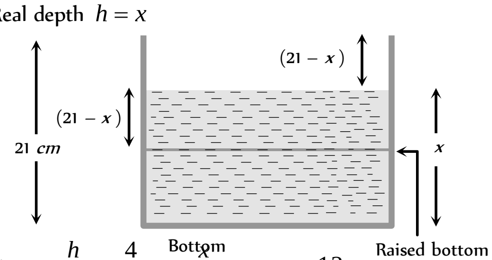
5. (d) Velocity and wavelength change but frequency remains same.

6. (a) $\mu=\frac{c}{v}=\frac{c}{v\lambda}=\frac{3\times10^8}{4\times10^{14}\times5\times10^{-7}}=1.5$

7. (c) To see the container half-filled from top, water should be filled up to height x so that bottom of the container should appear to be raised upto height $(21-x)$.

As shown in figure apparent depth $h'=(21-x)$

Real depth $h=x$



$\therefore\ \mu=\frac{h}{h'}\Rightarrow\frac{4}{3}=\frac{x}{21-x}\Rightarrow x=12\,cm$

8. (d) In vacuum, the speed of light is independent of wave length. Thus vacuum (or air) is a non dispersive medium in which all colours travel with the same speed.

9. (c) $\lambda\propto\frac{1}{\mu}\Rightarrow\frac{\lambda_1}{\lambda_2}=\frac{\mu_2}{\mu_1}=\frac{\mu}{1}$

10. (a) $v\propto\frac{1}{\mu},\mu_{\text{rarer}}<\mu_{\text{denser}}$

11. (b) $\mu\propto\frac{1}{\lambda}$

12. (d) $v=\frac{c}{\mu}=\frac{3\times10^8}{2}=1.5\times10^8\,m/s=1.5\times10^{10}\,cm/s$

13. (b) $\because\ \angle i>\angle r$, it means light ray is going from rarer medium (A) to denser medium.

So $v(A)>v(B)$ and $n(A)<n(B)$

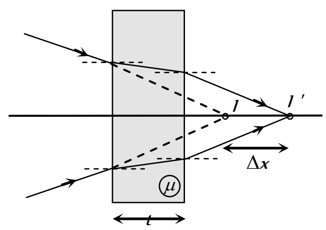
14. (a) $\mu=\frac{h}{h'}\Rightarrow h'=\frac{8}{4/3}=6\,m$

15. (b) $h'=\frac{d_1}{\mu_1}+\frac{d_2}{\mu_2}=d\left(\frac{1}{\mu_1}+\frac{1}{\mu_2}\right)$

16. (a) Normal

shift $\Delta x=\left(1-\frac{1}{\mu}\right)t$

and shift takes place in direction of ray.



17. (c)

$\text{time}=\frac{\text{distance}}{\text{speed}}=\frac{t}{c/x}=\frac{nt}{c}$

18. (c) Let ν' and λ' represents frequency and wavelength of light in medium respectively.

so $\nu' = \frac{v}{\lambda'} = \frac{c/\mu}{\lambda/\mu} = \frac{c}{\lambda} = \nu$

19. (d) $\mu = \frac{c_a}{c_w} = \frac{t_w}{t_a} \Rightarrow t_w = \frac{25}{3} \times \frac{4}{9} = 11\frac{1}{9} = 11\ min\ 6\ sec$

20. (a) Optical path = μt

In medium (1), optical path = $\mu_1 d_1$

In medium (2), optical path = $\mu_2 d_2$

$\therefore$ Total path = $\mu_1 d_1 + \mu_2 d_2$

21. (b) Refractive index of liquid C is same as that of glass piece. So it will not be visible in liquid C.

22. (b) ${}_a\mu_g = \frac{3}{2}$, ${}_a\mu_w = \frac{4}{3}$

$\therefore {}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} = \frac{3/2}{4/3} = \frac{9}{8}$

23. (c) ${}_2\mu_1 \times {}_3\mu_2 \times {}_4\mu_3 = \frac{\mu_1}{\mu_2} \times \frac{\mu_2}{\mu_3} \times \frac{\mu_3}{\mu_4} = \frac{\mu_1}{\mu_4} = {}_4\mu_1 = \frac{1}{{}_1\mu_4}$

24. (a) Colour of light is determined by its frequency and as frequency does not change, colour will also not change and will remains green.

25. (c) Ray optics fails if the size of the object is of the order of the wavelength.

26. (a) ${}_a n_w \times {}_w n_{gl} \times {}_{gl} n_{gas} \times {}_{gas} n_a = \frac{n_w}{n_a} \times \frac{n_{gl}}{n_w} \times \frac{n_{gas}}{n_{gl}} \times \frac{n_a}{n_{gas}} = 1$

27. (b) $v \propto \lambda \Rightarrow \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

$\therefore v_2 = \frac{v_1}{\lambda_1} \times \lambda_2 = 3 \times 10^8 \times \frac{4500}{6000} = 2.25 \times 10^8\ m/s$

28. (d) Since ${}_a\mu_g = \sqrt{2}$, so ${}_g\mu_a = \frac{\sin i}{\sin r} = \frac{1}{\sqrt{2}}$

$\therefore \sin r = 1 \Rightarrow r = 90^o$

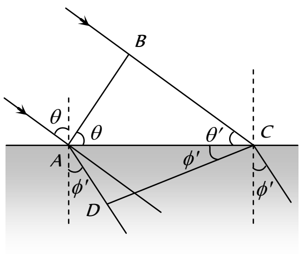
29. (a) $\mu = \frac{c}{v} = \frac{1/\sqrt{\mu_o \varepsilon_o}}{1/\sqrt{\mu\varepsilon}} = \sqrt{\frac{\mu\varepsilon}{\mu_o \varepsilon_o}}$

30. (c) $\mu \propto \frac{1}{\lambda} \Rightarrow \frac{1}{4/3} = \frac{x}{4200} \Rightarrow x = 3150\ Å$

31. (c) $\mu = \sqrt{\frac{\mu\,\varepsilon}{\mu_0 \varepsilon_0}} = \sqrt{\mu_r K}$

32. (c) $\mu = \frac{C}{C_m} \Rightarrow C_m = \frac{C}{1.5}$

33. (b) In the case of refraction if CD is the refracted wave front and v and v are the speed of light in the two media, then in the time the wavelets from B reaches C, the wavelet from A will reach D, such that



$t = \frac{BC}{v_a} = \frac{AD}{v_g} \Rightarrow \frac{BC}{AD} = \frac{v_a}{v_g}$

But in ΔACB, $BC = AC\sin\theta$ .....(ii)

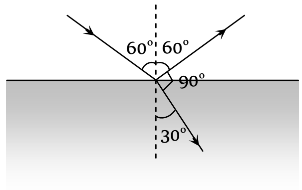
while in ΔACD, $AD = AC\sin\phi'$ .....(iii)

From equations (i), (ii) and (iii) $\frac{v_a}{v_g} = \frac{\sin\theta}{\sin\phi'}$

Also $\mu \propto \frac{1}{v} \Rightarrow \frac{v_a}{v_g} = \frac{\mu_g}{\mu_a} = \frac{\sin\theta}{\sin\phi'} \Rightarrow \mu_g = \frac{\sin\theta}{\sin\phi'}$

34. (b)

35. (b) From figure



$< i = 60^o$, $< r = 30^o$

so $\mu = \frac{\sin 60}{\sin 30} = \sqrt{3}$

36. (b) $\mu \propto \frac{1}{v} \Rightarrow \frac{\mu_g}{\mu_w} = \frac{v_w}{v_g} \Rightarrow \frac{3/2}{4/3} = \frac{v_w}{2 \times 10^8}$

$\Rightarrow v_w = 2.25 \times 10^8\ m/s$

37. (a) $\lambda_m = \frac{\lambda_a}{\mu} = \frac{c}{\nu\mu} = \frac{3 \times 10^8}{5 \times 10^{14} \times 1.5} = 4000\ Å$

38. (b) $\lambda_{glass} = \frac{\lambda_{air}}{\mu} = \frac{7200}{1.5} = 4800\ Å$

39. (c)

40. (d) $\frac{{}_a\mu_r}{{}_w\mu_r} = \frac{\mu_r/\mu_a}{\mu_r/\mu_w} = \frac{\mu_w}{\mu_a} = {}_a\mu_w$

41. (a) $t = \frac{\mu x}{c} = \frac{\frac{3}{2} \times 5 \times 10^{-3}}{3 \times 10^8} = 0.25 \times 10^{-10}\ s$

42. (d) Distance $= v \times t = \frac{c}{\mu} \times t = \frac{3 \times 10^8}{1.5} \times 10^{-9}$

$= 0.2\ m = 20\ cm.$

43. (c) $f \propto \frac{1}{\lambda}$. As $\lambda_b < \lambda_g \Rightarrow f_b > f_g$

44. (c) Real depth = $1\ m$

Apparent depth = $1 - 0.1 = 0.9\ m$

Refractive index $\mu = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{1}{0.9} = \frac{10}{9}$

45. (a) $\mu = \frac{h}{h'} \Rightarrow h' = \frac{h}{n}$

46. (a) Refractive index $\propto \frac{1}{(\text{Temperatu re})}$

47. (c) Snell's law in vector form is $\hat{i} \times \hat{n} = \mu(\hat{r} \times \hat{n})$

48. (a)

49. (c) $v = \frac{c}{\mu} = \frac{3 \times 10^8}{2.4} = 1.25 \times 10^8\ m/s$

50. (c) Velocity of light in the window

$= \frac{3 \times 10^8}{1.5} ms^{-1} = 2 \times 10^8\ ms^{-1}$

Hence $t = \frac{4\times10^{-3}}{2\times10^{8}} s = 2\times10^{-11} s$

51. (d) Ray optics is valid when size of the objects is much larger than the order of wavelength of light.

52. (b) $v = \frac{c}{\mu} = \frac{3\times10^8}{1.33} = 2.25\times10^8$ *m/s*

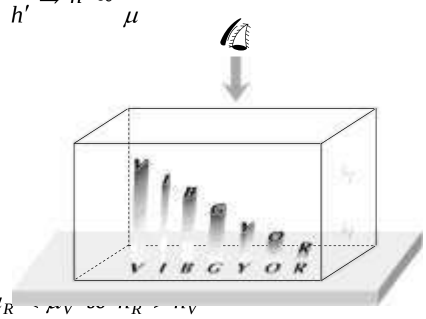
53. (b) $t = \frac{\mu x}{c} = \frac{1.5\times2\times10^{-3}}{3\times10^8} = 10^{-11}$ *sec*

54. (b) ${}_g\mu_w = \frac{\mu_w}{\mu_g} = \frac{4/3}{3/2} = \frac{8}{9}$

55. (b) Frequency does not change with medium but wavelength and velocity decrease with the increase in refractive index.

56. (a) $t = \frac{\mu x}{c} = \frac{3\times4\times10^{-3}}{3\times10^8} = 4\times10^{-11}$ *sec*

57. (d) $\mu = \frac{h}{h'} \Rightarrow h' \propto \frac{1}{\mu}$



$\because \mu_R < \mu_V$ so $h_R > h_V$

i.e. Red colour letter appears least raised.

58. (b) $\mu = \frac{c}{v} = \frac{\sin i}{\sin r} = \frac{\sin 45^o}{\sin 30^o}$

$\Rightarrow v = \frac{3\times10^8}{\sqrt{2}} = 2.12\times10^8\ m/s$

59. (c) $v \propto \frac{1}{\mu} \Rightarrow \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1} \Rightarrow \frac{v_g}{v_w} = \frac{\mu_w}{\mu_g} = \frac{4/3}{3/2} = \frac{8}{9}$

60. (b) Time taken by light to travel distance x through a medium of refractive index μ is

$t = \frac{\mu x}{c} \Rightarrow \frac{\mu_B}{\mu_A} = \frac{x_A}{x_B} = \frac{6}{4} \Rightarrow {}_A\mu_B = \frac{3}{2} = 1.5$

61. (d) ${}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} = \frac{1.5}{1.3}$

62. (a) $\mu = \frac{\text{Real depth}}{\text{apparent depth}} = \frac{120}{80} = 1.5$

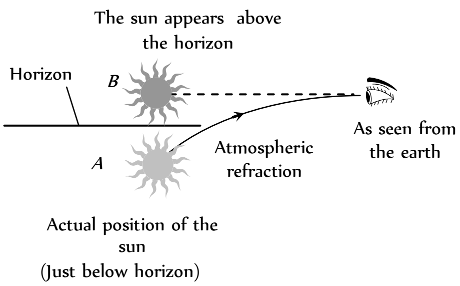
63. (b) Apparent depth of bottom

$= \frac{H/4}{\mu_1} + \frac{H/4}{\mu_2} + \frac{H/4}{\mu_3} + \frac{H/4}{\mu_4}$

$= \frac{H}{4}\left(\frac{1}{\mu_1} + \frac{1}{\mu_2} + \frac{1}{\mu_3} + \frac{1}{\mu_4}\right)$

64. (d) For successive refraction through different media $\mu\sin\theta =$ constant. Here as θ is same in the two extreme media, $\mu_1 = \mu_4$.

65. (b)



66. (a) $\mu = \frac{h'}{h} \Rightarrow h' = \mu h = \frac{4}{3}\times18 = 24\ cm$

67. (b) Optical path $\mu x =$ constant *i.e.* $\mu_1 x_1 = \mu_2 x_2$

$\Rightarrow 1.53\times4 = \mu_2\times4.5 \Rightarrow \mu_2 = 1.36$

68. (b) Velocity of light is maximum in vacuum.

69. (a) $\mu = \tan i \Rightarrow i = \tan^{-1}\mu = \tan^{-1}1.62 = 58.3°$

70. (d) Suppose water is poured up to the height *h*,

So $h\left(1 - \frac{1}{\mu}\right) = 1 \Rightarrow h = 4\ cm$

71. (c) $\mu \propto \frac{1}{v} \Rightarrow \frac{\mu_l}{\mu_g} = \frac{v_g}{v_l} \Rightarrow \frac{\mu_l}{1.5} = \frac{2\times10^8}{2.5\times10^8} \Rightarrow \mu_l = 1.2$

72. (c) Stars twinkle due to variation in *R.I.* of atmosphere.

73. (d) Refraction at air-oil point $\mu_{oil} = \frac{\sin i}{\sin r_1}$

$\therefore \sin r_1 = \frac{\sin 40}{1.45} = 0.443$

Refraction at oil-water point ${}_{oil}\mu_{water} = \frac{\sin r_1}{\sin r}$

$\therefore \frac{1.33}{1.45} = \frac{0.443}{\sin r}$ or $\sin r = \frac{0.443\times1.45}{1.33} \Rightarrow r = 28.9^o$

74. (d) Objects are invisible in liquid of R.I. equal to that of object.

75. (b) When light ray travels from denser to rarer, it deviates away from the normal.

76. (d) $\mu = \frac{c}{v} = \frac{3\times10^8}{1.5\times10^8} = 2.$

77. (c) Frequency remain unchanged.

78. (c) ${}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w} = \frac{1.5}{1.2} = \frac{5}{4} = 1.25$.

79. (b) $\lambda_g = \frac{\lambda_a}{\mu_g} = \frac{5890}{1.6} = 3681\,Å$.

80. (b) $t = \frac{s}{v} = \frac{1.5\times10^8\times10^3}{3\times10^8} = 500\sec = 8.33$ *min.*

81. (a) For vacuum $t = n\lambda_o$ .....(i)

For air $t = (n+1)\lambda_a$ .....(ii)

From equation (i) and (ii)

$t = \frac{\lambda}{\mu - 1} = \frac{6\times10^{-7}}{1.0003 - 1}$ $\left(\mu = \frac{\lambda_o}{\lambda_a}\right)$

$= 2\times10^{-3} m = 2 mm.$

82. (a) $\mu_m = \frac{c}{v} = \frac{n\lambda_a}{n\lambda_m} = \frac{\lambda_a}{\lambda_m}$

83. (b) As no scattering of light occurs. Space appears black.

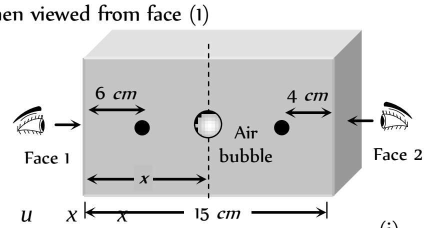
84. (b) $v \propto \frac{1}{\mu}$, μ is smaller for air than water, glass and diamond.

85. (c) In vacuum speed of light is constant and it is equal to 3 × 10[8] *m/sec*

86. (b) $\lambda_{medium} = \frac{\lambda_{vacuum}}{\mu}$

87. (d) In vacuum speed of light is constant and is equal to $3\times10^8 m/s$.

88. (d) When viewed from face (1)



$\mu = \frac{u}{v} = \frac{x}{v} = \frac{x}{6}$ .....(i)

Now when viewed from face (2)

$\mu = \frac{15-x}{v} = \frac{15-x}{4}$ .....(ii)

From equation (i) and (ii) $\mu = \frac{15-6\mu}{4} \Rightarrow \mu = 1.5$.

89. (b) The apparent depth of ink mark

$= \frac{\text{real depth}}{\mu} = \frac{3}{3/2} = 2\,cm$

Thus person views mark at a distance $= 2+2 = 4\,cm$.

90. (d) Apparent rise $= d\left(1 - \frac{1}{{}_a\mu_w}\right) = 12\times\left(1-\frac{3}{4}\right) = 3$ *cm.*

Total Internal Reflection

1. (b) Due to high refractive index its critical angle is very small so that most of the light incident on the diamond is total internally reflected repeatedly and diamond sparkles.

2. (c) When incident angle is greater than critical angle, then total internal reflection takes place and will come back in same medium.

3. (d)

4. (d) ${}_a\mu_g = \frac{1}{\sin C} \Rightarrow \sin C = \frac{1}{{}_a\mu_g}$

As μ for violet colour is maximum, so sin C is minimum and hence critical angle C is minimum for voilet colour.

5. (c) The critical angle C is given by

$\sin C = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{3500}{7000} = \frac{1}{2} \Rightarrow C = 30^o$

6. (c) From figure given in question $\theta = 2c = 98°$.

7. (b) $\mu = \frac{1}{\sin C} = \frac{1}{\sin 30} = 2$

$\therefore v = \frac{3\times10^8}{2} = 1.5\times10^8 m/s$

8. (c) ${}_D\mu_R = \frac{\sin i}{\sin r'} \Rightarrow {}_R\mu_D = \frac{\sin r'}{\sin i} = \frac{1}{\sin C}$

$\Rightarrow \sin C = \frac{\sin i}{\sin(90-r)} = \frac{\sin i}{\cos r} = \frac{\sin i}{\cos i}$ (as $\angle i = \angle r$)

$\Rightarrow \sin C = \tan i \Rightarrow C = \sin^{-1}(\tan i)$

9. (a) For total internal reflection $i > C$

$\Rightarrow \sin i > \sin C \Rightarrow \sin i > \frac{1}{\mu} \Rightarrow \frac{1}{\sin i} < \mu$.

10. (d) For total internal reflection light must travel from denser medium to rarer medium.

11. (b)

12. (c) Semi vertical angle $= C = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}\left(\frac{3}{4}\right)$

13. (c)

14. (d) $\mu = \frac{1}{\sin C} \Rightarrow C = \sin^{-1}\left(\frac{1}{2}\right) = 30^o$

15. (d)

16. (c) Critical angle = $\sin^{-1}\left(\frac{1}{\mu}\right)$

$\therefore \theta = \sin^{-1}\left(\frac{1}{\mu_{\lambda_1}}\right)$ and $\theta' = \sin^{-1}\left(\frac{1}{\mu_{\lambda_2}}\right)$

Since $\mu_{\lambda_2} > \mu_{\lambda_1}$, hence $\theta' < \theta$

17. (c)

18. (c, d) For TIR $i > C$

$\Rightarrow$ sin $i >$ sin $C \Rightarrow \sin 45° > \frac{1}{n} \Rightarrow n > \sqrt{2} \Rightarrow n > 1.4$

19. (c)

20. (d)

21. (a) ${}_w\mu_g = \frac{1}{\sin C} \Rightarrow \frac{\mu_g}{\mu_w} = \frac{5/3}{4/3} = \frac{1}{\sin C}$

$\Rightarrow \sin C = \frac{4}{5} \Rightarrow C = \sin^{-1}\left(\frac{4}{5}\right)$

22. (c) Total internal reflection occurs when light ray travels from denser medium to rarer medium.

23. (b) $\mu = \frac{c}{v} \Rightarrow \mu = \frac{c}{c/2} = 2$ also for total internal reflection

$i > c \Rightarrow \sin i \ge \sin c \Rightarrow \sin i \ge \frac{1}{\mu}$

Hence $i \ge \sin^{-1}\left(\frac{1}{\mu}\right)$ or $i \ge 30^o$

24. (c) $C = \sin^{-1}\left(\frac{1}{{}_w\mu_g}\right) = \sin^{-1}\left(\frac{\mu_w}{\mu_g}\right) = \sin^{-1}\left(\frac{8}{9}\right)$

25. (a) $\mu_w < \mu_g \Rightarrow c_w > c_g$.

26. (c) $\mu = \frac{1}{\sin C} = \frac{1}{\sin 30} = 2$

27. (c) Ray from setting sum will be refracted at angle equal to critical angle.

28. (a) Optical fibres are used to send signals from one place to another.

29. (d)

30. (d) When total internal reflection just takes place from lateral surface $i = C$ i.e. $60^o = C$

$\Rightarrow \sin 60^o = \sin C = \frac{1}{\mu} \Rightarrow \mu = \frac{2}{\sqrt{3}}$

Time taken by light to traverse some distance in a medium

$t = \frac{\mu x}{c} = \frac{\frac{2}{\sqrt{3}}\times10^3}{3\times10^8} = 3.85\,\mu$ *sec.*

31. (a) $\frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = \frac{1}{2} \Rightarrow \frac{\mu_1}{\mu_2} = 2(\mu_1 > \mu_2)$

For total internal reflection ${}_2\mu_1 = \frac{1}{\sin C} \Rightarrow \frac{\mu_1}{\mu_2}$

$= \frac{1}{\sin C} \Rightarrow 2 = \frac{1}{\sin C} \Rightarrow C = 30^o$

So, for total (Internal reflection angle of incidence must be greater than 30°.

32. (c)

33. (a) $\mu = \frac{1}{\sin C} = \frac{1}{\sin 60^o} = \frac{2}{\sqrt{3}}$

34. (c) ${}_a\mu_g = \frac{1}{\sin\theta} \Rightarrow \mu = \frac{1}{\sin\theta}$ .....(i)

Now from Snell's law $\mu = \frac{\sin i}{\sin r} = \frac{\sin\theta}{\sin r}$

$\Rightarrow \sin r = \frac{\sin\theta}{\mu}$ .....(ii)

From equation (i) and (ii)

$\sin r = \frac{1}{\mu^2} \Rightarrow r = \sin^{-1}\left(\frac{1}{\mu^2}\right)$

35. (a) $C = \sin^{-1}\left(\frac{1}{\mu}\right)$ and $\mu \propto \frac{1}{\lambda}$

Yellow, orange and red have higher wavelength than green, so μ will be less for these rays, consequently critical angle for these rays will be high, hence if green is just totally internally reflected then yellow, orange and red rays will emerge out.

36. (d) We know $C = \sin^{-1}\left(\frac{1}{\mu}\right)$

Given critical angle $i_B > i_A$

So $\mu_B < \mu_A$ *i.e.* B is rarer and A is denser.

Hence light can be totally internally reflected when it passes from A to B

Now critical angle for A to B

$C_{AB} = \sin^{-1}\left(\frac{1}{{}_B\mu_A}\right) = \sin^{-1}\left[{}_A\mu_B\right]$

$= \sin^{-1}\left[\frac{\mu_B}{\mu_A}\right] = \sin^{-1}\left[\frac{\sin i_A}{\sin i_B}\right]$

37. (b) At point A, by Snell's law

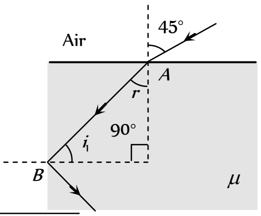
$\mu = \frac{\sin 45}{\sin r} \Rightarrow \sin r = \frac{1}{\mu\sqrt{2}}$ .....(i)

At point B, for total internal reflection $\sin i_1 = \frac{1}{\mu}$

From figure, $i_1 = 90 - r$

$\therefore \sin(90° - r) = \frac{1}{\mu}$

$\Rightarrow \cos r = \frac{1}{\mu}$ .....(ii)



Now $\cos r = \sqrt{1 - \sin^2 r} = \sqrt{1 - \frac{1}{2\mu^2}}$

$= \sqrt{\frac{2\mu^2 - 1}{2\mu^2}}$ .....(iii)

From equation (ii) and (iii) $\frac{1}{\mu} = \sqrt{\frac{2\mu^2 - 1}{2\mu^2}}$

Squaring both side and then solving we get $\mu = \sqrt{\frac{3}{2}}$

38. (b) ${}_2\mu_1 = \frac{1}{\sin\theta} \Rightarrow \frac{\mu_1}{\mu_2} = \frac{1}{\sin\theta} \Rightarrow \frac{v_2}{v_1} = \frac{1}{\sin\theta} \Rightarrow \frac{v_2}{v} = \frac{1}{\sin\theta}$

$\Rightarrow v_2 = \frac{v}{\sin\theta}$

39. (c) From the formula $\sin C = \frac{1}{{}_1\mu_2} \Rightarrow \sin C = {}_2\mu_1$

$= \frac{u_1}{u_2} = \frac{v_2}{v_1} \Rightarrow \sin C = \frac{10x/t_2}{x/t_1}$

$\Rightarrow \sin C = \frac{10\,t_1}{t_2} \Rightarrow C = \sin^{-1}\left(\frac{10\,t_1}{t_2}\right)$

40. (a) $\sin 45^o = \frac{1}{\mu} \Rightarrow \mu = \sqrt{2} = 1.41$

41. (c)

42. (b) Critical angle C is equal to incident angle if ray reflected normally $\therefore C = 90^o$

43. (b)

44. (d) $r = \frac{3h}{\sqrt{7}} = \frac{3 \times 12}{\sqrt{7}} = \frac{36}{\sqrt{7}}$.

45. (b) Here $\sin i = \frac{1}{\mu} = \frac{3}{5}$ and hence $\tan i = \frac{3}{4} = \frac{r}{4}$

This gives $r = 3\,m$, hence diameter = $6m$

46. (a) Radius of horizon circle $= \frac{3h}{\sqrt{7}} = \frac{3\sqrt{7}}{\sqrt{7}} = 3\,cm$.

Refraction at Curved Surface

1. (a) By formula $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$= (1.5 - 1)\left(\frac{1}{40} + \frac{1}{40}\right) = 0.5 \times \frac{1}{20} = \frac{1}{40}$

$\therefore f = 40\ cm$

2. (a) $\frac{v}{-u} = -m$ and $v + u = x \Rightarrow u = \frac{x}{1+m}$

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow f = \frac{mx}{(m+1)^2}$.

3. (d) $I \propto A^2 \Rightarrow \frac{I_2}{I_1} = \left(\frac{A_2}{A_1}\right)^2 = \frac{\pi r^2 - \frac{\pi r^2}{4}}{\pi r^2} = \frac{3}{4}$

$\Rightarrow I_2 = \frac{3}{4} I_1$ and focal length remains unchanged.

4. (c) $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{P_1}{100}+\frac{P_2}{100}=\frac{1}{100}\Rightarrow f=100\ cm$

$\therefore$ A convergent lens of focal length 100 *cm*.

5. (a) Focal length of the combination can be calculated as

$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}\Rightarrow\frac{1}{F}=\frac{1}{(+40)}+\frac{1}{(-25)}\quad\Rightarrow F=-\frac{200}{3}cm$

$\therefore P=\frac{100}{F}=\frac{100}{-200/3}=-1.5\ D$

6. (d) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}\Rightarrow\frac{1}{80}=\frac{1}{20}+\frac{1}{f_2}\quad\Rightarrow f_2=-\frac{80}{3}cm$

$\therefore$ Power of second lens

$P_2=\frac{100}{f_2}=\frac{100}{-80/3}=-3.75\ D$

7. (b) In each case two plane-convex lens are placed close to each other, and $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}$.

8. (a) Power of the combination $P=P_1+P_2\quad=12-2=10\,D$

$\therefore$ Focal length of the combination

$F=\frac{100}{P}=\frac{100}{10}=10\,cm$

9. (c) Resultant focal length $=\infty$

$\therefore$ It behaves as a plane slab of glass.

10. (c) $f=\frac{R}{(\mu-1)}\Rightarrow 30=\frac{10}{(\mu-1)}\Rightarrow\mu=1.33$.

11. (c) In case of convex lens if rays are coming from the focus, then the emergent rays after refraction are parallel to principal axis.

12. (d) Because to form the complete image only two rays are to be passed through the lens and moreover, since the total amount of light released by the object is not passing through the lens, therefore image is faint (intensity is decreased).

13. (b) $f=\frac{f_1 f_2}{f_1+f_2}=\frac{10(-10)}{10+(-10)}=\frac{-100}{10-10}=\infty$

14. (c) Focal length of the combination

$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{(+84)}+\frac{1}{(-12)}\Rightarrow F=-14\ cm$

$\therefore P=\frac{100}{F}=\frac{100}{-14}=-\frac{50}{7}D$

15. (b) $O=\sqrt{I_1I_2}=\sqrt{4\times16}=8\,cm$

16. (d) $\frac{f_l}{f_a}=\frac{({}_a\mu_g-1)}{({}_l\mu_g-1)}\Rightarrow\frac{f_w}{f_a}=\frac{(1.5-1)}{\left(\frac{1.5}{1.33}-1\right)}\Rightarrow f_w=32\,cm$

17. (c) If $n_l>n_g$ then the lens will be in more denser medium. Hence its nature will change and the convex lens will behave like a concave lens.

18. (d) $\frac{f_l}{f_a}=\frac{({}_a\mu_g-1)}{({}_l\mu_g-1)}\Rightarrow\frac{f_l}{15}=\frac{(1.5-1)}{\left(\frac{1.5}{4/3}-1\right)}\Rightarrow f_l=60\,cm$

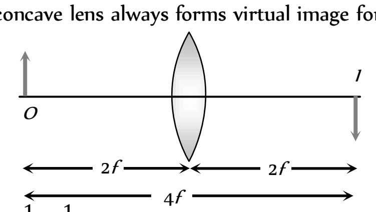
19. (c) $\frac{f_l}{f_a}=\frac{({}_a\mu_g-1)}{({}_l\mu_g-1)}\Rightarrow f_l=\infty$ if ${}_l\mu_g=1\Rightarrow{}_a\mu_l={}_a\mu_g$.

20. (c) $\frac{I_1}{O}=\frac{v}{u}$ and $\frac{I_2}{O}=\frac{u}{v}\Rightarrow O^2=I_1I_2$

21. (c) A lens shows opposite behaviour if $\mu_{\text{medium}}>\mu_{\text{lens}}$

22. (a) A concave lens always forms virtual image for real objects.

23. (d)



24. (a) $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ (Given $u=-20\ cm,\ f=10\ cm,\ v=?$)

$\therefore\ \frac{1}{10}=\frac{1}{v}-\frac{1}{(-20)}\Rightarrow v=20\,cm$

25. (d) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{60}+\frac{1}{(-20)}\Rightarrow F=-30$

26. (a) $f_{\text{water}}=4\times f_{\text{air}}$, air lens is made up of glass.

27. (b) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}=\frac{1}{20}+\frac{1}{25}\Rightarrow F=\frac{100}{9}\ cm=\frac{1}{9}\ metre$

$\therefore\ P=\frac{1}{1/9}D=9D$

28. (a) $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ (Given $u=\frac{-f}{2}$)

$\Rightarrow\frac{1}{f}=\frac{1}{v}+\left(\frac{1}{f/2}\right)\Rightarrow\frac{1}{v}=\frac{1}{f}-\frac{2}{f}$

$\Rightarrow\frac{1}{v}=\frac{-1}{f}$ and $m=\frac{v}{u}=\frac{f}{f/2}=2$

So virtual at the focus and of double size.

29. (a) $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

Given $R_1=+20cm, R_2=-20\,cm$, $\mu=1.5$

$\Rightarrow f=20\ cm$. Parallel rays converge at focus. So *L=f.*

30. (c) $\mu_{air}<\mu_{lens}<\mu_{water}$ *i.e.,* $1<\mu_{lens}<1.33$

31. (c) $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

For biconvex lens $R_2=-R_1\quad\therefore\ \frac{1}{f}=(\mu-1)\left(\frac{2}{R}\right)$

Given $R=\infty\ \therefore\ f=\infty$, so no focus at real distance.

32. (d) $f=\frac{R}{(\mu-1)}=\frac{15}{(1.6-1)}=25\,cm$

$\therefore P=\frac{100}{f}=\frac{100}{25}=+4\ D$

33. (d) $f\propto\frac{1}{(\mu-1)}$ and $\mu\propto\frac{1}{\lambda}$. Hence $f\propto\lambda$ and $\lambda_r>\lambda_v$

34. (c) $m_1=\frac{A_1}{O}$ and $m_2=\frac{A_2}{O}\quad\Rightarrow m_1m_2=\frac{A_1A_2}{O_2}$

Also it can be proved that $m_1m_2=1$

So $O = \sqrt{A_1 A_2}$

35. (b) Combined power $P = P_1 + P_2 = 6 - 2 = 4D$. So focal length of combination $F = \frac{1}{P} = \frac{1}{4} m$

36. (b) $\frac{1}{60} = \frac{1}{f_1} + \frac{1}{f_2}$ ...(i)

and $\frac{1}{30} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{10}{f_1 f_2}$ ...(ii)

On solving (i) and (ii) $f_1 f_2 = -600$ and $f_1 + f_2 = -10$

Hence $f_1 = 20\ cm$ and $f_2 = -30\ cm$

37. (c) For an achromatic combination $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$

i.e. 1 convex lens and 1 concave lens.

38. (d) $\frac{1}{F} = \frac{2}{f_l} + \frac{1}{f_m} \Rightarrow \frac{1}{F} = \frac{2}{20} + \frac{1}{\infty} \Rightarrow F = 10\ cm$

39. (b) Since aperture of lens reduces so brightness will reduce but their will be no effect on size of image.

40. (d) Convex mirror and concave lens do not form real image. For concave mirror $v > u$, so image will be enlarged, hence only convex lens can be used for the purpose.

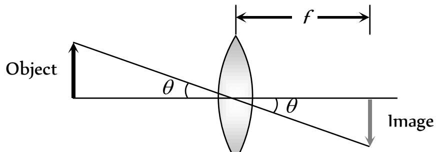
41. (a) $m = \frac{f}{f+u} \Rightarrow -\frac{1}{4} = \frac{30}{30+u} \Rightarrow u = -150\,cm$

42. (c) Covering a portion of lens does not effect position and size of image.

43. (a) $\frac{1}{f} = ({}_g\mu_a - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left(\frac{2}{3} - 1\right)\left(\frac{2}{10}\right)$

$\Rightarrow f = -15\,cm$, so behaves as concave lens.

44. (c) Size of image = $f\theta = 0.5 \times (1 \times 10^{-3})$ = 0.5 *mm*



45. (d) $\frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)} = \frac{\left(\frac{3}{2} - 1\right)}{\left(\frac{3/2}{5/4} - 1\right)} = \frac{5}{2}$

$\therefore\ f_l = f_a\left(\frac{5}{2}\right) = \frac{12 \times 5}{2} = 30\ cm$

46. (d) $P = \frac{1}{F} = \frac{f_1 + f_2}{f_1 f_2}$

47. (c) $f = \frac{R}{(\mu - 1)} = \frac{R}{(1.5 - 1)} = 2R$

48. (b) For achromatic combination, $\frac{w_1}{f_1} + \frac{w_2}{f_2} = 0$

$\Rightarrow w_1 f_2 + w_2 f_1 = 0$

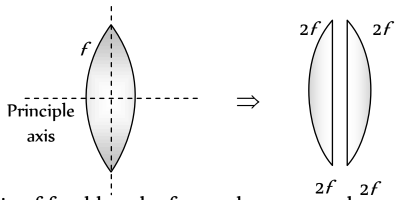
49. (a) $\frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2} \Rightarrow \frac{5}{3} = \frac{-(-15)}{f_2} \Rightarrow f_2 = 9\ cm$

50. (b) $f = \frac{R}{2(\mu - 1)} \Rightarrow f = \frac{40}{2(1.65 - 1)} \approx 31\,cm$

51. (c) Focal length of effective lens

$\frac{1}{F} = \frac{2}{f_l} + \frac{1}{f_m} = \frac{2}{f_l} + \frac{1}{\infty} \Rightarrow F = \frac{f_l}{2}$

52. (a)



Ratio of focal length of new plano convex lenses is 1 : 1

53. (a) $\frac{1}{f} = \left(\frac{n-1}{1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ and $\frac{1}{f'} = \left(\frac{n - n'}{n'}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\therefore\ \frac{f'}{f} = \frac{n-1}{1} \times \frac{n'}{n - n'} \Rightarrow f' = -\frac{fn'(n-1)}{n' - n}$

54. (b) $\frac{I}{O} = \frac{f - v}{f} \Rightarrow \frac{I}{+1.5} = \frac{(25 - 75)}{25} = -2 \Rightarrow I = -3\,cm$

55. (a) $P = P_1 + P_2$, if $P_1 = P_2 = P' \Rightarrow P' = P/2 = 2D.$

56. (b) $f = \frac{R}{(\mu - 1)} = \frac{60}{(1.6 - 1)} = 100\ cm.$

57. (a) $\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} = \frac{1.5 - 1}{\frac{1.5}{1.75} - 1} = -\frac{1.75 \times 0.50}{0.25} = -3.5$

$\therefore f_l = -3.5\ f_a \Rightarrow f_l = +3.5\ R$ $(\because f_a = R)$

Hence on immersing the lens in the liquid, it behaves as a converging lens of focal length 3.5 *R*.

58. (a) $P = P_1 + P_2 = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{(0.5)} + \frac{1}{(-1)} = 1\,D$

59. (d) $f = \frac{R}{2(\mu - 1)} \Rightarrow 30 = \frac{R}{2(1.5 - 1)} \Rightarrow R = 30\ cm$

60. (c) Total power $P = P_1 + P_2 = 11 - 6 = 5D$

Also $\frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)} \Rightarrow \frac{P_a}{P_l} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)}$

$\Rightarrow \frac{5}{P_l} = \frac{(1.5 - 1)}{(1.5/1.6 - 1)} \Rightarrow P_l = -0.625\,D$

61. (b) For first case : $\frac{1}{f} = \frac{1}{v} - \frac{1}{\infty} \Rightarrow f = v$

For second case $\frac{1}{f} = \frac{1}{(f+5)} - \frac{1}{-(f+20)} \Rightarrow f = 10\ cm$

Alternative sol. – $f^2 = x_1 x_2 \Rightarrow f = 10cm.$

62. (b) $f = \frac{D^2 - x^2}{4D}$ (Focal length by displacement method)

$\Rightarrow f = \frac{(100)^2 - (40)^2}{4 \times 40} = 21\ cm$

$\therefore P = \frac{100}{f} = \frac{100}{21} \approx 5\,D$

63. (d) $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{+5} = \frac{1}{v} - \frac{1}{(-10)} \Rightarrow v = 10\ cm$

64. (d) $\omega / f = -2\omega / f' \Rightarrow f' = -2f$

65. (d) $f = \frac{R}{2(\mu - 1)} \Rightarrow 10 = \frac{R}{2(1.6 - 1)} \Rightarrow R = 12\ cm$

66. (a)

67. (d) $P = P_1 + P_2 = 2.50 - 3.75 = -1.25D$

So $f = \frac{100}{1.25} = -80\ cm$

68. (c) $\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} \Rightarrow f_l = 4R$

69. (c) $\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} = \frac{{}_a\mu_g - 1}{\frac{{}_a\mu_g}{{}_a\mu_l} - 1} \Rightarrow \frac{f_l}{2} = \frac{1.5 - 1}{\frac{1.5}{1.25} - 1} \Rightarrow f_l = 5\ cm$

70. (b) $f \propto \frac{1}{\mu - 1}$ and $\mu \propto \frac{1}{\lambda}$

71. (d) $P = \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{(+0.8)} + \frac{1}{(-0.5)} = -0.75\ D$

72. (b) According to lens makers formula

$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \Rightarrow \frac{1}{f} \propto (\mu - 1)$

Since $\mu_{\text{Red}} < \mu_{\text{violet}} \Rightarrow f_v < f_r$ and $F_v < F_r$

Always keep in mind that whenever you are asked to compare (greater than or less than) *u, v* or *f* you must not apply sign conventions for comparison.

73. (a) Since light transmitting area is same, there is no effect on intensity.

74. (c) $m = \frac{f}{(f + u)} \Rightarrow -\frac{1}{n} = \frac{f}{(f + u)} \Rightarrow u = -(n + 1)f$

75. (a) $P = P_1 + P_2 = 2D - 4D = -2D.$

76. (c)

77. (a) $\frac{1}{F} = \frac{2}{f} + \frac{1}{f_m}$. Here $f_m = \infty$, hence $F = \frac{f}{2} = 10\,cm$

78. (b) $O = \sqrt{I_1 I_2} \Rightarrow O = \sqrt{4 \times 9} = 6\ cm$

79. (b) $P = P_1 + P_2 \Rightarrow P = +6 - 4 = +2\,D$. So focal length

$f = \frac{100}{2} = +50\ cm$, convex lens

80. (d) $f = \frac{R}{2(\mu - 1)} \Rightarrow P = \frac{2(\mu - 1)}{R} = \frac{2(1.5 - 1)}{0.2} = +5\,D$

81. (c) $P = \frac{1}{f} \Rightarrow f = \frac{1}{0.5} = 2m$

82. (a) $\frac{f_l}{f_a} = \left(\frac{{}_a\mu_g - 1}{{}_l\mu_g - 1}\right) \Rightarrow \frac{f_l}{4} = \frac{(1.4 - 1)}{\frac{1.4}{1.6} - 1} \Rightarrow f_l = -12.8\,cm$

83. (d) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow \frac{1}{F} = \frac{1}{(+18)} \Rightarrow F = 18\,cm$

84. (a) $\frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)}$; $f_a = \frac{R}{2(\mu_g - 1)} = \frac{15}{2(1.6 - 1)} = 12.5$

$\Rightarrow \frac{f_l}{12.5} = \frac{(1.6 - 1)}{\left(\frac{1.6}{1.63} - 1\right)} \Rightarrow f_l = -407.5\ cm$

85. (c) $P = P_1 + P_2 \Rightarrow P = +2 + (-1) = +1D,$

$f = \frac{+100}{P} = \frac{+100}{1} = 100\,cm$

86. (c)

87. (b) Nature of lens changes, if $\mu_{\text{mediume}} > \mu_{\text{lens}}$

88. (a) $u = -25\ cm, v = +75\,cm$

$\Rightarrow \frac{1}{f} = \frac{1}{+75} - \frac{1}{-25} \Rightarrow f = +18.75\ cm$; convex lens.

89. (a) $F = \frac{f_1 f_2}{f_2 - f_1}$, *F* will be negative if $f_1 > f_2$

90. (b) $f = \frac{R}{2(\mu - 1)} = \frac{10}{2(1.5 - 1)} = 10\,cm$

91. (b) $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$\Rightarrow \frac{1}{+10} = (1.5 - 1)\left(\frac{1}{+7.5} - \frac{1}{R_2}\right) \Rightarrow R_2 = -15\,cm$

92. (d) $f = \frac{R}{2(\mu - 1)}$, $f' = \frac{R}{(\mu - 1)} \Rightarrow f' = 2f$

93. (c) $m = \pm 3$, using $m = \frac{f}{f + u}$

For virtual image $3 = \frac{f}{f - 8}$ .....(i)

For real image $-3 = \frac{f}{f - 16}$ .....(ii)

Solving (i) and (ii) we get $f = 12\,cm$

94. (a) $\frac{1}{F} = \frac{1}{+18} + \frac{1}{(-9)} \Rightarrow F = -18\ cm$ (*i.e.* concave lens)

95. (c) $O = \sqrt{I_1 I_2} = \sqrt{8 \times 2} = 4cm$

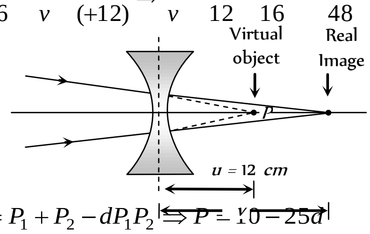
96. (c) $P = \frac{100}{f_1} + \frac{100}{f_2} = \frac{100}{(+25)} + \frac{100}{(-10)} = -6D$

97. (c)

98. (a) $f_w = 4 \times f_a = 4 \times 12 = 48\ cm.$

99. (d) By using lens formula

$\frac{1}{-16} = \frac{1}{v} - \frac{1}{(+12)} \Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{16} = \frac{4 - 3}{48} \Rightarrow v = 48\ cm$



100. (a) $P = P_1 + P_2 - dP_1P_2 \Rightarrow P = 10 - 25d$

$\Rightarrow$ For P to be negative $25d > 10$

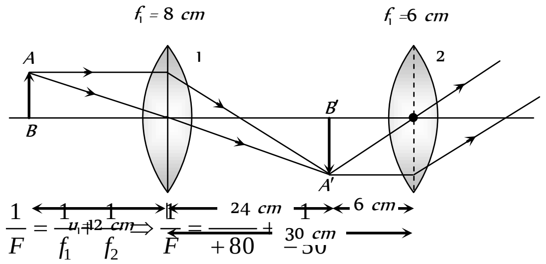
$\Rightarrow\ d > 0.4\,m$ or $d > 40\ cm$

101. (a) $m = \frac{f}{f + u} \Rightarrow -m = \frac{f}{f + u} \Rightarrow u = -\left(\frac{m + 1}{m}\right)f$

102. (d) Number of images = (Number of materials)

103. (c) For lens (1) $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{(+8)}=\frac{1}{v}-\frac{1}{(-12)}$

$\Rightarrow v=24\ cm$ *i.e.* Image $A'B'$ is obtained 6 *cm* before the lens 2 or at the focus of lens 2. Hence final image formed by lens 2 will be real enlarged and it is obtained at ∞.



104. (d) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}\Rightarrow\frac{1}{F}=\frac{1}{+80}+\frac{1}{-50}$

$\Rightarrow\ F=-\frac{400}{3}\Rightarrow P=\frac{-3}{4}D$

105. (a) By using formula $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

$\Rightarrow\frac{1.5}{v}-\frac{1}{(-15)}=\frac{(1.5-1)}{+30}\Rightarrow v=-30\,cm$.

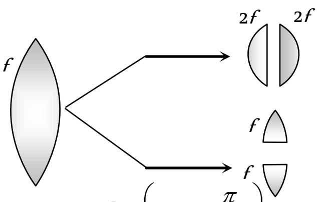
Negative sign shows that, image is obtained on the same side of object *i.e.* towards left.

106. (c) By using $\frac{f_l}{f_a}=\frac{({}_a\mu_g-1)}{({}_l\mu_g-1)}\Rightarrow f_w=4f_a=4\times30=120\ cm.$

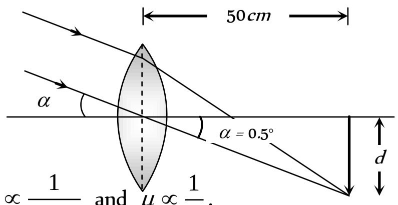
107. (b)

108. (a)

109. (d)



110. (b) Diameter of image $d=\left(0.5\times\frac{\pi}{180}\right)\times500=4.36\ mm$



111. (c) $f\propto\frac{1}{\mu-1}$ and $\mu\propto\frac{1}{\lambda}$.

112. (c) Since intensity $\propto$ (Aperature)², so intensity of image will decrease but no change in the size occurs.

113. (c) In liquids converging ability (power) of convex lens decreases.

114. (d) Since $f\propto\frac{1}{\mu}\propto\lambda$, so voilet colour is focused nearer to the lens.

115. (a) Focal length for voilet is minimum.

116. (c) $m=\frac{v}{u}=5\Rightarrow v=5$ *inch* (Given $u=1$ *inch*)

Using sign convention $u=-1\ inch,\ v=-5\ inch$

$\therefore\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=\frac{1}{-5}-\frac{1}{-1}\Rightarrow f=1.25\ inch$

117. (a) $m_L=4$

$m_A=(m_1)^2$ so that $A'=A_0\times16=1600\ cm^2$

118. (d) $u=-10\ cm,\ v=20\ cm$

$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}=\frac{1}{20}-\left(-\frac{1}{10}\right)=\frac{3}{20}\Rightarrow f=\frac{20}{3}cm$

Now $P=\frac{100}{f}=\frac{100}{20/3}=+15\ D$

119. (c) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}$

120. (b) $f=\frac{R}{2(\mu-1)}\Rightarrow R=2f(\mu-1)=2\times0.2(1.5-1)=0.2m.$

121. (c) Using refraction formula $\frac{{}_1\mu_2-1}{R}=\frac{{}_1\mu_2}{v}-\frac{1}{u}$

in given case, medium (1) is glass and (2) is air

So $\frac{{}_g\mu_a-1}{R}=\frac{{}_g\mu_a}{v}-\frac{1}{u}\Rightarrow\frac{\frac{1}{1.5}-1}{-6}=\frac{1}{1.5v}-\frac{1}{-6}$

$\Rightarrow\frac{1-1.5}{-6}=\frac{1}{v}+\frac{1.5}{6}\Rightarrow\frac{0.5}{6}=\frac{1}{v}+\frac{1}{4}$

$\Rightarrow\frac{1}{v}=\frac{1}{12}-\frac{1}{4}=-\frac{2}{12}=-\frac{1}{6}\Rightarrow v=6\ cm.$

122. (d) For real image $m=-2$

$\therefore m=\frac{f}{u+f}\Rightarrow-2=\frac{f}{u+f}=\frac{20}{u+20}\Rightarrow u=-30\ cm.$

123. (a) Focal length of the system (concave mirror)

$F=\frac{R}{2\mu}=\frac{30}{2\times1.5}=10\ cm$

In order to have a real image of the same size of the object, object must be placed at centre of curvature $u=(2f)$.

124. (b) $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$=(1.5-1)\left(\frac{1}{10}+\frac{1}{10}\right)=\frac{1}{10}\Rightarrow f=10\ cm$

$\therefore$ Radius of curvature of concave mirror $=2f=20\ cm.$

125. (d) $m=-\frac{1}{2}$

$\therefore m=\frac{f}{u+f}\Rightarrow-\frac{1}{2}=\frac{30}{u+30}\Rightarrow u=-90\,cm$

126. (c) $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$\frac{1}{f}=(1.6-1)\left(\frac{1}{60}-\frac{1}{\infty}\right)=\frac{1}{100}\Rightarrow f=100\,cm$

127. (d) $\frac{1}{F}=(1.5-1)\left(\frac{1}{20}-\frac{1}{\infty}\right)\Rightarrow F=40\,cm$.

128. (b) For minimum spherical and chromatic aberration distance between lenses.

$d = f_1 - f_2 = 0.3 - 0.1 = 0.2\,m$.

129. (b) $\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} = \frac{(1.5-1)\times 1.7}{(1.5-1.7)}$

$\Rightarrow f_l = \frac{0.85}{-0.2} f_a = -4.25 f_a$.

130. (c)

131. (b) $\omega = \frac{f_R - f_V}{f_y} = \frac{f_R - f_V}{\sqrt{f_V f_R}}$

Putting value of f_V and f_R we get $\omega = 0.0325$.

132. (b) $P_1 + P_2 = 2D$ and $P_1 = 5D$, so $P_2 = -3D$

For achromatic combination

$\frac{\omega_1}{\omega_2} = \left(-\frac{p_2}{p_1}\right) = -\left(\frac{-3}{5}\right) = \frac{3}{5}$

133. (b) $f \propto \frac{1}{\mu - 1}$ and $\mu \propto \frac{1}{\lambda}$

134. (d) $P = P_1 + P_2 = +12 - 2 = 10D$

Now $F = \frac{1}{P} = \frac{1}{10} m = 10\,cm$.

135. (b) Focal length for voilet colour is minimum

136. (d) $\frac{f_1}{f_2} = \frac{2}{3}$ .....(i)

$\frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{30}$ .....(ii)

Solving equation (i) and (ii)

$f_2 = -15\,cm$ (Concave)

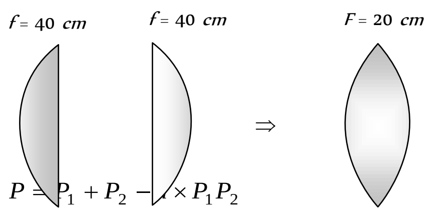
$f_1 = 10\,cm$ (Convex)

137. (d) $\frac{f_l}{f_a} = \frac{({}_a\mu_g - 1)}{({}_l\mu_g - 1)}$

$\Rightarrow \frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} = \frac{1.5 - 1}{\frac{1.5}{1.6} - 1} = \frac{0.5 \times 1.6}{-0.1} = -8$

$\Rightarrow P_l = \frac{P_a}{8} = \frac{5}{8}$

138. (b) To obtain, an inverted and equal size image, object must be paced at a distance of $2f$ from lens, *i.e.* 40 *cm* in this case.



139. (a) Using $P = P_1 + P_2 - d \times P_1 P_2$

for equivalent power to be negative

$d \times P_1 P_2 > P_1 + P_2 \Rightarrow d \times 25 > 10$

$\Rightarrow d > \frac{10}{25} m \Rightarrow d > \frac{10 \times 100}{25} \Rightarrow d > 40cm.$

140. (c) Combination of lenses will act as a simple glass plate.

141. (b) For achromatic combination $\frac{f_1}{f_2} = -\frac{\omega_2}{\omega_1} = -\frac{0.036}{0.024} = -\frac{3}{2}$

and $\frac{1}{f_1} - \frac{1}{f_2} = \frac{1}{90}$

solving above equations be get $f_1 = 30cm,\ f_2 = -45cm$

142. (b)

143. (c) $f \propto \frac{1}{\mu - 1}$ and $\mu \propto \frac{1}{\lambda}$.

144. (b) $\frac{f_l}{f_a} = \frac{{}_a\mu_g - 1}{{}_l\mu_g - 1} \Rightarrow \frac{-0.5}{0.2} = \frac{1.5 - 1}{{}_l\mu_g - 1} \Rightarrow {}_l\mu_g - 1 = -0.2$

$\Rightarrow {}_l\mu_g = 0.8 = \frac{4}{5} \Rightarrow \frac{{}_a\mu_g}{{}_a\mu_l} = \frac{4}{5} \Rightarrow \frac{1.5}{{}_a\mu_l} = \frac{4}{5}$

$\Rightarrow {}_a\mu_l = \frac{15}{8}$.

145. (c) Longitudinal chromatic aberration

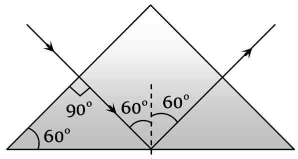
$= \omega f = 0.08 \times 20 = 1.6cm$.

Prism Theory & Dispersion of Light

1. (b) Neon street sign emits light of specific wavelengths.

2. (b)

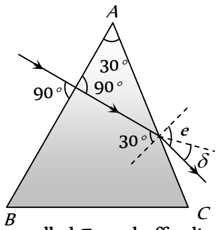
3. (b)



4. (c) $\delta \propto (\mu - 1) \Rightarrow \mu_R$ is least so δ_R is least.

5. (c)

6. (a) For surface $AC\ \frac{1}{\mu} = \frac{\sin 30°}{\sin e} \Rightarrow \sin e = \mu \sin 30°$



$\Rightarrow \sin e = 1.5 \times \frac{1}{2} = 0.75$

$\Rightarrow e = \sin^{-1}(0.75) = 48^o 36'$

From figure $\delta = e - 30^o$

$= 48^o\,36' - 30^o = 18^o 36'$

7. (a) The black lines in solar spectrum are called Fraunhoffer lines.

8. (d) $\frac{\sin\frac{A + \delta m}{2}}{\sin\frac{A}{2}} = \mu$, But $\frac{A + \delta_m}{2} = i = 45^o$

So $\frac{\sin 45^o}{\sin(A/2)} = \sqrt{2} \Rightarrow \frac{1}{2} = \sin\frac{A}{2} \Rightarrow A = 60^o$

9. (d) We know that $\frac{\delta_v - \delta_r}{\delta_{mean}} = \omega$

$\Rightarrow$ Angular dispersion $= \delta_v - \delta_r = \theta = \omega\delta_{mean}$

10. (d) According to Kirchhoff's law, a substance in unexcited state will absorb these wavelength which it emits in de-excitation.

11. (c) By prism formula $n = \frac{\sin\frac{A + A}{2}}{\sin\frac{A}{2}} = \frac{2\sin\frac{A}{2}\cos\frac{A}{2}}{\sin\frac{A}{2}}$

$\therefore \cos\frac{A}{2} = \frac{n}{2} = \frac{1.5}{2} = 0.75 = \cos 41^o \Rightarrow A = 82^o$

12. (b)

13. (b) ω depend only on nature of material.

14. (a) Because achromatic combination has same μ for all wavelengths.

15. (a) $\because \mu = a + \frac{b}{\lambda^2}$ (Cauchy's equation)

and dispersion $D = -\frac{d\mu}{d\lambda} \Rightarrow D = -(-2\lambda^{-3})b = \frac{2b}{\lambda^3}$

$\Rightarrow D \propto \frac{1}{\lambda^3} \Rightarrow \frac{D'}{D} = \left(\frac{\lambda}{\lambda'}\right)^3 = \left(\frac{\lambda}{2\lambda}\right) = \frac{1}{8} \Rightarrow D' = \frac{D}{8}$

16. (b) $\mu = \frac{\sin i}{\sin A/2} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin\left(\frac{60}{2}\right)}$

$\Rightarrow \sqrt{2} \times \sin 30 = \sin i \Rightarrow i = 45^o$

17. (d) $\frac{\delta_w}{\delta_a} = \frac{({}_w\mu_g - 1)}{({}_a\mu_g - 1)} = \frac{\left(\frac{9}{8} - 1\right)}{\left(\frac{3}{2} - 1\right)} = \frac{1}{4}$

18. (a) Since $A(\mu_y - 1) + A'(\mu_{y'} - 1) = 0 \Rightarrow \frac{A'}{A} = -\left(\frac{\mu_y - 1}{\mu_{y'} - 1}\right)$

19. (d)

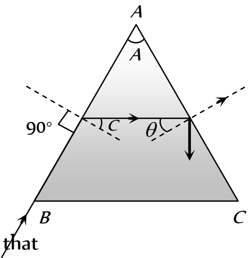
20. (b)

21. (a)

22. (c) From ray diagram

$A = C + \theta$ for TIR at AC

$\theta > C$ so $A > 2C$



23. (a) By the hypothesis, we know that

$i_1 + i_2 = A + \delta \Rightarrow 55^o + 46^o = 60^o + \delta \Rightarrow \delta = 41^o$

But $\delta_m < \delta$, so $\delta_m < 41^o$

24. (a)

25. (b) $\delta_m = (\mu - 1)A$. $A =$ angle of prism.

26. (c)

27. (c)

28. (b)

29. (a) Total deviation = 0

$\delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 = (\mu_1 - 1)A_1 - (\mu_2 - 1)A_2$

$+(\mu_3 - 1)A_3 - (\mu_4 - 1)A_4 + (\mu_5 - 1)A_5 = 0$

$\Rightarrow 2 \times A_2(1.6 - 1) = 3(1.53 - 1)9$

$\Rightarrow A_2 = 3\left(\frac{0.53 \times 9}{1.2}\right) = 11.9^o$

30. (a) The dispersive power for crown glass $\omega = \frac{n_v - n_r}{n_y - 1}$

$= \frac{1.5318 - 1.5140}{(1.5170 - 1)} = \frac{0.0178}{0.5170} = 0.034$

and for flint glass $\omega' = \frac{1.6852 - 1.6434}{(1.6499 - 1)} = 0.064$

31. (c)

32. (b)

33. (a) For dispersion without deviation $\frac{A}{A'} = \left(\frac{\mu'_y - 1}{\mu_y - 1}\right)$

$\therefore \frac{A}{10} = \frac{(1.602 - 1)}{(1.500 - 1)} = \frac{0.602}{0.500} \Rightarrow A = 12°2.4'$

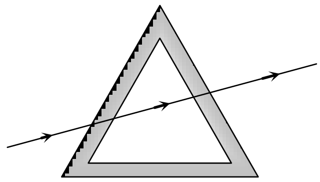
34. (c) $i = \frac{A + \delta_m}{2}$ =50°

35. (d) In minimum deviation position $\angle i = \angle e$

36. (a) Yellow (Primary) + Blue (Primary) = Green (Secondary)

37. (b) All colours are reflected.

38. (a) Effectively there is no deviation or dispersion.

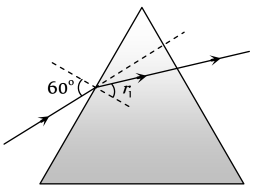


39. (d) From figure it is clear that $\angle e = \angle r_2 = 0$

From $A = r_1 + r_2$

$\Rightarrow r_1 = A = 45^o$

$\therefore \mu = \frac{\sin i}{\sin r_1} = \frac{\sin 60}{\sin 45} = \sqrt{\frac{3}{2}}$



Also from $i + e = A + \delta \Rightarrow 60 + 0 = 45 + \delta \Rightarrow \delta = 15^o$

40. (b) Deviation is zero only for a particular colour, it is generally taken to be yellow.

41. (b) $5 = (\mu - 1)A = (1.5 - 1)A \Rightarrow A = 10^o$

42. (b) $\delta = (\mu_v - \mu_r)A = 0.02 \times 10 = 0.2$

43. (a) $\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin(A/2)} = \frac{\sin 45^o}{\sin 30^o} = \sqrt{2}$

44. (c) $\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1} = \frac{1.65 - 1.61}{1.63 - 1}$

45. (a) For minimum angle of deviation for a prism

$A = 2r$, $\therefore A = 60^o$

Now $\mu = \frac{\sin\frac{60 + 30}{2}}{\sin\frac{60}{2}} = \frac{\sin 45^o}{\sin 30^o} = \frac{1}{\sqrt{2}} \times \frac{2}{1} = \sqrt{2}$

46. (c) In minimum deviation condition $\angle i = \angle e$, $\angle r_1 = \angle r_2$

47. (b) For dispersion without deviation $\frac{A}{A'} = \frac{(\mu' - 1)}{(\mu - 1)}$

$$\frac{4}{A_F}=\frac{(1.72-1)}{(1.54-1)}=\frac{0.72}{0.54} \text{ or } A_F=\frac{4\times 0.54}{0.72}=3^o$$

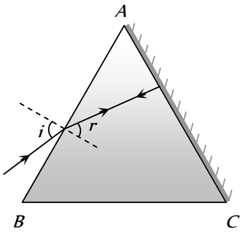
48. (a) $A(\mu_v-\mu_r)+A'(\mu_v'-\mu_r')=0^o \Rightarrow A'=5^o$

49. (c) $A=r+0 \Rightarrow r=30^o$

From Snell's law at surface *AB*

$$\mu=\frac{\sin i}{\sin r}$$

$$\Rightarrow \sqrt{2}=\frac{\sin i}{\sin 30^o} \Rightarrow i=45^o$$



50. (c) $\omega=\frac{1.64-1.52}{1.6-1}=\frac{0.12}{0.6}=0.2$

51. (c) Because band spectrum can be found in case of molecules (generally gas).

52. (a) Solids and liquids give continuous and line spectra. Only gases are known to give band spectra.

53. (d)

54. (d)

55. (a) Hydrogen is molecular, therefore it gives band spectrum but not continuous spectrum.

56. (c)

57. (a) Dispersion take place because the refractive index of medium for different colour is different, for example, red light bends less than violet, refractive index of the material of the prism for red light is less than that for violet light. Equivalently, we can say that red light travels faster than violet light in a glass prism.

58. (a) We know that $\delta=i+e-A \Rightarrow e=\delta+A-i$

$=30^o+30^o-60^o=0^o$

$\therefore$ Emergent ray will be perpendicular to the face.

Therefore it will make an angle of 90° with the face through which it emerges.

59. (a) $\delta_m=(\mu-1)(2r)=(1.5-1)2r=0.5\times 2r=r$

60. (c)

61. (c)

62. (b)

63. (d) Given $i=e=\frac{3}{4}A=\frac{3}{4}\times 60=45^o$

In the position of minimum deviation

$2i=A+\delta_m$ or $\delta_m=2i-A=90-60=30^o$

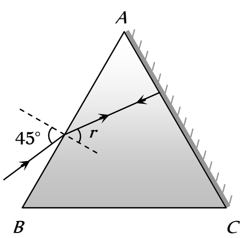
64. (d)

65. (a) Sky appears white due to scattering. In absence of atmosphere no scattering will occur.

66. (b)

67. (c) $A=r+0 \Rightarrow r=30°$

$$\therefore \mu=\frac{\sin i}{\sin r}=\frac{\sin 45°}{\sin 30°}=\sqrt{2}$$



68. (c) By formula $\delta=(n-1)A \Rightarrow 34=(n-1)A$ and in the second position $\delta'=(n-1)\frac{A}{2}$

$$\therefore \frac{34}{\delta'}=\frac{(n-1)A}{(n-1)\frac{A}{2}} \text{ or } \delta'=\frac{34}{2}=17^o$$

69. (b) From figure

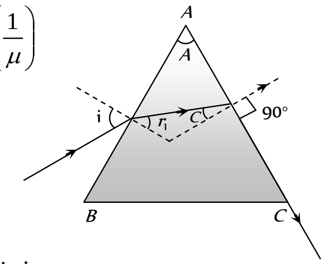
$$A=r_1+c=r_1+\sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\Rightarrow r_1=75-\sin^{-1}\left(\frac{1}{\mu}\right)$$

$\Rightarrow 75-45=30^o$

From Snell's law At *B*

$$\mu=\frac{\sin i}{\sin r_1} \Rightarrow \sqrt{2}=\frac{\sin i}{\sin 30^o} \Rightarrow i=45^o$$



70. (c) In both *A* and *B*, the refracted ray is parallel to the base of prism.

71. (a) According to given conditions TIR must take place at both the surfaces *AB* and *AC*. Hence only option (*a*) is correct.

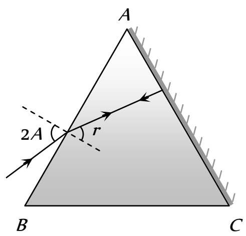
72. (d)

73. (a)

74. (b) $A=r+0$ and $\mu=\frac{\sin i}{\sin r}$

$$\Rightarrow \mu=\frac{\sin 2A}{\sin A}$$

$$=\frac{2\sin A\cos A}{\sin A}=2\cos A$$



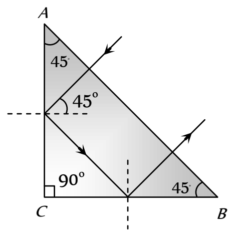
75. (a) From figure it is clear that TIR takes place at surface *AC* and *BC*

i.e. $45^o>C$

$\Rightarrow \sin 45^o>\sin C$

$$\Rightarrow \frac{1}{\sqrt{2}}>\frac{1}{\mu} \Rightarrow \mu>\sqrt{2}$$

Hence $\mu_{\text{least}}=\sqrt{2}$



76. (b)

77. (b) According to Rayleigh's law of scattering, intensity scattered is inversely proportional to the forth power of wavelength. So red is least scattered and sun appears Red.

78. (b)

79. (d)

80. (a) Only red colour will be seen in spectrum.

81. (b) $i=\frac{A+\delta_m}{2}=\frac{60°+30°}{2}=45°$

82. (a) $$\mu=\frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}}=\frac{\sin\left(\frac{60°+60°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}=\sqrt{3}$$

83. (b) Because in dispersion of white light, the rays of different colours are not parallel to each other. Also deviation takes place in same direction.

84. (c)

85. (a) $\omega = \frac{\mu_F - \mu_C}{(\mu_D - 1)} = \frac{(1.6333 - 1.6161)}{(1.622 - 1)} = 0.0276$

86. (c) For total internal reflection $\theta > C$

$\Rightarrow \sin\theta > \sin C \Rightarrow \sin\theta > \frac{1}{\mu}$

or $\mu > \frac{1}{\sin\theta} \Rightarrow \mu > \frac{1}{\sin 45^o} \Rightarrow \mu > \sqrt{2} \Rightarrow \mu > 1.41$

87. (c)

88. (a) $\theta = (\mu_v - \mu_r)A = 0.02 \times 5^o = 0.1^o$

89. (b)

90. (b) $\frac{A'}{A} = \frac{(\mu_y - 1)}{(\mu_{y'} - 1)} \Rightarrow \frac{A'}{6} = -\frac{(1.54 - 1)}{(1.72 - 1)}$

$\Rightarrow A' = -4.5^o = 4^o 30'$

91. (c) $\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\frac{A}{2}} \Rightarrow \sqrt{3} = \frac{\sin\left(\frac{60° + \delta_m}{2}\right)}{\sin\frac{60°}{2}}$

$\Rightarrow \frac{\sqrt{3}}{2} = \sin\left(30° + \frac{\delta_m}{2}\right) \Rightarrow \delta_m = 60^o$

92. (a) Dispersion is caused due to refraction as μ depends on λ.

93. (c) From colour triangle

94. (c) Due to the absorption of certain wavelengths by the elements in outer layers of sun.

95. (b)

96. (c)

97. (c) $\omega = \frac{\mu_v - \mu_R}{\mu_y - 1} = \frac{1.62 - 1.52}{1.55 - 1} = 0.18$

98. (a) $\frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2} = -\frac{2}{3}$.

99. (a) $\omega = \frac{\mu_V - \mu_R}{\mu_Y - 1} = \frac{1.62 - 1.42}{1.5 - 1} = 0.4$

100. (c) Since the ray emerges normally, therefore $e = 0$.

According to relation $A + \delta = i + e$, we get $i = A + \delta$.

Hence by $\delta = (\mu - 1)A$, we get $i = \mu A$.

101. (a) The atoms in the chromosphere absorb certain wavelengths of light coming from the photosphere. This gives rise to absorption lines.

102. (b) $\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \Rightarrow \sqrt{2}\mu = \frac{\sin\left(\frac{60 + \delta_m}{2}\right)}{\sin\left(\frac{60}{2}\right)}$

$\Rightarrow \sqrt{2} \times \sin 30 = \sin\left(\frac{60 + \delta_m}{2}\right) \Rightarrow \sin 45^o$

$= \sin\left(\frac{60 + \delta_m}{2}\right) \Rightarrow \delta_m = 30^o$

103. (a) Intensity of scattered light $I \propto \frac{1}{\lambda^4}$, since λ_{blue} is least that's why sky looks blue.

104. (b) In continuos spectrum all wavelength are present.

105. (d)

106. (b) Deviation is greater for lower wavelengths.

107. (b) $\frac{\delta_a}{\delta_w} = \frac{({}_a\mu_g - 1)}{({}_w\mu_g - 1)} = \frac{\left(\frac{3}{2} - 1\right)}{\left(\frac{3/2}{4/3} - 1\right)} = 4 \Rightarrow \delta_w = \frac{\delta_a}{4}$

108. (a) $\theta = (\mu_v - \mu_r)A = (1.66 - 1.64) \times 10^o = 0.2^o$

109. (b) $\omega = \frac{(\mu_v - \mu_R)}{(\mu_y - 1)} \Rightarrow \frac{(1.69 - 1.65)}{(1.66 - 1)} = 0.06$

110. (a) $\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{3.72 - 2.84}{3.28} = 0.268$

111. (a)

112. (d) $\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} = \frac{\sin\left(\frac{60° + 30°}{2}\right)}{\sin\frac{60°}{2}} = \frac{\sin 45^o}{\sin 30^o} = 1.414$

113. (a) Rock salt prism is used to see infrared radiations.

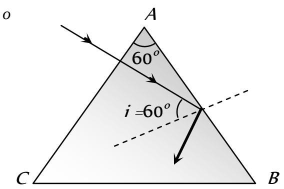
114. (b) For different colours μ changes so deviation of different colour is also different.

115. (a) By using $\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0 \Rightarrow \frac{0.02}{f_1} + \frac{0.04}{40} = 0$

$f_1 = -20\ cm$

116. (d) Critical angle for the material of prism $C = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1} = 42^o$

since angle of incidence at surface $AB\,(60^o)$ is greater then the critical angle (42^o) so total internal reflection takes place.



117. (d) Line and band spectrum are also known as atomic and molecular spectra respectively.

118. (d) In minimum deviation $i = e = 30^o$, so angle between emergent ray and second refracting surface is $90^o - 30^o = 60^o$

119. (c) $\theta = (\mu_v - \mu_R)A = (1.6 - 1.5) \times 5 = 0.5^o$

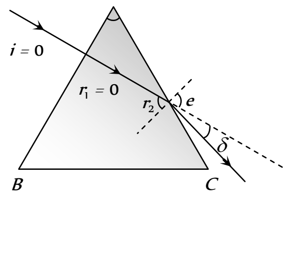
120. (d) $\frac{\delta_1}{\delta_2} = \frac{A_1}{A_2}$

121. (a) Sunlight consists of all the wavelength with some black lines.

122. (d) $A = 30^o, \mu = \sqrt{2}$. As we know

$A = r_1 + r_2 = 0 + r_2 \Rightarrow A = r_2$.

Applying Snell's law for the surface AC



$$\frac{1}{\mu} = \frac{\sin r_2}{\sin e} = \frac{\sin A}{\sin e}$$

$$\Rightarrow \frac{1}{\sqrt{2}} = \frac{\sin 30^o}{\sin e} \Rightarrow e = 45^o$$

$$\delta = e - r_2 = 45^o - 30^o = 15°$$

123. (c) $\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}} = \frac{\sin\frac{A+A}{2}}{\sin\frac{A}{2}} = \frac{\sin A}{\sin\frac{A}{2}}$

$$= \frac{2\sin\frac{A}{2}\cos\frac{A}{2}}{\sin\frac{A}{2}} = 2\cos\frac{A}{2}$$

So, $\sqrt{3} = 2\cos\frac{A}{2} \Rightarrow \frac{\sqrt{3}}{2} = \cos\frac{A}{2} \Rightarrow A = 60°$

124. (d) Light from lamp or electric heater gives continuos spectrum.

125. (b) $A = 60^o, \delta_m = 30^o$ so $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$$\mu = \frac{\sin\left(\frac{60°+30°}{2}\right)}{\sin\left(\frac{60°}{2}\right)} = \frac{\sin 45°}{\sin 30°} = \sqrt{2}$$

Also $\mu = \frac{1}{\sin C} \Rightarrow C = \sin^{-1}\left(\frac{1}{\mu}\right) \Rightarrow C = 45^o$

126. (a) $\delta \propto (\mu - 1)$

127. (c) In minimum deviation position $\angle i_1 = \angle i_2$ and $\angle r_1 = \angle r_2$.

128. (c) $\theta_{net} = \theta + \theta' = 0 \Rightarrow \omega d + \omega' d' = 0$

(θ = Angular dispersion = $\omega . \delta_y$)

129. (d) $A = 60^o, i = e = 45^o$ By $i + e = A + \delta$

$\Rightarrow 45 + 45 = 60 + \delta \Rightarrow \delta = 30^o$

130. (a) At the time of solar eclipse light received from chromosphere. The bright lines appear exactly at the places where dark lines were there. Hence at the time of solar eclipse continuos spectrum is obtained.

131. (a) In the morning or evening, the sun is at the horizon and refractive index in the atmosphere of the earth decreases with height. Due to this, the light reaching the earth's atmosphere, bends unequally, and the image of the sun get's distorted and it appears elliptical and larger.

132. (c) In Rainbow formation dispersion and TIR both takes place.

133. (a)

134. (c) Given $\delta_m = A$, as $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$$\Rightarrow \mu = \frac{\sin\left(\frac{A+A}{2}\right)}{\sin\left(\frac{A}{2}\right)} = 2\cos\frac{A}{2} \Rightarrow A = 2\cos^{-1}\left(\frac{\mu}{2}\right)$$

135. (b) As the prisms Q and R are of the same material and have identical shape they combine to form a slab with parallel faces. Such a slab does not cause any deviation.

136. (c) Angle of prism is the angle between incident and emergent surfaces.

137. (a) $\mu = \frac{\sin i}{\sin\frac{A}{2}} \Rightarrow \sqrt{2} = \frac{\sin i}{\sin\left(\frac{60}{2}\right)} \Rightarrow i = 45^o$

138. (d) Convex lens, glass slab, prism and glass sphere they all disperse the light.

139. (c) For a lens $f_r - f_v = \omega f_y$

$$\Rightarrow \omega = \frac{f_r - f_v}{f_y} = \frac{0.214 - 0.200}{0.205} = \frac{14}{205}.$$

140. (b) $\omega = \frac{(\mu_v - \mu_R)}{(\mu_y - 1)} \Rightarrow \frac{(1.69 - 1.65)}{(1.66 - 1)} = 0.06$

141. (a) In minimum deviation condition $r = \frac{A}{2} = \frac{60}{2} = 30^o$

142. (a) $\omega = \frac{\mu_v - \mu_r}{\mu_y - 1} = \frac{1.67 - 1.63}{1.65 - 1} = 0.615.$

143. (b) In minimum deviation position refracted ray inside the prism is parallel to the base of the prism.

144. (b) Angle of refraction will be different, due to which red and green emerge from different points and will be parallel.

145. (a) Deviation $\delta \propto \mu \propto \frac{1}{\lambda}$

146. (a) $\mu = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}} = \frac{\sin\frac{60+38}{2}}{\sin\frac{60}{2}}$

$$= \frac{\sin 49^o}{\sin 30^o} = \frac{0.7547}{0.5} = 1.5.$$

147. (d) Using $\delta = i_1 + i_2 - A \Rightarrow 55 = 15 + i_2 - 60 \Rightarrow i_2 = 100^o$

148. (b) Sodium light gives emission spectrum having two yellow lines.

149. (c) Colour of the sky is highly scattered light (colour).

150. (a)

151. (c)

Human Eye and Lens Camera

1. (c) Man is suffering from hypermetropia. The hole works like a convex lens.

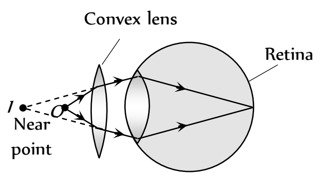
2. (a)

3. (b) In myopia, $u = \infty$, $v = d$ = distance of far point

By $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$, we get $f = -d$

Since f is negative, hence the lens used is concave.

4. (d) Hypermetropia is removed by convex lens.



5. (b)

6. (c) Cylindrical lens are used for removing astigmatism.

7. (b)

8. (a) Image formed at retina is real and inverted.

9. (d) Visible region decreases, so the depth of image will not be seen.

10. (a) $P = \frac{1}{f} = -\frac{1}{v} + \frac{1}{u} = -\frac{1}{100} + \frac{1}{25} = \frac{3}{100} = +3\,D$

11. (c) If eye is kept at a distance d, then $MP = \frac{L(D-d)}{f_0 f_e}$, MP decreases.

12. (c) For lens u = want's to see = ∞

v = can see = – 5 m

$\therefore$ From $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-5} - \frac{1}{\infty} \Rightarrow f = -5\,m.$

13. (a) For improving near point, convex lens is required and for this convex lens

$u = -25\ cm,\ v = -75\ cm$

$\therefore \frac{1}{f} = \frac{1}{-75} - \frac{1}{-25} \Rightarrow f = \frac{75}{2} cm$

So power $P = \frac{100}{f} = \frac{100}{75/2} = +\frac{8}{3} D$

14. (b) In short sightedness, the focal length of eye lens decreases, so image is formed before retina.

15. (d) The image of object at infinity should be formed at 100 cm from the eye

$\frac{1}{f} = \frac{1}{\infty} - \frac{1}{100} = -\frac{1}{100}$

So the power $= \frac{-100}{100} = -1\,D$

(Distance is given in cm but $P = \frac{1}{f}$ in *metres*)

16. (b) For improving far point, concave lens is required and for this concave lens $u = \infty,\ v = -30\ cm$

So $\frac{1}{f} = \frac{1}{-30} - \frac{1}{\infty} \Rightarrow f = -30\ cm$

for near point $\frac{1}{-30} = \frac{1}{-15} - \frac{1}{u} \Rightarrow u = -30\ cm$

17. (c) For myopic eye f = – (defected far point)

$\Rightarrow f = -40\,cm \Rightarrow P = \frac{100}{-40} = -2.5\,D$

18. (c) For lens u = want's to see $= -60\,cm$

v = can see $= -10\,cm$

$\therefore \frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-10} - \frac{1}{(-60)} \Rightarrow f = -12\,cm$

19. (b) Focal length = – (Detected far point)

20. (c) In this case, for seeing distant objects the far point is 40 cm. Hence the required focal length is

$f = -d$ (distance of far point) = – 40 cm

Power $P = \frac{100}{f} cm = \frac{100}{-40} = -2.5\ D$

21. (b)

22. (a)

23. (a)

24. (a) For viewing far objects, concave lenses are used and for concave lens

u = wants to see $= -60\,cm$; v = can see $= -15\,cm$

so from $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow f = -20\,cm$.

25. (d)

26. (a) In short sightedness, the focal length of eye lens decreases and so the power of eye lens increases.

27. (d) Colour blindness is a genetic disease and still cannot be cured.

28. (c) Convexity to lens changes by the pressure applied by ciliary muscles.

29. (b) $f = -d = -100\ cm = -1\ m$

$\therefore P = \frac{1}{f} = \frac{1}{-1} = -1\ D$

30. (c) For correcting myopia, concave lens is used and for lens.

u = wants to see $= -50\,cm$

v = can see $= -25\,cm$

From $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-25} - \frac{1}{(-50)} \Rightarrow f = -50\,cm$

So power $P = \frac{100}{f} = \frac{100}{-50} = -2\,D$

31. (c)

32. (c) $f = -d = -60\ cm$

$\therefore P = \frac{100}{f} = -\frac{100}{60} = -\frac{10}{6} = -1.66\ D$

33. (b) For correcting the near point, required focal length

$f = \frac{50 \times 25}{(50-25)} = 50\,cm$

So power $P = \frac{100}{50} = +2\,D$

For correcting the far point, required focal length

$f = -(\text{defected far point}) = -3\,m$

$\therefore P = -\frac{1}{3} D = -0.33\,D$

34. (b) Negative power is given, so defect of eye is nearsigntedness

Also defected far point $= -f = -\frac{1}{p} = -\frac{100}{(-2.5)} = 40\,cm$

35. (a) In myopia, eye ball may be elongated so, light rays focussed before the retina.

36. (c)

37. (d) $P = \frac{1}{f} = \frac{1}{-(\text{defected far point})} = -\frac{1}{2} = -0.5\,D$

38. (a) Resolving limit of eye is one minute (1′).

39. (d) Because for healthy eye image is always formed at retina.

40. (a) The defect is myopia (nearsightness)

As we know for myopic person f = – (defected far point)

$\Rightarrow$ Defected far point = – $f = -\frac{1}{P} = -\frac{1}{(-2)} = 0.5\,m$

= 50 cm

41. (b) Power of convex lens $P_1 = \frac{100}{40} = 2.5\ D$

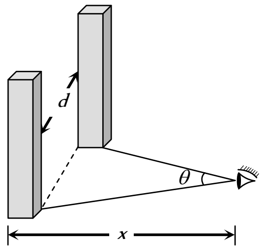
Power of concave lens $P_2 = -\frac{100}{25} = -4\ D$

Now $P = P_1 + P_2 = 2.5\ D - 4\ D = -1.5\ D$

42. (c)

43. (d)

44. (a) As limit of resolution of eye is $\left(\frac{1}{60}\right)^o$, the pillars will be seen distinctly if $\theta > \left(\frac{1}{60}\right)^o$



i.e., $\frac{d}{x} > \left(\frac{1}{60}\right) \times \frac{\pi}{180}$

$\Rightarrow d > \frac{\pi \times x}{60 \times 180}$

$\Rightarrow d > \frac{3.14 \times 11 \times 10^3}{60 \times 180} \Rightarrow d > 3.2\ m$

45. (b)

46. (b)

47. (d)

48. (d) f = – (defected far point) = – 20 cm

49. (b) Power of the lens given positive so defect is hypermetropia.

50. (b) Far point of the eye = focal length of the lens

$= \frac{100}{P} = \frac{100}{0.66} = 151\ cm$

51. (c) A bifocal lens consist of both convex or concave lenses with lower part is convex.

52. (a) For lens u = wants to see = – 30 cm

and v = can see = – 10 cm

$\therefore \frac{1}{f} = \frac{1}{v} - \frac{1}{u} = \frac{1}{-10} - \frac{1}{(-30)} \Rightarrow f = -15\,cm$

53. (a) Focal length = – (far point)

54. (c) For lens u = wants to see = – 12 cm

v = can see = – 3 m

$\therefore P = \frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow P = \frac{1}{-3} - \frac{1}{(-12)} = -\frac{1}{4} D$

55. (d) $I_1 D_1^2 t_1 = I_2 D_2^2 t_2$

Here D is constant and $I = \frac{L}{r^2}$

So $\frac{L_1}{r_1^2} \times t_1 = \frac{L_2}{r_2^2} \times t_2 \Rightarrow \frac{60}{(2)^2} \times 10 = \frac{120}{(4)^2} \times t \Rightarrow 20\ sec$

56. (a) $f = -40\ cm$ and $P = \frac{100}{-40} = -2.5\ D$

57. (a) Focal length of the lens $f = \frac{100}{3} cm$

By lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\Rightarrow \frac{1}{+100/3} = \frac{1}{v} - \frac{1}{-25} \Rightarrow v = -100\ cm = -1\ m$

58. (d) This is the defect of hypermetropia.

59. (a) For large objects, large image is formed on retina.

60. (d) $v = -15 cm,\ u = -300 cm,$

From lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$\Rightarrow \frac{1}{f} = \frac{1}{-15} - \frac{1}{-300} = \frac{-19}{300} \Rightarrow f = \frac{-300}{19} = -15.8\,cm$

and power $P = \frac{100}{f} cm = \frac{-100 \times 19}{300} = -6.33\ D.$

61. (d) Time of exposure $\propto \frac{1}{(\text{Aperture})^2}$

62. (a) Light gathering power ∝ Area of lens aperture or d

63. (b) Time of exposure $\propto (f.\text{number})^2 \Rightarrow \frac{t_2}{t_1} = \left(\frac{5.6}{2.8}\right)^2 = 4$

$t_2 = 4\,t_1 = 4 \times \frac{1}{200} = \frac{1}{50}\ sec = 0.02\ sec.$

64. (d)

65. (a)

Microscope and Telescope

1. (c) By using $m_\infty = \frac{(L_\infty - f_o - f_e).D}{f_o f_e}$

$\Rightarrow 45 = \frac{(L_\infty - 1 - 5) \times 25}{1 \times 5} \Rightarrow L_\infty = 15\,cm.$

2. (b) For a compound microscope $m \propto \frac{1}{f_o f_e}$

3. (b) For a compound microscope $f_{objective} < f_{eye\ piece}$

4. (b) In microscope final image formed is enlarged which in turn increases the visual angle.

5. (b)

6. (d) Magnification of a compound microscope is given by

$m = -\frac{v_o}{u_o} \times \frac{D}{u_e} \Rightarrow |m| = m_o \times m_e.$

7. (c) Magnifying power of a microscope $m \propto \frac{1}{f}$

Since $f_{\text{violet}} < f_{\text{red}};\ \therefore m_{\text{violet}} > m_{\text{red}}$

8. (a) $L_\infty = v_o + f_e \Rightarrow 14 = v_o + 5 \Rightarrow v_o = 9\ cm$

Magnifying power of microscope for relaxed eye

$m = \frac{v_o}{u_o} . \frac{D}{f_e}$ or $25 = \frac{9}{u_o} . \frac{25}{5}$ or $u_o = \frac{9}{5} = 1.8\ cm$

9. (b) $m_\infty = -\frac{v_o}{u_o} \times \frac{D}{f_e}$

From $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$\Rightarrow \frac{1}{(+1.2)} = \frac{1}{v_o} - \frac{1}{(-1.25)} \Rightarrow v_o = 30\ cm$

$\therefore |m_\infty| = \frac{30}{1.25} \times \frac{25}{3} = 200$

10. (b) For objective lens $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$\Rightarrow \frac{1}{(+4)} = \frac{1}{v_o} - \frac{1}{(-4.5)} \Rightarrow v_o = 36\ cm$

$\therefore |m_D| = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = \frac{36}{4.5}\left(1 + \frac{24}{8}\right) = 32$

11. (a) For a microscope $|m| = \frac{v_o}{u_o} \times \frac{D}{u_e}$ and $L = v_o + u_e$

For a given microscope, with increase in L, u will increase and hence magnifying power (m) will decrease.

12. (b) In compound microscope objective forms real image while eye piece forms virtual image.

13. (b) $m = 1 + \frac{D}{f}$

Smaller the focal length, higher the magnifying power.

14. (a) In electron microscope, electron beam $(\lambda \approx 1\mathring{A})$ is used so it's $R.P.$ is approx. 5000 times more than that of ordinary microscope $(\lambda \approx 5000\mathring{A})$.

15. (c) If nothing is said then it is considered that final image is formed at infinite and $m_\infty = \frac{(L_\infty - f_o - f_e).D}{f_o f_e} \simeq \frac{LD}{f_0 f_e}$

$\Rightarrow 400 = \frac{20 \times 25}{0.5 \times f_e} \Rightarrow f_e = 2.5\ cm.$

16. (d) $m_{\max} = 1 + \frac{D}{f} = 1 + \frac{25}{2.5} = 11$.

17. (a)

18. (b) $m = 1 + \frac{D}{f} = 1 + DP$ (m increases with P)

19. (b)

20. (b) Like Gallilean telescope.

21. (a) $|m| \propto \frac{1}{f_o f_e}$

22. (d) A microscope consists of lens of small focal lengths. A telescope consists of objective lens of large focal length.

23. (c) $m = m_o \times m_e = 25 \times 6 = 150$

24. (a) When final image is formed at infinity,

length of the tube $= v_o + f_e$

$\Rightarrow 15 = v_o + 3 \Rightarrow v_o = 12\ cm$

For objective lens $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$\Rightarrow \frac{1}{(+2)} = \frac{1}{(+12)} - \frac{1}{u_o} \Rightarrow u_o = -2.4\ cm$

25. (d) R.P. of microscope $= \frac{2\mu \sin\theta}{\lambda}$

26. (c) $m = m_o \times m_e \Rightarrow m = m_o \times \left(1 + \frac{D}{f_e}\right)$

$\Rightarrow 100 = 10 \times \left(1 + \frac{25}{f_e}\right) \Rightarrow f_e = \frac{25}{9}\ cm$

27. (c) A simple microscope is just a convex lens with object lying between optical centre and focus of the lens.

28. (d) In general, the simple microscope is used with image at D, hence

$m = 1 + \frac{D}{f} = 1 + \frac{25}{5} = 6$

29. (d)

30. (b) Resolving power of microscope $\propto \frac{1}{\lambda}$

31. (a) Cross wire arrangement is used to make measurements.

32. (d) $L = v_o + u_e = \frac{u_o f_o}{(u_o - f_o)} + \frac{f_e D}{f_e + D}$

$\Rightarrow L = \frac{2 \times 1.5}{(2 - 1.5)} + \frac{6.25 \times 25}{(6.25 + 25)} = 11\ cm$

33. (d) $m \simeq \frac{LD}{f_o f_e} \Rightarrow m = \frac{10 \times 25}{0.5 \times 1} = 500$.

34. (c) Intermediate image means the image formed by objective, which is real, inverted and enlarged.

35. (d) $m \propto \frac{1}{f_o f_e}$

36. (b) R.P. $\propto \frac{1}{\lambda}$; $\lambda_{\text{Blue}} < \lambda_{\text{Red}}$ so $(R.P.)_{\text{Blue}} > (R.P.)_{\text{Red}}$

37. (a) $m = 1 + \frac{D}{f} \Rightarrow 6 = 1 + \frac{25}{f} \Rightarrow f = 5\ cm = 0.05\ m$

38. (a) Resolving limit

$x \propto \lambda \Rightarrow \frac{x_1}{x_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{0.1}{x_2} = \frac{6000}{4800} \Rightarrow x_2 = 0.08\ mm$

39. (b) $m = m_o \times m_e \Rightarrow 100 = 5 \times m_e \Rightarrow m_e = 20$

40. (d) $m \propto \frac{1}{f} \propto P$

41. (d) R.P. $\propto \frac{1}{\lambda} \Rightarrow \frac{(R.P.)_1}{(R.P.)_2} = \frac{\lambda_2}{\lambda_1} = \frac{5}{4}$

42. (b) Resolving limit (minimum separation) $\propto \lambda$

$\Rightarrow \frac{P_A}{P_B} = \frac{2000}{3000} \Rightarrow P_A < P_B$

43. (d) Similar to Q.No. 34

44. (a) For achromatic telescope objective lens, convergent of crown and divergent of flint is the best combination because $\mu_{\text{crown}} < \mu_{\text{flint}}$

45. (c)

46. (b) Magnifying power of telescope is $\frac{f_o}{f_e}$, so as $\frac{1}{f_e}$ increases, magnifying power increases.

47. (b) Since $m = \frac{f_o}{f_e}$

Also $m = \frac{\text{Anglesubtended by the image}}{\text{Anglesubtended by the object}}$

$\therefore \frac{f_o}{f_e} = \frac{\alpha}{\beta} \Rightarrow \alpha = \frac{f_o \times \beta}{f_e} = \frac{60 \times 2}{5} = 24^o$

48. (d) Resolving power $= \frac{d}{1.22\,\lambda} = \frac{0.1}{1.22 \times 6000 \times 10^{-10}}$

$\cong 1.36 \times 10^5\, radian$

49. (b) Because size of the aperture decreases.

50. (d) Resolving power $\propto$ aperture.

51. (c) Telescope is used to see the distant objects. More magnifying power means more nearer image.

52. (a) When the final image is at the least distance of distinct vision, then

$m = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) = \frac{200}{5}\left(1 + \frac{5}{25}\right) = \frac{200 \times 6}{5 \times 5} = -48$

When the final image is at infinity, then

$m = \frac{-f_o}{f_e} = \frac{200}{5} = -40$

53. (a) In terrestrial telescope erecting lens absorbs a part of light, so less constant image. But binocular lens gives the proper three dimensional image.

54. (a) By formula $m = \frac{f_o}{f_e}$

55. (b) In telescope $f_o >> f_e$ as compared to microscope.

56. (a) Because magnification in this case becomes reciprocal of initial magnification.

57. (d) $m = \frac{f_o}{f_e} \Rightarrow \frac{80}{f_e} = 20 \Rightarrow f_e = 4\ cm$

Hence length of terrestrial telescope

$= f_o + f_e + 4f = 80 + 4 + 4 \times 20 = 164\ cm$

58. (d) In this case $|m| = \frac{f_o}{f_e} = 5$ .... (i)

and length of telescope $= f_o + f_e = 36$ .... (ii)

Solving (i) and (ii), we get $f_e = 6\ cm$, $f_o = 30\, cm$.

59. (c) $|m| = \frac{f_o}{f_e} = \frac{180}{6} = 30$

60. (c) Same as Q. No. 58.

61. (c) $f_o = \frac{1}{1.25} = 0.8\, m$ and $f_e = \frac{1}{-20} = -0.05\, m$

$\therefore |L_\infty| = |f_o| - |f_e| = 0.8 - 0.05 = 0.75\, m = 75\, cm$

and $|m_\infty| = \frac{f_o}{f_e} = \frac{0.8}{0.05} = 16$

62. (a) For greater aperture of lens, light passing through lens is more and so intensity of image increases.

63. (b)

64. (a) Same as Q. No. 58.

65. (b) $m = \frac{f_o}{f_e} = \frac{60}{10} = 6$.

66. (a) $f_o + f_e = 54$ and $\frac{f_o}{f_e} = m = 8 \Rightarrow f_o = 8 f_e$

$\Rightarrow 8 f_e + f_e = 54 \Rightarrow f_e = \frac{54}{9} = 6$

$\Rightarrow f_o = 8 f_e = 8 \times 6 = 48$

67. (a) $f_o - f_e = 9\ cm$ and $f_e = f_o - 9 = 15 - 9 = 6\ cm$

$\Rightarrow m = \frac{f_o}{f_e} = \frac{15}{6} = 2.5$

68. (c) $f_o + f_e = 80$ and $\frac{f_o}{f_e} = 19 \Rightarrow f_o = 76$ and $f_e = 4\ cm$.

69. (a)

70. (b) $R.P. \propto \frac{D}{\lambda}$

71. (c) $m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$

72. (b) Resolving power $\propto$ Aperture

73. (a) If final image is formed at infinity, then the distance between the two lenses of telescope is equal to length of tube $= f_o + f_e = 0.3 + 0.05 = 0.35\ m$

74. (a) Limit of resolution $= \frac{1.22\,\lambda}{a} \times \frac{180}{\pi}$ (in degree)

$= \left(\frac{1.22 \times (6000 \times 10^{-10})}{5} \times \frac{180}{\pi}\right)^o = 0.03\ sec$

75. (b) Final image formed by astronomical telescope is inverted not erect.

76. (d)

77. (c)

78. (b) For normal vision (relaxed eye), the image is formed at infinity. Hence the magnifying power of Gallilean telescope $= \frac{f_o}{f_e} = \frac{200}{2} = 100$.

79. (a) $m = -\frac{f_o}{f_e} = -\frac{100}{2} = -50$.

80. (c)

81. (b) Magnifying power of astronomical telescope

$m = -\frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) = -\frac{200}{5}\left(1 + \frac{5}{25}\right) = -48$.

82. (b) $m \propto \frac{1}{f_e}$

83. (b) $f_0 > f_e$ for telescope.

84. (a) $m = -\frac{f_0}{f_e}$.

85. (b) $|m| = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) = \frac{100}{5}\left(1 + \frac{5}{25}\right) = 24$

86. (a, b, c, d)

87. (a) $|m| = \frac{f_o}{f_e} = 20$ and $L = f_o + f_e = 105 \Rightarrow f_o = 100\ cm$

88. (a) Total length $L = f_o + f_e$ and both lenses are convex.

89. (b) $L = f_o + f_e = 44$ and $|m| = \frac{f_o}{f_e} = 10$

This gives $f_o = 40\ cm$

90. (c) In case of a telescope if object and final image are at infinity then $m = \frac{f_o}{f_e}$

91. (b) Three lenses are $\rightarrow$ objective, eye piece and erecting lens.

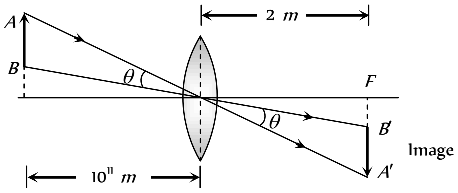
92. (d) Length of the telescope when final image is formed at least distance of distinct vision is

$$L = f_o + u_e = f_o + \frac{f_e D}{f_e + D} = 50 + \frac{5 \times 25}{5 + 25} = \frac{325}{6}\ cm$$

93. (c) $\frac{\beta}{\alpha} = \frac{f_o}{f_e} \Rightarrow \frac{\beta}{0.5^o} = \frac{100}{2} \Rightarrow \beta = 25^o$

94. (d)

95. (c) $\theta = \frac{AB}{10^{11}} = \frac{A'B'}{2} \Rightarrow A'B' = \frac{2 \times 1.4 \times 10^9}{10^{11}} = 2.8\ cm$



96. (c) $m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) \Rightarrow m = \frac{90}{6}\left(1 + \frac{6}{30}\right) \Rightarrow m = 18$

97. (d) Resolving power of telescope $= \frac{d}{1.22\ \lambda}$

98. (a) For largest magnification focal length of eye lens should be least.

99. (b) $m = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right) = \frac{150}{6}\left(1 + \frac{6}{25}\right) = 30$.

100. (d) To make telescope of higher magnifying power, f_o should be large and f_e should be least.

101. (c) $f_o = 50\ cm,\ f_e = 5\ cm,\ D = 25\ cm$ and $u_o = 200\ cm.$

Separation between the objective and the eye lens is

$$L = \frac{u_o f_o}{(u_o - f_o)} + \frac{f_e D}{(f_e + D)} = \frac{200 \times 50}{(200 - 50)} + \frac{5 \times 25}{(5 + 25)} = 71\ cm$$

102. (b) Resolving power $= \frac{d}{1.22\ \lambda} = \frac{1.22}{1.22 \times 5000 \times 10^{-10}} = 2 \times 10^6$

103. (a)

104. (b) By using $m = \frac{f_o}{f_e} \Rightarrow f_e = \frac{100}{50} = 2\ cm$

Also $L = f_o - f_e = 100 - 2 = 98\ cm$

105. (b) $m = \frac{f_o}{f_e} \Rightarrow 10 = \frac{f_o}{20} \Rightarrow f_o = 200\ cm$

106. (c) Minimum angular separation $\Delta\theta = \frac{1}{R.P.} = \frac{1.22\ \lambda}{d}$

$$= \frac{1.22 \times 5000 \times 10^{-10}}{2} = 0.3 \times 10^{-6}\ rad$$

107. (c) $m = 1 + \frac{D}{f_e} \Rightarrow 10 = 1 + \frac{25}{f_e} \Rightarrow f_e = \frac{25}{9} \simeq 25\ mm$

108. (a) $\frac{D}{F}$ or $\frac{25}{F}$

109. (c) $L = v_0 + u_e$ and $v_0 >> f_0,\ u_e \simeq f_e$

110. (c) Magnification will be done by compound microscope only when $f_o < f_e$

111. (d) Angular resolution $d\theta = \frac{1.22\ \lambda}{a}$

$$= \frac{1.22 \times 5000 \times 10 \times 10^{-10}}{10 \times 10^{-2}} = 6.1 \times 10^{-6}\ rad.$$

112. (a) Resolving power $= \frac{a}{1.22\ \lambda}$

113. (d) $M = \frac{f_o}{f_e} = \frac{P_e}{P_o} = \frac{20}{0.5} = 40$.

114. (a) Radio, waves can pass through dust, clouds, fog, etc, in a radio, telescope. It can detect very faint radio signal due to enormous size of its reflector. So it can be used at night and even in cloudy weather.

115. (a) Resolving limit

$$d\theta = \frac{1.22\ \lambda}{a} = \frac{1.22 \times 4538 \times 10^{-10}}{1} = 5.54 \times 10^{-7}\ rad.$$

116. (a) Magnification of objective lens $m = \frac{I}{O} = \frac{v_0}{u_0} = \frac{f_0}{u_0}$

$\Rightarrow \frac{I}{50} = \frac{200 \times 10^{-2}}{2 \times 10^3} \Rightarrow I = 5 \times 10^{-2}\ m = 5\ cm.$

117. (b) $m = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = m_o\left(1 + \frac{D}{f_e}\right)$

$\Rightarrow 30 = m_o\left(1 + \frac{25}{5}\right) = m_0 \times 6 \Rightarrow m_o = 5$.

118. (a)

119. (a) $m = \frac{f_o}{f_e} \Rightarrow \frac{100}{f_e} = 50 \Rightarrow f_e = 2\ cm$

Normal distance $f_o - f_e = 100 - 2 = 98\ cm.$

120. (a) For objective lens $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$

$\Rightarrow \frac{1}{v_o} = \frac{1}{f_o} + \frac{1}{u_o} = \frac{1}{4} + \frac{1}{-5} = \frac{1}{20} \Rightarrow v_o = 20 cm$

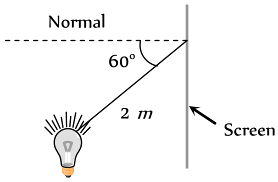
Now $M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right) = \frac{20}{5}\left(1 + \frac{20}{10}\right) = 12.$

Photometry

1. (d) Luminous flux $= 4\pi\ L = 4 \times 3.14 \times 42 = 528$ *Lumen*

Power of lamp $= \frac{\text{Luminous flux}}{\text{Luminous efficiency}} = \frac{528}{2} = 264\ W$

2. (b) $I = \dfrac{L\cos\theta}{r^2}$



$\Rightarrow L = \dfrac{I \times r^2}{\cos\theta}$

$= \dfrac{5\times10^{-4}\times10^4\times2^2}{\cos 60^\circ} = 40\ Candela$

3. (d) $I = \dfrac{L}{r^2} \Rightarrow \dfrac{dI}{I} = -\dfrac{2dr}{r}$ ($\because L$ = constant)

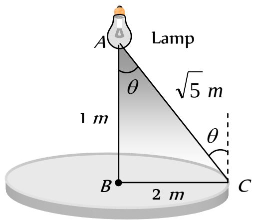
$\Rightarrow \dfrac{dI}{I}\times100 = -\dfrac{2\times dr}{r}\times100 = -2\times1 = -2\%$

4. (c) For equal fogging $I_2 \times t_2 = I_1 \times t_1$

$\Rightarrow \dfrac{L_2}{r_2^2}\times t_2 = \dfrac{L_1}{r_1^2}\times t_1 \Rightarrow \dfrac{16}{4}\times t_2 = \dfrac{20}{1}\times10$

$\Rightarrow t_2 = 50\ \text{sec}.$

5. (d) The illuminance at B



$I_B = \dfrac{L}{1^2}$ ....(i)

and illuminance at point C

$I_C = \dfrac{L\cos\theta}{(\sqrt5)^2} = \dfrac{L}{(\sqrt5)^2}\times\dfrac{1}{\sqrt5}$

$\Rightarrow I_C = \dfrac{L}{5\sqrt5}$ ...... (ii)

From equation (i) and (ii) $I_B = 5\sqrt5\ I_0$

6. (b) $I \propto \dfrac{1}{r^2}$ so,

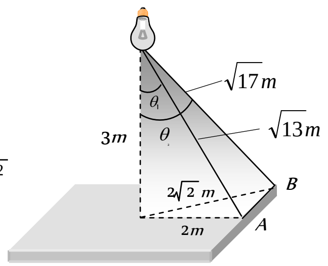
$$\frac{\text{Illuminance on slide}}{\text{Illuminance on screen}} = \frac{(\text{Length of image on screen})^2}{(\text{Length of object on slide})^2}$$

$= \left(\dfrac{3.5\ m}{35\ mm}\right)^2 = 10^4 : 1$

7. (a) The illuminance at A is

$I_A = \dfrac{L}{(\sqrt{13})^2}\times\cos\theta_1 = \dfrac{L}{13}\times\dfrac{3}{\sqrt{13}} = \dfrac{3L}{(13)^{3/2}}$

The illuminance at B is



$I_B = \dfrac{L}{(\sqrt{17})^2}\times\cos\theta_2$

$= \dfrac{L}{17}\times\dfrac{3}{\sqrt{17}} = \dfrac{3L}{(17)^{3/2}}$

$\therefore \dfrac{I_A}{I_B} = \left(\dfrac{17}{13}\right)^{3/2}$

8. (b)

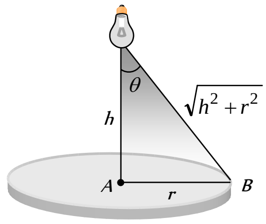
9. (c) Luminous intensity $L = \dfrac{\phi}{4\pi} \Rightarrow 1 = \dfrac{\phi}{4\pi} \Rightarrow \phi = 4\pi.$

10. (c) $\phi = 4\pi L = 4\times3.14\times100 = 1256$ *lumen.*

11. (a) $I = \dfrac{L}{r^2} \Rightarrow L = I.r^2 = 22\times2^2 = 100$

Now $\phi = 4\pi L = 4\times3.14\times100 = 1256$ *lumen.*

12. (c) Illuminance at A,



$I_A = \dfrac{L}{h^2}$

Illuminance at B,

$I_B = \dfrac{L}{\sqrt{(h^2+r^2)^2}}\cos\theta$

$= \dfrac{Lh}{(r^2+h^2)^{3/2}}$

$\therefore \dfrac{I_A}{I_B} = \left(1+\dfrac{r^2}{h^2}\right)^{3/2} = \left(1+\dfrac{8^2}{8^2}\right)^{3/2} = 2^{3/2} = 2\sqrt2 : 1$

13. (c) $I = \dfrac{L}{r^2}$

14. (c) Efficiency of light source

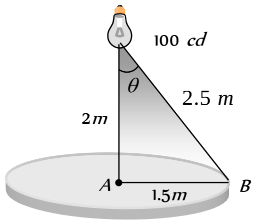
$\eta = \dfrac{\phi}{p}$ ..... (i)

and $L = \dfrac{\phi}{4\pi}$ ..... (ii)

From equation (i) and (ii)

$\Rightarrow p = \dfrac{4\pi L}{\eta} = \dfrac{4\pi\times35}{5} \approx 88\ W.$

15. (a) Case I

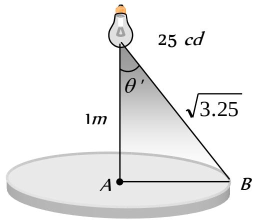


$I_A = \dfrac{100}{2^2} = 25\ cd$

and $I_B = \dfrac{100}{(2.5)^2}\cos\theta$

$= \dfrac{100}{2.5^2}\times\dfrac{2}{2.5} = \dfrac{200}{(2.5)^3}$

Case II,



$I'_B = X\,I_B = \dfrac{25}{(3.25)^{3/2}}$

so $\dfrac{I'_B}{I_B} = \dfrac{25}{200}\times\dfrac{(2.5)^3}{(3.25)^{3/2}}$

$\Rightarrow X = 1/3$

16. (a) $I \propto \dfrac{1}{r^2} \Rightarrow \dfrac{I_2}{I_1} = \dfrac{r_1^2}{r_2^2} = \dfrac{60^2}{180^2} = \dfrac{1}{9}$

17. (b)

18. (b) $I \propto \dfrac{1}{r^2}$

19. (c) To develop a print a fix amount of energy is required. Total light energy incident on photo print

$I\times A\,t = \dfrac{L}{r^2}A\,t \Rightarrow \dfrac{L_1}{r_1^2}A_1t_1 = \dfrac{L_2}{r_2^2}A_2t_2$

$\Rightarrow \dfrac{t_1}{r_1^2} = \dfrac{t_2}{r_2^2}$ ($\because L_1 = L_2$ and $A_1 = A_2$)

$$\Rightarrow t_2 = \frac{r_2^2}{r_1^2}.t_1 = \left(\frac{0.40}{0.25}\right) 2 \times 5 = 12.8 \; sec.$$

20. (b) $\frac{I_{centre}}{I_{edge}} = \frac{(r^2+h^2)^{3/2}}{h^3} = \frac{\left(1+\frac{1}{4}\right)^{3/2}}{1^3} = \left(\frac{5}{4}\right)^{3/2}$

21. (c) $I = \frac{L}{r^2} \Rightarrow \frac{L_1}{r_1^2} = \frac{L_2}{r_2^2}$ (I is same)

$$\Rightarrow \frac{L_1}{L_2} = \frac{r_1^2}{r_2^2} = \left(\frac{1}{10}\right)^2 = 1:100.$$

22. (c) $I_\theta = I_o \cos\theta = I_o \cos 60^o = \frac{I_o}{2}$

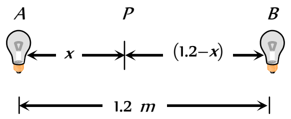
23. (a)

24. (b) $\phi = 4\pi L = 200\,\pi$ *lumen.*

so $I = \frac{\phi}{100\,A} = \frac{200\,\pi}{100 \times \pi r^2} = \frac{2}{(0.1)^2} = 200$ *lux.*

25. (b,c) According to the problem

$\frac{I_A}{x^2} = 4\frac{I_B}{(1.2-x)^2}$

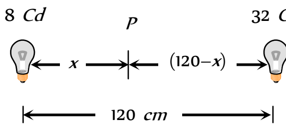


$$\Rightarrow \frac{1}{x^2} = \frac{4}{(1.2-x)^2}$$

$$\Rightarrow \frac{1}{x} = \frac{2}{1.2-x} \Rightarrow x = 0.4\,m \text{ and } 1.2 - x = 0.8\,m.$$

26. (c) $I = \frac{L}{r^2} \Rightarrow \frac{L_1}{L_2} = \frac{r_1^2}{r_2^2}$

or $\frac{8}{x^2} = \frac{32}{(120-x)^2}$



Solving it we get $x = 40\,cm$.

27. (d) $\frac{I_{center}}{I_{edge}} = \frac{(r^2+h^2)^{3/2}}{h^3}$

$$\Rightarrow 8 = \frac{(r^2+h^2)^{3/2}}{h^3} \Rightarrow 2h = (r^2+h^2)^{1/2}$$

$$\Rightarrow 4h^2 = r^2 + h^2 \Rightarrow 3h^2 = r^2 \Rightarrow h = \frac{r}{\sqrt{3}}$$

28. (b) $I = \frac{L}{r^2} = \frac{100}{5^2} = 4$ *Lux.*

29. (d) $I_1 = \frac{L}{r_1^2} = \frac{L}{1600}$ and $I_2 = \frac{L}{2500}$

$\therefore$ % decease in illuminance

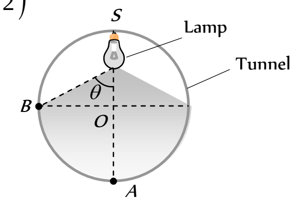
$$= \frac{I_1 - I_2}{I_1} \times 100 = \left(1 - \frac{1600}{2500}\right) \times 100 = \frac{900}{2500} \times 100 = 36$$

30. (b)

31. (d) $I_A = \frac{L}{(2r)^2}$ and $I_B = \frac{L}{(r\sqrt{2})^2}\cos\theta$

$$= \frac{L}{2r^2}.\frac{r}{r\sqrt{2}} = \frac{L}{2\sqrt{2}\,r^2}$$

$$\therefore \frac{I_A}{I_B} = \frac{2\sqrt{2}}{4} = \frac{1}{\sqrt{2}}$$



32. (a) $I = \frac{L}{r^2} \Rightarrow L = 1.57 \times 10^5 \times (1.5 \times 10^{11})^2 = 3.53 \times 10^{27}\; Cd$

33. (d) $\phi = 4\pi L = 4 \times 3.14 \times 3.53 \times 10^{27} = 4.43 \times 10^{28}$ *lumen.*

34. (d) $\phi = \frac{3}{1.5 \times 10^{-3}} \times 0.685 = 1.37 \times 10^3$ *lumen*

35. (a) $\phi_{surface} = \frac{3000}{6} = 500$ *lumen.*

36. (c) Rotation of area about incident light doesn't change the inclination of the light ray on the area.

37. (c) $I = \frac{Lh}{r^3}$

38. (d) By the symmetry of the rays and location of the points.

39. (d) If η is the luminous efficiency of the bulb then.

luminous flux by 120 *watt* at 555 *nm* $= \eta \times 120$

Let bulb of P watt at 600 *nm* produces the same luminous flux as by 120 *watt* at 555 *nm* then

$$\eta \times 120 = \eta P \times 0.6 \Rightarrow P = \frac{120}{0.6} = 200 \; watt.$$

40. (c) Illuminance produce by the sun $= \frac{L}{(1.5 \times 10^{11})^2}$

Illuminance produce by the bulb $= \frac{10000}{(0.3)^2}$

According to problem $\frac{L}{(1.5 \times 10^{11})^2} = \frac{10000}{(0.3)^2}$

$$\Rightarrow L = \frac{2.25 \times 10^{22} \times 10^4}{9 \times 10^{-2}} = 25 \times 10^{26}\, Cd$$

41. (c) $I_1 = \frac{L}{r_1^2} = \frac{L}{16}$ and $I_2 = \frac{L}{r_2^2} = \frac{L}{9}$

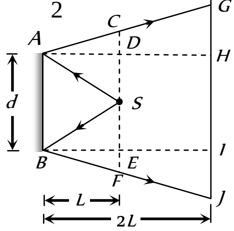
% increase in illuminance

$$= \frac{I_2 - I_1}{I} \times 100 = \left(\frac{16}{9} - 1\right) \times 100 \approx 78\%$$

Critical Thinking Questions

1. (d) According to the following ray diagram $HI = AB = d$

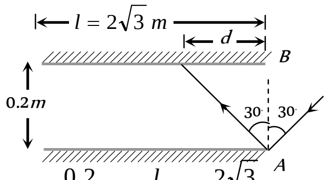
and $DS = CD = \frac{d}{2}$



$\because AH = 2AD \Rightarrow GH = 2CD = \frac{2d}{2} = d$

Similarly $IJ = d$ so $GJ = GH + HI + IJ = d + d + d = 3d$

2. (b) From the following ray diagram

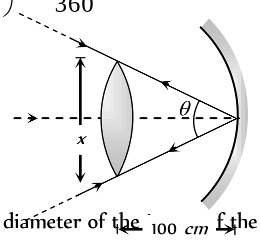


$d = 0.2\tan 30° = \frac{0.2}{\sqrt{3}} \Rightarrow \frac{l}{d} = \frac{2\sqrt{3}}{0.2/\sqrt{3}} = 30$

Therefore maximum number of reflections are 30.

3. (b) The angle subtended by the image of the sun at the mirror

$= 30' = \left(\frac{1}{2}\right)^o = \frac{\pi}{360}\ rad$



If x be the diameter of the [illegible]f the sun, then

$\frac{\text{Arc}}{\text{Radius}} = \frac{x}{100} = \frac{1}{2}.\frac{2\pi}{360} = \frac{\pi}{360} \Rightarrow x = \frac{100\pi}{360} = 0.87\ cm$

4. (a) $m = \frac{I}{O} = \frac{f}{u-f} = \frac{10}{25-10} = \frac{10}{15} = \frac{2}{3}$

$m^2 = \frac{A_i}{A_o} \Rightarrow A_i = m^2 \times A_o = \left(\frac{2}{3}\right)^2 \times (3)^2 = 4\ cm^2$

5. (d) From mirror formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ .....(i)

Differentiating equation (i), we obtain

$0 = -\frac{1}{v^2}dv - \frac{1}{u^2}du \Rightarrow dv = -\left(\frac{v}{u}\right)^2 du$ .....(ii)

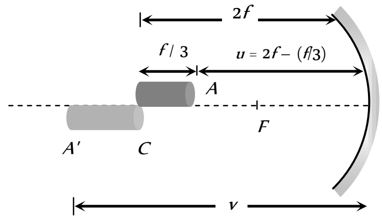
Also from equation (i) $\frac{v}{u} = \frac{f}{u-f}$ .....(iii)

From equation (ii) and (iii) we get $dv = -\left(\frac{f}{u-f}\right)^2 . l$

Therefore size of image is $\left(\frac{f}{u-f}\right)^2 l$.

6. (b) If end A of rod acts an object for mirror then it's image will be A' and if

$u = 2f - \frac{f}{3} = \frac{5f}{3}$ so by using $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$

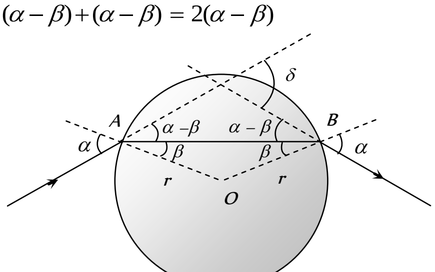


$$\Rightarrow \frac{1}{-f} = \frac{1}{v} + \frac{1}{\frac{-5f}{3}} \Rightarrow v = -\frac{5}{2}f$$

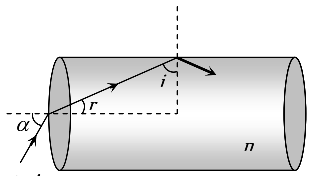
$$\therefore \text{ Length of image } = \frac{5}{2}f - 2f = \frac{f}{2}$$

7. (b) From the following ray diagram it is clear that

$$\delta = (\alpha - \beta) + (\alpha - \beta) = 2(\alpha - \beta)$$



8. (a) From the following figure



$r + i = 90^\circ \Rightarrow i = 90^\circ - r$

For ray not to emerge from curved surface $i > C$

$\Rightarrow \sin i > \sin C \Rightarrow \sin(90^\circ - r) > \sin C \Rightarrow \cos r > \sin C$

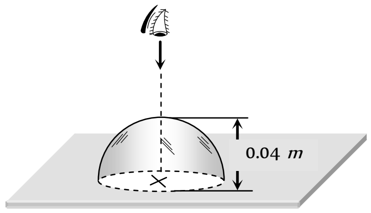
$$\Rightarrow \sqrt{1 - \sin^2 r} > \frac{1}{n} \qquad \left\{\because \sin C = \frac{1}{n}\right\}$$

$$\Rightarrow 1 - \frac{\sin^2 \alpha}{n^2} > \frac{1}{n^2} \Rightarrow 1 > \frac{1}{n^2}(1 + \sin^2 \alpha)$$

$$\Rightarrow n^2 > 1 + \sin^2 \alpha \Rightarrow n > \sqrt{2} \qquad \{\sin i \to 1\}$$

$\Rightarrow$ Least value $= \sqrt{2}$

9. (b) **Case (i)** When flat face is in contact with paper.



$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \quad \text{where}$$

$\mu_2 = R.I.$ of medium in which light rays are going = 1

$\mu_1 = R.I.$ of medium from which light rays are coming = 1.6

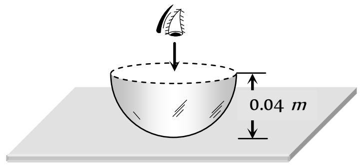
u = distance of object from curved surface = – 0.04 m

R = – 0.04 m.

$$\therefore \frac{1}{v} - \frac{1.6}{(-0.04)} = \frac{1 - 1.6}{(-0.04)} \Rightarrow v = -0.04\,m$$

i.e. the image will be formed at the same position of cross.

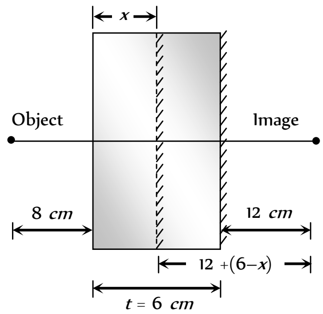
Case (ii) When curved face is in contact with paper



$$\mu = \frac{\text{Real depth }(h)}{\text{Apparent depth }(h')}$$

$$\Rightarrow 1.6 = \frac{0.04}{h'} \Rightarrow h' = 0.025\,m \qquad \text{(Below the flat face)}$$

10. (c) Let x be the apparent position of the silvered surface.

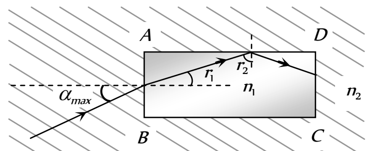


According to property of plane mirror

$x + 8 = 12 + 6 - x \Rightarrow x = 5\ cm$

Also $\mu = \frac{t}{x} \Rightarrow \mu = \frac{6}{5} = 1.2$

11. (a) Ray comes out from CD, means rays after refraction from AB get, total internally reflected at AD



$$\frac{n_1}{n_2} = \frac{\sin\alpha_{max}}{\sin r_1} \Rightarrow \alpha_{max} = \sin^{-1}\left[\frac{n_1}{n_2}\sin r_1\right] \qquad \text{...(i)}$$

Also $r_1 + r_2 = 90^o \Rightarrow r_1 = 90 - r_2 = 90 - C$

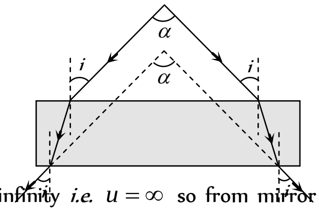
$$\Rightarrow r_1 = 90 - \sin^{-1}\left(\frac{1}{{}_2\mu_1}\right) \Rightarrow r_1 = 90 - \sin^{-1}\left(\frac{n_2}{n_1}\right) \qquad \text{...(ii)}$$

Hence from equation (i) and (ii)

$$\alpha_{max} = \sin^{-1}\left[\frac{n_1}{n_2}\sin\left\{90 - \sin^{-1}\frac{n_2}{n_1}\right\}\right]$$

$$= \sin^{-1}\left[\frac{n_1}{n_2}\cos\left(\sin^{-1}\frac{n_2}{n_1}\right)\right]$$

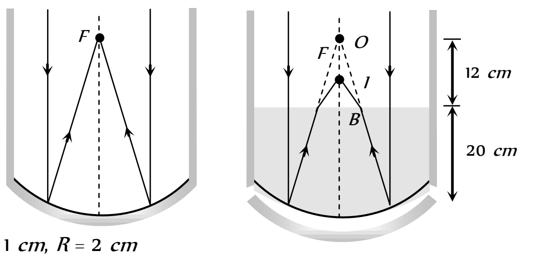
12. (b) Since rays after passing through the glass slab just suffer lateral displacement hence we have angle between the emergent rays as α.



13. (b) Sun is at infinity *i.e.* $u = \infty$ so from mirror formula we have $\frac{1}{f} = \frac{1}{-32} + \frac{1}{(-\infty)} \Rightarrow f = -32\ cm$.

When water is filled in the tank upto a height of 20 *cm*, the image formed by the mirror will act as virtual object for water surface. Which will form it's image at I such that $\frac{\text{Actual height}}{\text{Apperant height}} = \frac{\mu_w}{\mu_a}$ *i.e.* $\frac{BO}{BI} = \frac{4/3}{1}$

$$\Rightarrow BI = BO \times \frac{3}{4} = 12 \times \frac{3}{4} = 9\ cm.$$



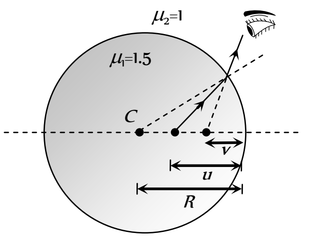
14. (a) $v = 1\ cm$, $R = 2\ cm$

By using

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

$$\frac{1}{-1} - \frac{1.5}{u} = \frac{1-1.5}{-2}$$

$$\Rightarrow u = -1.2\,cm$$

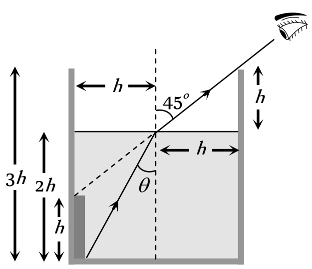


15. (b) The line of sight of the observer remains constant, making an angle of 45° with the normal.

$$\sin\theta = \frac{h}{\sqrt{h^2 + (2h)^2}} = \frac{1}{\sqrt{5}}$$

$$\mu = \frac{\sin 45^o}{\sin\theta}$$

$$= \frac{1/\sqrt{2}}{1/\sqrt{5}} = \sqrt{\left(\frac{5}{2}\right)}$$



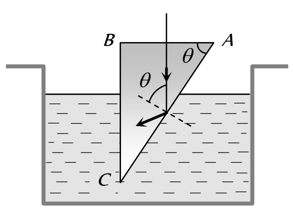
16. (b) For *glass-water* interface ${}_g\mu_w = \frac{\sin i}{\sin r}$ ...(i)

For *water-air* interface ${}_w\mu_a = \frac{\sin r}{\sin 90^o}$ ...(ii)

$$\Rightarrow {}_g\mu_w \times {}_w\mu_a = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin 90^o} = \sin i$$

$$\Rightarrow \frac{\mu_w}{\mu_g} \times \frac{\mu_a}{\mu_w} = \sin i \Rightarrow \mu_g = \frac{1}{\sin i}$$

17. (a) For TIR at AC



$$\theta > C$$

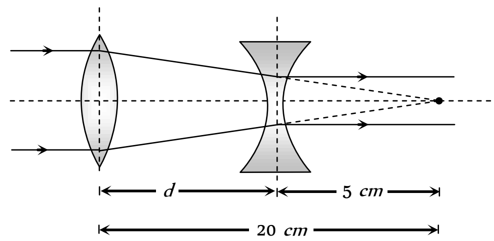
$$\Rightarrow \sin\theta \geq \sin C$$

$$\Rightarrow \sin\theta \geq \frac{1}{{}_w\mu_g}$$

$$\Rightarrow \sin\theta \geq \frac{\mu_w}{\mu_g} \Rightarrow \sin\theta \geq \frac{8}{9}$$

18. (b) From figure it is clear that separation between lenses

$$d = 20 - 5 = 15\,cm$$



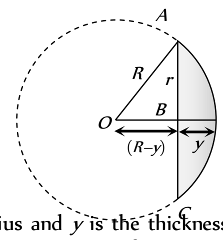
19. (c) According to lens formula $\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$

The lens is plano-convex *i.e.*, $R_1 = R$ and $R_2 = \infty$

Hence $\frac{1}{f} = \frac{\mu - 1}{R} \Rightarrow f = \frac{R}{\mu - 1}$

Speed of light in medium of lens $v = 2 \times 10^8\ m/s$

$$\Rightarrow \mu = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = \frac{3}{2} = 1.5$$



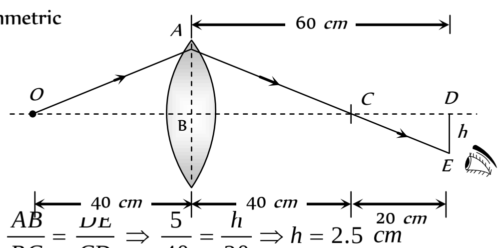
If r is the radius and y is the thickness of lens (at the centre), the radius of curvature R of its curved surface in accordance with the figure is given by

$$R^2 = r^2 + (R - y)^2 \Rightarrow r^2 + y^2 - 2Ry = 0$$

Neglecting y^2; we get $R = \frac{r^2}{2y} = \frac{(6/2)^2}{2 \times 0.3} = 15\ cm$

Hence $f = \frac{15}{1.5 - 1} = 30\ cm$

20. (c) In the following ray diagram Δ's, ABC and CDE are symmetric

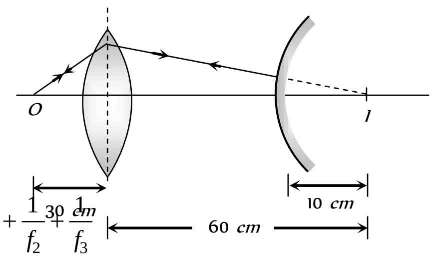


So, $\frac{AB}{BC} = \frac{DE}{CD} \Rightarrow \frac{5}{40} = \frac{h}{20} \Rightarrow h = 2.5\ cm$

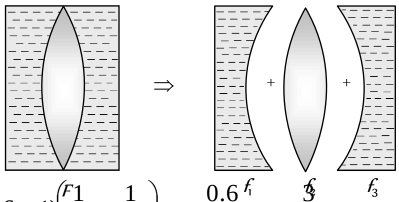
21. (c) For lens $u = 30\ cm$, $f = 20\,cm$, hence by using

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{+20} = \frac{1}{v} - \frac{1}{-30} \Rightarrow v = 60\ cm$$

The final image will coincide the object, if light ray falls normally on convex mirror as shown. From figure it is seen clear that separation between lens and mirror is 60 – 10 = 50 *cm*.



22. (d) $\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}$



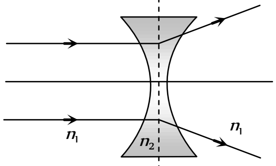
$$\frac{1}{f_1}=(1.6-1)\left(\frac{1}{\infty}-\frac{1}{20}\right)=-\frac{0.6}{20}=-\frac{3}{100} \quad ...(i)$$

$$\frac{1}{f_2}=(1.5-1)\left(\frac{1}{20}-\frac{1}{-20}\right)=\frac{1}{20} \quad ...(ii)$$

$$\frac{1}{f_3}=(1.6-1)\left(\frac{1}{-20}-\frac{1}{\infty}\right)=-\frac{3}{100} \quad ...(iii)$$

$$\Rightarrow \frac{1}{F}=-\frac{3}{100}+\frac{1}{20}-\frac{3}{100}\Rightarrow F=-100\ cm$$

23. (d) $\frac{1}{f}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ where n_2 and n_1 are the refractive indices of the material of the lens and of the surroundings respectively. For a double concave lens, $\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ is always negative.



Hence f is negative only when $n_2>n_1$

24. (a, d) For a lens $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}\Rightarrow\frac{1}{v}=\frac{1}{u}+\frac{1}{f}$ .....(i)

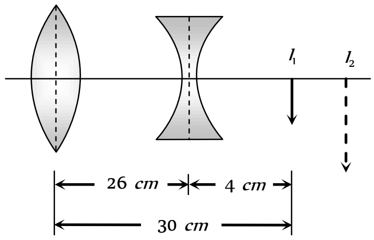
Also $m=\frac{f-v}{f}=1-\frac{v}{f}\Rightarrow m=\left(-\frac{1}{f}\right)v+1$ ....(ii)

On comparing equations (i) and (ii) with $y=mx+c$.

It is clear that relationship between $\frac{1}{v}$ *vs* $\frac{1}{u}$ and *m vs v* is linear.

25. (c) The dispersion produced by a spherical surface depends on it's radius of curvature. Hence, a lens will not exhibit dispersion only if it's two surfaces have equal radii, with one being convex and the other concave.

26. (b) Convex lens will form image I_1 at it's focus which acts like a virtual object for concave lens.



Hence for concave lens $u=+4\,cm$, $f=20\ cm$. So by lens formula $\frac{1}{-20}=\frac{1}{v}-\frac{1}{4}\Rightarrow v=5\,cm$ *i.e.* distance of final image (I_2) from concave lens $v=5\,cm$ by using $\frac{v}{u}=\frac{I}{O}\Rightarrow\frac{5}{4}=\frac{I}{2}\Rightarrow(I_2)=2.5\,cm$

27. (d) For achromatic combination $\omega_C=-\omega_F$

$[(\mu_v-\mu_r)A]_C=-[(\mu_v-\mu_r)A]_F$

$\Rightarrow[\mu_rA]_C+[\mu_rA]_F=[\mu_vA]_C+[\mu_vA]_F$

$=\ 1.5\times19+6\times1.66=38.5$

Resultant $\delta=[(\mu_r-1)Al]_C+[(\mu_r-1)A]_F$

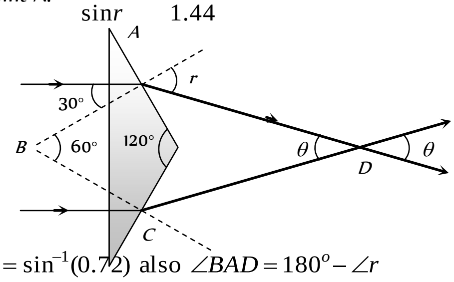
$=\ [\mu_rA]_C+[\mu_rA]_F-(A_C+A_F)=38.5-(19+6)=13.5^o$

28. (d) By using $\mu=\frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}\Rightarrow\cot\frac{A}{2}=\frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$

$$\Rightarrow\frac{\cos\frac{A}{2}}{\sin\frac{A}{2}}=\frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$$

$$\Rightarrow\sin\left(90°-\frac{A}{2}\right)=\sin\left(\frac{A+\delta_m}{2}\right)\Rightarrow\delta_m=180-2A$$

29. (d) At point A. $\frac{\sin30^o}{\sin r}=\frac{1}{1.44}$



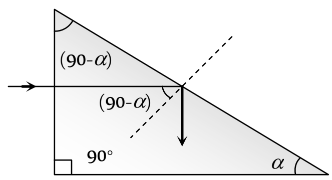
$\Rightarrow r=\sin^{-1}(0.72)$ also $\angle BAD=180^o-\angle r$

In rectangle *ABCD*, ∠ *A* + ∠ *B* + ∠ *C* + ∠ *D* = 360°

$\Rightarrow(180°-r)+60°+(180°-r)+\theta=360°$

$\Rightarrow\theta=2[\sin^{-1}(0.72)-30^o]$

30. (d) If α = maximum value of base angle for which light is totally reflected form hypotenuse.

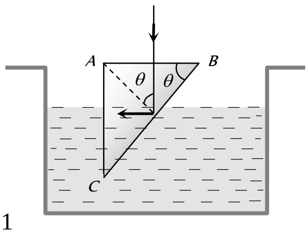


$(90^\circ - \alpha) = C$ = minimum value of angle of incidence at hypotenuse for total internal reflection

$$\sin(90^\circ - \alpha) = \sin C = \frac{1}{\mu} \Rightarrow \cos\alpha = \frac{1}{\mu} \Rightarrow \alpha = \cos^{-1}\left(\frac{1}{\mu}\right)$$

31. (b) For total internal reflection from surface BC

$\theta \geq C \Rightarrow \sin\theta \geq \sin C$



$\Rightarrow \sin\theta \geq \left(\frac{1}{{}_l\mu_g}\right)$

$\Rightarrow \sin\theta \geq \left(\frac{\mu_{\text{Liquid}}}{\mu_{\text{Prism}}}\right)$

$\sin\theta \geq \left(\frac{1.32}{1.56}\right) \Rightarrow \sin\theta \geq \frac{11}{13}$

32. (a) $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \Rightarrow \frac{1.5}{+OQ} - \frac{1}{(-OP)} = \frac{(1.5-1)}{+R}$

On putting $OQ = OP,\ OP = 5R$

33. (d) Here $\frac{1}{F} = \frac{2}{f} + \frac{1}{f_m}$

Plano-convex lens silvered on plane side has $f_m = \infty$.

$\therefore \frac{1}{F} = \frac{2}{f} + \frac{1}{\infty} \Rightarrow \frac{1}{30} = \frac{2}{f} \Rightarrow f = 60\ cm$

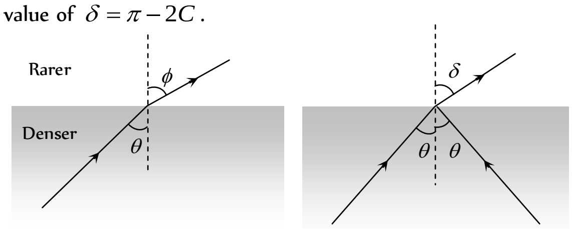
Plano-convex lens silvered on convex side has $f_m = \frac{R}{2}$

$\therefore \frac{1}{F} = \frac{2}{f} + \frac{2}{R} \Rightarrow \frac{1}{10} = \frac{2}{60} + \frac{2}{R} \Rightarrow R = 30\ cm$

Now using $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R}\right)$, we get $\mu = 1.5$

34. (c) When the ray passes into the rarer medium, the deviation is $\delta = \phi - 0$. This can have a maximum value of $\left(\frac{\pi}{2} - C\right)$ for $\theta = C$ and $\phi = \frac{\pi}{2}$.

When total internal reflection occurs, the deviation is $\delta = \pi - 2$, the minimum value of θ being C. The maximum value of $\delta = \pi - 2C$.



35. (c) $\frac{}{r} = \frac{}{d} \rightarrow x = \frac{}{d}$

$$= \frac{1.22 \times 500 \times 10^{-9} \times 400 \times 10^3}{5 \times 10^{-3}} = 50\ m$$

36. (d) Resolving power $= \frac{1.22\ \lambda}{a} = \frac{1.22 \times 6000 \times 10^{-10}}{5}$

Also resolving power $= \frac{d}{D} = \frac{d}{38.6 \times 10^7}$

$\therefore \frac{1.22 \times 6 \times 10^{-7}}{5} = \frac{d}{38.6 \times 10^7}$

$\Rightarrow d = \frac{1.22 \times 6 \times 10^{-7} \times 38.6 \times 10^7}{5} m = 56.51\ m$

37. (a) As limit of resolution

$\Delta\theta = \frac{1}{\text{Resolving Power(RP)}}$; and if x is the distance between points on the surface of moon which is at a distance r from the telescope.

$\Delta\theta = \frac{x}{r}$

So $\Delta\theta = \frac{1}{RP} = \frac{x}{r}$ *i.e.* $x = \frac{r}{RP} = \frac{r}{d/1.22\ \lambda} \Rightarrow x = \frac{1.22\ \lambda r}{d}$

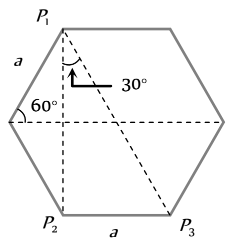
$= \frac{1.22 \times 5500 \times 10^{-10} \times (3.8 \times 10^8)}{500 \times 10^{-2}} = 51\ m$

38. (b) $I_{\text{edge}} = \frac{L\cos\theta}{(h^2 + r^2)} = \frac{Lh}{(h^2 + r^2)^{3/2}}$

For maximum extensity $\frac{dI}{dh} = 0$

Applying this condition have get $h = \frac{r}{\sqrt{2}}$

39. (a) From the geometry of the figure



$p_1 p_2 = 2a\sin 60^o$

so, $I_{P_2} = \frac{L}{p_1 p_2^2}$

$= \frac{L}{(2a\sin 60^o)^2} = \frac{L}{3a^2}$

and $I_{P_3} = \frac{L}{(P_1 P_2^2 + a^2)} \cos 30^o$

$= \frac{L}{[(2a\sin 60^o)^2 + a^2]} \frac{\sqrt{3}}{2} = \frac{\sqrt{3}\ L}{8\ a^2}$

$\Rightarrow I_{P_3} = \frac{3\sqrt{3}}{8} I_{P_2} = \frac{3\sqrt{3}}{8} I_0$

All options are wrong.

40. (c) Distance of object from mirror

$= 15 + \frac{33.25}{4} \times 3 = 39.93\ cm$

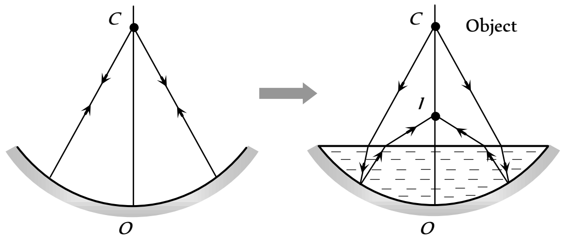
Distance of image from mirror $= 15 + \frac{25}{4} \times 3 = 33.75$

For mirror, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

$\Rightarrow \frac{1}{-33.75} - \frac{1}{39.93} = \frac{1}{f} \Rightarrow f \approx -18.3\ cm.$

41. (c) $v_i = -\left(\frac{f}{f-u}\right)^2 . v_o = -\left(\frac{-24}{-24-(-60)}\right)^2 \times 9 = 4\ cm/sec.$

42. (d) From the following figures it is clear that real image (I) will be formed between C and O



43. (b) $|m| = \frac{f_o}{f_e} = \frac{400}{10} = 40$

Angle subtented by moon on the objective of telescope

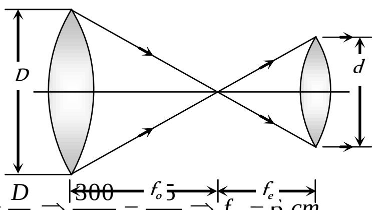
$\propto = \frac{3.5\times 10^3}{3.8\times 10^3} = \frac{3.5}{3.8}\times 10^{-2}\,rad$

Also $|m| = \frac{\beta}{\alpha} \Rightarrow$ Angular size of final image

$\beta = |m|\times\alpha = 40\times\frac{3.5}{3.8}\times 10^{-2} = 0.36\ rad$

$= 0.3\times\frac{180}{\pi} \approx 21^o$

44. (a) Full use of resolving power means whole aperture of objective in use. And for relaxed vision.



$\frac{f_o}{f_e} = \frac{D}{d} \Rightarrow \frac{300}{f_e} = \frac{5}{0.3} \Rightarrow f_e = 6\ cm$

45. (b) Wave length of the electron wave be $10\times 10^{-12}\,m$,

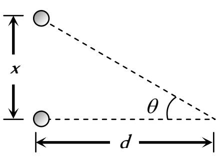
Using $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E = \frac{h^2}{\lambda^2\times 2m}$

$= \frac{(6.63\times 10^{-34})^2}{(10\times 10^{-12})^2\times 2\times 9.1\times 10^{-31}}\,Joule$

$= \frac{(6.63\times 10^{-34})^2}{(10\times 10^{-12})^2\times 2\times 9.1\times 10^{-31}\times 1.6\times 10^{-19}}\,eV$

= 15.1 *KeV.*

46. (c) $\theta = \frac{x}{d} = \frac{1.22\lambda}{a}$



$\Rightarrow x = \frac{1.22\times d}{a}$

$= \frac{1.22\times 5000\times 10^{-10}\times 10^3}{10\times 10^{-2}} = 6.1\ mm$

i.e. order will be 5 *mm.*

47. (c) $\frac{1.22\lambda}{a} = \frac{x}{d} \Rightarrow d = \frac{x\times a}{1.22\lambda} = \frac{1\times 10^{-3}\times 3\times 10^{-3}}{1.22\times 500\times 10^{-9}} = 5m$

48. (c) Let distance between lenses be x. As per the given condition, combination behaves as a plane glass plate, having focal length ∞.

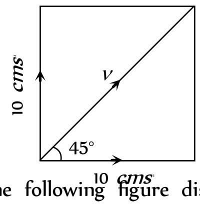
So by using $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$

$\Rightarrow \frac{1}{\infty} = \frac{1}{+30} + \frac{1}{-10} - \frac{x}{(+30)(-10)} \Rightarrow x = 20\ cm$

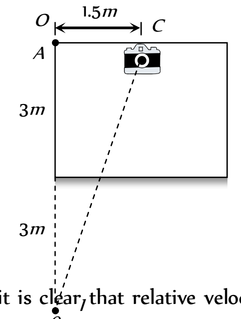
49. (a) When plane mirror rotates through an angle θ, the reflected ray rotates through an angle 2θ. So spot on the screen will make $2n$ revolution per second.

50. (d) $v\cos 45° = 10 \quad v = 10\sqrt{2}\ cms$

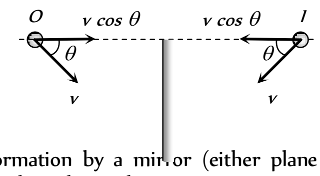
In the ceiling mirror the original velocity will be seen.



51. (d) According to the following figure distance of image I from camera $= \sqrt{(6)^2 + (1.5)^2} = 6.18\,m$



52. (c) From figure it is clear that relative velocity between object and it's image = $2v\cos\theta$



53. (b) Image formation by a mirror (either plane or spherical) does not depend on the medium.

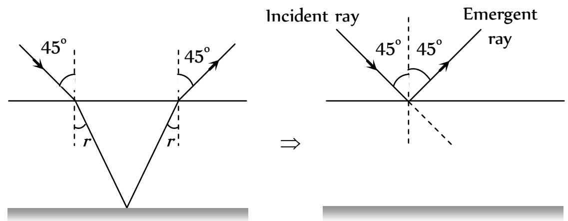
The image of P will be formed at a distance h below the mirror. If d = depth of liquid in the tank.

Apparent depth of $P = x_1 = \frac{d-h}{\mu}$

Apparent depth of the image of $P = x_2 = \frac{d+h}{\mu}$

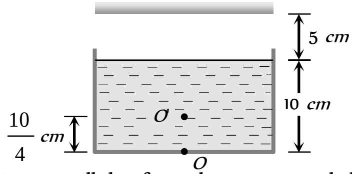
$\therefore$ Apparent distance between P and it's image $= x_2 - x_1 = \frac{2h}{\mu}$

54. (a) From the figure it is clear that the angle between incident ray and the emergent ray is 90°.



55. (b) From figure it is clear that object appears to be raised by $\frac{10}{4}cm\ (2.5\ cm)$

Hence distance between mirror and $O' = 5 + 7.5 = 12.5\ cm$



So final image will be formed at 12.5 *cm* behind the plane mirror.

56. (d) Velocity of approach of man towards the bicycle = $(u - v)$

Hence velocity of approach of image towards man is $2(u - v)$.

57. (c) For *A*

Total number of waves = $\frac{(1.5)t}{\lambda}$ ....(i)

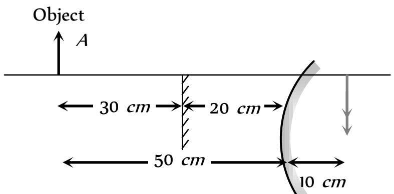
$\because \begin{pmatrix}\text{Total number}\\ \text{of waves}\end{pmatrix} = \left(\frac{\text{optical path length}}{\text{wavelength}}\right)$

For *B* and *C*

Total number of waves = $\frac{n_B\left(\frac{t}{3}\right)}{\lambda} + \frac{(1.6)\left(\frac{2t}{3}\right)}{\lambda}$ ....(ii)

Equating (i) and (ii) $n_B = 1.3$

58. (b) Since there is no parallex, it means that both images (By plane mirror and convex mirror) coinciding each other.



According to property of plane mirror it will form image at a distance of 30 *cm* behind it. Hence for convex mirror $u = -50$ *cm*, $v = +10$ *cm*

By using $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$ $\Rightarrow \frac{1}{f} = \frac{1}{+10} + \frac{1}{-50} = \frac{4}{50}$

$\Rightarrow f = \frac{25}{2}cm$ $\Rightarrow R = 2f = 25cm.$

59. (d) For surface *P*, $\frac{1}{v_1} = \frac{1}{f} - \frac{1}{u} = 1 - \frac{1}{3} = \frac{2}{3} \Rightarrow v_1 = \frac{3}{2}m$

For surface *Q*, $\frac{1}{v_2} = \frac{1}{f} - \frac{1}{u} = 1 - \frac{1}{5} = \frac{4}{5} \Rightarrow v_2 = \frac{5}{4}m$

$\therefore v_1 - v_2 = 0.25m$

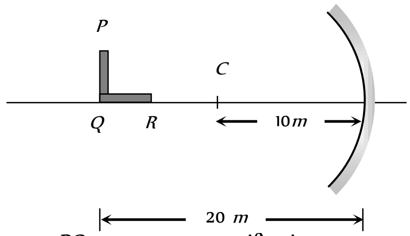
Magnification of $P = \frac{v_1}{u} = \frac{3/2}{3} = \frac{1}{2}$

$\therefore$ Height of $P = \frac{1}{2} \times 2 = 1m$

Magnification of $Q = \frac{v_2}{u} = \frac{5/4}{5} = \frac{1}{4}$

$\therefore$ Height of $Q = \frac{1}{4} \times 2 = 0.5m$

60. (b) Focal length of mirror $f = \frac{R}{2} = \frac{10}{2} = 5cm$



For part PQ : transverse magnification

length of image $L = \left(\frac{f}{f-u}\right) \times L_0$

$= \left(\frac{-5}{-5-(-20)}\right) \times L_0 = \frac{-L_0}{3}$

For part QR : longitudinal magnification

Length of image $L_2 = \left(\frac{f}{f-u}\right)^2 L_0$

$= \left(\frac{-5}{-5-(-20)}\right)^2 \times L_0 = \frac{L_0}{9} \Rightarrow \frac{L_1}{L_2} = \frac{3}{1}$

61. (d) The two slabs will shift the image a distance

$d = 2\left(1 - \frac{1}{\mu}\right)t = 2\left(1 - \frac{1}{1.5}\right)(1.5) = 1\,cm$

Therefore, final image will be 1 *cm* above point *P*.

62. (a) Here optical distance between fish and the bird is

$s = y' + \mu y$

Differentiating *w.r.t* *t* we get $\frac{ds}{dt} = \frac{dy'}{dt} + \frac{\mu dy}{dt}$

$\Rightarrow 9 = 3 + \frac{4}{3}\frac{dy}{dt} \Rightarrow \frac{dy}{dt} = 4.5\ m/\text{sec}$

63. (a) The real depth $= \mu$ (apparent depth)

$\Rightarrow$ In first case, the real depth $h_1 = \mu(b - a)$

Similarly in the second case, the real depth $h_2 = \mu(d - c)$

Since $h_2 > h_1$, the difference of real depths $= h_2 - h_1 = \mu(d - c - b + a)$

Since the liquid is added in second case, $h_2 - h_1 = (d - b)$

$\Rightarrow \mu = \frac{(d-b)}{(d-c-b+a)}$

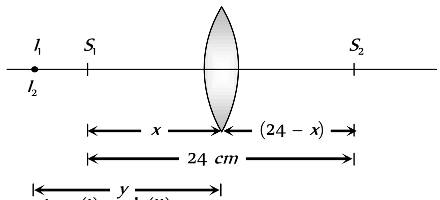
64. (a) The given condition will be satisfied only if one source (*S*) placed on one side such that $u < f$ (*i.e.* it lies under the focus). The other source (*S*) is placed on the other side of the lens such that $u > f$ (*i.e.* it lies beyond the focus).

If S_1 is the object for lens then $\frac{1}{f} = \frac{1}{-y} - \frac{1}{-x}$

$\Rightarrow \frac{1}{y} = \frac{1}{x} - \frac{1}{f}$ .....(i)

If S_2 is the object for lens then

$\frac{1}{f}=\frac{1}{+y}-\frac{1}{-(24-x)} \Rightarrow \frac{1}{y}=\frac{1}{f}-\frac{1}{(24-x)}$ .....(ii)



From equation (i) and (ii)

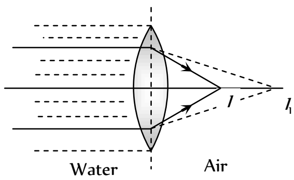
$$\frac{1}{x}-\frac{1}{f}=\frac{1}{f}-\frac{1}{(24-x)} \Rightarrow \frac{1}{x}+\frac{1}{(24-x)}=\frac{2}{f}=\frac{2}{9}$$

$\Rightarrow x^2-24x+108=0$. After solving the equation $x=18\ cm$, 6 *cm*.

65. (c) Consider the refraction of the first surface *i.e.* refraction from rarer medium to denser medium

$$\frac{\mu_2-\mu_1}{R}=\frac{\mu_1}{-u}+\frac{\mu_2}{v_1} \Rightarrow \frac{\left(\frac{3}{2}\right)-\left(\frac{4}{3}\right)}{R}=\frac{\frac{4}{3}}{\infty}+\frac{\frac{3}{2}}{v_1} \Rightarrow v_1=9R$$

Now consider the refraction at the second surface of the lens *i.e.* refraction from denser medium to rarer medium



$$\frac{1-\frac{3}{2}}{-R}=-\frac{\frac{3}{2}}{9R}+\frac{1}{v_2} \Rightarrow v_2=\left(\frac{3}{2}\right)R$$

The image will be formed at a distance of $\frac{3}{2}R$. This is equal to the focal length of the lens.

66. (c) $\delta_{Prism}=(\mu-1)A=(1.5-1)4^o=2^o$

$\therefore\ \delta_{Total}=\delta_{Prism}+\delta_{Mirror}$

$=(\mu-1)A+(180-2i)=2^o+(180-2\times 2)=178^o$

67. (b) Here the requirement is that $i>c$

$\Rightarrow \sin i>\sin c \Rightarrow \sin i>\frac{\mu_2}{\mu_1}$ .....(i)

From Snell's law $\mu_1=\frac{\sin\alpha}{\sin r}$ .....(ii)

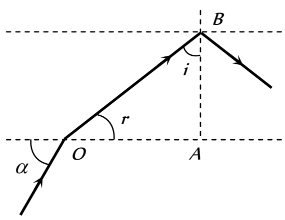
Also in ΔOBA

$r+i=90^o \Rightarrow r=(90-i)$

Hence from equation (ii)

$\sin\alpha=\mu_1\sin(90-i)$

$\Rightarrow \cos i=\frac{\sin\alpha}{\mu_1}$



$\sin i=\sqrt{1-\cos^2 i}=\sqrt{1-\left(\frac{\sin\alpha}{\mu_1}\right)^2}$ .....(iii)

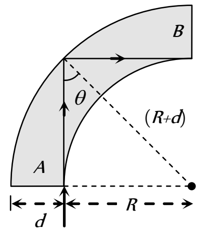
From equation (i) and (iii) $\sqrt{1-\left(\frac{\sin\alpha}{\mu_1}\right)^2}>\frac{\mu_2}{\mu_1}$

$\Rightarrow \sin^2\alpha<(\mu_1^2-\mu_2^2) \Rightarrow \sin\alpha<\sqrt{\mu_1^2-\mu_2^2}$

$\alpha_{max}=\sin^{-1}\sqrt{\mu_1^2-\mu_2^2}$

68. (b) Consider the figure if smallest angle of incidence θ is greater than critical angle then all light will emerge out of *B*

$\Rightarrow \theta\geq\sin^{-1}\left(\frac{1}{\mu}\right) \Rightarrow \sin\theta\geq\frac{1}{\mu}$



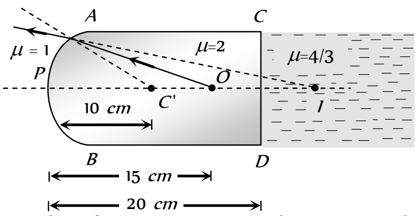
from figure $\sin\theta=\frac{R}{R+d}$

$\Rightarrow \frac{R}{R+d}\geq\frac{1}{\mu} \Rightarrow \left(1+\frac{d}{R}\right)\leq\mu$

$\Rightarrow \frac{d}{R}\leq\mu-1 \Rightarrow \left(\frac{d}{R}\right)_{max}=0.5$

69. (b) In case of refraction from a curved surface, we have

$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R} \Rightarrow \frac{1}{v}-\frac{2}{(-15)}=\frac{(1-2)}{-10} \Rightarrow v=-30\ cm.$

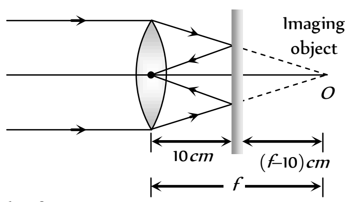


i.e. the curved surface will form virtual image *I* at distance of 30 *cm* from *P*. Since the image is virtual there will be no refraction at the plane surface *CD* (as the rays are not actually passing through the boundary), the distance of final image *I* from *P* will remain 30 *cm*.

70. (d) As $\mu_2>\mu_1$, the upper half of the lens will become diverging.

As $\mu_1>\mu_3$, the lower half of the lens will become converging

71. (b)



From the figure,

Using property of plane mirror

Image distance = Object distance

$f-10=10 \Rightarrow f=20\ cm$

72. (d) If initially the objective (focal length *F*) forms the image at distance *v* then $v_o=\frac{u_o f_o}{u_o-f_o}=\frac{3\times 2}{3-2}=6\ cm$

Now as in case of lenses in contact

$$\frac{1}{F_o}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+.....=\frac{1}{f_1}+\frac{1}{F_o'}$$

$$\left\{\text{where } \frac{1}{F_o'}=\frac{1}{f_2}+\frac{1}{f_3}+.....\right\}$$

So if one of the lens is removed, the focal length of the remaining lens system

$$\frac{1}{F_o'}=\frac{1}{F_0}-\frac{1}{f_1}=\frac{1}{2}-\frac{1}{10} \Rightarrow F_o'=2.5\,cm$$

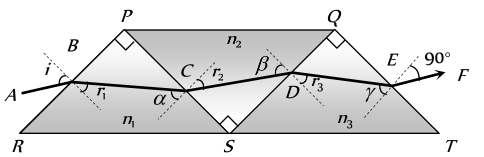
This lens will form the image of same object at a distance v_o' such that $v_o'=\frac{u_oF_o'}{u_o-F_o'}=\frac{3\times 2.5}{(3-2.5)}=15\,cm$

So to refocus the image, eye-piece must be moved by the same distance through which the image formed by the objective has shifted *i.e.* 15 – 6 = 9 *cm*.

73. (b) By using $m_\infty=\frac{(L_\infty-f_o-f_e)D}{f_of_e}$

$=\frac{(16-0.4-2.5)\times 25}{0.4\times 2.5}$ = 327.5

74. (d)



α = 90 – r_1 $\quad\beta$ = 90 – r_2 $\quad\gamma$ = 90 – r_3

At *B*

$\sin i=n_1\sin r_1 \Rightarrow \sin^2 i=n_1^2\sin^2 r_1$ .... (i)

At *C*

$n_1\sin(90-r_1)=n_2\sin r_2 \Rightarrow n_2^2\sin^2 r_2=n_1^2\cos^2 r_1$ ....(ii)

At *D*

$n_2\sin(90-r_2)=n_3\sin r_3 \Rightarrow n_2^2\cos^2 r_2=n_3^2\sin^2 r_3$ ....(iii)

At *E*

$n_3\sin(90-r_3)=(1)\sin(90-1) \Rightarrow \cos^2 i=n_3^2\cos^2 r_3$ ....(iv)

Adding (i), (ii), (iii) and (iv) we get $1+n_2^2=n_1^2+n_3^2$

75. (a) $L_D=v_o+u_e$ and for objective lens $\frac{1}{f_o}=\frac{1}{v_o}-\frac{1}{u_o}$

Putting the values with proper sign convention.

$$\frac{1}{+2.5}=\frac{1}{v_o}-\frac{1}{(-3.75)} \Rightarrow v_o=7.5\,cm$$

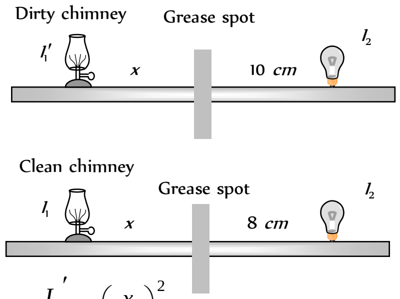
For eye lens $\frac{1}{f_e}=\frac{1}{v_e}-\frac{1}{u_e}$

$$\Rightarrow \frac{1}{+5}=\frac{1}{(-25)}-\frac{1}{u_e} \Rightarrow u_e=-4.16\,cm$$

$\Rightarrow |u_e|=4.16\,cm$

Hence $L_D=7.5+4.16=11.67\,cm$

76. (c) The actual luminous intensity of the lamp is I_1 whereas the intensity is I_1' in the dirty state.

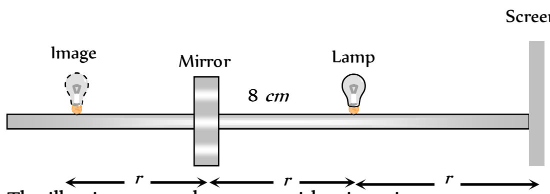


I position, $\frac{I_1'}{I_2}=\left(\frac{x}{10}\right)^2$

II position, $\frac{I_1}{I_2}=\left(\frac{x}{8}\right)^2 \Rightarrow \frac{I_1'}{I_1}=0.64$

$\Rightarrow I_1'=0.64\,I_1$. Thus, % of light absorbed = 36%.

77. (c) The illuminance on the screen without mirror is $I_1=\frac{L}{r^2}$

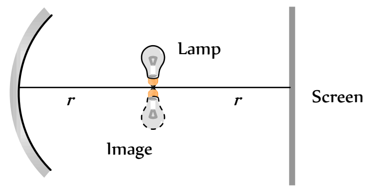


The illuminance on the screen with mirror is

$$I_2=\frac{L}{r^2}+\frac{L}{(3r)^2}=\frac{10}{9}\times\frac{L}{r^2}$$

$$\therefore \frac{I_2}{I_1}=\frac{10}{9}=10:9$$

78. (b) Illuminance on the screen without mirror is $I_1=\frac{L}{r^2}$



Illuminance on the screen with mirror

$$I_2=\frac{L}{r^2}+\frac{L}{r^2}=\frac{2L}{r^2} \Rightarrow \frac{I_2}{I_1}=2:1$$

79. (b) Apparent depth $h'=\frac{h}{_{air}\mu_{liquid}}$

$$\Rightarrow \frac{dh'}{dt}=\frac{1}{_a\mu_w}=\frac{1}{_a\mu_w}\frac{dh}{dt}\Rightarrow x=\frac{1}{_a\mu_w}\frac{dh}{dt}\Rightarrow\frac{dh}{dt}={_a\mu_w}\,x$$

Now volume of water $V=\pi R^2h$

$$\Rightarrow \frac{dV}{dt}=\pi R^2\frac{dh}{dt}=\pi R^2\cdot{_a\mu_w}\,x$$

$$={_a\mu_w}\pi R^2x=\frac{\mu_w}{\mu_a}\pi R^2x=\left(\frac{n_2}{n_1}\right)\pi R^2x$$

Graphical Questions

1. (c) As $u\to f,\ v\to\infty$; $\quad u\to\infty,\ v\to f$

2. (a) At $u = f$, $v = \infty$

At $u = 0$, $v = 0$ (*i.e.* object and image both lies at pole)

Satisfying these two conditions, only option (a) is correct.

3. (b, c) From graph $\tan 30^o = \frac{\sin r}{\sin i} = \frac{1}{{}_1\mu_2}$

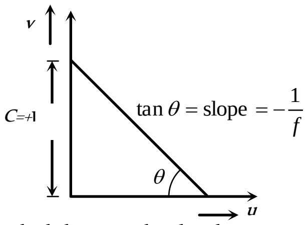
$\Rightarrow {}_1\mu_2 = \sqrt{3} \Rightarrow \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2} = 1.73 \Rightarrow v_1 = 1.73 v_2$

Also from $\mu = \frac{1}{\sin C} \Rightarrow \sin C = \frac{1}{{}_{Rarer}\mu_{Denser}}$

$\Rightarrow \sin C = \frac{1}{{}_1\mu_2} = \frac{1}{\sqrt{3}}$.

4. (c) For a lens $m = \frac{f - v}{f} \Rightarrow m = \left(-\frac{1}{f}\right)v + 1$

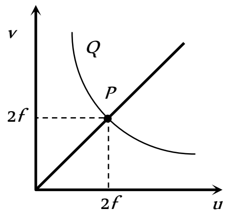
Comparing this equation with $y = mx + c$ (equation of straight line)



5. (c) At P, $u = v$ which happened only when $u = 2f$

At another point Q on the graph (above P)

$v > 2f$



6. (d) For a lens $m = \frac{f - v}{f} = -\frac{1}{f}v + 1$

Comparing it with $y = mx + c$

Slope $= m = -\frac{1}{f}$

From graph, slope of the line $= \frac{b}{c}$

Hence $-\frac{1}{f} = \frac{b}{c} \Rightarrow |f| = \frac{c}{b}$

7. (a) $\mu = A + \frac{B}{\lambda^2}$

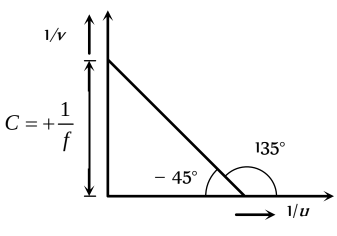
8. (a) Since $\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$

Putting the sign convention properly

$\frac{1}{(-v)} = \frac{-1}{(-u)} + \frac{1}{(-f)} \Rightarrow \frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$

Comparing this equation with $y = mx + c$

Slope $= m = \tan\theta = -1 \Rightarrow \theta = 135°$ or $-45°$ and intercept $C = +\frac{1}{f}$



9. (a) As u goes from 0 to $-\infty$, v goes from $+0$ to $+f$

10. (a) For convex lens (for real image) $u + v \geq 4f$

For $u = 2f$, v is also equal to $2f$

Hence $u + v = 4f$

11. (d) For concave mirror $m = \frac{f}{f - u}$

For real image $m = -\frac{f}{(u - f)} = -\frac{f}{x}$

$= -\frac{f}{(\text{Distance of object from focus})} \Rightarrow m \propto \frac{1}{x}$.

12. (a) For a prism, as the angle of incidence increases, the angle of deviation first decreases, goes to a minimum value and then increases.

13. (b) From Newton's formula $xy = f^2$. This is the equation of a rectangular hyperbola.

14. (a, c) At P, $\delta = 0 = A(\mu - 1) \Rightarrow \mu = 1$.

Also $\delta_m = (\mu - 1)A = A\mu_m - A$

Comparing it with $y = mx + c$

Slope of the line $= m = A$

15. (b) From graph, slope $= \tan\left(\frac{2\pi}{10}\right) = \frac{\sin r}{\sin i}$

Also ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r} = \frac{1}{\tan\left(\frac{2\pi}{10}\right)} = \frac{4}{3} \Rightarrow \mu_2 > \mu_1$

It means that medium 2 is denser medium. So total internal reflection cannot occur.

16. (d) From graph it is clear that $\tan 30^o = \frac{\sin r}{\sin i}$

$\Rightarrow \frac{1}{\sqrt{3}} = \frac{\sin r}{\sin i} = \frac{1}{\mu} \Rightarrow \mu = \sqrt{3}$

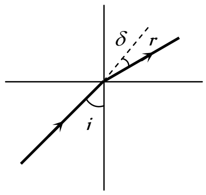
Also $v = \frac{c}{\mu} = nc \Rightarrow n = \frac{1}{\mu} = \frac{1}{\sqrt{3}} = (3)^{-1/2}$

17. (b) In concave mirror, if virtual images are formed, u can have values zero and f

At $u = 0$, $m = \frac{f}{f - u} = \frac{f}{f} = 1$

At $u = f$, $m = \frac{f}{f - u} = -\frac{f}{-f - (-f)} = \infty$

18. (a) The ray of light is refracted at the plane surface. However, since the ray is travelling from a denser to a rarer medium, for an angle of incidence (i) greater then the critical angle (c) the ray will be totally internally reflected.

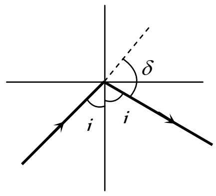


For $i < c$; deviation $\delta = r - i$ with $\frac{1}{\mu} = \frac{\sin i}{\sin r}$

Hence $\delta = \sin^{-1}(\mu \sin i) - i$

This is a non-linear relation. The maximum value of δ is $\delta_1 = \frac{\pi}{2} - c$; where $i = c$ and

$\mu = \frac{1}{\sin c}$



For $i > c$, deviation $\delta = \pi - 2i$

δ decreases linearly with i

$\delta_2 = \pi - 2c = 2\delta_1$

19. (d) For a lens $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

If $u = \infty$, $v = f$ and if $u = f$, $v = \infty$

20. (d)

Assertion and Reason

1. (b)
2. (b) The stars twinkle while the planets do not. It is due to variation in density of atmospheric layer. As the stars are very far and giving light continuously to us. So, the light coming from stars is found to change their intensity continuously. Hence they are seen twinkling. Also stars are much bigger in size than planets but it has nothing to deal with twinkling phenomenon.
3. (c) Owls can move freely during night, because they have large number of cones on their retina which help them to see in night.
4. (c) Shining of air bubble in water is on account of total internal reflection.
5. (c) After the removal of stimulus the image formed on retina is sustained up to 1/6 second.
6. (a) Because of smallest wavelength of blue colour it is scattered to large extent than other colours, so the sky appears blue.
7. (e) For total internal reflection the angle of incidence should be greater than the critical angle. As critical angle is approximately 35°. Therefore, total internal reflection is not possible. So, assertion is not true but reason is true.
8. (c) The sun and its surroundings appears red during sunset or sunrise because of scattering of light. The amount of scattered light is inversely proportional to the fourth power of wavelength of light *i.e.* $I \propto \frac{1}{\lambda^4}$
9. (a) Focal length of lens immersed in water is four times the focal length of lens in air. It means

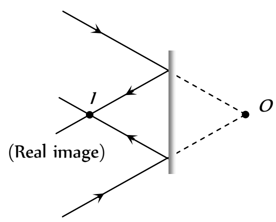
   $f_w = 4f_a = 4 \times 10 = 40\,cm$
10. (e) The velocity of light of different colours (all wavelengths) is same in vacuum and $\mu \propto \frac{1}{\lambda}$.
11. (a) The red glass absorbs the radiations emitted by green flowers; so flower appears black.
12. (a) Magnification produced by mirror $m = \frac{I}{O} = \frac{f}{f-u} = \frac{f}{x}$

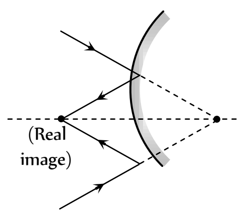
   x is distance from focus.
13. (e) Apparent shift for different coloured letter is $d = h\left(1 - \frac{1}{\mu}\right)$

   $\Rightarrow \lambda_R > \lambda_V$ so $\mu_R < \mu_V$

   Hence $d_R < d_V$ *i.e.* red coloured letter raised least.
14. (a) The efficiency of fluorescent tube is about 50 *lumen/watt*, whereas efficiency of electric bulb is about 12 *lumen/watt*. Thus for same amount of electric energy consumed, the tube gives nearly 4 times more light than the filament bulb.
15. (c) Polar caps receives almost the same amount of radiation as the equatorial plane. For the polar caps angle between sun rays and normal (to polar caps) tends to 90°. As per Lambert's cosine law, $E \propto \cos\theta$, therefore E is zero. For the equatorial plane, $\theta = 0°$, therefore E is maximum. Hence polar caps of earth are so cold. (where E is radiation received).
16. (b) At noon, rays of sun light fall normally on earth. Therefore $\theta = 0°$. According to Lambert's cosine law, $E \propto \cos\theta$, when $\theta = 0°$, $\cos\theta = \cos 0° = 1$ = max. Therefore, E is maximum.
17. (d) When an object is placed between two plane parallel mirrors, then infinite number of images are formed. Images are formed due to multiple reflections. At each reflection, a part of light energy is absorbed. Therefore, distant images get fainter.
18. (c) In search lights, we need an intense parallel beam of light. If a source is placed at the focus of a concave spherical mirror, only paraxial rays are rendered parallel. Due to large aperture of mirror, marginal rays give a divergent beam.

   But in case of parabolic mirror, when source is at the focus, beam of light produced over the entire cross-section of the mirror is a parallel beam.
19. (d) The size of the mirror does not affect the nature of the image except that a bigger mirror forms a brighter image.
20. (a) When the sun is close to setting, refraction will effect the top part of the sun differently from the bottom half. The top half will radiate its image truly, while the bottom portion will send an apparent image. Since the bottom portion of sun is being seen through thicker, more dense atmosphere. The bottom image is being bent intensely and gives the impression of being squashed or "flattened" or elliptical shape.
21. (c) $\mu \propto \frac{1}{\lambda} \propto \frac{1}{C}$. λ_V is least so C is also least. Also the greatest wavelength is for red colour.
22. (e) We can produce a real image by plane or convex mirror.

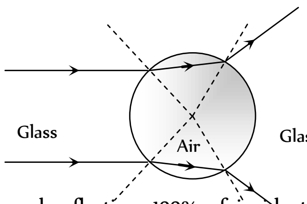




Focal length of convex mirror is taken positive.

23. (d) The colour of glowing red glass in dark will be green as red and green are complimentary colours.

24. (d) The air bubble would behave as a diverging lens, because refractive index of air is less than refractive index of glass. However, the geometrical shape of the air bubble shall resemble a double convex lens.



25. (a) In total internal reflection, 100% of incident light is reflected back into the same medium, and there is no loss of intensity, while in reflection from mirrors and refraction from lenses, there is always some loss of intensity. Therefore images formed by total internal reflection are much brighter than those formed by mirrors or lenses.

26. (d) Focal length of the lens depends upon it's refractive index as $\frac{1}{f} \propto (\mu - 1)$. Since $\mu_b > \mu_r$ so $f_b < f_r$

Therefore, the focal length of a lens decreases when red light is replaced by blue light.

27. (b) After refraction at two parallel faces of a glass slab, a ray of light emerges in a direction parallel to the direction of incidence of white light on the slab. As rays of all colours emerge in the same direction (of incidence of white light), hence there is no dispersion, but only lateral displacement.

28. (d) It is not necessary for a material to have same colour in reflected and transmitted light. A material may reflect one colour strongly and transmit some other colour. For example, some lubricating oils reflect green colour and transmit red. Therefore, in reflected light, they will appear green and in transmitted light, they will appear red.

29. (d) Dispersion of light cannot occur on passing through air contained in a hollow prism. Dispersion take place because the refractive index of medium for different colour is different. Therefore when white light travels from air to air, refractive index remains same and no dispersion occurs.

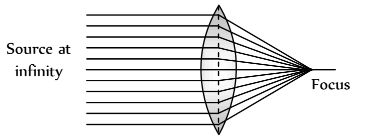
30. (b) The light gathering power (or brightness) of a telescope $\propto$ (diameter)^2. So by increasing the objective diameter even far off stars may produce images of optimum brightness.

31. (c) Very large apertures gives blurred images because of aberrations. By reducing the aperture the clear image is obtained and thus the sensitivity of camera increases.

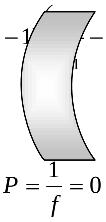
Also the focussing of object at different distance is achieved by slightly altering the separation of the lens from the film.

32. (d) We cannot interchange the objective and eye lens of a microscope to make a telescope. The reason is that the focal length of lenses in microscope are very small, of the order of *mm* or a few *cm* and the difference $(f_o - f_e)$ is very small, while the telescope objective have a very large focal length as compared to eye lens of microscope.

33. (a) Image formed by convex lens



34. (a) The focal length of a lens is given by $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

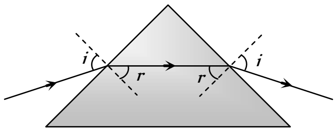


For, goggle, $R_1 = R_2$

$\therefore \ \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = 0$. Therefore, $P = \frac{1}{f} = 0$

35. (c) The wavelength of wave associated with electrons (de Broglie waves) is less than that of visible light. We know that resolving power is inversely proportional to wavelength of wave used in microscope. Therefore the resolving power of an electron microscope is higher than that of an optical microscope.

36. (a) In case of minimum deviation of a prism $\angle i = \angle e$ so $\angle r_1 = \angle r_2$



37. (b) The velocity of light in a material medium depends upon it's colour (wavelength). If a ray of white light incident on a prism, then on emerging, the different colours are deviated through different angles.

Also dispersive power $\omega = \frac{(\mu_V - \mu_R)}{(\mu_Y - 1)}$

i.e. ω depends upon only μ.

38. (c) The ray of light incident on the water air interface suffers total internal reflections, in that case the angle of incidence is greater than the critical angle. Therefore, if the tube is viewed from suitable direction (so that the angle of incidence is greater than the critical angle), the rays of light incident on the tube undergoes total internal reflection. As a result, the test tube appears as highly polished *i.e.* silvery.

39. (a) In wide beam of light, the light rays of light which travel close to the principal axis are called paraxial rays, while the rays which travel quite away from the principal axis is called marginal rays. In case of lens having large aperture, the behaviour of the paraxial and marginal rays are markedly different from each other. The two types of rays come to focus at different points on the principal axis of the lens, thus the spherical aberration occur. However in case of a lens with small aperture, the two types of rays come to focus quite close to each other.

40. (e)

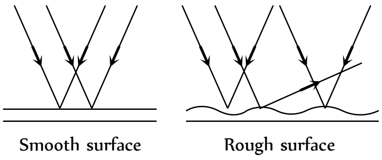
41. (b)

42. (b)

43. (c)

44. (a) Resolving power $=\frac{a}{1.22\lambda}$.

45. (c) When glass surface is made rough then the light falling on it is scattered in different direction due to which its transparency decreases.



46. (b) Diamond glitters brilliantly because light enters in diamond suffers total internal reflection. All the light entering in it comes out of diamond after number of reflections and no light is absorb by it.

47. (c) The clouds consist of dust particles and water droplets. Their size is very large as compared to the wavelength of the incident light from the sun. So there is very little scattering of light. Hence the light which we receive through the clouds has all the colours of light. As a result of this, we receive almost white light. Therefore, the cloud are generally white.

Ray Optics

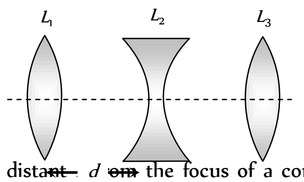
SET Self Evaluation Test - 29

1. In an astronomical telescope in normal adjustment, a straight black line of length L is drawn on the objective lens. The eyepiece forms a real image of this line. The length of this image is l. The magnification of the telescope is

(a) $\frac{L}{l}$ (b) $\frac{L}{l}+1$

(c) $\frac{L}{l}-1$ (d) $\frac{L+l}{L-l}$

2. Three lenses L_1, L_2, L_3 are placed co-axially as shown in figure. Focal length's of lenses are given 30 *cm*, 10 *cm* and 5 *cm* respectively. If a parallel beam of light falling on lens L_1, emerging L_3 as a convergent beam such that it converges at the focus of L_3. Distance between L_1 and L_2 will be



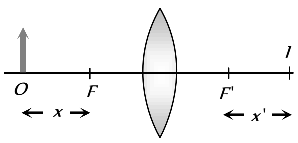
(a) 40 *cm*

(b) 30 *cm*

(c) 20 *cm*

(d) 10 *cm*

3. An object is placed at a point distant d cm the focus of a convex lens and its image is formed at I as shown in the figure. The distances x, x' satisfy the relation



(a) $\frac{x+x'}{2}=f$

(b) $f=xx'$

(c) $x+x'\leq 2f$

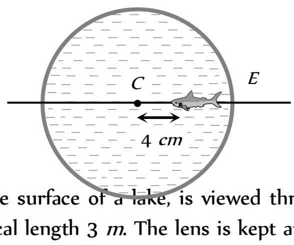
(d) $x+x'\geq 2f$

4. The diameter of the eye-ball of a normal eye is about 2.5 *cm*. The power of the eye lens varies from

(a) 2 *D* to 10 *D* (b) 40 *D* to 32 *D*

(c) 9 *D* to 8 *D* (d) 44 *D* to 40 *D*

5. In a thin spherical fish bowl of radius 10 *cm* filled with water of refractive index 4/3 there is a small fish at a distance of 4 *cm* from the centre C as shown in figure. Where will the image of fish appears, if seen from E



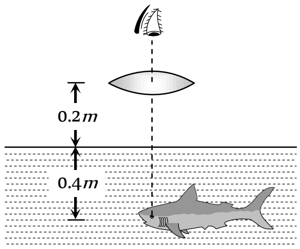
(a) 5.2 *cm*

(b) 7.2 *cm*

(c) 4.2 *cm*

(d) 3.2 *cm*

6. A small fish 0.4 *m* below the surface of a lake, is viewed through a simple converging lens of focal length 3 *m*. The lens is kept at 0.2 *m* above the water surface such that fish lies on the optical axis of the lens. The image of the fish seen by observer will be at $\left(\mu_{water}=\frac{4}{3}\right)$



(a) A distance of 0.2 *m* from the water surface

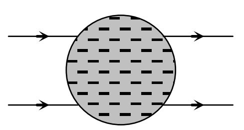
(b) A distance of 0.6 *m* from the water surface

(c) A distance of 0.3 *m* from the water surface

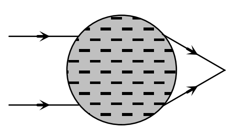
(d) The same location of fish

7. A water drop in air refractes the light ray as

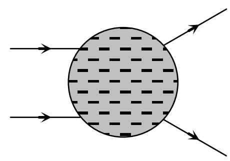
(a)



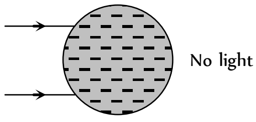
(b)



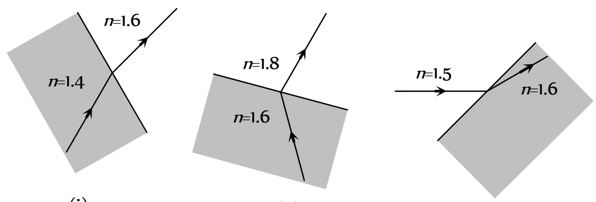
(c)



(d)



8. Which of the following ray diagram show physically possible refraction

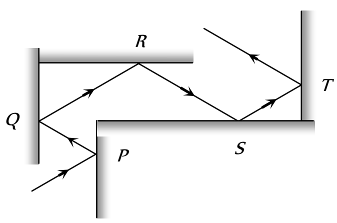


(i) (ii) (iii)

(a) (i) (b) (ii)

(c) (iii) (d) None of these

9. Following figure shows the multiple reflections of a light ray along a glass corridor where the walls are either parallel or perpendicular to one another. If the angle of incidence at point P is 30°, what are the angles of reflection of the light ray at points Q, R, S and T respectively



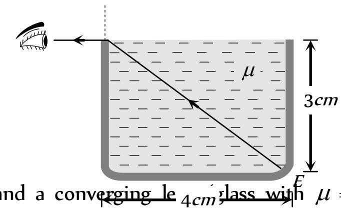
(a) 30°, 30°, 30°, 30°

(b) 30°, 60°, 30°, 60°

(c) 30°, 60°, 60°, 30°

(d) 60°, 60°, 60°, 60°

10. When the rectangular metal tank is filled to the top with an unknown liquid, as observer with eyes level with the top of the tank can just see the corner *E*; a ray that refracts towards the observer at the top surface of the liquid is shown. The refractive index of the liquid will be



(a) 1.2

(b) 1.4

(c) 1.6

(d) 1.9

11. A concave mirror and a converging lens (glass with $\mu = 1.5$) both have a focal length of 3 *cm* when in air. When they are in water $\left(\mu = \frac{4}{3}\right)$, their new focal lengths are

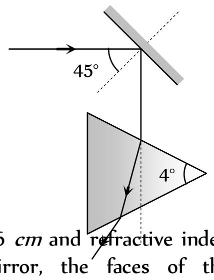
(a) $f_{Lens} = 12\ cm$, $f_{Mirror} = 3cm$

(b) $f_{Lens} = 3\ cm$, $f_{Mirror} = 12cm$

(c) $f_{Lens} = 3\ cm$, $f_{Mirror} = 3cm$

(d) $f_{Lens} = 12\ cm$, $f_{Mirror} = 12cm$

12. A ray of light strikes a plane mirror *M* at an angle of 45° as shown in the figure. After reflection, the ray passes through a prism of refractive index 1.5 whose apex angle is 4°. The total angle through which the ray is deviated is



(a) 90°

(b) 91°

(c) 92°

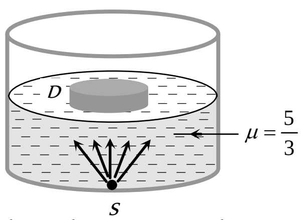
(d) 93°

13. A slab of glass, of thickness 6 *cm* and refractive index 1.5, is placed in front of a concave mirror, the faces of the slab being perpendicular to the principal axis of the mirror. If the radius of curvature of the mirror is 40 *cm* and the reflected image coincides with the object, then the distance of the object from the mirror is

(a) 30 *cm* (b) 22 *cm*

(c) 42 *cm* (d) 28 *cm*

14. A point source of light *S* is placed at the bottom of a vessel containing a liquid of refractive index 5/3. A person is viewing the source from above the surface. There is an opaque disc *D* of radius 1 *cm* floating on the surface of the liquid. The centre of the disc lies vertically above the source *S*. The liquid from the vessel is gradually drained out through a tap. The maximum height of the liquid for which the source cannot be seen at all from above is



(a) 1.50 *cm*

(b) 1.64 *cm*

(c) 1.33 *cm*

(d) 1.86 *cm*

15. A point object is placed mid-way between two plane mirrors distance '*a*' apart. The plane mirror forms an infinite number of images due to multiple reflection. The distance between the *n*th order image formed in the two mirrors is

(a) *na* (b) 2*na*

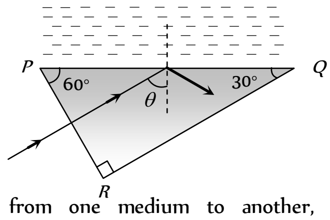
(c) *na*/2 (d) $n^2 a$

16. A convergent beam of light is incident on a convex mirror so as to converge to a distance 12 *cm* from the pole of the mirror. An inverted image of the same size is formed coincident with the virtual object. What is the focal length of the mirror

(a) 24 *cm* (b) 12 *cm*

(c) 6 *cm* (d) 3 *cm*

17. *PQR* is a right angled prism with other angles as 60° and 30°. Refractive index of prism is 1.5. *PQ* has a thin layer of liquid. Light falls normally on the face *PR*. For total internal reflection, maximum refractive index of liquid is



(a) 1.4

(b) 1.3

(c) 1.2

(d) 1.6

18. When a ray is refracted from one medium to another, the wavelength changes from 6000 Å to 4000 Å. The critical angle for the interface will be

(a) $\cos^{-1}\left(\frac{2}{3}\right)$ (b) $\sin^{-1}\left(\frac{2}{\sqrt{3}}\right)$

(c) $\sin^{-1}\left(\frac{2}{3}\right)$ (d) $\cos^{-1}\left(\frac{2}{\sqrt{3}}\right)$

19. Two thin lenses, when in contact, produce a combination of power + 10 *D*. When they are 0.25 *m* apart, the power reduces to + 6*D*. The focal lengths of the lenses (in *m*) are

(a) 0.125 and 0.5 (b) 0.125 and 0.125

(c) 0.5 and 0.75 (d) 0.125 and 0.75

20. The plane faces of two identical plano convex lenses, each with focal length *f* are pressed against each other using an optical glue to form a usual convex lens. The distance from the optical centre at which an object must be placed to obtain the image same as the size of object is

(a) $\frac{f}{4}$ (b) $\frac{f}{2}$

(c) *f* (d) 2 *f*

21. A parallel beam of light emerges from the opposite surface of the sphere when a point source of light lies at the surface of the sphere. The refractive index of the sphere is

(a) $\frac{3}{2}$ (b) $\frac{5}{3}$

(c) 2 (d) $\frac{5}{2}$

22. A ray of light makes an angle of 10° with the horizontal above it and strikes a plane mirror which is inclined at an angle θ to the horizontal. The angle θ for which the reflected ray becomes vertical is

(a) 40° (b) 50°

(c) 80° (d) 100°

23. A thin rod of $5cm$ length is kept along the axis of a concave mirror of $10cm$ focal length such that its image is real and magnified and one end touches the rod. Its magnification will be

(a) 1 (b) 2

(c) 3 (d) 4

24. A telescope using light having wavelength 5000 Å and using lenses of focal 2.5 and 30 *cm*. If the diameter of the aperture of the objective is 10 *cm*, then the resolving limit and magnifying power of the telescope is respectively

(a) $6.1\times10^{-6} rad$ and 12

(b) $5.0\times10^{-6} rad$ and 12

(c) $6.1\times10^{-6} rad$ and 8.3×10^{-2}

(d) $5.0\times10^{-6} rad$ and 8.3×10^{-2}

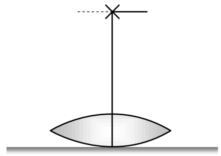
25. A lens when placed on a plane mirror then object needle and its image coincide at 15 *cm*. The focal length of the lens is

(a) 15 *cm*

(b) 30 *cm*

(c) 20 *cm*

(d) ∞



Answers and Solutions

(SET -29)

1. (a) Here we treat the line on the objective as the object and the eyepiece as the lens.

Hence $u = -(f_o + f_e)$ and $f = f_e$

Now $\frac{1}{v} - \frac{1}{-(f_o+f_e)} = \frac{1}{f_e}$

Solving we get $v = \frac{(f_o+f_e)f_e}{f_o}$

Magnification $= \left|\frac{v}{u}\right| = \frac{f_e}{f_o} = \frac{\text{Image size}}{\text{Object size}} = \frac{l}{L}$

∴ Magnification of telescope in normal adjustment

$= \frac{f_o}{f_e} = \frac{L}{l}$

2. (c) According to the problem, combination of L_1 and L_2 act a simple glass plate. Hence according to formula $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

$$\frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} = 0 \Rightarrow \frac{1}{f_1} + \frac{1}{f_2} = \frac{d}{f_1 f_2}$$

$\Rightarrow \frac{1}{30}-\frac{1}{10}=\frac{d}{30\times -10} \Rightarrow \frac{-20}{30\times 10}=-\frac{d}{30\times 10}$

$\Rightarrow d = 20\,cm$

3. (d) From the figure for real image formation

$x + x' + 2f \geq 4f \Rightarrow x + x' \geq 2f.$

4. (d) An eye sees distant objects with full relaxation

So $\frac{1}{2.5\times 10^{-2}}-\frac{1}{-\infty}=\frac{1}{f}$ or $P=\frac{1}{f}=\frac{1}{25\times 10^{-2}}=40D$

An eye sees an object at 25 *cm* with strain

So $\frac{1}{2.5\times 10^{-2}}-\frac{1}{-25\times 10^{-2}}=\frac{1}{f}$

or $P=\frac{1}{f}=40+4=44D$

5. (a) By using $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$

where $\mu_1=\frac{4}{3}$, $\mu_2=1$, $u=-6\,cm$, $v=?$

On putting values $v=-5.2\,cm$

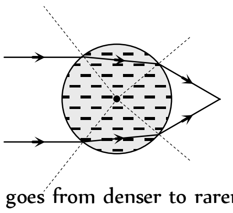
6. (d) Apparent distance of fish from lens $u=0.2+\frac{h}{\mu}$

$=0.2+\frac{0.4}{4/3}=0.5\,m$

From $\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \Rightarrow \frac{1}{(+3)}=\frac{1}{v}-\frac{1}{(-0.5)}$ $v=-0.6\,m$

The image of the fish is still where the fish is 0.4 *m* below the water surface.

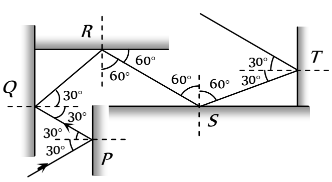
7. (b) A water drop in air behaves as converging lens.



8. (a) When light ray goes from denser to rarer medium (*i.e.* more μ to less μ) it deviates away from the normal while if light ray goes from rarer to denser medium (*i.e.* less μ more μ) it bend towards the normal.

This property is satisfying by the ray diagram (i) only.

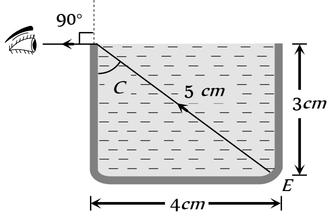
9. (c)



10. (a) Light ray is going from liquid (Denser) to air (Rarer) and angle of refraction is 90^o, so angle of incidence must be equal to critical angle

from figure

$\sin C=\frac{4}{5}$



Also $\mu=\frac{1}{\sin C}=\frac{5}{4}=1.2$

11. (a) Focal length of lens will increase by four times (*i.e.* 12 *cm)* while focal length of mirror will not affected by medium.

12. (c) $\delta_{\text{net}}=\delta_{\text{mirror}}+\delta_{\text{prism}}$

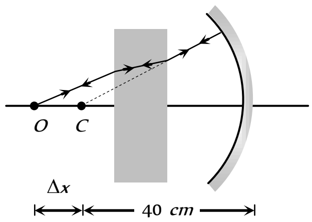
$=(180-2i)+(\mu-1)A$

$=(180-2\times 45)+(1.5-1)\times 4=92^o$

13. (c) $\Delta x=\left(1-\frac{1}{\mu}\right)t$

$=\left(1-\frac{1}{1.5}\right)\times 6$

= 2 *cm.*



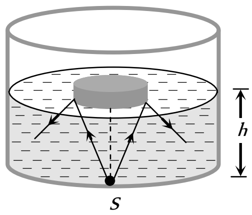
Distance of object from mirror = 42 *cm.*

14. (c) Suppose the maximum height of the liquid is *h* for which the source is not visible.

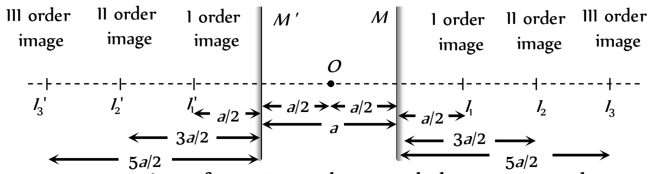
Hence radius of the disc

$r=\frac{h}{\sqrt{\mu^2-1}}$

$1=\frac{h}{\sqrt{\left(\frac{5}{3}\right)^2-1}} \Rightarrow h=1.33\,cm$



15. (b)

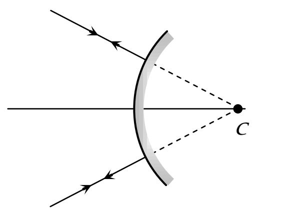


From above figure it can be proved that separation between *n*th order image formed in the two mirrors = $2na$

16. (c) Here object and image are at the same position so this position must be centre of curvature

$\therefore$ R = 12 *cm*

$\Rightarrow f=\frac{R}{2}$



17. (b) For *TIR* at *PQ* ; $\theta < C$

From geometry of figure $\theta=60$ *i.e.* $60>C$

$\Rightarrow \sin 60 > \sin C$

$\Rightarrow \frac{\sqrt{3}}{2} > \frac{\mu_{Liquid}}{\mu_{\text{Prism}}} \Rightarrow \mu_{Liquid} < \frac{\sqrt{3}}{2}\times \mu_{\text{Prism}}$

$\Rightarrow \mu_{Liquid} < \frac{\sqrt{3}}{2}\times 1.5 \Rightarrow \mu_{Liquid} < 1.3$.

18. (c) $_1\mu_2 = \frac{1}{\sin C} \Rightarrow \frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2} = \frac{1}{\sin C}$

$\Rightarrow \frac{6000}{4000} = \frac{1}{\sin C} \Rightarrow C = \sin^{-1}\left(\frac{2}{3}\right)$

19. (a) When lenses are in contact

$P = \frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \Rightarrow 10 = \frac{1}{f_1} + \frac{1}{f_2}$ ..... (i)

When they are distance d apart

$P' = \frac{1}{F'} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \Rightarrow 6 = \frac{1}{f_1} + \frac{1}{f_2} - \frac{0.25}{f_1 f_2}$ ..... (ii)

From equation (i) and (ii) $f_1 f_2 = \frac{1}{16}$ ..... (iii)

From equation (i) and (iii) $f_1 + f_2 = \frac{5}{8}$ ..... (iv)

Also $(f_1 - f_2)^2 = (f_1 + f_2)^2 - 4 f_1 f_2$

Hence $(f_1 - f_2)^2 = \left(\frac{5}{8}\right)^2 - 4 \times \frac{1}{16} = \frac{9}{64}$

$\Rightarrow f_1 - f_2 = \frac{3}{8}$ ..... (v)

On solving (iv) and (v) $f_1 = 0.5\,m$ and $f_2 = 0.125\,m$

20. (c) Two plano-convex lens of focal length *f*, when combined will give rise to a convex lens of focal length $f/2$.

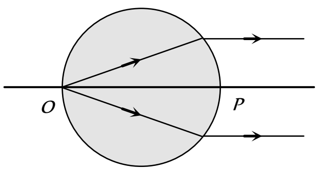
The image will be of same size if object is placed at $2f$ *i.e.* at a distance *f* from optical centre.

21. (c) Considering pole at *P*, we have

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

$\Rightarrow \frac{1}{\infty} - \frac{\mu}{(-2R)} = \frac{1-\mu}{(-R)}$

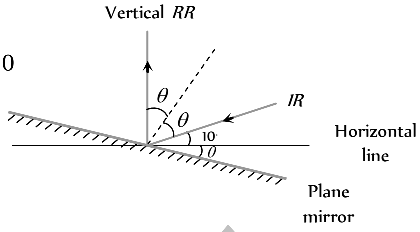
$\Rightarrow \frac{\mu}{2R} = \frac{1-\mu}{(-R)} \Rightarrow \mu = 2$



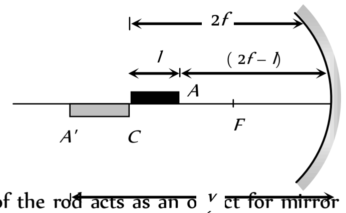
22. (a) From figure

$\theta + \theta + 10 = 90$

$\Rightarrow \theta = 40^o$



23. (b)



End *A* of the rod acts as an object for mirror and *A*′ will be its image so $u = 2f - l = 20 - 5 = 15\ cm$

$\because \frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow \frac{1}{-10} = \frac{1}{v} - \frac{1}{15} \Rightarrow v = -30\ cm$.

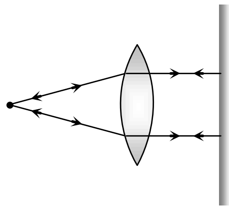
Now $m = \frac{\text{Length of image}}{\text{Length of object}} = \frac{(30-20)}{5} = 2$

24. (a) $m = \frac{f_0}{f_e} = \frac{30}{2.5} = 12$

Resolving limit $= \frac{1.22\,\lambda}{a} = \frac{1.22 \times (5000 \times 10^{-10})}{0.1}$

$= 6.1 \times 10^{-6}\,rad$

25. (a) When the object is placed at focus the rays are parallel. The mirror placed normal sends them back. Hence image is formed at the object itself as illustrated in figure.



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Chapter

30

Wave Optics

Newton's Corpuscular Theory

(1) Newton thought that light is made up of tiny, light and elastic particles called corpuscles which are emitted by a luminous body.

(2) The corpuscles travel with speed equal to the speed of light in all directions in straight lines.

(3) The corpuscles carry energy with them. When they strike retina of the eye, they produce sensation of vision.

(4) The corpuscles of different colour are of different sizes (red corpuscles larger than blue corpuscles).

(5) The corpuscular theory explains that light carry energy and momentum, light travels in a straight line, Propagation of light in vacuum, Laws of reflection and refraction

(6) The corpuscular theory fails to explain interference, diffraction and polarization.

(7) A major prediction of the corpuscular theory is that the speed of light in a denser medium is more than the speed of light in a rarer medium. The truth is that the speed of the light is smaller in a denser medium. Therefore, the Newton's corpuscular theory is wrong.

Huygen's Wave Theory

(1) Wave theory of light was given by Christian Huygen. According to this, a luminous body is a source of disturbance in a hypothetical medium ether. This medium pervades all space.

(2) It is assumed to be transparent and having zero inertia. The disturbance from the source is propagated in the form of waves through the space.

(3) The waves carry energy and momentum. Huygen assumed that the waves were longitudinal. Further when polarization was discovered, then to explain it, light waves were, assumed to be transverse in nature by Fresnel.

(4) This theory explains successfully, the phenomenon of interference and diffraction apart from other properties of light.

(5) The Huygen's theory fails to explain photo-electric effect, Compton's effect *etc*.

(6) The wave theory introduces the concept of wavefront.

Wavefront

(1) Suggested by Huygens

(2) The locus of all particles in a medium, vibrating in the same phase is called Wave Front (WF)

(3) The direction of propagation of light (ray of light) is perpendicular to the WF.

(4) Every point on the given wave front acts as a source of new disturbance called secondary wavelets which travel in all directions with the velocity of light in the medium.

(5) A surface touching these secondary wavelets tangentially in the forward direction at any instant gives the new wave front at that instant. This is called secondary wave front

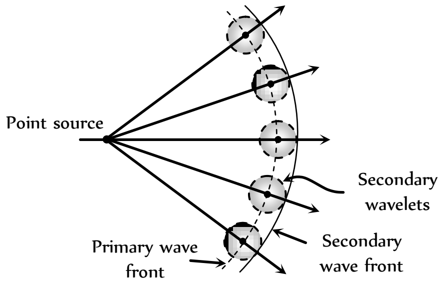
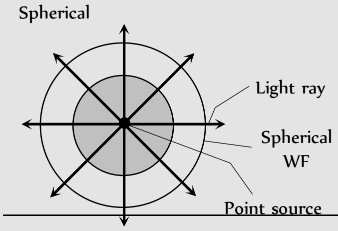
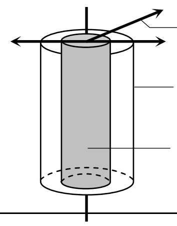
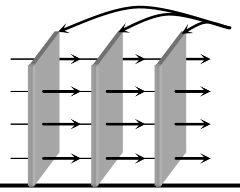


Fig. 30.1

Table 30.1 : Different types of wavefront

Type of wavefront	Intensity	Amplitude
Spherical 	$I \propto \frac{1}{r^2}$	$A \propto \frac{1}{r}$

Cylindrical 	$I \propto \frac{1}{r}$	$A \propto \frac{1}{\sqrt{r}}$
Plane 	$I \propto r^0$	$A \propto r^0$

Reflection and Refraction of Wavefront

Reflection

$BC = AD$

and $\angle i = \angle r$

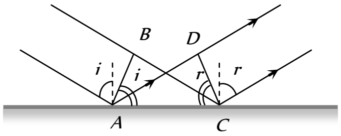


Fig. 30.2

Refraction

$$\frac{BC}{AD} = \frac{v_1}{v_2} = \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

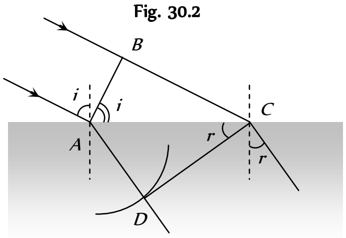


Fig. 30.3

Super Position of Waves

When two or more than two waves superimpose over each other at a common particle of the medium then the resultant displacement (y) of the particle is equal to the vector sum of the displacements (y_1 and y_2) produced by individual waves. *i.e.* $\vec{y} = \vec{y}_1 + \vec{y}_2$

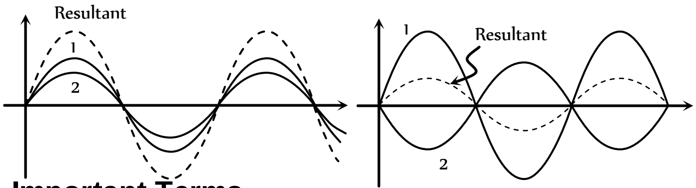


Fig. 30.4

Important Terms

(1) **Phase :** The argument of sine or cosine in the expression for displacement of a wave is defined as the phase. For displacement $y = a \sin \omega t$; term ωt = phase or instantaneous phase.

(2) **Phase difference (ϕ) :** The difference between the phases of two waves at a point is called phase difference *i.e.* if $y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin(\omega t + \phi)$ so phase difference = ϕ

(3) **Path difference (Δ) :** The difference in path length's of two waves meeting at a point is called path difference between the waves at that point. Also $\Delta = \frac{\lambda}{2\pi} \times \phi$

(4) **Time difference (*T.D.*) :** Time difference between the waves meeting at a point is ***T.D.*** $= \frac{T}{2\pi} \times \phi$

Resultant Amplitude and Intensity

Let us consider two waves that have the same frequency but have a certain fixed (constant) phase difference between them. Their super position shown below

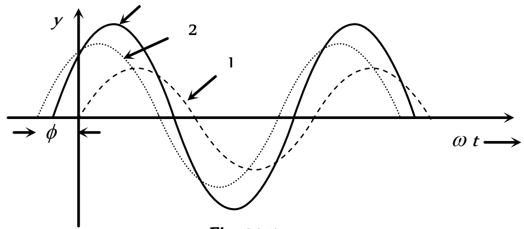


Fig. 30.5

Let the two waves are

$y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin(\omega t + \phi)$

where $a_1, a_2 =$ Individual amplitudes,

ϕ = Phase difference between the waves at an instant when they are meeting a point.

(1) **Resultant amplitude :** The resultant wave can be written as $y = A \sin(\omega t + \theta)$

where A = resultant amplitude $= \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos \varphi}$

(2) **Resultant intensity :** As we know intensity $\propto$ (Amplitude)^2

$\Rightarrow \quad I_1 = ka_1^2, I_2 = ka_2^2$ and $I = kA^2$ (k is a proportionality constant). Resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$

For two identical source $I_1 = I_2 = I_0 \Rightarrow I = I_0 + I_0 + 2\sqrt{I_0 I_0} \cos \phi$

$= 4I_0 \cos^2 \frac{\phi}{2}$ $\qquad$ $[1 + \cos\theta = 2\cos^2 \frac{\theta}{2}]$

Coherence

The phase relationship between two light waves can very from time to time and from point to point in space. The property of definite phase relationship is called coherence.

(1) **Temporal coherence :** In a light source a light wave (photon) is produced when an excited atom goes to the ground state and emits light.

(i) The duration of this transition is about 10^{-9} to 10^{-10} *sec.* Thus the emitted wave remains sinusoidal for this much time. This time is known as coherence time (τ_c).

(ii) Definite phase relationship is maintained for a length $L = c\tau_c$ called coherence length. For neon λ = 6328 Å, $\tau_c \approx 10^{-10}$ *sec* and L = 0.03 *m.*

For cadmium λ = 6438 Å, $\tau_c = 10^{-9}$ *sec* and L = 0.3 *m*

For Laser $\tau_c = 10^{-5}$ *sec* and L = 3 *km*

(iii) The spectral lines width $\Delta\lambda$ is related to coherence length L and coherence time τ. $\Delta\lambda \approx \frac{\lambda^2}{c\tau_c}$ or $\Delta\lambda \approx \frac{\lambda^2}{L}$

(2) **Spatial coherence :** Two points in space are said to be spatially coherence if the waves reaching there maintains a constant phase difference

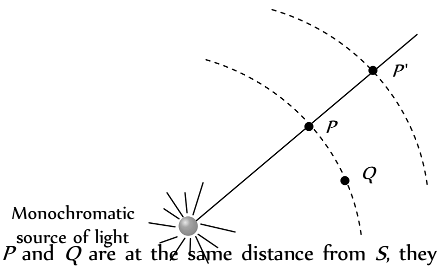


Fig. 30.6

Points P and Q are at the same distance from S, they will always be having the same phase. Points P and P' will be spatially coherent if the distance between P and P' is much less than the coherence length *i.e.* $PP' << c\tau_c$

(3) **Methods of obtaining coherent sources :** Two coherent sources are produced from a single source of light by two methods (i) By division of wavefront and (ii) By division of amplitude

(i) **Division of wave front :** The wave front emitted by a narrow source is divided in two parts by reflection, refraction or diffraction.

The coherent sources so obtained are imaginary. There produced in Fresnel's biprism, Llyod's mirror Youngs' double slit *etc.*

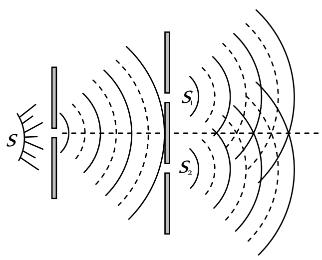


Fig. 30.7

(ii) **Division of amplitude :** In this arrangement light wave is partly reflected (50%) and partly transmitted (50%) to produced two light rays.

The amplitude of wave emitted by an extend source of light is divided in two parts by partial reflection and partial refraction.

The coherent sources obtained are real and are obtained in Newton's rings, Michelson's interferrometer, colours in thin films.

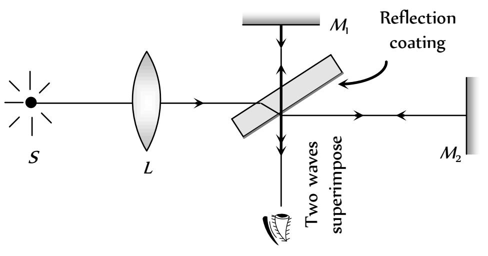
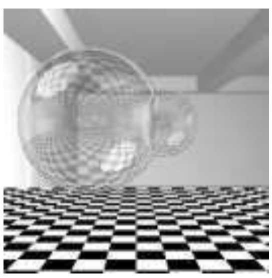


Fig. 30.8

Interference of Light

When two waves of exactly same frequency (coming from two coherent sources) travels in a medium, in the same direction simultaneously then due to their superposition, at some points intensity of light is maximum while at some other points intensity is minimum. This



phenomenon is called Interference of light. It is of following two types

(1) **Constructive interference :** When the waves meets a point with same phase, constructive interference is obtained at that point (*i.e.* maximum light)

(i) Phase difference between the waves at the point of observation $\phi = 0^o$ or $2n\pi$

(ii) Path difference between the waves at the point of observation $\Delta = n\lambda$ (*i.e.* even multiple of $\lambda/2$)

(iii) Resultant amplitude at the point of observation will be maximum $A_{max} = a_1 + a_2$

If $a_1 = a_2 = a_0 \Rightarrow A_{\max} = 2a_0$

(iv) Resultant intensity at the point of observation will be maximum

$$I_{\max} = I_1 + I_2 + 2\sqrt{I_1 I_2} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

If $I_1 = I_2 = I_0 \Rightarrow I_{\max} = 4I_0$

(2) **Destructive interference :** When the wave meets a point with opposite phase, destructive interference is obtained at that point (*i.e.* minimum light)

(i) Phase difference $\phi = 180^o$ or $(2n-1)\pi$; n = 1, 2, ...

or $(2n+1)\pi$; $n = 0,1,2.....$

(ii) Path difference $\Delta = (2n-1)\frac{\lambda}{2}$ (*i.e.* odd multiple of $\lambda/2$)

(iii) Resultant amplitude at the point of observation will be minimum $A_{\min} = a_1 - a_2$

If $a_1 = a_2 \Rightarrow A_{\min} = 0$

(iv) Resultant intensity at the point of observation will be minimum

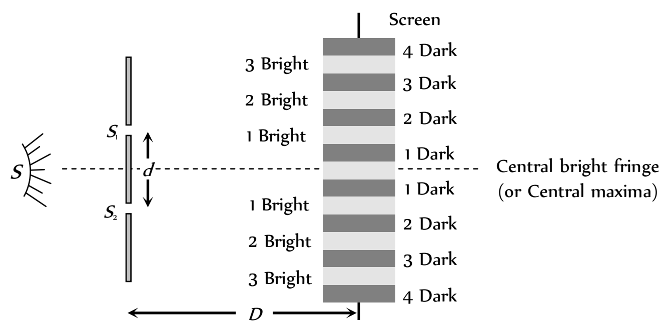
$$I_{\min} = I_1 + I_2 - 2\sqrt{I_1 I_2} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$$

If $I_1 = I_2 = I_0 \Rightarrow I_{\min} = 0$

(3) **Super position of waves of random phase difference :** When two waves (or more waves) having random phase difference between them super impose, then no interference pattern is produced. Then the resultant intensity is just the sum of the two intensities. $I = I_1 + I_2$

Young's Double Slit Experiment (YDSE)

Monochromatic light (single wavelength) falls on two narrow slits S_1 and S_2 which are very close together acts as two coherent sources, when waves coming from two coherent sources (S_1, S_2) superimposes on each other, an interference pattern is obtained on the screen. In YDSE alternate bright and dark bands obtained on the screen. These bands are called Fringes.



d = Distance between slits
D = Distance between slits and screen
λ = Wavelength of monochromatic light emitted from source

(1) Central fringe is always bright, because at central position $\phi = 0^o$ or $\Delta = 0$

(2) The fringe pattern obtained due to a slit is more bright than that due to a point.

(3) If the slit widths are unequal, the minima will not be complete dark. For very large width uniform illumination occurs.

(4) If one slit is illuminated with red light and the other slit is illuminated with blue light, no interference pattern is observed on the screen.

(5) If the two coherent sources consist of object and it's reflected image, the central fringe is dark instead of bright one.

Useful Results

(1) **Path difference :** Path difference between the interfering waves meeting at a point P on the screen is given by

$\Delta = \Delta_i + \Delta_f$; where Δ_i = initial path difference between the waves before the slits and Δ_f = path difference between the waves after emerging from the slits. In this case $\Delta_i = 0$ (Commonly used condition). So

$$\Delta = \Delta_f = \frac{xd}{D} = d \sin\theta$$

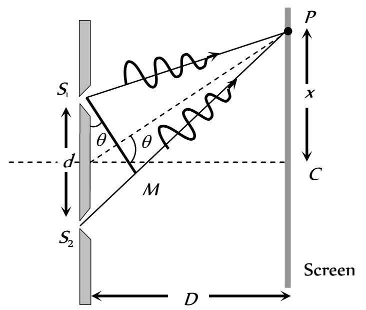


Fig. 30.10

where x is the position of point P from central maxima.

For maxima at P: $\Delta = n\lambda$; where n = 0, ± 1, ± 2, ...

and For minima at P: $\Delta = \frac{(2n-1)\lambda}{2}$; where n = ± 1, ± 2, ...

(2) **Location of fringe :** Position of n^{th} bright fringe from central maxima $x_n = \frac{n\lambda D}{d} = n\beta$; $n = 0, 1, 2 ....$

Position of n^{th} dark fringe from central maxima

$$x_n = \frac{(2n-1)\lambda D}{2d} = \frac{(2n-1)\beta}{2} \; ; \; n = 1, 2, 3 ....$$

(3) **Fringe width (β) :** The separation between any two consecutive bright or dark fringes is called fringe width. In *YDSE* all fringes are of equal width. Fringe width $\beta = \frac{\lambda D}{d}$.

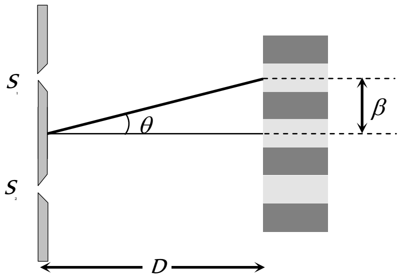


Fig. 30.11

and angular fringe width $\theta = \frac{\lambda}{d} = \frac{\beta}{D}$

(4) In YDSE, if n_1 fringes are visible in a field of view with light of wavelength λ_1 , while n_2 with light of wavelength λ_2 in the same field, then $\boldsymbol{n_1\lambda_1 = n_2\lambda_2}$.

(5) **Separation (Δx) between fringes**

(i) Between n^{th} bright and m^{th} bright fringes $(n > m)$

$$\Delta x = (n - m)\beta$$

(ii) Between n^{th} bright and m^{th} dark fringe

(a) If $n > m$ then $\Delta x = \left(n - m + \frac{1}{2}\right)\beta$

(b) If $n < m$ then $\Delta x = \left(m - n - \frac{1}{2}\right)\beta$

(6) **Identification of central bright fringe :** To identify central bright fringe, monochromatic light is replaced by white light. Due to overlapping central maxima will be white with red edges. On the other side of it we shall get a few coloured band and then uniform illumination.

If the whole YDSE set up is taken in another medium then λ changes so β changes

e.g. in water $\lambda_w = \frac{\lambda_a}{\mu_w} \Rightarrow \beta_w = \frac{\beta_a}{\mu_w} = \frac{3}{4}\beta_a$

Condition for Observing Interference

(1) The initial phase difference between the interfering waves must remain constant. Otherwise the interference will not be sustained.

(2) The frequency and wavelengths of two waves should be equal. If not the phase difference will not remain constant and so the interference will not be sustained.

(3) The light must be monochromatic. This eliminates overlapping of patterns as each wavelength corresponds to one interference pattern.

(4) The amplitudes of the waves must be equal. This improves contrast with $I_{max} = 4I_0$ and $I_{min} = 0$.

(5) The sources must be close to each other. Otherwise due to small fringe width $\left(\beta \propto \frac{1}{d}\right)$ the eye can not resolve fringes resulting in uniform illumination.

Shifting of Fringe Pattern in YDSE

If a transparent thin film of mica or glass is put in the path of one of the waves, then the whole fringe pattern gets shifted towards the slit in front of which glass plate is placed.

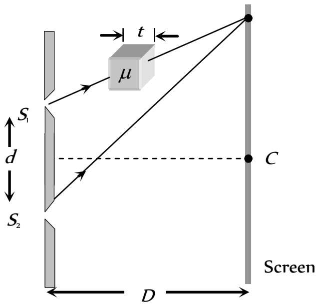


Fig. 30.12

(1) $\text{Fringe shift} = \frac{D}{d}(\mu-1)t = \frac{\beta}{\lambda}(\mu-1)t$

(2) Additional path difference $= (\mu-1)t$

(3) If shift is equivalent to n fringes then $n = \frac{(\mu-1)t}{\lambda}$ or $t = \frac{n\lambda}{(\mu-1)}$

(4) Shift is independent of the order of fringe (*i.e.* shift of zero order maxima = shift of n order maxima.

(5) Shift is independent of wavelength.

Fringe Visibility (*V*)

With the help of visibility, knowledge about coherence, fringe contrast an interference pattern is obtained.

$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = 2\frac{\sqrt{I_1 I_2}}{(I_1 + I_2)}$ If $I_{min} = 0$, $V = 1$ (maximum) *i.e.*, fringe visibility will be best.

Also if $I_{max} = 0, V = -1$ and If $I_{max} = I_{min}, V = 0$

Missing Wavelength in Front of One Slit in YDSE

Suppose P is a point of observation infront of slit S_1 as shown

Missing wavelength at P

$$\lambda = \frac{d^2}{(2n-1)D}$$

By putting $n = 1, 2, 3....$

Missing wavelengths are

$$\lambda = \frac{d^2}{D}, \frac{d^2}{3D}, \frac{d^2}{5D}....$$

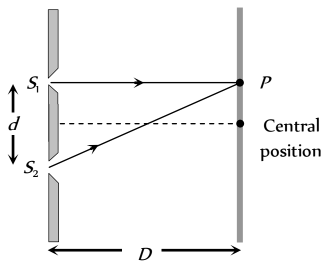
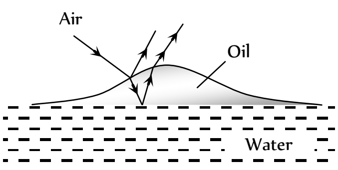


Fig. 30.13

Interference in Thin Films

Interference effects are commonly observed in thin films when their thickness is comparable to wavelength of incident light (If it is too thin as compared to wavelength of light it appears dark and if it is too thick, this will result in uniform illumination of film). Thin layer of oil on water surface and soap bubbles shows various colours in white light due to interference of waves reflected from the two surfaces of the film.



Oil film on water surface

Fig. 30.14

In thin films interference takes place between the waves reflected from it's two surfaces and waves refracted through it.

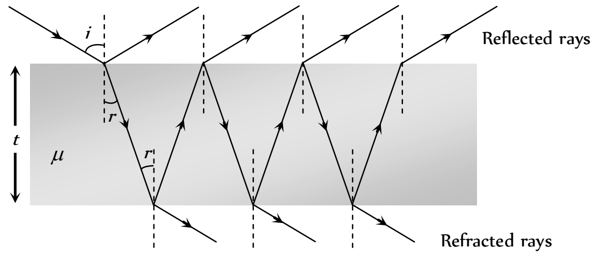


Fig. 30.15

(1) **Interference in reflected light :** Condition of constructive interference (maximum intensity)

$$\Delta = 2\mu\, t\cos r = (2n-1)\frac{\lambda}{2}.$$

For normal incidence $r = 0$ so $2\mu t = (2n-1)\frac{\lambda}{2}$

Condition of destructive interference (minimum intensity)

$\Delta = 2\mu t\cos r = (2n)\frac{\lambda}{2}$. For normal incidence $2\mu t = n\lambda$

(2) **Interference in refracted light :** Condition of constructive interference (maximum intensity)

$\Delta = 2\mu t\cos r = (2n)\frac{\lambda}{2}$. For normal incidence $2\mu t = n\lambda$

Condition of destructive interference (minimum intensity)

$$\Delta = 2\mu t\cos r = (2n-1)\frac{\lambda}{2}$$

For normal incidence $2\mu t = (2n-1)\frac{\lambda}{2}$

Lloyd's Mirror

A plane glass plate (acting as a mirror) is illuminated at almost grazing incidence by a light from a slit S_1. A virtual image S_2 of S_1 is formed closed to S_1 by reflection and these two act as coherent sources. The expression giving the fringe width is the same as for the double slit, but the fringe system differs in one important respect.

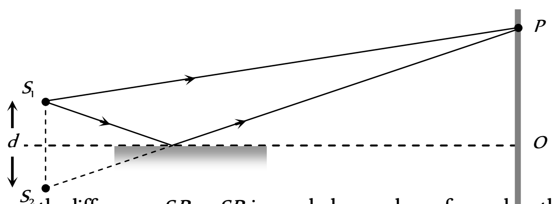


Fig. 30.16

The path difference $S_1P - S_2P$ is a whole number of wavelengths, the fringe at P is dark not bright. This is due to 180° phase change which occurs when light is reflected from a denser medium. At grazing incidence a fringe is formed at O, where the geometrical path difference between the direct and reflected waves is zero and it follows that it will be dark rather than bright.

Thus, whenever there exists a phase difference of a π between the two interfering beams of light, conditions of maximas and minimas are interchanged, *i.e.*, $\Delta x = n\lambda$ (for minimum intensity)

and $\Delta x = (2n-1)\lambda/2$ (for maximum intensity)

Fresnel's Biprims

(1) It is an optical device of producing interference of light Fresnel's biprism is made by joining base to base two thin prism of very small angle

(2) Acute angle of prism is about 1/2° and obtuse angle of prism is about 179°.

(3) When a monochromatic light source is kept in front of biprism two coherent virtual source S_1 and S_2 are produced.

(4) Interference fringes are found on the screen placed behind the biprism interference fringes are formed in the limited region which can be observed with the help eye piece.

(5) Fringe width is measured by a micrometer attached to the eye piece. Fringes are of equal width and its value is $\beta = \frac{\lambda D}{d}$

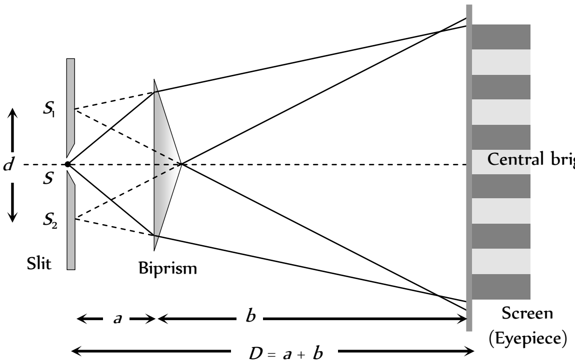


Fig. 30.17

(6) Let the separation between S_1 and S_2 be d and the distance of slits and the screen from the biprism be a and b respectively *i.e.* $D = (a + b)$. If angle of prism is α and refractive index is μ then $d = 2a(\mu - 1)\alpha$

$$\therefore \quad \lambda = \frac{\beta[2a(\mu-1)\alpha]}{(a+b)} \quad \Rightarrow \quad \beta = \frac{(a+b)\lambda}{2a(\mu-1)\alpha}$$

(7) If a convex lens is mounted between the biprism and eye piece. There will be two positions of lens when the sharp images of coherent sources will be observed in the eyepiece. The separation of the images in the two positions are measured. Let these be d_1 and d_2 then $d = \sqrt{d_1 d_2}$

$$\therefore \ \lambda = \frac{\beta d}{D} = \frac{\beta\sqrt{d_1 d_2}}{(a+b)}.$$

Newton's Rings

(1) If we place a plano-convex lens on a plane glass surface, a thin film of air is formed between the curved surface of the lens and plane glass plate.

(2) If we allow monochomatic light to fall normally on the surface of lens, then circular interference fringes of radius r can be seen in the reflected light. This circular fringes are called Newton rings.

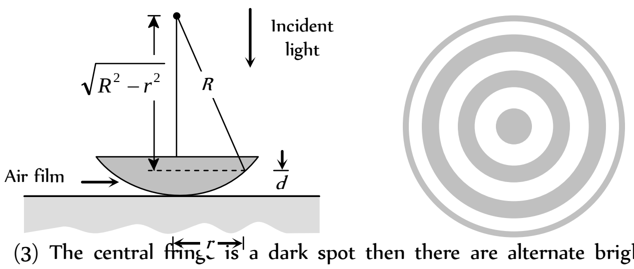


Fig. 30.18

(3) The central fringe is a dark spot then there are alternate bright and dark fringes (Ring shape).

(4) Radius of n^{th} dark ring $r_m \simeq \sqrt{n\lambda R}$

$n = 0, 1, 2, \ldots\ldots$, R = Radius of convex surface

(5) Radius of n^{th} bright ring $r_n = \sqrt{\left(n + \frac{1}{2}\right)\lambda R}$

(6) If a liquid of ref index μ is introduced between the lens and glass plate, the radii of dark ring would be $r_n = \sqrt{\frac{n\lambda R}{\mu}}$

(7) Newton's ring arrangement is used of determining the wavelength of monochromatic light. For this the diameter of n^{th} dark ring (D_n) and $(n + p)^{th}$ dark ring (D_{n+p}) are measured then

$$D_{(n+p)}^2 = 4(n+p)\lambda R \text{ and } D_n^2 = 4n\lambda R \quad \Rightarrow \quad \lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}$$

Doppler's Effect of Light

The phenomenon of apparent change in frequency (or wavelength) of the light due to relative motion between the source of light and the observer is called Doppler's effect.

If $\nu =$ actual frequency, $\nu' =$ Apparent frequency, v = speed of source *w.r.t* stationary observer, c = speed of light

(1) **Source of light moves towards the stationary observer :** When a light source is moving towards an observer with a relative velocity v then the apparent frequency (ν') is greater than the actual frequency (ν) of light. Thus apparent wavelength (λ') is lesser the actual wavelength (λ).

$$\nu' = \nu\sqrt{\frac{(1+v/c)}{(1-v/c)}} \text{ and } \lambda' = \lambda\sqrt{\frac{(1-v/c)}{(1+v/c)}}$$

For $v << c$:

(i) Apparent frequency $\nu' = \nu\left(1 + \frac{v}{c}\right)$ and

(ii) Apparent wavelength $\lambda' = \lambda\left(1 - \frac{v}{c}\right)$

(iii) Doppler's shift : Apparent wavelength < actual wavelength,

So spectrum of the radiation from the source of light shifts towards the violet end of spectrum. This is called violet shift

Doppler's shift $\Delta\lambda = \lambda.\frac{v}{c}$

(iv) The fraction decrease in wavelength $= \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

(2) **Source of light moves away from the stationary observer :** In this case $\nu' < \nu$ and $\lambda' > \lambda$

$$\nu' = \nu\sqrt{\frac{(1-v/c)}{(1+v/c)}} \text{ and } \lambda' = \lambda\sqrt{\frac{(1+v/c)}{(1-v/c)}}$$

For $v << c$:

(i) Apparent frequency $\nu' = \nu\left(1 - \frac{v}{c}\right)$ and

(ii) Apparent wavelength $\lambda' = \lambda\left(1 + \frac{v}{c}\right)$

(iii) Doppler's shift : Apparent wavelength > actual wavelength,

So spectrum of the radiation from the source of light shifts towards the red end of spectrum. This is called red shift

Doppler's shift $\Delta\lambda = \lambda . \frac{v}{c}$

(iv) The fractional increase in wavelength $= \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$.

(3) **Doppler broadening :** For a gas in a discharge tube, atoms are moving randomly in all directions. When spectrum of light emitted from these atoms is analyzed, then due to Doppler effect (because some atoms are moving towards detector, some atoms are moving away from detector), the frequency of a spectral line is not observed as having one value, but is spread over a range

$$\pm\Delta\nu = \pm\frac{v}{c}\nu, \quad \pm\Delta\lambda = \pm\frac{v}{c}\lambda$$

This broadens the spectral line by an amount $(2\Delta\lambda)$. It is called Doppler broadening. The Doppler broadening is proportional to *v*, which in turn is proportional to $\sqrt{T}$, where T is the temperature in Kelvin.

(4) **Radar :** Radar is a system for locating distant object by means of reflected radio waves, usually of microwave frequencies. Radar is used for navigation and guidance of aircraft, ships *etc*.,.

Radar employs the Doppler effect to distinguish between stationary and moving targets. The change in frequency between transmitted and received waves is measured. If v is the velocity of the approaching target, then the change in frequency is

$\Delta\nu = \frac{2v}{c}\nu$. (The factor of 2 arises due to refection of waves). For a receding target $\Delta\nu = -\frac{2v}{c}\nu$. (The minus sign indicates decrease in frequency).

(5) **Applications of Doppler effect**

(i) Determination of speed of moving bodies (aeroplane, submarine etc) in RADAR and SONAR.

(ii) Determination of the velocities of stars and galaxies by spectral shift.

(iii) Determination of rotational motion of sun.

(iv) Explanation of width of spectral lines.

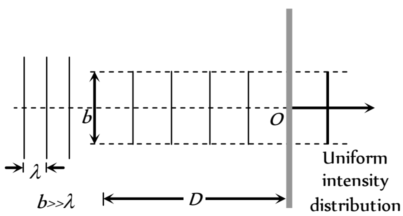
(v) Tracking of satellites.

(vi) In medical sciences in echo cardiogram, sonography *etc*.

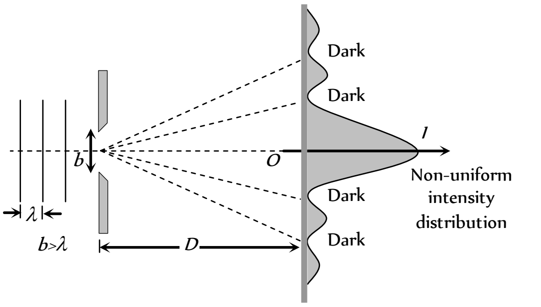
Diffraction of Light

The phenomenon of diffraction was first discovered by Girmaldi. It's experimental study was done by Newton's and young. The theoretical explanation was first given by Fresnel's.

(1) The phenomenon of bending of light around the corners of an obstacle/aperture of the size of the wave length of light is called diffraction.



(A) Size of the slit is very large compared to wavelength



(B) Size of the slit is comparable to wavelength

(2) The phenomenon resulting from the superposition of secondary wavelets originating from different parts of the same wave front is define as diffraction of light.

(3) Diffraction is the characteristic of all types of waves.

(4) Greater the wave length of wave higher will be it's degree of diffraction.

Types of Diffraction

(1) **Fresnel diffraction :** If either source or screen or both are at finite distance from the diffracting device (obstacle or aperture), the diffraction is called Fresnel type.

Common examples : Diffraction at a straight edge, narrow wire or small opaque disc *etc*.

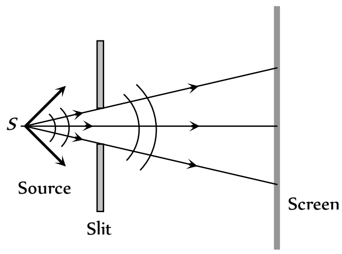


Fig. 30.20

(2) **Fraunhofer diffraction :** In this case both source and screen are effectively at infinite distance from the diffracting device.

Common examples : Diffraction at single slit, double slit and diffraction grating.

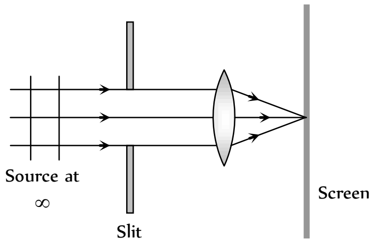
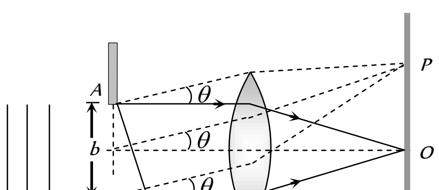


Fig. 30.21

Diffraction at Single Slit (Fraunhoffer Diffraction)

Suppose a plane wave front is incident on a slit *AB* (of width b). Each and every part of the expose part of the plane wave front (i.e. every part of the slit) acts as a source of secondary wavelets spreading in all directions. The diffraction is obtained on a screen placed at a large distance. (In practice, this condition is achieved by placing the screen at the focal plane of a converging lens placed just after the slit).



(1) The diffraction pattern consists of a central bright fringe (central maxima) surrounded by dark and bright lines (called secondary minima and maxima).

(2) At point *O* on the screen, the central maxima is obtained. The wavelets originating from points A and B meets in the same phase at this point, hence at *O*, intensity is maximum.

(3) **Secondary minima :** For obtaining *n* secondary minima at P on the screen, path difference between the diffracted waves $\Delta = b\sin\theta = n\lambda$

(i) Angular position of *n* secondary minima $\sin\theta \approx \theta = \frac{n\lambda}{b}$

(ii) Distance of *n* secondary minima from central maxima

$x_n = D.\theta = \frac{n\lambda D}{b} = \frac{n\lambda f}{b}$; where *D* = Distance between slit and screen. $f \approx D$ = Focal length of converging lens.

(4) **Secondary maxima :** For *n* secondary maxima at *P* on the screen.

Path difference $\Delta = b\sin\theta = (2n+1)\frac{\lambda}{2}$; where *n* = 1, 2, 3 .....

(i) Angular position of *n* secondary maxima

$$\sin \approx \theta \approx \frac{(2n+1)\lambda}{2b}$$

(ii) Distance of *n* secondary maxima from central maxima

$$x_n = D.\theta = \frac{(2n+1)\lambda D}{2b} = \frac{(2n+1)\lambda f}{2b}$$

(5) **Central maxima :** The central maxima lies between the first minima on both sides.

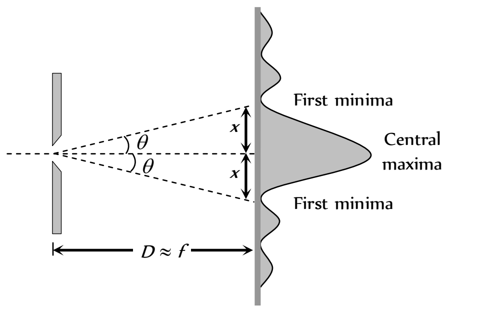
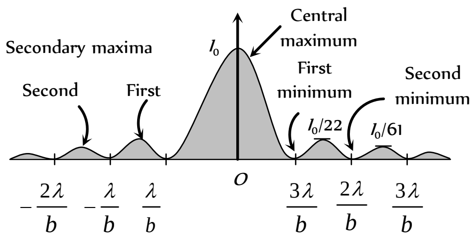


Fig. 30.23

(i) The Angular width *d* central maxima = $2\theta = \frac{2\lambda}{b}$

(ii) Linear width of central maxima $= 2x = 2D\theta = 2f\theta = \frac{2\lambda f}{b}$

(6) **Intensity distribution :** If the intensity of the central maxima is I_0 then the intensity of the first and second secondary maxima are found to be $\frac{I_0}{22}$ and $\frac{I_0}{61}$. Thus diffraction fringes are of unequal width and unequal intensities.



(i) The mathematical expression for in intensity distribution on the screen is given by

$I = I_0\left(\frac{\sin\alpha}{\alpha}\right)^2$ where α is just a convenient connection between the angle θ that locates a point on the viewing screening and light intensity *I*.

ϕ = Phase difference between the top and bottom ray from the slit width *b*.

Also $\alpha = \frac{1}{2}\phi = \frac{\pi b}{\lambda}\sin\theta$

(ii) As the slit width increases (relative to wavelength) the width of the control diffraction maxima decreases; that is, the light undergoes less flaring by the slit. The secondary maxima also decreases in width (and becomes weaker).

(iii) If $b >> \lambda$, the secondary maxima due to the slit disappear; we then no longer have single slit diffraction.

(iv) When the slit width is reduced by a factor of 2, the amplitude of the wave at the centre of the screen is reduced by a factor of 2, so the intensity at the centre is reduced by a factor of 4.

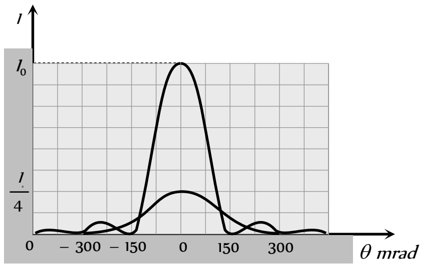


Fig. 30.25

Diffraction Gratings

One of the most useful tools in the study of light and of objects that emit and absorbs light is the diffraction grating.

(1) this device consists parallel slits of equal width and equal spacing called rulings, perhaps as many as several thousand per *mm*.

(2) The separation (*d*) between rulings is called grating spacing. (If *N*-rulings occupy a total width ω, then $d = \frac{\omega}{N}$)

(3) For light ray emerging from each slit at an angle θ, there is a path difference $d\sin\theta$, between each ray the one directly above. The *d* is called the grating element

$d = a + e$

where *a* = width of the slit

e = opaque part

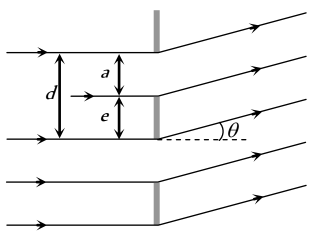


Fig. 30.26

(4) The condition for formation of bright fringe is $d \sin\theta = n\lambda$, where n = 0, 1, 2, ... is called the order of diffraction.

Fresnel's Half Period Zone (HPZ)

According to Fresnel's the entire wave front can be divided into a large number of parts of zones which are known as Fresnel's half period zones (HPZ's).

The resultant effect at any point on screen is due to the combined effect of all the secondary waves from the various zones.

Suppose ABCD is a plane wave front. We desire to find it's effect at point P consider a sphere of radius $\left(d+\frac{\lambda}{2}\right)$ with centre at P, then this sphere will cut the wave front in a circle (circle 1). This circular zone is called Fresnel's first (I) HPZ.

A sphere of radius $b+2\left(\frac{\lambda}{2}\right)$ with centre at P will cut the wave front in circle 2, the annular region between circle 2 and circle 1 is called second (II) HPZ.

The peripheral area enclosed between the n circle and $(n-1)^{th}$ circle is defined as n HPZ.

(1) **Radius of HPZ :** For n HPZ, it is given by

$$r_n = \sqrt{nd\lambda} \Rightarrow r_n \propto \sqrt{\lambda}$$

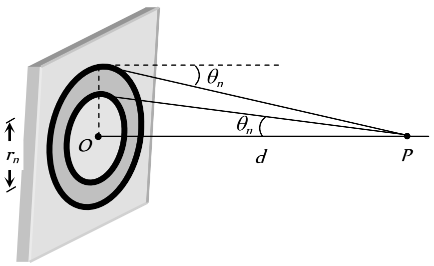


Fig. 30.28

(2) **Area of HPZ :** Area of n HPZ is given by

A_n = Area of n circle – Area of $(n-1)^{th}$ circle

$$= \pi(r_n^2 - r_{n-1}^2) = \pi d\lambda$$

(3) **Mean distance of the observation point P from n HPZ :** $d_n = \frac{r_n + r_{n-1}}{2} = b + \frac{(2n-1)\lambda}{4}$

(4) **Phase difference between the HPZ :** phase difference between the wavelets originating from two consecutive HPZ's and reaching the point P is π (or path difference is $\frac{\lambda}{2}$, time difference is $\frac{T}{2}$).

The phase difference between any two even or old number HPZ is 2π.

(5) **Amplitude of HPZ :** The amplitude of light at point P due to n HPZ is $R_n \propto \frac{A_n}{d_n}(1+\cos\theta_n)$; where A_n = Area of n HPZ, d_n = Mean distance of n HPZ

$(1+\cos\theta_n)$ = Obliquity factor.

On increasing the value of n, the value of R_n gradually goes on decreasing i.e. $R_1 > R_2 > R_3 > R_4 > ....\ .. > R_{n-1} > R_n$

(6) **Resultant Amplitude :** The wavelets from two consecutive HPZ's meets in opposite phase at P.

Hence Resultant amplitude at P

$$R = R_1 - R_2 + R_3 - R_4 + ...(-1)^{n-1} R_n$$

When $n = \infty$, then $R_{n-1} = R_n = 0$, therefore $R = \frac{R_1}{2}$

i.e. For large number of HPZ, the amplitude of light at point P due to whole wave front is half the amplitude due to first HPZ.

The ratio of amplitudes due to consecutive HPZ's is constant and is less than 1

$$\frac{R_n}{R_{n-1}} .... \frac{R_5}{R_4} = \frac{R_4}{R_3} = \frac{R_3}{R_2} = \frac{R_2}{R_1} = k \quad \text{(where } k < 1\text{)}$$

(7) **Resultant Intensity :** Intensity $\propto$ (amplitude)^2

For $n = \infty$, $I \propto \frac{R_1^2}{4} \propto \frac{I_1}{4}$

i.e. the resultant intensity due to whole wave front is $\frac{1}{4}th$ the intensity due to first HPZ.

Diffraction Due to a Circular Disc

When a disc is placed in the path of a light beam, then diffraction pattern is formed on the screen.

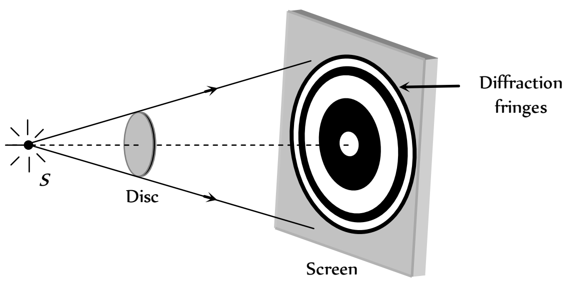


Fig. 30.29

(1) At the centre of the circular shadow of disc, there occurs a bright spot. This spot is called Fresnel's spot or Poisson's spot.

(2) The intensity of bright spot decreases, when the size of the disc is increased or when the screen is moved towards the disc.

(3) Circular alternate bright and dark fringes are formed around the bright spot with fringe width in decreasing order.

(4) Let r be the radius of the disc, d is the distance between screen and the disc and λ is the wavelength of light used.

If n HPZ are covered by disc then $nd\lambda = \pi r^2 \Rightarrow n = \frac{r^2}{d\lambda}$

(5) If the disc obstruct only first HPZ, the resultant amplitude at the central point $R = -R_2 + R_3 + ... \approx -\frac{R_2}{2}$.

So intensity is $\frac{kR_2^2}{4}$ which is slightly less than the intensity $\frac{k\,R_1^2}{4}$ due to whole wave front, when no obstacle is placed.

(6) The intensity at bright spot is given by $I = k\left[\frac{R_{n+1}}{2}\right]^2$

where n = Number of obstructed HPZ's

Diffraction Due to a Circular Aperture

When a circular aperture is placed in the path of a light beam, then following diffraction pattern is formed on the screen.

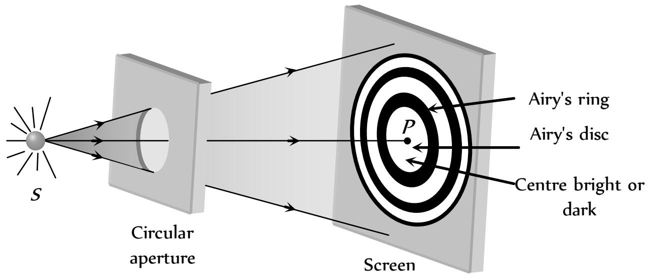
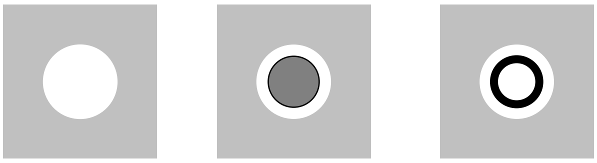


Fig. 30.30

(1) If only one HPZ is allowed by the aperture then the resultant amplitude at P would be R_1 which is twice the value of amplitude for the unobstructed wave front. The intensity would there fore be $4I$, where I represents the intensity at point P, due to unobstructed wave front.

(2) If the first two HPZ's are permitted by aperture than the resultant intensity at the centre point P will be very small (as $R_1 - R_2 \approx 0$). In this case the diffraction pattern consist of a bright circle of light with a dark spot.

(3) In general if number of HPZ's (n) passing through aperture is odd, then the central point will be bright and if n is even, central point will be dark.



(A) n=1, r^2=$b\lambda$ bright centre (B) n=2, r^2=2$b\lambda$ dark centre (C) n=3, r^2=3$b\lambda$ bright centre

Fig. 30.31

(4) The central bright disc is known as Airy's disc.

(5) In the non axial region bright and dark diffraction rings are obtained. The intensity of bright diffraction rings gradually goes on decreasing whereas that of dark diffraction goes on increasing.

(6) The first dark ring obtained around the central bright disc is known as Airy's ring.

Zone Plate

It is a diffracting device used to experimentally demonstrate the diffraction effect.

(1) It is formed on a glass plate by drawing a number of concentric circles on it whose radii are in the ratio of

$\sqrt{1} : \sqrt{2} : \sqrt{3}.........\ .i.e.\, r \propto \sqrt{n}$

For some specific distance from this plate the circles coincides with the HPZ's of the Fresnel's theory. (Alternate zones are made opaque).

(2) **Positive zone plate :** When odd zones are kept transparent to the light and even zones are made opaque, then it is called positive zone plate.

The resultant amplitude due to this zone plate in

$R = R_1 + R_3 + R_5 + ...\ >> \frac{R_1}{2}$

Thus, intensity of light tremendously increases.

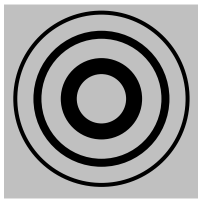


Fig. 30.32

(3) **Negative zone plate :** when even zones are kept transparent to light and odd zones are made opaque, then it is called negative zone plate.

The resultant amplitude due to this zone plate is

$R = R_2 + R_4 + R_6 + ...\ >> \frac{R_1}{2}$

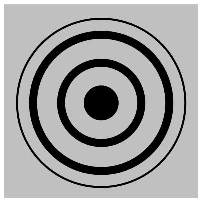


Fig. 30.33

(4) Zone plate behaves like a convex lens. For a plane wave front the image of source is formed at distance d *i.e.* d is equal to the principle focal length or first focal length $f_1 = d = \frac{r^2}{\lambda}$

(5) Multiple focii of zone plate are given by $f_p = \frac{r^2}{(2p-1)\lambda}$ where p = 1, 2, 3,......... represents the order of focii

(6) If the radius of n circle on zone plate is r_n then in terms of r_n.

Principal focal length $f_1 = \frac{r_n^2}{n\lambda}$

Other focal length $f_p = \frac{r_n^2}{(2p-1)n\lambda}$

(7) If a is the distance of the source from the zone plate then the distance b of the point where maximum intensity is observes is given by $\frac{1}{a} + \frac{1}{b} = \frac{n\lambda}{r_n^2}$

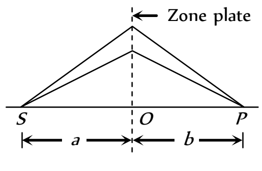


Fig. 30.34

Polarisation of Light

Light propagates as transverse EM waves. The magnitude of electric field is much larger as compared to magnitude of magnetic field. We generally prefer to describe light as electric field oscillations.

(1) **Unpolarised light :** In ordinary light (light from sun, bulb *etc.*) the electric field vectors are distributed in all directions in a light is called unpolarised light. The oscillation of propagation of light wave. This resolved into horizontal and vertical component.

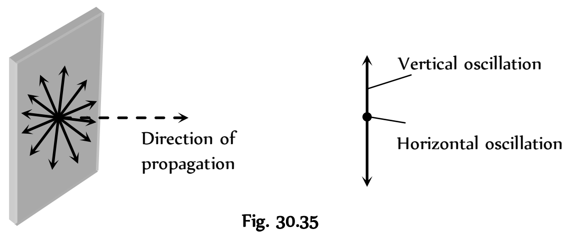


Fig. 30.35

(2) **Polarised light :** The phenomenon of limiting the vibrating of electric field vector in one direction in a plane perpendicular to the direction of propagation of light wave is called polarization of light.

(i) The plane in which oscillation occurs in the polarised light is called plane of oscillation.

(ii) The plane perpendicular to the plane of oscillation is called plane of polarisation.

(iii) Light can be polarised by transmitting through certain crystals such as tourmaline or polaroids.

(3) **Polaroids :** It is a device used to produce the plane polarised light. It is based on the principle of selective absorption and is more effective than the tourmaline crystal. or

It is a thin film of ultramicroscopic crystals of quinine idosulphate with their optic axis parallel to each other.

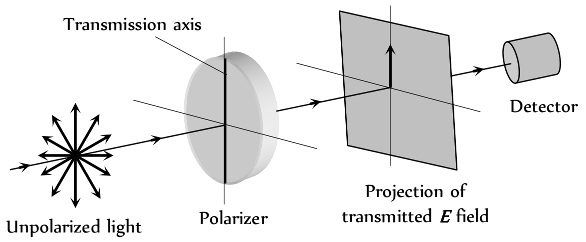
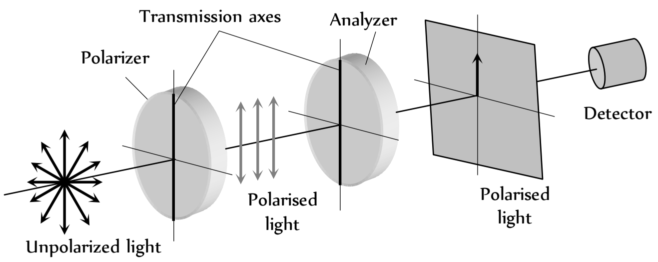


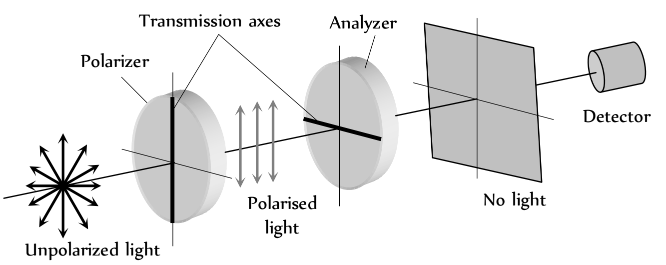
Fig. 30.36

(i) Polaroids allow the light oscillations parallel to the transmission axis pass through them.

(ii) The crystal or polaroid on which unpolarised light is incident is called polariser. Crystal or polaroid on which polarised light is incident is called analyser.



(A) Transmission axes of the polariser and analyser are parallel to each other, so whole of the polarised light passes through analyser



(B) Transmission axis of the analyser is perpendicular to the polariser, hence no light passes through the analyser

Fig. 30.37

(4) **Malus law :** This law states that the intensity of the polarised light transmitted through the analyser varies as the square of the cosine of the angle between the plane of transmission of the analyser and the plane of the polariser.

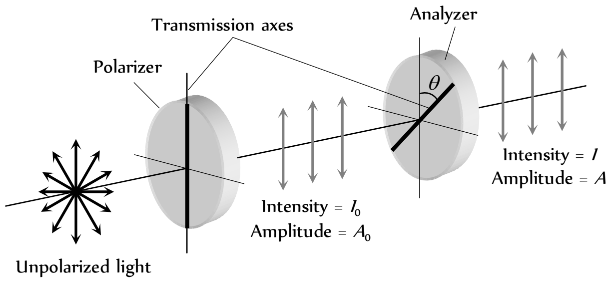


Fig. 30.38

(i) $I = I_0 \cos^2\theta$ and $A^2 = A_0^2\cos^2\theta \Rightarrow A = A_0\cos\theta$

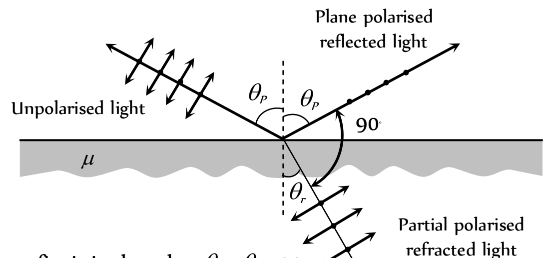
If $\theta = 0^o$, $I = I_0$, $A = A_0$, If $\theta = 90^o$, $I = 0$, $A = 0$

(ii) If $I_i =$ Intensity of unpolarised light.

So $I_0 = \dfrac{I_i}{2}$ *i.e.* if an unpolarised light is converted into plane polarised light (say by passing it through a Polaroid or a Nicol-prism), its intensity becomes half. and $I = \dfrac{I_i}{2}\cos^2\theta$

Methods of Producing Polarised Light

(1) **Polarisation by reflection :** Brewster discovered that when a beam of unpolarised light is reflected from a transparent medium (refractive index $=\mu$), the reflected light is completely plane polarised at a certain angle of incidence (called the angle of polarisation θ_p).



From fig. it is clear that $\theta_p + \theta_r = 90^\circ$

Also $\mu = \tan\theta_p$ Brewster's law

Fig. 30.39

(i) For $i < \theta_p$ or $i > \theta_p$

Both reflected and refracted rays becomes partially polarised

(ii) For glass $\theta_P \approx 57^o$, for water $\theta_P \approx 53^o$

(2) **By Dichroism :** Some crystals such as tourmaline and sheets of iodosulphate of quinine have the property of strongly absorbing the light with vibrations perpendicular to a specific direction (called transmission axis) transmitting the light with vibrations parallel to it. This selective absorption of light is called dichroism.

(3) **By double refraction :** In certain crystals, like calcite, quartz and tourmaline *etc*, incident unpolarized light splits up into two light beams of equal intensities with perpendicular polarization.

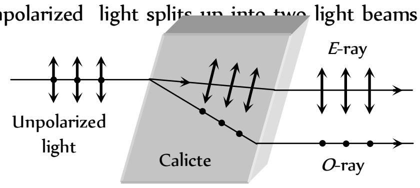


Fig. 30.40

(i) One of the ray is ordinary ray (*O*-ray) it obey's the Snell's law. Another ray's extra ordinary ray (*E*-ray) it doesn't obey's the Snell's law.

(ii) Along a particular direction (fixed in the crystal, the two velocities (velocity of *O*-ray v_o and velocity of *E*-ray v_e) are equal; this direction is known as the optic axis of the crystal (crystal's known as uniaxial crystal). Optic axis is a direction and not any line in crystal.

(iii) In the direction, perpendicular to the optic axis for negative crystal (calcite) $v_e > v_o$ and $\mu_e < \mu_o$.

For positive crystal $v_e < v_o$, $\mu_e > \mu_o$.

(4) **Nicol prism :** Nicol prism is made up of calcite crystal and in it *E*-ray is isolated from *O*-ray through total internal reflection of *O*-ray at canada balsam layer and then absorbing it at the blackened surface as shown in fig.

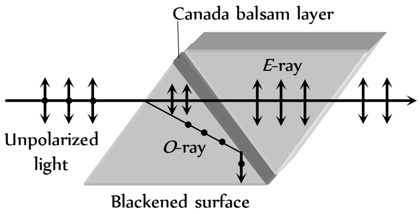


Fig. 30.41

The refractive index for the *O*-ray is more that for the *E*-ray. The refractive index of Canada balsam lies between the refractive indices of calcite for the *O*-ray and *E*-ray

(5) **By Scattering :** It is found that scattered light in directions perpendicular to the direction of incident light is completely plane polarised while transmitted light is unpolarised. Light in all other directions is partially polarised.

(6) **Optical activity and specific rotation :** When plane polarised light passes through certain substances, the plane of polarisation of the light is rotated about the direction of propagation of light through a certain angle. This phenomenon is called optical activity or optical rotation and the substances optically active.

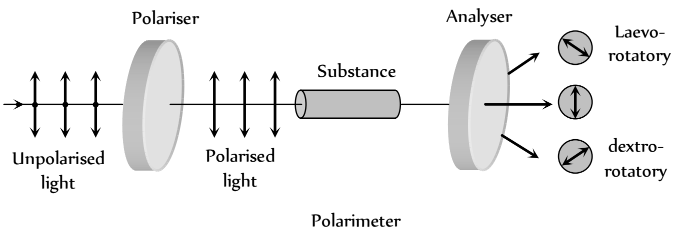


Fig. 30.42

If the optically active substance rotates the plane of polarisation clockwise (looking against the direction of light), it is said to be *dextro-rotatory* or *right-handed.* However, if the substance rotates the plane of polarisation anti-clockwise, it is called *laevo-rotatory* or *left-handed.*

The optical activity of a substance is related to the asymmetry of the molecule or crystal as a whole, *e.g.*, a solution of cane-sugar is dextro-rotatory due to asymmetrical molecular structure while crystals of quartz are dextro or laevo-rotatory due to structural asymmetry which vanishes when quartz is fused.

Optical activity of a substance is measured with help of polarimeter in terms of 'specific rotation' which is defined as the rotation produced by a solution of length 10 *cm* (1 *dm*) and of unit concentration (*i.e.* 1 *g*/cc) for a given wavelength of light at a given temperature. *i.e.* $[\alpha]_{t^o C}^{\lambda} = \dfrac{\theta}{L \times C}$

where θ is the rotation in length L at concentration C.

(7) **Applications and uses of polarisation**

(i) By determining the polarising angle and using Brewster's law, *i.e.* $\mu = \tan\theta$, refractive index of dark transparent substance can be determined.

(ii) It is used to reduce glare.

(iii) In calculators and watches, numbers and letters are formed by liquid crystals through polarisation of light called liquid crystal display (LCD).

(iv) In CD player polarised laser beam acts as needle for producing sound from compact disc which is an encoded digital format.

(v) It has also been used in recording and reproducing three-dimensional pictures.

(vi) Polarisation of scattered sunlight is used for navigation in solar-compass in polar regions.

(vii) Polarised light is used in optical stress analysis known as 'photoelasticity'.

(viii) Polarisation is also used to study asymmetries in molecules and crystals through the phenomenon of 'optical activity'.

(ix) A polarised light is used to study surface of nucleic acids (DNA, RNA)

Electromagnetic Waves

A changing electric field produces a changing magnetic field and vice versa which gives rise to a transverse wave known as electromagnetic wave. The time varying electric and magnetic field are mutually perpendicular to each other and also perpendicular to the direction of propagation of this wave.

The electric vector is responsible for the optical effects of an EM wave and is called the *light vector*.

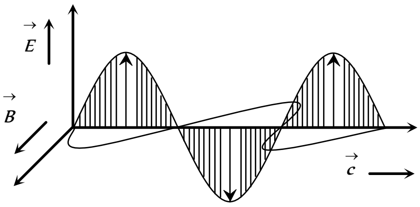


Fig. 30.43

(1) $\vec{E}$ and $\vec{B}$ always oscillates in phase.

(2) $\vec{E}$ and $\vec{B}$ are such that $\vec{E} \times \vec{B}$ is always in the direction of propagation of wave.

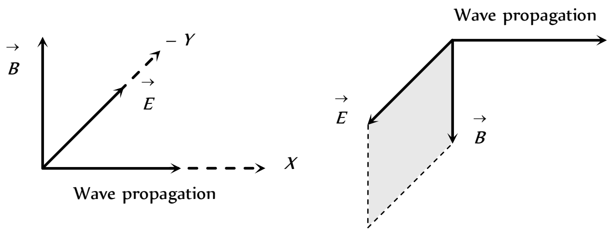


Fig. 30.44

(3) The EM wave propagating in the positive *x*-direction may be represented by

$$E = E_y = E_0 \sin (kx - \omega t)$$

$$B = B_z = B_0 \sin (kx - \omega t)$$

where E (or E_y), B (or B_z) are the instantaneous values of the fields, E_0, B_0 are amplitude of the fields and K = angular wave number $= \dfrac{2\pi}{\lambda}$.

Maxwell's Contribution

(1) **Ampere's Circuital law :** According to this law the line integral of magnetic field along any closed path or circuit is μ_0 times the total current threading the closed circuit *i.e.,* $\oint \vec{B}.\vec{dl} = \mu_0 i$

(2) **Inconsistency of Ampere's law :** Maxwell explained that Ampere's law is valid only for steady current or when the electric field does not change with time. To see this inconsistency consider a parallel plate capacitor being charged by a battery. During the charging time varying current flows through connecting wires.

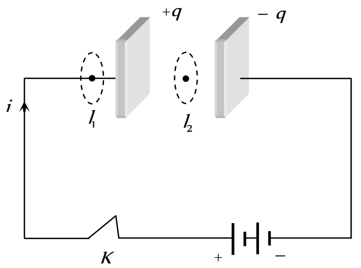


Fig. 30.45

Applying Ampere's law for loop l_1 and l_2 $\oint_{l_1} \vec{B}.\vec{dl} = \mu_0 i$

But $\oint_{l_2} \vec{B}.\vec{dl} = 0$ (Since no current flows through the region between the plates). But practically it is observed that there is a magnetic field between the plates. Hence Ampere's law fails

i.e. $\oint_{l_1} \vec{B}.\vec{dl} \neq \mu_0 i$.

(3) **Modified Ampere's Circuital law or Ampere- Maxwell's Circuital law :** Maxwell assumed that some sort of current must be flowing between the capacitor plates during charging process. He named it displacement current. Hence modified law is as follows

$$\oint \vec{B}.\vec{dl} = \mu_0(i_c + i_d) \text{ or } \oint \vec{B}.\vec{dl} = \mu_0(i_c + \varepsilon_0 \frac{d\phi_E}{dt})$$

where i_c = conduction current = current due to flow of charges in a conductor and

i_d = Displacement current = $\varepsilon_0 \frac{d\phi_E}{dt}$ = current due to the changing electric field between the plates of the capacitor

(4) **Maxwell's equations**

(i) $\oint_s \vec{E}.\vec{ds} = \frac{q}{\varepsilon_0}$ (Gauss's law in electrostatics)

(ii) $\oint_s \vec{B}.\vec{ds} = 0$ (Gauss's law in magnetism)

(iii) $\oint \vec{B}.\vec{dl} = -\frac{d\phi_B}{dt}$ (Faraday's law of EMI)

(iv) $\oint \vec{B}\ \vec{dl} = \mu_o(i_c + \varepsilon_o \frac{d\phi_E}{dt}$ (Maxwell- Ampere's Circuital law)

History of EM Waves

(1) **Maxwell :** Was the first to predict the EM wave.

(2) **Hertz :** Produced and detected electromagnetic waves experimentally at wavelengths of 6 *m*.

(3) **J.C. Bose :** Produced EM waves of wavelength ranging from 5*mm* to 25 *mm*.

(4) **Marconi :** Successfully transmitted the EM waves up to a few *kilometer*. Marconi discovered that if one of the spark gap terminals is connected to an antenna and the other terminal is Earthed, the electromagnetic waves radiated could go upto several kilometers.

Experimental Setup for Producing EM Waves

Hertz experiment based on the fact that a oscillating charge is accelerating continuously, it will radiate electromagnetic waves continuously. In the following figure

(1) The metallic plates (P_1 and P_2) acts as a capacitor.

(2) The wires connecting spheres S_1 and S_2 to the plates provide a low inductance.

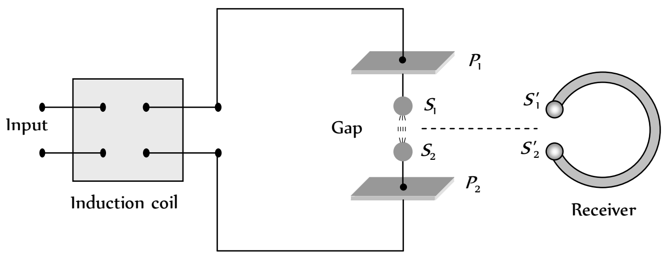


Fig. 30.46

(3) When a high voltage is applied across metallic plates these plates get discharged by sparking across the narrow gap. The spark will give rise to oscillations which in turn send out electromagnetic waves. Frequency of these wave is given by $\nu = \frac{1}{2\pi\sqrt{LC}}$

The succession of sparks send out a train of such waves which are received by the receiver.

Source, Production and Nature of EM Waves

(1) A charge oscillating harmonically is a source of EM waves of same frequency.

(2) A simple *LC* oscillator and energy source can produce waves of desired frequency $\left(\nu = \frac{1}{2\pi\sqrt{LC}}\right)$.

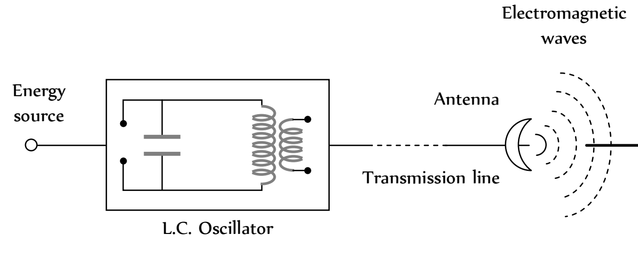


Fig. 30.47

(3) The EM Waves are transverse in nature. They do not require any material medium for their propagation.

Properties of EM Waves

(1) **Speed :** In free space it's speed

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = \frac{E_0}{B_0} = 3 \times 10^8 m/s.$$

In medium $v = \frac{1}{\sqrt{\mu\varepsilon}}$; where μ_0 = Absolute permeability, ε = Absolute permittivity.

(2) **Energy :** The energy in an EM waves is divided equally between the electric and magnetic fields.

Energy density of electric field $u_e = \frac{1}{2}\varepsilon_0 E^2$, Energy density of magnetic field $u_B = \frac{1}{2}\frac{B^2}{\mu_0}$

The total energy per unit volume is $u = u_e + u_m = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$.

Also $u_{av} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{B_0^2}{2\mu_0}$

(3) **Intensity (*I*) :** The energy crossing per unit area per unit time, perpendicular to the direction of propagation of EM wave is called intensity.

i.e. $I = \frac{\text{Total EM energy}}{\text{Surface area} \times \text{Time}} = \frac{\text{Total energy density} \times \text{Volume}}{\text{Surface area} \times \text{Time}}$

$\Rightarrow I = u_{av} \times c = \frac{1}{2}\varepsilon_0 E_0^2 c = \frac{1}{2}\frac{B_0^2}{\mu_0}.c\,\frac{Watt}{m^2}$.

(4) **Momentum :** EM waves also carries momentum, if a portion of EM wave of energy *u* propagating with speed *c*, then linear momentum $= \frac{\text{Energy}(u)}{\text{Speed }(c)}$

If wave incident on a completely absorbing surface then momentum delivered $p = \frac{u}{c}$. If wave incident on a totally reflecting surface then momentum delivered $-p = \frac{2u}{c}$.

(5) **Poynting vector** $(\vec{S})$. **:** In EM waves, the rate of flow of energy crossing a unit area is described by the Poynting vector.

(i) It's unit is $Watt/m^2$ and $\vec{S} = \frac{1}{\mu_o}(\vec{E} \times \vec{B}) = c^2\varepsilon_0(\vec{E} \times \vec{B})$.

(ii) Because in EM waves $\vec{E}$ and $\vec{B}$ are perpendicular to each other, the magnitude of $\vec{S}$ is $|\vec{S}| = \frac{1}{\mu_0}E\,B\sin 90^o = \frac{EB}{\mu_0} = \frac{E^2}{\mu C}$.

(iii) The direction of $\vec{S}$ does not oscillate but it's magnitude varies between zero and a maximum $\left(S_{\max} = \frac{E_0 B_0}{\mu_0}\right)$ each quarter of a period.

(iv) Average value of poynting vector is given by

$$\overline{S} = \frac{1}{2\mu_0}E_0 B_0 = \frac{1}{2}\varepsilon_0 E_0^2 c = \frac{cB_0^2}{2\mu_0}$$

The direction of the poynting vector $\vec{S}$ at any point gives the wave's direction of travel and direction of energy transport the point.

(6) **Radiation pressure :** Is the momentum imparted per second pre unit area. On which the light falls.

For a perfectly reflecting surface $P_r = \frac{2S}{c}$; *S* = Poynting vector; *c* = Speed of light

For a perfectly absorbing surface $P_a = \frac{S}{c}$.

(7) **Wave impedance (*Z*) :** The medium offers hindrance to the propagation of wave. Such hindrance is called wave impedance and it is given by $Z = \sqrt{\frac{\mu}{\varepsilon}} = \sqrt{\frac{\mu_r}{\varepsilon_r}}\sqrt{\frac{\mu_0}{\varepsilon_0}}$

For vacuum or free space $Z = \sqrt{\frac{\mu_0}{\varepsilon_0}} = 376.6\,\Omega$.

EM Spectrum

The whole orderly range of frequencies/wavelengths of the EM waves is known as the EM spectrum.

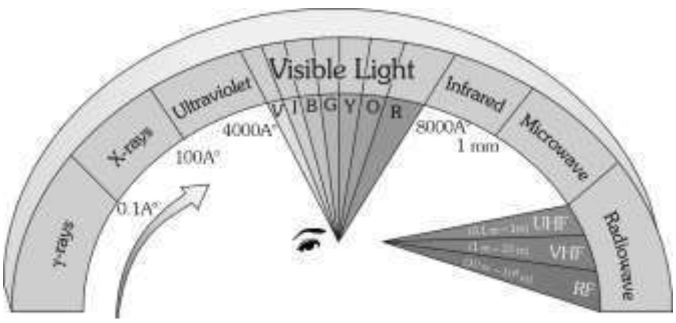


Fig. 30.48

Table 30.2 : Uses of EM spectrum

Radiation	Uses
γ-rays	Gives informations on nuclear structure, medical treatment *etc.*
X-rays	Medical diagnosis and treatment study of crystal structure, industrial radiograph.
UV- rays	Preserve food, sterilizing the surgical instruments, detecting the invisible writings, finger prints etc.
Visible light	To see objects
Infrared rays	To treat, muscular strain for taking photography during the fog, haze etc.
Micro wave and radio wave	In radar and telecommunication.

Earth's Atmosphere

The gaseous envelope surrounding the earth is called it's atmosphere. The atmosphere contains 78% N_2, 21% O_2, and traces of other gases (like helium, krypton, CO_2 etc.)

(1) **Division of earth's atmosphere :** Earth atmosphere has been divided into regions as shown.

(i) Troposphere : In this region, the temperature decreases with height from 290 *K* to 220 *K*.

(ii) Stratosphere : The temperature of stratosphere varies from 220 *K* to 200 *K*.

(iii) Mesosphere : In this region, the temperature falls to 180 *K*.

(iv) Ionosphere : Ionosphere is partly composed of charged particles, ions and electrons, while the rest of the atmosphere contains neutral molecules.

(v) Ozone layer absorbs most of the ultraviolet rays emitted by the sun.

(vi) Kennelly heaviside layer lies at about 110km from the earth's surface. In this layer concentration of electron is very high.

(vii) The ionosphere plays a vital role in the radio communication.

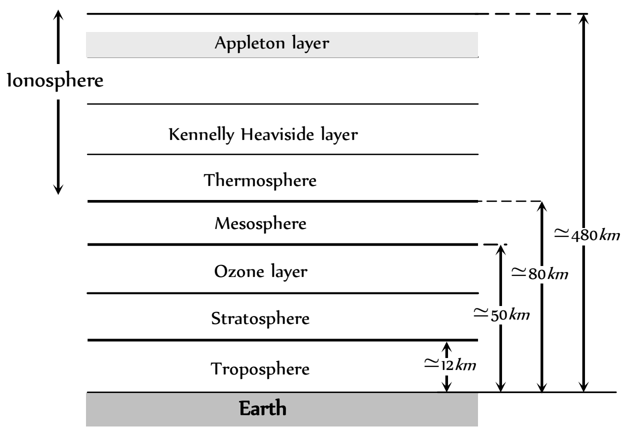


Fig. 30.49

(2) **Green house effect :** The warming of earth's atmosphere due to the infrared radiations reflected by low lying clouds and carbon dioxide in the atmosphere of earth is called green house effect.

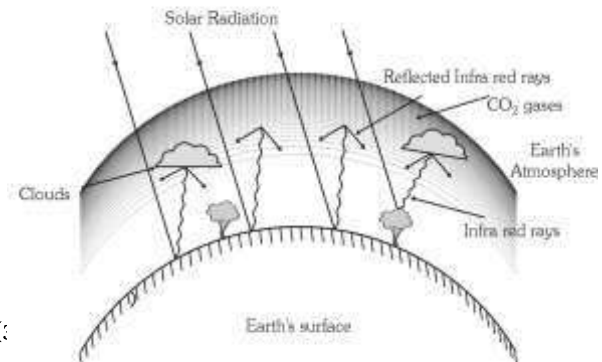


Fig. 30.50

(3

(i) **Radio waves classification**

(a) Very low frequency (VLF) $\rightarrow$ 10 KHz to 30 KHz

(b) Low frequency (LF) $\rightarrow$ 30 KHz to 300 KHz

(c) Medium frequency (MF) or medium wave (MW) $\rightarrow$ 300 KHz to 3000 KHz

(d) High frequency (HF) or short wave (SW) $\rightarrow$ 3 MHz to 30 MHz

(e) Very high frequency (VHF) $\rightarrow$ 30 MHz to 300 MHz

(f) Ultra high frequency (UHF) $\rightarrow$ 300 MHz to 3000 MHz

(g) Super high frequency or micro waves $\rightarrow$ 3000 MHz to 300, 000 MHz

(ii) **Amplitude modulated transmission :** Radio waves having frequency less than or equal to 30 MHz form an amplitude modulation band (or AM band). The signals can be transmitted from one place to another place on earth's surface in two ways

(a) Ground wave propagation : The radio waves following the surface of the earth are called ground waves.

(b) Sky wave propagation : The amplitude modulated radio waves which are reflected back by the ionosphere are called sky waves.

(iii) **Frequency modulated (FM) transmission :** Radio waves having frequencies between 80 MHz and 200 MHz form a frequency modulated bond. T.V. signals are normally frequency modulated.

(4) **T.V. Signals**

(i) T.V. signals are normally frequency modulated. So T.V. signals can be transmitted by using tall antennas.

(ii) Distance covered by the T.V. signals $d = \sqrt{2hR}$

(h = Height of the antenna, R = Radius of earth)

(iii) Area covered $A = \pi d^2 = 2\pi hR$

(iv) Population covered = Area × Population density.

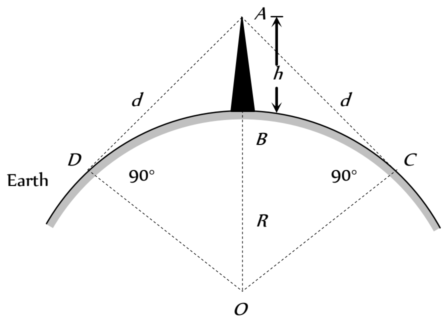


Fig. 30.51

Tips & Tricks

✍ In interference redistribution of energy takes place in the form of maxima and minima.

✍ Average intensity : $I_{av} = \frac{I_{max} + I_{min}}{2} = I_1 + I_2 = a_1^2 + a_2^2$

✍ Ratio of maximum and minimum intensities :

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\frac{\sqrt{I_1 / I_2} + 1}{\sqrt{I_1 / I_2} - 1}\right)^2$$

$$= \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\frac{a_1 / a_2 + 1}{a_1 / a_2 - 1}\right)^2 \text{ also } \sqrt{\frac{I_1}{I_2}} = \frac{a_1}{a_2} = \left(\frac{\sqrt{\frac{I_{max}}{I_{min}}} + 1}{\sqrt{\frac{I_{max}}{I_{min}}} - 1}\right)$$

✍ If two waves having equal intensity $(I_1 = I_2 = I)$ meets at two locations P and Q with path difference Δ_1 and Δ_2 respectively then the ratio of resultant intensity at point P and Q will be

$$\frac{I_P}{I_Q} = \frac{\cos^2 \frac{\phi_1}{2}}{\cos^2 \frac{\phi_2}{2}} = \frac{\cos^2\left(\frac{\pi\Delta_1}{\lambda}\right)}{\cos^2\left(\frac{\pi\Delta_2}{\lambda}\right)}$$

✍ The angular thickness of fringe width is defined as $\delta = \frac{\beta}{D} = \frac{\lambda}{d}$, which is independent of the screen distance *D*.

✍ Central maxima means the maxima formed with zero optical path difference. It may be formed anywhere on the screen.

✍ All the wavelengths produce their central maxima at the same position.

✍ The wave with smaller wavelength from its maxima before the wave with longer wavelength.

✍ The first maxima of violet colour is closest and that for the red colour is farthest.

✍ Fringes with blue light are thicker than those for red light.

✍ In an interference pattern, whatever energy disappears at the minimum, appears at the maximum.

✍ In YDSE, the nth maxima always comes before the nth minima.

✍ In YDSE, the ratio $\frac{I_{\max}}{I_{\min}}$ is maximum when both the sources have same intensity.

✍ For two interfering waves if initial phase difference between them is ϕ and phase difference due to path difference between them is ϕ. Then total phase difference will be

$$\phi = \phi_0 + \phi' = \phi_0 + \frac{2\pi}{\lambda}\Delta .$$

✍ Sometimes maximm number of maximas or minimas are asked in the question which can be obtained on the screen. For this we use the fact that value of sin θ (or cos θ) can't be greater than 1. For example in the first case when the slits are vertical

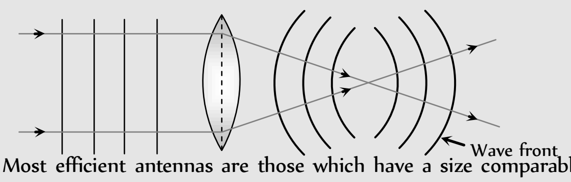
$$\sin\theta = \frac{n\lambda}{d} \qquad \text{(for maximum intensity)}$$

$$\because \quad \sin\theta \ngtr 1 \quad \therefore \quad \frac{n\lambda}{d} \ngtr 1 \qquad \text{or} \qquad n \ngtr \frac{d}{\lambda}$$

Suppose in some question d/λ comes out say 4.6, then total number of maximuas on the screen will be 9. Corresponding to $n = 0, \pm 1, \pm 2, \pm 3$ and ± 4.

✍ ***Shape of wave front***

If rays are parallel, wave front is plane. If rays are converging wave front is spherical of decreasing radius. If rays are diverging wave front is spherical of increasing radius.



✍ Most efficient antennas are those which have a size comparable to the wavelength of the of electromagnetic wave they emit or receive.

✍ A substance (like calcite quartz) which exhibits different properties in different direction is called an anisotopic substance.

Ordinary Thinking

Objective Questions

Wave Nature and Interference of Light

1. By corpuscular theory of light, the phenomenon which can be explained is
(a) Refraction (b) Interference
(c) Diffraction (d) Polarisation

2. According to corpuscular theory of light, the different colours of light are due to
(a) Different electromagnetic waves
(b) Different force of attraction among the corpuscles
(c) Different size of the corpuscles
(d) None of the above

3. Huygen's conception of secondary waves [CPMT 1975]
(a) Allow us to find the focal length of a thick lens
(b) Is a geometrical method to find a wavefront
(c) Is used to determine the velocity of light
(d) Is used to explain polarisation

4. The idea of the quantum nature of light has emerged in an attempt to explain [CPMT 1990]
(a) Interference
(b) Diffraction
(c) Radiation spectrum of a black body
(d) Polarisation

5. Two coherent sources of light can be obtained by [MH CET 2001]
(a) Two different lamps
(b) Two different lamps but of the same power
(c) Two different lamps of same power and having the same colour
(d) None of the above

6. By Huygen's wave theory of light, we cannot explain the phenomenon of [CPMT 1989; AFMC 1993, 99; MP PET 1995, 2003; RPMT 2003; BCECE 2003; Pb PMT 2004]
(a) Interference (b) Diffraction
(c) Photoelectric effect (d) Polarisation

7. The phenomenon of interference is shown by [MNR 1994; MP PMT 1997; AIIMS 1999, 2000; JIPMER 2000; UPSEAT 1994, 2000]
(a) Longitudinal mechanical waves only
(b) Transverse mechanical waves only
(c) Electromagnetic waves only
(d) All the above types of waves

8. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are [IIT-JEE 1988; RPMT 1995; AIIMS 1997; MP PMT 1997; MP PET 1999; BHU 2002; KCET 2000, 05]
(a) $5I$ and I (b) $5I$ and $3I$
(c) $9I$ and I (d) $9I$ and $3I$

9. Light appears to travel in straight lines since [RPMT 1997; CPMT 1987, 89, 90, 2001; AIIMS 1998, 2002; KCET 2002; BHU 2002; DCE 2003]
(a) It is not absorbed by the atmosphere
(b) It is reflected by the atmosphere
(c) Its wavelength is very small
(d) Its velocity is very large

10. The idea of secondary wavelets for the propagation of a wave was first given by [Orissa PMT 2004]
(a) Newton (b) Huygen
(c) Maxwell (d) Fresnel

11. By a monochromatic wave, we mean [AFMC 1995]
(a) A single ray
(b) A single ray of a single colour
(c) Wave having a single wavelength
(d) Many rays of a single colour

12. The similarity between the sound waves and light waves is [KCET 1994]
(a) Both are electromagnetic waves
(b) Both are longitudinal waves
(c) Both have the same speed in a medium
(d) They can produce interference

13. The ratio of intensities of two waves is 9 : 1. They are producing interference. The ratio of maximum and minimum intensities will be MP PET 1999; AMU (Engg.) 1999; AIIMS 2000]
(a) 10 : 8 (b) 9 : 1
(c) 4 : 1 (d) 2 : 1

14. A wave can transmit ...... from one place to another [CPMT 1984]
(a) Energy (b) Amplitude
(c) Wavelength (d) Matter

15. If the ratio of intensities of two waves is 1 : 25, then the ratio of their amplitudes will be [CPMT 1984]
(a) 1 : 25 (b) 5 : 1
(c) 26 : 24 (d) 1 : 5

16. Two identical light sources S_1 and S_2 emit light of same wavelength λ. These light rays will exhibit interference if [MP PMT 1993]
(a) Their phase differences remain constant
(b) Their phases are distributed randomly
(c) Their light intensities remain constant
(d) Their light intensities change randomly

17. Wave nature of light follows because [MP PMT 1993]
(a) Light rays travel in a straight line
(b) Light exhibits the phenomena of reflection and refraction
(c) Light exhibits the phenomenon of interference

(d) Light causes the phenomenon of photoelectric effect

18. If L is the coherence length and c the velocity of light, the coherent time is [MP PMT 1996]

(a) cL (b) $\frac{L}{c}$

(c) $\frac{c}{L}$ (d) $\frac{1}{Lc}$

19. If the amplitude ratio of two sources producing interference is 3 : 5, the ratio of intensities at maxima and minima is

[MP PMT 1996]

(a) 25 : 16 (b) 5 : 3

(c) 16 : 1 (d) 25 : 9

20. Colours of thin films result from

[CPMT 1972, 83, 96; RPMT 1997; DCE 2002; AIIMS 2005]

or

On a rainy day, a small oil film on water show brilliant colours. This is due to [MP PET 2004]

(a) Dispersion of light (b) Interference of light

(c) Absorption of light (d) Scattering of light

21. For constructive interference to take place between two monochromatic light waves of wavelength λ, the path difference should be [MNR 1992; UPSEAT 2001]

(a) $(2n-1)\frac{\lambda}{4}$ (b) $(2n-1)\frac{\lambda}{2}$

(c) $n\lambda$ (d) $(2n+1)\frac{\lambda}{2}$

22. Two sources of waves are called coherent if

[NCERT 1984; MNR 1995; RPMT 1996, 97; CPMT 1997; UPSEAT 1995, 2000; Orissa JEE 2002; RPET 2003; MP PMT 1996, 2004]

(a) Both have the same amplitude of vibrations

(b) Both produce waves of the same wavelength

(c) Both produce waves of the same wavelength having constant phase difference

(d) Both produce waves having the same velocity

23. Soap bubble appears coloured due to the phenomenon of

[AFMC 1995, 97; RPET 1997; CBSE PMT 1999; Pb PET 2001]

(a) Interference (b) Diffraction

(c) Dispersion (d) Reflection

24. Which of the following statements indicates that light waves are transverse [MP PMT 1995; AFMC 1996]

(a) Light waves can travel in vacuum

(b) Light waves show interference

(c) Light waves can be polarized

(d) Light waves can be diffracted

25. If two light waves having same frequency have intensity ratio 4 : 1 and they interfere, the ratio of maximum to minimum intensity in the pattern will be

[BHU 1995; MP PMT 1995; DPMT 1999; CPMT 2003]

(a) 9 : 1 (b) 3 : 1

(c) 25 : 9 (d) 16 : 25

26. Evidence for the wave nature of light cannot be obtained from

(a) Reflection (b) Doppler effect

(c) Interference (d) Diffraction

27. Two light sources are said to be coherent if they are obtained from

(a) Two independent point sources emitting light of the same wavelength

(b) A single point source

(c) A wide source

(d) Two ordinary bulbs emitting light of different wavelengths

28. Wavelength of light of frequency $100 Hz$ [CBSE PMT 1999]

(a) $2\times10^{6} m$ (b) $3\times10^{6} m$

(c) $4\times10^{6} m$ (d) $5\times10^{6} m$

29. Two waves having intensity in the ratio 25 : 4 produce interference. The ratio of the maximum to the minimum intensity is

(a) 5 : 2 (b) 7 : 3

(c) 49 : 9 (d) 9 : 49

30. Wavefront means [RPMT 1997, 98]

(a) All particles in it have same phase

(b) All particles have opposite phase of vibrations

(c) Few particles are in same phase, rest are in opposite phase

(d) None of these

31. Wavefront of a wave has direction with wave motion

[RPMT 1997]

(a) Parallel (b) Perpendicular

(c) Opposite (d) At an angle of θ

32. Which one of the following phenomena is not explained by Huygen's construction of wavefront [CBSE PMT 1992]

(a) Refraction (b) Reflection

(c) Diffraction (d) Origin of spectra

33. Interference was observed in interference chamber when air was present, now the chamber is evacuated and if the same light is used, a careful observer will see

[CBSE PMT 1993; DPMT 2000; BHU 2002]

(a) No interference

(b) Interference with bright bands

(c) Interference with dark bands

(d) Interference in which width of the fringe will be slightly increased

34. The ratio of intensities of two waves are given by 4 : 1. The ratio of the amplitudes of the two waves is

[CBSE PMT 1993]

(a) 2 : 1 (b) 1 : 2

(c) 4 : 1 (d) 1 : 4

35. For the sustained interference of light, the necessary condition is that the two sources should

[DPMT 1996; RPMT 1998, 2003]

(a) Have constant phase difference

(b) Be narrow

(c) Be close to each other

(d) Of same amplitude

36. If the ratio of amplitude of two waves is 4 : 3, then the ratio of maximum and minimum intensity is [AFMC 1997]

(a) 16 : 18 (b) 18 : 16

(c) 49 : 1 (d) 94 : 1

37. Which of the following is conserved when light waves interfere

(a) Intensity (b) Energy

(c) Amplitude (d) Momentum

38. Intensity of light depends upon [RPMT 1999]

(a) Velocity (b) Wavelength

(c) Amplitude (d) Frequency

39. Ray diverging from a point source from a wave front that is

[RPET 2000]

(a) Cylindrical (b) Spherical

(c) Plane (d) Cubical

40. Ratio of amplitude of interfering waves is 3 : 4. Now ratio of their intensities will be [RPET 2000]

(a) $\frac{16}{9}$ (b) 49 : 1

(c) $\frac{9}{16}$ (d) None of these

41. Two coherent sources have intensity in the ratio of $\frac{100}{1}$. Ratio of (intensity) max/(intensity) min is [RPET 2000]

(a) $\frac{1}{100}$ (b) $\frac{1}{10}$

(c) $\frac{10}{1}$ (d) $\frac{3}{2}$

42. If two waves represented by $y_1 = 4\sin\omega t$ and $y_2 = 3\sin\left(\omega t + \frac{\pi}{3}\right)$ interfere at a point, the amplitude of the resulting wave will be about [MP PMT 2000]

(a) 7 (b) 6

(c) 5 (d) 3.5

43. The two waves represented by $y_1 = a\sin(\omega t)$ and $y_2 = b\cos(\omega t)$ have a phase difference of [MP PMT 2000]

(a) 0 (b) $\frac{\pi}{2}$

(c) π (d) $\frac{\pi}{4}$

44. In a wave, the path difference corresponding to a phase difference of ϕ is [MP PET 2000]

(a) $\frac{\pi}{2\lambda}\phi$ (b) $\frac{\pi}{\lambda}\phi$

(c) $\frac{\lambda}{2\pi}\phi$ (d) $\frac{\lambda}{\pi}\phi$

45. Two coherent sources of intensities, I_1 and I_2 produce an interference pattern. The maximum intensity in the interference pattern will be[UPSEAT 2001; MP PET 2001]

(a) $I_1 + I_2$ (b) $I_1^2 + I_2^2$

(c) $(I_1 + I_2)^2$ (d) $(\sqrt{I_1} + \sqrt{I_2})^2$

46. Newton postulated his corpuscular theory on the basis of

[UPSEAT 2001; KCET 2001]

(a) Newton's rings

(b) Colours of thin films

(c) Rectilinear propagation of light

[MNR 1998]

(d) Dispersion of white light

47. The dual nature of light is exhibited by

[KCET 1999; AIIMS 2001; BHU 2001; MH CET 2003; BCECE 2004]

(a) Photoelectric effect

(b) Refraction and interference

(c) Diffraction and reflection

(d) Diffraction and photoelectric effect

48. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\frac{\pi}{2}$ at point A and π at point B. Then the difference between the resultant intensities at A and B is

[IIT JEE (Screening) 2001]

(a) $2I$ (b) $4I$

(c) $5I$ (d) $7I$

49. Coherent sources are those sources for which [RPET 2001]

(a) Phase difference remain constant

(b) Frequency remains constant

(c) Both phase difference and frequency remains constant

(d) None of these

50. Wave nature of light is verified by [RPET 2001]

(a) Interference (b) Photoelectric effect

(c) Reflection (d) Refraction

51. Two waves are represented by the equations $y_1 = a\sin\omega t$ and $y_2 = a\cos\omega t$. The first wave [MP PMT 2001]

(a) Leads the second by π

(b) Lags the second by π

(c) Leads the second by $\frac{\pi}{2}$

(d) Lags the second by $\frac{\pi}{2}$

52. Light waves producing interference have their amplitudes in the ratio 3 : 2. The intensity ratio of maximum and minimum of interference fringes is [EAMCET 2001]

(a) 36 : 1 (b) 9 : 4

(c) 25 : 1 (d) 6 : 4

53. Laser beams are used to measure long distance because

[DCE 2001]

(a) They are monochromatic

(b) They are highly polarised

(c) They are coherent

(d) They have high degree of parallelism

54. Two coherent sources of different intensities send waves which interfere. The ratio of maximum intensity to the minimum intensity is 25. The intensities of the sources are in the ratio

(a) 25 : 1 (b) 5 : 1

(c) 9 : 4 (d) 25 : 16

55. The frequency of light ray having the wavelength 3000 Å is [DPMT 2002]

(a) 9×10^{13} *cycles/sec* (b) 10^{15} *cycles/sec*

(c) 90 *cycles/sec* (d) 3000 *cycles/sec*

56. Two waves have their amplitudes in the ratio 1 : 9. The maximum and minimum intensities when they interfere are in the ratio

(a) $\frac{25}{16}$ (b) $\frac{16}{26}$

(c) $\frac{1}{9}$ (d) $\frac{9}{1}$

57. Huygen's principle of secondary wavelets may be used to [KCET 2002]

(a) Find the velocity of light in vacuum

(b) Explain the particle behaviour of light

(c) Find the new position of the wavefront

(d) Explain photoelectric effect

58. What is the path difference of destructive interference [AIIMS 2002]

(a) $n\lambda$ (b) $n(\lambda + 1)$

(c) $\frac{(n+1)\lambda}{2}$ (d) $\frac{(2n+1)\lambda}{2}$

59. If an interference pattern have maximum and minimum intensities in 36 : 1 ratio then what will be the ratio of amplitudes

(a) 5 : 7 (b) 7 : 4

(c) 4 : 7 (d) 7 : 5

60. Intensities of the two waves of light are *I* and 4*I*. The maximum intensity of the resultant wave after superposition is

(a) 5 *I* (b) 9 *I*

(c) 16 *I* (d) 25 *I*

61. As a result of interference of two coherent sources of light, energy is [MP PMT 2002; KCET 2003]

(a) Increased

(b) Redistributed and the distribution does not vary with time

(c) Decreased

(c) Redistributed and the distribution changes with time

62. To demonstrate the phenomenon of interference, we require two sources which emit radiation [AIEEE 2003]

(a) Of the same frequency and having a define phase relationship

(b) Of nearly the same frequency

(c) Of the same frequency

(d) Of different wavelengths

63. When a beam of light is used to determine the position of an object, the maximum accuracy is achieved if the light is [AIIMS 2003]

(a) Polarised (b) Of longer wavelength

(c) Of shorter wavelength (d) Of high intensity

64. If the distance between a point source and screen is doubled, then intensity of light on the screen will become [UPSEAT 2002]

[RPET 1997; RPMT 1999]

(a) Four times (b) Double

(c) Half (d) One-fourth

65. Huygen wave theory allows us to know [AFMC 2004]

(a) The wavelength of the wave

(b) The velocity of the wave

(c) The amplitude of the wave

(d) The propagation of wave fronts [KCET 2002]

66. The wave theory of light was given by [J & K CET 2004; KCET 2005]

(a) Maxwell (b) Planck

(c) Huygen (d) Young

67. The phase difference between incident wave and reflected wave is 180° when light ray [RPMT 1998, 2001]

(a) Enters into glass from air

(b) Enters into air from glass

(c) Enters into glass from diamond

(d) Enters into water from glass

68. Which of the following phenomena can explain quantum nature of light [RPMT 2001]

(a) Photoelectric effect (b) Interference

(c) Diffraction (d) Polarisation

69. Which of the following is not a property of light [AFMC 2005]

(a) It requires a material medium for propagation [AFMC 2002]

(b) It can travel through vacuum

(c) It involves transportation of energy

(d) It has finite speed [MP PET 2002]

70. What causes changes in the colours of the soap or oil films for the given beam of light [AFMC 2005]

(a) Angle of incidence (b) Angle of reflection

(c) Thickness of film (d) None of these

71. Select the right option in the following [KCET 2005]

(a) Christian Huygens a contemporary of Newton established the wave theory of light by assuming that light waves were transverse

(b) Maxwell provided the compelling theoretical evidence that light is transverse wave

(c) Thomas Young experimentally proved the wave behaviour of light and Huygens assumption

(d) All the statements give above, correctly answers the question "what is light"

72. Two waves of intensity *I* undergo Interference. The maximum intensity obtained is [BHU 2005]

(a) *I* / 2 (b) *I*

(c) 2*I* (d) 4*I*

Young's Double Slit Experiment

1. Young's experiment establishes that [CPMT 1972; MP PET 1994, 98; MP PMT 1998]
   (a) Light consists of waves
   (b) Light consists of particles
   (c) Light consists of neither particles nor waves
   (d) Light consists of both particles and waves

2. In the interference pattern, energy is
   (a) Created at the position of maxima
   (b) Destroyed at the position of minima
   (c) Conserved but is redistributed
   (d) None of the above

3. Monochromatic green light of wavelength $5 \times 10^{-7} m$ illuminates a pair of slits 1 *mm* apart. The separation of bright lines on the interference pattern formed on a screen 2 *m* away is
   (a) 0.25 *mm* (b) 0.1 *mm*
   (c) 1.0 *mm* (d) 0.01 *mm*

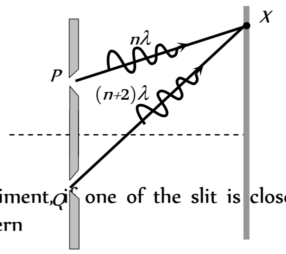
4. In Young's double slit experiment, if the slit widths are in the ratio 1 : 9, then the ratio of the intensity at minima to that at maxima will be [MP PET 1987]
   (a) 1 (b) 1/9
   (c) 1/4 (d) 1/3

5. In Young's double slit interference experiment, the slit separation is made 3 fold. The fringe width becomes [CPMT 1982, 89]
   (a) 1/3 *times* (b) 1/9 *times*
   (c) 3 *times* (d) 9 *times*

6. In a certain double slit experimental arrangement interference fringes of width 1.0 *mm* each are observed when light of wavelength 5000 Å is used. Keeping the set up unaltered, if the source is replaced by another source of wavelength 6000 Å, the fringe width will be [CPMT 1988]
   (a) 0.5 *mm* (b) 1.0 *mm*
   (c) 1.2 *mm* (d) 1.5 *mm*

7. Two coherent light sources S_1 and S_2 (λ= 6000 Å) are 1*mm* apart from each other. The screen is placed at a distance of 25 *cm* from the sources. The width of the fringes on the screen should be
   (a) 0.015 *cm* (b) 0.025 *cm*
   (c) 0.010 *cm* (d) 0.030 *cm*

8. The figure shows a double slit experiment *P* and *Q* are the slits. The path lengths *PX* and *QX* are $n\lambda$ and $(n+2)\lambda$ respectively, where *n* is a whole number and λ is the wavelength. Taking the central fringe as zero, what is formed at *X*



   (a) First bright
   (b) First dark
   (c) Second bright
   (d) Second dark

9. In Young's double slit experiment, one of the slit is closed fully, then in the interference pattern
   (a) A bright slit will be observed, no interference pattern will exist
   (b) The bright fringes will become more bright
   (c) The bright fringes will become fainter
   (d) None of the above

10. In Young's double slit experiment, a glass plate is placed before a slit which absorbs half the intensity of light. Under this case
   (a) The brightness of fringes decreases
   (b) The fringe width decreases
   (c) No fringes will be observed
   (d) The bright fringes become fainter and the dark fringes have finite light intensity

11. In Young's experiment, the distance between the slits is reduced to half and the distance between the slit and screen is doubled, then the fringe width [IIT 1981; MP PMT 1994; RPMT 1997; KCET 2000; CPMT 2003; AMU (Engg.) 2000; DPMT 2003; UPSEAT 2000, 04; Kerala PMT 2004]
   (a) Will not change (b) Will become half
   (c) Will be doubled [CPMT 1977; DPMT 1999] (d) Will become four times

12. The maximum intensity of fringes in Young's experiment is *I*. If one of the slit is closed, then the intensity at that place becomes I_0. Which of the following relation is true ? [NCERT 1982; MP PMT 1994, 99; BHU 1998; RPMT 1996; RPET 1999; AMU (Engg.) 1999]
   (a) $I = I_0$
   (b) $I = 2I_0$
   (c) $I = 4I_0$
   (d) There is no relation between *I* and I_0

13. In the Young's double slit experiment, the ratio of intensities of bright and dark fringes is 9. This means that [IIT 1982]
   (a) The intensities of individual sources are 5 and 4 units respectively
   (b) The intensities of individual sources are 4 and 1 units respectively
   (c) The ratio of their amplitudes is 3
   (d) The ratio of their amplitudes is 2

14. An oil flowing on water seems coloured due to interference. For observing this effect, the approximate thickness of the oil film should be [DPET 1987; JIPMER 1997; RPMT 2002, 04]
   (a) 100 Å (b) 10000 Å
   (c) 1 *mm* [CPMT 1990] (d) 1 *cm*

15. The Young's experiment is performed with the lights of blue (λ = 4360 Å) and green colour (λ = 5460 Å), If the distance of the 4th fringe from the centre is *x*, then [CPMT 1987]
   (a) *x* (Blue) = *x* (Green) (b) *x* (Blue)> *x* (Green)
   (c) *x* (Blue) < *x* (Green) (d) $\frac{x(Blue)}{x(Green)} = \frac{5460}{4360}$

16. In the Young's double slit experiment, the spacing between two slits is 0.1 *mm*. If the screen is kept at a distance of 1.0 *m* from the slits and the wavelength of light is 5000 Å, then the fringe width is [MP PMT 1993; R
   (a) 1.0 *cm* (b) 1.5 *cm*
   (c) 0.5 *cm* (d) 2.0 *cm*

17. In Young's double slit experiment, if *L* is the distance between the slits and the screen upon which interference pattern is observed, *x* is

the average distance between the adjacent fringes and d being the slit separation. The wavelength of light is given by

(a) $\frac{xd}{L}$ (b) $\frac{xL}{d}$

(c) $\frac{Ld}{x}$ (d) $\frac{1}{Ldx}$

18. In a Young's double slit experiment, the central point on the screen is [MP PMT 1996]

(a) Bright (b) Dark

(c) First bright and then dark (d) First dark and then bright

19. In a Young's double slit experiment, the fringe width is found to be 0.4 *mm*. If the whole apparatus is immersed in water of refractive index 4/3 without disturbing the geometrical arrangement, the new fringe width will be [CBSE PMT 1990]

(a) 0.30 *mm* (b) 0.40 *mm*

(c) 0.53 *mm* (d) 450 *micron*

20. Young's experiment is performed in air and then performed in water, the fringe width [CPMT 1990; MP PMT 1994; RPMT 1997; Kerala PMT 2004]

(a) Will remain same (b) Will decrease

(c) Will increase (d) Will be infinite

21. In double slits experiment, for light of which colour the fringe width will be minimum [MP PMT 1994]

(a) Violet (b) Red

(c) Green (d) Yellow

22. In Young's experiment, light of wavelength 4000 Å is used to produce bright fringes of width 0.6 *mm*, at a distance of 2 meters. If the whole apparatus is dipped in a liquid of refractive index 1.5, then fringe width will be [MP PMT 1994]

(a) 0.2 *mm* (b) 0.3 *mm*

(c) 0.4 *mm* (d) 1.2 *mm*

23. In Young's double slit experiment, the phase difference between the light waves reaching third bright fringe from the central fringe will be (λ =6000 Å) [MP PMT 1994]

(a) Zero (b) 2π

(c) 4π (d) 6π

24. In Young's double slit experiment, if the widths of the slits are in the ratio 4 : 9, the ratio of the intensity at maxima to the intensity at minima will be [Manipal MEE 1995]

(a) 169 : 25 (b) 81 : 16

(c) 25 : 1 (d) 9 : 4

25. In Young's double slit experiment when wavelength used is 6000 Å and the screen is 40 *cm* from the slits, the fringes are 0.012 *cm* wide. What is the distance between the slits [MP PMT 1995; Pb PET 2002]

(a) 0.024 *cm* (b) 2.4 *cm*

(c) 0.24 *cm* (d) 0.2 *cm*

26. In two separate set - ups of the Young's double slit experiment, fringes of equal width are observed when lights of wavelengths in the ratio 1 : 2 are used. If the ratio of the slit separation in the two cases is 2 : 1, the ratio of the distances between the plane of the slits and the screen in the two set - ups is [MP PET 1993]

(a) 4 : 1 (b) 1 : 1

(c) 1 : 4 (d) 2 : 1

27. In an interference experiment, the spacing between successive maxima or minima is [MP PET 1996]

(a) $\frac{\lambda d}{D}$ (b) $\frac{\lambda D}{d}$

(c) $\frac{dD}{\lambda}$ (d) $\frac{\lambda d}{4D}$

(Where the symbols have their usual meanings)

28. If yellow light in the Young's double slit experiment is replaced by red light, the fringe width will [MP PMT 1996]

(a) Decrease

(b) Remain unaffected

(c) Increase

(d) First increase and then decrease

29. In Young's double slit experiment, the fringe width is $1 \times 10^{-4}\,m$ if the distance between the slit and screen is doubled and the distance between the two slit is reduced to half and wavelength is changed from $6.4 \times 10^{7}\,m$ to $4.0 \times 10^{-7}\,m$, the value of new fringe width will be

(a) $0.15 \times 10^{-4}\,m$ (b) $2.0 \times 10^{-4}\,m$

(c) $1.25 \times 10^{-4}\,m$ (d) $2.5 \times 10^{-4}\,m$

30. In Young's experiment, one slit is covered with a blue filter and the other (slit) with a yellow filter. Then the interference pattern

(a) Will be blue (b) Will be yellow

(c) Will be green (d) Will not be formed

31. Two sources give interference pattern which is observed on a screen, D distance apart from the sources. The fringe width is $2w$. If the distance D is now doubled, the fringe width will

(a) Become $w/2$ (b) Remain the same

(c) Become w (d) Become $4w$

32. In double slit experiment, the angular width of the fringes is 0.20° for the sodium light (λ =5890 Å). In order to increase the angular width of the fringes by 10%, the necessary change in the wavelength is [MP PMT 1997]

(a) Increase of 589 Å (b) Decrease of 589 Å

(c) Increase of 6479 Å (d) Zero

33. In a biprism experiment, by using light of wavelength 5000 Å, 5 *mm* wide fringes are obtained on a screen 1.0 *m* away from the coherent sources. The separation between the two coherent sources is

(a) 1.0 *mm* (b) 0.1 *mm*

(c) 0.05 *mm* (d) 0.01 *mm*

34. The slits in a Young's double slit experiment have equal widths and the source is placed symmetrically relative to the slits. The intensity at the central fringes is I. If one of the slits is closed, the intensity at this point will be

[MP PMT 1999; Orissa JEE 2004; Kerala PET 2005]

(a) I (b) $I/4$

(c) $I/2$ (d) $4I$

35. A thin mica sheet of thickness $2\times10^{-6}\,m$ and refractive index $(\mu = 1.5)$ is introduced in the path of the first wave. The wavelength of the wave used is 5000 Å. The central bright maximum will shift [CPMT 1999]

(a) 2 fringes upward (b) 2 fringes downward

(c) 10 fringes upward (d) None of these

36. In a Young's double slit experiment, the fringe width will remain same, if (D = distance between screen and plane of slits, d = separation between two slits and λ = wavelength of light used)

(a) Both λ and D are doubled

(b) Both d and D are doubled

(c) D is doubled but d is halved

(d) λ is doubled but d is halved

37. In Young's double slit experiment, the slits are 0.5 *mm* apart and interference pattern is observed on a screen placed at a distance of 1.0 *m* from the plane containing the slits. If wavelength of the incident light is 6000 Å, then the separation between the third bright fringe and the central maxima is

(a) 4.0 *mm* (b) 3.5 *mm*

(c) 3.0 *mm* (d) 2.5 *mm*

38. In Young's double slit experiment, 62 fringes are seen in visible region for sodium light of wavelength 5893 Å. If violet light of wavelength 4358 Å is used in place of sodium light, then number of fringes seen will be [RPET 1997]

(a) 54 (b) 64

(c) 74 (d) 84

39. In Young's double slit experiment, angular width of fringes is 0.20° for sodium light of wavelength 5890 Å. If complete system is dipped in water, then angular width of fringes becomes

(a) 0.11° (b) 0.15°

(c) 0.22° (d) 0.30°

40. In Young's double slit experiment, the distance between the slits is 1 *mm* and that between slit and screen is 1 meter and 10th fringe is 5 *mm* away from the central bright fringe, then wavelength of light used will be [RPMT 1997]

(a) 5000 Å (b) 6000 Å

(c) 7000 Å (d) 8000 Å

41. In Young's double slit experiment, carried out with light of wavelength λ = 5000 Å, the distance between the slits is 0.2 *mm* and the screen is at 200 *cm* from the slits. The central maximum is at x =0. The third maximum (taking the central maximum as zeroth maximum) will be at x equal to

[CBSE PMT 1992; MH CET 2002]

(a) 1.67 *cm* (b) 1.5 *cm*

(c) 0.5 *cm* (d) 5.0 *cm*

42. In a Young's experiment, two coherent sources are placed 0.90 *mm* apart and the fringes are observed one metre away. If it produces the second dark fringe at a distance of 1 *mm* from the central fringe, the wavelength of monochromatic light used would be

[CBSE PMT 1992; KCET 2004]

(a) $60\times10^{-4}\,cm$ (b) $10\times10^{-4}\,cm$

(c) $10\times10^{-5}\,cm$ (d) $6\times10^{-5}\,cm$

43. In Young's double slit experiment, the distance between the two slits is 0.1 *mm* and the wavelength of light used is $4\times10^{-7}\,m$. If the width of the fringe on the screen is 4 *mm*, the distance between screen and slit is

[Bihar CMEET 1995]

(a) 0.1 *mm* (b) 1 *cm*

(c) 0.1 *cm* (d) 1 *m*

44. In Young's double slit experiment, the distance between sources is 1 *mm* and distance between the screen and source is 1 *m*. If the fringe width on the screen is 0.06 *cm*, then λ = [Bihar MEE 1995]

(a) 6000 Å (b) 4000 Å

(c) 1200 Å (d) 2400 Å

45. In Young's double slit experiment, a mica slit of thickness t and refractive index μ is introduced in the ray from the first source S. By how much distance the fringes pattern will be displaced [RPMT 1996, 97; JIPM

[AMU 1995]

(a) $\frac{d}{D}(\mu-1)t$ (b) $\frac{D}{d}(\mu-1)t$

(c) $\frac{d}{(\mu-1)D}$ (d) $\frac{D}{d}(\mu-1)$

46. In Young's double slit experiment using sodium light (λ = 5898 Å), 92 fringes are seen. If given colour (λ = 5461 Å) is used, how many fringes will be seen

[CPMT 1989; RPET 1996; JIPMER 2001, 02]

(a) 62 (b) 67

(c) 85 (d) 99

47. If a torch is used in place of monochromatic light in Young's experiment what will happens [RPET 1997]

[MH CET 1999; KCET 1999]

(a) Fringe will appear for a moment then it will disappear

(b) Fringes will occur as from monochromatic light

(c) Only bright fringes will appear

(d) No fringes will appear

48. When a thin metal plate is placed in the path of one of the interfering beams of light [KCET 1999]

(a) Fringe width increases (b) Fringes disappear

(c) Fringes become brighter (d) Fringes becomes blurred

49. In Young's experiment, the distance between slits is 0.28 *mm* and distance between slits and screen is 1.4 *m*. Distance between central bright fringe and third bright fringe is 0.9 *cm*. What is the wavelength of used light [KCET 1999]

(a) 5000 Å (b) 6000 Å

(c) 7000 Å (d) 9000 Å

50. Two parallel slits 0.6 *mm* apart are illuminated by light source of wavelength 6000 Å. The distance between two consecutive dark fringes on a screen 1 *m* away from the slits is

(a) 1 *mm* (b) 0.01 *mm*

(c) 0.1 *m* (d) 10 *m*

51. In young's double slit experiment with a source of light of wavelength 6320Å, the first maxima will occur when

[Roorkee 1999]

(a) Path difference is 9480 Å

(b) Phase difference is 2π radian

(c) Path difference is 6320 Å

(d) Phase difference is π radian

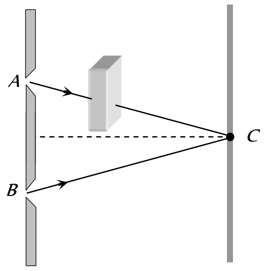
52. If a transparent medium of refractive index $\mu = 1.5$ and thickness $t = 2.5 \times 10^{-5}$ *m* is inserted in front of one of the slits of Young's Double Slit experiment, how much will be the shift in the interference pattern? The distance between the slits is 0.5 *mm* and that between slits and screen is 100 *cm*

(a) 5 *cm* (b) 2.5 *cm*

(c) 0.25 *cm* (d) 0.1 *cm*

53. In Young's experiment, monochromatic light is used to illuminate the two slits *A* and *B*. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed normally in the path of the beam coming from the slit

[UPSEAT 1993, 2000; AIIMS 1999, 2004]



(a) The fringes will disappear

(b) The fringe width will increase

(c) The fringe width will increase

(d) There will be no change in the fringe width but the pattern shifts

54. The fringe width in Young's double slit experiment increases when

[MP PMT 2000]

(a) Wavelength increases

(b) Distance between the slits increases

(c) Distance between the source and screen decreases

(d) The width of the slits increases

55. In a double slit experiment, instead of taking slits of equal widths, one slit is made twice as wide as the other. Then in the interference pattern [IIT-JEE (Screening) 2000]

(a) The intensities of both the maxima and the minima increase

(b) The intensity of maxima increases and the minima has zero intensity

(c) The intensity of maxima decreases and that of the minima increases

(d) The intensity of maxima decreases and the minima has zero intensity

56. Two slits, 4 *mm* apart, are illuminated by light of wavelength 6000 Å. What will be the fringe width on a screen placed 2*m* from the slits [MP PET 2000]

(a) 0.12 *mm* (b) 0.3 *mm*

(c) 3.0 *mm* (d) 4.0 *mm*

57. In the Young's double slit experiment, for which colour the fringe width is least [UPSEAT 2001, MP PET 2001]

(a) Red (b) Green

(c) Blue (d) Yellow

58. In a Young's double slit experiment, the separation of the two slits is doubled. To keep the same spacing of fringes, the distance *D* of the screen from the slits should be made [JIPMER 1999]

[MNR 1998; AMU (Engg.) 2001]

(a) $\frac{D}{2}$ (b) $\frac{D}{\sqrt{2}}$

(c) $2D$ (d) $4D$

59. Young's double slit experiment is performed with light of wavelength 550 *nm*. The separation between the slits is 1.10 *mm* and screen is placed at distance of 1 *m*. What is the distance between the consecutive bright or dark fringes

[Pb. PMT 2000]

(a) 1.5 *mm* (b) 1.0 *mm*

(c) 0.5 *mm* (d) None of these

60. In Young's experiment, the ratio of maximum to minimum intensities of the fringe system is 4 : 1. The amplitudes of the coherent sources are in the ratio [AIIMS 1999]

[RPMT 1996; MP PET 2000; RPET 2001; MP PMT 2001]

(a) 4 : 1 (b) 3 : 1

(c) 2 : 1 (d) 1 : 1

61. An interference pattern was made by using red light. If the red light changes with blue light, the fringes will become

[BHU 2001]

(a) Wider (b) Narrower

(c) Fainter (d) Brighter

62. If a white light is used in Young's double slit experiments then a very large number of coloured fringes can be seen

[KCET 2001]

(a) With first order violet fringes being closer to the central white fringes

(b) First order red fringes being closer to the central white fringes

(c) With a central white fringe

(d) With a central black fringe

63. In a Young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 *nm* is used. If the wavelength of light is changed to 400 *nm*, number of fringes observed in the same segment of the screen is given by [IIT-JEE (Screening) 2001]

(a) 12 (b) 18

(c) 24 (d) 30

64. In the Young's double slit experiment with sodium light. The slits are 0.589 *m* a part. The angular separation of the third maximum from the central maximum will be (given $\lambda = 589$ *mm*)

(a) $\sin^{-1}(0.33 \times 10^{8})$ (b) $\sin^{-1}(0.33 \times 10^{-6})$

(c) $\sin^{-1}(3 \times 10^{-8})$ (d) $\sin^{-1}(3 \times 10^{-6})$

65. In Young's double slit experiment, the distance between the two slits is made half, then the fringe width will become

[RPMT 1999; BHU 2002]

(a) Half (b) Double

(c) One fourth (d) Unchanged

66. In Young's double slit experiment, the central bright fringe can be identified [KCET 2002]

(a) By using white light instead of monochromatic light

(b) As it is narrower than other bright fringes

(c) As it is wider than other bright fringes

(d) As it has a greater intensity than the other bright fringes

67. In Young's double slit experiment, the wavelength of the light used is doubled and distance between two slits is half of initial distance, the resultant fringe width becomes [AIEEE 2002]

(a) 2 *times* (b) 3 *times*
(c) 4 *times* (d) 1/2 *times*

68. In a Young's double slit experiment, the source illuminating the slits is changed from blue to violet. The width of the fringes

(a) Increases (b) Decreases
(c) Becomes unequal (d) Remains constant

69. In Young's double slit experiment, the intensity of light coming from the first slit is double the intensity from the second slit. The ratio of the maximum intensity to the minimum intensity on the interference fringe pattern observed is [KCET 2002]

(a) 34 (b) 40
(c) 25 (d) 38

70. If the sodium light in Young's double slit experiment is replaced by red light, the fringe width will [MP PMT 2002]

(a) Decrease
(b) Increase
(c) Remain unaffected
(d) First increase, then decrease

71. In Young's double slit experiment the wavelength of light was changed from 7000 Å to 3500 Å. While doubling the separation between the slits which of the following is not true for this experiment [Orissa JEE 2002]

(a) The width of the fringes changes
(b) The colour of bright fringes changes
(c) The separation between successive bright fringes changes
(d) The separation between successive dark fringes remains unchanged

72. When a thin transparent plate of thickness t and refractive index μ is placed in the path of one of the two interfering waves of light, then the path difference changes by [MP PMT 2002]

(a) $(\mu+1)t$ (b) $(\mu-1)t$
(c) $\frac{(\mu+1)}{t}$ (d) $\frac{(\mu-1)}{t}$

73. In Young's double-slit experiment, an interference pattern is obtained on a screen by a light of wavelength 6000 Å, coming from the coherent sources S_1 and S_2. At certain point P on the screen third dark fringe is formed. Then the path difference $S_1P - S_2P$ in microns is [EAMCET 2003]

(a) 0.75 (b) 1.5
(c) 3.0 (d) 4.5

74. In a Young's double slit experiment, the slit separation is 1 *mm* and the screen is 1 *m* from the slit. For a monochromatic light of wavelength 500 *nm*, the distance of 3rd minima from the central maxima is [Orissa JEE 2003]

(a) 0.50 *mm* (b) 1.25 *mm*
(c) 1.50 *mm* (d) 1.75 *mm*

75. In Young's double-slit experiment the fringe width is β. If entire arrangement is placed in a liquid of refractive index n, the fringe width becomes [KCET 2003]

(a) $\frac{\beta}{n+1}$ (b) $n\beta$
(c) $\frac{\beta}{n}$ (d) $\frac{\beta}{n-1}$

76. In an interference experiment, third bright fringe is obtained at a point on the screen with a light of 700 *nm*. What should be the wavelength of the light source in order to obtain 5th bright fringe at the same point [KCET 2002] [KCET 2003]

(a) 500 *nm* (b) 630 *nm*
(c) 750 *nm* (d) 420 *nm*

77. If the separation between slits in Young's double slit experiment is reduced to $\frac{1}{3}rd$, the fringe width becomes n times. The value of n is [MP PET 2003]

(a) 3 (b) $\frac{1}{3}$
(c) 9 (d) $\frac{1}{9}$

78. A double slit experiment is performed with light of wavelength 500 *nm*. A thin film of thickness 2 μm and refractive index 1.5 is introduced in the path of the upper beam. The location of the central maximum will [AIIMS 2003]

(a) Remain unshifted
(b) Shift downward by nearly two fringes
(c) Shift upward by nearly two fringes
(d) Shift downward by 10 fringes

79. The two slits at a distance of 1 *mm* are illuminated by the light of wavelength $6.5\times10^{-7}\,m$. The interference fringes are observed on a screen placed at a distance of 1*m*. The distance between third dark fringe and fifth bright fringe will be [NCERT 1982; MP PET 1995; BVP 2003]

(a) 0.65 *mm* (b) 1.63 *mm*
(c) 3.25 *mm* (d) 4.88 *mm*

80. In a Young's double-slit experiment the fringe width is 0.2 *mm*. If the wavelength of light used is increased by 10% and the separation between the slits is also increased by 10%, the fringe width will be

(a) 0.20 *mm* (b) 0.401 *mm*
(c) 0.242 *mm* (d) 0.165 *mm*

81. Two coherent sources of intensity ratio 1 : 4 produce an interference pattern. The fringe visibility will be [J & K CET 2004]

(a) 1 (b) 0.8
(c) 0.4 (d) 0.6

82. In Young's double slit experiment the amplitudes of two sources are 3*a* and a respectively. The ratio of intensities of bright and dark fringes will be [J & K CET 2004]

(a) 3 : 1 (b) 4 : 1
(c) 2 : 1 (d) 9 : 1

83. In Young's double slit experiment, distance between two sources is 0.1 *mm*. The distance of screen from the sources is 20 *cm*. Wavelength of light used is 5460 Å. Then angular position of the first dark fringe is [DCE 2002]

(a) 0.08° (b) 0.16°

(c) 0.20° (d) 0.313°

84. In a Young's double slit experiment, the slit separation is 0.2 *cm*, the distance between the screen and slit is 1*m*. Wavelength of the light used is 5000 Å. The distance between two consecutive dark fringes (in *mm*) is

[DCE 2004]

(a) 0.25 (b) 0.26

(c) 0.27 (d) 0.28

85. A light of wavelength 5890 Å falls normally on a thin air film. The minimum thickness of the film such that the film appears dark in reflected light [Pb. PMT 2003]

(a) $2.945 \times 10^{-7} m$ (b) $3.945 \times 10^{-7} m$

(c) $4.95 \times 10^{-7} m$ (d) $1.945 \times 10^{-7} m$

86. In Young's double slit experiment, a minimum is obtained when the phase difference of super imposing waves is

[MH CET 2004]

(a) Zero (b) $(2n-1)\pi$

(c) $n\pi$ (d) $(n+1)\pi$

87. In Fresnel's biprism $(\mu = 1.5)$ experiment the distance between source and biprism is 0.3 *m* and that between biprism and screen is 0.7*m* and angle of prism is 1°. The fringe width with light of wavelength 6000 Å will be

[RPMT 2002]

(a) 3 *cm* (b) 0.011 *cm*

(c) 2 *cm* (d) 4 *cm*

88. In Young double slit experiment, when two light waves form third minimum, they have [RPMT 2003]

(a) Phase difference of 3π (b) Phase difference of $\frac{5\pi}{2}$

(c) Path difference of 3λ (d) Path difference of $\frac{5\lambda}{2}$

89. In Fresnel's biprism experiment, on increasing the prism angle, fringe width will [RPMT 2003]

(a) Increase

(b) Decrease

(c) Remain unchanged

(d) Depend on the position of object

90. If prism angle $\alpha = 1°$, $\mu = 1.54$, distance between screen and prism $(b) = 0.7\,m$, distance between prism and source $a = 0.3\,m$, $\lambda = 180\pi\ nm$ then in Fresnal biprism find the value of β (fringe width) [RPMT 2002]

(a) $10^{-4} m$ (b) $10^{-3} mm$

(c) $10^{-4} \times \pi m$ (d) $\pi \times 10^{-3} m$

91. If Fresnel's biprism experiment as held in water inspite of air, then what will be the effect on fringe width [RPMT 1997, 98]

(a) Decrease (b) Increase

(c) No effect (d) None of these

92. What is the effect on Fresnel's biprism experiment when the use of white light is made [RPMT 1998]

(a) Fringe are affected

(b) Diffraction pattern is spread more

(c) Central fringe is white and all are coloured

(d) None of these

93. What happens to the fringe pattern when the Young's double slit experiment is performed in water instead or air then fringe width

(a) Shrinks (b) Disappear

(c) Unchanged (d) Enlarged

94. In Young's doubled slit experiment, the separation between the slit and the screen increases. The fringe width

[BCECE 2005]

(a) Increases (b) Decreases

(c) Remains unchanged (d) None of these

95. In Young's double slit experiment, the aperture screen distance is 2*m*. The fringe width is 1 *mm*. Light of 600 *nm* is used. If a thin plate of glass (μ = 1.5) of thickness 0.06 *mm* is placed over one of the slits, then there will be a lateral displacement of the fringes by

(a) 0 *cm* (b) 5 *cm*

(c) 10 *cm* (d) 15 *cm*

96. In which of the following is the interference due to the division of wave front [UPSEAT 2005]

(a) Young's double slit experiment

(b) Fresnel's biprism experiment

(c) Lloyd's mirror experiment

(d) Demonstration colours of thin film

97. Two slits are separated by a distance of 0.5 *mm* and illuminated with light of $\lambda = 6000$ Å. If the screen is placed 2.5 *m* from the slits. The distance of the third bright image from the centre will be

(a) 1.5 *mm* (b) 3 *mm*

(c) 6 *mm* (d) 9 *mm*

Doppler's Effect of Light

1. The observed wavelength of light coming from a distant galaxy is found to be increased by 0.5% as compared with that coming from a terrestrial source. The galaxy is

[MP PMT 1993, 2003]

(a) Stationary with respect to the earth

(b) Approaching the earth with velocity of light

(c) Receding from the earth with the velocity of light

(d) Receding from the earth with a velocity equal to $1.5 \times 10^{6} m/s$

2. A star producing light of wavelength 6000 Å moves away from the earth with a speed of 5 *km/sec*. Due to Doppler effect the shift in wavelength will be $(c = 3 \times 10^{8} m/\sec)$

[MP PMT 1990]

(a) 0.1 Å (b) 0.05 Å

(c) 0.2 Å (d) 1 Å

3. If the shift of wavelength of light emitted by a star is towards violet, then this shows that star is

[RPET 1996; RPMT 1999]

(a) Stationary

(b) Moving towards earth

(c) Moving away from earth

(d) Information is incomplete

4. Assuming that universe is expanding, if the spectrum of light coming from a star which is going away from earth is tested, then in the wavelength of light

(a) There will be no change

(b) The spectrum will move to infrared region

(c) The spectrum will seems to shift to ultraviolet side

(d) None of the above

5. Doppler's effect in sound in addition to relative velocity between source and observer, also depends while source and observer or both are moving. Doppler effect in light depend only on the relative velocity of source and observer. The reason of this is

(a) Einstein mass - energy relation

(b) Einstein theory of relativity

(c) Photoelectric effect

(d) None of these

6. A rocket is moving away from the earth at a speed of $6 \times 10^7 m/s$. The rocket has blue light in it. What will be the wavelength of light recorded by an observer on the earth (wavelength of blue light = 4600 Å)

(a) 4600 Å (b) 5520 Å

(c) 3680 Å (d) 3920 Å

7. A spectral line λ = 5000 Å in the light coming from a distant star is observed as a 5200 Å. What will be recession velocity of the star

(a) $1.15 \times 10^7 cm/\sec$ (b) $1.15 \times 10^7 m/\sec$

(c) $1.15 \times 10^7 km/\sec$ (d) 1.15 *km/sec*

8. The apparent wavelength of the light from a star moving away from the earth is 0.01% more than its real wavelength. Then the velocity of star is **[CPMT 1979]**

(a) 60 *km/sec* (b) 15 *km/sec*

(c) 150 *km/sec* (d) 30 *km/sec*

9. A star emits light of 5500 Å wavelength. Its appears blue to an observer on the earth, it means **[DPMT 2002]**

(a) Star is going away from the earth

(b) Star is stationary

(c) Star is coming towards earth

(d) None of the above

10. The velocity of light emitted by a source *S* observed by an observer *O*, who is at rest with respect to *S* is *c*. If the observer moves towards *S* with velocity *v*, the velocity of light as observed will be

(a) $c + v$ (b) $c - v$

(c) c (d) $\sqrt{1 - \frac{v^2}{c^2}}$

11. In the context of Doppler effect in light, the term 'red shift' signifies

(a) Decrease in frequency

(b) Increase in frequency

(c) Decrease in intensity

(d) Increase in intensity

12. The sun is rotating about its own axis. The spectral lines emitted from the two ends of its equator, for an observer on the earth, will show **[MP PMT 1994]**

(a) Shift towards red end

(b) Shift towards violet end

(c) Shift towards red end by one line and towards violet end by other

(d) No shift

13. A star is moving away from the earth with a velocity of 100 *km/s*. If the velocity of light is $3 \times 10^8 m/s$ then the shift of its spectral line of wavelength 5700 Å due to Doppler's effect will be **[MP PET/PMT 1988]**

(a) 0.63 Å (b) 1.90 Å

(c) 3.80 Å (d) 5.70 Å

14. If a source of light is moving away from a stationary observer, then the frequency of light wave appears to change because of

(a) Doppler's effect

(b) Interference

(c) Diffraction

(d) None of these

15. A star emitting radiation at a wavelength of 5000 Å is approaching earth with a velocity of $1.5 \times 10^6 m/s$. The change in wavelength of the radiation as received on the earth, is

(a) 25 Å (b) Zero

(c) 100 Å (d) 2.5 Å

16. A star emitting light of wavelength 5896 Å is moving away from the earth with a speed of 3600 *km / sec*. The wavelength of light observed on earth will

[MP PET 1995, 2002]

(a) Decrease by 5825.25 Å

(b) Increase by 5966.75 Å

(c) Decrease by 70.75 Å

(d) Increase by 70.75 Å

($c = 3 \times 10^8 m/\sec$ is the speed of light)

17. A star moves away from earth at speed 0.8 *c* while emitting light of frequency $6 \times 10^{14} Hz$. What frequency will be observed on the earth (in units of 10^{14} *Hz*) (*c* = speed of light) **[NCERT 1980]**

(a) 0.24 (b) 1.2

(c) 30 (d) 3.3

18. A light source approaches the observer with velocity 0.8 *c*. The doppler shift for the light of wavelength 5500 Å is

[MP PET 1996]

(a) 4400 Å (b) 1833 Å

(c) 3167 Å (d) 7333 Å

19. Light coming from a star is observed to have a wavelength of 3737 Å, while its real wavelength is 3700 Å. The speed of the star relative to the earth is [Speed of light $3\times10^8 m/s$] **[MP PET 1997]**

(a) $3\times10^5 m/s$ (b) $3\times10^6 m/s$

(c) $3.7\times10^7 m/s$ (d) $3.7\times10^6 m/s$

20. In the spectrum of light of a luminous heavenly body the wavelength of a spectral line is measured to be 4747 Å while actual wavelength of the line is 4700 Å. The relative velocity of the heavenly body with respect to earth will be (velocity of light is $3\times10^8 m/s$)

(a) $3\times10^5 m/s$ moving towards the earth

(b) $3\times10^5 m/s$ moving away from the earth

(c) $3\times10^6 m/s$ moving towards the earth

(d) $3\times10^6 m/s$ moving away from the earth

21. The wavelength of light observed on the earth, from a moving star is found to decrease by 0.05%. Relative to the earth the star is

(a) Moving away with a velocity of $1.5\times10^5 m/s$

(b) Coming closer with a velocity of $1.5\times10^5 m/s$

(c) Moving away with a velocity of $1.5\times10^4 m/s$

(d) Coming closer with a velocity of $1.5\times10^4 m/s$

22. A star is going away from the earth. An observer on the earth will see the wavelength of light coming from the star **[MP PMT 1999]**

(a) Decreased

(b) Increased

(c) Neither decreased nor increased

(d) Decreased or increased depending upon the velocity of the star

23. A star is moving towards the earth with a speed of 4.5×10^6 *m/s*. If the true wavelength of a certain line in the spectrum received from the star is 5890 Å, its apparent wavelength will be about $[c=3\times10^8 m/s]$ **[MP PMT 1999]**

(a) 5890 Å (b) 5978 Å

(c) 5802 Å (d) 5896 Å

24. Due to Doppler's effect, the shift in wavelength observed is 0.1 Å for a star producing wavelength 6000 Å. Velocity of recession of the star will be

(a) 2.5 *km/s* (d) 10 *km/s*

(c) 5 *km/s* (d) 20 *km/s*

25. A rocket is going away from the earth at a speed of 10^6 *m/s* If the wavelength of the light wave emitted by it be 5700 Å, what will be its Doppler's shift **[RPMT 1996]**

(a) 200 Å (b) 19 Å

(c) 20 Å (d) 0.2 Å

26. A rocket is going away from the earth at a speed 0.2*c*, where *c* = speed of light. It emits a signal of frequency $4\times10^7 Hz$. What will be the frequency observed by an observer on the earth

(a) $4\times10^6 Hz$ (b) $3.2\times10^7 Hz$

(c) $3\times10^6 Hz$ (d) $5\times10^7 Hz$

27. If a star is moving towards the earth, then the lines are shifted towards **[AIIMS 1997]**

(a) Red (b) Infrared

(c) Blue (d) Green

28. When the wavelength of light coming from a distant star is measured it is found shifted towards red. Then the conclusion is **[MP PMT/PET 1998]**

(a) The star is approaching the observer

(b) The star recedes away from earth

(c) There is gravitational effect on the light

(d) The star remains stationary

29. A heavenly body is receding from earth such that the fractional change in λ is 1, then its velocity is **[DCE 2000]**

(a) C **[MP PMT/PET 1998]** (b) $\frac{3C}{5}$

(c) $\frac{C}{5}$ (d) $\frac{2C}{5}$

30. The 6563 Å line emitted by hydrogen atom in a star is found to be red shifted by 5 Å. The speed with which the star is receding from the earth is **[Pb. PMT 2002]**

(a) 17.29×10^9 *m/s* (b) 4.29×10^7 *m/s*

(c) 3.39×10^5 *m/s* (d) 2.29×10^5 *m/s*

31. Three observers *A*, *B* and *C* measure the speed of light coming from a source to be v_A, v_B and v_C. The observer *A* moves towards the source, the observer *C* moves away from the source with the same speed. The observer *B* stays stationary. the surrounding space is vacuum every where. Then **[KCET 2002]**

(a) $v_A > v_B > v_C$ (b) $v_A < v_B < v_C$

(c) $v_A = v_B = v_C$ (d) $v_A = v_B > v_C$

32. Light from the constellation Virgo is observed to increase in wavelength by 0.4%. With respect to Earth the constellation is

(a) Moving away with velocity 1.2×10^6 *m/s*

(b) Coming closer with velocity 1.2×10^6 *m/s*

(c) Moving away with velocity 4×10^6 *m/s*

(d) Coming closer with velocity 4×10^6 *m/s*

33. It is believed that the universe is expanding and hence the distant stars are receding from us. Light from such a star will show

(a) Shift in frequency towards longer wavelengths

(b) Shift in frequency towards shorter wavelength

(c) No shift in frequency but a decrease in intensity

(d) A shift in frequency sometimes towards longer and sometimes towards shorter wavelengths

Diffraction of Light

1. A slit of width *a* is illuminated by white light. For red light (λ = 6500 Å), the first minima is obtained at $\theta = 30^o$. Then the value of *a* will be [MP PMT 1987; CPMT 2002]

(a) 3250 Å (b) $6.5 \times 10^{-4} mm$

(c) 1.24 *microns* (d) $2.6 \times 10^{-4} cm$

2. The light of wavelength 6328 Å is incident on a slit of width 0.2 *mm* perpendicularly, the angular width of central maxima will be [MP PMT 1987; Pb. PMT 2002]

(a) 0.36^o (b) 0.18^o

(c) 0.72^o (d) 0.09^o

3. The bending of beam of light around corners of obstacles is called [NCERT 1990; AFMC 1995; RPET 1997; RPMT 1997; CPMT 1999; JIPMER 2000]

(a) Reflection (b) Diffraction

(c) Refraction (d) Interference

4. The penetration of light into the region of geometrical shadow is called [CPMT 1999; JIPMER 2000]

(a) Polarisation (b) Interference

(c) Diffraction (d) Refraction

5. A slit of size 0.15 *cm* is placed at 2.1 *m* from a screen. On illuminated it by a light of wavelength 5×10^{-5} *cm*. The width of central maxima will be [RPMT 1999]

(a) 70 *mm* (b) 0.14 *mm*

(c) 1.4 *mm* (d) 0.14 *cm*

6. A diffraction is obtained by using a beam of red light. What will happen if the red light is replaced by the blue light [KCET 2000; BHU 2001]

(a) Bands will narrower and crowd full together

(b) Bands become broader and further apart

(c) No change will take place

(d) Bands disappear

7. What will be the angle of diffracting for the first minimum due to Fraunhoffer diffraction with sources of light of wave length 550 *nm* and slit of width 0.55 *mm*

(a) 0.001 *rad* (b) 0.01 *rad*

(c) 1 *rad* (d) 0.1 *rad*

8. Angular width (β) of central maximum of a diffraction pattern on a single slit does not depend upon [DCE 2000; 01]

(a) Distance between slit and source

(b) Wavelength of light used

(c) Width of the slit

(d) Frequency of light used

9. A single slit of width 0.20 *mm* is illuminated with light of wavelength 500 *nm*. The observing screen is placed 80 *cm* from the slit. The width of the central bright fringe will be [AMU (Med.) 2002]

(a) 1 *mm* (b) 2 *mm*

(c) 4 *mm* (d) 5 *mm*

10. Yellow light is used in single slit diffraction experiment with slit width 0.6 *mm*. If yellow light is replaced by *X*-rays then the pattern will reveal [IIT-JEE (Screening) 1999; MP PMT 2002; KCET 2003]

(a) That the central maxima is narrower

(b) No diffraction pattern

(c) More number of fringes

(d) Less number of fringes

11. Which statement is correct for a zone plate and a lens [RPMT 2002]

(a) Zone plate has multi focii whereas lens has one

(b) Zone plate has one focus whereas lens has multiple focii

(c) Both are correct

(d) Zone plate has one focus whereas a lens has infinite

12. In Fresnel diffraction, if the distance between the disc and the screen is decreased, the intensity of central bright spot will

(a) Increase (b) Decrease

(c) Remain constant (d) None of these

13. A plane wavefront $(\lambda = 6 \times 10^{-7} m)$ falls on a slit $0.4\,mm$ wide. A convex lens of focal length $0.8\,m$ placed behind the slit focusses the light on a screen. What is the linear diameter of second maximum [RPMT 2001]

(a) $6\,mm$ (b) $12\,mm$

(c) $3\,mm$ (d) $9\,mm$

14. A zone plate of focal length $60\,cm$, behaves as a convex lens, If wavelength of incident light is $6000\ \mathring{A}$, then radius of first half period zone will be [RPMT 2001]

(a) $36 \times 10^{-8} m.$ (b) $6 \times 10^{-8} m.$

(c) $\sqrt{6} \times 10^{-8} m.$ (d) $6 \times 10^{-4} m.$

15. Radius of central zone of circular zone plate is $2.3\,mm.$ Wavelength of incident light is $5893\ \mathring{A}.$ Source is at a distance of $6\,m.$ Then the distance of first image will be [RPMT 2001] [Pb. PMT 2001]

(a) $9\,m$ (b) $12\,m$

(c) $24\,m$ (d) $36\,m$

16. Red light is generally used to observe diffraction pattern from single slit. If blue light is used instead of red light, then diffraction pattern [RPMT 2001; BCECE 2005; CPMT 2005]

(a) Will be more clear (b) Will contract

(c) Will expanded (d) Will not be visualized

17. In the experiment of diffraction at a single slit, if the slit width is decreased, the width of the central maximum [KCET 2001]

(a) Increases in both Fresnel and Fraunhofer diffraction

(b) Decreases both in Fresnal and Fraunhofer diffraction

(c) Increases in Fresnel diffraction but decreases in Fraunhofer diffraction

(d) Decreases in Fresnel diffraction but increases is Fraunofer diffraction.

18. Conditions of diffraction is [RPET 2001]

(a) $\frac{a}{\lambda} = 1$ (b) $\frac{a}{\lambda} >> 1$

(c) $\frac{a}{\lambda} << 1$ (d) None of these

19. Light of wavelength $589.3\,nm$ is incident normally on the slit of width $0.1\,mm$. What will be the angular width of the central diffraction maximum at a distance of $1\,m$ from the slit

(a) $0.68°$ (b) $1.02°$

(c) $0.34°$ (d) None of these

20. The phenomenon of diffraction of light was discovered by [KCET 2000]

(a) Hygens (b) Newton

(c) Fresnel (d) Grimaldi

21. The radius r of half period zone is proportional to [RPMT 1998, 2002]

(a) $\sqrt{n}$ (b) $\frac{1}{\sqrt{n}}$

(c) n^2 (d) $\frac{1}{n}$

22. In a diffraction pattern by a wire, on increasing diameter of wire, fringe width [RPMT 1998]

(a) Decreases

(b) Increases

(c) Remains unchanged

(d) Increasing or decreasing will depend on wavelength

23. What will be the angular width of central maxima in Fraunhoffer diffraction when light of wavelength $6000\,Å$ is used and slit width is $12 \times 10^{-5}\,cm$. [RPMT 2004]

(a) 2 *rad* (b) 3 *rad*

(c) 1 *rad* (d) 8 *rad*

24. When a compact disc is illuminated by a source of white light. Coloured 'lanes' are observed. This is due to [DCE 2003; AIIMS 2004]

(a) Dispersion (b) Diffraction

(c) Interference (d) Refraction

25. The diffraction effect can be observed in [J & K CET 2004]

(a) Only sound waves

(b) Only light waves

(c) Only ultrasonic waves

(d) Sound as well as light waves

26. If we observe the single slit Fraunhofer diffraction with wavelength λ and slit width *e*, the width of the central maxima is 2θ. On decreasing the slit width for the same λ [UPSEAT 2004]

(a) θ increases

(b) θ remains unchanged

(c) θ decreases

(d) θ increases or decreases depending on the intensity of light

27. When light is incident on a diffraction grating the zero order principal maximum will be [KCET 2004]

(a) One of the component colours

(b) Absent

(c) Spectrum of the colours

(d) White

28. A beam of light of wavelength 600 *nm* from a distant source falls on a single slit 1 *mm* wide and the resulting diffraction pattern is observed on a screen 2 *m* away. The distance between the first dark fringes on either side of the central bright fringe is [IIT-JEE 1994; KCET 2004]

(a) 1.2 *mm* (b) 1.2 *cm*

(c) 2.4 *cm* [BHU (Med.) 1999] (d) 2.4 *mm*

29. In order to see diffraction the thickness of the film is [J&K CEE 2001]

(a) 100 Å (b) 10,000 Å

(c) 1 *mm* (d) 1 *cm*

30. Diffraction effects are easier to notice in the case of sound waves than in the case of light waves because [RPET 1978; KCET 1994, 2000]

(a) Sound waves are longitudinal

(b) Sound is perceived by the ear

(c) Sound waves are mechanical waves

(d) Sound waves are of longer wavelength

31. Direction of the first secondary maximum in the Fraunhofer diffraction pattern at a single slit is given by (*a* is the width of the slit) [KCET 1999]

(a) $a\sin\theta = \frac{\lambda}{2}$ (b) $a\cos\theta = \frac{3\lambda}{2}$

(c) $a\sin\theta = \lambda$ (d) $a\sin\theta = \frac{3\lambda}{2}$

32. A parallel monochromatic beam of light is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of incident beam. At the first maximum of the diffraction pattern the phase difference between the rays coming from the edges of the slit is

(a) 0 (b) $\frac{\pi}{2}$

(c) π (d) 2π

33. Diffraction and interference of light suggest [CPMT 1995; RPMT 1998]

(a) Nature of light is electro-magnetic

(b) Wave nature

(c) Nature is quantum

(d) Nature of light is transverse

34. A light wave is incident normally over a slit of width $24 \times 10^{-5}\,cm$. The angular position of second dark fringe from the central maxima is 30°. What is the wavelength of light

(a) 6000 Å (b) 5000 Å

(c) 3000 Å (d) 1500 Å

35. A parallel beam of monochromatic light of wavelength 5000 Å is incident normally on a single narrow slit of width 0.001 *mm*. The light is focused by a convex lens on a screen placed on the focal plane. The first minimum will be formed for the angle of diffraction equal to [CBSE PMT 1993]

(a) 0° (b) 15°

(c) 30° (d) 60°

36. The condition for observing Fraunhofer diffraction from a single slit is that the light wavefront incident on the slit should be

(a) Spherical (b) Cylindrical

(c) Plane (d) Elliptical

37. To observe diffraction the size of an obstacle [CPMT 1982]

(a) Should be of the same order as wavelength

(b) Should be much larger than the wavelength

(c) Have no relation to wavelength

(d) Should be exactly $\frac{\lambda}{2}$

38. In the far field diffraction pattern of a single slit under polychromatic illumination, the first minimum with the wavelength λ_1 is found to be coincident with the third maximum at λ_2. So

(a) $3\lambda_1 = 0.3\lambda_2$ (b) $3\lambda_1 = \lambda_2$

(c) $\lambda_1 = 3.5\lambda_2$ (d) $0.3\lambda_1 = 3\lambda_2$

39. Light of wavelength λ = 5000 $Å$ falls normally on a narrow slit. A screen placed at a distance of 1 *m* from the slit and perpendicular to the direction of light. The first minima of the diffraction pattern is situated at 5 *mm* from the centre of central maximum. The width of the slit is

(a) 0.1 *mm* (b) 1.0 *mm*

(c) 0.5 *mm* (d) 0.2 *mm*

40. The width of the *n* *HPZ* will be

(a) $\sqrt{nb\lambda}$ (b) $\sqrt{b\lambda}\,[\sqrt{n} - \sqrt{n-1}]$

(c) $(\sqrt{n} - \sqrt{n-1})$ (d) $\frac{\sqrt{b\lambda}}{[\sqrt{n} - \sqrt{n-1}]}$

41. A single slit of width *a* is illuminated by violet light of wavelength 400 *nm* and the width of the diffraction pattern is measured as *y*. When half of the slit width is covered and illuminated by yellow light of wavelength 600 *nm*, the width of the diffraction pattern is

(a) The pattern vanishes and the width is zero

(b) $y/3$

(c) 3*y*

(d) None of these

Polarization of Light

1. A polariser is used to [CPMT 1999]

(a) Reduce intensity of light

(b) Produce polarised light

(c) Increase intensity of light

(d) Produce unpolarised light

2. Light waves can be polarised as they are

[CBSE PMT 1993; KCET 1994; AFMC 1997; J & K CET 2002; CPMT 2005]

(a) Transverse (b) Of high frequency

(c) Longitudinal (d) Reflected

3. Through which character we can distinguish the light waves from sound waves [CBSE PMT 1990; RPET 2000, 02]

(a) Interference (b) Refraction

(c) Polarisation [MP PMT 1987] (d) Reflection

4. The angle of polarisation for any medium is 60°, what will be critical angle for this [UPSEAT 1999]

(a) $\sin^{-1}\sqrt{3}$ (b) $\tan^{-1}\sqrt{3}$

(c) $\cos^{-1}\sqrt{3}$ (d) $\sin^{-1}\frac{1}{\sqrt{3}}$

5. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refraction index *n*) is

(a) $\sin^{-1}(n)$ (b) $\sin^{-1}\left(\frac{1}{n}\right)$

(c) $\tan^{-1}\left(\frac{1}{n}\right)$ (d) $\tan^{-1}(n)$

6. Which of following can not be polarised [Kerala PMT 2001]

(a) Radio waves (b) Ultraviolet rays

(c) Infrared rays (d) Ultrasonic waves

7. A polaroid is placed at 45° to an incoming light of intensity I_0. Now the intensity of light passing through polaroid after polarisation would be [CPMT 1995]

(a) I_0 (b) $I_0/2$

(c) $I_0/4$ (d) Zero

8. Plane polarised light is passed through a polaroid. On viewing through the polaroid we find that when the polariod is given one complete rotation about the direction of the light, one of the following is observed [MNR 1993]

(a) The intensity of light gradually decreases to zero and remains at zero

(b) The intensity of light gradually increases to a maximum and remains at maximum

(c) There is no change in intensity

(d) The intensity of light is twice maximum and twice zero

9. Out of the following statements which is not correct

[KCET 2005] [CPMT 1991]

(a) When unpolarised light passes through a Nicol's prism, the emergent light is elliptically polarised

(b) Nicol's prism works on the principle of double refraction and total internal reflection

(c) Nicol's prism can be used to produce and analyse polarised light

(d) Calcite and Quartz are both doubly refracting crystals

10. A ray of light is incident on the surface of a glass plate at an angle of incidence equal to Brewster's angle ϕ. If μ represents the refractive index of glass with respect to air, then the angle between reflected and refracted rays is

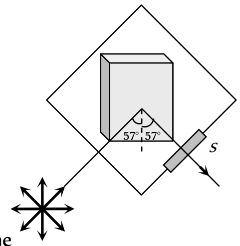
[CPMT 1989]

(a) $90 + \phi$ (b) $\sin^{-1}(\mu\cos\phi)$

(c) 90° (d) $90^o - \sin^{-1}(\sin\phi/\mu)$

11. Figure represents a glass plate placed vertically on a horizontal table with a beam of unpolarised light falling on its surface at the polarising angle of 57° with the normal. The electric vector in the reflected light on screen *S* will vibrate with respect to the plane of incidence in a

[CPMT 1988]



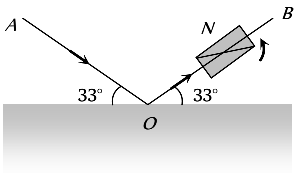
(a) Vertical plane

(b) Horizontal plane

(c) Plane making an angle of 45° with the vertical

(d) Plane making an angle of 57° with the horizontal

12. A beam of light *AO* is incident on a glass slab $(\mu = 1.54)$ in a direction as shown in figure. The reflected ray *OB* is passed through a Nicol prism on viewing through a Nicole prism, we find on rotating the prism that [CPMT 1986]



(a) The intensity is reduced down to zero and remains zero

(b) The intensity reduces down some what and rises again

(c) There is no change in intensity

(d) The intensity gradually reduces to zero and then again increases

13. Polarised glass is used in sun glasses because [CPMT 1981]

(a) It reduces the light intensity to half an account of polarisation

(b) It is fashionable

(c) It has good colour

(d) It is cheaper

14. In the propagation of electromagnetic waves the angle between the direction of propagation and plane of polarisation is

(a) 0° (b) 45°

(c) 90° (d) 180°

15. The transverse nature of light is shown by [CPMT 1972, 74, 78; RPMT 1999; AFMC 2001; AIEEE 2002; MP PET 2004; MP PMT 2000, 04; UPSEAT 2005]

(a) Interference of light (b) Refraction of light

(c) Polarisation of light (d) Dispersion of light

16. A calcite crystal is placed over a dot on a piece of paper and rotated, on seeing through the calcite one will be see

[CPMT 1971]

(a) One dot

(b) Two stationary dots

(c) Two rotating dots

(d) One dot rotating about the other

17. A light has amplitude *A* and angle between analyser and polariser is 60°. Light is reflected by analyser has amplitude

[UPSEAT 2001]

(a) $A\sqrt{2}$ (b) $A/\sqrt{2}$

(c) $\sqrt{3}A/2$ (d) $A/2$

18. When light is incident on a doubly refracting crystal, two refracted rays-ordinary ray (*O*-ray) and extra ordinary ray (*E*-ray) are produced. Then [KCET 2001]

(a) Both *O*-ray and *E*-ray are polarised perpendicular to the plane of incidence

(b) Both *O*-ray and *E*-ray are polarised in the plane of incidence

(c) *E*-ray is polarised perpendicular to the plane of incidence and *O*-ray in the plane of incidence

(d) *E*-ray is polarised in the plane of incidence and *O*-ray perpendicular to the plane of incidence

19. Light passes successively through two polarimeters tubes each of length 0.29*m*. The first tube contains dextro rotatory solution of concentration 60kgm^{-3} and specific rotation 0.01$rad\,m^2 kg^{-1}$. The second tube contains laevo rotatory solution of concentration 30kg/m^3 and specific rotation 0.02 $rad\,m^2 kg^{-1}$. The net rotation produced is[KCET 2002]

(a) 15° (b) 0°

(c) 20° (d) 10°

20. V_o and V_E represent the velocities, μ_o and μ_E the refractive indices of ordinary and extraordinary rays for a doubly refracting crystal. Then [KCET 2002]

(a) $V_o \ge V_E,\ \mu_o \le \mu_E$ if the crystal is calcite

(b) $V_o \le V_E,\ \mu_o \le \mu_E$ if the crystal is quartz

(c) $V_o \le V_E,\ \mu_o \ge \mu_E$ if the crystal is calcite

(d) $V_o \ge V_E,\ \mu_o \ge \mu_E$ if the crystal is quartz

21. Polarising angle for water is 53°4'. If light is incident at this angle on the surface of water and reflected, the angle of refraction is

(a) 53°4' (b) 126°56'

(c) 36°56' (d) 30°4'

22. When a plane polarised light is passed through an analyser and analyser is rotated through 90°, the intensity of the emerging light

(a) Varies between a maximum and minimum

(b) Becomes zero

(c) Does not vary [CPMT 1978]

(d) Varies between a maximum and zero

23. Consider the following statements *A* to *B* and identify the correct answer

A. Polarised light can be used to study the helical surface of nucleic acids.

B. Optics axis is a direction and not any particular line in the crystal [EAMCET (Med.) 2003]

(a) A and B are correct

(b) A and B are wrong

(c) A is correct but B is wrong

(d) A is wrong but B is correct

24. Two Nicols are oriented with their principal planes making an angle of 60°. The percentage of incident unpolarized light which passes through the system is

(a) 50% (b) 100%

(c) 12.5% (d) 37.5%

25. Unpolarized light falls on two polarizing sheets placed one on top of the other. What must be the angle between the characteristic directions of the sheets if the intensity of the final transmitted light is one-third the maximum intensity of the first transmitted beam

(a) 75° (b) 55°

(c) 35° (d) 15°

26. Unpolarized light of intensity 32 Wm passes through three polarizers such that transmission axes of the first and second polarizer makes and angle 30° with each other and the transmission axis of the last polarizer is crossed with that of the first. The intensity of final emerging light will be

(a) 32 Wm (b) 3 Wm

(c) 8 Wm (d) 4 Wm

27. In the visible region of the spectrum the rotation of the place of polarization is given by $\theta = a + \frac{b}{\lambda^2}$. The optical rotation produced by a particular material is found to be 30° *per mm* at $\lambda = 5000$ Å and 50° *per mm* at $\lambda = 4000$Å. The value of constant a will be

(a) $+\frac{50°}{9}$ *per mm* (b) $-\frac{50°}{9}$ *per mm*

(c) $+\frac{9°}{50}$ *per mm* (d) $-\frac{9°}{50}$ *per mm*

28. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is [AIEEE 2005]

(a) Zero (b) I_0

(c) $\frac{1}{2}I_0$ (c) $\frac{1}{4}I_0$

29. Refractive index of material is equal to tangent of polarising angle. It is called [AFMC 2005]

(a) Brewster's law (b) Lambert's law

(c) Malus's law (d) Bragg's law

30. In case of linearly polarized light, the magnitude of the electric field vector: [AIIMS 2005]

(a) Does not change with time

(b) Varies periodically with time

(c) Increases and decreases linearly with time

(d) Is parallel to the direction of propagation

31. When unpolarised light beam is incident from air onto glass (n = 1.5) at the polarising angle [KCET 2005]

(a) Reflected beam is polarised 100 percent

(b) Reflected and refracted beams are partially polarised

(c) The reason for (a) is that almost all the light is reflected

(d) All of the above

32. An optically active compound [DCE 2005]

(a) Rotates the plane polarised light

(b) Changing the direction of polarised light

(c) Do not allow plane polarised light to pass through

(d) None of the above

33. When the angle of incidence on a material is 60°, the reflected light is completely polarized. The velocity of the refracted ray inside the material is (in ms) [Kerala PMT 2005]

(a) 3×10^8 (b) $\left(\frac{3}{\sqrt{2}}\right)\times10^8$

(c) $\sqrt{3}\times10^8$ (d) 0.5×10^8

34. Two polaroids are placed in the path of unpolarized beam of intensity I_0 such that no light is emitted from the second polaroid. If a third polaroid whose polarization axis makes an angle θ with the polarization axis of first polaroid, is placed between these polaroids then the intensity of light emerging from the last polaroid will be [UPSEAT 200

(a) $\left(\frac{I_0}{8}\right)\sin^2 2\theta$ (b) $\left(\frac{I_0}{4}\right)\sin^2 2\theta$

(c) $\left(\frac{I_0}{2}\right)\cos^4\theta$ (d) $I_0\cos^4\theta$

35. For the study of the helical structure of nucleic acids, the property of electromagnetic radiation generally used is [EAMCET 2005]

(a) Reflection (b) Interference

(c) Diffraction (d) Polarization

EM Waves

1. Which of the following statement is wrong [NCERT 1976]

(a) Infrared photon has more energy than the photon of visible light

(b) Photographic plates are sensitive to ultraviolet rays

(c) Photographic plates can be made sensitive to infrared rays

(d) Infrared rays are invisible but can cast shadows like visible light rays

2. Pick out the longest wavelength from the following types of radiations [CBSE PMT 1990]

(a) Blue light (b) γ-rays

(c) X-rays (d) Red light

3. Wave which cannot travel in vacuum is [MP PMT 1994]

(a) X-rays (b) Infrasonic

(c) Ultraviolet (d) Radiowaves

4. Light is an electromagnetic wave. Its speed in vacuum is given by the expression [CBSE PMT 1993; MP PMT 1994; RPMT 1999; MP PET 2001; Kerala PET 2001; AIIMS 2002]

(a) $\sqrt{\mu_o\varepsilon_o}$ (b) $\sqrt{\frac{\mu_o}{\varepsilon_o}}$

(c) $\sqrt{\frac{\varepsilon_o}{\mu_o}}$ (d) $\frac{1}{\sqrt{\mu_o\varepsilon_o}}$

5. The range of wavelength of the visible light is [MP PMT 2000; MP PET 2002]

(a) 10 Å to 100 Å (b) 4,000 Å to 8,000 Å

(c) 8,000 Å to 10,000 Å (d) 10,000 Å to 15,000 Å

6. Which radiation in sunlight, causes heating effect [AFMC 2001]

(a) Ultraviolet (b) Infrared

(c) Visible light (d) All of these

7. Which of the following represents an infrared wavelength

[CPMT 1975; MP PET/PMT 1988]

(a) 10^{-4} *cm* (b) 10^{-5} *cm*

(c) 10^{-6} *cm* (d) 10^{-7} *cm*

8. The wavelength of light visible to eye is of the order of [CPMT 1982, 84]

(a) 10^{-2} *m* (b) 10^{-10} *m*

(c) 1 *m* (d) 6×10^{-7} *m*

9. The speed of electromagnetic wave in vacuum depends upon the source of radiation [Kerala PMT 2004]

(a) Increases as we move from γ-rays to radio waves

(b) Decreases as we move from γ-rays to radio waves

(c) Is same for all of them

(d) None of these

10. Which of the following radiations has the least wavelength [AIEEE 2003]

(a) γ -rays (b) β-rays

(c) α-rays (d) *X*-rays

11. The maximum distance upto which TV transmission from a TV tower of height *h* can be received is proportional to [AIIMS 2003]

(a) $h^{1/2}$ (b) *h*

(c) *h* (d) h^2

12. Which of the following are not electromagnetic waves [AIEEE 2002; CBSE PMT 2003]

(a) Cosmic rays (b) Gamma rays

(c) β-rays (d) *X*-rays

13. Ozone is found in [DPMT 2002]

(a) Stratosphere (b) Ionosphere

(c) Mesosphere (d) Troposphere

14. The electromagnetic waves travel with a velocity [J & K CET 2002]

(a) Equal to velocity of sound

(b) Equal to velocity of light

(c) Less than velocity of light

(d) None of these

15. The ozone layer absorbs [Kerala PET 2002]

(a) Infrared radiations (b) Ultraviolet radiations

(c) *X*-rays (d) γ-rays

16. Electromagnetic radiation of highest frequency is [Kerala PMT 2002]

(a) Infrared radiations (b) Visible radiation

(c) Radio waves (d) γ-rays

17. Which of the following shows green house effect [CBSE PMT 2002]

(a) Ultraviolet rays (b) Infrared rays

(c) *X*-rays (d) None of these

18. Which of the following waves have the maximum wavelength [AFMC 2002]

(a) *X*-rays (b) I.R. rays

(c) UV rays (d) Radio waves

19. Electromagnetic waves are transverse in nature is evident by [AIEEE 2002]

(a) Polarization (b) Interference

(c) Reflection (d) Diffraction

20. If $\vec{E}$ and $\vec{B}$ are the electric and magnetic field vectors of E.M. waves then the direction of propagation of E.M. wave is along the direction of [CBSE PMT 1992, 2002; DCE 2002, 05]

(a) $\vec{E}$ (b) $\vec{B}$

(c) $\vec{E}\times\vec{B}$ (d) None of these

21. Biological importance of Ozone layer is [CBSE PMT 2001]

(a) It stops ultraviolet rays

(b) Ozone rays reduce green house effect

(c) Ozone layer reflects radio waves

(d) Ozone layer controls O_2 / H_2 radio in atmosphere

22. What is ozone hole [AFMC 2001]

(a) Hole in the ozone layer

(b) Formation of ozone layer

(c) Thinning of ozone layer in troposphere

(d) Reduction in ozone thickness in stratosphere

23. Which rays are not the portion of electromagnetic spectrum [Haryana CEET 2000]

(a) *X*-rays (b) Microwaves

(c) α-rays (d) Radio waves

24. Radio wave diffract around building although light waves do not. The reason is that radio waves [AMU 2000]

(a) Travel with speed larger than *c*

(b) Have much larger wavelength than light

(c) Carry news

(d) Are not electromagnetic waves

25. The frequencies of *X*-rays, γ-rays and ultraviolet rays are respectively *a*, *b* and *c*. Then [CBSE PMT 2000]

(a) $a < b, b > c$ (b) $a > b, b > c$

(c) $a > b, b < c$ (d) $a < b, b < c$

26. Radio waves and visible light in vacuum have [KCET 2000]

(a) Same velocity but different wavelength

(b) Continuous emission spectrum

(c) Band absorption spectrum

(d) Line emission spectrum

27. Energy stored in electromagnetic oscillations is in the form of [Haryana CEET 2000; AFMC 1994]

(a) Electrical energy (b) Magnetic energy

(c) Both (a) and (b) (d) None of these

28. Heat radiations propagate with the speed of [AMU 2000]

(a) α-rays (b) β-rays

(c) Light waves (d) Sound waves

29. If a source is transmitting electromagnetic wave of frequency $8.2 \times 10^6\ Hz$, then wavelength of the electromagnetic waves transmitted from the source will be [DPMT 1999]

(a) 36.6 m (b) 40.5 m

(c) 42.3 m (d) 50.9 m

30. In an apparatus, the electric field was found to oscillate with an amplitude of 18 V/m. The magnitude of the oscillating magnetic field will be [Pb. PMT 1999]

(a) $4 \times 10^{-6}\ T$ (b) $6 \times 10^{-8}\ T$

(c) $9 \times 10^{-9}\ T$ (d) $11 \times 10^{-11}\ T$

31. According to Maxwell's hypothesis, a changing electric field gives rise to [AIIMS 1998]

(a) An e.m.f. (b) Electric current

(c) Magnetic field (d) Pressure radiant

32. In an electromagnetic wave, the electric and magnetising fields are $100\ V m^{-1}$ and $0.265\ A m^{-1}$. The maximum energy flow is

(a) $26.5\ W/m^2$ (b) $36.5\ W/m^2$

(c) $46.7\ W/m^2$ (d) $765\ W/m^2$

33. The 21 cm radio wave emitted by hydrogen in interstellar space is due to the interaction called the hyperfine interaction is atomic hydrogen. the energy of the emitted wave is nearly

(a) 10^{-17} *Joule* (b) 1 *Joule*

(c) 7×10^{-8} *Joule* (d) 10^{-24} *Joule*

34. TV waves have a wavelength range of 1-10 *meter*. Their frequency range in *MHz* is [KCET 1998]

(a) 30-300 (b) 3-30

(c) 300-3000 (d) 3-3000

35. Maxwell's equations describe the fundamental laws of [CPMT 1996]

(a) Electricity only (b) Magnetism only

(c) Mechanics only (d) Both (a) and (b)

36. The oscillating electric and magnetic vectors of an electromagnetic wave are oriented along [CBSE PMT 1994]

(a) The same direction but differ in phase by 90°

(b) The same direction and are in phase

(c) Mutually perpendicular directions and are in phase

(d) Mutually perpendicular directions and differ in phase by 90°

37. In which one of the following regions of the electromagnetic spectrum will the vibrational motion of molecules give rise to absorption [SCRA 1994]

(a) Ultraviolet (b) Microwaves

(c) Infrared (d) Radio waves

38. An electromagnetic wave travels along z-axis. Which of the following pairs of space and time varying fields would generate such a wave

(a) E_x, B_y (b) E_y, B_x

(c) E_z, B_x (d) E_y, B_z

39. Which of the following rays has the maximum frequency [CBSE PMT 1994]

(a) Gamma rays (b) Blue light

(c) Infrared rays (d) Ultraviolet rays

40. A signal emitted by an antenna from a certain point can be received at another point of the surface in the form of [CPMT 1993]

(a) Sky wave (b) Ground wave

(c) Sea wave (d) Both (a) and (b)

41. Approximate height of ozone layer above the ground is [CBSE PMT 1991]

(a) 60 to 70 km (b) 59 km to 80 km

(c) 70 km to 100 km (d) 100 km to 200 km

42. The electromagnetic waves do not transport [Pb. PET 1991]

(a) Energy (b) Charge

(c) Momentum [Pb. PMT 1997, 98] (d) Information

43. A plane electromagnetic wave is incident on a material surface. If the wave delivers momentum p and energy E, then

(a) $p = 0, E = 0$ (b) $p \neq 0, E \neq 0$

(c) $p \neq 0, E = 0$ (d) $p = 0, E \neq 0$

44. An electromagnetic wave, going through vacuum is described by [CBSE PMT 1998] $E = E_0 \sin(kx - \omega t)$. Which of the following is independent of wavelength

(a) k (b) ω

(c) k/ω (d) $k\omega$

45. An electromagnetic wave going through vacuum is described by $E = E_0 \sin(kx - \omega t)$; $B = B_0 \sin(kx - \omega t)$. Which of the following equation is true

(a) $E_0 k = B_0 \omega$ (b) $E_0 \omega = B_0 k$

(c) $E_0 B_0 = \omega k$ (d) None of these

46. An LC resonant circuit contains a 400 pF capacitor and a 100 μH inductor. It is set into oscillation coupled to an antenna. The wavelength of the radiated electromagnetic waves is

(a) 377 mm (b) 377 *metre*

(c) 377 cm (d) 3.77 cm

47. A radio receiver antenna that is 2 m long is oriented along the direction of the electromagnetic wave and receives a signal of intensity $5 \times 10^{-16}\ W/m^2$. The maximum instantaneous potential difference across the two ends of the antenna is

(a) 1.23 μV (b) 1.23 mV

(c) 1.23 V (d) 12.3 mV

48. Television signals broadcast from the moon can be received on the earth while TV broadcast [CBSE PMT 1994] from Delhi cannot be received at places about 100 km distant from Delhi. This is because

(a) There is no atmosphere around the moon

(b) Of strong gravity effect on TV signals

(c) TV signals travel straight and cannot follow the curvature of the earth

(d) There is atmosphere around the earth

49. A TV tower has a height of 100 *m*. The average population density around the tower is 1000 per *km*. The radius of the earth is 6.4×10^6 *m*. the population covered by the tower is

(a) 2×10^6 (b) 3×10^6

(c) 4×10^6 (d) 6×10^6

50. The wavelength 21 *cm* emitted by atomic hydrogen in interstellar space belongs to

(a) Radio waves (b) Infrared waves

(c) Microwaves (d) γ-rays

51. Which scientist experimentally proved the existence of electromagnetic waves [AFMC 2004]

(a) Sir J.C. Bose (b) Maxwell

(c) Marconi (d) Hertz

52. An electromagnetic wave of frequency $\nu = 3.0\ MHz$ passes from vacuum into a dielectric medium with permitivity $\varepsilon = 4.0$. Then

(a) Wavelength is doubled and the frequency remains unchanged

(b) Wavelength is doubled and frequency becomes half

(c) Wavelength is halved and frequency remains unchanged

(d) Wavelength and frequency both remain unchanged

53. Frequency of a wave is $6\times10^{15}\,Hz$. The wave is [Orissa PMT 2004]

(a) Radiowave (b) Microwave

(c) X-ray (d) None of these

54. The region of the atmosphere above troposphere is known as

(a) Lithosphere (b) Uppersphere

(c) Ionosphere (d) Stratosphere

55. Which of the following electromagnetic waves have minimum frequency [Pb PET 2000]

(a) Microwaves (b) Audible waves

(c) Ultrasonic waves (d) Radiowaves

56. Which one of the following have minimum wavelength [Pb PET 2001]

(a) Ultraviolet rays (b) Cosmic rays

(c) *X*-rays (d) $\gamma-$rays

57. Radiations of intensity $0.5\ W/m^2$ are striking a metal plate. The pressure on the plate is [DCE 2004]

(a) $0.166\times10^{-8}\ N/m^2$ (b) $0.332\times10^{-8}\ N/m^2$

(c) $0.111\times10^{-8}\ N/m^2$ (d) $0.083\times10^{-8}\ N/m^2$

58. Electromagnetic waves travel in a medium which has relative permeability 1.3 and relative permittivity 2.14. Then the speed of the electromagnetic wave in the medium will be

(a) $13.6\times10^6\ m/s$ (b) $1.8\times10^2\ m/s$

(c) $3.6\times10^8\ m/s$ (d) $1.8\times10^8\ m/s$

59. The intensity of gamma radiation from a given source is *I*. On passing through 36 *mm* of lead, it is reduced to $\frac{I}{8}$. The thickness of lead which will reduce the intensity to $\frac{I}{2}$ will be [AIEEE 2005]

(a) 18 *mm* (b) 12 *mm*

(c) 6 *mm* (d) 9 *mm*

60. If λ_v, λ_r and λ_m represent the wavelength of visible light *x*-rays and microwaves respectively, then [CBSE PMT 2005]

(a) $\lambda_m > \lambda_x > \lambda_v$ (b) $\lambda_v > \lambda_m > \lambda_y$

(c) $\lambda_m > \lambda_v > \lambda_v$ (d) $\lambda_v > \lambda_x > \lambda_m$

61. For skywave propagation of a 10 *MHz* signal, what should be the minimum electron density in ionosphere [AFMC 2005]

(a) $\sim 1.2\times10^{12}m^{-3}$ (b) $\sim 10^6 m^{-3}$

(c) $\sim 10^{14}m^{-3}$ (d) $\sim 10^{22}m^{-3}$

62. The pressure exerted by an electromagnetic wave of intensity *I* (*watts*/*m*) on a nonreflecting surface is [*c* is the velocity of light]

(a) Ic (b) Ic^2

(c) I/c (d) I/c^2

63. Infrared radiation was discovered in 1800 by [AIEEE 2004] [KCET 2005]

(a) William Wollaston (b) William Herschel

(c) Wilhelm Roentgen (d) Thomas Young

64. Which of the following is electromagnetic wave [BCECE 2005]

(a) *X*-rays and light waves

(b) Cosmic rays and sound waves

(c) Beta rays and sound waves

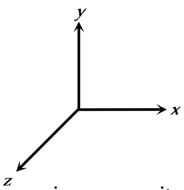
(d) Alpha rays and sound waves

65. Which one of the following is not electromagnetic in nature [Kerala PMT 2005] [BCECE 2004]

(a) *X*-rays (b) Gamma rays

(c) Cathode rays (d) Infrared rays

66. Light wave is travelling along y-direction. If the corresponding $\vec{E}$ vector at any time is along the x-axis, the direction of $\vec{B}$ vector at that time is along [UPSEAT 2005]



(a) *y*-axis

(b) *x*-axis

(c) + *z*-axis

(d) − *z* axis

67. If *c* is the speed of electromagnetic waves in vacuum, its speed in a medium of dielectric constant *K* and relative permeability μ_r is [MH CET 2003]

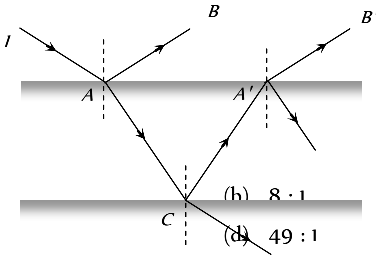
(a) $v = \frac{1}{\sqrt{\mu_r K}}$ (b) $v = c\sqrt{\mu_r K}$

(c) $v = \frac{c}{\sqrt{\mu_r K}}$ (d) $v = \frac{K}{\sqrt{\mu_r C}}$

Critical Thinking

Objective Questions

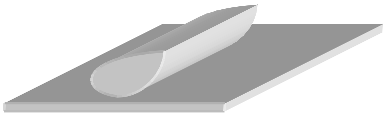
1. A ray of light of intensity I is incident on a parallel glass-slab at a point A as shown in fig. It undergoes partial reflection and refraction. At each reflection 25% of incident energy is reflected. The rays AB and $A'B'$ undergo interference. The ratio I_{max} / I_{min} is



(a) 4 : 1 (b) 8 : 1

(c) 7 : 1 (d) 49 : 1

2. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate as shown. The observed interference fringes from this combination shall be



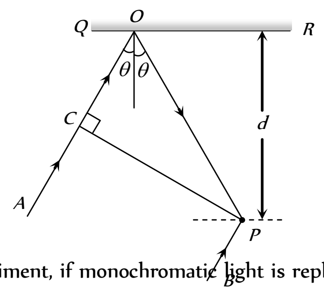
(a) Straight

(b) Circular

(c) Equally spaced

(d) Having fringe spacing which increases as we go outwards

3. In the adjacent diagram, CP represents a wavefront and AO & BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray OP



(a) $\cos\theta = 3\lambda/2d$

(b) $\cos\theta = \lambda/4d$

(c) $\sec\theta - \cos\theta = \lambda/d$

(d) $\sec\theta - \cos\theta = 4\lambda/d$

4. In Young's double slit experiment, if monochromatic light is replaced by white light

[AIIMS 2001; Kerala PET 2000; KCET 2004]

(a) All bright fringes become white

(b) All bright fringes have colours between violet and red

(c) Only the central fringe is white, all other fringes are coloured

(d) No fringes are observed

5. In Young's double slit experiment, if the two slits are illuminated with separate sources, no interference pattern is observed because

(a) There will be no constant phase difference between the two waves

(b) The wavelengths are not equal

(c) The amplitudes are not equal

(d) None of the above

6. In Young's double slit experiment, white light is used. The separation between the slits is b. The screen is at a distance d ($d >> b$) from the slits. Some wavelengths are missing exactly in front of one slit. These wavelengths are

[IIT 1984; AIIMS 1995]

(a) $\lambda = \dfrac{b^2}{d}$ (b) $\lambda = \dfrac{2b^2}{d}$

(c) $\lambda = \dfrac{b^2}{3d}$ (d) $\lambda = \dfrac{2b^2}{3d}$

[IIT 1990]

7. In a Young's double slit experiment the source S and the two slits A and B are vertical with slit A above slit B. The fringes are observed on a vertical screen K. The optical path length from S to B is increased very slightly (by introducing a transparent material of higher refractive index) and the optical path length from S to A is not changed, as a result the fringe system on K moves

(a) Vertically downwards slightly

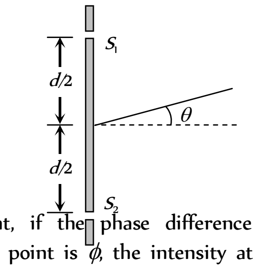
(b) Vertically upwards slightly

(c) Horizontally, slightly to the left

(d) Horizontally, slightly to the right

[IIT-JEE (Screening)1999]

8. In an interference arrangement similar to Young's double slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources each of frequency 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by distance d = 150 m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is maximum intensity, then $I(\theta)$ for $0 \le \theta \le 90^o$ is given by



(a) $I(\theta) = I_0$ for $\theta = 0^o$

(b) $I(\theta) = I_0 / 2$ for $\theta = 30^o$

(c) $I(\theta) = I_0 / 4$ for $\theta = 90^o$

(d) $I(\theta)$ is constant for all values of θ

[IIT-JEE (Screening) 2003]

9. In the Young's double slit experiment, if the phase difference between the two waves interfering at a point is ϕ, the intensity at that point can be expressed by the expression

[MP PET 1998; MP PMT 2003]

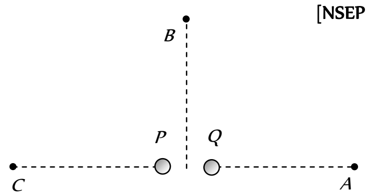
(a) $I = \sqrt{A^2 + B^2 \cos^2 \phi}$ (b) $I = \dfrac{A}{B}\cos\phi$

(c) $I = A + B\cos\dfrac{\phi}{2}$ (d) $I = A + B\cos\phi$

Where A and B depend upon the amplitudes of the two waves.

10. Figure here shows P and Q as two equally intense coherent sources emitting radiations of wavelength 20 m. The separation PQ is 5.0 m and phase of P is ahead of the phase of Q by 90°. A, B and C are three distant points of observation equidistant from the mid-point of PQ. The intensity of radiations at A, B, C will bear the ratio

[NSEP 1994]



(a) 0 : 1 : 4

(b) 4 : 1 : 0

(c) 0 : 1 : 2

(d) 2 : 1 : 0

11. In Young's double slit experiment, the intensity on the screen at a point where path difference is λ is K. What will be the intensity at the point where path difference is $\lambda / 4$

[RPET 1996]

(a) $\dfrac{K}{4}$ (b) $\dfrac{K}{2}$

(c) K (d) Zero

12. When one of the slits of Young's experiment is covered with a transparent sheet of thickness 4.8 *mm*, the central fringe shifts to a position originally occupied by the 30th bright fringe. What should be the thickness of the sheet if the central fringe has to shift to the position occupied by 20th bright fringe

(a) 3.8 *mm* (b) 1.6 *mm*

(c) 7.6 *mm* (d) 3.2 *mm*

13. In the ideal double-slit experiment, when a glass-plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wavelength λ), the intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass-plate is [IIT-JEE (Screening) 2002]

(a) 2λ (b) $\frac{2\lambda}{3}$

(c) $\frac{\lambda}{3}$ (d) λ

14. The time period of rotation of the sun is 25 days and its radius is $7\times10^8 m$. The Doppler shift for the light of wavelength 6000 Å emitted from the surface of the sun will be [MP PMT 1994]

(a) 0.04 Å (b) 0.40 Å

(c) 4.00 Å (d) 40.0 Å

15. In hydrogen spectrum the wavelength of H_α line is 656 *nm* whereas in the spectrum of a distant galaxy, H_α line wavelength is 706 *nm*. Estimated speed of the galaxy with respect to earth is [IIT-JEE 1999; UPSEAT 2003]

(a) $2\times10^8 m/s$ (b) $2\times10^7 m/s$

(c) $2\times10^6 m/s$ (d) $2\times10^5 m/s$

16. A rocket is going towards moon with a speed *v*. The astronaut in the rocket sends signals of frequency ν towards the moon and receives them back on reflection from the moon. What will be the frequency of the signal received by the astronaut (Take *v*<<*c*) [RPMT 1996; DPMT 2000]

(a) $\frac{c}{c-v}\nu$ (b) $\frac{c}{c-2v}\nu$

(c) $\frac{2v}{c}\nu$ (d) $\frac{2c}{v}\nu$

17. The periodic time of rotation of a certain star is 22 days and its radius is 7×10^8 *metres*. If the wavelength of light emitted by its surface be 4320 Å, the Doppler shift will be (1 day = 86400 *sec*) [MP PET 2001]

(a) 0.033 Å (b) 0.33 Å

(c) 3.3 Å (d) 33 Å

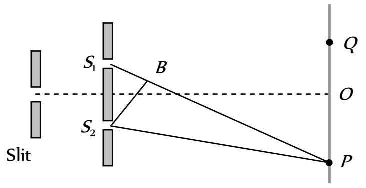
18. In a two slit experiment with monochromatic light fringes are obtained on a screen placed at some distance from the sits. If the screen is moved by $5\times10^{-2}m$ towards the slits, the change in fringe width is $3\times10^{-5}m$. If separation between the slits is $10^{-3}m$, the wavelength of light used is

[Roorkee 1992]

(a) 6000 *Å* (b) 5000 *Å*

(c) 3000 *Å* (d) 4500 *Å*

19. In the figure is shown Young's double slit experiment. Q is the position of the first bright fringe on the right side of O. P is the 11th fringe on the other side, as measured from Q. If the wavelength of the light used is $6000\times10^{-10}m$, then S_1B will be equal to [KCET 2002]



(a) $6\times10^{-6}m$

(b) $6.6\times10^{-6}m$

(c) $3.138\times10^{-7}m$

(d) $3.144\times10^{-7}m$

20. In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and wavelength λ. In another experiment with the same set up the two slits are of equal amplitude A and wavelength λ but are incoherent. The ratio of the intensity of light at the mid-point of the screen in the first case to that in the second case is

[IIT-JEE 1986; RPMT 2002]

(a) 1 : 2 (b) 2 : 1

(c) 4 : 1 (d) 1 : 1

21. Four light waves are represented by

(i) $y = a_1 \sin\omega t$ (ii) $y = a_2 \sin(\omega t+\phi)$

(iii) $y = a_1 \sin 2\omega t$ (iv) $y = a_2 \sin 2(\omega t+\phi)$

Interference fringes may be observed due to superposition of

(a) (i) and (ii) (b) (i) and (iii)

(c) (ii) and (iv) (d) (iii) and (iv)

22. In Young's double slit experiment the *y*-coordinates of central maxima and 10th maxima are 2 *cm* and 5 *cm* respectively. When the YDSE apparatus is immersed in a liquid of refractive index 1.5 the corresponding *y*-coordinates will be

(a) 2 *cm*, 7.5 *cm*

(b) 3 *cm*, 6 *cm*

(c) 2 *cm*, 4 *cm*

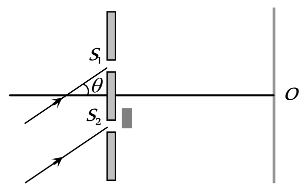
(d) 4/3 *cm*, 10/3 *cm*

23. The maximum intensity in Young's double slit experiment is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance $D = 10\,d$

(a) $\frac{I_0}{2}$ (b) $\frac{3}{4}I_0$

(c) I_0 (d) $\frac{I_0}{4}$

24. A monochromatic beam of light falls on YDSE apparatus at some angle (say θ) as shown in figure. A thin sheet of glass is inserted in front of the lower slit S_2. The central bright fringe (path difference = 0) will be obtained



(a) At O

(b) Above O

(c) Below O

(d) Anywhere depending on angle θ, thickness of plate t and refractive index of glass μ

25. In Young's double slit experiment how many maximas can be obtained on a screen (including the central maximum) on both sides of the central fringe if $\lambda = 2000\,Å$ and $d = 7000\,Å$

(a) 12 (b) 7

(c) 18 (d) 4

26. In a Young's double slit experiment, the slits are 2 mm apart and are illuminated with a mixture of two wavelength $\lambda_0 = 750nm$ and $\lambda = 900nm$. The minimum distance from the common central bright fringe on a screen $2m$ from the slits where a bright fringe from one interference pattern coincides with a bright fringe from the other is

(a) 1.5 mm (b) 3 mm

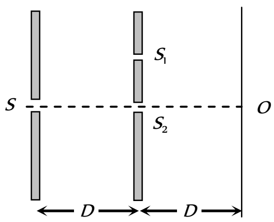
(c) 4.5 mm (d) 6 mm

27. A flake of glass (refractive index 1.5) is placed over one of the openings of a double slit apparatus. The interference pattern displaces itself through seven successive maxima towards the side where the flake is placed. if wavelength of the diffracted light is $\lambda = 600nm$, then the thickness of the flake is

(a) 2100 nm (b) 4200 nm

(c) 8400 nm (d) None of these

28. Two ideal slits S_1 and S_2 are at a distance d apart, and illuminated by light of wavelength λ passing through an ideal source slit S placed on the line through S_2 as shown. The distance between the planes of slits and the source slit is D. A screen is held at a distance D from the plane of the slits. The minimum value of d for which there is darkness at O is



(a) $\sqrt{\frac{3\lambda D}{2}}$

(b) $\sqrt{\lambda D}$

(c) $\sqrt{\frac{\lambda D}{2}}$

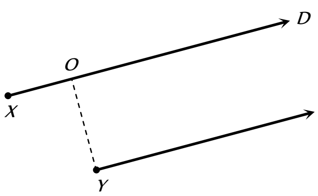
(d) $\sqrt{3\lambda D}$

29. In a double slit arrangement fringes are produced using light of wavelength 4800 $Å$. One slit is covered by a thin plate of glass of refractive index 1.4 and the other with another glass plate of same thickness but of refractive index 1.7. By doing so the central bright shifts to original fifth bright fringe from centre. Thickness of glass plate is

(a) 8 μm (b) 6 μm

(c) 4 μm (d) 10 μm

30. Two point sources X and Y emit waves of same frequency and speed but Y lags in phase behind X by $2\pi l$ radian. If there is a maximum in direction D the distance XO using n as an integer is given by



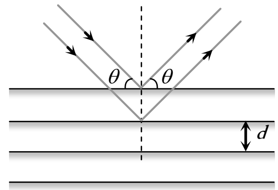
(a) $\frac{\lambda}{2}(n - l)$

(b) $\lambda(n + l)$

(c) $\frac{\lambda}{2}(n + l)$

(d) $\lambda(n - l)$

31. A beam with wavelength λ falls on a stack of partially reflecting planes with separation d. The angle θ that the beam should make with the planes so that the beams reflected from successive planes may interfere constructively is (where n =1, 2, ...)



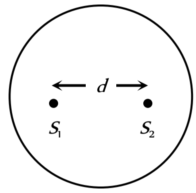
(a) $\sin^{-1}\left(\frac{n\lambda}{d}\right)$

(b) $\tan^{-1}\left(\frac{n\lambda}{d}\right)$

(c) $\sin^{-1}\left(\frac{n\lambda}{2d}\right)$

(d) $\cos^{-1}\left(\frac{n\lambda}{2d}\right)$

32. Two coherent sources separated by distance d are radiating in phase having wavelength λ. A detector moves in a big circle around the two sources in the plane of the two sources. The angular position of n = 4 interference maxima is given as



(a) $\sin^{-1}\frac{n\lambda}{d}$

(b) $\cos^{-1}\frac{4\lambda}{d}$

(c) $\tan^{-1}\frac{d}{4\lambda}$

(d) $\cos^{-1}\frac{\lambda}{4d}$

33. Two coherent sources S_1 and S_2 are separated by a distance four times the wavelength λ of the source. The sources lie along y axis whereas a detector moves along + x axis. Leaving the origin and far off points the number of points where maxima are observed is

(a) 2 (b) 3

(c) 4 (d) 5

34. A circular disc is placed in front of a narrow source. When the point of observation is at a distance of 1 $meter$ from the disc, then the disc covers first HPZ. The intensity at this point is I_0. The intensity at a point distance 25 cm from the disc will be

(a) $I_1 = 0.531I_0$ (b) $I_1 = 0.053I_0$

(c) $I_1 = 53I_0$ (d) $I_1 = 5.03I_0$

35. A wavefront presents one, two and three HPZ at points A, B and C respectively. If the ratio of consecutive amplitudes of HPZ is 4 : 3, then the ratio of resultant intensities at these point will be

(a) 169 : 16 : 256 (b) 256 : 16 : 169

(c) 256 : 16 : 196 (d) 256 : 196 : 16

36. A circular disc is placed in front of a narrow source. When the point of observation is 2 m from the disc, then it covers first HPZ. The intensity at this point is I. When the point of observation is 25 cm from the disc then intensity will be

(a) $\left(\frac{R_6}{R_2}\right)^2 I$ (b) $\left(\frac{R_7}{R_2}\right)^2 I$

(c) $\left(\frac{R_8}{R_2}\right)^2 I$ (d) $\left(\frac{R_9}{R_2}\right)^2 I$

37. In a single slit diffraction of light of wavelength λ by a slit of width e, the size of the central maximum on a screen at a distance b is

(a) $2b\lambda + e$ (b) $\frac{2b\lambda}{e}$

(c) $\frac{2b\lambda}{e} + e$ (d) $\frac{2b\lambda}{e} - e$

38. Angular width of central maxima in the Fraunhoffer diffraction pattern of a slit is measured. The slit is illuminated by light of wavelength 6000 Å. When the slit is illuminated by light of another wavelength, the angular width decreases by 30%. The wavelength of this light will be

(a) 6000 Å (b) 4200 Å

(c) 3000 Å (d) 1800 Å

39. In a single slit diffraction experiment first minimum for red light (660 *nm*) coincides with first maximum of some other wavelength λ'. The value of λ' is

(a) 4400 Å (b) 6600 Å

(c) 2000 Å (d) 3500 Å

40. The ratio of intensities of consecutive maxima in the diffraction pattern due to a single slit is

(a) 1 : 4 : 9 (b) 1 : 2 : 3

(c) $1 : \frac{4}{9\pi^2} : \frac{4}{25\pi^2}$ (d) $1 : \frac{1}{\pi^2} : \frac{9}{\pi^2}$

41. Light is incident normally on a diffraction grating through which the first order diffraction is seen at 32°. The second order diffraction will be seen at

(a) 48°

(b) 64°

(c) 80°

(d) There is no second order diffraction in this case

42. White light may be considered to be a mixture of waves with λ ranging between 3900 Å and 7800 Å. An oil film of thickness 10,000 Å is examined normally by reflected light. If μ = 1.4, then the film appears bright for

(a) 4308 Å, 5091 Å, 6222 Å

(b) 4000 Å, 5091 Å, 5600 Å

(c) 4667 Å, 6222 Å, 7000 Å

(d) 4000 Å, 4667 Å, 5600 Å, 7000Å

43. Among the two interfering monochromatic sources *A* and *B*; *A* is ahead of *B* in phase by 66°. If the observation be taken from point *P*, such that *PB* – *PA* = λ/4. Then the phase difference between the waves from *A* and *B* reaching *P* is

(a) 156° (b) 140°

(c) 136° (d) 126°

44. The ratio of the intensity at the centre of a bright fringe to the intensity at a point one-quarter of the distance between two fringe from the centre is

(a) 2 (b) 1/2

(c) 4 (d) 16

45. A parallel plate capacitor of plate separation 2 *mm* is connected in an electric circuit having source voltage 400 *V*. if the plate area is 60 *cm*, then the value of displacement current for 10^{-6} sec will be

(a) 1.062 *amp* (b) 1.062×10^{-2} *amp*

(c) 1.062×10^{-3} *amp* (d) 1.062×10^{-4} *amp*

46. A long straight wire of resistance *R*, radius *a* and length *l* carries a constant current *I*. The Poynting vector for the wire will be

(a) $\frac{IR}{2\pi a l}$ (b) $\frac{IR^2}{al}$

(c) $\frac{I^2R}{al}$ (d) $\frac{I^2R}{2\pi a l}$

47. In an electromagnetic wave, the amplitude of electric field is 1 *V/m*. the frequency of wave is 5×10^{14} Hz. The wave is propagating along *z*-axis. The average energy density of electric field, in *Joule/m*, will be

(a) 1.1×10^{-11} (b) 2.2×10^{-12}

(c) 3.3×10^{-13} (d) 4.4×10^{-14}

48. A laser beam can be focussed on an area equal to the square of its wavelength *A He-Ne* laser radiates energy at the rate of 1*mW* and its wavelength is 632.8 *nm*. The intensity of focussed beam will be

(a) 1.5×10^{13} W/m^2 (b) 2.5×10^{9} W/m^2

(c) 3.5×10^{17} W/m^2 (d) None of these

49. A lamp emits monochromatic green light uniformly in all directions. The lamp is 3% efficient in converting electrical power to electromagnetic waves and consumes 100 *W* of power. The amplitude of the electric field associated with the electromagnetic radiation at a distance of 10*m* from the lamp will be

(a) 1.34 *V/m* (b) 2.68 *V/m*

(c) 5.36 *V/m* (d) 9.37 *V/m*

50. A point source of electromagnetic radiation has an average power output of 800 *W*. The maximum value of electric field at a distance 4.0 *m* from the source is

(a) 64.7 *V/m* (b) 57.8 *V/m*

(c) 56.72 *V/m* (d) 54.77 *V/m*

51. A wave is propagating in a medium of electric dielectric constant 2 and relative magnetic permeability 50. The wave impedance of such a medium is

(a) 5 Ω (b) 376.6 Ω

(c) 1883 Ω (d) 3776 Ω

52. A plane electromagnetic wave of wave intensity 6 *W/m* strikes a small mirror area 40 *cm*, held perpendicular to the approaching wave. The momentum transferred by the wave to the mirror each second will be

(a) $6.4 \times 10^{-7} kg - m/s^2$ (b) $4.8 \times 10^{-8} kg - m/s^2$

(c) $3.2 \times 10^{-9} kg - m/s^2$ (d) $1.6 \times 10^{-10} kg - m/s^2$

53. Specific rotation of sugar solution is 0.01 SI units. 200 kgm^{-3} of impure sugar solution is taken in a polarimeter tube of length 0.25m and an optical rotation of 0.4*rad* is observed. The percentage of purity of sugar is the sample is

[KCET 2004]

(a) 80% (b) 89%

(c) 11% (d) 20%

54. A 20 *cm* length of a certain solution causes right-handed rotation of 38°. A 30*cm* length of another solution causes left-handed rotation of 24°. The optical rotation caused by 30*cm* length of a mixture of the above solutions in the volume ratio 1 : 2 is

(a) Left handed rotation of 14°

(b) Right handed rotation of 14°

(c) Left handed rotation of 3°

(d) Right handed rotation of 3°

55. A beam of natural light falls on a system of 6 polaroids, which are arranged in succession such that each polaroid is turned through 30° with respect to the preceding one. The percentage of incident intensity that passes through the system will be

(a) 100% (b) 50%

(c) 30% (d) 12%

56. A beam of plane polarized light falls normally on a polarizer of cross sectional area $3\times10^{-4} m^2$. Flux of energy of incident ray in 10^{-3} *W*. The polarizer rotates with an angular frequency of 31.4 *rad/sec*. The energy of light passing through the polarizer per revolution will be

(a) 10^{-4} *Joule* (b) 10^{-3} *Joule*

(c) 10^{-2} *Joule* (d) 10^{-1} *Joule*

57. In a YDSE bi-chromatic light of wavelengths 400 *nm* and 560 *nm* are used. The distance between the slits is 0.1 *mm* and the distance between the plane of the slits and the screen is 1*m*. The minimum distance between two successive regions of complete darkness is

[IIT JEE (Screening) 2004]

(a) 4 *mm* (b) 5.6 *mm*

(c) 14 *mm* (d) 28 *mm*

58. The maximum number of possible interference maxima for slit-separation equal to twice the wavelength in Young's double-slit experiment is **[AIEEE 2004]**

(a) Infinite (b) Five

(c) Three (d) Zero

59. The *k* line of singly ionised calcium has a wavelength of 393.3 *nm* as measured on earth. In the spectrum of one of the observed galaxies, this spectral line is located at 401.8 *nm*. The speed with which the galaxy is moving away from us, will be

[Pb. PET 2003]

(a) 6480 *km/s* (b) 3240 *km/s*

(c) 4240 *km/sec* (d) None of these

60. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is

[AIEEE 2005]

(a) Straight line (b) Parabola

(c) Hyperbola (d) Circle

61. If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled **[AIEEE 2005]**

(a) I_0 (b) $\frac{I_0}{2}$

(c) $2I_0$ (d) $4\,I_0$

62. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is

[IIT-JEE (Screening) 2005]

(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$

(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

63. A beam of electron is used in an *YDSE* experiment. The slit width is d. When the velocity of electron is increased, then

[IIT-JEE (Screening) 2005]

(a) No interference is observed

(b) Fringe width increases

[KCET 2001]

(c) Fringe width decreases

(d) Fringe width remains same

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
   Reason : The energy of a wave is proportional to velocity of wave.
2. Assertion : A narrow pulse of light is sent through a medium. The pulse will retain its shape as it travels through the medium.
   Reason : A narrow pulse is made of harmonic waves with a large range of wavelengths.
3. Assertion : No interference pattern is detected when two coherent sources are infinitely close to each other.
   Reason : The fringe width is inversely proportional to the distance between the two slits.
4. Assertion : Newton's rings are formed in the reflected system. When the space between the lens and the glass plate is filled with a liquid of refractive index greater than that of glass, the central spot of the pattern is dark.
   Reason : The reflection is Newton's ring cases will be from a denser to a rarer medium and the two interfering rays are reflected under similar conditions. **[AIIMS 1998]**
5. Assertion : The film which appears bright in reflected system will appear dark in the transmitted light and vice-versa.
   Reason : The conditions for film to appear bright or dark in reflected light are just reverse to those in the transmitted light.
6. Assertion : For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of light emerging out of the two slits should be equal.
   Reason : The intensity of interference pattern is proportional to square of amplitude.
7. Assertion : In Young's double slit experiment, the fringes become indistinct if one of the slits is covered with cellophane paper.
   Reason : The cellophane paper decrease the wavelength of light.
8. Assertion : The unpolarised light and polarised light can be distinguished from each other by using polaroid.
   Reason : A polaroid is capable of producing plane polarised beams of light.
9. Assertion : Nicol prism is used to produce and analyse plane polarised light.
   Reason : Nicol prism reduces the intensity of light to zero.
10. Assertion : In everyday life the Doppler's effect is observed readily for sound waves than light waves.

Reason : Velocity of light is greater than that of sound. **[AIIMS 1995]**

11. Assertion : In Young's experiment, the fringe width for dark fringes is different from that for white fringes.

Reason : In Young's double slit experiment the fringes are performed with a source of white light, then only black and bright fringes are observed. **[AIIMS 2001]**

12. Assertion : Coloured spectrum is seen when we look through a muslin cloth.

Reason : It is due to the diffraction of white light on passing through fine slits. **[AIIMS 2002]**

13. Assertion : When a tiny circular obstacle is placed in the path of light from some distance, a bright spot is seen at the centre of shadow of the obstacle.

Reason : Destructive interference occurs at the centre of the shadow. **[AIIMS 2002]**

14. Assertion : Thin films such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light.

Reason : It happens due to the interference of light reflected from the upper surface of the thin film. **[AIIMS 2002]**

15. Assertion : Microwave communication is preferred over optical communication.

Reason : Microwaves provide large number of channels and band width compared to optical signals. **[AIIMS 2003]**

16. Assertion : Corpuscular theory fails in explaining the velocities of light in air and water.

Reason : According to corpuscular theory, light should travel faster in denser medium than, in rarer medium. **[AIIMS 1998]**

17. Assertion : Interference pattern is made by using blue light instead of red light, the fringes becomes narrower.

Reason : In Young's double slit experiment, fringe width is given by relation $B = \frac{\lambda D}{d}$.

[AIIMS 1999]

18. Assertion : The cloud in sky generally appear to be whitish.

Reason : Diffraction due to clouds is efficient in equal measure at all wavelengths. **[AIIMS 2005]**

19. Assertion : Television signals are received through sky-wave propagation.

Reason : The ionosphere reflects electromagnetic waves of frequencies greater than a certain critical frequency. **[AIIMS 2005]**

20. Assertion : It is necessary to use satellites for long distance T.V. transmission.

Reason : The television signals are low frequency signals.

21. Assertion : The electrical conductivity of earth's atmosphere decrease with altitude.

Reason : The high energy particles (*i.e.* γ-rays and cosmic rays) coming from outer space and entering our earth's atmosphere causes ionisation of the atoms of the gases present there and the pressure of gases decreases with increase in altitude.

22. Assertion : Only microwaves are used in radar.

Reason : Because microwaves have very small wavelength.

23. Assertion : In Hertz experiment, the electric vector of radiation produced by the source gap is parallel to the gap.

Reason : Production of sparks between the detector gap is maximum when it is placed perpendicular to the source gap.

24. Assertion : For cooking in a microwave oven, food is always kept in metal containers.

Reason : The energy of microwave is easily transferred to the food in metal container.

25. Assertion : *X*-ray astronomy is possible only from satellites orbiting the earth.

Reason : Efficiency of *X*-rays telescope is large as compared to any other telescope.

26. Assertion : Short wave bands are used for transmission of ratio waves to a large distance

Reason : Short waves are reflected by ionosphere

[AIIMS 1994]

27. Assertion : Ultraviolet radiation are of higher frequency waves are dangerous to human being.

Reason : Ultraviolet radiation are absorbed by the atmosphere **[AIIMS 1995]**

28. Assertion : Environmental damage has increased the amount of ozone in the atmosphere.

Reason : Increase of ozone increases the amount of ultraviolet radiation on earth. **[AIIMS 1996]**

29. Assertion : Radio waves can be polarised.

Reason : Sound waves in air are longitudinal in nature.

[AIIMS 1998]

30. Assertion : The earth without atmosphere would be inhospitably cold.

Reason : All heat would escape in the absence of atmosphere. **[AIIMS 2002]**

Answers

Wave Nature and Interference of Light

1	a	2	c	3	b	4	c	5	d
6	c	7	d	8	c	9	c	10	b
11	a	12	d	13	c	14	a	15	d
16	a	17	c	18	b	19	c	20	b
21	c	22	c	23	a	24	c	25	a
26	a	27	b	28	b	29	c	30	a
31	b	32	d	33	d	34	a	35	a
36	c	37	b	38	c	39	b	40	c
41	d	42	b	43	b	44	c	45	d
46	c	47	d	48	b	49	c	50	a
51	d	52	c	53	d	54	c	55	b
56	a	57	c	58	d	59	d	60	b
61	b	62	a	63	c	64	d	65	d
66	c	67	a	68	a	69	a	70	c
71	b	72	d						

Young's Double Slit Experiment

1	a	2	c	3	c	4	c	5	a
6	c	7	a	8	c	9	a	10	d
11	d	12	c	13	bd	14	b	15	c
16	c	17	a	18	a	19	a	20	b
21	a	22	c	23	d	24	c	25	d
26	a	27	b	28	c	29	d	30	d
31	d	32	a	33	b	34	b	35	a
36	b	37	b	38	d	39	b	40	a
41	b	42	d	43	d	44	a	45	b
46	d	47	d	48	b	49	b	50	a
51	bc	52	b	53	d	54	a	55	a

56	b	57	c	58	c	59	c	60	b
61	b	62	c	63	b	64	d	65	b
66	a	67	c	68	b	69	a	70	b
71	d	72	b	73	b	74	b	75	c
76	d	77	a	78	c	79	b	80	a
81	b	82	b	83	d	84	a	85	a
86	b	87	b	88	d	89	b	90	a
91	a	92	c	93	a	94	a	95	b
96	b	97	d						

Doppler's Effect of Light

1	d	2	a	3	b	4	b	5	b
6	b	7	b	8	d	9	c	10	c
11	a	12	c	13	b	14	a	15	a
16	d	17	b	18	c	19	b	20	d
21	b	22	b	23	c	24	c	25	b
26	b	27	c	28	b	29	a	30	d
31	c	32	a	33	a				

Diffraction of Light

1	c	2	a	3	b	4	c	5	c
6	a	7	a	8	a	9	c	10	b
11	a	12	b	13	a	14	d	15	a
16	b	17	a	18	a	19	a	20	d
21	a	22	a	23	c	24	b	25	d
26	a	27	d	28	d	29	b	30	d
31	d	32	d	33	b	34	a	35	c
36	c	37	a	38	c	39	a	40	b
41	c								

Polarisation of Light

1	b	2	a	3	c	4	d	5	d
6	d	7	b	8	d	9	a	10	c
11	a	12	d	13	a	14	a	15	c
16	d	17	d	18	d	19	b	20	c
21	c	22	d	23	a	24	c	25	b
26	b	27	b	28	c	29	a	30	b
31	a	32	a	33	c	34	a	35	d

EM Waves

1	a	2	d	3	b	4	d	5	b
6	b	7	a	8	d	9	c	10	a
11	a	12	c	13	a	14	b	15	b
16	d	17	b	18	d	19	a	20	c
21	a	22	d	23	c	24	b	25	a
26	a	27	c	28	c	29	a	30	b
31	c	32	a	33	d	34	a	35	d
36	c	37	b	38	a	39	a	40	d
41	a	42	b	43	b	44	c	45	a
46	b	47	a	48	c	49	c	50	a
51	c	52	c	53	d	54	d	55	b
56	b	57	a	58	d	59	b	60	c
61	a	62	c	63	b	64	a	65	c
66	d	67	c						

Critical Thinking Questions

1	d	2	a	3	b	4	c	5	a
6	ac	7	a	8	ab	9	d	10	d
11	b	12	d	13	a	14	a	15	b
16	b	17	a	18	a	19	a	20	b
21	ad	22	c	23	a	24	d	25	b
26	c	27	c	28	c	29	a	30	b
31	c	32	b	33	b	34	a	35	b
36	d	37	c	38	b	39	a	40	c
41	d	42	a	43	a	44	a	45	b
46	d	47	b	48	b	49	a	50	d
51	c	52	d	53	a	54	d	55	d
56	a	57	d	58	b	59	a	60	c
61	d	62	c	63	b				

Assertion and Reason

1	d	2	e	3	b	4	a	5	a
6	b	7	c	8	a	9	c	10	b
11	d	12	a	13	c	14	c	15	a
16	a	17	a	18	c	19	d	20	c
21	e	22	a	23	c	24	d	25	c
26	b	27	b	28	d	29	b	30	a

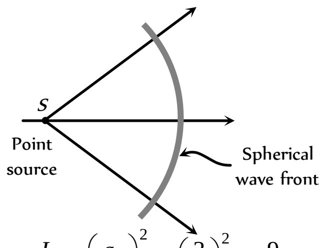
Answers and Solutions

Wave Nature and Interference of Light

1. (a) Corpuscular theory explains refraction of light.
2. (c) According to Corpuscular theory different colour of light are due to different size of Corpuscules.
3. (b)
4. (c) According to Plank's hypothesis, black bodies emits radiations in the form of photons.
5. (d) The coherent source cannot be obtained from two different light sources.
6. (c) Huygen's wave theory fails to explain the particle nature of light (*i.e.* photoelectric effect)
7. (d) Interference is shown by transverse as well as mechanical waves.
8. (c) $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (\sqrt{I} + \sqrt{4I})^2 = 9I$

   $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2 = (\sqrt{I} - \sqrt{4I})^2 = I$
9. (c)
10. (b) The idea of secondary wavelets is given by Huygen.
11. (c) Monochromatic wave means of single wavelength not the single colour.
12. (d) Sound wave and light waves both shows interference.
13. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 = \left(\frac{\sqrt{\frac{9}{1}}+1}{\sqrt{\frac{9}{1}}-1}\right) = \frac{4}{1}$
14. (a) A wave can transmit energy from one place to another.
15. (d) $\frac{I_1}{I_2} = \frac{1}{25}$; $\therefore \frac{a_1^2}{a_2^2} = \frac{1}{25} \Rightarrow \frac{a_1}{a_2} = \frac{1}{5}$
16. (a) For interference phase difference must be constant.
17. (c) Interference is explained by wave nature of light.
18. (b) Coherent time $= \frac{\text{Coherence length}}{\text{Velocity of light}} = \frac{L}{c}$
19. (c) $\frac{a_1}{a_2} = \frac{3}{5}$

    $\therefore \frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(3+5)^2}{(3-5)^2} = \frac{16}{1}$
20. (b) Colour's of thin film are due to interference of light.
21. (c) For constructive interference path difference is even multiple of $\frac{\lambda}{2}$.
22. (c) Two coherent source must have a constant phase difference otherwise they can not produce interference.
23. (a) Phenomenon of interference of light takes place.
24. (c) Transverse waves can be polarised.
25. (a) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 = \left(\frac{\sqrt{\frac{4}{1}}+1}{\sqrt{\frac{4}{1}}-1}\right)^2 = \frac{9}{1}$
26. (a) Reflection phenomenon is shown by both particle and wave nature of light.
27. (b) When two sources are obtained from a single source, the wavefront is divided into two parts. These two wavefronts acts as if they emanated from two sources having a fixed phase relationship.
28. (b) $\lambda = \frac{c}{\nu} = \frac{3\times10^8}{100} = 3\times10^6 m$
29. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 = \left(\frac{\sqrt{\frac{25}{4}}+1}{\sqrt{\frac{25}{4}}-1}\right)^2 = \frac{49}{9}$
30. (a) Wavefront is the locus of all the particles which vibrates in the same phase.
31. (b) Direction of wave is perpendicular to the wavefront.
32. (d) Origin of spectra is not explained by Huygen's theory.
33. (d) The refractive index of air is slightly more than 1. When chamber is evacuated, refractive index decreases and hence the wavelength increases and fringe width also increases.
34. (a) $I \propto a^2 \Rightarrow \frac{a_1}{a_2} = \left(\frac{4}{1}\right)^{1/2} = \frac{2}{1}$
35. (a) The essential condition for sustained interference is constancy of phase difference.
36. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \left(\frac{\frac{4}{3}+1}{\frac{4}{3}-1}\right)^2 = \frac{49}{1}$
37. (b) Energy is conserved in the interference of light.
38. (c) $I \propto a^2$
39. (b)



40. (c) $I \propto a^2 \Rightarrow \frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$
41. (d) $\frac{I_1}{I_2} = \frac{100}{1}$

Now $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 = \left(\frac{\sqrt{100}+1}{\sqrt{100}-1}\right)^2 = \frac{121}{81} \approx \frac{3}{2}$

42. (b) $\phi = \pi/3, a_1 = 4, a_2 = 3$

So, $A = \sqrt{a_1^2 + a_2^2 + 2a_1.a_2 \cos\phi} \Rightarrow A \approx 6$

43. (b) $y_1 = a\sin\omega t$, and $y_2 = b\cos\omega t = b\sin\left(\omega t + \frac{\pi}{2}\right)$

So phase difference $\phi = \pi/2$

44. (c) For 2π phase difference $\rightarrow$ Path difference is λ

$\therefore$ For ϕ phase difference $\rightarrow$ Path difference is $\frac{\lambda}{2\pi}\times\phi$

45. (d) Resultant intensity $I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

For maximum I_R, $\phi = 0^o$

$\Rightarrow I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

46. (c) Newton first law of motion states that every particle travels in a straight line with a constant velocity unless disturbed by an external force. So the corpuscles travels in straight lines.

47. (d) Diffraction shows the wave nature of light and photoelectric effect shows particle nature of light.

48. (b) At point *A*, resultant intensity

$I_A = I_1 + I_2 = 5I$; and at point *B*

$I_B = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\pi = 5I + 4I$

$I_B = 9I$ so $I_B - I_A = 4I$.

49. (c)

50. (a) Photoelectric effect varifies particle nature of light. Reflection and refraction varifies both particle nature and wave nature of light.

51. (d) $y_1 = a\sin\omega t, y_2 = a\cos\omega t = a\sin\left(\omega t + \frac{\pi}{2}\right)$

52. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \frac{25}{1}$

53. (d) Laser beams are perfectly parallel. So that they are very narrow and can travel a long distance without spreading. This is the feature of laser while they are monochromatic and coherent these are characteristics only.

54. (c) $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right)^2 \Rightarrow \frac{I_1}{I_2} = \frac{9}{4}$

55. (b) $\nu = \frac{c}{\lambda} = \frac{3\times10^8}{3000\times10^{-10}} = 10^{15}$ *cycles/sec*

56. (a) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 = \left(\frac{\frac{1}{9}+1}{\frac{1}{9}-1}\right)^2 = \left(\frac{5}{4}\right)^2 = \frac{25}{16}$.

57. (c)

58. (d) For destructive interference path difference is odd multiple of $\frac{\lambda}{2}$.

59. (d) $\frac{I_{max}}{I_{min}} = \left(\frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1}\right)^2 \Rightarrow \frac{a_1+a_2}{a_1-a_2} = 6$

$\frac{a_2}{a_1} = 7:5$

60. (b) $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

So, $I_{max} = I + 4I + 2\sqrt{I.4I} = 9I$

61. (b) In interference energy is redistribution.

62. (a) For interference frequency must be same and phase difference must be constant.

63. (c) When a beam of light is used to determine the position of an object, the maximum accuracy is achieved if the light is of shorter wavelength, because

$\text{Accuracy} \propto \frac{1}{\text{Wavelength}}$

64. (d) Intensity $\propto \frac{1}{(\text{Distance})^2}$

65. (d) Huygen's theory explains propagation of wavefront.

66. (c) Wave theory of light is given by Huygen.

67. (a) When light reflect from denser surface phase change of π occurs.

68. (a) Photoelectric effect explain the quantum nature of light while interference, diffraction and polarization explain the wave nature of light.

69. (a) Light is electromagnetic in nature it does not require any material medium for its propagation.

70. (c) For viewing interference in oil films or soap bubble, thickness of film is of the order of wavelength of light.

71. (b)

72. (d) For maximum intensity $\phi = 0°$

$\therefore I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi = I + I + 2\sqrt{II}\cos 0° = 4I$

Young's Double Slit Experiment

1. (a)

2. (c) In interference of light the energy is transferred from the region of destructive interference to the region of constructive interference. The average energy being always equal to the sum of the energies of the interfering waves. Thus the phenomenon of interference is in complete agreement with the law of conservation of energy.

3. (c) $\beta = \frac{\lambda D}{d} = \frac{5\times10^{-7}\times 2}{10^{-3}} m = 10^{-3} m = 1.0\ mm$.

4. (c) Slit width ratio = 1 : 9
Since slit width ratio is the ratio of intensity and intensity ∝ (amplitude)

$\therefore I_1 : I_2 = 1:9$

$\Rightarrow a_1^2 : a_2^2 = 1:9 \Rightarrow a_1 : a_2 = 1:3$

$I_{\max} = (a_1+a_2)^2,\ I_{\min} = (a_1-a_2)^2 \Rightarrow \frac{I_{\min}}{I_{\max}} = \frac{1}{4}$

5. (a) $\beta \propto \frac{1}{d} \Rightarrow$ If d becomes thrice, then β become becomes $\frac{1}{3}$ times.

6. (c) $\frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2}$ or $\frac{1.0}{\beta_2} = \frac{5000}{6000}$ or $\beta_2 = \frac{6000}{5000} = 1.2\ mm$.

7. (a) $\beta = \frac{6000\times10^{-10}\times 25\times10^{-2}}{10^{-3}}$

$= 150000\times10^{-9} = 0.15\times10^{-3} m = 0.015\ cm$.

8. (c) For brightness, path difference $= n\lambda = 2\lambda$
So second is bright.

9. (a) If one of slit is closed then interference fringes are not formed on the screen but a fringe pattern is observed due to diffraction from slit.

10. (d)

11. (d) $\beta = \frac{\lambda D}{d} \Rightarrow$ If D becomes twice and d becomes half so β becomes four times.

12. (c) Suppose slit width's are equal, so they produces waves of equal intensity say I'. Resultant intensity at any point $I_R = 4\,I'\cos^2\phi$ where ϕ is the phase difference between the waves at the point of observation.

For maximum intensity $\phi = 0^o \Rightarrow I_{\max} = 4I' = I$ ...(i)

If one of slit is closed, Resultant intensity at the same point will be I' only *i.e.* $I' = I_O$ ...(ii)

Comparing equation (i) and (ii) we get

$I = 4I_O$

13. (b, d) $\frac{I_{\max}}{I_{\min}} = 9 \Rightarrow \left(\frac{a_1+a_2}{a_1-a_2}\right)^2 = 9 \Rightarrow \frac{a_1+a_2}{a_1-a_2} = 3$

$\Rightarrow \frac{a_1}{a_2} = \frac{3+1}{3-1} \Rightarrow \frac{a_1}{a_2} = 2$. Therefore $I_1 : I_2 = 4:1$

14. (b)

15. (c) Distance of n bright fringe $y_n = \frac{n\lambda D}{d}$ *i.e.* $y_n \propto \lambda$

$\therefore \frac{x_{n_1}}{x_{n_2}} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{x(\text{Blue})}{x(\text{Green})} = \frac{4360}{5460}$

∴ x (Green) > x (Blue).

16. (c) $\beta = \frac{\lambda D}{d} = \frac{5000\times10^{-10}\times 1}{0.1\times10^{-3}} m = 5\times10^{-3} m = 0.5\ cm$.

17. (a) We know that fringe width $\beta = \frac{D\lambda}{d}$

$\therefore x = \frac{L\lambda}{d} \Rightarrow \lambda = \frac{xd}{L}$

18. (a) In the normal adjustment of young's, double slit experiment, path difference between the waves at central location is always zero, so maxima is obtained at central position.

19. (a) $\beta = \frac{\lambda D}{d};\ \therefore B \propto \lambda$

$\frac{\lambda'}{\lambda} = \frac{0.4}{4/3} \Rightarrow \lambda' = 0.3\ mm$.

20. (b) $\beta \propto \lambda,\ \therefore \lambda \propto \frac{1}{\mu}$

21. (a) $\beta \propto \lambda,\ \therefore \lambda_v =$ minimum.

22. (c) $\beta_{\text{medium}} = \frac{\beta_{\text{air}}}{\mu} = \frac{0.6}{1.5} = 0.4\ mm$.

23. (d) $\because n = 3,\ \therefore 2n\pi = 2\times 3\pi = 6\pi$

24. (c) Slit width ratio $= 4:9$; hence $I_1 : I_2 = 4:9$

$\therefore \frac{a_1^2}{a_2^2} = \frac{4}{9} \Rightarrow \frac{a_1}{a_2} = \frac{2}{3}$

$\therefore \frac{I_{\max}}{I_{\min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{25}{1}$

25. (d) $\beta = \frac{\lambda D}{d} \Rightarrow d = \frac{\lambda D}{\beta} = \frac{6000\times10^{-10}\times(40\times10^{-2})}{0.012\times10^{-2}} = 0.2\,cm$.

26. (a) As $\beta = \frac{D\lambda}{d} \Rightarrow \frac{\beta_1}{\beta_2} = \left(\frac{D_1}{D_2}\right)\left(\frac{\lambda_1}{\lambda_2}\right)\left(\frac{d_2}{d_1}\right)$

$\Rightarrow 1 = \left(\frac{D_1}{D_2}\right)\times\left(\frac{1}{2}\right)\times\left(\frac{1}{2}\right) \Rightarrow \frac{D_1}{D_2} = \frac{4}{1}$

27. (b)

28. (c) Fringe width $(\beta) = \frac{D\lambda}{d} \Rightarrow \beta \propto \lambda$

As $\lambda_{\text{red}} > \lambda_{\text{yellow}}$, hence fringe width will increase.

29. (d) $\beta = \frac{\lambda D}{d} \Rightarrow \frac{\beta_2}{\beta_1} = \frac{\lambda_2 D_2 d_1}{\lambda_1 D_1 d_2} \Rightarrow \beta_2 = 2.5\times10^{-4} m$.

30. (d) For interference, λ of both the waves must be same.

31. (d) $\beta \propto D$

32. (a) $\theta = \frac{\lambda}{d}$; θ can be increased by increasing λ, so here λ has to be increased by 10%

i.e., % Increase $= \frac{10}{100}\times 5890 = 589\mathring{A}$

33. (b) $d = \frac{D\lambda}{\beta} = \frac{1\times5\times10^{-7}}{5\times10^{-3}} = 10^{-4} m = 0.1\ mm$.

34. (b) If intensity of each wave is I, then initially at central position $I_o = 4I$. when one of the slit is covered then intensity at central position will be I only *i.e.*, $\frac{I_o}{4}$.

35. (a) Shift $= \frac{\beta}{\lambda}(\mu-1)\,t = \frac{\beta}{(5000\times10^{-10})}(1.5)\times2\times10^{-6} = 2\beta$

i.e., 2 fringes upwards.

36. (b) $\beta = \dfrac{\lambda D}{d}$

37. (b) Separation n^{th} bright fringe and central maxima is $x_n = \dfrac{n\lambda D}{d}$

So, $x_3 = \dfrac{3 \times 6000 \times 10^{-10} \times 1}{0.5 \times 10^{-3}} = 3.5\, mm.$

38. (d) $n_1\lambda_1 = n_2\lambda_2 \Rightarrow 62 \times 5893 = n_2 \times 4358 \Rightarrow n_2 = 84.$

39. (b) Angular fringe width $\theta = \dfrac{\lambda}{d} \Rightarrow \theta \propto \lambda$

$\lambda_w = \dfrac{\lambda_a}{\mu_w}$

So $\theta_w = \dfrac{\theta_{air}}{\mu_w} = \dfrac{0.20}{\frac{4}{3}} = 0.15°$

40. (a) By using $x_n = \dfrac{n\lambda D}{d}$

$\Rightarrow (5 \times 10^{-3}) = \dfrac{10 \times \lambda \times 1}{(1 \times 10^{-3})} \Rightarrow \lambda = 5 \times 10^{-7} m = 5000\, Å$

41. (b) Distance of third maxima from central maxima is $x = \dfrac{3\lambda D}{d} = \dfrac{3 \times 5000 \times 10^{-10} \times (200 \times 10^{-2})}{0.2 \times 10^{-3}} = 1.5\, cm.$

42. (d) Distance of n^{th} dark fringe from central fringe

$x_n = \dfrac{(2n-1)\lambda D}{2d}$

$\therefore x_2 = \dfrac{(2 \times 2 - 1)\lambda D}{2d} = \dfrac{3\lambda D}{2d}$

$\Rightarrow 1 \times 10^{-3} = \dfrac{3 \times \lambda \times 1}{2 \times 0.9 \times 10^{-3}} \Rightarrow \lambda = 6 \times 10^{-5}\, cm$

43. (d) $\beta = \dfrac{\lambda D}{d} \Rightarrow (4 \times 10^{-3}) = \dfrac{4 \times 10^{-7} \times D}{0.1 \times 10^{-3}} \Rightarrow D = 1m$

44. (a) $\beta = \dfrac{\lambda D}{d} \Rightarrow (0.06 \times 10^{-2}) = \dfrac{\lambda \times 1}{1 \times 10^{-3}} \Rightarrow \lambda = 6000\, Å$

45. (b)

46. (d) $(n_1\lambda_1 = n_2\lambda_2)$ $\dfrac{n_1}{n_2} = \dfrac{\lambda_2}{\lambda_1} \Rightarrow \dfrac{n_1}{92} = \dfrac{5898}{5461} \Rightarrow n_1 = 99$

47. (d) If we use torch light in place of monochromatic light then overlapping of fringe pattern take place. Hence no fringe will appear.

48. (b)

49. (b) Position of 3rd bright fringe $x_3 = \dfrac{3D\lambda}{d}$

$\Rightarrow \lambda = \dfrac{x_3 d}{3D} = \dfrac{(0.9 \times 10^{-2}) \times (0.28 \times 10^{-3})}{3 \times 1.4} = 6000 Å$

50. (a) Distance between two consecutive

Dark fringes $= \dfrac{\lambda D}{d} = \dfrac{6000 \times 10^{-10} \times 1}{0.6 \times 10^{-3}}$

$= 1 \times 10^{-3} m = 1\, mm.$

51. (b, c) For maxima, path difference $\Delta = n\lambda$

So for $n = 1$, $\Delta = \lambda = 6320 Å$

52. (b) Shift in the fringe pattern $x = \dfrac{(\mu - 1)t.D}{d}$

$= \dfrac{(1.5 - 1) \times 2.5 \times 10^{-5} \times 100 \times 10^{-2}}{0.5 \times 10^{-3}} = 2.5\, cm.$

53. (d) In the presence of thin glass plate, the fringe pattern shifts, but no change in fringe width.

54. (a) $\beta = \dfrac{\lambda D}{d} \Rightarrow \beta \propto \lambda$

55. (a) In interference between waves of equal amplitudes *a*, the minimum intensity is zero and the maximum intensity is proportional to $4a^2$. For waves of unequal amplitudes *a* and *A* ($A > a$), the minimum intensity is non zero and the maximum intensity is proportional to $(a + A)^2$, which is greater than $4a^2$.

56. (b) $\beta = \dfrac{\lambda D}{d} = \dfrac{6000 \times 10^{-10} \times 2}{4 \times 10^{-3}} = 3 \times 10^{4} m = 0.3\, mm$

57. (c) $\beta \propto \lambda$

58. (c) $\beta = \dfrac{\lambda D}{d}$

59. (c) Distance between consecutive bright fringes or dark fringes $= \beta$

$\beta = \dfrac{\lambda D}{d} = \dfrac{550 \times 10^{-9} \times 1}{1.1 \times 10^{-3}} = 500 \times 60^{-6} = 0.5\, mm$

60. (b) $\dfrac{I_{max}}{I_{min}} = \dfrac{\left(\dfrac{a_1}{a_2} + 1\right)^2}{\left(\dfrac{a_1}{a_2} - 1\right)^2} = \dfrac{4}{1} \Rightarrow \dfrac{a_1}{a_2} = \dfrac{3}{1}$

61. (b) $\beta = \dfrac{\lambda D}{d} \Rightarrow \beta \propto \lambda$

62. (c)

63. (b) $n_1\lambda_1 = n_2\lambda_2 \Rightarrow n_2 = n_1 \times \dfrac{\lambda_1}{\lambda_2} = 12 \times \dfrac{600}{400} = 18$

64. (d) Using relation, $d\sin\theta = n\lambda \Rightarrow \sin\theta = \dfrac{n\lambda}{d}$

For $n = 3$, $\sin\theta = \dfrac{3\lambda}{d} = \dfrac{3 \times 589 \times 10^{-9}}{0.589}$

$= 3 \times 10^{-6}$ or $\theta = \sin^{-1}(3 \times 10^{-6})$

65. (b) $\beta \propto \dfrac{1}{d}$

66. (a) When white light is used, central fringe will be white with red edges, and on either side of it, we shall get few coloured bands and then uniform illumination.

67. (c) $\beta \propto \dfrac{\lambda}{d}$

68. (b) $\beta \propto \lambda$

69. (a) $\dfrac{I_{max}}{I_{min}} = \left(\dfrac{\sqrt{\dfrac{I_1}{I_2}} + 1}{\sqrt{\dfrac{I_1}{I_2}} - 1}\right)^2 = \left(\dfrac{\sqrt{2} + 1}{\sqrt{2} - 1}\right)^2 \approx 34$; (given $I_1 = 2I_2$)

70. (b) $B \propto \lambda$

71. (d) $\beta \propto \dfrac{\lambda}{d}$

72. (b)

73. (b) For dark fringe at P

$$S_1P - S_2P = \Delta = (2n-1)\lambda/2$$

Here $n = 3$ and $\lambda = 6000$

So, $\Delta = \dfrac{5\lambda}{2} = 5 \times \dfrac{6000}{2} = 15000 Å = 1.5\ micron$

74. (b) Distance of n^{th} minima from central bright fringe

$$x_n = \frac{(2n-1)\lambda D}{2d}$$

For $n=3$ *i.e.* 3^{rd} minima

$$x_3 = \frac{(2\times 3-1)\times 500\times 10^{-9}\times 1}{2\times 1\times 10^{-3}}$$

$$= \frac{5\times 500\times 10^{-6}}{2} = 1.25\times 10^{-3} m = 1.25\ mm.$$

75. (c) $\beta = \dfrac{\lambda D}{d}$ and $\lambda \propto \dfrac{1}{\mu}$

76. (d) $n_1\lambda_1 = n_2\lambda_2 \Rightarrow 3\times 700 = 5\times \lambda_2 \Rightarrow \lambda_2 = 420\ nm$

77. (a) $\beta \propto \dfrac{\lambda}{d}$ as $d \to \dfrac{d}{3}$ so $\beta \to 3\beta\ \therefore\ n = 3$

78. (c) If shift is equal to n fringes width, then

$$n = \frac{(\mu-1)t}{\lambda} = \frac{(1.5-1)\times 2\times 10^{-6}}{500\times 10^{-9}} = \frac{1}{500}\times 10^3 = 2$$

Since a thin film is introduced in upper beam. So shift will be upward.

79. (b) Distance between n^{th} Bright fringe and m^{th} dark fringe $(n > m)$

$$\Delta x = \left(n - m + \frac{1}{2}\right)\beta = \left(5 - 3 + \frac{1}{2}\right)\times \frac{6.5\times 10^{-7}\times 1}{1\times 10^{-3}}$$

$= 1.63\ mm$

80. (a) $\beta = \dfrac{\lambda D}{d}$; If λ and d both increase by 10%, there will be no change in fringe width (β).

81. (b) $\dfrac{I_1}{I_2} = \dfrac{1}{4} \Rightarrow I_1 = k$ and $I_2 = 4k$

$\therefore$ Fringe visibility $V = \dfrac{2\sqrt{I_1 I_2}}{(I_1 + I_2)} = \dfrac{2\sqrt{k\times 4k}}{(k+4k)} = 0.8$

82. (b) $\dfrac{I_{max}}{I_{min}} = \left(\dfrac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\dfrac{3a + a}{3a - a}\right)^2 = \dfrac{4}{1}$

83. (d) Angular position of first dark fringe

$$\theta = \frac{\lambda}{d} = \frac{5460\times 10^{-10}}{0.1\times 10^{-3}} \times \frac{180}{\pi}\ \text{(in degree)}$$

$= 0.313°$

84. (a) Distance between two consecutive dark fringes $\beta = \dfrac{\lambda D}{d}$

$$= \frac{5000\times 10^{-10}\times 1}{0.2\times 10^{-2}} = 0.25\ mm.$$

85. (a) If thin film appears dark

$2\mu t \cos r = n\lambda$ for normal incidence $r = 0^o$

$\Rightarrow 2\ \mu\ t = n\lambda \Rightarrow t = \dfrac{n\lambda}{2\mu}$

$\Rightarrow t_{min} = \dfrac{\lambda}{2\mu} = \dfrac{5890\times 10^{-10}}{2\times 1} = 2.945\times 10^{-7} m$.

86. (b) In case of destructive interference (minima) phase difference is odd multiple of π.

87. (b) $\beta = \dfrac{(a+b)\lambda}{2a(\mu-1)\alpha}$

where a = distance between source and biprism = 0.3 m

b = distance between biprism and screen = 0.7 m.

α = Angle of prism = 1°, μ = 1.5, λ = 6000 × 10^{-10} m

Hence, $\beta = \dfrac{(0.3+0.7)\times 6\times 10^{-7}}{2\times 0.3(1.5-1)\times (1^o \times \dfrac{\pi}{180})}$

= 1.14 × 10^{-4} m = 0.0114 cm.

88. (d) For minima, path difference $\Delta = (2n-1)\dfrac{\lambda}{2}$

For third minima $n = 3 \Rightarrow \Delta = (2\times 3 - 1)\dfrac{\lambda}{2} = \dfrac{5\lambda}{2}$

89. (b) Fringe width $(\beta) \propto \dfrac{1}{\text{prism Angle}(\alpha)}$

90. (a) By using $\beta = \dfrac{(a+b)\lambda}{2a(\mu-1)\alpha} = \dfrac{(0.3+0.7)\times 180\pi\times 10^{-9}}{2\times 0.3(1.54-1)\times\left(1\times\dfrac{\pi}{180}\right)}$

$= 10^{-4} m$

91. (a) $\because\ \beta \propto \lambda \Rightarrow \lambda_w < \lambda_a$ so $\beta_w < \beta_a$

92. (c) With white light, the rays reaching the centre has zero path difference. So we get white fringe at the centre and coloured near the central fringe.

93. (a) $\beta_{water} = \dfrac{\beta_{air}}{\mu_w}$

94. (a) $\beta = \dfrac{\lambda D}{d}$

95. (b) Lateral displacement of fringes = $\dfrac{\beta}{\lambda}(\mu-1)t$

$$= \frac{1\times 10^{-3}}{600\times 10^{-9}}(1.5-1)\times 0.06\times 10^{-3} = \frac{1}{20} m = 5\ cm.$$

96. (b)

97. (d) Distance of the n^{th} bright fringe from the centre $x_n = \dfrac{n\lambda D}{d}$

$$\Rightarrow x_3 = \frac{3\times 6000\times 10^{-10}\times 2.5}{0.5\times 10^{-3}} = 9\times 10^{-3} m = 9\ mm.$$

Doppler's Effect of Light

1. (d) $\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c}$, Now $\Delta\lambda = \dfrac{0.5}{100}\lambda \Rightarrow \dfrac{\Delta\lambda}{\lambda} = \dfrac{0.5}{100}$

$$\therefore v = \frac{0.5}{100}\times c = \frac{0.5}{100}\times 3\times 10^8 = 1.5\times 10^6 m/s$$

Increase in λ indicates that the star is receding.

2. (a) Doppler's shift is given by

$$\Delta\lambda = \frac{v\lambda}{c} = \frac{5000 \times 6000}{3 \times 10^8} = 0.1\mathring{A}$$

3. (b) Shifting towards ultraviolet region shows that Apparent wavelength decreased. Therefore the source is moving towards the earth.

4. (b) Due to expansion of universe, the star will go away from the earth thereby increasing the observed wavelength. Therefore the spectrum will shift to the infrared region.

5. (b) With reference to this theory the velocity of the observer is neglected *w.r.t.* the light velocity.

6. (b) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} = \frac{6 \times 10^7}{3 \times 10^8} = 0.2$

$$\Delta\lambda = \lambda' - \lambda = 0.2\lambda \Rightarrow \lambda' = 1.2\lambda = 1.2 \times 4600 = 5520\mathring{A}$$

7. (b) $\Delta\lambda = 5200 - 5000 = 200\mathring{A}$

Now $\frac{\Delta\lambda}{\lambda'} = \frac{v}{c} \Rightarrow v = \frac{c\Delta\lambda}{\lambda'} = \frac{3 \times 10^8 \times 200}{5000}$

$$= 1.2 \times 10^7 \, m/\sec \approx 1.15 \times 10^7 \, m/\sec$$

8. (d) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow v = \frac{c}{\lambda}\Delta\lambda = \frac{c}{\lambda}(\lambda' - \lambda) = c \times \frac{0.01}{100}$

$$= 3 \times 10^4 \, m/s = 30 \, km/\sec$$

9. (c) Blue radiations have the wavelength around 4600 $\overset{o}{A}$. It shows that apparent wavelength is smaller than the real wavelength. It means that the star is proceeding towards earth.

10. (c)

11. (a)

12. (c)

13. (b) $\Delta\lambda = \lambda\frac{v}{c} = 5700 \times \frac{100 \times 10^3}{3 \times 10^8} = 1.90\mathring{A}$

14. (a) According to Doppler's effect, wherever there is a relative motion between source and observer, the frequency observed is different from that given out by source.

15. (a) $\Delta\lambda = \lambda.\frac{v}{c} = \frac{1.5 \times 10^6}{3 \times 10^8} \times 5000 = 25\mathring{A}$

16. (d) $\Delta\lambda = \frac{v}{c}\lambda = \frac{3600 \times 10^3}{3 \times 10^8} \times 5896 = 70.75\mathring{A}$

So the increased wavelength of light is observed.

17. (b) Observed frequency $\nu' = \nu\left(1 - \frac{v}{c}\right)$

$$\Rightarrow \nu' = 6 \times 10^{14}\left(1 - \frac{0.8\,c}{c}\right) = 1.2 \times 10^{14}\,Hz$$

18. (c) According to Doppler's principle $\lambda' = \lambda\sqrt{\frac{1 - v/c}{1 + v/c}}$ for $v = c$

$$\lambda' = 5500\sqrt{\frac{(1 - 0.8)}{1 + 0.8}} = 1833.3$$

$\therefore$ Shift = 5500 – 1833.3 = 3167 Å

19. (b) $\Delta\lambda = \lambda\frac{v}{c}$

$$\Rightarrow (3737 - 3700) = 3700 \times \frac{v}{3 \times 10^8} \Rightarrow v = 3 \times 10^6 \, m/s$$

20. (d) $\Delta\lambda = \frac{v_s}{c}\lambda \Rightarrow v_s = \frac{\Delta\lambda.c}{\lambda} = \frac{47 \times 3 \times 10^8}{4700}$

$= 3 \times 10^6 \, m/s$ away from earth

21. (b) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow \frac{0.05}{100} = \frac{v}{3 \times 10^8} \Rightarrow v = 1.5 \times 10^5 \, m/s$

(Since wavelength is decreasing, so star coming closer)

22. (b)

23. (c) $\lambda' = \lambda\left(1 - \frac{v}{c}\right) = 5890\left(1 - \frac{4.5 \times 10^6}{3 \times 10^8}\right) \approx 5802$Å

24. (c) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \therefore v = \frac{\Delta\lambda}{\lambda}c = \frac{0.1}{6000} \times 3 \times 10^5 \, km/s = 5 \, km/s$

25. (b) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow \Delta\lambda = \frac{5700 \times 10^6}{3 \times 10^3} = 19\mathring{A}$

26. (b) $\nu' = \nu\left(1 - \frac{v}{c}\right) = 4 \times 10^7\left(1 - \frac{0.2c}{c}\right) = 3.2 \times 10^7 \, Hz$

27. (c) When the source and observer approach each other, apparent frequency increases and hence wavelength decreases.

28. (b)

29. (a) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow 1 = \frac{v}{c} \Rightarrow v = c$

30. (d) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow v = \frac{\Delta\lambda}{\lambda}.c = \frac{5}{6563} \times (3 \times 10^8) = 2.29 \times 10^5$ *m/sec*

31. (c)

32. (a) Using $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow v = \frac{\Delta\lambda}{\lambda}c$

$\Rightarrow v = 0.004 \times 3 \times 10^8 = 1.2 \times 10^6$ *m/sec*

33. (a)

Diffraction of Light

1. (c) For first minima $\theta = \frac{\lambda}{a}$ or $a = \frac{\lambda}{\theta}$

$\therefore a = \frac{6500 \times 10^{-8} \times 6}{\pi}$ (As $30^\circ = \frac{\pi}{6}$ radian)

$= 1.24 \times 10^{-4} \, cm = 1.24$ microns

2. (a) The angular half width of the central maxima is given by $\sin\theta = \frac{\lambda}{a} \Rightarrow \theta = \frac{6328 \times 10^{-10}}{0.2 \times 10^{-3}}$ *rad*

$= \frac{6328 \times 10^{-10} \times 80}{0.2 \times 10^{-3} \times \pi}$ *degree* = 0.18°

Total width of central maxima $= 2\theta = 0.36^o$

3. (b)

4. (c) It is caused due to turning of light around corners.

5. (c) Width of central maxima $= \frac{2\lambda D}{d}$

$$= \frac{2 \times 2.1 \times 5 \times 10^{-7}}{0.15 \times 10^{-2}} = 1.4 \times 10^{-3} m = 1.4 \, mm$$

6. (a) Band width $\propto \lambda$,

$\because \lambda_{blue} < \lambda_{red}$, hence for blue light the diffraction bands becomes narrower and crowded together.

7. (a) Using $d\sin\theta = n\lambda$, for n =1

$$\sin\theta = \frac{\lambda}{d} = \frac{550\times10^{-9}}{0.55\times10^{-3}} = 10^{-3} = 0.001\,rad$$

8. (a) For single slit diffraction pattern $d\sin\theta = \lambda$ (d = slit width)

Angular width = $2\theta = 2\sin^{-1}\left(\frac{\lambda}{d}\right)$

It is independent of D *i.e.* distance between screen and slit

9. (c) Width of central bright fringe.

$$= \frac{2\lambda D}{d} = \frac{2\times500\times10^{-9}\times80\times10^{-2}}{0.20\times10^{-3}} = 4\times10^{-3}m = 4mm.$$

10. (b) Diffraction is obtained when the slit width is of the order of wavelength of EM waves (or light). Here wavelength of X-rays (1-100 Å) is very-very lesser than slit width (0.6 *mm*). Therefore no diffraction pattern will be observed.

11. (a) Multiple focii of zone plate given by $f_p = \frac{r_n^2}{(2p-1)\lambda}$, where $p = 1, 2, 3......$

12. (b) $A = n\pi d\lambda \Rightarrow nd = \frac{A}{\pi\lambda}$ = constant $\Rightarrow n \propto \frac{1}{d}$ (n = number of blocked HPZ) on decreasing d, n increases, hence intensity decreases.

13. (a) For secondary maxima $d\sin\theta = \frac{5\lambda}{2}$

$$\Rightarrow d\theta = d.\frac{x}{D(\approx f)} = \frac{5\lambda}{2}$$

$$\Rightarrow 2x = \frac{5\lambda f}{d} = \frac{5\times0.8\times10^{-7}}{4\times10^{-4}} = 6\times10^{-3}m = 6mm$$

14. (d) By using $f_p = \frac{r^2}{(2p-1)\lambda}$

For first HPZ $r = \sqrt{f_p\lambda} = \sqrt{0.6\times6000\times10^{-10}}$

$= 6\times10^{-4}m.$

15. (a) $f_1 = \frac{r^2}{\lambda} = \frac{(2.3\times10^{-3})^2}{5893\times10^{-10}} = 9\,m.$

16. (b) $\lambda_{Blue} < \lambda_{Red}$. Therefore fringe pattern will contract because fringe width $\propto \lambda$

17. (a)

18. (a) For diffraction size of the obstacle must be of the order of wavelength of wave *i.e.* $a \approx \lambda$

19. (a) Angular width of central maxima

$$= \frac{2\lambda}{d} = \frac{2\times589.3\times10^{-9}}{0.1\times10^{-3}}rad = 0.0117\times\frac{180}{\pi} = 0.68°$$

20. (d)

21. (a) $r_n = \sqrt{nd\lambda} \Rightarrow r_n \propto \sqrt{n}$

22. (a) $\beta = \frac{\lambda.D}{d}$ w here D = distance of screen from wire, d = diameter of wire

23. (c) Angular width $= \frac{2\lambda}{d} = \frac{2\times6000\times10^{-10}}{12\times10^{-5}\times10^{-2}} = 1\,rad.$

24. (b)

25. (d)

26. (a) $2\theta = \frac{2\lambda}{d}$ (where d = slit width)

As d decreases, θ increases.

27. (d)

28. (d) Distance between the first dark fringes on either side of central maxima = width of central maxima $= \frac{2\lambda D}{d} =$

$\frac{2\times600\times10^{-9}\times2}{1\times10^{-3}}$ = 2.4 *mm.*

29. (b) Thickness of the film must be of the order of wavelength of light falling on film (*i.e.* visible light)

30. (d)

31. (d) For n secondary maxima path difference

$$d\sin\theta = (2n+1)\frac{\lambda}{2} \Rightarrow a\sin\theta = \frac{3\lambda}{2}$$

32. (d) The phase difference (ϕ) between the wavelets from the top edge and the bottom edge of the slit is $\phi = \frac{2\pi}{\lambda}(d\sin\theta)$ where d is the slit width. The first minima of the diffraction pattern occurs at $\sin\theta = \frac{\lambda}{d}$ so $\phi = \frac{2\pi}{\lambda}\left(d\times\frac{\lambda}{d}\right) = 2\pi$

33. (b)

34. (a) For second dark fringe $d\sin\theta = 2\lambda$

$$\Rightarrow 24\times10^{-5}\times10^{-2}\times\sin30 = 2\lambda$$

$$\Rightarrow \lambda = 6\times10^{-7}\,m = 6000\,Å$$

35. (c) For the first minima $d\sin\theta = \lambda$

$$\Rightarrow \sin\theta = \frac{\lambda}{d} \Rightarrow \theta = \sin^{-1}\left(\frac{5000\times10^{-10}}{0.001\times10^{-3}}\right) = 30^o$$

36. (c)

37. (a)

38. (c) Position of first minima = position of third maxima *i.e.*, $\frac{1\times\lambda_1 D}{d} = \frac{(2\times3+1)}{2}\frac{\lambda_2 D}{d} \Rightarrow \lambda_1 = 3.5\lambda_2$

39. (a) Position of nth minima $x_n = \frac{n\lambda D}{d}$

$$\Rightarrow 5\times10^{-3} = \frac{1\times5000\times10^{-10}\times1}{d}$$

$$\Rightarrow d = 10^{-4}\,m = 0.1\,mm.$$

40. (b) Width of n HPZ $B_n = r_n - r_{n-1}$

$r_n = \sqrt{nb\lambda}$, $r_{n-1} = \sqrt{(n-1)b\lambda}$

$B_n = \sqrt{nb\lambda} - \sqrt{(n-1)b\lambda} = \sqrt{b\lambda}\,[\sqrt{n} - \sqrt{(n-1)}]$

41. (c) In single slit experiment,

Width of central maxima (y) = $2\lambda D/d$

$$\Rightarrow \frac{y'}{y} = \frac{\lambda'}{d'}\times\frac{d}{\lambda} = \frac{600}{d/2}\times\frac{d}{400} \Rightarrow y' = 3y.$$

Polarisation of Light

1. (b) Polariser produced prolarised light.
2. (a) Only transverse waves can be polarised.
3. (c) Polarisation is not shown by sound waves.
4. (d) By using $\mu = \tan\theta_p \Rightarrow \mu = \tan 60 = \sqrt{3}$,

also $C = \sin^{-1}\left(\frac{1}{\mu}\right) \Rightarrow C = \sin^{-1}\left(\frac{1}{\sqrt{3}}\right)$

5. (d) $\mu = \tan\theta_p \Rightarrow \theta_p = \tan^{-1} n$
6. (d) Ultrasonic waves are longitudinal waves.
7. (b) $I = I_0 \cos^2\theta = I_0 \cos^2 45 = \frac{I_0}{2}$
8. (d)
9. (a) It magnitude of light vector varies periodically during it's rotation, the tip of vector traces an ellipse and light is said to be elliptically polarised. This is not in nicol prism.
10. (c) At polarizing angle, the reflected and refracted rays are mutually perpendicular to each other.
11. (a) When unpolarised light is made incident at polarising angle, the reflected light is plane polarised in a direction perpendicular to the plane of incidence.

Therefore $\vec{E}$ in reflected light will vibrate in vertical plane with respect to plane of incidence.

12. (d) In the arrangement shown, the unpolarised light is incident at polarising angle of 90° – 33° = 57°. The reflected light is thus plane polarised light. When plane polarised light is passed through Nicol prism (a polariser or analyser), the intensity gradually reduces to zero and finally increases.
13. (a)
14. (a) A plane which contains $\vec{E}$ and the propagation direction is called the plane of polarization.
15. (c)
16. (d) Light suffers double refraction through calcite.
17. (d) The amplitude will be $A\cos 60^o = A/2$
18. (d)
19. (b) Rotation produced $\theta = Slc$

Net rotation produced $\theta = \theta_1 - \theta_2 = l(S_1c_1 - S_2c_2)$

= 0.29 × [0.01 × 60 – 0.02 × 30] = 0

20. (c) In double refraction light rays always splits into two rays (*O*-ray & *E*-ray). *O*-ray has same velocity in all direction but *E*-ray has different velocity in different direction.

For calcite $\mu_e < \mu_o \Rightarrow v_e > v_o$

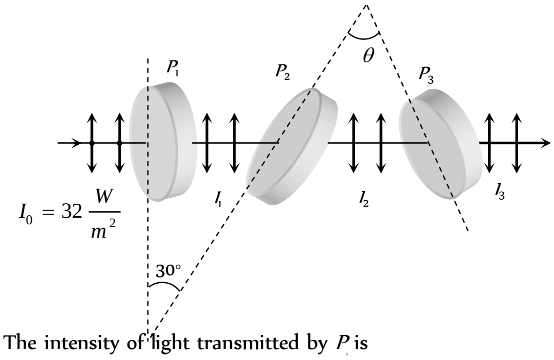
For quartz $\mu_e > \mu_o \Rightarrow v_o > v_e$

21. (c) $\theta_P + r = 90^\circ$ or $r = 90 - \theta_p$ = 90° – 53°4' = 36°56'.
22. (d)
23. (a)
24. (c) Intensity of polarized light from first polarizer $= \frac{100}{2} = 50$

$I = 50\cos^2 60^\circ = \frac{50}{4} = 12.5$

25. (b) $I' = \frac{I}{2}\cos^2\theta = \frac{I}{6}$ or $\cos\theta = \frac{1}{\sqrt{3}}$ $\therefore$ $\theta = 55°$
26. (b) Angle between P_1 and P_2 = 30° (given)

Angle between P_2 and P_3 = θ = 90° – 30° = 60°



The intensity of light transmitted by P_1 is

$I_1 = \frac{I_0}{2} = \frac{32}{2} = 16\frac{W}{m^2}$

According to Malus law the intensity of light transmitted by P_2

is $I_2 = I_1\cos^2 30^\circ = 16\left(\frac{\sqrt{3}}{2}\right)^2 = 12\frac{W}{m^2}$

Similarly intensity of light transmitted by P_3 is

$I_3 = I_2\cos^2\theta = 12\cos^2 60^\circ = 12\left(\frac{1}{2}\right)^2 = 3\frac{W}{m^2}$

27. (b) $\theta = a + \frac{b}{\lambda^2}$

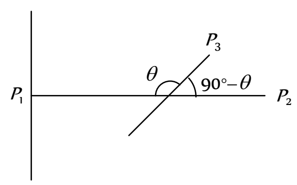
$30 = a + \frac{b}{(5000)^2}$ and $50 = a + \frac{b}{(4000)^2}$

Solving for a, we get $a = -\frac{50^\circ}{9}$ *per mm*

28. (c) If an unpolarised light is converted into plane polarised light by passing through a polaroid, it's intensity becomes half.
29. (a)
30. (b) The magnitude of electric field vector varies periodically with time because it is the form of electromagnetic wave.
31. (a) According to Brewster's law, when a beam of ordinary light (i.e. unpolarised) is reflected from a transparent medium (like glass), the reflected light is completely plane polarised at certain angle of incidence called the angle of polarisation.
32. (a) When the plane-polarised light passes through certain substance, the plane of polarisation of the light is rotated about the direction of propagation of light through a certain angle.
33. (c) From Brewster's law $\mu = \tan i_p \Rightarrow \frac{c}{v} = \tan 60^\circ = \sqrt{3}$

$\Rightarrow v = \frac{c}{\sqrt{3}} = \frac{3\times 10^8}{\sqrt{3}} = \sqrt{3}\times 10^8$ *m/sec.*

34. (a) No light is emitted from the second polaroid, so P_1 and P_2 are perpendicular to each other



Let the initial intensity of light is I_0 . So Intensity of light after transmission from first polaroid = $\frac{I_0}{2}$.

Intensity of light emitted from P_3 $I_1 = \frac{I_0}{2}\cos^2\theta$

Intensity of light transmitted from last polaroid *i.e.* from $P_2 = I_1\cos^2(90^o - \theta) = \frac{I_0}{2}\cos^2\theta.\sin^2\theta$

$= \frac{I_0}{8}(2\sin\theta\cos\theta)^2 = \frac{I_0}{8}\sin^2 2\theta$.

35. (d)

EM Waves

1. (a)

2. (d) $\lambda_{Red} > \lambda_{Blue} > \lambda_{X-ray} > \lambda_\gamma$

3. (b) Infrasonic waves are mechanical waves.

4. (d) $\mu_0 = 4\pi\times10^{-7}, \varepsilon_0 = 8.85\times10^{-12}\frac{N\text{-}m^2}{C^2}$

so $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3\times10^8\frac{meter}{sec}$.

5. (b) Wavelength of visible spectrum is 3900 Å – 7800 Å.

6. (b) Infrared causes heating effect.

7. (a)

8. (d)

9. (c) Speed of EM waves in vacuum = $\frac{1}{\sqrt{\mu_0\in_0}}$ =constant

10. (a) $\lambda_{\gamma-rays} < \lambda_{x-rays} < \lambda_{\alpha-rays} < \lambda_{\beta-rays}$.

11. (a) Distance covered by T.V. signals = $\sqrt{2hR}$

$\Rightarrow$ maximum distance $\propto h$

12. (c) β-rays are beams of fast electrons.

13. (a)

14. (b) Velocity of EM waves = $\frac{1}{\sqrt{\mu_0\in_0}}$ $3\times10^8 m/s$ =velocity of light

15. (b) Ozone layer absorbs most of the *UV* rays emitted by sun.

16. (d) $\nu_{\gamma-rays} > \nu_{\text{visible radiation}} > \nu_{\text{Infrared}} > \nu_{\text{Radio waves}}$

17. (b) Infrared radiations reflected by low lying clouds and keeps the earth warm.

18. (d) $\lambda_{Radiowaves} > \lambda_{UV\ rays} > \lambda_{J\ Rays} > \lambda_{X-rays}$

19. (a) Polarization is shown by only transverse waves.

20. (c) EM waves travels with perpendicular to *E* and *B*. Which are also perpendicular to each other $\vec{v} = \vec{E}\times\vec{B}$

21. (a)

22. (d) Ozone hole is depletion of ozone layer in stratosphere because of gases like CFC'S etc.

23. (c)

24. (b)

25. (a) $\nu_{\gamma-rays} > \nu_{X-rays} > \nu_{UV-rays}$

26. (a) In vacuum velocity of all EM waves are same but their wavelengths are different.

27. (c)

28. (c)

29. (a) $\lambda = \frac{c}{\nu} = \frac{3\times10^8}{8.2\times10^6} = 36.5\ m$

30. (b) $c = \frac{E}{B} \Rightarrow B = \frac{E}{c} = \frac{18}{3\times10^8} = 6\times10^{-8}T$.

31. (c) According to the Maxwell's EM theory, the EM waves propagation contains electric and magnetic field vibration in mutually perpendicular direction. Thus the changing of electric field give rise to magnetic field.

32. (a) Here $E_0 = 100\ V/m,\ B_0 = 0.265\ A/m$.

$\therefore$ Maximum rate of energy flow $S = E_0\times B_0$

$= 100\times.265 = 26.5\frac{W}{m^2}$

33. (d) $E = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^8}{21\times10^{-2}} = 0.94\times10^{-24} \approx 10^{-24}J$

34. (a) $\nu = \frac{C}{\lambda} \Rightarrow \nu_1 = \frac{3\times10^8}{1} = 3\times10^8 Hz = 300\ MHz$

and $\nu_2 = \frac{3\times10^8}{10} = 3\times10^7 Hz = 30 MHz$

35. (d)

36. (c) $\vec{E}$ and $\vec{B}$ are mutually perpendicular to each other and are in phase i.e. they become zero and minimum at the same place and at the same time.

37. (b) Molecular spectra due to vibrational motion lie in the microwave region of EM-spectrum. Due to Kirchhoff's law in spectroscopy the same will be absorbed.

38. (a) E_x and B_y would generate a plane EM wave travelling in *z*-direction. $\vec{E}$, $\vec{B}$ and $\vec{k}$ form a right handed system $\vec{k}$ is along z-axis. As $\hat{i}\times\hat{j} = \hat{k}$

$\Rightarrow E_x\hat{i}\times B_y\hat{j} = C\hat{k}$ *i.e.* *E* is along *x*-axis and *B* is along *y-axis.*

39. (a) $\nu_{\gamma-rays} > \nu_{UV\text{-rays}} > \nu_{\text{Blue light}} > \nu_{\text{Infrared rays}}$

40. (d) Ground wave and sky wave both are amplitude modulated wave and the amplitude modulated signal is transmitted by a transmitting antenna and received by the receiving antenna at a distance place.

41. (a)

42. (b) EM waves transport energy, momentum and information but not charge. EM waves are uncharged

43. (b) EM waves carry momentum and hence can exert pressure on surfaces. They also transfer energy to the surface so $p \neq 0$ and $E \neq 0$.

44. (c) The angular wave number $k = \frac{2\pi}{\lambda}$; where λ is the wave length. The angular frequency is $w = 2\pi\nu$.

The ratio $\frac{k}{\omega} = \frac{2\pi/\lambda}{2\pi\nu} = \frac{1}{\nu\pi} = \frac{1}{c}$ = constant

45. (a) $\frac{E_0}{B_0} = C$. also $k = \frac{2\pi}{\lambda}$ and $\omega = 2\pi\nu$

These relation gives $E_0K = B_0\omega$

46. (b) $\nu = \frac{1}{2\pi\sqrt{LC}}$ and $\lambda = \frac{C}{\nu}$

47. (a) $I = \frac{1}{2}\varepsilon_0 C E_0^2$

$\Rightarrow E_0 = \sqrt{\frac{2I}{\varepsilon_0 C}} = \sqrt{\frac{2 \times 5 \times 10^{-16}}{8.85}} = 0.61 \times 10^{-6}\ \frac{V}{m}$

Also $E_0 = \frac{V_0}{d} \Rightarrow V_0 = E_0 d = 0.61 \times 10^{-6} \times 2 = 1.23 \mu V$

48. (c)

49. (c) Population covered = $2\pi hR \times$ Population density

$= 2\pi \times 100 \times 6.4 \times 10^{6} \times \frac{1000}{(10^3)^2} = 4 \times 10^{6}$

50. (a)

51. (c)

52. (c) Refractive index $= \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

Here μ is not specified so we can consider $\mu = \mu_0$

then refractive index $= \sqrt{\frac{\varepsilon}{\varepsilon_0}} = 2$

$\therefore$ Speed and wavelength of wave becomes half and frequency remain unchanged.

53. (d)

54. (d)

55. (b)

56. (b)

57. (a) Intensity or power per unit area of the radiations $P = fv \Rightarrow$

$f = \frac{P}{v} = \frac{0.5}{3 \times 10^8} = 0.166 \times 10^{-8}\ N/m^2$

58. (d) $v = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{3 \times 10^8}{\sqrt{1.3 \times 2.14}} = 1.8 \times 10^8\ m/sec$

59. (b) $I' = I e^{-\mu x} \Rightarrow x = \frac{1}{\mu}\log_e \frac{I}{I'}$ (where I = original intensity, I' = changed intensity)

$36 = \frac{1}{\mu}\log_e \frac{I}{I/8} = \frac{3}{\mu}\log_e 2$ ....(i)

$x = \frac{1}{\mu}\log_e \frac{I}{I/2} = \frac{1}{\mu}\log_e 2$ .....(ii)

From equation (i) and (ii), $x = 12\ mm$.

60. (c) $\lambda_m > \lambda_v > \lambda_x$

61. (a) If maximum electron density of the ionosphere is N_{max} per m^3 then the critical frequency f_c is given by $f_c = 9(N_{max})^{1/2}$.

$\Rightarrow 1 \times 10^6 = 9(N)^{1/2} \Rightarrow N = 1.2 \times 10^{12}\ m^{-3}$

62. (c)

63. (b)

64. (a)

65. (c)

66. (d) Direction of wave propagation is given by $\vec{E} \times \vec{B}$.

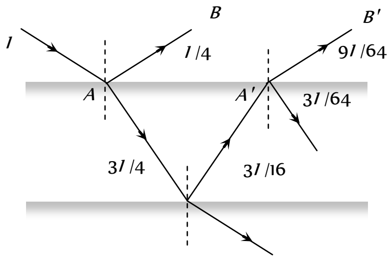
67. (c) Speed of light of vacuum $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$ and in another medium

$v = \frac{1}{\sqrt{\mu\varepsilon}}$

$\therefore \frac{c}{v} = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}} = \sqrt{\mu_r K} \Rightarrow v = \frac{c}{\sqrt{\mu_r K}}$

Critical Thinking Questions

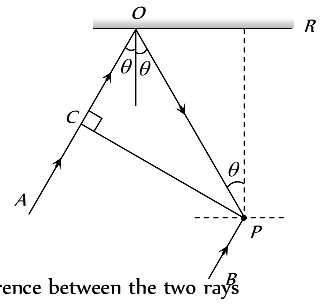
1. (d) From figure $I_1 = \frac{I}{4}$ and $I_2 = \frac{9I}{64}$ $\Rightarrow \frac{I_2}{I_1} = \frac{9}{16}$



By using $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{\frac{I_2}{I_1}}+1}{\sqrt{\frac{I_2}{I_1}}-1}\right) = \left(\frac{\sqrt{\frac{9}{16}}+1}{\sqrt{\frac{9}{16}}-1}\right) = \frac{49}{1}$

2. (a) The cylindrical surface touches the glass plate along a line parallel to axis of cylinder. The thickness of wedge shaped film increases on both sides of this line. Locus of equal path difference are the lines running parallel to the axis of the cylinder. Hence straight fringes are obtained.

3. (b) $\because PR = d \Rightarrow PO = d\sec\theta$ and $CO = PO\cos 2\theta$ $= d\sec\theta\cos 2\theta$ is



Path difference between the two rays

$\Delta = CO + PO = (d\sec\theta + d\sec\theta\cos 2\theta)$

Phase difference between the two rays is

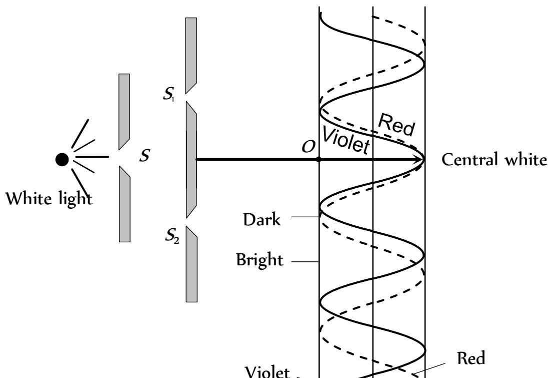
$\phi = \pi$ (One is reflected, while another is direct)

Therefore condition for constructive interference should be $\Delta = \frac{\lambda}{2}, \frac{3\lambda}{2}$ ......

or $d\sec\theta(1+\cos 2\theta) = \frac{\lambda}{2}$

or $\frac{d}{\cos\theta}(2\cos^2\theta) = \frac{\lambda}{2} \Rightarrow \cos\theta = \frac{\lambda}{4d}$

4. (c) In young's double slit experiment, if white light is used in place of monochromatic light, then the central fringe is white and some coloured fringes around the central fringe are formed.



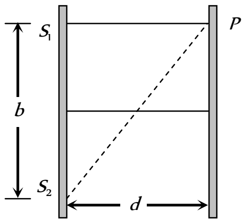
Since $\beta_{red} > \beta_{violet}$ etc., the bright fringe of violet colour forms first and that of the red forms later.

It may be noted that, the inner edge of the dark fringe is red, while the outer edge is violet. Similarly, the inner edge of the bright fringe is violet and the outer edge is red.

5. (a) In conventional light source, light comes from a large number of independent atoms, each atom emitting light for about 10^{-9} *sec i.e.* light emitted by an atom is essentially a pulse lasting for only 10^{-9} *sec*. Light coming out from two slits will have a fixed phase relationship only for 10^{-9} *sec*. Hence any interference pattern formed on the screen would last only for 10^{-9} *sec*, and then the pattern will change. The human eye can notice intensity changes which last at least for a tenth of a second and hence we will not be able to see any interference pattern. In stead due to rapid changes in the pattern, we will only observe a uniform intensity over the screen.

6. (a,c) Path difference between the rays reaching infront of slit S_1 is.

$S_1P - S_2P = (b^2 + d^2)^{1/2} - d$



For distructive interference at P

$S_1P - S_2P = \frac{(2n-1)\lambda}{2}$

i.e., $(b^2 + d^2)^{1/2} - d = \frac{(2n-1)\lambda}{2}$

$\Rightarrow d\left(1+\frac{b^2}{d^2}\right)^{1/2} - d = \frac{(2n-1)\lambda}{2}$

$\Rightarrow d\left(1+\frac{b^2}{2d^2}+......\right) - d = \frac{(2n-1)\lambda}{2}$

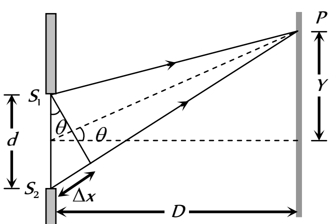
(Binomial Expansion)

$\Rightarrow \frac{b}{2d} = \frac{(2n-1)\lambda}{2} \Rightarrow \lambda = \frac{b^2}{(2n-1)d}$

For $n = 1, 2$......... .., $\lambda = \frac{b^2}{d}, \frac{b^2}{3d}$

7. (a)

8. (a,b) For microwave $\lambda = \frac{c}{f} = \frac{3\times 10^8}{10^6} = 300\ m$



As $\Delta x = d\sin\theta$

Phase difference $\phi = \frac{2\pi}{\lambda}$ (Path difference)

$= \frac{2\pi}{\lambda}(d \sin\theta) = \frac{2\pi}{300}(150 \sin\theta) = \pi \sin\theta$

$I_R = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

Here $I_1 = I_2$ and $\phi = \pi \sin\theta$

$\therefore I_R = 2I_1[1 + \cos(\pi \sin\theta)] = 4I_1 \cos^2\left(\frac{\pi \sin\theta}{2}\right)$

I will be maximum when $\cos^2\left(\frac{\pi \sin\theta}{2}\right) = 1$

$\therefore (I_R)_{\max} = 4I_1 = I_o$

Hence $I = I_o \cos^2\left(\frac{\pi \sin\theta}{2}\right)$

If $\theta = 0$, then $I = I_o \cos\theta = I_o$

If $\theta = 30°$, then $I = I_o \cos^2(\pi/4) = I_o/2$

If $\theta = 90^o$, then $I = I_o \cos^2(\pi/2) = 0$

9. (d) $I = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$

Put $a_1^2 + a_2^2 = A$ and $a_1a_2 = B;\ \therefore I = A + B\cos\phi$

10. (d) Since P is ahead of Q by 90° and path difference between P and Q is $\lambda/4$. Therefore at A, phase difference is zero, so intensity is $4I$. At C it is zero and at B, the phase difference is 90°, so intensity is $2I$.

11. (b) By using phase difference $\phi = \frac{2\pi}{\lambda}(\Delta)$

For path difference λ, phase difference $\phi_1 = 2\pi$ and for path difference $\lambda/4$, phase difference $\phi_2 = \pi/2$.

Also by using $I = 4I_0 \cos^2\frac{\phi}{2} \Rightarrow \frac{I_1}{I_2} = \frac{\cos^2(\phi_1/2)}{\cos^2(\phi_2/2)}$

$\Rightarrow \frac{K}{I_2} = \frac{\cos^2(2\pi/2)}{\cos^2\left(\frac{\pi/2}{2}\right)} = \frac{1}{1/2} \Rightarrow I_2 = \frac{K}{2}$.

12. (d) If shift is equivalent to n fringes then

$n = \frac{(\mu-1)t}{\lambda} \Rightarrow n \propto t \Rightarrow \frac{t_2}{t_1} = \frac{n_2}{n_1} \Rightarrow t_2 = \frac{n_2}{n_1} \times t$

$t_2 = \frac{20}{30} \times 4.8 = 3.2\ mm$.

13. (a) According to given condition

$(\mu - 1)t = n\lambda$ for minimum t, $n = 1$

So, $(\mu - 1)t_{\min} = \lambda$

$t_{\min} = \frac{\lambda}{\mu - 1} = \frac{\lambda}{1.5 - 1} = 2\lambda$

14. (a) $\Delta\lambda = \lambda\frac{v}{c}$ and $v = r\omega$

$v = 7 \times 10^8 \times \frac{2\pi}{25 \times 24 \times 3600}$, $c = 3 \times 10^8\ m/s$

$\therefore \Delta\lambda = 0.04 Å$

15. (b) $v = \frac{c\Delta\lambda}{\lambda} = \frac{3 \times 10^8 \times (706 - 656)}{656} = \frac{1500}{656} \times 10^7$

$= 2 \times 10^7\ m/s$

16. (b) In this case, we can assume as if both the source and the observer are moving towards each other with speed v. Hence $\nu' = \frac{c - u_o}{c - u_s}\nu = \frac{c - (-v)}{c - v}\nu = \frac{c + v}{c - v}\nu$

$= \frac{(c + v)(c - v)}{(c - v)^2}\nu = \frac{c^2 - v^2}{c^2 + v^2 - 2vc}\nu$

Since $v << c$, therefore $\nu' = \frac{c^2}{c^2 - 2vc} = \frac{c}{c - 2v}\nu$

17. (a) $\Delta\lambda = \lambda.\frac{v}{c}$ where $v = r\omega = r \times \left(\frac{2\pi}{T}\right)$

$\therefore \Delta\lambda = \frac{4320 \times 7 \times 10^8 \times 2 \times 3.14}{3 \times 10^8 \times 22 \times 86400} = 0.033 Å$

18. (a) $\beta = \frac{\lambda D}{d} \Rightarrow \beta \propto D$

$\Rightarrow \frac{\beta_1}{\beta_2} = \frac{D_1}{D_2} \Rightarrow \frac{\beta_1 - \beta_2}{\beta_2} = \frac{D_1 - D_2}{D_2} \Rightarrow \frac{\Delta\beta}{\Delta D} = \frac{\beta_2}{D_2} = \frac{\lambda_2}{d_2}$

$= \lambda_2 = \frac{3 \times 10^{-5}}{5 \times 10^{-2}} \times 10^{-3} = 6 \times 10^{-7}\ m = 6000 Å$

19. (a) P is the position of 11th bright fringe from Q. From central position O, P will be the position of 10th bright fringe.

Path difference between the waves reaching at $P = SB = 10\ \lambda = 10 \times 6000 \times 10^{-10} = 6 \times 10^{-6}\ m$.

20. (b) Resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

At central position with coherent source (and $I_1 = I_2 = I_0$

$I_{con} = 4I_0$ ... (i)

In case of incoherent at a given point, ϕ varies randomly with time so $(\cos\phi)_{av} = 0$

$\therefore\ I_{Incoh} = I_1 + I_2 = 2I_0$ ... (ii)

Hence $\frac{I_{coh}}{I_{Incoh}} = \frac{2}{1}$.

21. (a, d) These waves are of same frequencies and they are coherent

22. (c) Fringe width $\beta \propto \lambda$. Therefore, λ and hence β decreases 1.5 times when immersed in liquid. The distance between central maxima and 10th maxima is 3 cm in vacuum. When immersed in liquid it will reduce to 2 cm. Position of central maxima will not change while 10th maxima will be obtained at $y = 4cm$.

23. (a) Suppose P is a point infront of one slit at which intensity is to be calculated from figure it is clear that $x = \frac{d}{2}$. Path difference between the waves reaching at P

$$\Delta = \frac{xd}{D} = \frac{\left(\frac{d}{2}\right)d}{10d} = \frac{d}{20} = \frac{5\lambda}{20} = \frac{\lambda}{4}$$

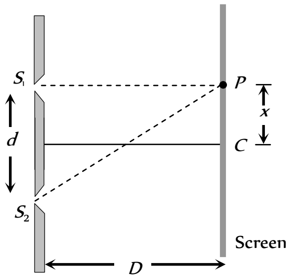
Hence corresponding phase difference

$$\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

Resultant intensity at P

$$I = I_{max}\cos^2\frac{\phi}{2}$$

$$= I_0\cos^2\left(\frac{\pi}{4}\right) = \frac{I_0}{2}$$



24. (d) If $d\sin\theta = (\mu - 1)t$, central fringe is obtained at O

If $d\sin\theta > (\mu - 1)t$, central fringe is obtained above O and

If $d\sin\theta < (\mu - 1)t$, central fringe is obtained below O.

25. (b) For maximum intensity on the screen

$$d\sin\theta = n\lambda \Rightarrow \sin\theta = \frac{n\lambda}{d} = \frac{n(2000)}{7000} = \frac{n}{3.5}$$

Since maximum value of $\sin\theta$ is 1

So $n = 0, 1, 2, 3,$ only. Thus only seven maximas can be obtained on both sides of the screen.

26. (c) From the given data, note that the fringe width (β) for $\lambda_1 = 900\,nm$ is greater than fringe width (β) for $\lambda_2 = 750\,nm$. This means that at though the central maxima of the two coincide, but first maximum for $\lambda_1 = 900\,nm$ will be further away from the first maxima for $\lambda_2 = 750\,nm$, and so on. A stage may come when this mismatch equals β, then again maxima of $\lambda_1 = 900\,nm$, will coincide with a maxima of $\lambda_2 = 750\,nm$, let this correspond to n order fringe for λ. Then it will correspond to $(n+1)^{th}$ order fringe for λ.

Therefore $\frac{n\lambda_1 D}{d} = \frac{(n+1)\lambda_2 D}{d}$

$$\Rightarrow n \times 900 \times 10^{-9} = (n+1)750 \times 10^{-9} \Rightarrow n = 5$$

Minimum distance from

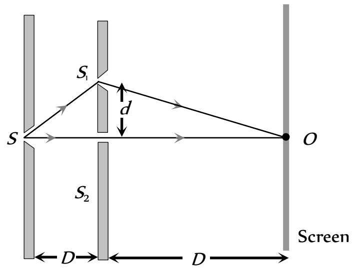
Central maxima $= \frac{n\lambda_1 D}{d} = \frac{5 \times 900 \times 10^{-9} \times 2}{2 \times 10^{-3}}$

$$= 45 \times 10^{-4}\,m = 4.5\,mm$$

27. (c) Shift $= \frac{\beta}{\lambda}(\mu - 1)t$

$$\Rightarrow 7\beta = \frac{\beta}{\lambda}(\mu - 1)t \Rightarrow t = \frac{7\lambda}{(\mu - 1)} = \frac{7 \times 600}{(1.5 - 1)} = 8400\,nm.$$

28. (c) Path difference between the waves reaching at P, $\Delta = \Delta_1 + \Delta_2$



where $\Delta_1 =$ Initial path difference

$\Delta_2 =$ Path difference between the waves after emerging from slits.

$$\Delta_1 = SS_1 - SS_2 = \sqrt{D^2 + d^2} - D$$

and $\Delta_2 = S_1O - S_2O = \sqrt{D^2 + d^2} - D$

$$\therefore\ \Delta = 2\left\{(D^2 + d^2)^{\frac{1}{2}} - D\right\} = 2\left\{(D^2 + \frac{d^2}{2D}) - D\right\}$$

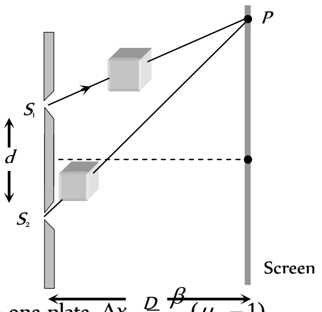
$$= \frac{d^2}{D} \qquad \text{(From Binomial expansion)}$$

For obtaining dark at O, Δ must be equals to $(2n-1)\frac{\lambda}{2}$ *i.e.*

$$\frac{d^2}{D} = (2n-1)\frac{\lambda}{2} \Rightarrow d\sqrt{\frac{(2n-1)\lambda D}{2}}$$

For minimum distance $n = 1$ so $d = \sqrt{\frac{\lambda D}{2}}$

29. (a) Shift $\Delta x = \frac{\beta}{\lambda}(\mu - 1)t$



Shift due to one plate $\Delta x_1 = \frac{\beta}{\lambda}(\mu_1 - 1)$

Shift due to another path $\Delta x_2 = \frac{\beta}{\lambda}(\mu_2 - 1)t$

Net shift $\Delta x = \Delta x_2 - \Delta x_1 = \frac{\beta}{\lambda}(\mu_2 - \mu_1)t$ .....(i)

Also it is given that $\Delta x = 5\beta$ .....(ii)

Hence $5\beta = \frac{\beta}{\lambda}(\mu_1 - \mu_2)t$

$$\Rightarrow t = \frac{5\lambda}{(\mu_2 - \mu_1)} = \frac{5 \times 4800 \times 10^{-10}}{(1.7 - 1.4)} = 8 \times 10^{-6}\,m = 8\,\mu m.$$

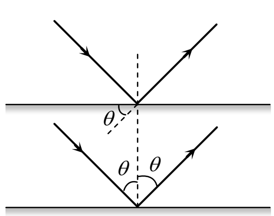
30. (b) For maxima $2\pi n = \frac{2\pi}{\lambda}(XO) - 2\pi l$

or $\frac{2\pi}{\lambda}(XO) = 2\pi(n + l)$ or $(XO) = \lambda(n + l)$

31. (c) Path difference $= 2d\sin\theta$

$\therefore$ For constructive interference

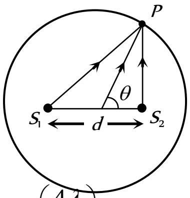
$$2d\sin\theta = n\lambda$$



$\Rightarrow \theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$

32. (b) Here path difference at a point P on the circle is given by

$\Delta x = d\cos\theta$ ..... (i)



For maxima at P

$\Delta x = n\lambda$ ..... (ii)

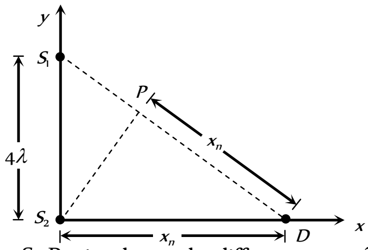
From equation (i) and (ii)

$n\lambda = d\cos\theta \Rightarrow \theta \cos^{-1}\left(\frac{n\lambda}{d}\right) = \cos^{-1}\left(\frac{4\lambda}{d}\right)$

33. (b) From ΔS_1S_2D,

$(S_1D)^2 = (S_1S_2)^2 + (S_2D)^2$

$(S_1P + PD)^2 = (S_1S_2)^2 + (S_2D)^2$



Here S_1P is the path difference $= n\lambda$ for maximum intensity.

$\therefore (n\lambda + x_n)^2 = (4\lambda)^2 + (x_n)^2$

or $x_n = \frac{16\lambda^2 - n^2\lambda^2}{2n\lambda}$

Then $x_1 = \frac{16\lambda^2 - \lambda^2}{2\lambda} = 7.5\,\lambda$

$x_2 = \frac{16\lambda^2 - 4\lambda^2}{4\lambda} = 3\lambda$

$x_3 = \frac{16\lambda^2 - 9\lambda^2}{6\lambda} = \frac{7}{6}\lambda$

$x_4 = 0$.

$\therefore$ Number of points for maxima becomes 3.

34. (a) $I_0 = R^2 = \frac{R_2^2}{4}$

Number of *HPZ* covered by the disc at $b = 25\,cm$

$n_1b_1 = n_2b_2$

$n_2 = \frac{n_1b_1}{b_2} + \frac{1\times 1}{0.25} = 4$

Hence the intensity at this point is

$I = R'^2 = \left(\frac{R_5}{2}\right)^2 = \left(\frac{R_5}{R_4}\times\frac{R_4}{R_3}\times\frac{R_3}{R_2}\right)^2 \times \left(\frac{R_2}{2}\right)^2$

or $1 = [0.9]^6$

$I_1 = 0.531\, I_0$

Hence the correct answer will be (a).

35. (b) $I_A = R_1^2$

$I_B = (R_1 - R_2)^2 = R_1^2\left(1 - \frac{R_2}{R_1}\right)^2 = R_1^2\left(1 - \frac{3}{4}\right)^2 = \frac{R_1^2}{16}$

$I_C = (R_1 - R_2 + R_3)^2 = R_1^2\left(1 - \frac{R_2}{R_1} + \frac{R_3}{R_1}\right)^2$

$= R_1^2\left(1 - \frac{R_2}{R_1} + \frac{R_3}{R_2}\times\frac{R_2}{R_1}\right)^2$

$= R_1^2\left(1 - \frac{3}{4} + \frac{3}{4}\times\frac{3}{4}\right)^2 = \left(\frac{13}{16}\right)^2 R_1^2 = \frac{169}{256}R_1^2$

$\therefore I_A : I_B : I_C = R_1^2 : \frac{R_1^2}{16} : \frac{169}{256}R_1^2 = 256 : 16 : 169$

36. (d) $I = \frac{R_2^2}{4}$ given $n_1b_1 = n_2b_2 \Rightarrow 1\times 200 = n_2 \times 25$

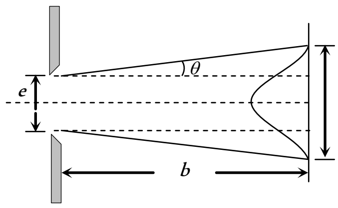
$\therefore n_2 = 8\ HPZ$

$\therefore I = \left(\frac{R_9}{2}\right)^2$

$= \left(\frac{R_9}{R_8}\times\frac{R_8}{R_7}\times\frac{R_7}{R_6}\times\frac{R_6}{R_5}\times\frac{R_5}{R_4}\times\frac{R_4}{R_3}\times\frac{R_3}{R_2}\times\frac{R_2}{R_2}\right)^2$

$= \left(\frac{R_9}{R_2}\right)^2 I$

37. (c) The direction in which the first minima occurs is θ (say). Then $e\sin\theta = \lambda$ or $e\theta = \lambda$ or, $\theta = \frac{\lambda}{e}$ ($\because \theta = \sin\theta$ when θ small)



Width of the central maximum $= 2b\theta + e = 2b.\frac{\lambda}{e} + e$

38. (b) Angular width $\beta = \frac{2\lambda}{d} \Rightarrow \beta \propto \lambda$

$\Rightarrow \frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{\beta}{\frac{70}{100}\beta} = \frac{6000}{\lambda_2} \Rightarrow \lambda_2 = 4200\,Å$

39. (a) In a single slit diffraction experiment, position of minima is given by $d\sin\theta = n\lambda$

So for first minima of red $\sin\theta = 1\times\left(\frac{\lambda_R}{d}\right)$

and as first maxima is midway between first and second minima, for wavelength λ', its position will be

$$d\sin\theta' = \frac{\lambda' + 2\lambda'}{2} \Rightarrow \sin\theta' = \frac{3\lambda'}{2d}$$

According to given condition $\sin\theta = \sin\theta'$

$$\Rightarrow \lambda' = \frac{2}{3}\lambda_R \text{ so } \lambda' = \frac{2}{3}\times 6600 = 440\,nm = 4400\,Å$$

40. (c) $I = I_0\left[\frac{\sin\alpha}{\alpha}\right]^2$, where $\alpha = \frac{\phi}{2}$

For n^{th} secondary maxima $d\sin\theta = \left(\frac{2n+1}{2}\right)\lambda$

$$\Rightarrow \alpha = \frac{\phi}{2} = \frac{\pi}{\lambda}[d\sin\theta] = \left(\frac{2n+1}{2}\right)\pi$$

$$\therefore\ I = I_0\left[\frac{\sin\left(\frac{2n+1}{2}\right)\pi}{\left(\frac{2n+1}{2}\right)\pi}\right]^2 = \frac{I_0}{\left\{\frac{(2n+1)}{2}\pi\right\}^2}$$

So $I_0 : I_1 : I_2 = I_0 : \frac{4}{9\pi^2}I_0 : \frac{4}{25\pi^2}I_0$

$$= 1 : \frac{4}{9\pi^2} : \frac{4}{25\pi^2}$$

41. (d) For a grating $(e+d)\sin\theta_n = n\lambda$

where $(e+d) =$ grating element

$$\sin\theta_n = \frac{n\lambda}{(e+d)}$$

For $n = 1$, $\sin\theta_1 = \frac{\lambda}{(e+d)} = \sin 32°$

This is more than 0.5. Now $\sin\theta_2$ will be more than 2×0.5, which is not possible.

42. (a) The film appears bright when the path difference $(2\mu t\cos r)$ is equal to odd multiple of $\frac{\lambda}{2}$

i.e. $2\mu t\cos r = (2n-1)\,\lambda/2$ where $n = 1, 2, 3$ .....

$$\therefore\ \lambda = \frac{4\mu t\cos r}{(2n-1)}$$

$$= \frac{4\times 1.4\times 10{,}000\times 10^{-10}\times\cos 0}{(2n-1)} = \frac{56000}{(2n-1)}Å$$

$\therefore\ \lambda = 56000\,Å$ $18666\,Å$, $8000\,Å$, $6222\,Å$, $5091\,Å$, $4308\,Å$, $3733\,Å$.

The wavelength which are not within specified range are to be refracted.

43. (a) Total phase difference

= Initial phase difference + Phase difference due to path

$$= 66° + \frac{360°}{\lambda}\times\Delta x = 66° + \frac{360°}{\lambda}\times\frac{\lambda}{4} = 66° + 90 = 156°$$

44. (a) $I = 4I_0\cos^2\frac{\phi}{2}$

At central position $I_1 = 4I_0$ ......(i)

Since the phase difference between two successive fringes is 2π, the phase difference between two points separated by a distance equal to one quarter of the distance between the two, successive fringes is equal to $\delta = (2\pi)\left(\frac{1}{4}\right) = \frac{\pi}{2}$ radian

$$\Rightarrow I_2 = 4I_0\cos^2\left(\frac{\frac{\pi}{2}}{2}\right) = 2I_0 \quad ......(ii)$$

Using (i) and (ii), $\frac{I_1}{I_2} = \frac{4I_0}{2I_0} = 2$

45. (b) $I_D = \varepsilon_0\frac{d\phi_E}{dt} = \varepsilon_0\frac{EA}{t} = \varepsilon_0\left(\frac{V}{d}\right).\frac{A}{t}$.

$$= \frac{8.85\times 10^{-12}\times 400\times 60\times 10^{-4}}{10^{-3}\times 10^{-6}} = 1.602\times 10^{-2}\,amp$$

46. (d) Electric field $E = \frac{V}{l} = \frac{iR}{l}$ (R = Resistance of wire)

Magnetic field at the surface of wire $B = \frac{\mu_0 i}{2\pi a}$ (a = radius of wire)

Hence poynting vector, directed radially inward is given by

$$S = \frac{EB}{\mu_0} = \frac{iR}{\mu_0 l}.\frac{\mu_0 i}{2\pi a} = \frac{i^2R}{2\pi a l}$$

47. (b) Average energy density of electric field is given by

$$u_e = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}\varepsilon_0\left(\frac{E_0}{\sqrt{2}}\right)^2 = \frac{1}{4}\varepsilon_0 E_0^2$$

$$= \frac{1}{4}\times 8.85\times 10^{-12}(1)^2 = 2.2\times 10^{-12}\,J/m^3.$$

48. (b) Area through which the energy of beam passes

$$= (6.328\times 10^{-7}) = 4\times 10^{-13}\,m^2$$

$$\therefore\ I = \frac{P}{A} = \frac{10^{-3}}{4\times 10^{-13}} = 2.5\times 10^9\,W/m^2$$

49. (a) $S_{av} = \frac{1}{2}\varepsilon_0 cE_0^2 = \frac{P}{4\pi R^2}$

$$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2\varepsilon_0 C}}$$

$$= \sqrt{\frac{3}{2\times 3.14\times 100\times 8.85\times 10^{-12}\times 3\times 10^8}}$$

= 1.34 V/m

50. (d) Intensity of EM wave is given by

$$I = \frac{P}{4\pi R^2} = v_{av}.c = \frac{1}{2}\varepsilon_0 E_0^2\times c$$

$$\Rightarrow E_0 = \sqrt{\frac{P}{2\pi R^2 \varepsilon_0 c}}$$

$$= \sqrt{\frac{800}{2\times 3.14\times (4)^2\times 8.85\times 10^{-12}\times 3\times 10^8}}$$

$= 54.77\ \frac{V}{m}$

51. (c) Wave impedance $Z = \sqrt{\frac{\mu_r}{\varepsilon_r}} \times \sqrt{\frac{\mu_0}{\varepsilon_0}}$

$$= \sqrt{\frac{50}{2}} \times 376.6 = 1883\,\Omega$$

52. (d) Momentum transferred in one second

$$p = \frac{2U}{c} = \frac{2S_{av}A}{c} = \frac{2\times 6\times 40\times 10^{-4}}{3\times 10^8}$$

$= 1.6\times 10^{-10}$ *kg-m/s*.

53. (a) Specific rotation

$$(\alpha) = \frac{\theta}{l\,c} \Rightarrow c = \frac{\theta}{\alpha l} = \frac{0.4}{0.01\times 0.25} = 160\ kg/m^3$$

Now percentage purity of sugar solution

$$= \frac{160}{200}\times 100 = 80\%$$

54. (d) As $\theta \propto l$

Volume ratio 1 : 2 in a tube of length 30 *cm* means 10 *cm* length of first solution and 20 *cm* length of second solution .

Rotation produced by 10 *cm* length of first solution

$$\theta_1 = \frac{38°}{20}\times 10 = 19°$$

Rotation produced by 20*cm* length of second solution

$$\theta_2 = -\frac{24°}{30}\times 20 = -16°$$

$\therefore$ Total rotation produced = 19° – 16° = 3°

55. (d) If I is the final intensity and I_0 is the initial intensity then

$$I = \frac{I_0}{2}(\cos^2 30°)^5 \quad \text{or} \quad \frac{I}{I_0} = \frac{1}{2}\times\left(\frac{\sqrt{3}}{2}\right)^{10} = 0.12$$

56. (a) Using Matus law, $I = I_0 \cos^2\theta$

As here polariser is rotating *i.e.* all the values of θ are possible.

$$I_{av} = \frac{1}{2\pi}\int_0^{2\pi} I\,d\theta = \frac{1}{2\pi}\int_0^{2\pi} I_0\cos^2\theta\,d\theta$$

On integration we get $I_{av} = \frac{I_0}{2}$

where $I_0 = \frac{\text{Energy}}{\text{Area}\times\text{Time}} = \frac{p}{A} = \frac{10^{-3}}{3\times 10^{-4}} = \frac{10}{3}\ \frac{Watt}{m^2}$

$$\therefore I_{av} = \frac{1}{2}\times\frac{10}{3} = \frac{5}{3}\,Watt$$

and Time period $T = \frac{2\pi}{\omega} = \frac{2\times 3.14}{31.4} = \frac{1}{5}\,sec$

$\therefore$ Energy of light passing through the polariser per revolution

$$= I_{av}\times\text{Area}\times T = \frac{5}{3}\times 3\times 10^{-4}\times\frac{1}{5} = 10^{-4}\ J.$$

57. (d) Let *n*th minima of 400 *nm* coincides with *m*th minima of 560 *nm* then

$$(2n-1)400 = (2m-1)560 \Rightarrow \frac{2n-1}{2m-1} = \frac{7}{5} = \frac{14}{10} = \frac{21}{15}$$

i.e. 4th minima of 400 *nm* coincides with 3rd minima of 560 *nm*.

The location of this minima is

$$= \frac{7(1000)(400\times 10^{-6})}{2\times 0.1} = 14\,mm$$

Next, 11th minima of 400 *nm* will coincide with 8th minima of 560 *nm*

Location of this minima is

$$= \frac{21(1000)(400\times 10^{-6})}{2\times 0.1} = 42\,mm$$

$\therefore$ Required distance = 28 *mm*

58. (b) For maxima $\Delta = d\sin\theta = n\lambda$

$$\Rightarrow 2\lambda\sin\theta = n\lambda \Rightarrow \sin\theta = \frac{n}{2}$$

since value of sin θ can not be greater 1.

$\therefore$ n = 0, 1, 2

Therefore only five maximas can be obtained on both side of the screen.

59. (a) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow \frac{(401.8-393.3)}{393.3} = \frac{v}{3\times 10^8}$

$\Rightarrow v = 6.48\times 10^6$ *m/s* = 6480 *km/sec*.

60. (c) The interference fringes for two slits are hyperbolic.

61. (d) If you divide the original slit into N strips and represents the light from each strip, when it reaches the screen, by a phasor, then at the central maximum in the diffraction pattern you add N phasors, all in the same direction and each with the same amplitude. The intensity is therefore N. If you double the slit width, you need $2N$ phasors, if they are each to have the amplitude of the each to have the amplitude of the phasors you used for the narrow slit. The intensity at the central maximum is proportional to $(2N)^2$ and is, therefore, four times the intensity for the narrow slit.

62. (c) $I = 4I_0\cos^2(\phi/2) \Rightarrow \phi = 2\pi/3$

$\Rightarrow \Delta x\times(2\pi/\lambda) = 2\pi/3 = \lambda/3$

sin $\theta = \Delta x/d \Rightarrow$ sin $\theta = \lambda/3d$

63. (b) Momentum of the electron will increase. So the wavelength ($\lambda = h/p$)of electrons will decrease and fringe width decreases as $\beta \propto \lambda$.

Assertion and Reason

1. (d) When a light wave travel from a rarer to a denser medium it loses speed, but energy carried by the wave does not depend on its speed. Instead, it depends on the amplitude of wave.

2. (e) A narrow pulse is made of harmonic waves with a large range of wavelength. As speed of propagation is different for different wavelengths, the pulse cannot retain its shape while travelling through the medium.

3. (b) When d is negligibly small, fringe width β which is proportional to $1/d$ may become too large. Even a single fringe may occupy the whole screen. Hence the pattern cannot be detected.

4. (a) The central spot of Newton's rings is dark when the medium between plano convex lens and plane glass is rarer than the medium of lens and glass. The central spot is dark because the phase change of π is introduced between the rays reflected from surfaces of denser to rarer and rarer to denser media.

5. (a) For reflected system of the film, the maxima or constructive interference is $2\mu t\cos r = \frac{(2n-1)\lambda}{2}$ while the maxima for transmitted system of film is given by equation $2\mu t\cos r = n\lambda$

where t is thickness of the film and r is angle of reflection.

From these two equations we can see that condition for maxima in reflected system and transmitted system are just opposite.

6. (b) When intensity of light emerging from two slits is equal, the intensity at minima,

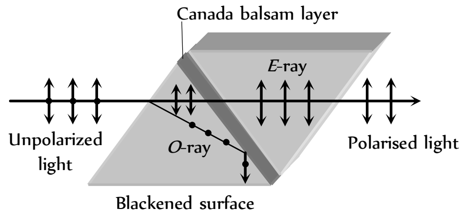
$$I_{\min} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2 = 0, \text{ or absolute dark.}$$

It provides a better contrast.

7. (c) When one of slits is covered with cellophane paper, the intensity of light emerging from the slit is decreased (because this medium is translucent). Now the two interfering beam have different intensities or amplitudes. Hence intensity at minima will not be zero and fringes will become indistinct.

8. (a) When a polaroid is rotated in the path of unpolarised light, the intensity of light transmitted from polaroid remains undiminished (because unpolarised light contains waves vibrating in all possible planes with equal probability). However, when the polaroid is rotated in path of plane polarised light, its intensity will vary from maximum (when the vibrations of the plane polarised light are parallel to the axis of the polaroid) to minimum (when the direction of the vibrations becomes perpendicular to the axis of the crystal). Thus using polaroid we can easily verify that whether the light is polarised or not.

9. (c) The nicol prism is made of calcite crystal. When light is passed through calcite crystal, it breaks up into two rays (i) the ordinary ray which has its electric vector perpendicular to the principal section of the crystal and (ii) the extra ordinary ray which has its electric vector parallel to the principal section. The nicol prism is made in such a way that it eliminates one of the two rays by total internal reflection, thus produces plane polarised light. It is generally found that the ordinary ray is eliminated and only the extra ordinary ray is transmitted through the prism. The nicol prism consists of two calcite crystal cut at – 68° with its principal axis joined by a glue called Canada balsam.



10. (b) Doppler's effect is observed readily in sound wave due to larger wavelengths. The same is not the case with light due to shorter wavelength in every day life.

11. (d) In Young's experiments fringe width for dark and white fringes are same while in Young's double slit experiment when a white light as a source is used, the central fringe is white around which few coloured fringes are observed on either side.

12. (a) It is quite clear that the coloured spectrum is seen due to diffraction of white light on passing through fine slits made by fine threads in the muslin cloth.

13. (c) As the waves diffracted from the edges of circular obstacle, placed in the path of light interfere constructively at the centre of the shadow resulting in the formation of a bright spot.

14. (c) The beautiful colours are seen on account of interference of light reflected from the upper and the lower surfaces of the thin films.

15. (a) Microwave communication is preferred over optical communication because microwaves provide large number of channels and wider band width compared to optical signals as information carrying capacity is directly proportional to band width. So, wider the band width, greater the information carrying capacity.

16. (a)

17. (a) $\beta = \frac{\lambda D}{d}$

18. (c) The clouds consists of dust particles and water droplets. Their size is very large as compared to the wavelength of the incident light from the sun. So there is very little scattering of light. Hence the light which we receive through the clouds has all the colours of light. As a result of this, we receive almost white light. Therefore, the cloud are generally white.

19. (d) In sky wave propagation, the radio waves having frequency range 2 *MHz* to 30 *MHz* are reflected back by the ionosphere. Radio waves having frequency nearly greater than 30 *MHz* penetrates the inosphere and is not reflected back by the ionosphere. The TV signal having frequency greater than 30 *MHz* therefore cannot be propagated through sky wave propagation.

In case of sky wave propagation, critical frequency is defined as the highest frequency is returned to the earth by the considered layer of the ionosphere after having sent straight to it. Above this frequency, a wave will penetrate the inosphere and is not reflected by it.

20. (c) The television signals being of high frequency are not reflected by the ionosphere. So the T.V. signals are broadcasted by tall antenna to get large coverage, but for transmission over large distance satellites are needed. That is way, satellites are used for long distance T.V. transmission.

21. (e) We know, with increase in altitude, the atmospheric pressure decreases. The high energy particles (*i.e.* γ-rays and cosmic rays) coming from outer space and entering out earth's atmosphere cause ionisation of the atoms of the gases present there. The ionising power of these radiation decreases rapidly as they approach to earth, due to increase in number of collisions with the gas atoms. It is due to this reason the electrical conductivity of earth's atmosphere increase with altitude.

22. (a) In a radar, a beam signal is needed in particular direction which is possible if wavelength of wave is very small. Since the wavelength of microwaves is a few millimeter, hence they are used in radar.

23. (c) Hertz experimentally observed that the production of spark between the detector gap is maximum when it is placed parallel to source gap. This means that the electric vector of radiation produced by the source gap is parallel to the two gaps *i.e.,* in the direction perpendicular to the direction of propagation of the radiation.

24. (d) The atoms of the metallic container are set into forced vibrations by the microwaves. Hence, energy of the microwaves is not efficiently transferred to the metallic container. Hence food in metallic containers cannot be cooked in microwave oven. Normally in microwave oven the energy of waves is transferred to the kinetic energy of the molecules. This raises the temperature of any food.

25. (c) The earth's atmosphere is transparent to visible light and radio waves, but absorbs *X*-rays. Therefore *X*-rays telescope cannot be used on earth surface.

26. (b) Short wave (wavelength 30 *km* to 30 *cm*). These waves are used for radio transmission and for general communication purpose to a longer distance from ionosphere.

27. (b) The wavelength of these waves ranges between 4000 Å to 100 Å that is smaller wavelength and higher frequency. They are absorbed by atmosphere and convert oxygen into ozone. They cause skin diseases and they are harmful to eye and cause permanent blindness.

28. (d) Ozone layer in the stratosphere helps in protecting life of organism from ultraviolet radiation on earth. Ozone layer is depleted due to of several factors like use of chlorofluoro carbon (CFC) which is the cause of environmental damages.

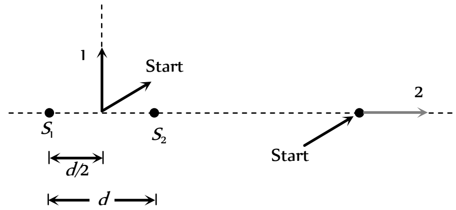
29. (b) Radio waves can be polarised becomes they are transverse in nature. Sound waves in air are longitudinal in nature.

30. (a) In the absence of atmosphere, all the heat will escape from earth's surface which will make earth in hospitably cold.

Wave Optics

SET Self Evaluation Test - 30

1. Following figure shows sources S_1 and S_2 that emits light of wavelength λ in all directions. The sources are exactly in phase and are separated by a distance equal to 1.5λ. If we start at the indicated start point and travel along path 1 and 2, the interference produce a maxima all along



(a) Path 1 (b) Path 2

(c) Any path (d) None of these

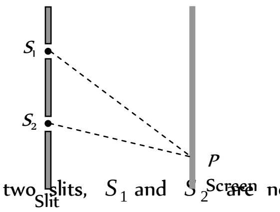
2. In a Young's double slit experimental arrangement shown here, if a mica sheet of thickness t and refractive index μ is placed in front of the slit S_1, then the path difference $(S_1P - S_2P)$

(a) Decreases by $(\mu - 1)t$

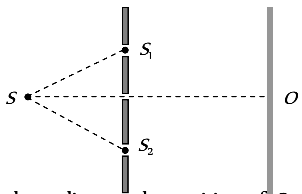
(b) Increases by $(\mu - 1)t$

(c) Does not change

(d) Increases by μt



3. In the set up shown in Fig the two slits, S_1 and S_2 are not equidistant from the slit S. The central fringe at O is then



(a) Always bright

(b) Always dark

(c) Either dark or bright depending on the position of S

(d) Neither dark nor bright.

4. The intensity ratio of two coherent sources of light is p. They are interfering in some region and produce interference pattern. Then the fringe visibility is

(a) $\frac{1+p}{2\sqrt{p}}$ (b) $\frac{2\sqrt{p}}{1+p}$

(c) $\frac{p}{1+p}$ (d) $\frac{2p}{1+p}$

5. Three waves of equal frequency having amplitudes $10\mu m$, $4\mu m$, $7\mu m$ arrive at a given point with successive phase difference of $\frac{\pi}{2}$, the amplitude of the resulting wave in μm is given by

(a) 4 (b) 5

(c) 6 (d) 7

6. Four different independent waves are represented by

(i) $y_1 = a_1 \sin\omega t$ (ii) $y_2 = a_2 \sin 2\omega t$

(iii) $y_3 = a_3 \cos\omega t$ (iv) $y_4 = a_4 \sin\left(\omega t + \frac{\pi}{3}\right)$

With which two waves interference is possible

(a) In (i) and (iii) (b) In (i) and (iv)

(c) In (iii) and (iv) (d) Insufficient data to predict.

7. A beam of light consisting of two wavelengths 650 *nm* and 520 *nm* is used to illuminate the slit of a Young's double slit experiment. Then the order of the bright fringe of the longer wavelength that coincide with a bright fringe of the shorter wavelength at the least distance from the central maximum is

(a) 1 (b) 2

(c) 3 (d) 4

8. Two identical radiators have a separation of $d = \lambda/4$ where λ is the wavelength of the waves emitted by either source. The initial phase difference between the sources is $\pi/4$. Then the intensity on the screen at a distant point situated at an angle $\theta = 30°$ from the radiators is (here I_o is intensity at that point due to one radiator alone)

(a) I_o (b) $2I_o$

(c) $3I_o$ (d) $4I_o$

9. In Young's double slit experiment, the $8th$ maximum with wavelength λ_1 is at a distance d_1 from the central maximum and the $6th$ maximum with a wavelength λ_2 is at a distance d_2. Then (d_1/d_2) is equal to

(a) $\frac{4}{3}\left(\frac{\lambda_2}{\lambda_1}\right)$ (b) $\frac{4}{3}\left(\frac{\lambda_1}{\lambda_2}\right)$

(c) $\frac{3}{4}\left(\frac{\lambda_2}{\lambda_1}\right)$ (d) $\frac{3}{4}\left(\frac{\lambda_1}{\lambda_2}\right)$

10. Light of wavelength $500\,nm$ is used to form interference pattern in Young's double slit experiment. A uniform glass plate of refractive index 1.5 and thickness $0.1\,mm$ is introduced in the path of one of the interfering beams. The number of fringes which will shift the cross wire due to this is

(a) 100 (b) 200

(c) 300 (d) 400

11. The two coherent sources of equal intensity produce maximum intensity of 100 units at a point. If the intensity of one of the sources is reduced by 36% by reducing its width then the intensity of light at the same point will be

(a) 90 (b) 89

(c) 67 (d) 81

12. The path difference between two interfering waves of equal intensities at a point on the screen is $\frac{\lambda}{4}$. The ratio of intensity at this point and that at the central fringe will be

(a) 1 : 1 (b) 1 : 2

(c) 2 : 1 (d) 1 : 4

13. In a Young's double slit experiment, I_o is the intensity at the central maximum and β is the fringe width. The intensity at a point *P* distant *x* from the centre will be

(a) $I_o \cos\frac{\pi x}{\beta}$ (b) $4I_o \cos^2\frac{\pi x}{\beta}$

(c) $I_o \cos^2\frac{\pi x}{\beta}$ (d) $\frac{I_o}{4}\cos^2\frac{\pi x}{\beta}$

14. In a Fresnel's diffraction arrangement, the screen is at a distance of 2 meter from a circular aperture. It is found that for light of wavelengths λ_1 and λ_2, the radius of $4th$ zone for λ_1 coincides with the radius of 5 zone for λ_2. Then the ratio $\lambda_1 : \lambda_2$ is

(a) $\sqrt{4/5}$ (b) $\sqrt{5/4}$

(c) $5/4$ (d) $4/5$

15. If *n* represents the order of a half period zone, the area of this zone is approximately proportional to n^m where *m* is equal to

(a) Zero (b) Half

(c) One (d) Two

16. A screen is placed $50\,cm$ from a single slit, which is illuminated with $6000\mathring{A}$ light. If distance between the first and third minima in the diffraction pattern is $3\,mm$, the width of the slit is

(a) $0.1\,mm$ (b) $0.2\,mm$

(c) $0.3\,mm$ (d) $0.4\,mm$

17. In Young's double slit experiment, the fringes are displaced by a distance *x* when a glass plate of one refractive index 1.5 is introduced in the path of one of the beams. When this plate in replaced by another plate of the same thickness, the shift of fringes is $(3/2)x$. The refractive index of the second plate is

(a) 1.75 (b) 1.50

(c) 1.25 (d) 1.00

18. Two waves of equal amplitude and frequency interfere each other. The ratio of intensity when the two waves arrive in phase to that when they arrive $90°$ out of phase is

(a) 1 : 1 (b) $\sqrt{2}$: 1

(c) 2 : 1 (d) 4 : 1

19. In Young's double slit experiment, we get 60 fringes in the field of view of monochromatic light of wavelength $4000\mathring{A}$. If we use monochromatic light of wavelength $6000\mathring{A}$, then the number of fringes obtained in the same field of view is

(a) 60 (b) 90

(c) 40 (d) 1.5

20. A parallel plate capacitor with plate are *A* and seperation between the plates *d*, is charged by a constant current *i*, consider a plane surface of area *A*/2 parallel to the plates and drawn symmetrically between the plates, the displacement current through this area, will be.

(a) i (b) $\frac{i}{2}$

(c) $\frac{i}{4}$ (d) None of these

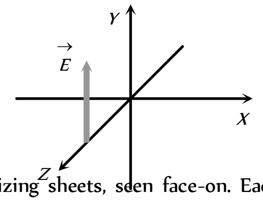
21. The figure here gives the electric field of an EM wave at a certain point and a certain instant. The wave is transporting energy in the negative *z* direction. What is the direction of the magnetic field of the wave at that point and instant

(a) Towards + *X* direction

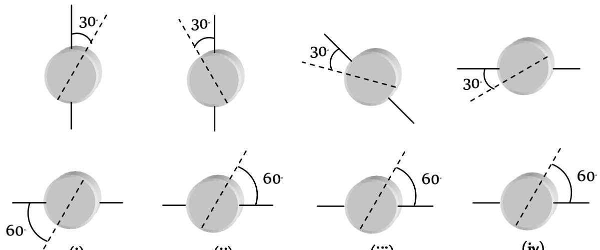
(b) Towards – *X* direction

(c) Towards + *Z* direction

(d) Towards – *Z* direction



22. The figure shows four pairs of polarizing sheets, seen face-on. Each pair is mounted in the path of initially unpolarized light. The polarizing direction of each sheet (indicated by the dashed line) is referenced to either a horizontal *x*-axis or a vertical *y* axis. Rank the pair according to the fraction of the initial intensity that they pass, greatest first



(a) (i) > (ii) > (iii) > (iv) (b) (i) > (iv) > (ii) > (iii)

(c) (i) > (iii) > (ii) > (iv) (d) (iv) > (iii) > (ii) > (i)

23. An astronaut floating freely in space decides to use his flash light as a rocket. He shines a 10 *watt* light beam in a fixed direction so that he acquires momentum in the opposite direction. If his mass is 80 *kg*, how long must he need to reach a velocity of 1 *ms*

(a) 9 *sec* (b) 2.4 × 10 *sec*

(c) 2.4 × 10 *sec* (d) 2.4 × 10 *sec*

Answers and Solutions

(SET -30)

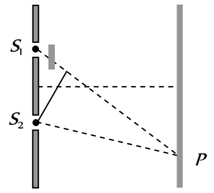
1. (a) At any point along the path 1, path difference between the waves is 0.

Hence maxima is obtained all along the path 1.

At any point along the path 2, path difference is 1.5 λ which is odd multiple of $\frac{\lambda}{2}$, so minima is obtained all along the path 2.

2. (b) Path difference at P $\Delta = (S_1P + (\mu - 1)t) - S_2P$

$= (S_1P - S_2P) + (\mu - 1)t$



3. (c) If path difference $\Delta = (SS_1 + S_1O) - (SS_2 + S_2O) = n\lambda$ n = 0, 1, 2, 3, ... the central fringe at O is a bright fringe and if the path difference $\Delta = \left(n - \frac{1}{2}\right)\lambda$, n = 1, 2, 3, ... the central bright fringe will be a dark fringe.

4. (b) Visibility $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2\sqrt{I_1 I_2}}{(I_1 + I_2)}$

$= \frac{2\sqrt{I_1 / I_2}}{\left(\frac{I_1}{I_2} + 1\right)} = \frac{2\sqrt{P}}{(P+1)}$

5. (b) The amplitudes of the waves are

$a_1 = 10\ \mu m$, $a_2 = 4\ \mu m$ and $a_3 = 7\mu m$

and the phase difference between 1st and 2nd wave is $\frac{\pi}{2}$ and that between 2nd and 3rd wave is $\frac{\pi}{2}$. Therefore, phase difference between 1st and 3rd is π. Combining 1st with 3rd, their resultant amplitude is given by

$A_1^2 = a_1^2 + a_3^2 + 2a_1a_3 \cos\phi$

or $A_1 = \sqrt{10^2 + 7^2 + 2\times 10\times 7 \cos\pi} = \sqrt{100 + 49 - 140}$

$= \sqrt{9} = 3\mu m$ in the direction of first.

Now combining this with 2nd wave we have, the resultant amplitude

$A^2 = A_1^2 + a_2^2 + 2A_1a_2 \cos\frac{\pi}{2}$

or $A = \sqrt{3^2 + 4^2 + 2\times 3\times 4 \cos 90^o} = \sqrt{9+16} = 5\mu m$

6. (d) Since the sources are independent, interference will not occur unless they are coherent (such as laser beams *etc*). So, insufficient data to predict.

7. (d) $n\beta_1 = (n+1)\beta_2$

$\Rightarrow \frac{n\times 650\times 10^{-19} D}{d} = \frac{(n+1)\times 520\times 10^{-19}\times D}{d}$

$\Rightarrow n = 4$

8. (b) The intensity at a point on screen is given by

$I = 4I_0 \cos^2(\phi/2)$

where ϕ is the phase difference. In this problem ϕ arises (i) due to initial phase difference of $\pi/4$ and (ii) due to path difference for the observation point situated at $\theta = 30^o$. Thus

$\phi = \frac{\pi}{4} + \frac{2\pi}{\lambda}(d\sin\theta) = \frac{\pi}{4} + \frac{2\pi}{\lambda}.\frac{\lambda}{4}(\sin 30°) = \frac{\pi}{4} + \frac{\pi}{4} = \frac{\pi}{2}$

Thus $\frac{\phi}{2} = \frac{\pi}{4}$ and $I = 4I_0\cos^2(\pi/4) = 2I_0$

9. (b) Position of n^{th} maxima from central maxima is given by $x_n = \frac{n\lambda D}{d}$

$\Rightarrow x_n \propto n\lambda \Rightarrow \frac{d_1}{d_2} = \frac{n_1\lambda_1}{n_2\lambda_2} = \frac{8\lambda_1}{6\lambda_2} = \frac{4}{3}\left(\frac{\lambda_1}{\lambda_2}\right)$

10. (a) The number of fringes shifting is decided by the extra path difference produced by introducing the glass plate. The extra path difference is $(\mu - 1)\ t = n\lambda$

or $(1.5 - 1)\times 0.1\times 10^{-3} = n\times 500\times 10^{-9}$

$\Rightarrow n = 100$

11. (d) Intensity of each source $= I_0 = \frac{100}{4} = 25\,unit$

If the intensity of one of the source is reduced by 36% then

$I_1 = 25\,unit$ and $I_2 = 25 - 25\times\frac{36}{100} = 16\,(unit)$

Hence resultant intensity at the same point will be

$I = I_1 + I_2 + 2\sqrt{I_1I_2} = 25 + 16 + 2\sqrt{25\times 16} = 81\,unit$

12. (b) By using $I = 4I_0\cos^2\left(\frac{\phi}{2}\right) = 4I_0\cos^2\left(\frac{\pi\Delta}{\lambda}\right)$

$\left\{\because \phi = \frac{2\pi}{\lambda}\Delta\right\}$

$\Rightarrow \frac{I_1}{I_2} = \frac{\cos^2\left(\frac{\pi\Delta_1}{\lambda}\right)}{\cos^2\left(\frac{\pi\Delta_2}{\lambda}\right)} = \frac{\cos^2\left(\frac{\pi.\frac{\lambda}{4}}{\lambda}\right)}{\cos^2(0)} = \frac{1}{2}$

13. (c) Path difference at point $P = \frac{xd}{D}$

Phase difference at point $P = \frac{2\pi}{\lambda}\frac{xd}{D} = \frac{2\pi x}{\beta}$

$I_0 = 4I_1$, intensity at point P

$I = I_1 + I_1 + 2I_1\cos\frac{2\pi x}{\beta} = 2I_1\left[1 + \cos\frac{2\pi x}{\beta}\right]$

$= I_0\cos^2\frac{\pi x}{\beta}$

14. (c) It is given that $r_4 = \sqrt{4b\lambda_1}$ and $r_5 = \sqrt{5b\lambda_2}$ are equal. Therefore $\sqrt{4b\lambda_1} = \sqrt{5b\lambda_2}$

or $4b\lambda_1 = 5b\lambda_2$

or $\frac{\lambda_1}{\lambda_2} = \frac{5}{4}$.

15. (a) Area of half period zone is independent of order of zone. Therefore, m is equal to zero in π.

16. (b) Position of n^{th} minima $y_n = \frac{n\lambda D}{d}$

$\Rightarrow (y_3 - y_1) = \frac{\lambda D}{d}(3-1) = \frac{2\lambda D}{d}$

$\Rightarrow 3\times 10^{-3} = \frac{2\times 6000\times 10^{-10}\times 0.5}{d}$

$\Rightarrow d = 0.2\times 10^{-3} m = 0.2\, mm$

17. (b) Fringe shift is given by $x = \frac{(\mu - 1)t\,\beta}{\lambda}$

For first plate, $x = \frac{(\mu_1 - 1)t\,\beta}{\lambda}$

For second plate $\frac{3}{2}x = \frac{(\mu_2 - 1)t\beta}{\lambda}$

$\Rightarrow \left(\frac{\mu_2 - 1}{\mu_1 - 1}\right) = \frac{3}{2} \Rightarrow \left(\frac{\mu_2 - 1}{1.5 - 1}\right) = \frac{3}{2}$

$\Rightarrow \mu_2 = 1.75$

18. (c) Resultant intensity $I = 4I_0\cos^2(\phi/2)$

$\Rightarrow \frac{I_1}{I_2} = \frac{\cos^2(\phi_1/2)}{\cos^2(\phi_2/2)} = \frac{\cos^2 0}{\cos^2(90/2)} = \frac{2}{1}$

19. (c) $n_1\lambda_1 = n_2\lambda_2 \Rightarrow 60\times 4000 = n_2\times 6000 \Rightarrow n_2 = 40$

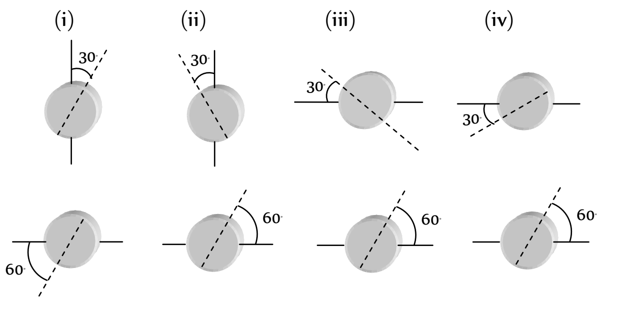
20. (b) Suppose the charge on the capacitor at time t is Q, the electric field between the plates of the capacitor is $E = \frac{Q}{\varepsilon_0 A}$. The flux through the area considered is $\phi_E = \frac{Q}{\varepsilon_0 A}.\frac{A}{2} = \frac{Q}{2\varepsilon_0}$

$\therefore$ The displacement current

$i_d = \varepsilon_0\frac{d\phi_E}{dt} = \varepsilon_0\left(\frac{1}{2\varepsilon_0}\right)\frac{dQ}{dt} = \frac{i}{2}.$

21. (a) The direction of EM wave is given by the direction of $\vec{E}\times\vec{B}$.

22. (b) Final intensity of light is given by Brewster's law $I = I_0\cos^2\theta$; where θ = Angle between transmission axes of polariser and analyser.



Hence decreasing order of intensity is (i) > (iv) > (ii) > (iii)

23. (d) Let it take t sec for astronaut to acquire a velocity of 1 ms^{-1}. Then energy of photons = 10 t

Momentum $= \frac{10t}{C} = 80\times 1$

$t = \frac{80\times 1\times 3\times 10^8}{10} = 2.4\times 10^9\ sec$

***

Chapter 31 Universe

Universe is the limitless expanse of space around us consisting of solar system. star, galaxies *etc*.

Solar System

Solar system is a family of nine planets, satellites, asteroids, comets, meteors, meteorites and dust particles orbiting around the Sun.

(1) **Planets :** Nine planets revolving around the sun in elliptical orbits. In order of increasing distance from Sun, these are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

(i) The gravitational pull of the Sun on the planets control their motion.

(ii) There are other heavenly bodies (about 32) which revolve around the planets called satellites (or moons) of the planets.

(iii) A planet does not emit light of its own.

(iv) A planet do not twinkle at night.

(v) The planets are very small in size as compared to stars or Sun.

(vi) The relative positions of planets keep on changing day by day.

(vii) Most of the planets move around the sun from west to east.

(viii) The planets are made of rocks and metals.

(ix) The temperature of planet depends upon its distance from sun.

(2) **Asteroids :** The small pieces of planet revolving around the sun between orbits of Mars and Jupiter are called Asteroids.

(i) Astronomers have identified about 2000 asteroids ranging from the largest 770 *km* diameter to bodies 1.5 *km* in diameter.

Table 31.1 : Some information about planets

Planet	Radius $R \times 10^3$ *km*	Mean distance from sun $\times 10^6$ *km*	Mass as compared to earth	Time of revolution around the sun	Time taken to complete one rotation around its own axis	Number of satellites
Mercury	2.4	57.9	0.055	88 days	59 days	—
Venus	6.1	108.2	0.815	225 days	243 days	—
Earth	6.3	149.6	1	1 Year	23 hrs. 56 min.	1
Mars	3.4	227.9	0.108	1.9 Year	24 hrs. 27 min	2
Jupiter	71.4	778.3	317.9	11.8 Year	9 hrs. 50 min	14
Saturn	60.0	1427	95.2	29.5 Year	10 hrs. 14 min	10 + Ring
Uranus	23.4	2870	14.6	85 Year	10 hrs. 49 min	5 + Ring
Neptune	22.3	4594	17.2	165 Year	15 hrs.	2
Pluto	3.2	5900	0.002	248 Year	6.39 days	—

(ii) The largest asteroids are called Ceres.

(iii) The largest asteroid complete one revolution around the sun in 4.6 years.

(3) **Comets :** These are composed of rock like materials surrounded by large masses of easily vaporisable substances like, ice, water, ammonia and methane.

(i) They revolve around the Sun in highly elliptical orbits.

(ii) Their time period of revolution around the Sun is very large.

(iii) Comets appear to be having a bright head and a long tail while passing close to the Sun and when away from sun generally they show no tail.

(iv) The tail of comet is formed when the comet is passing close to the Sun and the heat of Sun exerts a pressure on the material which gets evaporated due to heat of Sun.

(v) Hally comet was seen in early 1986 and is expected to be seen again in 2062.

(4) **Meteors and meteorites :** Meteors are the smaller pieces of stones and metals which may be produced due to the breaking up of comets while approaching the Sun. When they reach earth's atmosphere due to friction they start buring. They are also called shooting stars.

Sometimes, the large pieces of stones (acting as meteors) do not burn completely and reach the surface of the earth as stony, iron balls resulting in crators on the earth surface. These are called meteorites.

Measurement of Size of Planet

We can measure the size of a planet by measuring the angle subtended by its diameter *AB* at a point on the earth. This angle is called angular diameter of planet. If *d* denotes diameter of planet and *D* its distance from the earth

$$\alpha \simeq \frac{d}{D}$$

or $\quad d \simeq D\alpha$

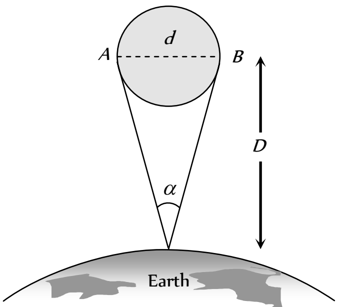


Fig. 31.1

Measurement of Distance of Planet From the Earth

(1) **Parallax method :** The planet *O* is observed from two points P_1 and P_2 on the surface of the earth. The distance between these two points, $P_1P_2 = b$, is called basis. The angle subtended by planet at these two points is called parallax angle or parallactic angle

From figure $\theta \simeq \dfrac{b}{D}$

or $\quad D \simeq \dfrac{b}{\theta}$

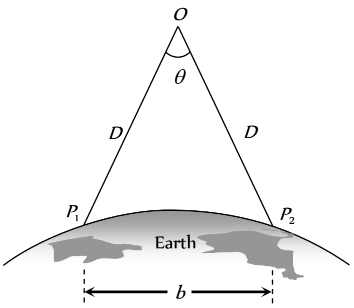


Fig. 31.2

(2) **Copernicus method :** The inferior planets (Mercury and Venus) have nearly circular orbits. Angle between directions of observation from earth to sun and earth to planet is called planet's elongation.

r_{es} = The distance of earth from Sun, r_{ps} = The distance of planet from Sun and r_{pe} = The distance of planet from Earth

The r_{ps} and r_{es} are fixed distances as orbits have been assumed to be circular. During orbital motion of the planet the distance r_{pe} changes. Planet's elongation is maximum when earth and sun subtend an angle 90° at the planet. From figure,

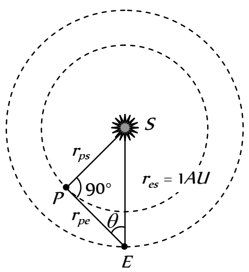


Fig. 31.3

$$\sin\theta = \frac{PS}{ES} = \frac{r_{ps}}{1\,AU}$$

where 1 *AU* = 1.496×10^{11} *m*

Thus $\sin\theta = r_{ps}$, similarly $\cos\theta = \dfrac{PE}{ES} = \dfrac{r_{pe}}{1\,AU} \Rightarrow r_{pe} = \cos\theta$

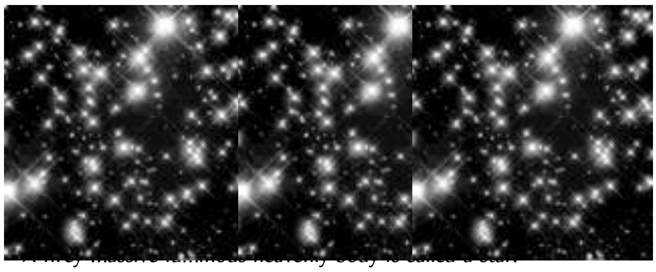
(3) **Kepler's law :** According to Kepler's law the square of time period of planet around sun is proportional to cube of semi-major axis of the orbit of planet around sun *i.e.* $\dfrac{a^3}{T^2} = \text{constant}$, if a_1 and a_2 are semi-major axes of planets 1 and 2 and T_1 and T_2 their respective periods of revolution, then

$$\frac{a_1^3}{T_1^2} = \frac{a_2^3}{T_2^2} \quad \text{or} \quad a_2 = \left(\frac{T_2}{T_1}\right)^{2/3} a_1$$

For circular orbits a_1 and a_2 represent the radii of orbits.

(4) **Spectroscopic method :** In this method, photograph of two different planets P_1 and P_2 are taken on similar photographic plates from one place of the earth. Let I_1 and I_2 be the intensities of the images of these two planets. If R_1 and R_2 be the distances of these planets from the earth then $\dfrac{I_1}{I_2} = \dfrac{R_2^2}{R_1^2}$ ($\because$ intensity at a point is inversely proportional to the square of the distance)

Stars



(1) **Some features**

(i) Stars twinkle at night.

(ii) Stars are countless in number ; about 10^{22} in a universe.

(iii) Stars are very big in size but they appear small because they are very far off.

(iv) The relative positions of stars do not change day by day.

(v) Stars appear to be moving from west to east.

(vi) The temperature of stars is very high.

(vii) The Sun is the nearest star to the earth. Its light reaches the earth in 8.3 minutes.

(viii) After Sun the next nearest star to earth is Alpha centuri. Its distance is 4.3 light year from earth.

(ix) Other bright stars in the sky are known as Spica (Chitra), Arcturus (Swati), Polaris (Dhruva), Sirius (Vydha), Canopus (Agasti) *etc.*

(x) The temperature of a star is estimated from the colour of its light received on earth. The blue coloured star is at higher temperature than red coloured star.

(2) **Constellation :** Many of the stars appear to be bunched together in groups. These groups are called constellations.

(i) The Great-bear (Saptarishi), Taurus (Vrishabha) Aries (Mesha) *etc.* are the other constellations near the north and south celestial poles.

(ii) According to modern astronomy there are 88 constellations in the sky.

(3) **Brightness of star :** Brightness of stars is represented through system of magnitudes. Magnitude of star is the measure of its brightness when observed from earth.

(i) Hipporacus, a Greek astronomer divided the stars (visible with naked eye) into six magnitude classes. Brightness goes on decreasing as the magnitude increases. A first magnitude star is about 100 times as bright as a sixth magnitude star. Decrease in magnitude number by one increases brightness by ratio $100^{1/5} = 2.5119$. In general

$$\frac{\text{The brightness of star in } n^{\text{th}} \text{ magnitude class}}{\text{The brightness of star in } (n+m)^{\text{th}} \text{ magnitude class}} = (2.512)^m$$

(ii) If two stars have magnitudes m_1 and m_2 ($m_2 > m_1$) and brightness l_1 and l_2($l_2 < l_1$), then $\frac{l_1}{l_2} = 100^{(m_2 - m_1)/5}$

Taking logarithm to base 10 of both sides, we get

$$(m_2 - m_1) = -2.5 \log \frac{l_2}{l_1}$$

(iii) For a star of zero magnitude $m_1 = 0$, $l_1 = l_0$, $m_2 = m$ and $l_2 = l$.

$$\Rightarrow m = 2.5 \log \frac{l_0}{l}$$

(iv) The star vega is of zero magnitude and of brightness $l_0 = 2.52 \times 10^{-8} W/m^2$.

(v) A star having negative magnitude is brighter; *e.g.*, a star having magnitude – 5 will be 100 times more bright than a star of zero magnitude.

(4) **Absolute luminosity :** The total energy radiated into space per second from the surface of a star is called absolute luminosity of the star. The absolute luminosity of the Sun is $\approx 3.9 \times 10^{26} J/sec$.

(5) **Birth of a star :** Star dust and gases present in interstellar space come closer together with a gravitational force in the form of a cloud.

(i) When the cloud is quite big, due to compression cloud heats up and starts radiating

(ii) At this temperature, fusion of hydrogen atom into helium atom takes place and a star is said to have come into existence.

(iii) This process result in the release of energy, which keeps the star shining for millions of years.

(6) **Death of a star :** When large number of hydrogen atoms of a star are converted into *He*, the core of star begins to contract and other layers begin to expand. At this stage star appears red, the stage is called Red Giant.

(i) Now a violet explosion occurs in star. This is called nova or super nova explosion.

(ii) Due to explosion, the outer layers are thrown back into interstellar leaving behind the core of the star. This is known as **death of the star**.

The core of the star may further end up into one of the following three dead bodies (stellar dead materials) :

(a) White dwarf (b) Neutron star (c) Black hole

(a) **White dwarf :** When the original mass of the star is less than $2M_s$ (M_s being solar mass), the core of the star tends to die as White dwarf. It was theoretically discovered by S. Chandrasekhar in1930 and is known as **Chandrasekhar limit**. As the core keeps on emitting heat and light for millions of year, it colour changes from white to yellow, then to red finally it becomes black. Now this becomes invisible for ever.

(c) **Neutron star :** When the original mass of the star is lies between $2M_s$ *and* $5M_s$ the core of the star tends to finish up as neutron star. In such a case, when super nova explosion occurs, the core of the star is compressed and electrons and protons combine to form neutrons. Due to this reason, this is called as neutron star. It is found to have a radius of about 10 *km*.

(7) **Black hole :** When the original mass of the star is more than 5*M*, then on supernova explosion, the core continues suffering compression indefinitely due to recoil. This gives rise to a black hole. The mass of the black hole is greater than the mass of the Sun but its size is very small. Due to this fact, the gravitational pull of black hole is very strong. This is the reason that the photon of radiation emitted by it cannot escape from its surface. On the other hand, a photon approaching a black hole is swallowed by it. Hence it is called a black hole.

The black hole is said to have been formed if the star of mass *M* has contracted within a radius *r* which is given by $r \le \frac{2GM}{c^2}$

Sun

The Sun called the centre of the solar system, is a star nearest to the earth.

(1) **Properties of the Sun**

(i) It's average distance from earth is 1.49×10^8 *km* = 1 *AU*

(ii) It's mass is 1.99×10^{30} *kg*

(iii) It's mean diameter is 1.392×10^6 *km*

(iv) The density of the Sun varies from 10^{-4} kg/m^3 at the surface to 10^4 kg/m^3 at the centre. It's mean density is 1410 $kg\ m^{-3}$.

(v) The pressure at the centre of the Sun is about 2×10^6 N/m^2.

(vi) Light takes 8 minute to reach earth from the Sun.

(vii) 70% of Sun's mass is H_2, 28% *He* and 2% Lithium or Uranium.

(viii) The Sun is also called Yellow Dwarf.

(2) **Structure of Sun :** The Sun structure consist of four parts : Photosphere (*P*), Reversing layer (*R*), Chromosphere (*CH*) and Corona (*C*).

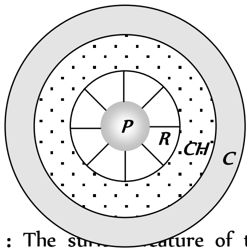


Fig. 36.4

(3) **Solar activity :** The surface feature of the Sun are called Solar activity. This can be classified as follows

(i) **Sun spots :** These are dark spots on the surface of sun associated with strong magnetic fields. The sun spots move across Sun slowly, so there numbers vary over a cycle of 11 year called Sun spot cycle. After every eleven year activity of sun spots tends to be maximum. Movements of sun spots have revealed the time period of rotation of sun on its own axis as about 25 days.

(ii) **Faculae :** These are bright patches near Sun spots.

(iii) **Granules :** Small granules form a covering over photosphere.

(iv) **Flares :** Sudden increase in magnetic activity is called flare. During these flares Sun emits streams of protons, α-particles and electrons.

(v) **Spicules :** Bright spikes emerging from chromosphere are termed spicules. Spicules are source of large number of charged particles into the corona.

(vi) **Prominences :** Surface of photosphere is covered by rising clouds called prominences.

(vii) **Filaments :** These are thin markings on the photosphere.

(4) **Solar constant (S) :** Energy falling in one second on the unit area of the earth's surface held normal to Sun's rays is called solar constant. It is given by $S = \frac{\sigma T^4 R^2}{r^2} = 1.388 \times 10^3 W/m^2$

where σ = Stefan's constant

= 5.68×10^{-8} S.I. unit

T = Surface temperature of Sun

R = Radius of Sun

r = Radius of Earth's orbit

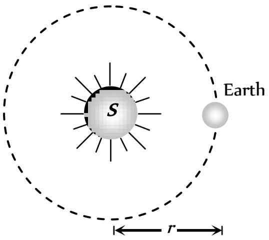


Fig. 31.5

(5) **Solar Luminosity (L) :** It is defined as the amount of energy emitted by the Sun per second in all directions.

$$L_s = (4\pi r^2)S = 3.9 \times 10^{26} W$$

(6) **Temperature of Sun (T) :** The surface temperature of the Sun is given by $T = \left(\frac{r}{R}\right)^{1/2}\left(\frac{S}{\sigma}\right)^{1/4}$

(7) **Mass of the Sun (M) :** Let M be the mass of sun and m be the mass of a planet moving around it, then as gravitational force of attraction between them supplies the necessary centripetal force

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow \text{Mass of Sun } M = \frac{v^2 r}{G}$$

$$= \frac{r^2\omega^2 r}{G} = \frac{r^3\omega^2}{G} = \frac{r^3\left(\frac{2\pi}{T}\right)^2}{G} = \frac{4\pi^2 r^3}{GT^2}$$

where $G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$ and r is distance between the sun and planet. T period of revolution of planet around the sun.

If we consider the planet and its satellite, mass of the planet can similarly be found

Stellar Radii, Mass and Spectra

(1) **Stellar radii :** The total energy radiated by the star per second is given by $E = \sigma T^4 \times$ Surface area of the star

$$\Rightarrow E = \sigma T^4 \times 4\pi R^2 \Rightarrow \text{Radius of star } (R) = \left(\frac{E}{4\pi\sigma}\right)^{1/2} T^2$$

Usually, the radius of star is expressed in terms of solar radius $(R_s = 6.95 \times 10^8 m)$. Thus star radius $= \left(\frac{E}{4\pi\sigma}\right)^{1/2} \frac{T^2}{6.95 \times 10^8}$ solar radius.

$\Rightarrow$ The radii of most of the stars lie in the range 0.02 to 220 solar radii.

(2) **Stellar masses :** Let M_1 and M_2 be the masses of two stars revolving about their common centre of mass in circular orbits of radii r_1 and r_2 respectively such that $r_1 + r_2 = r$. Now

$$M_1 + M_2 = \frac{4\pi^2}{G} \times \frac{r^3}{T^2} \quad \text{......(i)}$$

where T is common period of revolution.

If a planet of mass M_1 moves round the Sun of mass M_S, then the mass M_1 can be neglected in comparison with M_S because $M_S >> M_1$. Then equation (i) can be written as

$$M_S = \frac{4\pi^2}{G} \times \frac{r^3}{T^2} \quad \text{.....(ii)}$$

As M_S is constant, it implies that $\frac{r^3}{T^2}$ = constant

which is Kepler's third law.

In binary system, r = 1 AU, T = 1 year and $M_1 + M_2 = 1$ solar mass. Hence equation (i) gives $G = 4\pi^2$

$$\therefore \quad M_1 + M_2 = \frac{r^3}{T^2} \quad \text{..... (iii)}$$

Equation (iii) can be used to find the masses of two stars in binary system.

(3) **Spectra of stars :** The different stars are of different colours and the spectrum of a star is related to its colour, There are seven classes of stellar spectra denoted by letters O, B, A, F, G, K and M. Our sun belongs to G class star.

Table 31.2 : Spectrum of stars

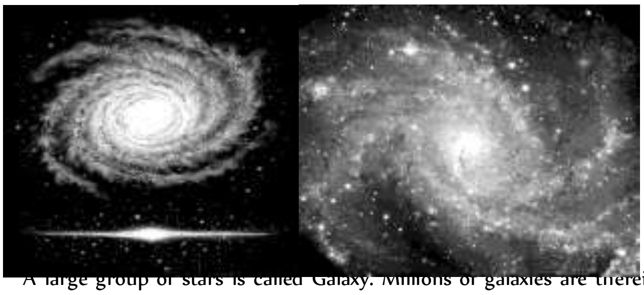
Spectra type	Colour	Surface temp (K)	Description of absorption spectra
O	Dark blue	3×10^4 to 4×10^4	Ionized helium lines
B	Blue	$1.s5 \times 10^4$ to 2.3×10^4	Lines of neutral helium
A	White	9.5×10^3 to 1.1×10^4	Lines of H_2
F	Green	6.5×10^3 to 7.5×10^3	Lines of H_2 and ionised metals
G	Yellow	5800	Lines of ionised Ca, Fe, C
K	Orange	4500	Bands due to hydrocarbons
M	Red	3500	Bands of Titanium oxide

These relationship between the colour of a star and its temperature is expressed by Wien's displacement law. According to this law

$$\lambda_m \propto \frac{1}{T} \quad \text{or} \quad \lambda_m T = b \quad \text{or} \quad T = \frac{b}{\lambda_m}$$; where $b = 2.89 \times 10^{-3}$ *mK*.

So those stars which appear blue (minimum wavelength) such as class *O* and *B*, are very hot and which appear red (maximum wavelength) such as class *M* are less hot.

Galaxies



A large group of stars is called Galaxy. Millions of galaxies are therein the sky. Each galaxy contains about 10^{11} stars.

The Sun and the planets of the solar system belong to the galaxy, called Milky way (Akash Ganga).

(1) **Types of galaxies :** There are two types of galaxies

(i) Normal galaxies, and (ii) Radio-galaxies.

(i) **Normal galaxies :** Besides milky way, there are billions of other galaxies in the universe. All these galaxies are called normal galaxies. There are three types of normal galaxies. (a) Elliptical galaxies (18%), (ii) Spiral galaxies (80%), and (iii) Irregular galaxies (2%).

(a) **Elliptical galaxies :** The galaxies which look like the flat elliptical discs are called elliptical galaxies. These generally consist of red giants, white dwarfs *etc. i.e.*, those stars which are nearing their ends.

(b) **Spiral galaxies :** The galaxies have lens-shaped central portion surrounded by a flat disc. It has two spiral arms which spiral around the central portion.

Example : Milky way and Andromeda.

(c) **Irregular galaxies :** These have no specific form of their own. Irregular galaxies are youngest normal galaxies and are middle aged and elliptical galaxies are quite old galaxies.

(2) **Radio galaxies :** The galaxies which emit electromagnetic radiations in the radio frequency are called radio galaxies. These have been classified as (i) Ordinary radio galaxies (ii) Quasars.

(i) **Ordinary radio galaxies :** A normal optical galaxy (*O*) which has two strong radio sources (R_1 and R_2) occurring symmetrically on either side of it, is called an ordinary radio galaxy. It appears like two ears on the two sides of the face of a person. The radio power output lies in the range 10^{30} to 10^{38} *watt*.

(ii) **Quasars :** Quasars are quasi-stellar radio sources. They are star like in structure and they emit powerful radio waves. They have a radio output of 10^{37} to 10^{38} *watt*. Quasars are farthest objects known. They are millions of light years away from Earth. These seem to be lying at the limit of the universe. They are moving away from Earth with a velocity of about 0.9 times the velocity of light. Their size is much smaller. It is of the order of light days. They form very dense galaxies. The density is also very large and their gravitational field is also very high. The cause of tremendous energy of the quasars is unknown. About 150 quasars have been detected so far.

(3) **Milky way (Akash Ganga) :** It is the name of the galaxy to which our earth belongs. The milky way is the glowing belt of the sky formed by the combined light of a very large number of stars. It is called milky way or Akash Ganga because the light from the various stars together gives the impression of a stream of milk flowing across the sky.

Milky way is a spiral galaxy. Its mass is 150 solar masses

(*i.e.* 3×10^{41} *kg*).

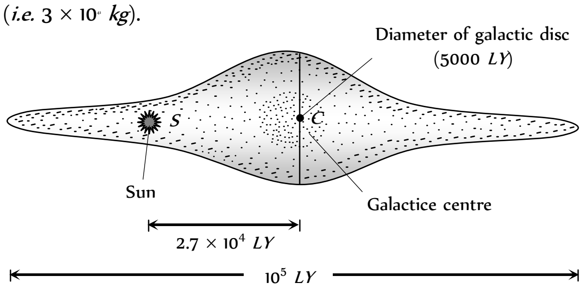


Fig. 31.6

Milky way contains 150 billions sun like stars.

Milky way contains clouds of dust and gases.

Pulsars

As the age of a star increases, its hydrogen content goes on decreasing. Ultimately, the star explodes as a supernova, in the universe. After explosion of a supernova, a variable star is born. It is not an ordinary star. It is the remaining part of a supernova. The variable star is called a pulsar. A pulsar emits electromagnetic waves in pulses and not continuously. The pulses are of very short duration (0.033 *s* to 0.088 *s*). The pulses may lie either in visible region or in radio region. About 50 pulsars have been detected, two in visible region and others in radio region. It is expected that there are about 100 pulsars in the universe.

Evolution of the Universe

Important theories about the origin and evolution of universe are as follows.

(1) **Big Bang theory :** The whole of the matter of the universe was concentrated in a very dense and hot fire ball about 20 billion years ago. An explosion occurred. The matter was broken into pieces in the form of stars and galaxies. The faster moving galaxies have gone farther than the slower ones. A galaxy situated at 20 billion light years is the boundary of the universe.

(2) **Expanding universe theory :** All the galaxies would continue to move away from the Earth and we will have an empty universe because on account of continuous expansion of the universe, more and more galaxies will go beyond the boundary of the universe and will be lost.

The motions of galaxies relative to the earth can be measured by observing the shifts in the wavelengths of their spectra. For distant galaxies these shifts are always toward longer wavelength, so they appear to be receding from us and from each other. Astronomers first assumed that these were Doppler shifts and used a relation between the wavelength λ_0 of light measured now from a source receding at speed v and the wavelength λ_S measured in the rest frame of the source when it was emitted.

$$\lambda_0 = \lambda_S \sqrt{\frac{c+v}{c-v}}$$

For $v << c$, Red shift (or Doppler's shift) $\Delta\lambda = \lambda_S \dfrac{v}{c}$

(3) **Pulsating universe theory :** As the galaxies move away, the expansion of the galaxies would be stopped by the gravitational pull. The galaxies would come so close that again a new explosion would take place. The same sequence will be repeated. Thus, we have alternate expansion and contraction of the universe giving rise to a pulsating universe. This takes place after every 80 billion years.

(4) **Steady state theory :** As the farthest galaxies speed away from each other, new galaxies are born to take their places. The total number of galaxies in the universe remains constant.

It is certain that : (i) The age of the universe is about 20 to 30 billion years. (ii) The most distant galaxy is situated at a distance of two billion light years away from the Earth. (iii) This galaxy is receding away from the Earth with a velocity 0.3 times that of light. (iv) The universe will live for about 100 million years more. Thus, the universe is quite young at present.

Hubble's law

(1) The speed of recession v of a galaxy is proportional to it's distance r from us *i.e.* $v \propto r \Rightarrow v = Hr$ this relation is called Hubble's law.

(2) Here H = An experimental quantity, called Hubble's constant. It's value is 19.3 *mm/sec* for each light year.

(3) Determining H has been a key goal of the Hubble's space telescope.

(4) The quantity $\frac{1}{H}$ has the dimensions of time.

(5) This time is called Hubble's times, which is an estimate of the order of magnitude of time that has elapsed since the Big Bange, and thus of the age of universe.

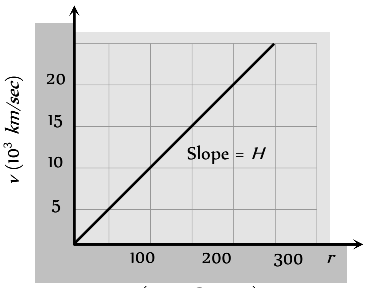


Fig. 31.7

Tips & Tricks

✍ The name black hole is given because it's gravity is so high that it prevents even light to radiate into space.

✍ Visible light is restricted from entering a telescope by dust particles in universe. Therefore range of a telescope is limited. Observation made in visible range are referred to as optical astronomy. Whereas observations made in radio range is called Radio-Astronomy.

✍ **Albedo :** The presence of atmosphere, clouds, *etc.* is acknowledged by a parameter known as albedo. It is the ratio of energy reflected by a planet to that incident on it. Clouds being good reflectors of light, they considerably increase the reflecting power of the planet and hence it's albedo is large. Venus has an albedo of 85% (highest).

✍ Mercury, Pluto and Venus do not have any satellites.

✍ On a clear night 5000 stars can be observed with naked eye.

✍ Closet star is alpha centuri (after the Sun) which is 4.3 light years away.

✍ Astronomy is branch of science which deals with the study of universe.

✍ Study of heavenly bodies is based upon visible light (λ ranging from 4000 Å to 8000 Å) and radio waves (λ ranging from 1 *mm* to 20 *m*).

✍ Hipparchus, a Greek astronomer, divided naked eye stars into six magnitude classes, on the basis of their brightness. The brightest stars were placed in the first magnitude class. Faintest visible stars were put in the sixth magnitude class.

✍ A comet does not have any tail when it is far from the Sun.

✍ **Mercury**

(i) Smallest planet (ii) Closest to the Sun

(iii) Fastest (iv) No atmosphere.

✍ Cygnus is a group of five stars. Which forms a cross like a swan.

✍ The clouds of dusty gas are called nebulae.

Ordinary Thinking

Objective Questions

Universe

1. A study of binary stars is most helpful in [CBSE PMT 1993]

(a) Finding their distances

(b) Finding their temperature

(c) Finding their masses

(d) Verifying Newton's force law of gravitation

2. A group of bright and faint stars is called [AFMC 1994]

(a) Galaxy (b) Comet

(c) Black hole (d) Constellation

3. According to modern astronomers into how many constellations, the whole sky is divided [BHU 1994]

(a) 10 (b) 88

(c) 880 (d) 5000

4. Which of the following theories is the most satisfactory about the origin of the universe [CBSE PMT 1994]

(a) Big Bang theory (b) Pulsating theory

(c) Steady state theory (d) None of these

5. Which of the planet is brightest [BHU 1999]

(a) Mercury (b) Venus

(c) Mars (d) Jupiter

6. A star which appears blue will be [CPMT 1998]

(a) As hot as the sun (b) Cooler than the sun

(c) Very cold indeed (d) Much hotter than the sun

7. Hubble showed that the universe as a whole is expanding and the distant stars are receding from us. The spectral line from a star, when compared with the corresponding line from an source will then show [Haryana CEE 1996]

(a) A shift in frequency towards the red end

(b) A shift in frequency towards the violet end

(c) No shift in frequency at all

(d) A shift in frequency towards the violet end as well as a decrease in intensity

8. The solar constant on the surface of the earth is *S*. What will be its value on the surface of another planet which is about 5.3 *A.U.* away from sun [AMU 1996, 97]

(a) $\frac{S}{5.3}$ (b) $\frac{S}{(5.3)^2}$

(c) 5.3 S (d) $(5.3)^2\ S$

9. CO_2 gas is found in which of the following pairs of the planet [AFMC 1994]

(a) Earth and Mercury (b) Mercury and Saturn

(c) Venus and Saturn (d) Venus and Mars

10. The wavelength of maximum energy, released during an atomic explosion, was $2.93 \times 10^{-10}\ m$. Given that the Wien's constant is $2.93 \times 10^{-3}\ m\ K$, the maximum temperature attained must be of the order of [Haryana CEE 1996]

(a) $10^{-7}\ K$ (b) $10^{7}\ K$

(c) $10^{-13}\ K$ (d) $5.86 \times 10^{7}\ K$

11. Black hole is a [BHU 1995; MH CET 2003]

(a) Hole in the ozone layer of atmosphere

(b) Hole in earth's centre

(c) Highly dense matter available in the atmosphere

(d) Hole in troposphere

12. A planet of mass M has a satellite of mass m, revolving around the planet in a circular orbit of radius r and time period T. The mass (M) of the planet is [AMU 2000]

(a) $\frac{4\pi^2 r^3}{GT^2}$ (b) $\frac{4\pi^2 r^2}{GT^3}$

(c) $\frac{GT^2}{4\pi r^3}$ (d) $\frac{r^3 G}{4\pi T^2}$

13. The age of universe is believed to be [NTSE 1995]

(a) 1 billion years (b) 10 billion years

(c) 10-20 billion years (d) 1000 billion years

14. A planet which is born sister of earth is [AFMC 2000]

(a) Mercury (b) Venus

(c) Mars (d) Jupiter

15. Source of Sun's energy is [CBSE PMT 1992; KCET 1994; AFMC 1998; BHU 2000; DCE 2001]

(a) Burning of hydrogen

(b) Fission reactions involving hydrogen

(c) Fusion reactions involving hydrogen

(d) Some other source

16. Asteroids are [DPMT 2000]

(a) Small planets

(b) Shooting stars

(c) Found in a belt between Earth ad Venus

(d) None of these

17. Sun radiates continuously and maintains its brightness because [MP PMT 1990; JIPMER 1997]

(a) Helium is converted into iron in its core

(b) Of fusion of hydrogen nuclei into helium

(c) Fusion of helium in hydrogen

(d) Burning of carbon, in its core

18. Venus appears brighter than other stars because [MP PMT 1990]

(a) It is heavier than other planets

(b) Its density is more than other planets

(c) It is nearer to earth in comparison to other planets

(d) Nuclear fusion takes place at its surface

19. There is no atmosphere on moon because [MP PMT 1990]

(a) There is no vegetation

(b) The escape velocity at its surface is very low

(c) Diffusion constant of gases is high

(d) There is vacuum in space

20. Which of the following planets have rings around it [MP PMT 1991]

(a) Uranus (b) Mars

(c) Jupiter (d) Saturn

21. Milky way is [MP PMT 1991; Kerala PMT 2001]

(a) A planet of our system

(b) A sun

(c) One of the solar system

(d) One of the enormous galaxies of universe

22. Hubble's law states that the velocity with which the 'milky way' is moving away from the earth is proportional to [MP PMT 1991; Kerala PMT 2004]

(a) Square of the distance of the milky way from the earth

(b) Distance of milky way from the earth

(c) Mass of the milky way

(d) Product of the mass of the milky way and its distance from the earth

23. The hottest planet of solar system is [CBSE PMT 1992]

(a) Mars (b) Mercury

(c) Venus (d) Pluto

24. Towards the centre of sun [MP PMT 1992]

(a) Density decreases

(b) Pressure decreases

(c) Temperature decreases

(d) Density and pressure increases

25. Period of revolution increases in the order of [MP PMT 1992]

(a) Saturn, Uranus, Venus (b) Mars, Saturn, Pluto

(c) Mercury, Neptune, Mars (d) Mars, Jupiter, Venus

26. The length of Milky way is [MP PMT 1992]

(a) 100,000 light years (b) 10,000 light years

(c) 1000 light years (d) 100 light years

27. Which of the nine planets is nearest to sun [CBSE PMT 1992]

(a) Venus (b) Mercury

(c) Mars (d) Jupiter

28. An extremely hot star would appear to be [AMU 1996, 97]

(a) Red (b) Blue

(c) Yellow (d) Orange

29. The sun emits a light with maximum wavelength 510 mm while another star X emits a light with maximum wavelength of 350 nm. What is the ratio of surface temperature of sun and the star X

(a) 2.1 (b) 0.68

(c) 0.46 (d) 1.45

30. A double star is a system of two stars rotating about their centre of mass only under their mutual gravitational attraction. Let the star have mass m and $2m$ and their separation be l. Their time period of rotation about their centre of mass will be proportional to [JIPMER 2000]

(a) $l^{2/3}$ (b) l

(c) $m^{1/2}$ (d) $m^{-1/2}$

31. Hubble's law is related with [AIIMS 2002; Pb. PET 2002]

(a) Comet (b) Speed of galaxy

(c) Black hole (d) Planetary motion

32. 'Albedo' is [Pb. PET 2001; BHU 2001; Kerala PET 2002; AFMC 2002]

(a) Reflecting power of a heavenly body

(b) Transmitive power of a heavenly body

(c) Absorptive power of a heavenly body

(d) Refracting power of a heavenly body

33. According to the pulsating theory the expansion and contraction of the universe repeats after every [TNPCEE 2002]

(a) 11 years (b) 8 billion years
(c) 8 million years (d) 80 billion years

34. Meteors are [TNPCEE 2002]
(a) Small stars
(b) Burnt pieces of comets that fall on earth
(c) Comets without tails
(d) None of these

35. Which of the following helps us in the determination of the temperature of sun [CBSE PMT 2001]
(a) Kirchhoff's law (b) Maxwell Boltzmann law
(c) Planck's law (d) Stefan's law

36. How does the red shift confirms that the universe is expanding
(a) Due to Wien's law (b) Due to Stefan's law
(c) Due to Kirchhoff's law (d) Due to Doppler's effect

37. Two stars P and Q are observed at night. Star P appears reddish while, star Q is white. From this we conclude [Roorkee 1992]
(a) Temperature of Q is higher than that of P
(b) Temperature of Q is lower than that of P
(c) Star Q is at the same distance at that of star P
(d) Star P is farther than star Q

38. Albedo is maximum for [Pb. PET 2000]
(a) Pluto (b) Venus
(c) Earth (d) Mercury

39. When original mass of star is greater than 5 M (M = mass of the sun). The death of this star will give rise to [Pb. PET 2000]
(a) White dwarf (b) Black hole
(c) Quasars (d) Nebula

40. The tail of the comet is due to [Pb. PET 2002]
(a) Vaporisation of water on the comet
(b) Sublimation of vapour in the comet
(c) Cooling of water in the comet
(d) Vaporisation of heat in the comet

41. In our solar system, there is one sun and [BHU 2004]
(a) Seven planets
(b) Nine planets
(c) Eleven planets
(d) Indefinite number of planets

42. Which one of the following planet has the longest day [AFMC 2003]
(a) Venus (b) Mars
(c) Mercury (d) Earth

43. Which one of the following is known as Saptarishi [AFMC 2003]
(a) Orion (b) Ursa major
(c) Ursa minor (d) Scorpion

44. Smaller pieces of heavy stones and metals which on entering earth's atmosphere burns out are [AFMC 2003]
(a) Comets (b) Meteorites
(c) Asteroids (d) All of these

45. In determining the temperature of a distant star, one makes use of
(a) Kirchhoff's law (b) Stefan's law
(c) Wien's displacement law (d) None of these

46. The motion of planets in the solar system is an example of conservation of [DCE 2001, 03]
(a) Mass (b) Momentum
(c) Angular momentum (d) Kinetic energy

47. Mass of earth has been determined through [Kerala (Engg.) 2002]
(a) Use of Kepler's T/R constancy law
(b) Sampling the density of earth's crust and using R
(c) Cavendish's determination of G and using R and 'g' at the surface
[Pb. PMT 1997; AIIMS 2001]
(d) Use of periods of satellites at different heights above earth's surface

48. The galaxies are moving away from each other. It is explained by
(a) White dwarf star (b) Red shift
(c) Neutron star (d) None of these

49. Speed of recession of galaxy is proportional to it's distance [DCE 1999]
(a) Directly (b) Inversely
(c) Exponentially (d) None of these

50. Great bear is a [DCE 1998]
(a) Star (b) Galaxy
(c) Constellation (d) Planet

51. Surface temperature of the sun is of the order of [DCE 1996]
(a) 5000 K (b) 7000 K
(c) 6000 K (d) 12000 K

52. The colour of a star is an indication of its [BCECE 2005]
(a) Weight (b) Distance
(c) Surface temperature (d) Size

53. Which of the following is coldest planet [BCECE 2005]
(a) Mercury (b) Pluto
(c) Earth (d) Venus

54. According to Hubble's law, the redshift (Z) of a receding galaxy and its distance r from earth are related as [AIIMS 2005]
(a) $Z \propto r$ (b) $Z \propto 1/r$
(c) $Z \propto 1/r^2$ (d) $Z \propto r^{3/2}$

55. The condition for a uniform spherical mass m of radius r to be a black hole is [G = gravitational constant and g = acceleration due to gravity] [AIIMS 2005]
(a) $(2Gm/r)^{1/2} \le c$ (b) $(2Gm/r)^{1/2} = c$
(c) $(2Gm/r)^{1/2} \ge c$ (d) $(gm/r)^{1/2} \ge c$

56. Fraunhofer lines of the solar system is an example of [AIIMS 2001]
(a) Emission spectrum
(b) Emission band spectrum
(c) Continuous emission spectrum
(d) Line absorption spectrum

57. The difference in the lengths of a mean solar day and a sidereal day is about [AIIMS 2003]
(a) 1 m[DCE 2003] (b) 4 min

(c) 15 min (d) 56 min

Critical Thinking

Objective Questions

1. A bright star is indicated to have a brightness magnitude of – 5 compared to a star of brightness zero magnitude. It means that this star compared to the reference star of zero brightness is

   (a) 100 times less bright (b) 5 times more bright

   (c) 5 times less bright (d) 100 times more bright

2. The sun revolves around the galaxy with a speed of 250 *km/sec* and it's radius is 3×10^4 light year. The mass of the milky way is

   (a) 3×10^{40} *kg* (b) 3×10^{41} *kg*

   (c) 5×10^{40} *kg* (d) 6×10^{41} *kg*

3. There are certain types of stars called visible stars which undergo periodic change in their light output. If such a star quadruple it's light output, how much does it's magnitude change

   (a) – 1.25 (b) – 1.5

   (c) – 1.75 (d) – 2

4. A particular emission line, detected in the light from a galaxy, has a wavelength $\lambda' = 1.1\lambda$, where λ is the proper wavelength of the line. The galaxy distance from us

   (a) $1.6 \times 10^9 ly$ (b) $0.97 \times 10^9 ly$

   (c) $2.4 \times 10^9 ly$ (d) $1.62 \times 10^{11} ly$

5. Assuming that the dimmest visible star to the naked eye has a magnitude of about 6. Brightness of planet Venus (magnitude = – 4) *w.r.t.* this star is

   (a) 10,000 times brighter (b) 2000 times brighter

   (c) 15000 times brighter (d) 4000 times brighter

6. A galaxy is observed to be moving with a velocity of 8600 *km-sec*. If it is at a distance of 430 million light year from us, Hubble constant and corresponding age of the universe are respectively

   (a) $2 \times 10^{-5} \dfrac{kms^{-1}}{ly}, 1.49 \times 10^{10}\ year$

   (b) $2 \times 10^{-6} \dfrac{kms^{-1}}{ly}, 1.58 \times 10^{3} year$

   (c) $10^6 \dfrac{kms^{-1}}{ly}, 1.49 \times 10^{10} year$

   (d) None of these

7. Consider a binary star system consisting of two stars of masses M_1 and M_2 separated by a distance of 30 AU with a period of revolution equal to 30 years. If one of the two stars is 5 times farther from the centre of mass than the other. The masses of the two stars in terms of solar masses are

   (a) 5, 15 (b) 25, 5

   (c) 25, 10 (d) 7, 25

8. A planet of mass *m* moves in an ellipse around the sun of mass M_S so that its maximum and minimum distances are r_1 and r_2 respectively. The angular momentum of the planet relative to the centre of the sun is

   (a) $\sqrt{\dfrac{2GM_S r_1}{(r_1 + r_2)}}$ (b) $\sqrt{\dfrac{2GM_S m^2 r_1 r_2}{(r_1 + r_2)}}$

   (c) $\sqrt{\dfrac{GM_S r_1 r_2}{(r_1 + r_2)}}$ (d) $\sqrt{\dfrac{2GM_S}{r_1 r_2 (r_1 + r_2)}}$

9. The percentage of Sun's total energy which reaches the earth's surface is

   (a) 10^{-7} % [Kerala PMT 2003] (b) 10^{-6} %

   (c) 10^{-3} % (d) 10^{-2} %

10. Suppose a planet goes around Sun with a linear speed twice as fast that of earth. What will be it's orbit size as compared to that of earth ? (Radius of earth = *R*) [BHU 1993]

    (a) $R/4$ (b) $R/2$

    (c) R (d) $2R$

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : The stars twinkle while the planets do not.

   Reason : The stars are much bigger in size than the planets.[AIIMS 2003

2. Assertion : A pulsor is a source of radio waves which change in terms of intensity at regular interval of time

   Reason : A pulsor is a rotating neutron star

   [AIIMS 1998, 2002]

3. Assertion : The comet do not obey Kepler's laws of planetary motion

   Reason : The comet do not have elliptical orbit

   [AIIMS 1995]

4. Assertion : A star which appears blue will be much hotter than the sun

   Reason : It is based on Wien's law

5. Assertion : There is no atmosphere on moon

   Reason : Escape velocity at the surface of moon is low.

6. Assertion : Red shift confirms that the universe is expanding

   Reason : Wavelength of red light is maximum in the visible region

7. Assertion : Sun is at the galactic centre C of the milky way

   Reason : All planets of solar system revolve around the sun.

8. Assertion : Moon is seen as it partly reflects the sun light falling on it

   Reason : Moon is a satellite of earth. It does not emit light of its own

9. Assertion : The value of Hubble's constant is 16 km/s

Reason : Hubble's constant means that a galaxy at 1 million light years away is receding at the rate of 16 *km/s*.

Answers

Universe

1	d	2	d	3	b	4	a	5	b
6	d	7	a	8	b	9	d	10	b
11	c	12	a	13	c	14	b	15	c
16	a	17	b	18	c	19	b	20	d
21	d	22	b	23	b	24	d	25	b
26	a	27	b	28	b	29	b	30	d
31	b	32	a	33	d	34	b	35	d
36	d	37	a	38	b	39	b	40	a
41	b	42	a	43	b	44	b	45	c
46	c	47	c	48	b	49	a	50	c
51	c	52	c	53	b	54	a	55	c
56	d	57	b						

Critical Thinking Questions

1	d	2	b	3	b	4	a	5	a
6	a	7	b	8	b	9	a	10	a

Assertion and Reason

1	b	2	b	3	b	4	a	5	a
6	b	7	e	8	a	9	e		

Answers and Solutions

Universe

1. (d) A study of binary star is most helpful in verifying Newton's law of gravitation.

2. (d) A group of bright and faint stars is called a constellation

3. (b) The sky is divided into 88 constellations.

4. (a) Big Bang theory is the most satisfactory theory about the origin of universe.

5. (b) Venus is the brightest planet.

6. (d) A star which appears blue will be much hotter than the sun.

7. (a) When distant stars are receding from us, spectral line from the star, when compared to with the corresponding line from source will show red shift *i.e.* a shift in frequency towards the red end.

8. (b) Solar constant is the energy crossing per unit area per sec at earth's distance, area being normal to the sun's rays. Also energy falling is inversely proportional to the square of distance from the source.

$$\therefore\ S' = \frac{S}{(5.3)^2}$$

9. (d) Venus and Mars have both CO_2 present.

10. (b) $\lambda_m T = b \Rightarrow 2.93\times10^{-10}\times T = 2.93\times10^{-3} \Rightarrow T = 10^7\ K$

11. (c) Black hole is highly dense malter in the atmosphere which has very large value of gravitational pull, so that nothing escapes from it.

12. (a) $F = \frac{GMm}{r^2} = mr\omega^2 = mr\left(\frac{2\pi}{T}\right)^2$

$$M = \frac{mr^3 4\pi^2}{GmT^2} = \frac{4\pi^2 r^3}{GT^2}$$

13. (c) The age of universe is believed to be 10-20 billion years.

14. (b) Planet Venus is called Earth's sister.

15. (c) Source of Sun's energy is fusion reactions involving hydrogen.

16. (a) Asteroids are a group of rock pieces moving around the Sun in between Mars and Jupiter. They are believed to be the remains of a large planet which exploded due to gravitative attraction of Sun and that planet, may be called small planets.

17. (b) The energy of the sun is due to fusion of hydrogen nuclei into helium.

18. (c) Venus appears brighter as it is nearest to the earth and the light of sun reflected form sun reaches earth with greater intensity.

19. (b)

20. (d) Saturn only has ring around it.

21. (d) Milky way is one of the enormous galaxies of the universe.

22. (b) According to Hubble's law, $v \propto r$.

23. (b) The hottest planet of solar system is one which is nearest to sun and has no atmosphere.

24. (d) As we move towards the centre of the sun, the density and pressure increases.

25. (b) As $T^2 \propto r^3$ and distance of planet from sun in increasing order is for Mars, Saturn and Pluto.

26. (a) Length of milky way is 10^5 light years.

27. (b) Mercury is the nearest planet to sun.

28. (b) According to Wien's law, $\lambda_m \propto \frac{1}{T}$. It means higher the temperature of a star, the lower is the wavelength of maximum intensity radiation emitted from star which tells the colour of star.

29. (b) As $\lambda \propto \frac{1}{T}$; so $\frac{T_1}{T_2} = \frac{\lambda_2}{\lambda_1} = \frac{350}{510} = 0.68$

30. (d) $\frac{Gm\times 2m}{l^2} = m\times\frac{2l}{3}\frac{4\pi^2}{T^2}$ or $T = \left(\frac{4\pi^2 l^3}{3Gm}\right)^{1/2}$ *i.e.* $T \propto m^{-1/2}$

31. (b) Speed of galaxy is proportional to it's distance from us *i.e.* $U \propto r$. This is Hubble's law

32. (a) Reflecting power of a heavenly body is called albedo.

33. (d)

34. (b) Meteors are burnt piece of comet. When they reach earth's atmosphere, they start burning due to friction.

35. (d) According to Stefan's law $E = \sigma T^4$

36. (d) If the light received from galaxies indicates a shift towards the red end of spectrum of light, it means that the galaxies should be receding away (Doppler's effect). Therefore we conclude that the universe is expanding.

37. (a) The star which appears red is at less temperature, than the star which appears white. Therefore, temperature of *Q* is higher than that of *P*.

38. (b) The albedo (reflection power) is maximum for Venus, because it reflects 85% of incident light. It's value of albedo is 0.85.

39. (b) It is well known that if the mass of the star is more than that of mass of Sun, it explodes after it's red giant stage and dies out giving rise to supernova and a black hole.

40. (a) If a comet approaches the sun, the substances like water *etc.* on the comet, get vaporised due to the heat of Sun, and radiation pressure forces of these vapours move away from the Sun. Hence, it forms the tail of the comet.

41. (b)

42. (a) Venus has the longest day.

43. (b) Ursa major is known as saptarishi.

44. (b)

45. (c) The temperature of stars can be determined by Wiens displacement law which is $\lambda_m . T = \text{constant}$.

46. (c) The motion of planets in the solar system is based on the conservation of angular momentum.

47. (c)

48. (b)

49. (a) Hubble's law state that. Speed of recession (v) $\propto$ distance (r).

50. (c) Great bear is a constellation, which is a group of some stars.

51. (c) Surface temperature of Sun is about 6000 *K*.

52. (c) By using $\lambda_m T = \text{constant}$

53. (b) Because pluto is farthest from Sun.

54. (a) Hubble's law is a statement of a direct correlation between the distance (r) to a galaxy and its recessional velocity as determined by the red shift (Z). It is stated as $Z = Hr$.

55. (c) The criterion for a star to be black hole is

$$\frac{GM}{c^2R} \geq \frac{1}{2} \text{ or, } \sqrt{\frac{2GM}{R}} \geq c.$$

56. (d) Fraunhofer lines are produced by the absorption of rays of the Sun in the atmosphere. When white light from photosphere passes through chromosphere, the vapours and gases present in it absorbs certain wavelengths and produces dark lines (Fraunhofer lines).

57. (b) The difference in the length of mean solar day and a sidereal day is about 4 min.

Critical Thinking Questions

1. (d) Given that magnitude for brightest star = – 5
and magnitude of given star = 0
Now $m_2 - m_1 = 0 - (-5) = 5$
The brightness ratio is given by

$$\frac{l_1}{l_2} = 100^{(m_2 - m_1)/s} = 100^{5/5} = 100$$

So bright star is 100 time bright that the dim star.

2. (b) The mass of galaxy is given by $M = \frac{v^2 r}{G}$

where v = 250 *km/sec* = $250 \times 10^3 \frac{m}{\text{sec}}$

$r = 3 \times 10^4$ *ly* $= 3 \times 10^4 \times 9.46 \times 10^{12}$ *km* $\approx 3 \times 10^{20}$ *m*

$$\therefore m = \frac{(250 \times 10^3)^2 \times (3 \times 10^{20})}{6.6 \times 10^{-11}} \approx 3 \times 10^{41} \text{ kg.}$$

3. (b) $\frac{l_2}{l_1} = 4 \Rightarrow m_2 - m_1 = -2.5 \log\left(\frac{l_2}{l_1}\right) = -2.5 \log 4$

$= -2.5 \times 0.6021 = -1.5$.

4. (a) From Hubble's law $v = Hr$ where H = Hubble's constant = 19.3 *mm/sec-ly* and r = Distance of Galaxy from us.

According to Doppler's effect speed of Galaxy $v = \frac{c\Delta\lambda}{\lambda}$

$$\Rightarrow r = \frac{c\Delta\lambda}{H\lambda} = \frac{c \times 0.1\lambda}{H\lambda} = \frac{0.1 \times 3 \times 10^8}{19.3 \times 3 \times 10^{-3}} = 1.6 \times 10^9 \, ly$$

5. (a) Here, for Venus $m_1 = -4$, for star $m_2 = 6$ using

$$\frac{l_1}{l_2} = 100^{(m_2 - m_1)/5} = 100^{[6-(-4)]/5} = 100^2 = 10{,}000.$$

6. (a) $H = \frac{v}{r} = \frac{8600}{430 \times 10^6} = 2 \times 10^{-5} \frac{kms^{-1}}{ly}$

Age of the universe, $t_0 = \frac{1}{H} = \frac{r}{v}$

Taking $r = 430 \times 10^6$ *ly* $= 430 \times 10^6 \times 9.46 \times 10^{12}$ *km*

$$\Rightarrow t_0 = \frac{430 \times 10^6 \times 9.46 \times 10^{12}}{8600} \text{sec}$$

$$= \frac{430 \times 10^6 \times 9.46 \times 10^{12}}{8600 \times 3600 \times 24 \times 365} = 1.49 \times 10^{10} \, year$$

7. (b) $M_1 + M_2 = \frac{4\pi^2}{G} \cdot \frac{r^3}{T^2}$

If T is measured in years, r in *A.U.* and masses in Solar masses then $G = 4\pi^2$.

$$\therefore M_1 + M_2 = \frac{r^3}{T^2} = \frac{(30)^3}{(30)^2} = 30 \quad \text{.....(i)}$$

Now $r_1 + r_2 = 30 \Rightarrow r_1 + 5r_1 = 60$

$\Rightarrow r_1 = 5$ and $r_2 = 25$

Again $M_1 r_1 = M_2 r_2 \Rightarrow \frac{M_1}{M_2} = 5$ .....(ii)

After solving (i) and (ii) we get $M_1 = 25$ and $M_2 = 5$

8. (b) From conservation of energy

$\frac{1}{2}mv_1^2 - \frac{GM_S m}{r_1} = \frac{1}{2}mv_2^2 - \frac{GM_S m}{r_2}$. Angular momentum is conserved, that is $mv_1 r_1 = mv_2 r_2$

or $v_2 = v_1 \frac{r_1}{r_2} \Rightarrow \frac{1}{2}mv_1^2 - \frac{GM_S m}{r_1} = \frac{1}{2}m\left(\frac{v_1 r_1}{r_2}\right)^2 - \frac{GM_S m}{r_2}$

or $v_1 = \sqrt{\frac{2GM_S r_2}{r_1(r_1 + r_2)}} \Rightarrow L = mv_1 r_1 = \sqrt{\frac{2GM_S m^2 r_1 r_2}{r_1 + r_2}}$

9. (a) If S is the total energy emitted by Sun per second and r is the distance of earth from Sun; then energy reaching earth of radius R per second $= \frac{S}{4\pi r^2} \times 2\pi R^2 = \frac{SR^2}{2r^2}$.

$\therefore$ Percentage of energy reaching earth

$$= \frac{SR^2}{2r^2 S} \times 100 = \frac{(6.4 \times 10^6)^2 \times 100}{2 \times (1.5 \times 10^{11})^2} \simeq 10^{-7}\%$$

10. (a) From Kepler's law $T \propto R^{3/2}$ and also $T = \frac{2\pi R}{v}$

$$\Rightarrow v \propto \frac{1}{R^{1/2}} \Rightarrow \frac{v_1}{v_2} = \left(\frac{R_2}{R_1}\right)^{1/2} \Rightarrow \frac{v_1}{2v_1} = \left(\frac{R_2}{R_1}\right)^{1/2}$$

$$\Rightarrow R_2 = \frac{R_1}{4} = \frac{R}{4}$$

Assertion and Reason

1. (b) Stars twinkles due to variation in density of atmospheric layer. Also stars are much bigger in size than planets but it has nothing to deal with twinkling phenomenon.
2. (b) Pulsar is a source of radio waves which emits pulses of radio waves at short and regular time of intervals.
   Pulsar is formed, due to super nova explosion, when super nova explosion occurs, the core of the star is compressed and electrons and protons combine to form a neutron. Due to this region pulsar is called neutron star.
3. (b) Comets do not revolve around the sun in fixed elliptical orbit like other planets and don't obey Kepler's law for planetary motion.
4. (a) According to Wien's law, $\lambda_m T = b =$ constant. As λ_m for the star is blue, which is less than λ_m for sun, which is yellow, therefore temp. T of star will be much higher than the temperature of the sun.
5. (a) At the surface of moon $v_{rms} > v_{escape}$ hence molecules escape out before reaching their *rms* velocity that's why there is no atmosphere present.
6. (b) Red shift means that wavelength of light received from stars is increasing *i.e.,* apparent frequency is decreasing. Therefore, the stars/galaxies must be receding away. Hence the universe is expanding. Reason is also true, but it does not explain the assertion appropriately.
7. (e) The reason is true, but the assertion is false. Infect, distance of sun of our solar system from galactic centre is 3×10^4 light years.
8. (a) Both the assertion and reason are true and reason is a correct explanation of the assertion.
9. (e) The assertion is not true. Infect, the value of Hubble's constant is 16 km per sec per million light years.

Universe

SET Self Evaluation Test - 31

1. "The universe is expanding" means
   (a) Size of the hole in Ozon layer is increasing
   (b) Universe is expanding into something
   (c) Infinite universe is becoming more infinite
   (d) None of these

2. The galaxy in which we live is
   (a) Spiral galaxy (b) Radio galaxy
   (c) Irregular galaxy (d) None of these

3. The distance of Venus from the sun is 0.72 AU. the orbital period of the Venus is
   (a) 200 days (b) 320 days
   (c) 225 days (d) 325 days

4. Suppose the sun was located at the position occupied by the nearest star, say, alphacenturi 4 light years away. By what factor the solar radiation received per sec per unit area decrease
   (a) 1.5×10^{-6} (b) 1.5×10^{-8}
   (c) 1.5×10^{-9} (d) 1.5×10^{-11}

5. If a galaxy is at a distance 430 million light years from us, determine Hubble's constant. Its speed being $6.48\times10^{6}ms^{-1}$
   (a) 16 kms^{-1} per million light year
   (b) 15 kms^{-1} per million light year
   (c) 14 kms^{-1} per million light year
   (d) None of these

6. The magnitude of two stars A and B are 2.5 and –5 respectively. The brightness ratio of $\frac{B}{A}$ is
   (a) 7.5 (b) 10^{2}
   (c) 10^{3} (d) $10^{7.5}$

7. A body at 1500 K emits maximum energy at a wavelength 20,000 Å. If the Sun emits maximum energy at wavelength 5500 Å, then the temperature of Sun is
   (a) 5454 (b) 4454
   (c) 4550 (d) 5400

8. The hottest type of stars are called
   (a) A type (b) B type
   (c) O type (d) M type

9. Venus appears brighter than other stars because
   (a) It is heavier than other planets
   (b) Its density is more than other planets
   (c) It is nearer to earth in comparison to other planets
   (d) Nuclear fusion takes place at its surface

10. The death of a star results is in a neutron star if the original mass of star in terms of mass of Sun (M) is
    (a) Less than 2M
    (b) Between 2M and 4M
    (c) Greater than 5 M
    (d) Exactly equal to M

11. The tail of a comet points
    (a) Towards the Sun
    (b) Away from the Sun
    (c) In arbitrary
    (d) Away from the earth

12. The angle of maximum elongation for Venus is 47°. The distance of Venus from earth in A.U. is
    (a) 0.68 A.U. (b) 0.86 A.U.
    (c) 1 A.U. (d) 0.73 A.U.

13. The number of stars in our solar system is
    (a) 9 (b) 5
    (c) 1 (d) More than 9

14. If angular diameter of Sun is about 30′ and it's distance from earth is 1.5×10^{11} m, then solar diameter is
    (a) 1.1×10^{7} m
    (b) 1.5×10^{8} m
    (c) 1.4×10^{9} m
    (d) 1.9×10^{11} m

AS Answers and Solutions

(SET -31)

1. (c)

2. (a) The galaxy in which we live is spiral galaxy. Our galaxy Milky way is a spiral galaxy.

3. (c) $\frac{T_2^2}{T_1^2} = \left(\frac{r_2}{r_1}\right)^3$ or $T_2 = T_1\left(\frac{r_2}{r_1}\right)^{3/2} = 1\left(\frac{0.72}{1}\right)^{3/2}$

= 0.62 year or 225 days.

4. (d) $\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}$ or $\frac{E_2}{E_1} = \frac{r_1^2}{r^2} \Rightarrow \frac{(1.5\times10^{11})^2}{(4\times9.46\times10^{15})^2} = 1.5\times10^{-11}$

where r_1 = Distance of Sun from earth = 1.5×10^{11} m = 1 AU, r_2 = 4 ly = $4 \times 9.46 \times 10^{15}$ m

5. (b) $H = \frac{v}{r} = \frac{6.48\times10^6}{430} = 15.07\, kms^{-1}$ per million light year

6. (c) $m_B - m_A = -2.5\log_{10}\left(\frac{I_B}{I_A}\right)$

$\Rightarrow -5-(2.5) = -2.5\log_{10}\frac{I_B}{I_A} \Rightarrow \log_{10}\frac{I_B}{I_A} = 3$

$\Rightarrow \frac{I_B}{I_A} = 10^3$.

7. (a) According to Wien's displacement law $\lambda_m T$ = constant

or $\lambda_m T = \lambda_m' T'$

or $T' = \frac{\lambda_m}{\lambda_m'}\times T = \frac{20{,}000Å\times1500K}{5500Å} = 5454K.$

8. (c) O type stars are hottest.

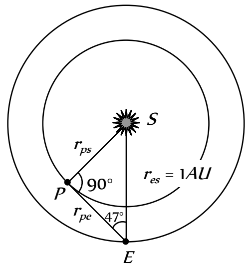
9. (c) Venus appears brighter than other stars because it is nearest to earth than other stars.

10. (b)

11. (b) Tail of comet points away from the sun.

12. (a) The angle formed at earth between earth planet and earth sun direction is called planet's elongation represented by ε, when planet appears farthest from the Sun, the angle subtended by the Sun and earth at the planet is $90°$.

From the geometry of figure



$\frac{r_{PE}}{r_{sE}} = \cos\varepsilon = \cos 47°$

$r_P = r_{sE}\cos 47°$

$= (\cos 47°)\times 1AU = 0.68AU$

Choice (a) is correct

[$\cos 45° = \frac{1}{\sqrt{2}} = 0.707$. As angle increases its cosine decreases $\cos 47°$ can not be 0.86, 0.73 or 1]

13. (c) The number of stars in our solar system in one (our Sun).

14. (c) We know that

$D = r\theta = 1.5\times10^{11}\times\frac{1}{2}\times\frac{\pi}{180°} = 1.4\times10^9 m$

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