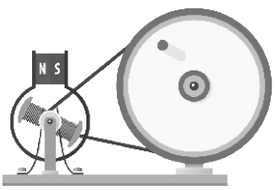


Class-XII

MHT-CET

Study Material

PHYSICS

Booklet-1

Contents

Ch.No.	Chapter Name	Page No.
1.	Rotational Dynamics	1-24
2.	Mechanical Properties of Fluids	25-46
3.	Kinetic Theory of Gases and Radiation	47-66
4.	Thermodynamics	67-84
5.	Oscillations	85-108
6.	Superposition of Waves	109-130
7.	Wave Optics	131-152
8.	Electrostatics	153-178

1 Rotational Dynamics

TOPIC 1.1 : KINEMATICS OF CIRCULAR MOTION, DYNAMICS OF CIRCULAR MOTION, APPLICATIONS OF UNIFORM CIRCULAR MOTION, MOTION IN A VERTICAL CIRCLE

KINEMATICS OF CIRCULAR MOTION

Angular Displacement

The angle described by radius vector is called **angular displacement.**

$$\text{Angular displacement } (\theta) = \frac{\text{Linear displacement } (s)}{\text{Radius}(r)}$$

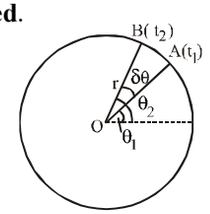
Angular displacement is a vector quantity.

S.I. Unit : radian and it is a **dimensionless quantity**

Angular Velocity And Its relation with linear velocity

The rate of change of angular displacement is called **angular velocity**. It is a vector quantity. The angle traced per unit time by the radius vector is called **angular speed**.

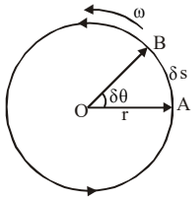
Instantaneous angular velocity



$$\omega = \lim_{\delta t \to 0} \frac{\delta\theta}{\delta t} \quad \text{or} \quad \omega = \frac{d\theta}{dt}$$

S.I. Unit : rad/sec

Relation Between Angular Velocity and Linear Velocity



$$\lim_{\delta t \to 0} \frac{\delta\theta}{\delta t} = \omega = \text{angular velocity}$$

$\therefore \quad v = r \cdot \omega$ [For circular motion only]

i.e., (Linear velocity) = (radius) × (angular velocity)

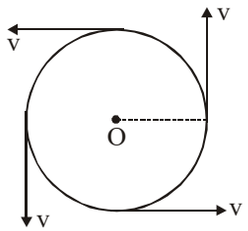
Angular Acceleration

Average angular acceleration ; Instantaneous angular acceleration

$$\bar{\alpha} = \frac{\omega_2 - \omega_1}{t_2 - t_1} = \frac{\Delta\omega}{\Delta t} \quad ; \quad \alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

Uniform Circular Motion

In case of uniform circular motion : $\frac{dv}{dt} = 0$



Kinetic equations for rotational motion with uniform angular acceleration are :

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

Radial Acceleration and its Expression in Uniform Circular Motion

The acceleration of a particle performing uniform circular motion is along the radius and towards the centre. It is called **radial acceleration**. It is also known as **centripetal acceleration**.

$$\vec{a} = -\omega^2\vec{r}$$

Negative sign shows that acceleration has direction opposite to that of the radius vector.

It has magnitude $\omega^2 r$ or $\frac{v^2}{r}$. i.e., $\mathbf{a_c = \omega^2 r}$ or $\mathbf{\frac{v^2}{r}}$

Non-uniform Circular Motion

If the speed of a particle moving on a horizontal circle changes with time then the motion of the particle is called non-uniform circular motion.

$$a_{net} = \sqrt{a_r^2 + a_t^2}$$

$$= \sqrt{\left(\frac{v^2}{r}\right)^2 + \left(\frac{dv}{dt}\right)^2}$$

DYNAMICS OF CIRCULAR MOTION

Centripetal Force

In circular motion the force acting on the particle along the radius and towards the centre keeps the body moving along the circular path. This force is called centripetal force.

$F = -m\omega^2 r$

Centrifugal Force

The pseudo force experienced by a particle performing uniform circular motion due to accelerated frame of reference which is along the radius and directed away from the centre is called centrifugal force, $F = m\omega^2 r$

APPLICATIONS OF UNIFORM CIRCULAR MOTION

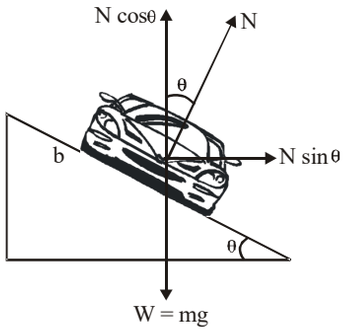
Banking of Road

If a driver moves with slow velocity, then friction does not play any role in negotiating the turn.

The various forces acting on the vehicle are :

(i) Weight of the vehicle (mg) in the downward direction.

(ii) Normal reaction (N) perpendicular to the inclined surface of the road.

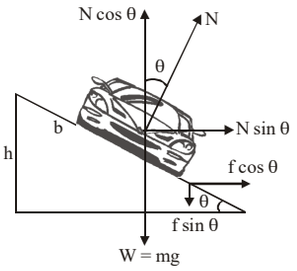


$$\tan\theta = \frac{v^2}{rg} \qquad \therefore\ \theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

Where θ is the banking angle $\left(\sin\theta = \frac{h}{b}\right)$.

$\because\quad v^2 = gr\tan\theta \quad \therefore\ v = \sqrt{gr\tan\theta}$ **(maximum safe speed)**

If the driver moves faster than the safe speed mentioned above, a friction force must act parallel to the road, inwards towards the centre of the turn.



or $\quad v = \sqrt{\frac{\tan\theta + \mu}{1 - \mu\tan\theta} rg}$

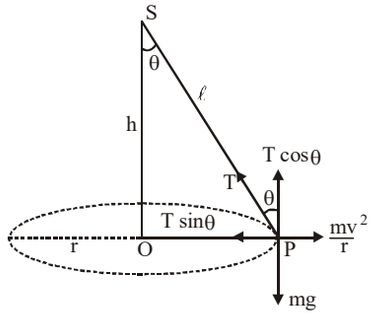
The best speed to negotiate a curve is obtained by putting $\mu = 0$.

$\therefore\quad v = \sqrt{rg\tan\theta}$

With this speed, there will be minimum wear and tear of the tyres.

Conical Pendulum

The force acting on the bob are (a) tension T and, (b) weight mg



The horizontal component T sinθ of the tension T provides the centripetal force and the vertical component Tcosθ balances the weight of bob

$$\therefore\qquad T\sin\theta = \frac{mv^2}{r} \text{ and } T\cos\theta = mg$$

The time period of conical bendulrm

$$T = 2\pi\sqrt{\frac{h}{g}} = 2\pi\sqrt{\frac{\ell\cos\theta}{g}}$$

Death Well and Rotor

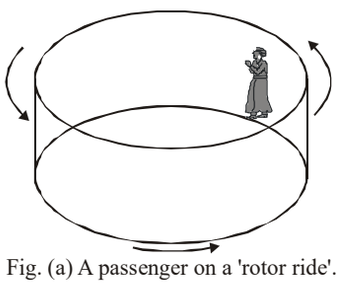


Fig. (a) A passenger on a 'rotor ride'.

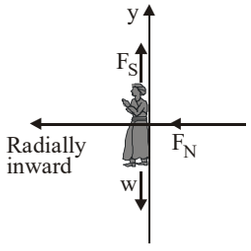


Fig. (b) A force diagram for the person.

In both these cases friction balances the weight of person while reaction provides the centripetal force necessary for circular motion i.e., force of friction, $F_S = mg$

Normal reaction $F_N = \frac{mv^2}{r}$

So, $\frac{F_N}{F_S} = \frac{v^2}{rg}$, i.e., $v = \sqrt{\frac{rgF_N}{F_S}}$

Now for v to be minimum F_S must be maximum,

i.e., $v_{min} = \sqrt{\frac{rg}{\mu}}$ [as $F_{S\,max} = \mu F_N$]

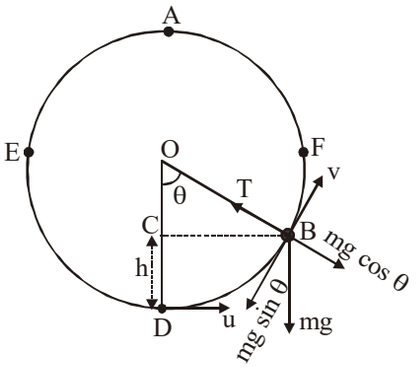
MOTION IN A VERTICAL CIRCLE

Motion of a body suspended by string : This is the best example of non-uniform circular motion.

Resolve weight (mg) into two components

(i) mg cos θ (along radial direction)

(ii) mg sin θ (along tangential direction)



Force T– mg cos θ provides necessary centripetal force.

Then $T - mg\cos\theta = \frac{mv^2}{r}$ ...(i)

Velocity of Different Position in Vertical Circular Motion

At the top most point (A)

$mg + T_A = \frac{mv_A^2}{r}$

$(V_A)_{min} = \sqrt{gr}$ (minimum)

At the lower most point (D)

$T_B - mg = \frac{mv_B^2}{r}$

$(V_D) = \sqrt{5rg}$ (maximum)

At the horizontal points (E and F)

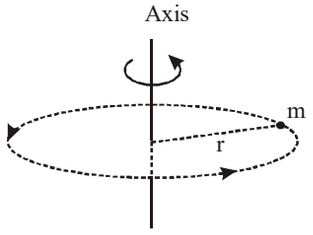
$T_C - T_A = T_D - T_A = 3mg$

$(V_E) = (V_F) = \sqrt{3rg}$

TOPIC 1.2 : MOMENT OF INERTIA, RADIUS OF GYRATION, THEOREM OF PERPENDICULAR AND PARALLEL AXES, ANGULAR MOMENTUM, CONSERVATION OF ANGULAR MOMENTUM

MOMENT OF INERTIA

The virtue by which a body revolving about an axis opposes the change in rotational motion is known as moment of inertia. *The moment of inertia of a particle with respect to an axis of rotation is equal to the product of mass of the particle and square of distance from rotational axis.*



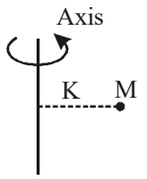
$I = mr^2$

Where, r = perpendicular distance from axis of rotation.

RADIUS OF GYRATION (K)

The radius of gyration of a body is the distance from axis of rotation.

Radius of gyration $K = \sqrt{\frac{I}{M}}$



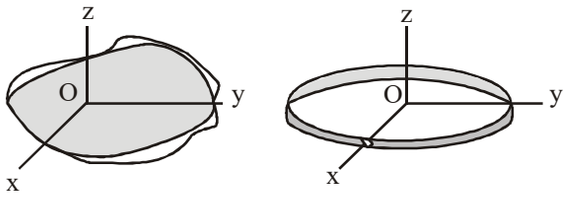
It has no meaning without axis of rotation, it is a scalar quantity.

THEOREM OF PERPENDICULAR AND PARALLEL AXES

Theorem of Perpendicular Axes

(Applicable only for two dimensional bodies or plane laminas)

$$I_z = I_x + I_y$$

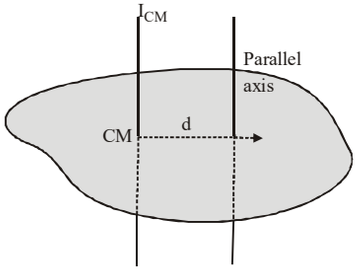


Where, I_x = MI of the body about X-axis

I_y = MI of the body about Y-axis

I_z = MI of the body about Z-axis

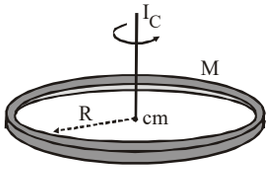
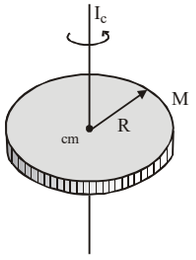
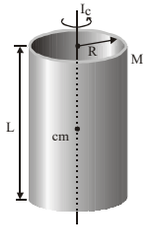
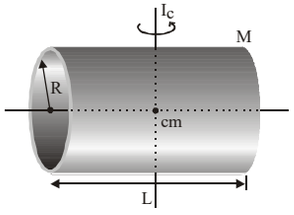
Theorem of Parallel Axes (Applicable for all Types of Bodies)

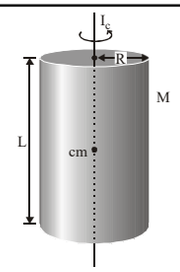
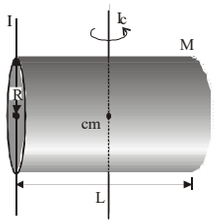
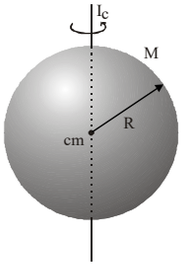
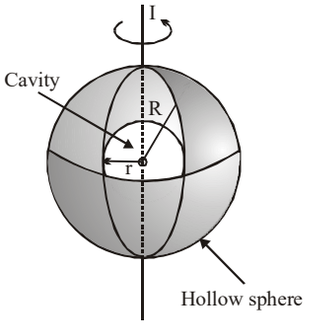
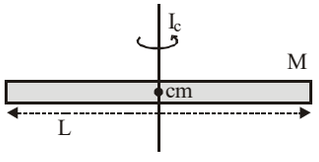
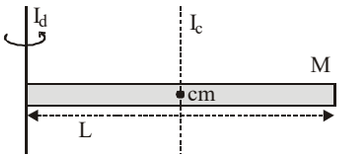


$$I = I_{CM} + Md^2$$

I_{CM} = moment of inertia about the axis passing through centre of mass.

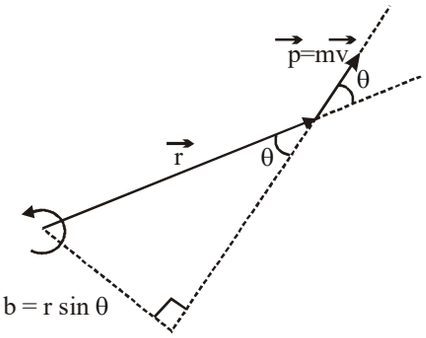
Moment of inertia and radius of gyration of different objects

Shape of body	Rotational axis	Figure	Moment of inertia	Radius of gyration
(1) Ring M = mass R = radius	Perpendicular to plane passing through centre of mass		MR^2	R
(2) Disc	Perpendicular to plane passing through centre of mass		$\frac{1}{2}MR^2$	$\frac{R}{\sqrt{2}}$
(3) Thin walled cylinder	(a) Geometrical axis		MR^2	R
	(b) Perpendicular to length passing through centre of mass		$M\left(\frac{R^2}{2}+\frac{L^2}{12}\right)$	$\sqrt{\frac{R^2}{2}+\frac{L^2}{12}}$

(4) Solid cylinder	(a) Geometrical axis		$\frac{MR^2}{2}$	$\frac{R}{\sqrt{2}}$
	(b) Perpendicular to length passing through centre of mass		$M\left(\frac{R^2}{4}+\frac{L^2}{12}\right)$	$\sqrt{\frac{R^2}{4}+\frac{L^2}{12}}$
(5) Solid sphere	Along the diameter		$\frac{2}{5}MR^2$	$\sqrt{\frac{2}{5}}R$
(6) Hollow sphere	Along the diameter		$\frac{2}{5}M\left[\frac{R^5-r^5}{R^3-r^3}\right]$	$\sqrt{\frac{2}{5}\frac{(R^5-r^5)}{(R^3-r^3)}}$
(7) Thin rod	(a) Perpendicular to length passing through centre of mass		$\frac{ML^2}{12}$	$\frac{L}{2\sqrt{3}}$
	(b) Perpendicular to length passing through one end		$\frac{ML^2}{3}$	$\frac{L}{\sqrt{3}}$

ANGULAR MOMENTUM (MOMENT OF LINEAR MOMENTUM)

Angular momentum = linear momentum × perpendicular distance of line of action of momentum from the axis of rotation.



$\Rightarrow$ Angular momentum, $\vec{L} = \vec{r} \times \vec{p}$

Unit of angular momentum in SI system. J-sec or kg-m^2/sec

In case of rotational motion

$$\frac{d\vec{L}}{dt} = I\vec{\alpha} = \vec{\tau}$$

Torque

If a force acts on a single particle at a point P whose position with respect to the origin O is vector **r** the moment of the force acting on the particle with respect to the origin O is defined as $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

Torque, $\vec{\tau} = \vec{r} \times \vec{F}$

Unit of torque in SI system (Nm) cannot be written as joule, because joule is used specifically for work or energy however, unit Nm is same as that of work or energy.

The magnitude of torque :

Torque = force × perpendicular distance of line of action of force from the axis of rotation.

CONSERVATION OF ANGULAR MOMENTUM

Suppose on a system of particles of a rigid body no external force is acting then its angular momentum remains conserved, this is known as conservation of angular momentum.

We know,

$$\frac{dL}{dt} = \tau \quad \text{if} \quad \tau = 0$$

$$dL = 0$$

$L_{initial} = L_{final}$ or $I\omega = \text{const.}$

Some Important Formulae in Translatory Motion and Rotatory Motion :

	Translatory motion	Rotatory motion
1.	Acceleration, $a = \frac{dv}{dt}$	Angular acceleration, $\alpha = \frac{d\omega}{dt}$
2.	Force, $\vec{F} = \frac{d\vec{p}}{dt}, \vec{F} = m\vec{a}$	Torque $\vec{\tau} = \frac{d\vec{L}}{dt}, \vec{\tau} = I\vec{\alpha}$
3.	Linear momentum $\vec{p} = m\vec{v}$	Angular momentum $\vec{L} = I\vec{\omega}$
4.	Linear kinetic energy KE = $\frac{1}{2}mv^2$	Rotational kinetic energy, $E = \frac{1}{2}I\omega^2$
5.	Work done $W = \vec{F}.\vec{S}$ (constant force)	Work done $W = \vec{\tau}.\vec{\theta}$ (constant torque)
6.	Work done $W = \int \vec{F}.\vec{S}$ (variable force)	Work done $W = \int \vec{\tau}.d\vec{\theta}$ (variable torque)
7.	Power $P = \frac{dW}{dt} = \frac{\vec{F}.d\vec{s}}{dt} = \vec{F}.\vec{v}$	Power $P = \frac{dW}{dt} = \frac{\vec{\tau}.d\vec{\theta}}{dt} = \vec{\tau}.\vec{\omega}$
8.	Work energy theorem : $W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$	Work energy theorem : $W = \frac{1}{2}I\omega_2^2 - \frac{1}{2}I\omega_1^2$
9.	Linear impulse $= \vec{F}\Delta t = \Delta P$	Angular impulse = $\vec{\tau}\Delta t = \Delta L$
10.	Impulse momentum theorem : $\Delta\vec{p} = \vec{F}\Delta t$	Angular impulse momentum theorem : $\Delta\vec{L} = \vec{\tau}\,\Delta t$

TOPIC 1.3 : ROLLING MOTION

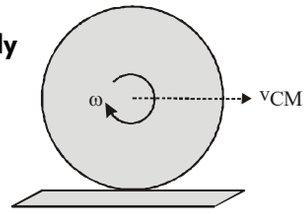
ROLLING MOTION

When a body performs translatory motion as well as rotatory motion then it is known as rolling motion.

$v = \omega r$

Kinetic Energy of Rolling Body

By the law of conservation of energy



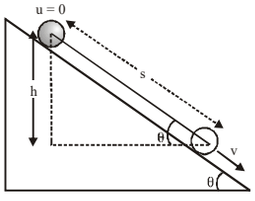
$$= \frac{1}{2}mv^2\left[1+\frac{K^2}{R^2}\right]$$

Where R is the radius and k is radius of gyration.

$$E_{translation} : E_{rotation} : E_{total} = 1 : \frac{K^2}{R^2} : 1+\frac{K^2}{R^2}$$

Energy distribution table for different rolling bodies

Body	$\frac{K^2}{R^2}$	Translatory(K_T) $\frac{1}{2}mv^2$	Rotatory(K_R) $\frac{1}{2}mv^2\frac{K^2}{R^2}$	Total(K_N) $\frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right)$	$\frac{K_T}{K_N}$(%)	$\frac{K_R}{K_N}$(%)
Ring and cylindrical shell	1	$\frac{1}{2}mv^2$	$\frac{1}{2}mv^2$	mv^2	$\frac{1}{2}(50\%)$	$\frac{1}{2}(50\%)$
Disc and solid cylinder	$\frac{1}{2}$	$\frac{1}{2}mv^2$	$\frac{1}{4}mv^2$	$\frac{3}{4}mv^2$	$\frac{2}{3}(66.6\%)$	$\frac{1}{3}(33.3\%)$
Solid sphere	$\frac{2}{5}$	$\frac{1}{2}mv^2$	$\frac{1}{5}mv^2$	$\frac{7}{10}mv^2$	$\frac{5}{7}(71.5\%)$	$\frac{2}{7}(28.5\%)$
Hollow sphere	$\frac{2}{3}$	$\frac{1}{2}mv^2$	$\frac{1}{3}mv^2$	$\frac{5}{6}mv^2$	$\frac{3}{5}(60\%)$	$\frac{2}{5}(40\%)$



From law of conservation of mechanical energy,

Velocity at the lowest point, $v = \sqrt{\frac{2gh}{1+\frac{k^2}{R^2}}}$

From equation,

$v = u + at \;;\; u = 0$

Time of descent, $t = \frac{v}{a}$

$$t = \frac{1}{\sin\theta}\sqrt{\frac{2h\left(1+\frac{k^2}{R^2}\right)}{g}}$$

CHAPTER AT A GLANCE

Angular displacement $(\theta) = \frac{\textit{Linear displacement (s)}}{\textit{Radius(r)}}$

Instantaneous angular velocity

$$\omega = \lim_{\delta t \to 0}\frac{\delta\theta}{\delta t} \quad \text{or} \quad \omega = \frac{d\theta}{dt}$$

Instantaneous angular acceleration $\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$

Centripetal acceleration $\mathbf{a_c} = \omega^2\mathbf{r}$ or $\frac{\mathbf{v^2}}{\mathbf{r}}$

Centripetal force, $F = -m\omega^2 r$, centrifugal force, $F = m\omega^2 r$

Maximum safe velocity on horizontal circular track

$v = \sqrt{gr\tan\theta}$ **(maximum safe speed)**

Maximum safe velocity on a banked road.

$v = \sqrt{\frac{\tan\theta + \mu}{1 - \mu\tan\theta} rg}$

The time period of conical pendulum

$T = 2\pi\sqrt{\frac{h}{g}} = 2\pi\sqrt{\frac{\ell\cos\theta}{g}}$

Minimum velocity in Death well and Rotor, $v_{min} = \sqrt{\frac{rg}{\mu}}$

Velocity at lower point of vertical circle, $v = \sqrt{gr}$

Velocity at highest point of vertical circle, $v = \sqrt{5gr}$

Moment of inertia of a body about the given axis of rotation, $I = m_1r_1^2 + m_2r_2^2 ..... m_nr_n^2 = \sum_{i=1}^{n} m_i r_i^2$

Perpendicular axes theorem for linear body. $I_z = I_x + I_y$

Theorem of parallel axes : $I = I_{cm} + Mr^2$

Torque, $\vec{\tau} = (\vec{r} \times \vec{F}).\hat{n}$ where $\hat{n}$ is a unit vector, $|\vec{\tau}| = rF\sin\theta$

Angular momentum $L = p\ (r \sin\theta) = \vec{r} \times \vec{p}$ (always applicable), $\vec{L} = I\vec{\omega}$ (only in rotatory motion)

Law of conservation of angular momentum; In the absence of any external torque $L = I\omega =$ constant or, $I_1\omega_1 = I_2\omega_2$

Rotational kinetic energy K. $E_{rot} = \frac{1}{2}I\omega^2$

In case of pure rolling (without slipping) motion of a body,

velocity $v = \left[\frac{2gh}{1 + \frac{k^2}{R^2}}\right]^{1/2}$

Acceleration $a = \frac{g\sin\theta}{1 + \frac{k^2}{R^2}}$; Time taken $t = \left[\frac{2s\left(1 + \frac{k^2}{R^2}\right)}{g\sin\theta}\right]^{1/2}$

Exercise 1 : WARM-UP
Topic-wise MCQs

1.1 Kinematics of Circular Motion, Dynamics of Circular Motion, Applications of Uniform Circular Motion, Motion in a Vertical Circle

1. Angular velocity of each particle of a rotating rigid body about axis of rotation is
(a) same
(b) different
(c) depends on relative position
(d) None of these

2. A mass is revolving in a circle which is in the plane of paper. The direction of angular acceleration is
(a) upward the radius
(b) towards the radius
(c) tangential
(d) at right angle to angular velocity

3. A car of mass 800 kg moves on a circular track of radius 40 m. If the coefficient of friction is 0.5, then maximum velocity with which the car can move is
(a) 7 m/s (b) 14 m/s
(c) 8 m/s (d) 12 m/s

4. A cyclist riding the bicycle at a speed of $14\sqrt{3}$ ms^{-1} takes a turn around a circular road of radius $20\sqrt{3}$ m without skidding. Given g = 9.8 ms^{-2}, what is his inclination to the vertical
(a) 30° (b) 90°
(c) 45° (d) 60°

5. A car is moving on a curved road with constant speed. If N_1 and N_2 are the reactions at A and B then:

(a) $N_1 < N_2$ (b) $N_1 > N_2$
(c) $N_1 = N_2$ (d) none of these

6. The angular speed of seconds needle in a mechanical watch is
(a) $\frac{\pi}{30}$ rad/s (b) 2π rad/s
(c) π rad/s (d) $\frac{60}{\pi}$ rad/s

7. A train is moving with a speed of 36 km/hour on a curved path of radius 200 m. If the distance between the rails is 1.5 m, the height of the outer rail over the inner rail is
(a) 1 m (b) 0.5 m
(c) 0.75 m (d) 0.075 m

8. A particle is moving along a circular path with a uniform speed. Through what angle does its angular velocity change when it completes half of the circular path?
(a) 0° (b) 45°
(c) 180° (d) 360°

9. A particle moving in uniform circle makes 18 revolution in 1 minute. If the radius of the circle is 10 cm, the speed of the particle is
(a) $3\pi \times 10^{-2}$ ms^{-1} (b) $4\pi \times 10^{-2}$ ms^{-1}
(c) $5\pi \times 10^{-2}$ ms^{-1} (d) $6\pi \times 10^{-2}$ ms^{-1}

10. If the body is moving in a circle of radius r with a constant speed v, its angular velocity is
(a) v^2/r (b) vr
(c) v/r (d) r/v

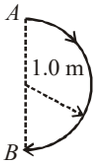
11. The acceleration of a train travelling with speed of 400 m/s as it goes round a curve of radius 160 m, is
(a) 1 km/s^2 (b) 100 m/s^2
(c) 10 m/s^2 (d) 1 m/s^2

12. An aeroplane is flying with a uniform speed of 100 m/s along a circular path of radius 100 m. The angular speed of the aeroplane will be
(a) 1 rad/sec (b) 2 rad/sec
(c) 3 rad/sec (d) 4 rad/sec

13. The angular velocity of a wheel is 70 rad/sec. If the radius of the wheel is 0.5 m, then linear velocity of the wheel is
(a) 70 m/s (b) 35 m/s
(c) 30 m/s (d) 20 m/s

14. A body is whirled in a horizontal circle of radius 20 cm. It has angular velocity of 10 rad/s. What is the linear velocity at any point on circular path?
(a) 10 m/s (b) 2 m/s
(c) 20 m/s (d) $\sqrt{2}$ m/s

15. In 1.0 s, a particle goes from point A to point B, moving in a semicircle of radius 1.0 m (see figure). The magnitude of the string is
(a) 3.14 m/s
(b) 2.0 m/s
(c) 1.0 m/s
(d) Zero



16. A fly wheel rotating at 420 rpm slows down at a constant rate of 2 rad s^{-2}. The time required to stop the fly wheel is
(a) 22 s (b) 11 s
(c) 44 s (d) 12 s

17. The wheel of a car is rotating at the rate of 1200 rpm. On pressing the accelerator for 10 s, it starts rotating at 4500 rpm. The angular acceleration of the wheel is
(a) 30 rads^{-2} (b) 1880 degs^{-2}
(c) 40 rads^{-2} (d) 1980 degs^{-2}

18. The angular velocity of a wheel increases from 100 rps to 300 rps in 10 s. The number of revolutions made during that time is
(a) 600 (b) 1500
(c) 1000 (d) 2000

19. The direction of the angular velocity vector is along
(a) the tangent to the circular path
(b) the axis of rotation
(c) either (a) or (b)
(d) None of these

20. If a flywheel makes 120 revolutions/minute, then its angular speed will be
(a) 8 π rad/sec (b) 6 π rad/sec
(c) 4 π rad/sec (d) 2 π rad/s

21. A wheel is rotating at 900 r.p.m. about its axis. When the power is cut-off, it comes to rest in 1 minute. The angular retardation in radian/s^2 is
(a) π/2 (b) π/4
(c) π/6 (d) π/8

22. The linear acceleration of a particle moving in a circle of radius 0.4 m at the instant when its angular acceleration is 5 rad/s^2, is
(a) 2.0 m/s^2 (b) 3.6 m/s^2
(c) 5.6 m/s^2 (d) 6.6 m/s^2

23. A wheel of angular speed 600 rev/min is made to slow down at a rate of 2 rad s^{-2}. The number of revolutions made by the wheel before coming to rest is
(a) 157 (b) 314
(c) 177 (d) 117

24. Around a hollow cylinder of mass 2kg and radius 20 cm a rope is wounded. If a rope is pulled with a force of 25 N, the angular acceleration of the cylinder is
(a) 25 rad/s^2 (b) 32 rad/s^2
(c) 62.5 rad/s^2 (d) 50 rad/s^2

25. A wheel is rotating at 1800 rpm about its own axis. When the power is switched off, it comes to rest in 2 minutes. Then the angular retardation in rad s^{-1} is
(a) 2π (b) π
(c) $\frac{\pi}{2}$ (d) $\frac{\pi}{4}$

26. Which of the following is incorrect?
(a) $\vec{v} = \vec{\omega} \times \vec{r}$ (b) $\vec{a} = \vec{v} \times \vec{r}$
(c) $\alpha = \frac{d\omega}{dt}$ (d) None of these

27. A circular road of radius r in which maximum velocity is v, has angle of banking

(a) $\tan^{-1}\left(\frac{v^2}{rg}\right)$ (b) $\tan^{-1}\left(\frac{rg}{v^2}\right)$

(c) $\tan^{-1}\left(\frac{v}{rg}\right)$ (d) $\tan^{-1}\left(\frac{rg}{v}\right)$

28. A person with his hand in his pocket is skating on ice at the rate of 10m/s and describes a circle of radius 50 m. What is his inclination to vertical : ($g = 10\ m/sec^2$)

(a) $\tan^{-1}(½)$ (b) $\tan^{-1}(1/5)$

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

29. A car of mass 1000 kg negotiates a banked curve of radius 90 m on a frictionless road. If the banking angle is 45°, the speed of the car is :

(a) 20 ms^{-1} (b) 30 ms^{-1}

(c) 5 ms^{-1} (d) 10 ms^{-1}

30. An aircraft executes a horizontal loop of radius 9 km at a constant speed of 540 kmh^{-1}. The wings of the aircraft are banked at an angle of (Acceleration due to gravity = 10 ms^{-2})

(a) $\text{cosec}^{-1}(4)$ (b) $\cot^{-1}(4)$

(c) $\tan^{-1}(4)$ (d) $\sec^{-1}(4)$

31. A car moves at a speed of 20 ms^{-1} on a banked track and describes an arc of a circle of radius $40\sqrt{3}$ m. The angle of banking is ($g = 10\ ms^{-2}$)

(a) 25° (b) 60°

(c) 45° (d) 30°

32. For safe turning, roads are banked with an angle θ. If m = mass of vehicle, r = radius of turing, v = velocity of vehicle then, tanθ is

(a) $\propto m$ (b) $\propto v^2$

(c) $\propto r$ (d) $\propto m^2$

33. The minimum velocity (in ms^{-1}) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is

(a) 60 (b) 30

(c) 15 (d) 25

34. A car turns a corner on a slippery road at a constant speed of 12 m/s. If the coefficient of friction is 0.4, the minimum radius of the arc in metres in which the car turns is

(a) 72 (b) 36

(c) 18 (d) 9

35. An unbanked curve has a radius of 60 m. The maximum speed at which a car can make a turn if the coefficient of static friction is 0.75, is

(a) 2.1 m/s (b) 14 m/s

(c) 21 m/s (d) 7 m/s

36. A motor car is moving with a speed of 20ms^{-1} on a circular track of radius 100 m. If its speed is increasing at the rate of 3 ms^{-1}, its resultant acceleration is

(a) 3 ms^{-2} (b) 5 ms^{-2} (c) 2.5 ms^{-2} (d) 3.5 ms^{-2}

37. A car takes a circular turn with a uniform speed u. If the reaction at inner and outer wheels be denoted by R_1 and R_2, then

(a) $R_1 = R_2$ (b) $R_1 < R_2$

(c) $R_1 > R_2$ (d) None of these

38. Centripetal force :

(a) can change speed of the body.

(b) is always perpendicular to direction of motion

(c) is constant for uniform circular motion.

(d) all of these

39. Centripetal acceleration is

(a) a constant vector

(b) a constant scalar

(c) a magnitude changing vector

(d) not a constant vector

40. A body is tied with a string and is given a circular motion with velocity *v* in radius *r*. The magnitude of the acceleration is

(a) $\frac{v}{r}$ (b) $\frac{v^2}{r}$

(c) $\frac{v}{r^2}$ (d) $\frac{v^2}{r^2}$

41. Two particles of equal masses are revolving in circular paths of radii r_1 and r_2 respectively with the same speed. The ratio of their centripetal forces is

(a) $\frac{r_2}{r_1}$ (b) $\sqrt{\frac{r_2}{r_1}}$

(c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\left(\frac{r_2}{r_1}\right)^2$

42. A particle is moving in a circle of radius R with constant speed *v*, if radius is double then its centripetal force to keep the same speed should be

(a) Doubled (b) Halved

(c) Quadrupled (d) Unchanged

43. Two bodies of mass 10 kg and 5 kg moving in concentric orbits of radii *R* and *r* such that their periods are the same. Then the ratio between their centripetal acceleration

(a) R/r (b) r/R

(c) R^2/r^2 (d) r^2/R^2

44. Two cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2 respectively. Their speeds are such that they make complete circles in the same time *t*. The ratio of their centripetal acceleration is

(a) $r_1r_2 : m_1m_2$ (b) $m_1 : m_2$

(c) $r_1 : r_2$ (d) 1 : 1

45. A can filled with water is revolved in a vertical circle of radius 4 m and the water just does not fall down. The time period of revolution will be

(a) 1 sec (b) 10 sec

(c) 8 sec (d) 4 sec

46. A 2 kg stone at the end of a string 1 m long is whirled in a vertical circle at a constant speed. The speed of the stone is 4 m/s. The tension in the string will be 52 N, when the stone is

(a) at the top of the circle

(b) at the bottom of the circle

(c) halfway down

(d) none of the above

47. A body is moving in a circular path with acceleration *a*. If its velocity gets doubled, find the ratio of acceleration after and before the charge.

(a) 1 : 4 (b) $\frac{1}{4}:2$

(c) 2 : 1 (d) 4 : 1

48. A car is moving with speed 30 m/sec on a circular path of radius 500 m. Its speed is increasing at the rate of 2 m/s^2. What is the acceleration of the car.

(a) 2 m/sec^2 (b) 2.7 m/sec^2

(c) 1.8 m/sec^2 (d) 9.8 m/sec^2

49. When a car is moving along a circle on a level road, the centripetal force is provided by f, where f denotes as

(a) $f < \mu_s N = \frac{mv^2}{r}$ (b) $\frac{mv^2}{r} = f \le \mu_s N$

(c) $f = \mu_s N = \frac{mv^2}{r}$ (d) $f = \mu_s N = \frac{mv^2}{r}$

50. A particle is moving on a circular path of 10 m radius. At any instant of time, its speed is 5 ms^{-1} and the speed is increasing at a rate of 2 ms^{-2}. The magnitude of net acceleration at this instant is

(a) 5 ms^{-2} (b) 2 ms^{-2}

(c) 3.2 ms^{-2} (d) 4.3 ms^{-2}

51. If the radius of curvature of the path of two particles of same mass are in the ratio 3 : 4, then in order to have constant centripetal force, their velocities will be in the ratio of :

(a) $1:\sqrt{3}$ (b) $\sqrt{3}:1$

(c) $\sqrt{3}:2$ (d) $2:\sqrt{3}$

52. A child of mass 5 kg is going round a merry-go-round that makes 1 rotation in 3.14 s. The radius of the merry-go-round is 2 m. The centrifugal force on the child will be

(a) 80 N (b) 50 N

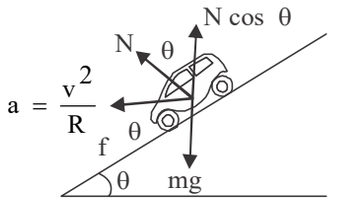
(c) 100 N (d) 40 N

53. A vehicle of mass 200 kg is moving along a levelled curved road of radius 70 m with angular velocity of 0.2 rad/s. The centripetal force acting on the vehicle is :

(a) 560 N (b) 2800 N

(c) 14 N (d) 2240 N

54. The motion of a car on a banked road is shown in the figure. The centripetal force equation will be given by



(a) $N\sin\theta + f\cos\theta = \frac{mv^2}{R}$

(b) $f = \frac{mv^2}{R}$

(c) $N\cos\theta + f = \frac{mv^2}{R}$

(d) $N\sin\theta + f = \frac{mv^2}{R}$

55. An aircraft executes a horizontal loop of radius 1.00 km with a stedy speed of 900 km/h. The ratio of centripetal acceleration to acceleration due to gravity is [g = 9.8 m/s^2]

(a) 6.38 (b) 9.98 (c) 11.33 (d) 12.13

56. An electric fan has blades of length 30 cm measured from the axis of rotation. If the fan is rotating at 120 rpm, the acceleration of a point on the tip of the blade is

(a) 1600 ms^{-2} (b) 47.4 ms^{-2}

(c) 23.7 ms^{-2} (d) 50.55 ms^{-2}

57. A car moves on a circular road. It describes equal angles about the centre in equal intervals of time. Which of the following statement about the velocity of the car is true

(a) Magnitude of velocity is not constant

(b) Both magnitude and direction of velocity change

(c) Velocity is directed towards the centre of the circle

(d) Magnitude of velocity is constant but direction changes

58. A wheel starting from rest gains an angular velocity of 10 rad s^{-1} after uniformly accelerated for 5 sec. The total angle through which it has turned is

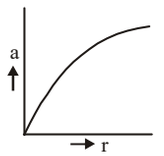
(a) 25π rad

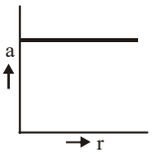
(b) 50π rad about a vertical axis

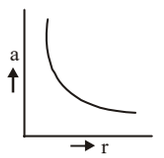
(c) 25 rad

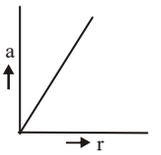
(d) 100 rad

59. If a body moving in circular path maintains constant speed of 10 ms^{-1}, then which of the following correctly describes relation between magnitude of acceleration and radius ?

(a) 

(b) 

(c) 

(d) 

60. The acceleration of an object moving with speed v in circle of radius r is

(a) $\frac{v^2}{r}$ towards the centre

(b) $\frac{v}{r}$ away from the centre

(c) $\frac{v}{r^2}$ away from the centre

(d) $\frac{r}{v^2}$ towards from the centre

61. The centripetal acceleration of a particle in uniform circular motion is 18 ms^{-2}. If the radius of the circular path is 50 cm, the change in velocity of the particle in a time of $\frac{\pi}{18}$ s is

(a) 9 ms^{-1} (b) 2 ms^{-1}

(c) 3 ms^{-1} (d) 6 ms^{-1}

62. A car is travelling at 30 ms^{-1} speed on a circular road of radius 300 m. If its speed is increasing at the rate of 4 ms^{-2}, then its acceleration is

(a) 2.7 ms^{-2} (b) 3 ms^{-2}

(c) 4 ms^{-2} (d) 5 ms^{-2}

63. A body is moving with a uniform speed of 20 ms^{-1} on a horizontal circle. The change in velocity of the body in half revolution is

(a) 20 ms^{-1} (b) 10 ms^{-1}

(c) 40 ms^{-1} (d) $\frac{20}{\sqrt{2}} ms^{-1}$

64. If the radii of circular paths of two particles of same mass are in the ratio of 1 : 2, then to have a constant centripetal force, the ratio of their speeds should be

(a) 4 : 1 (b) $1:\sqrt{2}$

(c) 1 : 4 (d) $\sqrt{2}:1$

65. A car is travelling with linear velocity 'V' on a circular road of radius 'r'. If its velocity is increasing at a rate of 'a' ms^{-2}, then the resultant acceleration will be

(a) $\sqrt{\left(\frac{V^2}{r^2}-a^2\right)}$ (b) $\sqrt{\left(\frac{V^4}{r^2}+a^2\right)}$

(c) $\sqrt{\left(\frac{V^4}{r^2}-a^2\right)}$ (d) $\sqrt{\left(\frac{V^2}{r^2}+a^2\right)}$

66. Two cars A and B move along a concentric circular path of radius r_A and r_B with velocities v_A and b_B maintaining constant distance, then $\frac{v_A}{v_B}$ is equal to

(a) $\frac{r_B}{r_A}$ (b) $\frac{r_A}{r_B}$

(c) $\frac{r_A^2}{r_B^2}$ (d) $\frac{r_B^2}{r_A^2}$

67. Two stones are moving with same angular speeds in the radii of circular paths 1 m and 2 m. The ratio of their linear speed is ...X.... Here, X refers to

(a) 2 (b) 1/2

(c) 1/3 (d) 3

68. Two bodies are moving in concentric orbits of radii 2cm and 4 cm such that their time periods are the same. The ratio of their centripetal accelerations is :

(a) $\frac{1}{2}$ (b) $\frac{1}{8}$ (c) $\frac{3}{2}$ (d) $\frac{4}{9}$

69. What is the centripetal acceleration of a point mass which is moving on a circular path of radius 5m with speed 23 ms^{-1}?

(a) 106 ms^{-2} (b) 90 ms^{-2}

(c) 60 ms^{-2} (d) None of these

1.2 Moment of Inertia, Radius of Gyration, Theorem of Perpendicular and Parallel Axes, Angular Momentum, Conservation of Angular Momentum

70. A force $\vec{F}=5\hat{i}+2\hat{j}-5\hat{k}$ acts on a particle whose position vector is $\vec{r}=\hat{i}-2\hat{j}+\hat{k}$. What is the torque about the origin?

(a) $8\hat{i}-10\hat{j}-8\hat{k}$ (b) $8\hat{i}+10\hat{j}+12\hat{k}$

(c) $10\hat{i}-10\hat{j}-\hat{k}$ (d) $8\hat{i}+10\hat{j}-12\hat{k}$

71. Let $\vec{F}$ be the force acting on a particle having position vector $\vec{r}$, and $\vec{\tau}$ be the torque of this force about the origin. Then

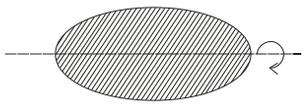
(a) $\vec{r}.\vec{\tau}=0$ and $\vec{F}.\vec{\tau}\neq 0$

(b) $\vec{r}.\vec{\tau}\neq 0$ and $\vec{F}.\vec{\tau}=0$

(c) $\vec{r}.\vec{\tau}\neq 0$ and $\vec{F}.\vec{\tau}\neq 0$

(d) $\vec{r}.\vec{\tau}=0$ and $\vec{F}.\vec{\tau}=0$

72. A disc of mass M and radius R is rotating about one of its diameter. The value of radius of gyration for the disc is



(a) R/4 (b) R/2

(c) R/6 (d) 2R/3

73. The moment of inertia of a solid sphere about its diameter is 20 kg m^2 . The moment of inertia of a thin spherical shell having the same mass and radius about its diameter is

(a) 16.6 kg m^2 (b) 30.3 kg m^2

(c) 33.3 kg m^2 (d) 66.6 kg m^2

74. Three particles of each mass 'm' are kept at the three vertices of an equilateral triangle of side '1'. The moment of inertia of system of the particles about any side of the triangle is

(a) $\frac{ml^2}{4}$ (b) ml^2

(c) $\frac{3}{4}ml^2$ (d) $\frac{2}{3}ml^2$

75. The moment of inertia of a solid sphere of mass 20 kg and diameter 20 cm about the tangent to the sphere is

(a) $0.24\,kgm^2$ (b) $0.14\,kgm^2$

(c) $0.28\,kgm^2$ (d) $0.08\,kgm^2$

76. The moments of inertia of a solid cylinder and a hollow cylinder of same mass and same radius about the axes of the cylinders are I_1 and I_2. The relation between I_1 and I_2 is

(a) $I_1 < I_2$ (b) $I_1 = I_2$

(c) $I_1 > I_2$ (d) $I_1 = I_2 = 0$

77. The correct relation between moment of inertia I, radius of gyration K and mass M of the body is

(a) $K = I^2M$ (b) $K = IM^2$

(c) $K = \sqrt{\frac{M}{I}}$ (d) $K = \sqrt{\frac{I}{M}}$

78. The rate of change of angular momentum of a particle is equal to

(a) force (b) acceleration

(c) torque (d) linear momentum

79. Moment of inertia of a uniform circular disc about a diameter is I. Its moment of inertia about an axis perpendicular to its plane and passing through a point on its rim, will be

(a) 5 I (b) 6 I

(c) 3 I (d) 4 I

80. The moment of inertia of a hollow cylinder of length 30 cm (inner radius 10 cm and outer radius 20 cm) about its axis be I. The radius of a thin cylinder of the same mass such that its moment of inertia about its axis is also I, is

(a) 16 cm (b) 14 cm

(c) 12 cm (d) 18 cm

81. To maintain a rotor at a uniform angular speed of $100\,rads^{-1}$, an engine needs to transmit torque of 100 N-m. The power of the engine is

(a) 10 kW (b) 100 kW

(c) 10 MW (d) 100 MW

82. A flywheel of moment of inertia 10 kg m^2 is rotating with angular velocity 50 rad/s. It is brought to rest in 10 s. The required average power is

(a) 1250 W (b) 625 W

(c) 2500 W (d) 500 W

83. An ice skater spins at $3\pi\,rads^{-1}$ with her arms extended. If her moment of inertia with arms folded is 75% of that with arms extended, her angular velocity when she folds her arms is

(a) $\pi\,rad\,s^{-1}$ (b) $2\pi\,rad\,s^{-1}$

(c) $3\pi\,rad\,s^{-1}$ (d) $4\pi\,rad\,s^{-1}$

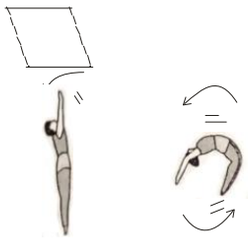
84. When acrobat bends his body (assume no external torque)

(a) $I_{acrobat}$ decreases

(b) $I_{acrobat}$ increases

(c) $\omega_{acrobat}$ decrease

(d) $\omega_{acrobat}$ remains constant



85. A uniform thin bar of mass 6 m and length 12L is bent to make a regular hexagon. Its moment of inertia about an axis passing through the centre of mass and perpendicular to the plane of the hexagon is:

(a) $20\,mL^2$ (b) $6\,mL^2$

(c) $\frac{12}{5}mL^2$ (d) $30\,mL^2$

86. A thin uniform wire of mass 'm' and linear mass density 'ρ' is bent in the form of a circular loop. The moment of inertia of the loop about its diameter is

(a) $\frac{m^2}{4\pi^2\rho^2}$ (b) $\frac{m^3}{4\rho^2}$ (c) $\frac{m^3}{8\pi^2\rho^2}$ (d) $\frac{m^3}{8\rho^2}$

87. The ratio of the radii of gyration of a circular disc about a tangential axis in the plane of the disc and of a circular ring of the same radius about a tangential axis in the plane of the ring is

(a) 1 : √2 (b) 1 : 3

(c) 2 : 1 (d) √5 : √6

88. Four point masses, each of value m, are placed at the corners of a square ABCD of side ℓ. The moment of inertia of this system about an axis passing through A and parallel to BD is

(a) $2m\ell^2$ (b) $\sqrt{3}m\ell^2$

(c) $3m\ell^2$ (d) $m\ell^2$

89. Consider a uniform square plate of side 'a' and mass 'm'. The moment of inertia of this plate about an axis perpendicular to its plane and passing through one of its corners is

(a) $\frac{5}{6}ma^2$ (b) $\frac{1}{12}ma^2$

(c) $\frac{7}{12}ma^2$ (d) $\frac{2}{3}ma^2$

90. Point masses 1, 2, 3 and 4 kg are lying at the points (0, 0, 0), (2, 0, 0), (0, 3, 0) and (–2, –2, 0) respectively. The moment of inertia of this system about X-axis will be

(a) 43 kg m^2 (b) 34 kg m^2

(c) 27 kg m^2 (d) 72 kg m^2

91. Two bodies have their moments of inertia I and 2I respectively about their axis of rotation. If their kinetic energies of rotation are equal, their angular momenta will be in the ratio

(a) $2:1$ (b) $1:2$ (c) $\sqrt{2}:1$ (d) $1:\sqrt{2}$

92. The moment of inertia of a uniform circular disc of radius 'R' and mass 'M' about an axis passing from the edge of the disc and normal to the disc is

(a) MR^2 (b) $\frac{1}{2}MR^2$ (c) $\frac{3}{2}MR^2$ (d) $\frac{7}{2}MR^2$

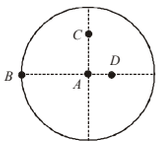
93. Moment of inertia of a hollow cylinder of mass M and radius r about its own axis is

(a) $\frac{2}{3}Mr^2$ (b) $\frac{2}{5}Mr^2$ (c) $\frac{1}{3}Mr^2$ (d) Mr^2

94. The radius of gyration of a uniform rod of length ℓ, about an axis passing through a point $\ell/2$ away from the centre of the rods and perpendicular to it is

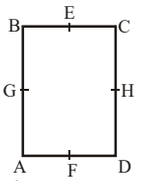
(a) $\frac{\ell}{\sqrt{3}}$ (b) $\frac{\ell}{4}$ (c) $\frac{\ell}{2}$ (d) ℓ

95. The moment of inertia of a uniform circular disc (figure) is maximum about an axis perpendicular to the disc and passing through



(a) *B*
(b) *C*
(c) *D*
(d) *A*

96. The moment of inertia of the rectangular plate ABCD, (AB = 2 BC) is minimum along the axis



(a) GH
(b) EF
(c) BC
(d) AC

97. One solid sphere *A* and another hollow sphere *B* are of same mass and same outer radii, Their moments of inertia about their diameters are respectively I_A and I_B, such that

(a) $I_A = I_B$ (b) $I_A > I_B$
(c) $I_A < I_B$ (d) $I_A / I_B = \rho_A = \rho_B$

Here ρ_A and ρ_B represent their densities.

98. During summersault, a swimmer bends his body to

(a) increase moment of inertia
(b) decrease moment of inertia
(c) decrease the angular momentum
(d) reduce the angular velocity

99. The moment of inertia of a uniform circular disc of mass M and of radius R about one of its diameters is

(a) $\frac{1}{4}MR^2$ (b) $\frac{1}{2}MR^2$
(c) $\frac{2}{3}MR^2$ (d) $\frac{2}{5}MR^2$

100. A wheel of mass 10 kg has a moment of inertia of 160 kg-m^2 about its own axis, the radius of gyration will be

(a) 10 m (b) 8 m (c) 6 m (d) 4 m

101. The ratio of the radii of gyration of a circular disc to that of a circular ring, each of same mass and radius, around their respective axes is

(a) $\sqrt{2}:1$ (b) $\sqrt{2}:\sqrt{3}$
(c) $\sqrt{3}:\sqrt{2}$ (d) $1:\sqrt{2}$

102. If the angular velocity of a body rotating about an axis is doubled and its moment of inertia halved, the rotational kinetic energy will change by a factor of :

(a) 4 (b) 2 (c) 1 (d) $\frac{1}{2}$

103. The rotational kinetic energy of a body is E and its moment of inertia is *I*. The angular momentum is

(a) EI (b) $2\sqrt{EI}$ (c) $\sqrt{2EI}$ (d) E/I

104. A ring of mass m and radius r rotates about an axis passing through its centre and perpendicular to its plane with angular velocity ω. Its kinetic energy is

(a) $\frac{1}{2}mr^2\omega^2$ (b) $mr\omega^2$
(c) $mr^2\omega^2$ (d) $\frac{1}{2}mr\omega^2$

105. A body of moment of inertia 3 kg-m^2 rotating with an angular velocity of 2 rad/sec has the same kinetic energy as that of a body of mass 12 kg moving with a velocity of

(a) 8 m/s (b) 0.5 m/s (c) 2 m/s (d) 1 m/s

106. What is moment of inertia in terms of angular moment (L) and kinetic energy (K) ?

(a) $\frac{L^2}{K}$ (b) $\frac{L^2}{2K}$ (c) $\frac{L}{2K^2}$ (d) $\frac{L}{2K}$

107. When a sphere of moment of inertia *I* about its centre of gravity and mass '*m*' rolls from rest down an inclined plane without slipping, its kinetic energy is

(a) $\frac{1}{2}I\omega^2$ (b) $\frac{1}{2}m\upsilon^2$
(c) $I\omega + m\upsilon$ (d) $\frac{1}{2}I\omega^2 + \frac{1}{2}m\upsilon^2$

108. A body is rolling without slipping on a horizontal surface and its rotational kinetic energy is equal to the translational kinetic energy. The body is

(a) Disc (b) Sphere (c) Cylinder (d) Ring

109. A flywheel rotating about a fixed axis has a kinetic energy of 360 joule when its angular speed is 30 rad/sec. The moment of inertia of the wheel about the axis of rotation is

(a) $0.6\ kg \times m^2$ (b) $0.15\ kg \times m^2$
(c) $0.8\ kg \times m^2$ (d) $0.75\ kg \times m^2$

110. The moments of inertia of two freely rotating bodies *A* and *B* are I_A and I_B respectively. $I_A > I_B$ and their angular moments are equal. If K_A and K_B are their kinetic energies, then

(a) $K_A = K_B$ (b) $K_A > K_B$
(c) $K_A < K_B$ (d) $K_A = 2K_B$

1.3 Rolling Motion

111. A spherical ball rolls on a table without slipping. Then the fraction of its total energy associated with rotation is

(a) 2/5 (b) 2/7 (c) 3/5 (d) 3/7

112. A thin uniform circular ring is rolling down an inclined plane of inclination 30° without slipping. Its linear acceleration along the inclination plane will be

(a) $\frac{g}{2}$ (b) $\frac{g}{3}$

(c) $\frac{g}{4}$ (d) $\frac{2g}{3}$

113. The speed of a homogenous solid sphere after rolling down an inclined plane of vertical height h from rest without sliding is

(a) $\sqrt{\frac{10}{7}gh}$ (b) $\sqrt{gh}$

(c) $\sqrt{\frac{6}{5}gh}$ (d) $\sqrt{\frac{4}{3}gh}$

114. A solid cylinder of mass m and radius R rolls down an inclined plane of height h without slipping. The speed of its centre of mass when it reaches the bottom is

(a) $\sqrt{(2gh)}$ (b) $\sqrt{4gh/3}$

(c) $\sqrt{3gh/4}$ (d) $\sqrt{4g/h}$

115. A uniform solid disk rolling down an incline making angle θ with the horizontal. The minimum coefficient of friction required to maintain pure rolling motion for the disk is

(a) $\left(\frac{2}{3}\tan\theta\right)$ (b) $\left(\frac{1}{3}\tan\theta\right)$

(c) $\left(\frac{2}{5}\tan\theta\right)$ (d) $\left(\frac{1}{2}\tan\theta\right)$

116. A rolling object rolls without slipping down an inclined plane (angle of inclination θ), then the minimum acceleration it can have is

(a) g sin θ (b) $\frac{2g\sin\theta}{3}$

(c) $\frac{g\sin\theta}{2}$ (d) zero

117. The moments of inertia of two rotating bodies A and B are I_A and I_B ($I_A > I_B$). If their angular momenta are equal then

(a) Kinetic energy of A = Kinetic energy of B
(b) Kinetic energy of A > Kinetic energy of B
(c) Kinetic energy of A < Kinetic energy of B
(d) Kinetic energy of the two bodies cannot be compared with the given data

118. A body is rolling down an inclined plane. If kinetic energy of rotation is 40% of kinetic energy in translatory state, then the body is a

(a) ring (b) cylinder
(c) hollow ball (d) solid ball

119. A hollow sphere is rolling on a plane surface about its axis of symmetry. The ratio of rotational kinetic energy to its total kinetic energy is $\frac{x}{5}$. The value of x is

(a) 2 (b) 4 (c) 6 (d) 8

120. A solid circular disc of mass 50 kg rolls along a horizontal floor so that its center of mass has a speed of 0.4 m/s. The absolute value of work done on the disc to stop it is

(a) 2 J (b) 4 J (c) 6 J (d) 8 J

121. A cylinder is rolling down on an inclined plane of inclination 60°. It's acceleration during rolling down will be $\frac{x}{\sqrt{3}}$ m/s^2, where x = (use g = 10 m/s^2).

(a) 5 (b) 10
(c) 15 (d) 20

122. A ring and a disc of same mass and same diameter are rolling without slipping. Their linear velocities are same, then the ratio of their kinetic energy is

(a) 0.75 (b) 1.33
(c) 0.5 (d) 2.66

123. A solid cylinder rolls down on an inclined plane of height '*h*' and inclination 'θ'. The speed of the cylinder at the bottom is

124. A solid cylinder rolls down an inclined plane without slipping. If the translational kinetic energy of the cylinder is 140 J, the total kinetic energy of the cylinder is

(a) 105 J (b) 70 J (c) 210 J (d) 280 J

125. In a bicycle, the radius of rear wheel is twice the radius of front wheel. It r_f and r_r are the radii and v_f and v_r are the speeds of topmost points of wheels then

(a) $v_r = 2v_f$ (b) $v_f = 2v_r$
(c) $v_f = v_r$ (d) $v_f = 4v_r$

126. A sphere rolls down on an inclined plane of inclination θ. What is the acceleration as the sphere reaches the bottom?

(a) $\frac{5}{7}g\sin\theta$ (b) $\frac{3}{5}g\sin\theta$

(c) $\frac{2}{7}g\sin\theta$ (d) $\frac{2}{5}g\sin\theta$

127. A solid sphere, a hollow sphere and a ring are released from top of an inclined plane (frictionless) so that theyslide down the plane. Then maximum acceleration down the plane is for (no rolling)

(a) Solid sphere (b) Hollow sphere
(c) Ring (d) All same

128. A ring solid sphere and a disc are rolling down from the top of the same height, then the sequence to reach on surface is

(a) Ring, disc, sphere (b) Sphere, disc, ring
(c) Disc, ring, sphere (d) Sphere, ring, disc

Exercise 2 : ACCELERATOR
Topic-wise MCQs

1.1 Kinematics of Circular Motion, Dynamics of Circular Motion, Applications of Uniform Circular Motion, Motion in a Vertical Circle

1. The earth moves round the sun in a near circular orbit of radius 1.5×10^{11} m. Its centripetal acceleration is
(a) 1.5×10^{-3} m/s^2 (b) 3×10^{-3} m/s^2
(c) 6×10^{-3} m/s^2 (d) 12×10^{-3} m/s^2

2. A body moving along a circular path of radius R with velocity v, has centripetal acceleration a. If its velocity is made equal to $2v$, then its centripetal acceleration is
(a) $4a$ (b) $2a$
(c) $\frac{a}{4}$ (d) $\frac{a}{2}$

3. A bucket full of water is revolved in vertical circle of radius 2m. What should be the maximum time-period of revolution so that the water doesn't fall off the bucket
(a) 1 sec (b) 2 sec (c) 3 sec (d) 4 sec

4. A bridge is in the form of a semi-circle of radius 40 m. The greatest speed with which a motor cycle can cross the bridge without leaving the ground at the highest point is (g = 10 ms^{-2})
(Frictional force is negligibly small)
(a) 40 ms^{-1} (b) 20 ms^{-1} (c) 30 ms^{-1} (d) 15 ms^{-1}

5. Roads are banked on curves so that
(a) The speeding vehicles may not fall outwards
(b) The frictional force between the road and vehicle may be decreased
(c) The wear and tear of tyres may be avoided
(d) The weight of the vehicle may be decreased

6. For a body moving in a circular path, a condition for no skidding if μ is the coefficient of friction, is
(a) $\frac{mv^2}{r} \le \mu mg$ (b) $\frac{mv^2}{r} \ge \mu mg$
(c) $\frac{v}{r} = \mu g$ (d) $\frac{mv^2}{r} = \mu mg$

7. A particle moves with constant angular velocity in circular path of certain radius and is acted upon by a certain centripetal force F. If the angular velocity is doubled keeping the radius same, the new force will be
(a) 2 F (b) F^2
(c) 4 F (d) F/2

8. If the angular velocity is kept same but the radius of the path is halved, the new force will be
(a) 2 F (b) F^2
(c) F/2 (d) F/4

9. When a car moves on a level road, then the centripetal force required for circular motion is provided by
(a) weight of the car
(b) normal reaction
(c) friction between the road & tyres along the surface.
(d) All of these

10. A wheel initially at rest, is rotated with a uniform angular acceleration. The wheel rotates through an angle θ_1 in first one second and through an additional angle θ_2 in the next one second. The ratio θ_2/θ_1 is
(a) 4 (b) 2
(c) 3 (d) 1

11. A block (P) is rotating in contact with the vertical wall of a rotor as shown in figures A, B, C. The relation between angular velocities ω_A, ω_B and ω_C so that block does not slide down. ($R_A < R_B < R_C$ radii)

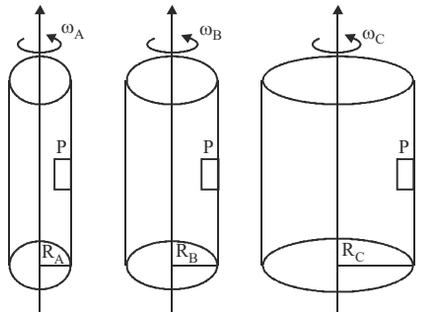
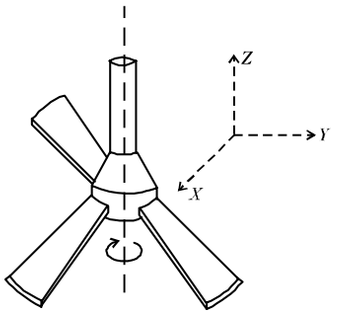


Fig A Fig B Fig C

(a) $\omega_A < \omega_B < \omega_C$ (b) $\omega_A = \omega_B = \omega_C$
(c) $\omega_C < \omega_B < \omega_A$ (d) $\omega_C = \omega_A + \omega_B$

12. A ceiling fan is rotating around a fixed axle as shown. The direction of angular velocity is along



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

13. A particle rests on the top of a hemisphere of radius R. Find the smallest horizontal velocity that must be imparted to the particle if it is to leave the hemisphere without sliding down is

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

(c) $\sqrt{3gR}$ (d) $\sqrt{5gR}$

14. A car is moving along a circular path of radius 500 m with a speed of 30 m/s. If at some instant, its speed increases at the rate of 2 m/s per second, then at that instant the magnitude of resultant acceleration will be

(a) 4.7 m/s^2 (b) 3.8 m/s^2

(c) 3 m/s^2 (d) 2.7 m/s^2

15. A particle moves along a circle of radius $\left(\frac{20}{\pi}\right)$m with constant tangential acceleration. If the velocity of the particle is 80 m/s at the end of the second revolution after motion has begun, the tangential acceleration is

(a) 40 π m/s^2 (b) 40 m/s^2

(c) 640 π m/s^2 (d) 160 π m/s^2

16. A stone tied to a string is rotated with a uniform speed in a vertical plane . If mass of the stone is m, the length of the string is r and the linear speed of the stone is v, when the stone is at its lowest point, then the tension in the string will be (g = acceleration due to gravity) :

(a) $\frac{mv^2}{r}+mg$ (b) $\frac{mv^2}{r}-mg$

(c) $\frac{mv}{r}$ (d) mg

17. A particle describes a horizontal circle in a conical funnel whose inner surface is smooth with speed of 0.5 m/s. What is the height of the plane of circle from vertex of the funnel?

(a) 0.25 cm (b) 2 cm

(c) 4 cm (d) 2.5 cm

18. A bucket tied at the end of a 1.6 m long string is whirled in a vertical circle with constant speed. What should be the minimum speed so that the water from the bucket does not spill when the bucket is at the highest position?

(a) 4 m/sec (b) 6.25 m/sec

(c) 16 m/sec (d) None of these

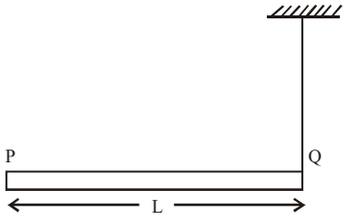
19. Radius of the curved road on national highway is *R*. Width of the road is *b*. The outer edge of the road is raised by *h* with respect to inner edge so that a car with velocity v can pass safe over it. The value of *h* is

(a) $\frac{v^2b}{Rg}$ (b) $\frac{v}{Rgb}$

(c) $\frac{v^2R}{g}$ (d) $\frac{v^2b}{R}$

1.2 Moment of Inertia, Radius of Gyration, Theorem of Perpendicular and Parallel Axes, Angular Momentum, Conservation of Angular Momentum

20. A rod PQ of mass M and length L is hinged at end P. The rod is kept horizontal by a massless string tied to point Q as shown in figure. When string is cut, the initial angular acceleration of the rod is



(a) g /L (b) 2g/L (c) $\frac{2g}{3L}$ (d) $\frac{3g}{2L}$

21. Torque of a force $F = 2\hat{i}+3\hat{j}$ N acting at a point (1m, 0, 3m) about an axis in XY-plane whose equation is y = 3x is

(a) $\frac{9}{\sqrt{10}}$Nm (b) $\frac{19}{\sqrt{10}}$Nm

(c) 6 Nm (d) 0

22. For a particle of a mass 100 gm, position and velocity at any instant are given as $10\hat{i}+6\hat{j}$ cm and $\vec{v}=5\hat{i}$ cm/s. Calculate the angular momentum about the point (1, 1) cm.

(a) $25\times10^{-5}\left(-\hat{k}\right)$kgm^{2}s^{-1}

(b) $30\times10^{-5}\left(-\hat{k}\right)$kgm^{2}s^{-1}

(c) $3\times10^{-3}\left(-\hat{k}\right)$kgm^{2}s^{-1}

(d) $25\times10^{-4}\left(-\hat{k}\right)$kgm^{2}s^{-1}

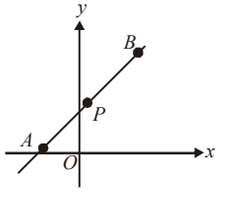
23. A particle is moving uniformly along a straight line as shown in the figure. During the motion of the particle from *A* to *B*, the angular momentum of the particle about '*O*'

(a) remains constant

(b) increases

(c) first increases then decreases

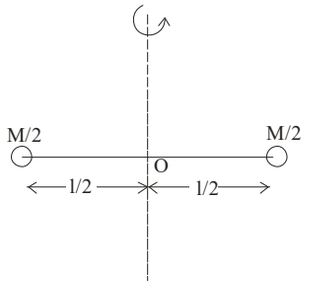
(d) decreases.



24. A circular disc of radius R and thickness $\frac{R}{6}$ has moment of inertia I about an axis passing through its centre perpendicular to its plane. It is melted and recasted into a solid sphere. The moment of inertia of the sphere about its diameter is

(a) *I* (b) $\frac{2I}{8}$ (c) $\frac{I}{5}$ (d) $\frac{I}{10}$

25. Two masses are joined with a light rod and the system is rotating about the fixed axis as shown in the figure. The moment of inertia of the system about the axis is



(a) $Ml^2/2$ (b) $Ml^2/4$ (c) Ml^2 (d) $Ml^2/6$

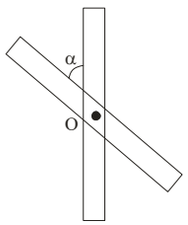
26. Two identical rods of mass M and length l are lying in a horizontal plane at an angle α. The moment of inertia of the system of two rods about an axis passing through O and perpendicular to the plane of the rods is

(a) $Ml^2/3$

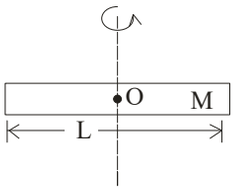
(b) $Ml^2/12$

(c) $Ml^2/4$

(d) $Ml^2/6$



27. A rod is rotating about an axis passing through its centre and perpendicular to its length. The radius of gyration for the rod is



(a) $\frac{L}{12}$ (b) $\frac{L}{\sqrt{12}}$

(c) $\frac{L}{6}$ (d) $\frac{L}{\sqrt{6}}$

28. A dancer spins about himself with an angular speed ω. With his arms extended. When he draws his hands in, his moment of inertia reduces by 40%, then his new angular velcoity would be

(a) $\frac{3\omega}{5}$ (b) $\frac{4\omega}{5}$

(c) $\frac{5\omega}{4}$ (d) $\frac{5\omega}{3}$

29. Consider two uniform discs of the same thickness and different radii $R_1 = R$ and $R_2 = \alpha R$ made of the same material. If the ratio of their moments of inertia I_1 and I_2, respectively, about their axes is $I_1 : I_2 = 1 : 16$ then the value of α is :

(a) $2\sqrt{2}$ (b) $\sqrt{2}$ (c) 2 (d) 4

30. From a solid sphere of mass M and radius R a cube of maximum possible volume is cut. Moment of inertia of cube about an axis passing through its center and perpendicular to one of its faces is

(a) $\frac{4MR^2}{9\sqrt{3}\pi}$ (b) $\frac{4MR^2}{3\sqrt{3}\pi}$

(c) $\frac{MR^2}{8\sqrt{2}\pi}$ (d) $\frac{MR^2}{36\sqrt{2}\pi}$

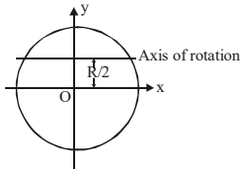
31. M.I of a circular loop of radius R about the axis in figure is

(a) MR^2

(b) $(3/4)\ MR^2$

(c) $MR^2/2$

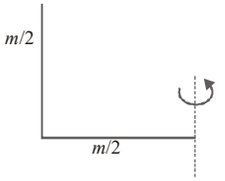
(d) $2MR^2$



32. A rod of mass *m* and length *l* is bent in to shape of *L*. Its moment of inertia about the axis shown in figure

(a) $\frac{ml^2}{6}$ (b) $\frac{ml^2}{3}$

(c) $\frac{ml^2}{2}$ (d) None



33. The moment of inertia of a hollow thick spherical shell of mass M and its inner radius R_1 and outer radius R_2 about its diameter is

(a) $\frac{2M}{5}\frac{(R_2^5 - R_1^5)}{(R_2^3 - R_1^3)}$ (b) $\frac{2M}{3}\frac{(R_2^5 - R_1^5)}{(R_2^3 - R_1^3)}$

(c) $\frac{4M}{5}\frac{(R_2^5 - R_1^5)}{(R_2^3 - R_1^3)}$ (d) $\frac{4M}{3}\frac{(R_2^5 - R_1^5)}{(R_2^3 - R_1^3)}$

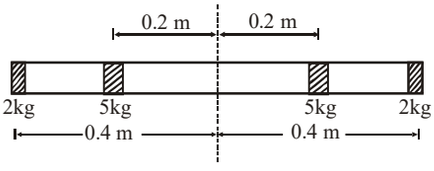
34. Four masses are fixed on a massless rod as shown in the adjoining figure. The moment of inertia about the dotted axis is about

(a) 2 kg m^2

(b) 1 kg m^2

(c) 0.5 kg m^2

(d) 0.3 kg m^2



35. A ring and a solid sphere rotating about an axis passing through their centers have same radii of gyration. The axis of rotation is perpendicular to plane of ring. The ratio of radius of ring to that of sphere is $\sqrt{\frac{2}{x}}$. The value of x is

(a) 5 (b) 10

(c) 15 (d) 20

36. On light wooden metre scale 3 kg and 5 kg weights are placed on 20 cm and 70 cm sign respectively. What will be the moment of inertia of this system about the axis passing from the 0 cm sign and perpendicular to axis ?

(a) 4.37 kg m^2 (b) 1.37 kg m^2

(c) 2.31 kg m^2 (d) 2.57 kg m^2

37. Three rings each of mass M and radius R are arranged as shown in the figure. The moment of inertia of the system about YY′ will be

(a) $3MR^2$ (b) $\frac{3}{2}MR^2$

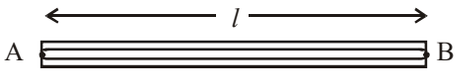
(c) $5MR^2$ (d) $\frac{7}{2}MR^2$

38. The instantaneous angular position of a point on a rotating wheel is given by the equation$\theta(t) = 2t^3 - 6t^2$. The torque on the wheel becomes zero at

(a) t = 1s (b) t = 0.5 s

(c) t = 0.25 s (d) t = 2s

39. A uniform rod of length l and mass m is free to rotate in a vertical plane about A. The rod initially in horizontal position is released. The initial angular acceleration of the rod is (Moment of inertia of rod about A is $\frac{ml^2}{3}$)



(a) $\frac{2l}{3g}$ (b) $\frac{3g}{2l^2}$

(c) $mg\frac{l}{2}$ (d) $\frac{3g}{2l}$

40. A body of certain mass travels with constant velocity parallel to x-axis. Its angular momentum with respect to origin of the axis

(a) is zero (b) remains constant

(c) goes on decreasing (d) goes on increasing

41. Two bodies with moment of inertia's I_1 and I_2 ($I_1 > I_2$) have equal angular momenta. If K.E. of rotation are E_1 and E_2, then

(a) $E_1 = E_2$ (b) $E_1 > E_2$

(c) $E_1 < E_2$ (d) $E_1 \geq E_2$

42. The moment of inertia of a uniform semicircular disc of mass M and radius r about a line perpendicular to the plane of the disc through the centre is

(a) $\frac{2}{5}Mr^2$ (b) $\frac{1}{4}Mr$

(c) $\frac{1}{2}Mr^2$ (d) Mr^2

43. Consider a uniform square plate of slide 'a' and mass 'm'. The moment of inertia of the plate about an axis perpendicular to its plane and passing through one of its corners is

(a) $\frac{1}{12}ma^2$ (b) $\frac{7}{12}ma^2$

(c) $\frac{2}{3}ma^2$ (d) $\frac{5}{6}ma^2$

44. The moment of inertia of a uniform thin rod of length L and mass M about an axis passing through a point at a distance of $\frac{L}{3}$ from one of its ends and perpendicular to the rod is

(a) $\frac{7ML^2}{48}$ (b) $\frac{ML^2}{9}$

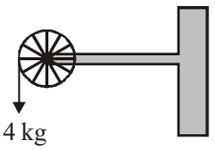
(c) $\frac{ML^2}{12}$ (d) $\frac{ML^2}{3}$

45. A force of $-F\hat{k}$ acts on O, the origin of the coordination system. The torque about the point (1, –1) is

(a) $-F(\hat{i}+\hat{j})$ (b) $F(\hat{i}+\hat{j})$

(c) $-F(\hat{i}-\hat{j})$ (d) $F(\hat{i}-\hat{j})$

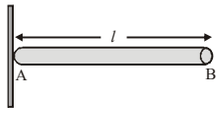
46. A wheel of radius 0.4 m can rotate freely about its axis as shown in the figure. A string is wrapped over its rim and a mass of 4 kg is hung. An angular acceleration of 8 rad-s^2 is produced in it due to the torque. Then, moment of inertia of the wheel is (g = 10 ms^{-2})



(a) 2 kg – m^2 (b) 1 kg – m^2

(c) 4 kg – m^2 (d) 8 kg – m^2

47. A uniform rod AB of length l and mass m is free to rotate about point A. The rod is released from rest in horizontal position. Given that the moment of inertia of the rod about A is $\frac{ml^2}{3}$ the initial angular acceleration of the rod will be



(a) $\frac{2g}{3l}$ (b) $mg\frac{1}{2}$

(c) $\frac{3}{2}gl$ (d) $\frac{3g}{2l}$

48. The angular momentum of a particle describing uniform circular motion is L. If its kinetic energy is halved and angular velocity doubled, its new angular momentum is

(a) 4 L (b) $\frac{L}{4}$

(c) $\frac{L}{2}$ (d) 2 L

49. A billiard ball of mass m and radius r, when hit in a horizontal direction by a cue at a height h above its centre, acquired a linear velocity v_0. The angular velocity ω_0 acquired by the ball is

(a) $\frac{5v_0r^2}{2h}$ (b) $\frac{2v_0r^2}{5h}$

(c) $\frac{2v_0h}{5r^2}$ (d) $\frac{5v_0h}{2r^2}$

50. A body of mass 1.5 kg rotating about an axis with angular velocity of 0.3 rad s^{-1} has the angular momentum of 1.8 kg m^2s^{-1}. The radius of gyration of the body about an axis is

(a) 2 m (b) 1.2 m

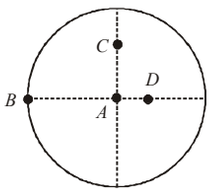
(c) 0.2 m (d) 1.6 m

51. A particle of mass 2 kg is moving such that at time t, its position, in meter, is given by $\vec{r}(t) = 5\hat{i} - 2t^2\hat{j}$. The angular momentum of the particle at $t = 2s$ about the origin in kg m^{-2} s^{-1} is :

(a) $-80\hat{k}$ (b) $(10\hat{i} - 16\hat{j})$

(c) $-40\hat{k}$ (d) $40\hat{k}$

52. The moment of inertia of a uniform circular disc is maximum about an axis perpendicular to the disc and passing through:



(a) B (b) C

(c) D (d) A

1.3 Rolling Motion

53. A hollow cylinder of mass m and radius R rolls down a sufficiently rough inclined plane of height h. The angular velocity of the hollow cylinder when it reaches the bottom of the plane will be

(a) $\frac{\sqrt{\frac{3}{2}gh}}{R}$ (b) $\frac{\sqrt{2gh}}{R}$

(c) $\frac{\sqrt{gh}}{R}$ (d) $\frac{2}{R}\sqrt{gh}$

54. A ring and a solid sphere roll down the same inclined plane without slipping. They start from rest. The radii of both bodies are identical and the ratio of their kinetic energies is $\frac{7}{x}$ where x is

(a) 7 (b) 14

(c) 21 (d) 28

55. A small disc of mass 500 g and radius 5 cm rolls down an inclined plane without slipping. Speed of its centre of mass when it reaches the bottom of the inclined plane depends on

(a) mass and radius

(b) mass and height of the incline

(c) height of the incline

(d) height of the incline and acceleration due to gravity

56. When a body rolls without sliding up an inclined plane, the frictional force is:

(a) directed up the plane

(b) directed down the plane

(c) zero

(d) dependent on its velocity

57. A hoop of radius 2 m weights 100 kg. It rolls along a horizontal floor so that its centre of mass has a speed of 20 m^{-1}. How much work has to be done to stop it?

(a) 2 J (b) 4 J

(c) 6 J (d) 8 J

58. A solid cylinder of mass M and radius R rolls without slipping down an inclined plane making an angle θ with the horizontal. The its acceleration is

(a) $\frac{1}{3}g\sin\theta$ (b) $\frac{2}{3}g\sin\theta$

(c) $\frac{2}{5}g\sin\theta$ (d) $\frac{2}{7}g\sin\theta$

59. If a sphere is rolling , the ratio of the translational energy to total kinetic energy is given by

(a) 7: 10 (b) 2 : 5

(c) 10 : 7 (d) 5 : 7

60. A body is rolling down an inclined plane. Its translational and rotational kinetic energies are equal. The body is a

(a) solid sphere

(b) hollow sphere

(c) solid cylinder

(d) hollow cylinder

61. A circular disc of mass 0.41 kg and radius 10 m rolls without slipping with a velocity of 2 m/s. The total kinetic energy of disc is

(a) $0.41J$ (b) $1.23J$

(c) $0.82J$ (d) $2.4J$

62. A mass m hangs with the help of a string wrapped around a pulley on a frictionless bearing. The pulley has mass m and radius R. Assuming pulley to be a perfect uniform circular disc, the acceleration of the mass m, if the string does not slip on the pulley, is

(a) g (b) $\frac{2}{3}g$

(c) $\frac{g}{3}$ (d) $\frac{3}{2}g$

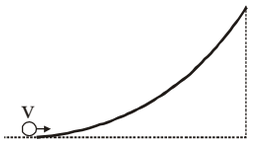
63. A small object of uniform density rolls up a curved surface with an initial velocity v. It reaches up to a maximum height of $\frac{3v^2}{4g}$ with respect to the initial position. The object is

(a) Ring

(b) Solid sphere

(c) Hollow sphere

(d) Disc



64. A drum of radius R and mass M, rolls down without slipping along an inclined plane of angle θ. The frictional force

(a) dissipates energy as heat.

(b) decreases the rotational motion.

(c) decreases the rotational and translational motion.

(d) converts translational energy to rotational energy

65. A solid sphere is rotating in free space. If the radius of sphere is increased keeping mass same which one of the following will not be affected?

(a) Angular velocity

(b) Angular momentum

(c) Moment of inertia

(d) Rotational kinetic energy

66. A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass is K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be

(a) $\frac{R^2}{K^2+R^2}$ (b) $\frac{K^2+R^2}{R^2}$

(c) $\frac{K^2}{R^2}$ (d) $\frac{K^2}{K^2+R^2}$

67. A solid sphere of mass 1 kg rolls on a table with linear speed 1 ms^{-1}. Its total kinetic energy is

(a) 1 J (b) 0.5 J

(c) 0.7 J (d) 1.4 J

68. A thin hollow cylinder open at both ends.

(i) Siding without rolling

(ii) Rolls without slipping with the same speed

The ratio of kinetic energy in the two cases is

(a) 1 : 1 (b) 4 : 1

(c) 1 : 2 (d) 2 : 1

69. A solid sphere (mass 2 M) and a thin hollow spherical shell (mass M) both of the same size, roll down an inclined plane, then

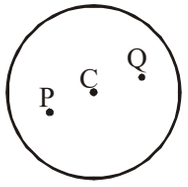
(a) Solid sphere will reach the bottom first

(b) Hollow spherical shell will reach the bottom first

(c) Both will reach at the same time

(d) None of these

70. A disc is rolling (without slipping) on a horizontal surface.C is its centre and Q and P are two points equidistant from C. Let V_p, V_q and V_c be the magnitude of velocities of points P , Q and C respectively, then



(a) $V_Q > V_C > V_P$ (b) $V_Q < V_C < V_P$

(c) $V_Q = V_P, V_C = \frac{1}{2}V_P$ (d) $V_Q < V_C > V_P$

71. A solid cylinder of mass 2 kg and radius 0.1 m rolls down an inclined plane of height 3m without slipping. Its rotational kinetic energy when it reaches the foot of the plane would be :

(a) 22.7 J (b) 19.6 J

(c) 10.2 J (d) 9.8 J

72. A solid cylinder of mass 20 kg rotates about its axis with angular speed 100 rad/s. The radius of the cylinder is 0.25 m. The K.E. associated with the rotation of the cylinder is

(a) 3025 J (b) 3225 J

(c) 3250 J (d) 3125 J

Exercise 3 : PREVIOUS YEARS MCQs

1. Two discs of moment of inertia I_1 and I_2 and angular speeds ω_1 and ω_2 are rotating along collinear axes passing through their centre of mass and perpendicular to their plane. If the two are made to rotate combindly along the same axis the rotational KE of system will be **[2025]**

(a) $\frac{I_1\omega_1 + I_2\omega_2}{2(I_1 + I_2)}$ (b) $\frac{(I_1 + I_2)(\omega_1 + \omega_2)^2}{2}$

(c) $\frac{(I_1\omega_1 + I_2\omega_2)^2}{2(I_1 + I_2)}$ (d) None of these

2. Four identical solid spheres each of mass 'm' and radius 'a' are placed with their centres on the four corners of a square of side 'b'. The moment of inertia of the system about one side of square where the axis of rotation is parallel to the plane of the square is : **[2025]**

(a) $\frac{4}{5}ma^2$ (b) $\frac{8}{5}ma^2 + mb^2$

(c) $\frac{8}{5}ma^2 + 2mb^2$ (d) $\frac{4}{5}ma^2 + 2mb^2$

3. A bucket tied at the end of a 1.6 m long string is whirled in a vertical circle with constant speed. What should be the minimum speed so that the water from the bucket does not spill when the bucket is at the highest position? **[2025]**

(a) 4 m/sec (b) 6.25 m/sec
(c) 16 m/sec (d) None of these

4. The minimum velocity (in ms^{-1}) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is **[2025]**

(a) 60 (b) 30
(c) 15 (d) 25

5. A fly wheel is accelerated uniformly from rest and rotates through 5 rad in the first second. The angle rotated by the fly wheel in the next second, will be : **[2022]**

(a) 7.5 rad (b) 15 rad (c) 20 rad (d) 30 rad

6. A mass m is revolving in a vertical circle at the end of a string of length 20 cm. By how much does the tension of the string at the lowest point exceed the tension at the topmost point? **[2020]**

(a) 2 m g (b) 4 m g
(c) 6 m g (d) 8 m g

7. A sotne of mass 1 kg is tied to a string of length 2 m long and is rotated at constant speed of 40 ms^{-1} in a vertical circle. The ratio of the tension at the top and the bottom is [Take $g = 10\ ms^{-2}$] **[2019]**

(a) $\frac{81}{79}$ (b) $\frac{79}{81}$ (c) $\frac{19}{12}$ (d) $\frac{12}{19}$

8. In non uniform circular motion, the ratio of tangential to radius acceleration is (r = radius of circle, v = speed of the particle, α = angular acceleration) **[2018]**

(a) $\frac{\alpha^2 r^2}{v}$ (b) $\frac{\alpha^2 r}{v^2}$

(c) $\frac{\alpha r^2}{v^2}$ (d) $\frac{v^2}{r^2\alpha}$

9. A mass attached to one end of a string crosses top-most point on a vertical circle with critical speed. Its centripetal acceleration when string becomes horizontal will be (g = gravitational acceleration) **[2018]**

(a) g (b) 3g (c) 4g (d) 6g

10. For a particle moving in vertical circle, the total energy at different positions along the path **[2017]**

(a) is conserved
(b) increases
(c) decreases
(d) may increase or decrease

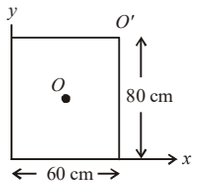
11. In vertical circular motion, the ratio of kinetic energy of a particle at highest point to that at lowest paint is **[2016]**

(a) 5 (b) 2 (c) 0.5 (d) 0.2

12. A thin circular disc of mass M and radius R is rotating in a horizontal plane about an axis passing through its centre and perpendicular to its plane with angular velocity ω. If another disc of same dimensions but of mass $M/2$ is placed gently on the first disc co-axially, then the new angular velocity of the system is : **[2024]**

(a) $\frac{4}{5}\omega$ (b) $\frac{5}{4}\omega$ (c) $\frac{2}{3}\omega$ (d) $\frac{3}{2}\omega$

13. For a uniform rectangular sheet shown in the figure, the ratio of moments of inertia about the axes perpendicular to the sheet and passing through O (the centre of mass) and O' (corner point) is : **[2024]**



(a) 2/3 (b) 1/4 (c) 1/8 (d) 1/2

14. If two circular rings A and B are of same mass but of radii r and 2r respectively, then the moment of inertia about an axis passing through C.G. and perpendicular to its plane, of A is **[2023]**

(a) same as that of B (b) twice that of B
(c) four times that of B (d) 1/4 that of B

15. A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass is K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be **[2021]**

(a) $\frac{K^2}{R^2}$ (b) $\frac{K^2}{K^2+R^2}$

(c) $\frac{R^2}{K^2+R^2}$ (d) $\frac{K^2+R^2}{R^2}$

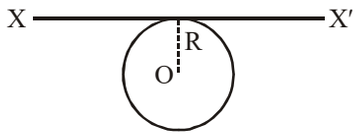
16. The moment of inertia of a circular disc of mass M and radius R about an axis passing through the centre of mass is I_0. The moment of inertia of another circular disc of same mass and thickness but half the density about the same axis is **[2021]**

(a) $\frac{I_0}{8}$ (b) $\frac{I_0}{4}$ (c) $8I_0$ (d) $2I_0$

17. If radius of the solid sphere is doubled by keeping its mass constant, the ratio of their moment of inertia about any of its diameter is **[2019]**

(a) 1 : 8 (b) 2 : 5 (c) 2 : 3 (d) 1 : 4

18. A thin metal wire of length 'L' and uniform linear mass density 'Q' is bent into a circular coil with 'o' as centre. The moment of inertia of a coil about the axis XX′ is **[2019]**



(a) $\frac{3QL^3}{8\pi^2}$ (b) $\frac{QL^3}{4\pi^2}$ (c) $\frac{3QL^2}{4\pi^2}$ (d) $\frac{QL^3}{8\pi^2}$

19. A dics has mass 'M' and radius 'R'. How much tangential force should be applied to the rim of the disc so as to rotate with angular velocity 'ω' in times 't' ? **[2018]**

(a) $\frac{MR\omega}{4t}$ (b) $\frac{MR\omega}{2t}$ (c) $\frac{MR\omega}{t}$ (d) $MR\omega t$

20. The moment of inertia of a ring about an axis passing through the centre and perpendicular to its plane is 'I'. It is rotating with angular velocity 'ω'. Another identical ring is gently placed on it so that their centres coincide. If both the rings are rotating about the same axis then loss in kinetic energy is **[2018]**

(a) $\frac{I\omega^2}{2}$ (b) $\frac{I\omega^2}{4}$ (c) $\frac{I\omega^2}{6}$ (d) $\frac{I\omega^2}{8}$

21. A wheel of moment of inertia 2 kg m^2 is rotating about an axis passing through centre and perpendicular to its plane at a speed 60 rad/s. Due to friction, it comes to rest in 5 minutes. The angular momentum of the wheel three minutes before it stops rotating is **[2017]**

(a) 24 kg m^2/s (b) 48 kg m^2/s

(c) 72 kg m^2/s (d) 96 kg m^2/s

22. A disc of moment of inertia 'I_1' is rotating in horizontal plane about an axis passing through a centre and perpendicular to its plane with constant angular speed 'ω_1'. Another disc of moment of inertia 'I_2' having zero angular speed is placed co-axially on a rotating disc. Now, both the discs are rotating with constant angular speed 'ω_2'. The energy lost by the initial rotating disc is **[2017, 2015]**

(a) $\frac{1}{2}\left[\frac{I_1+I_2}{I_1I_2}\right]\omega_1^2$ (b) $\frac{1}{2}\left[\frac{I_1I_2}{I_1-I_2}\right]\omega_1^2$

(c) $\frac{1}{2}\left[\frac{I_1-I_2}{I_1I_2}\right]\omega_1^2$ (d) $\frac{1}{2}\left[\frac{I_1I_2}{I_1+I_2}\right]\omega_1^2$

23. If the length of a thin uniform rod is 'L' and the radius of gyration of the rod about an axis perpendicular to its length and passing through one end is K, then K : L = **[2013]**

(a) $1:\sqrt{3}$ (b) $1:\sqrt{2}$ (c) 1 : 3 (d) 1 : 2

24. If the moment of inertia of a thin circular ring about an axis passing through its edge and perpendicular to its plane is I, then the moment of inertia of the ring about its diameter is **[2011]**

(a) $\frac{I}{4}$ (b) 4I (c) $\frac{I}{2}$ (d) 2I

25. Due to global warming, if the ice in the polar region melts and some of this water flows to the equatorial region, then **[2010]**

(a) Angular momentum of the earth increases and duration of day increases

(b) Angular momentum of the earth decreases and duration of day decreases

(c) Angular momentum of the earth is constant and duration of day decreases

(d) Angular momentum of the earth is constant and duration of day increases

26. A solid sphere of mass 2 kg and radius 0.5 m is rolling without slipping on a horizontal surface. The ratio of the rotational and translational kinetic energies of the sphere is **[2008]**

(a) 3 : 5 (b) 2 : 5 (c) 4 : 5 (d) 7 : 5

27. A thin uniform wire of mass 'm' and linear density 'ρ' is bent in the form of a circular ring. The moment of inertia of the ring about a tangent parallel to its diameter is **[2006]**

(a) $\frac{3m^3}{8\pi^2\rho^2}$ (b) $\frac{8m^3}{3\pi^2\rho^2}$ (c) $\frac{8\pi^2m^3}{3\rho^2}$ (d) $\frac{3\pi^2m^3}{8\rho^2}$

28. The ratio of radii of gyration of a thin circular ring and a circular disc of same radius about a tangential axis in their own planes is $\sqrt{12}:\sqrt{K}$. The value of K is **[2005]**

(a) 10 (b) 24 (c) 5 (d) 12

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(a)	**14**	(b)	**27**	(a)	**40**	(b)	**53**	(a)	**66**	(b)	**79**	(b)	**92**	(c)	**105**	(d)	**118**	(d)
2	(a)	**15**	(b)	**28**	(b)	**41**	(a)	**54**	(a)	**67**	(b)	**80**	(a)	**93**	(d)	**106**	(b)	**119**	(a)
3	(b)	**16**	(a)	**29**	(b)	**42**	(b)	**55**	(a)	**68**	(a)	**81**	(a)	**94**	(b)	**107**	(d)	**120**	(c)
4	(d)	**17**	(d)	**30**	(b)	**43**	(a)	**56**	(b)	**69**	(a)	**82**	(a)	**95**	(a)	**108**	(d)	**121**	(b)
5	(a)	**18**	(d)	**31**	(d)	**44**	(c)	**57**	(d)	**70**	(b)	**83**	(d)	**96**	(b)	**109**	(c)	**122**	(b)
6	(a)	**19**	(b)	**32**	(b)	**45**	(d)	**58**	(c)	**71**	(d)	**84**	(a)	**97**	(c)	**110**	(d)	**123**	(d)
7	(d)	**20**	(c)	**33**	(b)	**46**	(b)	**59**	(c)	**72**	(b)	**85**	(a)	**98**	(b)	**111**	(b)	**124**	(c)
8	(a)	**21**	(a)	**34**	(b)	**47**	(d)	**60**	(a)	**73**	(c)	**86**	(c)	**99**	(a)	**112**	(c)	**125**	(c)
9	(d)	**22**	(a)	**35**	(c)	**48**	(b)	**61**	(c)	**74**	(c)	**87**	(d)	**100**	(d)	**113**	(a)	**126**	(a)
10	(c)	**23**	(a)	**36**	(b)	**49**	(b)	**62**	(d)	**75**	(c)	**88**	(c)	**101**	(d)	**114**	(b)	**127**	(d)
11	(a)	**24**	(c)	**37**	(b)	**50**	(c)	**63**	(c)	**76**	(a)	**89**	(d)	**102**	(b)	**115**	(d)	**128**	(b)
12	(a)	**25**	(c)	**38**	(b)	**51**	(c)	**64**	(b)	**77**	(d)	**90**	(a)	**103**	(c)	**116**	(c)		
13	(b)	**26**	(b)	**39**	(d)	**52**	(d)	**65**	(b)	**78**	(c)	**91**	(d)	**104**	(a)	**117**	(c)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(c)	**9**	(c)	**17**	(d)	**25**	(b)	**33**	(a)	**41**	(c)	**49**	(d)	**57**	(b)	**65**	(b)		
2	(a)	**10**	(c)	**18**	(a)	**26**	(d)	**34**	(b)	**42**	(c)	**50**	(a)	**58**	(b)	**66**	(d)		
3	(c)	**11**	(c)	**19**	(a)	**27**	(b)	**35**	(a)	**43**	(c)	**51**	(a)	**59**	(d)	**67**	(c)		
4	(b)	**12**	(d)	**20**	(d)	**28**	(d)	**36**	(d)	**44**	(b)	**52**	(a)	**60**	(d)	**68**	(c)		
5	(a)	**13**	(a)	**21**	(a)	**29**	(c)	**37**	(d)	**45**	(b)	**53**	(c)	**61**	(b)	**69**	(a)		
6	(a)	**14**	(d)	**22**	(a)	**30**	(a)	**38**	(a)	**46**	(a)	**54**	(a)	**62**	(b)	**70**	(a)		
7	(c)	**15**	(b)	**23**	(a)	**31**	(b)	**39**	(d)	**47**	(d)	**55**	(c)	**63**	(d)	**71**	(b)		
8	(c)	**16**	(a)	**24**	(c)	**32**	(a)	**40**	(b)	**48**	(b)	**56**	(a)	**64**	(d)	**72**	(d)		
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(c)	**4**	(b)	**7**	(b)	**10**	(a)	**13**	(b)	**16**	(d)	**19**	(b)	**22**	(d)	**25**	(d)	**28**	(a)
2	(c)	**5**	(b)	**8**	(c)	**11**	(d)	**14**	(d)	**17**	(d)	**20**	(b)	**23**	(a)	**26**	(b)		
3	(a)	**6**	(c)	**9**	(b)	**12**	(c)	**15**	(b)	**18**	(a)	**21**	(c)	**24**	(a)	**27**	(a)		

2 Mechanical Properties of Fluids

TOPIC 2.1 : FLUIDS, PRESSURE, PASCAL'S LAW, VARIATION OF PRESSURE WITH DEPTH, TYPES OF PRESSURE

FLUIDS

Fluids are the substances that can flow. Therefore liquids and gases both are fluids. The study of fluids at rest is called **fluid statics** or **hydrostatics** and the study of fluids in motion is called **fluid dynamics** or **hydrodynamics**. Both combined are called **fluid mechanics**.

Density (ρ)

Mass per unit volume is defined as density. So density at a point of a fluid is represented as

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V} = \frac{dm}{dV}$$

where m is the mass and V is the volume of the fluid.
Density is a positive scalar quantity.
SI unit : kg/m^3 **Dimensions :** [ML^{-3}]

If a body is partially or wholly immersed in a fluid, it experiences an upward force due to the fluid surrounding it. This phenomenon of force exerted by fluid on the body is called **buoyancy** and force is called **buoyant force** or **upthrust**.

Archimedes' Principle : It states that the buoyant force on a body that is partially or totally immersed in a fluid is equal to the weight of the fluid displaced by it.

PRESSURE

If a uniform force is exerted normal to an area (A), then *average pressure (p_{av}) is defined as the normal force (F) per unit area.*

i.e., $p_{av} = \frac{F}{A}$ It is a scalar quantity.

SI unit : pascal (Pa), 1 Pa = 1 N/m^2
Dimensions : [ML^{-1}T^{-2}]

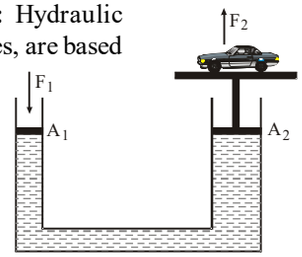
PASCAL'S LAW

Pascal's law is stated in following ways :

- The pressure in a fluid at rest is same at all the points if gravity is ignored.
- A liquid exerts equal pressures in all directions.
- If the pressure in an enclosed fluid is changed at a particular point, the change is transmitted to every point of the fluid and to the walls of the container without being diminished in magnitude.

Applications of Pascal's law : Hydraulic machines, lifts, presses and brakes, are based on the Pascal's law.

For the hydraulic lift :



Pressure $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

Upward force on A_2 is $F_2 = \frac{F_1}{A_1} A_2 = \frac{A_2}{A_1} \times F_1$

VARIATION OF PRESSURE WITH DEPTH

$P_2 = P_1 + h\rho g$

P_2 is the absolute pressure at depth h below the free surface of the liquid. Equation, shows that the absolute pressure at depth h is greater than the atmospheric pressure (P_1) by an amount equal to hρg.

TYPES OF PRESSURE

Pressure is of three types :

(i) Atmospheric pressure (P_0)
(ii) Gauge pressure (P_{gauge})
(iii) Absolute pressure (P_{abs})

(i) **Atmospheric pressure :** Force exerted by air column on unit cross-section area of sea level is called atmospheric pressure (P_0)

$$P_0 = \frac{F}{A} = 101.3\ kN/m^2$$

Barometer is used to measure atmospheric pressure which was discovered by **Torricelli**.

Atmospheric pressure varies from place to place and at a particular place from time to time.

(ii) **Gauge pressure:** Excess pressure ($P - P_a$) measured with the help of pressure measuring instrument is called Gauge pressure.

$$P_{gauge} = h\rho g \text{ or } P_{gauge} \propto h.$$

Gauge pressure is always measured by "**manometer**".

(iii) **Absolute pressure :** Sum of atmospheric and gauge pressure is called absolute pressure.

$$P_{abs} = P_{atm} + P_{gauge} \Rightarrow P_{abs} = P_0 + h\rho g$$

The pressure which we measure in our automobile tyres is gauge pressure.

TOPIC 2.2 : SURFACE TENSION, ANGLE OF CONTACT & CAPILLARITY

SURFACE TENSION

Surface tension is basically a property of liquid. The liquid surface behaves like a stretched elastic membrane which has a natural tendency to contract and tends to have a minimum possible surface area. This property of liquid is called surface tension.

Intermolecular Forces

The force which acts between the molecules of same or different substances is called intermolecular force. This force is of two types.

(i) **Cohesive force :** The force acting between the molecules of one type of molecules of same substance is called cohesive force.

(ii) **Adhesive force :** The force acting between different types of molecules of different substance is called adhesive force.

Intermolecular forces are different from the gravitational forces as they do not obey the inverse-square law.

The distance upto which these forces are effective, is called **molecular range**. This distance is nearly 10^{-8} m. Within this limit this increases very rapidly as the distance decreases.

Molecular range depends on the nature of the substance.

Factors Affecting Surface Tension

1. **Impurities:** If the impurity is completely soluble then on mixing it in the liquid, its surface tension increases e.g., on dissolving ionic salts in small quantities in a liquid, its surface tension increases. If the impurity is partially soluble in a liquid then its surface tension decreases because adhesive force between insoluble impurity molecules and liquid molecules decreases cohesive force effectively.
2. **Temperature:** On increasing temperature surface tension decreases. At critical temperature and boiling point it becomes zero. Surface tension of water is maximum at 4°C.

Surface Energy

According to molecular theory of surface tension the molecules in the surface have some additional energy due to their position. This additional energy per unit area of the surface is called surface energy.

i.e., $surface\ energy = \dfrac{Work\ done}{Increase\ in\ surface\ area}$

Its **SI unit** is Jm^{-2}

Also, $T = \dfrac{dW}{dA}$

Thus, *the surface tension T can also be defined as the work done in increasing the surface area by unity.*

Surface Energy In case of Drops and Bubbles

- Work done (surface energy) in the formation of a water drop of radius r = work done against surface tension

  W = surface tension $T \times$ change in area ΔA

  or $T \times \Delta A = T \times 4\pi r^2 = 4\pi r^2 T$

- Work done (surface energy) in the formation of a soap bubble of radius r

  $W = T \times \Delta A = T \times 2 \times 4\pi r^2 = 8\pi r^2 T$

  [$\because$ soap bubble has two surfaces]

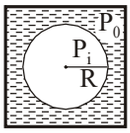
Excess Pressure Due to Surface Tension

The shape of any liquid drop is spherical due to the surface tension and the pressure on the concave side of curved liquid surface is greater than that on the convex side. Therefore pressure difference exists across two sides of a curved surface. This pressure difference is called excess pressure.

Case I : Excess pressure inside the drop

Excess pressure inside the drop

$$P_{ex} = (P_i - P_0) = \frac{2T}{r}$$

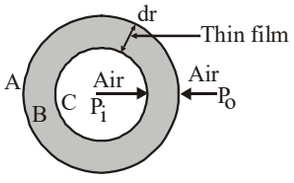


Case II : Excess pressure inside soap bubble

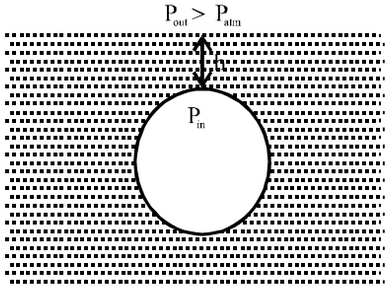
Since the soap bubble has two surfaces. The excess pressure will get double as compared to a drop

$$P_C - P_A = \frac{4T}{r},$$

$$\Rightarrow \quad Excess\ pressure = P_i - P_0 = \frac{4T}{r}$$



Case III : Excess pressure inside the cavity or air bubble in liquid



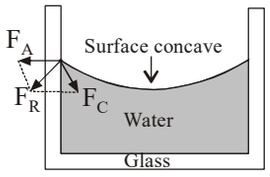
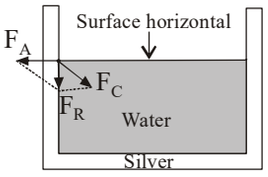
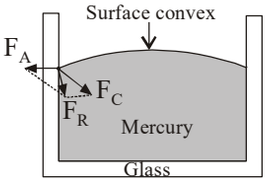
$$P_{excess} = P_{in} - P_{out} = hdg + \frac{2T}{R}$$

$$\Rightarrow \quad P_{inside} = P_{atm} + hdg + \frac{2T}{R}$$

ANGLE OF CONTACT

The angle enclosed between the tangent plane at the liquid surface and the tangent plane at the solid surface at the point of contact inside the liquid is termed as the ***angle of contact****.*
The angle of contact depends on the nature of the solid and liquid in contact.

The relation between cohesive and adhesive force, angle of contact and meniscus of the surface of liquid :

Relation between cohesive and adhesive force	 Here, $F_A > \frac{F_C}{\sqrt{2}}$	 Here, $F_A = \frac{F_C}{\sqrt{2}}$	 Here, $F_A < \frac{F_C}{\sqrt{2}}$
Shape of meniscus	Concave	Plane	Convex

Factors Affecting Angle of Contact

(i) **Temperature :** On increasing temperature surface tension decreases, thus cos θ_C increases $\left[\because \cos\theta_C \propto \frac{1}{T}\right]$ and θ_C decreases. So, on increasing temperature, θ_C decreases.

(ii) **Impurities :**
- (a) Soluble impurities increase surface tension, so cos θ_C decreases and angle of contact increases.
- (b) Partially soluble impurities decrease surface tension, so angle of contact θ_C decreases.

(iii) **Water proofing agent :** Angle of contact increases due to water proofing agent. It gets converted from acute to obtuse angle.

(iv) **Surfaces in contact :** Angle of contact depends upon the surfaces in contact.

CAPILLARITY

A glass tube with fine bore and open at both ends is known as **capillary tube**. The property by virtue of which a liquid rise or fall in a capillary tube is known as **capillarity**. Rise or fall of liquid in tubes of narrow bore (capillary tube) is called capillary action.

$$h = \frac{2T\cos\theta}{r\rho g}$$

Thus the height of rise of liquid in a capillary tube is inversely proportional to the radius of the capillary tube.

TOPIC 2.3 : VISCOSITY, STOKE'S LAW & TERMINAL VELOCITY

VISCOSITY

"This property of a fluid by virtue of which it opposes the relative motion between its different layers is known as viscosity and the force that is into play is called the viscous force".
If F is the viscous force on the layer, then $F \propto A$, where A is the area of the layer.

Also, $F \propto -\frac{dv}{dx}$

The negative sign is put to account for the fact that the viscous force is opposite to the direction of motion.

$$\Rightarrow \quad F = -\eta A\frac{dv}{dx}$$

where η is a constant depending upon the nature of the liquid and is called the **coefficient of viscosity**.

$\frac{dv}{dx}$ is called the **velocity gradient**.

Effect of Temperature and Pressure on Viscosity

Effect of temperature : On increasing temperature viscosity of a liquid decreases.
Effect of pressure : On increasing pressure viscosity of a liquid increases except water whose viscosity decreases with pressure ries.

STOKE'S LAW

The viscous drag on a spherical body of radius *r*, moving with velocity v, in a viscous medium of viscosity η is given by

$$F_{viscous} = 6\pi\eta r v$$

This relation is called Stokes' law.

TERMINAL VELOCITY

Terminal velocity *is the maximum constant velocity acquired by the body while falling freely in a viscous medium.*

$$Terminal\ velocity, v = \frac{2r^2(\rho - \rho_0)g}{9\eta}$$

TOPIC 2.4 : FLUIDS IN MOTION, BERNOULLI'S PRINCIPLE

FLUIDS IN MOTION

The motion of fluids are of following four types :

(i) Streamline motion : *In a fluid in motion, if fluid particles preceeding or succeeding a fluid particle follow the same path, then the path is called streamline; and then the motion of the fluid is called streamline motion*. This type of motion takes place in non-viscous fluids having very small speed.

Principle of continuity :

v_2A_2 or $Av = constant$ ....(i)

Since $\rho_1 = \rho_2$

Equation (i) said to be as **equation of continuity**.

(ii) Steady state motion : *In a liquid in motion, when liquid particles, crossing a point with same velocity, then the motion of the liquid is called steady state motion*. This type of motion takes place in non-viscous liquids having very small speed.

(iii) Laminar motion : *If a liquid is flowing over a horizontal surface with a steady flow and moves in the form of layers of different velocities which do not mix with each other, then the flow of liquid is called laminar flow.*

(iv) Turbulent motion : *When the velocity of a liquid is irregular, haphazard and large, i.e. beyond a limiting value called critical velocity the flow of liquid loses steadiness then the motion of the liquid is called turbulent motion.*

Critical velocity : The critical velocity is that velocity of liquid flow, upto which its flow is streamlined and above which its flow becomes turbulent. It is given by $v_C = \frac{K\eta}{\rho r}$

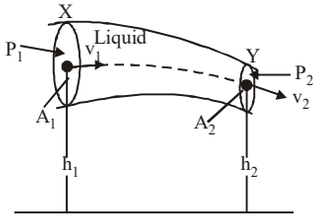
Reynold's Number

Reynolds defined a dimensionless number whose value gives an approximate idea, whether the flow rate would be turbulent.

This number, called the Reynolds number $R_e = \frac{\rho v D}{\eta}$

BERNOULLI'S PRINCIPLE

When incompressible, non-viscous, irrotational liquid i.e., ideal liquid flow from one position to another in streamline path then in its path at every point the sum of pressure energy, kinetic energy and potential energy per unit volume remains constant.



i.e., $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

$\therefore \quad P + \rho g h + \frac{\rho v^2}{2} = constant$

where P = pressure energy per unit volume

ρgh = potential energy per unit volume and

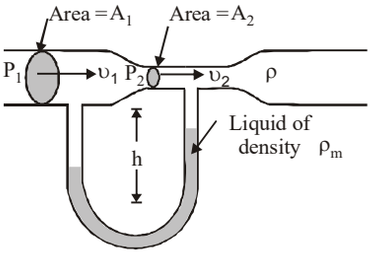
$\frac{1}{2}\rho v^2$ = kinetic energy per unit volume.

The above equation is known as **Bernoulli's equation**.

Applications of Bernoulli's Principle

Venturi-meter

It is a device used for the measurement of rate of flow of incompressible fluid through a tube. The working of venturi-meter is based on Bernoulli's principle.



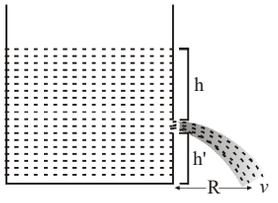
The rate of flow of fluid

$V = A_1A_2\sqrt{\frac{2gh\rho_m}{(A_1^2 - A_2^2)\rho}}$ ρ_m = density of liquid in U tube

ρ = density of liquid in tube

Torricelli's law (speed of efflux) : The speed with which the liquid flows out of an orifice is equal to the speed of a freely falling body, would acquire in falling through a vertical distances equal to the depth of orifice below the free surface of liquid.

i.e., $v = \sqrt{2gh}$



Some other applications of Bernoulli's principle

(i) The action of carburator, sprayer or atomizer based on Bernoulli's principle.

(ii) The action of bunsen burner, exhaust pump etc.

(iii) Air foil or lift on aircraft wing works on Bernoulli's principle.

(iv) Motion of a spinning ball i.e., magnus effect.

(v) Blowing of roofs by wind storms etc. based on Bernoullis principle.

CHAPTER AT A GLANCE

- Pressure $= \frac{\text{thrust}}{\text{area}}$; Thrust = total force exerted by a liquid on the surface in contact.

  A liquid always exerts force perpendicular to the surface of the container at every point.
- Pascal's law: The pressure exerted at any point of an enclosed liquid is transmitted equally in all directions.
- For a hydraulic lift, Pressure, $P = \frac{f}{a} = \frac{F}{A}$.
- Pressure exerted by a liquid column of height h and density p is P = h pg
- Absolute pressure = Atmospheric pressure + Gauge pressure; $P = P_a + P_g$
- Surface tension $= \frac{\text{force}(f)}{\text{length}(l)}$
- Increase in surface energy or work done

  w = surface tension × increase in the area of liquid surface
- Excess pressure inside a liquid drop, $P = \frac{2T}{R}$; Excess pressure inside a soap bubble, $P = \frac{4T}{R}$
- The surface tension of a liquid is zero at boiling point. The surface tension is zero at critical temperature.
- If a drop of water of radius *R* is broken into *n* identical drops, the work done in the process is $4\pi R^2 S(n^{1/3} - 1)$.
- The ratio of surface energy of the big drop to that of one smaller drop in the above case is $n^{2/3}$.
- Rise or fall of liquid in a capillary tube $h = \frac{2T\cos\theta}{rpg}$ or $h \propto \frac{1}{r}$ this is zurin's law.
- Newton's formula for viscous force between two parallel layers $F = -\eta A\frac{dv}{dx}$ where, η = coefficient of viscosity and $\frac{dv}{dx}$ = velocity gradient.
- According to stoke's law, Force of viscosity, $F = 6\pi\eta vr$
- Terminal velocity of a spherical body of density ρ and radius *r* moving through a liquid of density ρ'

  $$v = \frac{2}{9}\frac{r^2(\rho - \rho^1)}{\eta}g$$
- Reynold's number, $R_e = \frac{\rho vd}{\eta}$

  Flow is laminar for R_e between 0 and 2000

  Flow is turbulant for $R_e > 3000$

  Flow is unstable for R_e between 2000 and 3000
- Equation of continuity: av = constant or, $a_1v_1 = a_2v_2$
- According to Bernoulli's theorem, $\frac{P}{\rho} + gh + \frac{1}{2}v^2$ = constant
- Volume of a liquid flowing out per second through a venturimeter, $V = a_1a_2\sqrt{\frac{2gh}{a_1^2 - a_2^2}}$
- Toricelli's theorem, velocity of efflux $v = \sqrt{2gh}$

Exercise 1 : WARM-UP
Topic-wise MCQs

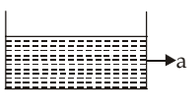
2.1 Fluids, Pressure, Pascal's Law, Variation of Pressure with Depth, Types of Pressure

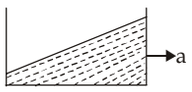
1. Hydraulic lifts and hydraulic brakes are based on
(a) Archimedes' principle
(b) Bernoulli's principle
(c) Stoke's law
(d) Pascal's law

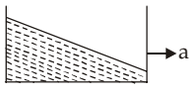
2. Pressure applied to enclosed fluid is
(a) increased and applied to every part of the fluid.
(b) diminished and transmitted to wall of container.
(c) increased in proportion to the mass of the fluid and then transmitted
(d) transmitted unchanged to every portion of the fluid and wall of containing vessel.

3. _____ and _____ play the same role in case of fluids as force and mass play in case of solids.
(a) Thrust and density
(b) Pressure and density
(c) Pressure and thrust
(d) Thrust and volume

4. The two thigh bones, each of cross-sectional area 10 cm^2 support the upper part of a human body of mass 40 kg. Estimate the average pressure sustained by the bones. Take $g = 10\ m/s^2$
(a) $2 \times 10^5\ N/m^2$ (b) $5 \times 10^4\ N/m^2$
(c) $2 \times 10^7\ N/m^2$ (d) $3 \times 10^6\ N/m^2$

5. A vessel containing water is given a constant acceleration '*a*' towards the right along a straight horizontal path. Which of the following diagrams represents the surface of the liquid?
(a) 

(b) 

(c) 

(d) None of these

6. Liquid pressure depends upon
(a) area of the liquid surface
(b) shape of the liquid surface
(c) height of the liquid column
(d) directions

7. Pressure at half of the depth of lake is equal to 3/4 pressure at the bottom of the lake, then what is the depth of the lake? ($p_{atm} = 10^5 N/m^2$)
(a) 20m (b) 10m
(c) 40m (d) 5m

8. In a hydraulic lift at a service station, the radii of the large and small pistons are in the ratio of 20 : 1. What weight placed on the small piston will be sufficient to lift a car of mass 1200 kg?
(a) 3 kgf (b) 30 kgf
(c) 300 kgf (d) 3000 kgf

9. The diameter of the piston of a hydraulic automobile is D metre. What pressure, in atmosphere is required to lift a car of mass m kg?
(a) $\frac{4mg}{\pi D^2 \times 10^5}$ (b) $\frac{2mg}{\pi D^2}$
(c) $\frac{mg}{\pi D^2}$ (d) $10^5 \times \frac{4mg}{\pi D^2}$

10. A 50 kg girl wearing heel shoes balances on a single heel. The heel is circular with a diameter 1 cm. The pressure exerted by the heel on the horizontal floor is (Take $g = 10\ m\ s^{-2}$)
(a) 6.4×10^4 Pa (b) 6.4×10^5 Pa
(c) 6.4×10^6 Pa (d) 6.4×10^7 Pa

11. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg. The area of cross-section of the piston carrying the load is 425 cm^2. What maximum pressure would the smaller piston have to bear?
(a) 15.82×10^5 Pa (b) 6.92×10^5 Pa
(c) 2.63×10^5 Pa (d) 1.12×10^5 Pa

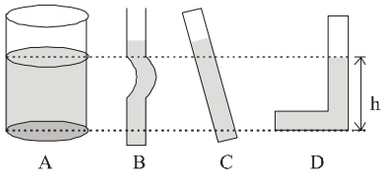
12. The gauge pressure at a depth of 50 m in a sea is (Density of sea water is 1025 $kg\ m^{-3}$ and $g = 10\ ms^{-2}$)
(a) 1025 Pa (b) 512500 Pa
(c) 20000 Pa (d) 15000 Pa

13. In a well pressure at a point 10 m below the surface of water is ($g = 10\ ms^{-2}$)
(a) $2 \times 10^4\ Nm^{-2}$ (b) $10^5\ Nm^{-2}$
(c) $10^4\ Nm^{-2}$ (d) $2 \times 10^5\ Nm^{-2}$

14. The pressure at a depth $\frac{1}{3}$ of the depth of the lake is equal to half of the pressure at the bottom of the lake. If the height of the water barometer is 10m, the depth of the lake is
(a) 60m (b) 30m (c) 40m (d) 20m

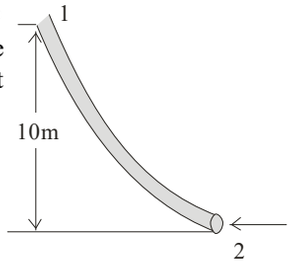
15. A car of mass 500 kg is lifted by a hydraulic jack that consist of two pistons. If the diameter of large and small pistons are 2 m and 20 cm respectively, then force required to lift the car by smaller piston is (take, $g = 10\ m/s^2$)
(a) 5000 N (b) 25 N (c) 500 N (d) 50 N

16. Figure shows four containers of olive oil. The pressure at depth h is



(a) least in B and C both
(b) greatest in A
(c) greatest in D
(d) equal in all the containers

17. Find the force acting on the piston of 3 cm^2 at point 2 due to the water column of height 10 m.



(a) 10 N
(b) 20 N
(c) 30 N
(d) 40 N

2.2 Surface Tension, Angle of Contact & Capillarity

18. When a pinch of salt or any other salt which is soluble in water is added to water, its surface tension
(a) increases
(b) decreases
(c) may increase or decrease depending upon salt
(d) None of these

19. A pin or a needle floats on the surface of water, the reason for this is
(a) Surface tension
(b) Less weight
(c) Upthrust of liquid
(d) None of these

20. Writing on black board with a piece of chalk is possible by the property of
(a) Adhesive force
(b) Cohesive force
(c) Surface tension
(d) Viscosity

21. The radius R of the soap bubble is doubled under isothermal condition. If T be the surface tension of soap bubble, the work done in doing so is given by
(a) $32\pi R^2T$ (b) $24\pi R^2T$
(c) $8\pi R^2T$ (d) $4\pi R^2T$

22. The surface tension of soap solution is σ. What is the work done in blowing soap bubble of radius r ?
(a) $\pi r^2\sigma$ (b) $2\pi r^2\sigma$
(c) $4\pi r^2\sigma$ (d) $8\pi r^2\sigma$

23. Energy needed in breaking a drop of radius R into n drops of radii r is given by
(a) $4\pi T(nr^2 - R^2)$ (b) $\frac{4}{3}\pi(r^3n - R^2)$
(c) $4\pi T(R^2 - nr^2)$ (d) $4\pi T(nr^2 + R^2)$

24. If T is the surface tension of soap solution, the amount of work done in blowing a soap bubble from a diameter D to $2D$ is
(a) $2\pi D^2T$ (b) $4\pi D^2T$
(c) $6\pi D^2T$ (d) $8\pi D^2T$

25. If work W is done is blowing a bubble of radius R form a soap solution, then the work done in blowing a bubble of radius 2R form the same solution is
(a) $W/2$ (b) $2W$
(c) $4W$ (d) $2\frac{1}{3}W$

26. If two identical mercury drops are combined to form a single drop, then its temperature will
(a) Decrease (b) Increase
(c) Remains the same (d) None of the above

27. If the surface tension of a liquid is T, the gain in surface energy for an increase in liquid surface by A is
(a) AT^{-1} (b) AT
(c) A^2T (d) A^2T^2

28. When 10^6 small drops coalesce to make a new large drop then the drop
(a) Density increases (b) Density decreases
(c) Temperature increases (d) Temperature decreases

29. The relation between surface tension T, surface area A and surface energy E is given by
(a) $T = \frac{E}{A}$ (b) $T = EA$
(c) $E = \frac{T}{A}$ (d) $T = \frac{A}{E}$

30. A big drop of radius R is formed by 1000 small droplets of water, then the radius of small drop is
(a) R/2 (b) R/5
(c) R/6 (d) R/10

31. The angle of contact between pure water and pure glass, is
(a) 0° (b) 45°
(c) 90° (d) 135°

32. The wetability of a surface by a liquid depends primarily on
(a) surface tension
(b) density
(c) angle of contact between the surface and the liquid
(d) viscosity

33. If the surface of a liquid is plane, then the angle of contact of the liquid with the walls of container is

(a) Acute angle
(b) Obtuse angle
(c) 90°
(d) 0°

34. For which of the two pairs, the angle of contact is same ?
(a) Water and glass; glass and mercury
(b) Pure water and glass; glass and alcohol
(c) Silver and water; mercury and glass
(d) Silver and chromium; water and chromium

35. What is the shape of a non-wetting liquid placed in a capillary tube ?
(a) Concave upward
(b) Convex upward
(c) Concave downward
(d) Convex downward

36. The angle of contact between glass and mercury is
(a) 0° (b) 30°
(c) 90° (d) 135°

37. Angle of contact of a liquid with a solid depends on
(a) Solid only
(b) Liquid only
(c) Both solid and liquid only
(d) Orientation of the solid surface in liquid

38. The value of contact angle for kerosene with solid surface.
(a) 0° (b) 90°
(c) 45° (d) 33°

39. Nature of meniscus for liquid of 0° angle of contact
(a) Plane
(b) Parabolic
(c) Semi-spherical
(d) Cylindrical

40. A liquid wets a solid completely. The meniscus of the liquid in a sufficiently long tube is
(a) Flat (b) Concave
(c) Convex (d) Cylindrical

41. The meniscus of mercury in the capilary tube is
(a) Convex (b) Concave
(c) Plane (d) Uncertain

42. By inserting a capillary tube upto a depth l in water, the water rises to a height h. If the lower end of the capillary is closed inside water and the capillary is taken out and closed end opened, to what height the water will remain in the tube?
(a) Zero (b) $l + h$
(c) 2h (d) h

43. If two capillary tubes of radii r_1 and r_2 in the ratio 1 : 2 are dipped vertically in water, then the ratio of capillary rises in the respective tubes is
(a) 1 : 4 (b) 4 : 1
(c) 1 : 2 (d) 2 : 1

44. Water rises in a capillary tube to a height h. It will rise to a height more than h
(a) on the surface of sun
(b) in a lift moving down with an acceleration
(c) at the poles
(d) in a lift moving up with an acceleration

45. Due to capillary action, a liquid will rise in a tube if angle of contact is
(a) acute (b) obtuse
(c) 90° (d) zero

46. Two capillaries made of same material but of different radii are dipped in a liquid. The rise of liquid in one capillary is 2.2 cm and that in the other is 6.6 cm. The ratio of their radii is
(a) 9 : 1 (b) 1 : 9
(c) 3 : 1 (d) 1 : 3

47. In a capillary tube, water rises by 1.2 mm. The height of water that will rise in another capilary tube having half the radius of the first, is
(a) 1.2 mm (b) 2.4 mm
(c) 0.6 mm (d) 0.4 mm

48. Water rises in a vertical capillary tube upto a height of 2.0 cm. If the tube is inclined at an angle of 60° with the vertical, then upto what length the water will rise in the tube.
(a) 2.0 cm (b) 4.0 cm
(c) $\frac{4}{\sqrt{3}}$ cm (d) $2\sqrt{2}$ cm

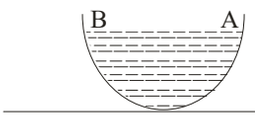
49. Two long capillary tubes A and B of radius $R_B > R_A$ dipped in same liquid. Then
(a) Liquid rise is more in A than B
(b) Liquid rises more in B than A
(c) Same liquid rise in both
(d) All of these according to the density of water

50. If the diameter of a capillary tube is doubled, then the height of the liquid that will rise is
(a) Twice (b) Half
(c) Same as earlier (d) None of these

51. Water rises in plant fibres due to
(a) Capillarity (b) Viscosity
(c) Fluid pressure (d) Osmosis

52. For different capillarities of radii (r), the condition of liquid rise (h) due to surface tension is
(a) rh = constant (b) $\frac{h}{r}$ = constant
(c) $h + r$ = constant (d) $h - r$ = constant

53. A liquid is kept in a bowl opened to atmosphere.



Consider two consecutive layers A and B as shown above, which of the following statement(s) is correct?

(a) Total energy of surface A = Total energy of surface B.
(b) Number of molecules in surface A > Number of molecules in surface B.
(c) Energy of a molecule of layer B is equal to energy of layer A.
(d) Net force on a molecule of surface B is zero.

54. The surface tension of a liquid at its boiling point

(a) becomes zero
(b) becomes infinity
(c) is equal to the value at room temperature
(d) is half to the value at room temperature

55. If T be the surface tension, the amount of work done in blowing a soap bubble from a diameter d to diameter D is

(a) $\pi(D^2 - d^2)T$
(b) $2\pi(D^2 - d^2)T$
(c) $4\pi(D^2 - d^2)T$
(d) $8\pi(D^2 - d^2)T$

56. The shape of drops and bubbles are spherical due to its

(a) surface with minimum energy
(b) surface with maximum energy
(c) high pressure
(d) low pressure

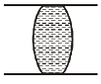
57. If work W is done in blowing a bubble of radius R from a soap solution, then the work done in blowing a bubble of radius 2R from the same solution is

(a) W/2 (b) 2W
(c) 4 W (d) $\frac{7}{3}$W

58. Surface tension of a liquid is due to

(a) gravitational force between molecules
(b) electrical force between molecules
(c) adhesive force between molecules
(d) cohesive force between molecules

59. If a water drop is kept between two glass plates, then its shape is

(a)  (b)
(c) (d) None of these

60. A drop of oil is placed on the surface of water. Which of the following is correct?

(a) It will remain on it as a sphere
(b) It will spread as a thin layer
(c) It will partly be a spherical droplet and partly a thin film
(d) It will float as a distorted drop on the water surface

61. Due to capillary action, a liquid will rise in a tube if angle of contact is

(a) acute (b) obtuse
(c) 90° (d) zero

62. If a soap bubble formed at the end of the tube is blown very slowly, then the graph between excess pressure inside the bubble with time will be a

(a) straight line sloping up
(b) straight line sloping down
(c) parabolic curve sloping down
(d) parabolic curve sloping up

63. If two soap bubbles of different radii are in communication with each other then

(a) air flows from the larger bubble into the smaller one until the two bubbles are of equal size
(b) the size of the bubbles remains the same
(c) air flows from the smaller bubble into the larger one and the larger one grows at the expense of the smaller one
(d) the air flows from the larger into the smaller bubble until the radius of the smaller one becomes equal to that of the larger one and of the larger one equal to that of the smaller one.

64. Two water droplets merge with each other to form a larger droplet. In this process

(a) energy is liberated
(b) energy is absorbed
(c) energy is neither liberated nor absorbed
(d) some mass is converted into energy

65. Which of the following expressions represents the excess of pressure inside the soap bubble?

(a) $P_i - P_o = \frac{s}{r}$
(b) $P_i - P_o = \frac{2s}{r}$
(c) $P_i - P_o = \frac{2s}{r} + h\rho g$
(d) $P_i - P_o = \frac{4s}{r}$

66. In a surface tension experiment with a capillary tube water rises upto 0.1 m. If the same experiment is repeated on an artificial satellite, which is revolving around the earth, water will rise in the capillary tube upto a height of

(a) 0.1 m
(b) 0.2 m
(c) 0.98 m
(d) full length of the capillary tube

67. If the surface tension of water is 0.06 Nm^{-1}, then the capillary rise in a tube of diameter 1 mm is ($\theta = 0°$)

(a) 1.22 cm (b) 2.44 cm
(c) 3.12 cm (d) 3.68 cm

68. The height upto which liquid rises in a capillary tube is given by $h = \frac{2S\cos\theta}{h\rho g}$ this is for which of the following cases, water will be depressed in such a tube?

(a) θ is acute (b) θ is a right angle
(c) θ is zero (d) θ is obtuse

69. Two capillary tubes A and B of diameter 1 mm and 2 mm respectively are dipped vertically in a liquid. If the capillary rise in A is 6 cm, then the capillary rise in B is

(a) 2 cm (b) 3 cm
(c) 4 cm (d) 6 cm

70. Water rises to a height of 10 cm in capillary tube and mercury falls to a depth of 3.1 cm in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the approximate ratio of surface tensions of water and mercury is

(a) 1 : 0.15 (b) 1 : 3
(c) 1 : 6 (d) 1.5 : 1

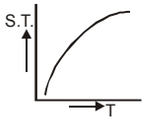
71. In a capillary rise experiment, the water level rises to a height of 5 cm. If the same capillary tube is placed in water such that only 3 cm of the tube projects outside the water level, then

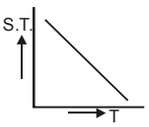
(a) water will begin to overflow through the capillary
(b) angle of contact decreases
(c) angle of contact increases
(d) the meniscus completely vanishes

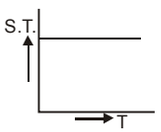
72. Surface tension may be defined as

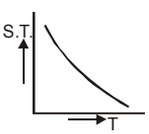
(a) the work done per unit area in increasing the surface area of a liquid under isothermal conditions
(b) the work done per unit area in increasing the surface area of a liquid under adiabatic conditions
(c) the work done per unit area in increasing the surface area of a liquid under adiabatic conditions
(d) free surface energy per unit volume

73. Which of the following graph represents the variation of surface tension with temperature over small temperature ranges for water?

(a) 

(b) 

(c) 

(d) 

74. A beaker of radius 15 cm is filled with a liquid of surface tension 0.075 N/m. Force across an imaginary diameter on the surface of the liquid is

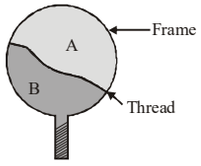
(a) 0.075 N (b) 1.5×10^{-2} N
(c) 0.225 N (d) 2.25×10^{-2} N

75. Small droplets of a liquid are usually more spherical in shape than larger drops of the same liquid because

(a) force of surface tension is equal and opposite to the force of gravity
(b) force of surface tension predominates the force of gravity
(c) force of gravity predominates the force of surface tension
(d) force of gravity and force of surface tension act in the same direction and are equal

76. A thread is tied slightly loose to a wire frame as in figure and the frame is dipped into a soap solution and taken out. The frame is completely covered with the film. When the portion A punctured with a pin, the thread.

(a) becomes concave toward A
(b) becomes convex towards A
(c) remains in the initial position
(d) either (a) or (b) depending on the size of A w.r. t. B



77. Surface tension of a liquid is due to

(a) gravitational force between molecules
(b) electrical force between molecules
(c) adhesive force between molecules
(d) cohesive force between molecules

78. At critical temperature, the surface tension of a liquid is

(a) zero
(b) infinity
(c) the same as that at any other temperature
(d) None of these

79. If more air is pushed in a soap bubble, the pressure in it

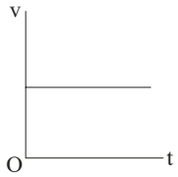
(a) decreases (b) becomes zero
(c) remains same (d) increases

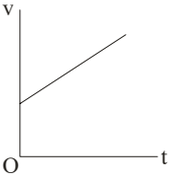
2.3 Viscosity, Stoke's Law & Terminal Velocity

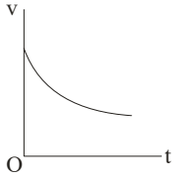
80. We have three beakers A, B and C containing three different liquids. They are stirred vigorously and placed on a table, then liquid which is

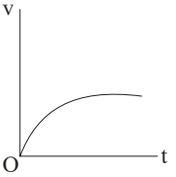
(a) most viscous comes to rest at the earliest
(b) most viscous comes to rest at the last
(c) most viscous comes down earliest but comes to rest at the last
(d) All of them come to rest at the same time

81. Which one shows the variation of the velocity v with time t for a small sized spherical body falling in a column of a viscous liquid?

(a) 

(b) 

(c) 

(d) 

82. A small drop of water falls from rest through a large height h in air, the final velocity is proportional to

(a) $\sqrt{h}$ (b) h

(c) 1/h (d) h^0

83. The terminal velocity of a copper ball of radius 2.0 mm falling through a tank of oil at 20°C is 6.5 cm^{-1}.

Compute the viscosity of the oil at 20°C. Density of oil is 1.5×10^3 kgm^{-3}, density of copper is 8.9×10^3 kgm^{-3} and g = 9.8 m/s^2.

(a) 1×10^{-1} kg ms^{-1}

(b) 9.9×10^{-1} kg ms^{-1}

(c) 24.3×10^{-2} kg ms^{-1}

(d) 2×10^{-2} kg ms^{-1}

84. A copper ball of radius r is moving with a uniform velocity u in the mustard oil. The dragging force acting on the ball is F. The dragging force on the copper ball of radius 2r moving with uniform velocity 2u in the mustard oil is

(a) F (b) 2F

(c) 4F (d) 8F

85. A small steel ball of mass m and radius r is falling under gravity through a viscous liquid of coefficient of viscosity η. If g the value of acceleration due to gravity, then the terminal velocity of the ball is proportional to (ignore buoyancy)

(a) $\frac{mg\eta}{r}$ (b) $mg\eta r$

(c) $\frac{mgr}{\eta}$ (d) $\frac{mg}{r\eta}$

86. A uniform solid sphere of relative density 5 is released in water filled in a long vertical tube. Its terminal velocity achieved is V. If another uniform solid sphere of same material but double the radius is released in the same water then the terminal velocity achieved will be.

(a) V (b) 4V (c) V/4 (d) 2V

87. Terminal velocity of ball depends on

(a) area of the ball

(b) density of liquid only

(c) density of ball only

(d) density difference of liquid and ball

88. When a ball is released from rest in a very long column of viscous liquid, its downward acceleration is 'a' (just after release). Its acceleration when it has acquired two third of the maximum velocity is a/X. Find the value of X.

(a) 2 (b) 3

(c) 4 (d) 5

89. An air bubble of negligible weight having radius r rises steadily through a solution of density σ at speed v. The coefficient of viscosity of the solution is given by:

(a) $\eta = \frac{4r\sigma g}{9v}$ (b) $\eta = \frac{4r^2\sigma g}{9v}$

(c) $\eta = \frac{2\pi r^2\sigma g}{9v}$ (d) $\eta = \frac{2r^2\sigma g}{3\pi v}$

90. If a ball of steel (density $\rho = 7.8$ g cm^{-3}) attains a terminal velocity of 10 cms^{-1} when falling in a tank of water (coefficient of viscosity $\eta_{water} = 8.5 \times 10^{-4}$ *Pa – s*) then its terminal velocity in glycerine ($\rho = 12$ gcm^{-3}, $\eta = 13.2$ *Pa – s*) would be nearly

(a) 1.6×10^{-5} cms^{-1}

(b) 6.25×10^{-4} cms^{-1}

(c) 6.45×10^{-4} cms^{-1}

(d) 1.5×10^{-5} cms^{-1}

91. A solid ball of volume V experiences a viscous force F when falling with a speed *v* in a liquid. If another ball of volume 8 V with the same velocity *v* is allowed to fall in the same liquid, it experiences a force

(a) F (b) l6 F (c) 4 F (d) 2 F

92. A small spherical ball falling through a viscous medium of negligible density has terminal velocity v. Another ball of the same mass but of radius twice that of the earlier falling through the same viscous medium will have terminal velocity

(a) v (b) v/4 (c) v/2 (d) 2 v

93. As the temperature of a liquid is raised, the coefficient of viscosity
(a) decreases
(b) increases
(c) remains the same
(d) may increase or decrease depending on the nature of liquid

94. Eight equal drops of water are falling through air with a steady speed of 10 cm/s. If the drops coalesce, the new velocity is:
(a) 10 cm/s (b) 40 cm/s
(c) 16 cm/s (d) 5 cm/s

95. The velocity of water in a river is 18 km/hr near the surface. If the river is 5 m deep, find the shearing stress between the horizontal layers of water. The co-efficient of viscosity of water = 10^{-2} poise.
(a) 10^{-1} N/m^2 (b) 10^{-2} N/m^2
(c) 10^{-3} N/m^2 (d) 10^{-4} N/m^2

96. After terminal velocity is reached, the acceleration of a body falling through a fluid is
(a) equal to g (b) zero
(c) less than g (d) greater than g

97. According to stokes law, the relation between terminal velocity (v_t) and viscosity of the medium (n) is
(a) $v_t = n$ (b) $v_t \propto n$
(c) $v_t \propto \frac{1}{n}$ (d) v_t is independent of n.

98. A rain drop of diameter 1 mm falls with a terminal velocity of 0.7 ms^{-1} in air. If the coefficient of viscosity of air is 2×10^{-5} Pas, the viscous force on the rain drop is
(a) 13.2×10^{-8}N (b) 6.6×10^{-8}N
(c) 26.4×10^{-8}N (d) 10.4×10^{-8}N

99. If the terminal velocity of a metal sphere of mass 8 g falling through a liquid is 3cms^{-1}, then the terminal velocity of another sphere of mass 64 g made of the same metal falling through same liquid is
(a) 6 cms^{-1} (b) 3 cms^{-1}
(c) 12 cms^{-1} (d) 18 cms^{-1}

2.4 Fluids in Motion, Bernoulli's Principle

100. According to Bernoulli's equation,

$$\frac{p}{pg} + h + \frac{1}{2}\frac{v^2}{g} = \text{constant}$$

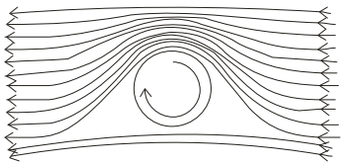
The terms, $\frac{p}{\rho g}$, h and $\frac{1}{2}\frac{v^2}{g}$ are generally called respectively.
(a) Gravitational head, pressure head and velocity head
(b) Gravity, gravitational head and velocity head
(c) Pressure head, gravitational head and velocity head
(d) Gravity, pressure and velocity head

101. In a turbulent flow, the velocity of the liquid molecules in contact with the walls of the tube is
(a) zero
(b) maximum
(c) equal to critical velocity
(d) may have any value

102. In a laminar flow, the velocity of the liquid in contact with the walls of the tube is
(a) zero
(b) maximum
(c) in between zero and maximum
(d) equal to critical velocity

103. Water is flowing continuously from a tap having cross-sectional area 10×10^{-5} m^2. The water velocity as it leaves the tap is 1 ms^{-1}. The cross-sectional area of the water stream at a distance 0.15 m below the tap is (g = 10 ms^{-2}).
(a) 5.0×10^{-4} m^2 (b) 5.0×10^{-5} m^2
(c) 1.0×10^{-5} m^2 (d) 2.0×10^{-5} m^2

104. A ball is moving in a straight line through a fluid which is spinning around its own centre of mass as shown.



Then, the ball experiences
(a) an upward force (b) a downward force
(c) a leftward force (d) a rightward force

105. An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is
(a) 9 : 4 (b) 3 : 2
(c) $\sqrt{3} : \sqrt{2}$ (d) $\sqrt{2} : \sqrt{3}$

106. A long cylindrical tank of radius 1 m is being filled by a pipe of radius 2 cm. The incoming water has a velocity of 1 m/s. The tank has a hole of radius 1 cm at the bottom. What is the height of water in the tank in steady state?
(a) 0.4 m
(b) 0.6 m
(c) 0.8 m
(d) the level will continue to increase

107. Two holes are made in the side of the tank such that the jets of water flowing out of them meet at the same point on the ground. If one hole is at a height of 3 cm above the bottom, then the distance of the other hole from the top surface of water is

(a) $\frac{3}{2}$cm (b) $\sqrt{6}$cm

(c) $\sqrt{3}$cm (d) 3 cm

108. A hole is made at the bottom of a tank filled with water. If the total pressure (absolute pressure) at the bottom is 3 atmosphere, then velocity of efflux is

(a) $20\ ms^{-1}$ (b) $10\sqrt{2}ms^{-1}$

(c) $10\sqrt{6}ms^{-1}$ (d) $10\sqrt{5}ms^{-1}$

109. A liquid of density 800 kg m^{-3} is filled in a tank open at the top. The pressure, of the liquid, at the bottom of the tank is 6.4 atmospheres. The velocity of efflux through a hole at the bottom is (1 atmosphere = 10^5 N m^{-2})

(a) $10\ ms^{-1}$ (b) $20\ ms^{-1}$

(c) $30\ ms^{-1}$ (d) $40\ ms^{-1}$

110. A cylindrical tank has a hole of $3cm^2$ in its bottom. If the water is allowed of flow into the tank from a tube above it at the rate of 80 cm^3/sec. then the maximum height up to which water can rise in the tank is

(a) 1.1 cm (b) 5 cm

(c) 10 cm (d) 0.25 cm

111. A water tank placed on the floor has two small holes. pinched in the vertical wall, one above the other. The holes are 3.3 cm and 4.7 cm above the floor. If the jets of water issuing out from the holes hit the floor at the same point on the floor, then the height of water in the tank is

(a) 3cm (b) 6cm

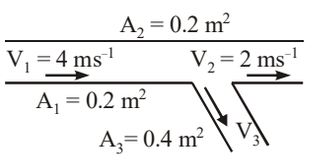
(c) 8cm (d) 9cm

112. There is a hole of area $\frac{1}{25}cm^2$ in the bottom of a cylindrical vessel containing fluid up to height h. The liquid flows out in time t. If the liquid were filled in the vessel up to height 4h, then it would flow out in time

(a) t (b) 2t

(c) 4t (d) $\frac{t}{2}$

113. In the figure, the velocity V_3 will be



(a) Zero (b) $4\ ms^{-1}$

(c) $1\ ms^{-1}$ (d) $3\ ms^{-1}$

114. A liquid is allowed to flow into a tube of truncated cone shape. Identify the correct statement from the following:

(a) the speed is high at the wider end and high at the narrow end.

(b) the speed is low at the wider end and high at the narrow end.

(c) the speed is same at both ends in a stream line flow.

(d) the liquid flows with uniform velocity in the tube.

115. A wide vessel with a small hole at the bottom is filled with water (density ρ_1, height h_1) and kerosene (density ρ_2, height h_2). Neglecting viscosity effects, the speed with which water flows out is :

(a) $[2g(h_1 + h_2)]^{1/2}$

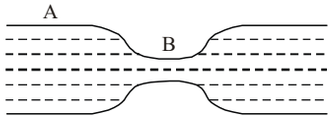
(b) $[2g(h_1\rho_1 + h_2\rho_2)]^{1/2}$

(c) $[2g(h_1 + h_2(\rho_2/\rho_1))]^{1/2}$

(d) $[2g\ (h_1 + h_2(\rho_1/\rho_2))]^{1/2}$

116. Water flows in a horizontal tube (see figure). The pressure of water changes by 700 Nm^{-2} between A and B where the area of cross section are 40 cm^2 and 20 cm^2, respectively. Find the rate of flow of water through the tube.

(density of water = 1000 kgm^{-3})



(a) 3020 cm^3/s (b) 2720 cm^3/s

(c) 2420 cm^3/s (d) 1810 cm^3/s

117. A liquid is filled upto a height of 20 cm in a cylindrical vessel. The speed of liquid coming out of a small hole at the bottom of the vessel is (g = 10 ms^{-2})

(a) $1.2\ ms^{-1}$ (b) $1\ ms^{-1}$

(c) $2\ ms^{-1}$ (d) $3.2\ ms^{-1}$

118. Beyond the critical speed, the flow of fluids becomes

(a) streamline (b) turbulent

(c) steady (d) very slow

119. The cylindrical tube of a spray pump has a cross - section of 8.0 cm^2, one end of which has 40 fine holes each of diameter 1.0 mm. If the liquid flow inside the tube is 1.5 m per minute, what is the speed of ejection of the liquid through the holes?

(a) $0.637\ ms^{-1}$ (b) $1.882\ ms^{-1}$

(c) $5.123\ ms^{-1}$ (d) $9.921\ ms^{-1}$

120. In which flow the velocity of fluid particles reaching a particular point is same at all time?

(a) vigrous flow

(b) steady flow

(c) turbulant flow

(d) None of these

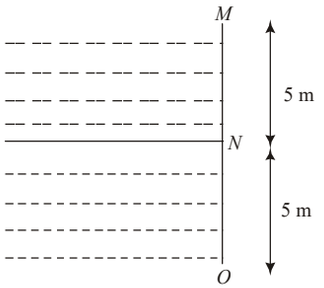
Exercise 2 : ACCELERATOR
Topic-wise MCQs

2.1 Fluids, Pressure, Pascal's Law, Variation of Pressure with Depth, Types of Pressure

1. A submarine experiences a pressure of 5.05×10^6 Pa at depth of d_1 in a sea. When it goes further to a depth of d_2, it experiences a pressure of 8.08×10^6 Pa. Then $d_1 - d_2$ is approximately (density of water = 10^3 kg/m^3 and acceleration due to gravity = 10 ms^{-2}):
(a) 300 m (b) 400 m
(c) 600 m (d) 500 m

2. A swimming pool has depth of 3 meters. The pressure at the bottom of the pool due to water alone is
(Density of water is 1000 kg m^{-3}, Acceleration due to gravity = 10 ms^{-2})
(a) 10^4 Pa (b) 3×10^3 Pa
(c) 29×10^3 Pa (d) 30×10^3 Pa

3. Two liquids of densities ρ_1 and $\rho_2(\rho_2 = 2\rho_1)$ are filled up behind a square wall of side 10 m as shown in figure. Each liquid has a height of 5 m. The ratio of the forces due to these liquids exerted on upper part *MN* to that at the lower part *NO* is (Assume that the liquids are not mixing):

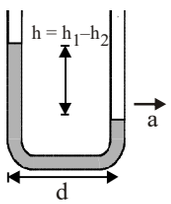


(a) 1/3 (b) 2/3
(c) 1/2 (d) 1/4

4. A U tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0 cm of water in one arm and 12.5 cm of spirit in the other, the relative density of spirit is
(a) 0.8 (b) 1.32
(c) 2.38 (d) 3.52

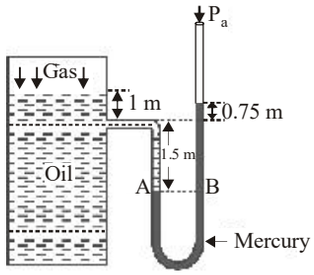
5. Figure shows a U-tube of uniform cross-sectional area A, accelerated with acceleration a as shown. If d is the separation between the limbs, then what is the difference in the levels of the liquid in the U-tube?

(a) $\frac{ad}{g}$
(b) $\frac{ag}{d}$
(c) $\frac{a}{d}$
(d) $\frac{dg}{a}$



6. Two cylindrical vessels A and B of different areas of cross–section kept on same horizontal plane are filled with water to the same height. If the volume of water in vessel A is 3 times the volume of water in vessel B, then the ratio of the pressures at the bottom of the vessels A and B is
(a) 1 : 1 (b) 1 : 3
(c) 1 : 9 (d) 1 : 6

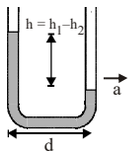
7. What is the absolute pressure of the gas above the liquid surface in the tank shown in fig. Density of oil = 820 kg/m^3, density of mercury = 13.6×10^3 kg/m^3. Given 1 atmospheric pressure = 1.01×10^5 N/m^2.



(a) 3.81×10^5 N/m^2
(b) 6×10^6 N/m^2
(c) 5×10^7 N/m^2
(d) 4.6×10^2 N/m^2

8. Figure shows a U-tube of uniform cross-sectional area A, accelerated with acceleration a as shown. If d is the separation between the limbs, then what is the difference in the levels of the liquid in the U-tube is

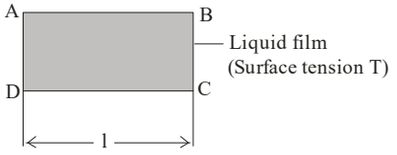
(a) $\frac{ad}{g}$ (b) $\frac{ag}{d}$
(c) $\frac{a}{d}$ (d) $\frac{dg}{a}$



9. In a hydraulic lift, compressed air exerts a force F_1 on a small piston having a radius of 5 cm. This pressure is transmitted to a second piston of radius 15 cm. If the mass of the load to be lifted is 1350 kg, find the value of F_1? The pressure necessary to accomplish this task is
(a) 1.4×10^5 Pa (b) 2×10^5 Pa
(c) 1.9×10^5 Pa (d) 1.9 Pa

10. The force acting on a window of area 50 cm × 50 cm of a submarine at a depth of 2000 m in an ocean, interior of which is maintained at sea level atmospheric pressure is
(Density of sea water = 10^3 kgm^{-3}, g = 10 ms^{-2})
(a) 10^6 N (b) 5×10^5 N
(c) 25×10^6 N (d) 5×10^6 N

11. A liquid film is formed over a frame ABCD as shown in figure. Wire CD can slide without friction. Maximum value of mass that can be hanged from CD without breaking the liquid film is



(a) $\frac{Tl}{g}$ (b) $\frac{2Tl}{g}$

(c) $\frac{2Tl}{g}$ (d) $T \times l$

2.2 Surface Tension, Angle of Contact & Capillarity

12. A 10 cm long wire is placed horizontally on the surface of water and is gently pulled up with a force of 2×10^{-2} N. To keep the wire in equilibrium, the surface tension in Nm^{-1} of water is

(a) 0.1 (b) 0.2

(c) 0.001 (d) 0.002

13. A wooden stick 2 m long is floating on the surface of water. The surface tension of water is 0.07 Nm^{-1}. By putting soap solution on one side of the stick, the surface tension is reduced to 0.06 Nm^{-1}. The net force on the stick will be

(a) 0.07 N (b) 0.06 N

(c) 0.01 N (d) 0.02 N

14. The excess pressure inside an air bubble of radius r just below the surface of water is p_1. The excess pressure inside a drop of the same radius just outside the surface is p_2. If T is the surface tension, then

(a) $p_1 = 2p_2$ (b) $p_1 = p_2$

(c) $p_2 = 2p_1$ (d) $p_2 = 0, p_1 \neq 0$

15. The surface tension of water at temperature of the experiment is 7.30×10^{-2} Nm^{-1}. (1 atm pressure = 1.01×10^5 Pa, density of water = 1000 kgm^{-3} and g = 9.80 ms^{-2}). Calculate the pressure inside a bubble of radius 1mm.

(a) 3×10^2 Pa (b) 8×10^4 Pa

(c) 1.01×10^5 Pa (d) 7×10^3 Pa

16. If the air bubble of radius r is formed at a depth h inside the container of soap solution of density ρ, the total pressure inside the bubble is (here, p_o denotes the atmospheric pressure and σ denotes surface tension)

(a) $\frac{2\sigma}{r} + h\rho g$ (b) $\frac{2\sigma}{r} - h\rho g$

(c) $\frac{2\sigma}{r} + p_o + h\rho g$ (d) $\frac{2\sigma}{r} + p_o - h\rho g$

17. Two capillary tube of radii 0.3 cm and 0.4 cm are dipped in the same liquid. The ratio of respective heights through which liquid will rise, is

(a) 3 : 4 (b) 4 : 3

(c) 1 : 1 (d) 1 : 2

18. A liquid rises to a height of 1.8 cm in a glass capillary A. Another glass capillary B having diameter 90% of capillary A is immersed in the same liquid. The rise of liquid in capillary B is

(a) 1.4 cm (b) 1.8 cm

(c) 2.0 cm (d) 2.2 cm

19. The lower end of a capillary tube of diameter 2.00 mm is dipped 8.00 cm below the surface of water in a beaker. What is the pressure required in the tube in order to blow a hemispherical bubble at its end in water?

(a) 2×10^5 Pa (b) 1.01784×10^5 Pa

(c) 3×10^3 Pa (d) 2.438×10^5 Pa

20. A drop of liquid pf density ρ is floating half immersed in a liquid of density σ and surface tension 7.5×10^{-4} Ncm^{-1}. The radius of drop in cm will be : (Take : g = 10 m/s^2)

(a) $\frac{15}{\sqrt{2\rho - \sigma}}$ (b) $\frac{15}{\sqrt{\rho - \sigma}}$

(c) $\frac{3}{2\sqrt{\rho - \sigma}}$ (d) $\frac{3}{20\sqrt{2\rho - \sigma}}$

21. The work done in increasing the size of a soap film from 10 cm × 6 cm to 10 cm × 11 cm is 3×10^{-4}J. The surface tension of the film is

(a) 11×10^{-2} N/m (b) 6×10^{-2} N/m

(c) 3×10^{-2} N/m (d) 1.5×10^{-2} N/m

22. A mercury drop of radius 1 cm is sprayed into 10^6 drops of equal size. The energy expressed in joule is (surface tension of Mercury is 460×10^{-3} N/m)

(a) 0.057 (b) 5.7

(c) 5.7×10^{-4} (d) 5.7×10^{-6}

23. Work done in increasing the size of a soap bubble from radius 3 cm to 5 cm is nearly (surface tension of soap solution = 0.03 Nm^{-1})

(a) 0.2 πmJ (b) 2 πmJ (c) 0.4 πmJ (d) 4 πmJ

24. Two small drops of mercury each of radius R coalesce to form a single large drop. The ratio of total surface energy before and after the change is :

(a) $2^{\frac{1}{3}} : 1$ (b) $1 : 2^{\frac{1}{3}}$

(c) 2 : 1 (d) 1 : 2

25. A glass capillary tube of inner diameter 0.28 mm is lowered vertically into water in a vessel. The pressure to be applied on the water in the tube so that water level in the tube is same as that in the vessel in N/m^2 is (surface tension of water = 0.07 N/m, atmospheric pressure = 10^5 N/m^2) :

(a) 10^3 (b) 99×10^3

(c) 100×10^3 (d) 101×10^3

26. A 20 cm long capillary tube is dipped in water. The water rises up to 8 cm. If the entire arrangement is put in a freely falling elevator the length of water column in the capillary tube will be

(a) 10 cm (b) 8 cm

(c) 20 cm (d) 4 cm

27. Water rises in a capillary tube to a certain height such that the upward force due to surface tension is balanced by 7.5×10^{-4}N force due to the weight of the liquid. If the surface tension of water is 6×10^{-2}Nm^{-1}, the inner circumference of the capillary tube must be

(a) 1.25×10^{-2}m (b) 0.50×10^{-2}m

(c) 6.5×10^{-2}m (d) 12.5×10^{-2}m

28. Radius of a capillary tube is 2×10^{-3}m. A liquid of weight 6.28×10^{-4}N may remain in the capillary then the surface tension of liquid will be

(a) 5×10^{3} N/m (b) 5×10^{-2} N/m

(c) 5 N/m (d) 50 N/m

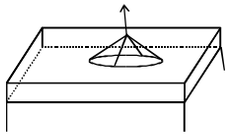
29. A water film is formed between two straight parallel wires of 10 cm length 0.5 cm apart. If the distance between wires is increased by 1 mm. What will be the work done?

(surface tension of water = 72 dyne/cm)

(a) 36 erg (b) 288 erg

(c) 144 erg (d) 72 erg

30. The surface tension of water is 75 dyne/cm. Find the minimum vertical force required to pull a thin wire ring up (refer figure) if it is initially resting on a horizontal water surface. The circumference of the ring is 20 cm and its weight is 0.1 N :



(a) 0.125 N

(b) 0.225 N

(c) 0.115 N

(d) 0.130 N

31. Two narrow bores of diameter 5.0 mm and 8.0 mm are joined together to form a U-shaped tube open at both ends. If this U-tube contains water, what is the difference in the level of two limbs of the tube.

[Take surface tension of water T = 7.3×10^{-2} Nm^{-1}, angle of contact = 0, g = 10 ms^{-2} and density of water = 1.0×10^{3} kg m^{-3}]

(a) 3.62 mm (b) 2.19 mm

(c) 5.34 mm (d) 4.97 mm

32. A water drop of radius 1 cm is borken into 729 equal droplets. If surface tension of water is 75 dyne/cm, then the gain in surface energy upto first decimal place will be : (Given π = 3.14)

(a) 8.5×10^{-4} J (b) 8.2×10^{-4} J

(c) 7.5×10^{-4} J (d) 5.3×10^{-4} J

33. A capillary tube made of glass of radius 0.15 mm is dipped vertically in a beaker filled with methylene iodide (surface tension = 0.05 Nm^{-1}, density = 667 kg m^{-3}) which rises to height h in the tube. It is observed that the two tangents drawn from liquid-glass interfaces (from opp. sides of the capillary) make an angle of 60° with one another. Then h is close to (g = 10 ms^{-2}).

(a) 0.049 m (b) 0.087 m

(c) 0.137 m (d) 0.172 m

34. The height of liquid column raised in a capillary tube of certain radius when dipped in liquid A vertically is, 5 cm. If the tube is dipped in a similar manner in another liquid B of surface tension and density double the values of liquid A, the height of liquid column raised in liquid B would be

(a) 0.20 m (b) 0.5 m

(c) 0.05 m (d) 0.10 m

35. Two soap bubbles coalesce to form a single bubble. If V is the consequent change in volume of contained air and S is the change in total surface area, T is the surface tension and P atmospheric pressure, then which of the following relation is correct?

(a) 4PV + 3ST = 0 (b) 3PV + 4ST = 0

(c) 2PV + 3ST = 0 (d) 3PV + 2ST = 0

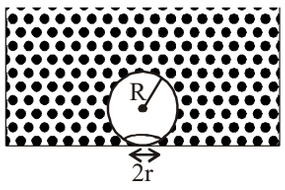
36. On heating water, bubbles being formed at the bottom of the vessel detach and rise. Take the bubbles to be sphere of radius R and making a circular contact of radius r with the bottom of the vessel. If r << R and the surface tension of water is T, value of r just before bubbles detach is: (density of water is ρ_w)

(a) $R^2\sqrt{\frac{\rho_w g}{3T}}$

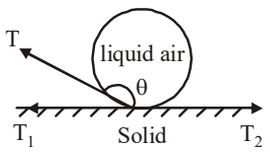
(b) $R^2\sqrt{\frac{2\rho_w g}{3T}}$

(c) $R^2\sqrt{\frac{\rho_w g}{T}}$

(d) $R^2\sqrt{\frac{3\rho_w g}{T}}$



37. Let T_1 be surface tension between solid and air, T_2 be the surface tension between solid and liquid and T be the surface tension between liquid and air. Then in equilibrium, for a drop of liquid on a clean glass plate, the relation is (θ is angle of contact)



(a) $\cos\theta = \frac{T}{T_1 + T_2}$ (b) $\cos\theta = \frac{T}{T_1 - T_2}$

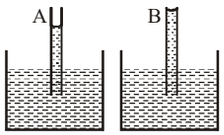
(c) $\cos\theta = \frac{T_1 + T_2}{T}$ (d) $\cos\theta = \frac{T_1 - T_2}{T}$

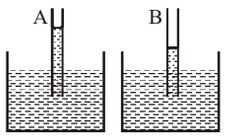
38. A thin metal disc of radius r floats on water surface and bends the surface downwards along the perimeter making an angle θ with vertical edge of the disc. If the disc displaces a weight of water W and surface tension of water is T, then the weight of metal disc is:

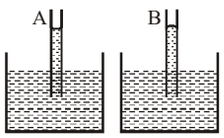
(a) $2\pi rT + W$ (b) $2\pi rT\cos\theta - W$

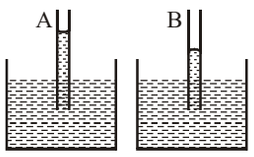
(c) $2\pi rT\cos\theta + W$ (d) $W - 2\pi rT\cos\theta$

39. A capillary tube (A) is dipped in water. Another identical tube (B) is dipped in a soap -water solution. Which of the following shows the relative nature of the liquid columns in the two tubes ?

(a) 

(b) 

(c) 

(d) 

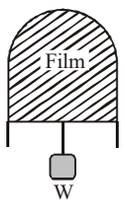
40. A thin liquid film formed between a U-shaped wire and a light slider supports a weight of 1.5×10^{-2} N (see figure). The length of the slider is 30 cm and its weight negligible. The surface tension of the liquid film is

(a) $0.0125\ \text{Nm}^{-1}$

(b) $0.1\ \text{Nm}^{-1}$

(c) $0.05\ \text{Nm}^{-1}$

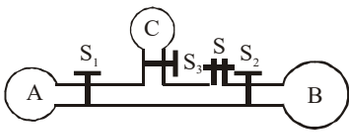
(d) $0.025\ \text{Nm}^{-1}$



41. Two soap bubbles A and B are kept in a closed chamber where the air is maintained at pressure 8 N/m^2. The radii of bubbles A and B are 2 cm and 4 cm, respectively.Surface tension of the soap-water used to make bubbles is 0.04 N/m. Find the ratio n_B/n_A, where n_A and n_B are the number of moles of air in bubbles A and B, respectively. [Neglect the effect of gravity]

(a) 2 (b) 9 (c) 8 (d) 6

42. The diagram below shows three soap bubbles A, B and C prepared by blowing the capillary tube fitted with stop cocks S, S_1, S_2 and S_3. When all the three stop cocks S_1, S_2 and S_3 are opened and S closed



(a) B will start collapsing with the increasing volume of A and C

(b) C will start collapsing with the increasing volume of A and B

(c) volumes of A, B and C will become equal at equilibrium

(d) C and A will both start collapsing with the increasing volume of B

43. A capillary tube of radius r is immersed vertically in a liquid such that liquid rises in it to height h (less than the length of the tube). Mass of liquid in the capillary tube is m. If radius of the capillary tube is increased by 50%, then mass of liquid that will rise in the tube, is

(a) $\frac{2}{3}$m (b) m (c) $\frac{3}{2}$m (d) $\frac{9}{4}$m

44. Assume that a drop of liquid evaporates by decrease in its surface energy, so that its temperature remains unchanged.What should be the minimum radius of the drop for this to be possible? The surface tension is T, density of liquid is ρ and L is its latent heat of vaporization.

(a) rL/T (b) $\sqrt{T/\rho L}$ (c) T/rL (d) 2T/rL

45. In the glass capillary tube, the shape of the surface of the liquid depends upon

(a) Only on the cohesive force of liquid molecules

(b) Only on the adhesive force between the molecules of glass and liquid

(c) Only on relative cohesive and adhesive force between the atoms

(d) Neither on cohesive nor on adhesive force

46. The lower end of a glass capillary tube is dipped in water. Water rises to a height of 8 cm. The tube is then broken at a height of 6 cm. The height of water column and angle of contact will be

(a) $6cm, \sin^{-1}\frac{3}{4}$ (b) $6cm, \cos^{-1}\frac{3}{4}$

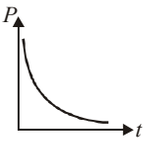
(c) $4cm, \sin^{-1}\frac{1}{2}$ (d) $4cm, \cos^{-1}\frac{1}{2}$

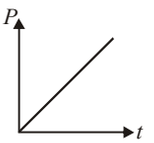
47. Two capillary tubes of same diameter are put vertically one each in two liquids whose relative densities are 0.8 and 0.6 and surface tensions are 60 and 50 dyne/cm respectively

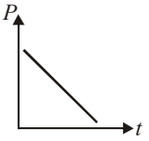
Ratio of heights of liquids in the two tubes $\frac{h_1}{h_2}$ is

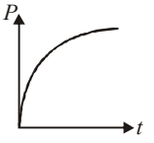
(a) 9 : 10 (b) 10 : 9 (c) 81 : 100 (d) 7 : 8

48. A soap bubble is blown with the help of a mechanical pump at the mouth of a tube. The pump produces a certain increase per minute in the volume of the bubble, irrespective of its internal pressure. The graph between the pressure inside the soap bubble and time t will be.

(a) 

(b) 

(c) 

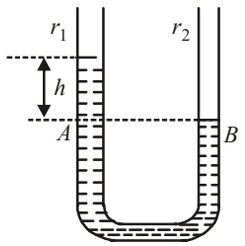
(d) 

49. Drops of liquid of density ρ are floating half immersed in a liquid of density σ. If the surface tension of liquid is T, the radius of the drop will be

(a) $\sqrt{\frac{3T}{g(3\rho-\sigma)}}$ (b) $\sqrt{\frac{6T}{g(2\rho-\sigma)}}$

(c) $\sqrt{\frac{3T}{g(2\rho-\sigma)}}$ (d) $\sqrt{\frac{3T}{g(4\rho-3\sigma)}}$

50. In the figure shown, radius of the limbs of the manometer are r_1 and r_2 ($< r_1$). The surface tension of the liquid is T. The difference of the heights of the liquid column h is equal to (Assume that the angle of contact is zero).



(a) $\frac{2T}{\rho g}\left(\frac{1}{r_2}-\frac{1}{r_1}\right)$

(b) $\frac{T}{\rho g}\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$

(c) $\frac{2T}{\rho g}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$

(d) $\frac{T}{\rho g}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$

51. In a capillary tube, water rises to 3 mm. The height of water that will rise in another capillary tube having one-third radius of the first is

(a) 1 *mm* (b) 3 *mm* (c) 6 *mm* (d) 9 *mm*

52. A small drop is formed using a dropper over a clean solid surface, then which of the following statement(s) is/are correct?

where, S_{la} = surface force of liquid and air,

S_{sa} = surface force of solid and air

and S_{ls} = surface force of liquid and solid.

(a) If $S_{ls} > S_{la}$, then angle of contact is less than 90°.

(b) If $S_{ls} > S_{la}$, then angle of contact is equal to 90°.

(c) If $S_{ls} > S_{la}$, then liquid spreads over solid surface.

(d) If $S_{ls} > S_{la}$, then liquid does not spread on solid surface

53. A mercury drop of radius 10^{-3} m is broken into 125 equal size droplets. Surface tension of mercury is 0.45 Nm^{-1}. The gain in surface energy is:

(a) 5×10^{-5} J (b) 2.26×10^{-5} J

(c) 17.5×10^{-5} J (d) 28×10^{-5} J

2.3 Viscosity, Stoke's Law & Terminal Velocity

54. A water drop of radius 1 μ*m* falls in a situation where the effect of buoyant force is negligible. Coefficient of viscosity of air is 1.8×10^{-5} Nsm^{-2} and its density is negligible as compared to that of water 10^6 gm^{-3}. Terminal velocity of the water drop is:

(Take acceleration due to gravity = 10 ms^{-2})

(a) 145.4×10^{-6} ms^{-1} (b) 118.0×10^{-6} ms^{-1}

(c) 132.6×10^{-6} ms^{-1} (d) 123.4×10^{-6} ms^{-1}

55. In an experiment to verify Stokes law, a small spherical ball of radius r and density ρ falls under gravity through a distance h in air before entering a tank of water. If the terminal velocity of the ball inside water is same as its velocity just before entering the water surface, then the value of h is proportional to :

(ignore viscosity of air)

(a) r^4 (b) r (c) r^3 (d) r^2

56. Consider two solid spheres P and Q each of density 8 gem^{-3} and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density 0.8 gcm^{-3} and viscosity η = 3 poiseuille. Sphere Q is dropped into a liquid of density 1.6 gcm^{-3} and viscosity η = 2 poiseiulle. The ratio of the terminal velocities of P and Q is

(a) 3 : 1 (b) 9 : 1 (c) 2 : 4 (d) 4 : 2

57. Two identical spherical drops of water and falling (vertically downwards) through air with a steady velocity of 5cm/sec. If both the drops coalesce (combine) to form a new spherical drop, the terminal velocity of the new drop will be (neglect buoyant force on the drops.)

(a) 5 × 2 cm/sec (b) $5 \times \sqrt{2}$ cm /sec

(c) $5 \times (4)^{1/3}$ cm/sec (d) $\frac{5}{\sqrt{2}}$ cm/sec

58. A metal ball B_1 (density 3.2 g/cc) is dropped in water while another metal ball B_2 (density 6.0 g/cc) is dropped in a liquid of density 1.6 g/cc. If both the balls have the same diameter and attain the same terminal velocity, the ratio of viscosity of water to that of the liquid is

(a) 2.0

(b) 0.5

(c) 4.0

(d) indeterminate due to insufficient data

59. Two uniform solid balls of same density and of radii r and 2r are dropped in air and fall vertically downwards. The terminal velocity of the ball with radius r is 1 cm s^{-1}, then the terminal velocity of the ball of radius 2r will be

(neglect buoyant force on the balls.)

(a) 0.5 cm s^{-1} (b) 4 cm s^{-1}

(c) 1 cm s^{-1} (d) 2 cm s^{-1}

60. What is the velocity v of a metallic ball of radius r falling in a tank of liquid at the instant when its acceleration is one-half that of a freely falling body? (The densities of metal and of liquid are ρ and σ respectively, and the viscosity of the liquid is η).

(a) $\frac{r^2 g}{9\eta}(\rho - 2\sigma)$ (b) $\frac{r^2 g}{9\eta}(2\rho - \sigma)$

(c) $\frac{r^2 g}{9\eta}(\rho - \sigma)$ (d) $\frac{2r^2 g}{9\eta}(\rho - \sigma)$

2.4 Fluids in Motion, Bernoulli's Principle

61. Water from a tap emerges vertically downwards with an initial speed of 1.0 ms^{-1}. The cross-sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water and that the flow is streamlined. The cross-sectional area of the stream, 0.15 m below the tap would be :

[Take g = 10 ms^{-2})

(a) $2\times10^{-5}\,m^2$ (b) $5\times10^{-5}\,m^2$

(c) $5\times10^{-4}\,m^2$ (d) $1\times10^{-5}\,m^2$

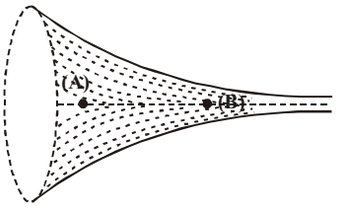
62. A fluid is flowing through a horizontal pipe of varying cross-section, with speed v ms^{-1} at a point where the pressure is P Pascal. At another point where pressure is $\frac{P}{2}$ Pascal its speed is V ms^{-1}. If the density of the fluid is ρ kg m^{-3} and the flow is streamline, then V is equal to :

(a) $\sqrt{\frac{P}{\rho}+v}$ (b) $\sqrt{\frac{2P}{\rho}+v^2}$ (c) $\sqrt{\frac{P}{2\rho}+v^2}$ (d) $\sqrt{\frac{P}{\rho}+v^2}$

63. An ideal fluid flows (laminar flow) through a pipe of non-uniform diameter. The maximum and minimum diameters of the pipes are 6.4 cm and 4.8 cm, respectively. The ratio of the minimum and the maximum velocities of fluid in this pipe is:

(a) $\frac{9}{16}$ (b) $\frac{\sqrt{3}}{2}$ (c) $\frac{3}{4}$ (d) $\frac{81}{256}$

64. The figure shows a liquid of given density flowing steadily in horizontal tube of varying cross-section. Cross sectional areas



at A is 1.5 cm^2, and B is 25 mm^2, if the speed of liquid at B is 60 cm/s then $(P_A - P_B)$ is :

(Given P_A and P_B are liquid pressures at A and B points.)

Density ρ = 1000 kg m^{-3}

A and B are on the axis of tube

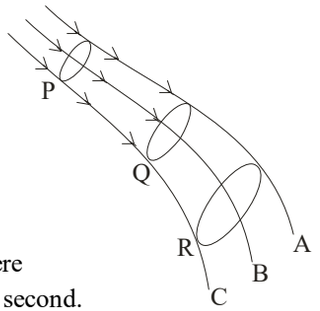
(a) 175 Pa (b) 27 Pa (c) 135 Pa (d) 36 Pa

65. A large tank filled with water to a height 'h' is to be emptied through a small hole at the bottom. The ratio of time taken for the level of water to fall from h to h/2 and from h/2 to zero is

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

66. In case of streamline flow of a fluid (which is incompressible), consider these streamlines A, B and C (as show in the figure)

Let, P, Q and R are 3 planes perpendicular to the direction of flow of streamlines, then which of the following is correct?



(a) $m_P > m_Q > m_R$, where m = mass flow per second.

(b) $v_P > v_Q > v_R$

(c) $n_P > n_Q > n_R$, where n = number of fluid particles crossing area per unit time

(d) $m_P < m_Q < m_R$

67. Air is streaming past a horizontal airplane's wing such that its speed is 120 ms^{-1} over the upper surface and 90 ms^{-1} at the lower surface. If the density of air is 1.3 kgm^{-3} and the wing is 10 m long and has an average width of 2m, then the difference of the pressure on the two sides of the wing is

(a) 4095.0 Pa (b) 409.50 Pa

(c) 40.950 Pa (d) 4.0950 Pa

68. Water from a tap emerges vertically downwards with an initial velocity V_0. Assume pressure is constant throughout the stream of water and the flow is steady. Find the distance from the tap at which cross-sectional area of stream is half of the cross-sectional area of stream at the tap.

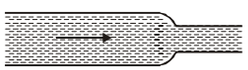
(a) $V_0^2/2g$ (b) $3V_0^2/2g$

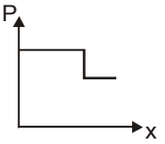
(c) $2V_0^2/g$ (d) $5V_0^2/2g$

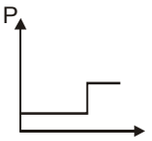
69. A large tank is filled with water to a height H. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to $\frac{H}{\eta}(\eta > 1)$; and it takes T_2 time to taken out the rest of water. If $T_1 = T_2$. then the value of η is

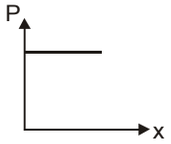
(a) 2 (b) 3 (c) 4 (d) $2\sqrt{2}$

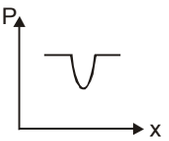
70. Water flows through a frictionless tube with a varying cross-section as shown in fig. Pressure P at points along the axis is represented by



(a) 

(b) 

(c) 

(d) 

Exercise 3 : PREVIOUS YEARS MCQs

1. A liquid is filled upto a height of 20 cm in a cylindrical vessel. The speed of liquid coming out of a small hole at the bottom of the vessel is ($g = 10\ ms^{-2}$) **[2025]**

(a) $1.2\ ms^{-1}$ (b) $1\ ms^{-1}$
(c) $2\ ms^{-1}$ (d) $3.2\ ms^{-1}$

2. The work done in increasing the size of a soap film from 10 cm × 6 cm to 10 cm × 11 cm is 3×10^{-4}J. The surface tension of the film is **[2025]**

(a) 11×10^{-2} N/m (b) 6×10^{-2} N/m
(c) 3×10^{-2} N/m (d) 1.5×10^{-2} N/m

3. A liquid does not wet the solid surface if angle of contact is **[2025]**

(a) zero (b) equal to 45°
(c) equal to 60° (d) greater than 90°

4. Pressure inside a soap bubble is greater than the pressure outside by an amount :
(given : R = Radius of bubble, S = Surface tension of bubble) **[2024]**

(a) $\frac{4S}{R}$ (b) $\frac{4R}{S}$ (c) $\frac{S}{R}$ (d) $\frac{2S}{R}$

5. A big drop is formed by coalescing 1000 small droplets of water. The surface energy will become: **[2024]**

(a) $\frac{1}{100}$th (b) $\frac{1}{10}$th
(c) 100 times (d) 10 times

6. Correct Bernoulli's equation is (symbols have their usual meaning) : **[2024]**

(a) $P + mgh + \frac{1}{2}mv^2 = \text{constant}$

(b) $P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

(c) $P + \rho gh + \rho v^2 = \text{constant}$

(d) $P + \frac{1}{2}\rho gh + \frac{1}{2}\rho v^2 = \text{constant}$

7. When two soap bubbles of radii a and b (b > a) coalesce, the radius of curvature of common surface is **[2024]**

(a) $\frac{ab}{b-a}$ (b) $\frac{ab}{a+b}$ (c) $\frac{b-a}{ab}$ (d) $\frac{a+b}{ab}$

8. A big drop is formed by coalescing 1000 small droplets of water. The surface energy will become: **[2024]**

(a) $\frac{1}{100}$th (b) $\frac{1}{10}$th
(c) 100 times (d) 10 times

9. If 'M' is the mass of water that rises in a capillary tube of radius 'r', then mass of water which will rise in a capillary tube of radius '2r' is : **[2024]**

(a) M (b) $\frac{M}{2}$ (c) 4 M (d) 2 M

10. A capillary is dipped in water vessel kept in a lift going up with acceleration 2 g. Then : **[2023]**

(a) The water will rise in the tube to the height observed under normal condition
(b) Water will rise to the maximum available height of the tube
(c) Water will rise to the height one third of the height of normal condition
(d) Water will rise to the height double the height of normal condition

11. Two spheres of the same material, but of radii R and $3R$ are allowed to fall vertically downwards through a liquid of density σ. The ratio of their terminal velocities is **[2023]**

(a) 1 : 3 (b) 1 : 6 (c) 1 : 9 (d) 1 : 1

12. A water drop of diameter 2 cm is broken into 64 equal droplets. The surface tension of water is 0.075 N/m. In this process the gain in surface energy will be : **[2022]**

(a) 2.8×10^{-4} J (b) 1.5×10^{-3} J
(c) 1.9×10^{-4} J (d) 9.4×10^{-5} J

13. If p is the density and η is coefficient of viscosity of fluid which flows with a speed v in the pipe of diameter d, the correct formula for Reynolds number R_e is : **[2022]**

(a) $R_e = \frac{\eta d}{\rho v}$ (b) $R_e = \frac{\rho v}{\eta d}$
(c) $R_e = \frac{\rho v d}{\eta}$ (d) $R_e = \frac{\eta}{\rho v d}$

14. Two capillary tubes A and B of diameter 1 mm and 2 mm respectively are dipped vertically in a liquid. If the capillary rise in A is 6 cm, then the capillary rise in B is **[2021]**

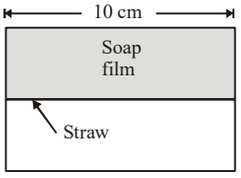
(a) 2 cm (b) 3 cm (c) 4 cm (d) 6 cm

15. A spherical solid ball of volume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_2 ($\rho_2 < \rho_1$). Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed v, *i.e.*, $F_{viscous} = -kv^2$ ($k > 0$). The terminal speed of the ball is **[2021]**

(a) $\sqrt{\frac{Vg(\rho_1 - \rho_2)}{k}}$ (b) $\frac{Vg\rho_1}{k}$

(c) $\sqrt{\frac{Vg\rho_1}{k}}$ (d) $\frac{Vg(\rho_1 - \rho_2)}{k}$

16. A soap film of surface tension 3×10^{-2} formed in a rectangular frame cam support a straw as shown in Fig. If $g = 10\ ms^{-12}$, the mass of the straw is **[2020]**



(a) 0.006 g

(b) 0.06 g

(c) 0.6 g

(d) 6 g

17. With the increase in temperature, the angle of contact

(a) decreases **[2020, 2006]**

(b) increases

(c) remains constant

(d) sometimes increases and sometimes decreases

18. A spherical ball of iron of radius 2 mm is falling through a column of glycerine. If densities of glycerine and iron are respectively 1.3×10^3 kg/m^3 and 8×10^3 kg/m^3. η for glycerine = 0.83 Nm^{-2} sec, then the terminal velocity is

(a) 0.7 m/s (b) 0.07 m/s **[2020]**

(c) 0.007 m/s (d) 0.0007 m/s

19. Two small drops of mercury each of radius 'R' coalesce to form a large single drop. The ratio of the total surface energies before and after the change is **[2019]**

(a) $2^{2/3} : 1$ (b) $\sqrt{2} : 1$

(c) $2^{1/3} : 1$ (d) $2 : 1$

20. Two capillary tubes of different diameters are dipped in water. The rise of water is **[2019, 2017]**

(a) zero in both the tube

(b) same in both the tube

(c) more in the tube of larger diameter

(d) more in the tube of smaller diameter

21. A metal sphere of radius 'R' and density 'e_1' is dropped in a liquid of density 'σ' moves with terminal velocity 'V'. Another metal sphere of same radius and density 'e_2' is dropped in the same liquid, its terminal velocity will be **[2019]**

(a) $V\left[\frac{(e_2 + \sigma)}{(e_1 + \sigma)}\right]$ (b) $V\left[\frac{(e_1 + \sigma)}{(e_2 + \sigma)}\right]$

(c) $V\left[\frac{(e_2 - \sigma)}{(e_1 - \sigma)}\right]$ (d) $V\left[\frac{(e_1 - \sigma)}{(e_2 - \sigma)}\right]$

22. A vessel completely filled with water has holes 'A' and 'B' at depths 'h' and '3h' from the top respectively. Hole 'A' is a square of side 'L' and 'B' is circle of radius 'r'. The water flowing out per second from both the holes is same. Then 'L' is equal to **[2018]**

(a) $r^{\frac{1}{2}}(\pi)^{\frac{1}{2}}(3)^{\frac{1}{2}}$ (b) $r \cdot (\pi)^{\frac{1}{2}}(3)^{\frac{1}{4}}$

(c) $r \cdot (\pi)^{\frac{1}{2}}(3)^{\frac{1}{4}}$ (d) $r^{\frac{1}{2}}(\pi)^{\frac{1}{3}}(3)^{\frac{1}{2}}$

23. In a capillary tube having area cross-section 'A' water rises to a height 'h'. If cross-sectional area is reduced to $\frac{A}{9}$, the rise of water in the capillary tube is **[2013]**

(a) 4h (b) 3h (c) 2h (d) h

24. When one end of the capillary is dipped in water, the height of water column is 'h'. The upward force of 105 dyne due to surface tension is balanced by the force due to the weight of water column. The inner circumference of capillary is

(Surface tension of water = 7×10^{-2} N/m) **[2010]**

(a) 1.5 cm (b) 2 cm (c) 2.5 cm (d) 3 cm

25. A big water drop is formed by the combination of 'n' small water drops of equal radii. The ratio of the surface energy of 'n'drops to the surface energy of big drop is **[2008]**

(a) $n^2 : 1$ (b) $n : 1$ (c) $\sqrt{n} : 1$ (d) $\sqrt[3]{n} : 1$

26. A liquid drop having surface energy E is spread into 512 droplets of same size. The final surface energy of the droplets is **[2007]**

(a) 2E (b) 4E (c) 8E (d) 12E

27. In a capillary tube of radius R, a straight thin metal wire of radius r ($R > r$) is inserted symmetrically and one end of the combination is dipped vertically in water such that the lower end of the combination is at same level. The rise of water in the capillary tube is

[T = surface tension of water, ρ = density of water and g = gravitational acceleration] **[2005]**

(a) $\frac{T}{(R+r)\rho g}$ (b) $\frac{R\rho g}{2T}$

(c) $\frac{2T}{(R-r)\rho g}$ (d) $\frac{(R-r)\rho g}{T}$

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(d)	**13**	(d)	**25**	(c)	**37**	(c)	**49**	(a)	**61**	(a)	**73**	(b)	**85**	(d)	**97**	(c)	**109**	(d)
2	(d)	**14**	(b)	**26**	(b)	**38**	(a)	**50**	(b)	**62**	(c)	**74**	(d)	**86**	(b)	**98**	(a)	**110**	(a)
3	(b)	**15**	(d)	**27**	(b)	**39**	(c)	**51**	(a)	**63**	(c)	**75**	(b)	**87**	(d)	**99**	(c)	**111**	(c)
4	(a)	**16**	(d)	**28**	(c)	**40**	(b)	**52**	(a)	**64**	(a)	**76**	(a)	**88**	(b)	**100**	(c)	**112**	(b)
5	(c)	**17**	(c)	**29**	(a)	**41**	(a)	**53**	(d)	**65**	(d)	**77**	(d)	**89**	(c)	**101**	(d)	**113**	(c)
6	(c)	**18**	(a)	**30**	(d)	**42**	(d)	**54**	(a)	**66**	(d)	**78**	(a)	**90**	(b)	**102**	(a)	**114**	(b)
7	(d)	**19**	(a)	**31**	(a)	**43**	(d)	**55**	(b)	**67**	(b)	**79**	(b)	**91**	(d)	**103**	(b)	**115**	(c)
8	(a)	**20**	(a)	**32**	(c)	**44**	(b)	**56**	(a)	**68**	(d)	**80**	(a)	**92**	(c)	**104**	(a)	**116**	(b)
9	(a)	**21**	(b)	**33**	(c)	**45**	(a)	**57**	(c)	**69**	(b)	**81**	(d)	**93**	(a)	**105**	(b)	**117**	(c)
10	(c)	**22**	(c)	**34**	(b)	**46**	(c)	**58**	(d)	**70**	(c)	**82**	(d)	**94**	(b)	**106**	(c)	**118**	(b)
11	(b)	**23**	(a)	**35**	(b)	**47**	(b)	**59**	(c)	**71**	(c)	**83**	(b)	**95**	(b)	**107**	(d)	**119**	(a)
12	(b)	**24**	(c)	**36**	(d)	**48**	(b)	**60**	(b)	**72**	(a)	**84**	(c)	**96**	(b)	**108**	(a)	**120**	(b)
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(a)	**8**	(a)	**15**	(c)	**22**	(a)	**29**	(c)	**36**	(b)	**43**	(c)	**50**	(a)	**57**	(c)	**64**	(a)
2	(d)	**9**	(c)	**16**	(c)	**23**	(c)	**30**	(d)	**37**	(d)	**44**	(d)	**51**	(d)	**58**	(b)	**65**	(b)
3	(d)	**10**	(d)	**17**	(b)	**24**	(a)	**31**	(b)	**38**	(c)	**45**	(c)	**52**	(d)	**59**	(b)	**66**	(b)
4	(a)	**11**	(b)	**18**	(c)	**25**	(b)	**32**	(c)	**39**	(b)	**46**	(b)	**53**	(d)	**60**	(c)	**67**	(a)
5	(a)	**12**	(a)	**19**	(b)	**26**	(c)	**33**	(b)	**40**	(d)	**47**	(d)	**54**	(d)	**61**	(b)	**68**	(b)
6	(a)	**13**	(d)	**20**	(a)	**27**	(a)	**34**	(c)	**41**	(d)	**48**	(a)	**55**	(a)	**62**	(d)	**69**	(c)
7	(a)	**14**	(b)	**21**	(c)	**28**	(b)	**35**	(b)	**42**	(d)	**49**	(c)	**56**	(a)	**63**	(a)	**70**	(a)
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(c)	**4**	(a)	**7**	(a)	**10**	(c)	**13**	(c)	**16**	(c)	**19**	(c)	**22**	(c)	**25**	(d)		
2	(c)	**5**	(b)	**8**	(b)	**11**	(c)	**14**	(b)	**17**	(a)	**20**	(d)	**23**	(b)	**26**	(c)		
3	(d)	**6**	(b)	**9**	(d)	**12**	(a)	**15**	(a)	**18**	(b)	**21**	(c)	**24**	(a)	**27**	(c)		

3 Kinetic Theory of Gases and Radiation

TOPIC 3.1 : IDEAL GAS AND REAL GAS, MEAN FREE PATH, PRESSURE OF IDEAL GAS, ROOT MEAN SQUARE (RMS) SPEED

IDEAL GAS AND REAL GAS

Ideal Gas Equation

For n mol of any gas, PV = nRT and

For 1 gm. mol of gas, PV = RT

$$PV = N_A kT \quad (\because N_A \cdot k = R)$$

For one gram of gas, $PV = \frac{RT}{M_w}$

The ideal gas equation $PV = nRT$, can be used for real gases at high temperature and low pressure at which intermolecular forces are negligibly small. Vander Waal modified this equation so that it can be used for real gases at a wide range of temperature and pressure. He made following corrections :

At T = constant, $V \propto \frac{1}{P}$ (Boyle's law)

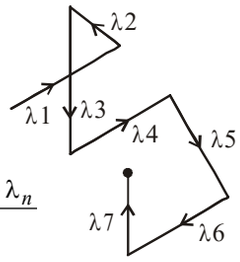
If P is constant, then we have $V \propto T$. (Charle's law)

when V = constant, $P \propto T$ (Gay Lussac's law or law of pressure)

MEAN FREE PATH (λ)

The mean free path of a gas molecule may be defined as the average distance travelled by the molecule between two successive collisions.

$$\text{Mean free path} = \frac{\text{Total distance travelled}}{\text{Number of collisions}}$$



$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 ... + \lambda_n}{n}$$

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 (N/V)}$$

PRESSURE OF IDEAL GAS

A gas exerts same pressure on the walls of a container which acts equally in all directions.

Expression for the Pressure Exerted by a Gas

$$\because \quad PV = \frac{1}{3} Nm.v_{rms}^2$$

$$\text{or} \quad P = \frac{1}{3} \frac{M}{V} \overline{v^2} \qquad (v_{rms}^2 = \overline{v^2})$$

$$P = \frac{1}{3} \rho v_{rms}^2 \quad (\because \frac{Nm}{V} = \rho \text{ density of gas})$$

ROOT MEAN SQUARE (RMS) SPEED

Root mean square speed . It is defined as the square root of mean of squares of the speed of different molecules, i.e.,

$$v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + ... + v_n^2}{n}}$$

According to kinetic theory of gases,

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

when M is the mass of one mole while m is the mass of one molecule.

As speed of sound in a gas $v = \sqrt{\frac{\gamma RT}{M}}$

$$\therefore \quad \frac{v}{v_{rms}} = \sqrt{\frac{\gamma}{3}}$$

$$v = \sqrt{\frac{\gamma}{3}} v_{rms}$$

Kinetic Interpretation of Temperature

KE of one molecule

N_A = Avogadro's number

$$KE \text{ per mole} = K_{\text{molecule}} = \frac{3}{2} \frac{RT}{N_A} = \frac{3}{2} kT$$

$$\text{Where k = Boltzmann's consant} = \frac{T}{N_A}$$

TOPIC 3.2 : LAW OF EQUIPARTITION OF ENERGY, DEGREE OF FREEDOM, SPECIFIC HEAT CAPACITY

LAW OF EQUIPARTITION OF ENERGY

According to this law, for a system in thermal equilibrium, the total energy of a dynamic system is equally distributed among its various degrees of freedom. The energy associated with each degree of freedom is $\frac{kT}{2}$ per molecule or $\frac{RT}{2}$ per mole.

DEGREE OF FREEDOM (f)

The term degree of freedom refers to the number of possible independent ways in which a system can have energy.

Degree of freedom of monatomic gas

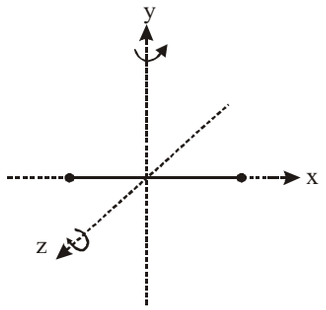
A monatomic gas molecule (like He) consists of a single atom. It can have translational motion in any direction in space. Thus, it has 3 translational degrees of freedom.

i.e., f = 3 (all translational)

It can also rotate but due to its small moment of inertia, rotational kinetic energy is neglected.

Degree of freedom of a diatomic and linear polyatomic gas :

The molecules of a diatomic and linear polyatomic gas (like O_2, CO_2 and H_2) cannot only move but also rotate about any one of the three co-ordinate axes as shown in fig. However, its moment of inertia about the axis joining the two atoms (x-axis) is negligible. Hence, it can have only two rotational degrees of freedom.



Thus, a diatomic molecule has 5 degrees of freedom : 3 translational and 2 rotational. At sufficiently high temperature it has vibrational energy as well, providing it two more degrees of freedom (one vibrational kinetic energy and another vibrational potential energy). Thus, at high temperature a diatomic molecule has 7 degrees of freedom : 3 translational, 2 rotational and 2 vibrational.

f = 5 (3 translational + 2 rotational) at room temperature and f = 7 (3 translational + 2 rotational + 2 vibrational) at high temperature.

SPECIFIC HEAT CAPACITY

When gases are heated, small change in temperature is accompanied with considerable change in both, volume and pressure. Hence it is necessary to define two specific heats of gases.

Specific Heat of a Gas at Constant Volume "c_v" :

It is the quantity of heat required to raise the temperature of unit mass of a gas through 1°C or 1K at constant volume.

Molar Specific Heat at Constant Volume "C_v" :

The amount of heat required to raise the temperature of 1 mole of gas through 1 K (or 1°C) at constant volume.

It is denoted by C_v.

If M_w is the molecular weight of the gas in gram, then

$$C_v = M_w \cdot c_v$$

At constant volume no external work is done by gas and total heat given to it is utilized for increase in internal energy.

So, $dU = \mu\, C_v\, dT$

Specific Heat of a Gas at Constant Pressure "c_p" :

It is the quantity of heat required to raise the temperature of unit mass of a gas through 1°C or 1 K at constant pressure.

Molar Specific Heat at Constant Pressure "C_p":

The amount of heat required to raise the temperature of 1 gram-mole of gas by 1 K (or 1°C) at constant pressure. It is denoted by C_p

$$C_p = M_w \cdot c_p$$

The S.I unit of both C_p and C_v : J K^{-1} mol^{-1}.

According to **Mayer's formula** $C_P - C_V = R$

Relation Between Principle and Molar Specific Heats

$$\boxed{n(C_p - C_v)dT = Pdv}$$

C_V, C_P and γ for different gases

1. **Monatomic Gas**

Degrees of freedom $f = 3$

Kinetic energy per mole $E = U = 3 \times \frac{RT}{2} = \frac{3RT}{2}$

Molar specific heat at constant volume

$$C_V = \frac{\partial U}{\partial T} = \frac{3R}{2}$$

Molar specific heat at constant pressure

$$C_P = C_V + R = \frac{5R}{2}$$

Ratio of specific heats $\gamma = \frac{C_P}{C_V} = \frac{5R/2}{3R/2}$

$$= \frac{5}{3} = 1.67$$

2. **Diatomic Gas**

Degree of freedom $f = 5$

Kinetic energy per mole $U = 5\times\frac{RT}{2} = \frac{5RT}{2}$

Molar specific heat at constant volume

$$C_V = \frac{\partial U}{\partial T} = \frac{5R}{2}$$

Molar specific heat at constant pressure

$$C_P = C_V + R = \frac{7R}{2}$$

Ratio of specific heats $\gamma = \frac{C_P}{C_V} = \frac{7R/2}{5R/2}$

$$= \frac{7}{5} = 1.4$$

3. **Triatomic or polyatomic**

Degrees of freedom $f = 6$

Kinetic energy per mole $U = 6\times\frac{RT}{2} = 3RT$

Molar specific heat at constant volume

$$C_V = \frac{\partial U}{\partial T} = 3R$$

Molar specific heat at constant pressure

$$C_P = C_V + R = 4R$$

Ratio of specific heats $\gamma = \frac{C_P}{C_V} = \frac{4R}{3R}$

$$= \frac{4}{3} = 1.33$$

For a molecule with f degrees of freedom

Kinetic energy per mole $U = f\times\frac{RT}{2} = \frac{fRT}{2}$

Molar specific heat at constant volume

$$C_V = \frac{\partial U}{\partial T} = \frac{fR}{2}$$

Molar specific heat at constant pressure

$$C_P = C_V + R = \frac{fR}{2} + R$$

$$= R\left(\frac{f}{2}+1\right)$$

Ratio of specific heats $\gamma = \frac{C_P}{C_V} = \frac{R(f/2+1)}{\frac{fR}{2}}$

or $\gamma = 1+\frac{2}{f}$

TOPIC 3.3 : ABSORPTION, REFLECTION AND TRANSMISSION OF HEAT RADIATION, PERFECT BLACK BODY, KIRCHHOFF'S LAW OF HEAT RADIATION, SPECTRAL DISTRIBUTION OF BLACK BODY RADIATION & STEFAN-BOLTZMANN LAW OF RADIATION

ABSORPTION, REFLECTION AND TRANSMISSION OF HEAT RADIATION

When a body is heated and placed in vacuum, it loses heat even when there is no medium surrounding it. The heat cannot go out from the body by the process of conduction or convection since both of these process require the presence of a material medium between source and surrounding objects. The process by which heat is lost in this case is called radiation. This does not require the presence of any material medium. It is by radiation that the heat from the sun reaches the earth.

Diathermanous substances : The substances which can transmit the radiant heat incident upon their surfaces are called diathermanous substances. ($t \neq 0$). The best diathermanous solids are rock salt, sylvine, quartz and certain other crystals. Pure air is highly diathermanous.

Athermanous substances : The substances which cannot transmit the radiant heat incident upon their surfaces are called athermanous substances. (t = 0). Water vapour and carbon dioxide are athermanous.

Absorption coefficient or absorptance:

$$a = \frac{Q_a}{Q} = \frac{Quantity\ of\ radiant\ energy\ absorbed\ by\ the\ body}{Quantity\ of\ radiant\ energy\ incident\ on\ the\ surface\ of\ the\ body}$$

Reflection coefficient or reflectance:

$$r = \frac{Q_r}{Q} = \frac{Quantity\ of\ radiant\ energy\ reflected}{Quantity\ of\ radiant\ energy\ incident\ on\ the\ surface\ of\ the\ body}$$

Transmission coefficient or transmittance:

$$t = \frac{Q_t}{Q} = \frac{Quantity\ of\ radiant\ energy\ transmitted\ by\ the\ body}{Quantity\ of\ radiant\ energy\ incident\ on\ the\ surface\ of\ the\ body}$$

And $Q_a + Q_r + Q_t = Q$

$\therefore \quad \frac{Q_a}{Q} + \frac{Q_r}{Q} + \frac{Q_t}{Q} = 1$ and also, $a + r + t = 1$

PERFECTLY BLACK BODY

A black body is defined as one that will completely absorb all the radiations of whatever wavelength which falls on it.

For perfectly black body, $a_\lambda = 1$.

Properties of perfectly black body :

(i) A perfectly black body absorbs all the radiant heat incident upon it. (i.e. a = 1)

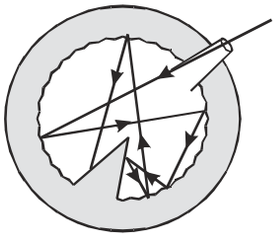
(ii) A perfectly black body does not reflect or transmit the radiant heat incident upon it. (i.e. t = 0, r = 0)

(iii) The coefficient of emission of a perfectly black body is 1. It is very good emitter of heat.

(iv) A perfectly black body does not exist in nature.

For practical purposes lamp black is treated as a perfectly black body as its coefficient of absorption is nearly 0.98.

Ferry's black body : It consists of a hollow copper sphere which is blackened inside with a small fine hole in the surface. The conical projection opposite the hole is to avoid direct reflection from surface opposite the hole.



Emissive power (e) : For a given surface it is defined as the radiant energy emitted per sec per unit area of the surface.

Spectral emissive power (e_λ) : If we consider emissive power of a surface for a particular wavelength instead of all wavelengths, it is called spectral emissive power and is represented by e_λ

Total emissive power, $e = \int_0^\infty e_\lambda d\lambda$.

Emissive power of a surface depends on its nature and temperature.

It is maximum for a perfectly black body and minimum for a smooth shining body.

Unit in SI system W/m^2

Absorptive power (a) : Absorptive power of a surface is defined as the ratio of the radiant energy absorbed by it in a given time to the total radiant energy incident on it in the same time. If Q calorie of heat fall on the surface and Q′ calorie out of it are absorbed, the absorptive power of the surface is given by,

$$a = \frac{Q'}{Q}$$

For a perfectly black body, absorptive power is maximum and unity. It has no unit and dimensions.

Spectral absorptive power (a_λ) : Spectral absorptive power is defined as the ratio of the radiant energy of a given wavelength absorbed by a given surface in a given time to the total radiant energy of that wavelength incident in the same time on the same surface within a unit wavelength range.

Total absorptive power, $a = \int_0^\infty a_\lambda d\lambda$.

Absolute emissivity : The emissivity e of a surface is defined as the quantity of heat radiated per second by one unit area of its surface when its temperature is 1°C above the surroundings.

Relative emissivity (e) : It is defined as the ratio of radiant energy emitted per unit time per unit surface area of a body at a given temperature (E) to the radiant energy emitted per unit time per unit surface area of a perfectly black body (E_b) at the same temperature.

i.e., $e = \frac{E}{E_b}$.

Different bodies

(i) *If a = t = 0 and r = 1 → body is perfect reflector*

(ii) *If r = t = 0 and a = 1 → body is perfectly black body*

(iii) *If a = r = 0 and t = 1 → body is perfect transmitter*

(iv) *If t = 0 ⇒ r + a = 1 or a = 1 – r, i.e., good reflectors are bad absorbers.*

KIRCHHOFF'S LAW OF HEAT RADIATION

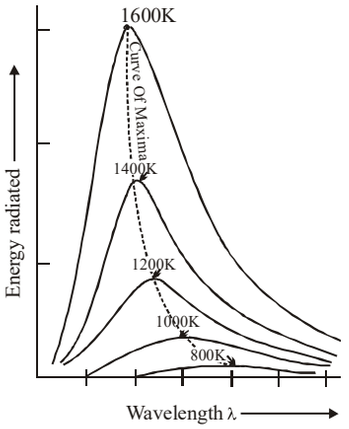
At any given temperature and for radiations of the same wavelength the ratio of the emissive power (e_λ) to the absorptive power (a_λ) is the same for all substances and is equal to the emissive power of a perfectly black body (E_λ).

i.e., $\frac{e_\lambda}{a_\lambda} = const. = E_\lambda$

Also, absorptive power of a body is equal to its emissivity.

i.e., $a_x = \varepsilon \quad \left[\because \frac{e_\lambda}{E_\lambda} = \varepsilon\right]$

SPECTRAL DISTRIBUTION OF BLACK BODY RADIATION



Each curve represents the variation of monochromatic emittance E_λ with wavelength λ for a certain temperature.

The following conclusions can be drawn from these curves:

The wavelength of maximum emission at various temperatures of the black body decreases as temp. increases. Therefore, the wavelength of maximum emission shifts towards smaller wavelength as the temperature of the black body increases. It is known as **Wien's displacement law**.

According to Wien's displacement law

$$\lambda_m \times T = b$$

Here, constant b is known as Wien's constant

STEFAN-BOLTZMANN LAW OF RADIATION

According to Stefan Boltzmann law, *the quantity of heat energy radiated in one second per unit area of a perfectly black body is directly proportional to the fourth power of its absolute temperature.*

i.e., $E_b \propto T^4$ *or* $E_b = \sigma T^4$

where σ is a universal constant known as Stefan-Boltzmann constant and T is its temperature on absolute scale. The measured value of σ is 5.67×10^{-8} W/m² –K⁴ or σ = 5.67×10^{-5} erg/cm²sK⁴.

Now, $\frac{Q_b}{A.t} = \sigma T^4$

Q_b = total energy radiated by the surface of a black body in time t.

or $Q_b = \sigma A t T^4$

From the eqⁿ., the emissive power E of a non-black body is given by: $E = \varepsilon E_b$ or $E = \varepsilon \sigma T^4$

∴ Total energy radiated by the surface of a body in time t

$Q = \varepsilon \sigma A t T^4$

CHAPTER AT A GLANCE

- Ideal gas -A gas which obeys the ideal gas equation PV = nRT at all temperatures and pressures.
- Ideal gas equation, PV = nRT or $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- Mean free path, $\bar{\lambda} = \frac{1}{\sqrt{2}n\pi d^2}$ n = number density, d = diameter of molecule
- Pressure exerted by a gas, $P = \frac{1}{3}\frac{M}{v}V_{rms}^2 = \frac{1}{3}\rho V_{rms}^2$
- Mean K.E. per molecule of a gas, $\bar{E} = \frac{1}{2}m\bar{v}^2 = \frac{3}{2}K_BT$
- Kinetic energy of a 1g of a gas $= \frac{1}{2}v_{rms}^2 = \frac{3}{2}\frac{R}{M}$
- R.M.S. speed, $v_{rms} = \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + ... + v_n^2}{n}}$
- $v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3Pv}{M}}$
- Energy associated with each degree of freedom per molecule, $= \frac{1}{2}K_BT$
- Number of degrees of freedom of the system, $f = 2N - K$
  N = number of particles in the system
  K = number of independent relations between the particles.
- For an ideal gas $C_p - C_v = R$
- Values of C_p, C_V and γ

Gas	C_V (in J/mol K)	C_p (in J/mol K)	$\gamma = \frac{C_p}{C_V}$
Monatomic	$\frac{3}{2}R$	$\frac{5}{2}R$	$\frac{5}{3} = 1.67$
Diatomic	$\frac{5}{2}R$	$\frac{7}{2}R$	$\frac{7}{5} = 1.4$
Polyatomic	3R	4R	$\frac{4}{3} = 1.33$

- The ratio of specific heats $\frac{C_P}{C_v} = \gamma$
- **Absorption coefficient or absorptance:**

$$a = \frac{Q_a}{Q} = \frac{\textit{Quantity of radiant energy absorbed by the body}}{\textit{Quantity of radiant energy incident on the surface of the body}}$$

- **Reflection coefficient or reflectance:**

$$r = \frac{Q_r}{Q} = \frac{\textit{Quantity of radiant energy reflected}}{\textit{Quantity of radiant energy incident on the surface of the body}}$$

- **Transmission coefficient or transmittance:**

$$t = \frac{Q_t}{Q} = \frac{\textit{Quantity of radiant energy transmitted by the body}}{\textit{Quantity of radiant energy incident on the surface of the body}}$$

- For perfectly black body, $a_\lambda = 1$
- From Kirchhoff's law of heat radiation

  i.e., $\frac{e_\lambda}{a_\lambda} = const. = E_\lambda$
- According to Wien's displacement law

  $\lambda_m \times T = b$
- From Stefan Boltzmann law, $E_b = \sigma T^4$

Exercise 1 : WARM-UP
Topic-wise MCQs

3.1 Ideal Gas and Real Gas, Mean Free Path, Pressure of Ideal Gas, Root Mean Square (RMS) Speed

1. In a cubical vessel are enclosed n molecules of a gas each having a mass m and an average speed v. If ℓ is the length of each edge of the cube, the pressure exerted by the gas will be

(a) $\frac{n m v^2}{\ell^3}$ (b) $\frac{n m^2 v}{2\ell^3}$

(c) $\frac{m n v^2}{3\ell^3}$ (d) $\frac{n m v}{2\ell}$

2. Pressure exerted by a gas is

(a) independent of density of the gas

(b) inversely proportional to the density of the gas

(c) directly proportional to the square of the density of the gas

(d) directly proportional to the density of the gas

3. A gas is enclosed in a cube of side *l*. What will be the change in momentum of the molecule, if it suffers an elastic collision with the plane wall parallel to *yz*-plane and rebounds with the same velocity ?

[(V_x, V_y & V_z) initial velocities of the gas molecules]

(a) mv_x (b) zero

(c) $-mv_x$ (d) $-2mv_x$.

4. At constant volume, temperature is increased then

(a) collision on walls will be less

(b) number of collisions per unit time will increase

(c) collisions will be in straight lines

(d) collisions will not change.

5. Gas at a pressure P_0 is contained in a vessel. If the masses of all the molecules are halved and their speeds are doubled, the resulting pressure *P* will be equal to

(a) $4P_0$ (b) $2P_0$

(c) P_0 (d) $\frac{P_0}{2}$

6. If 10^{22} gas molecules each of mass 10^{-26} kg collide with a surface (perpendicular to it) elastically per second over an area 1 m^2 with a speed 10^4 m/s, the pressure exerted by the gas molecules will be of the order of

(a) 10^4 N/m^2 (b) 10^8 N/m^2

(c) 10^3 N/m^2 (d) 10^{16} N/m^2

7. When the temperature of a gas is raised from 27°C to 90°C. The increase in the *rms* velocity of the gas molecules is

(a) 10% (b) 15%

(c) 20% (d) 17.5%

8. The rms velocity of a gas molecule of mass '*m*' at a given temperature is proportional to

(a) m° (b) m

(c) $\sqrt{m}$ (d) $\frac{1}{\sqrt{m}}$

9. The temperature at which the rms speed of oxygen molecules is 75% of rms speed of nitrogen molecules at a temperature of 287°C is

(a) 87°C (b) 127°C

(c) 227°C (d) 360°C

10. If the temperature of a gas is increased from 27°C to 159°C, the increase in the rms speed of the gas molecules is

(a) 142% (b) 71%

(c) 80% (d) 20%

11. If the rms speeds of helium and oxygen are equal, then the ratio of the temperatures of helium and oxygen is

(a) 1:8 (b) 2:1

(c) 1:4 (d) 4:1

12. If the temperature of a gas is increased from 27 °C to 159 °C, then the percentage increase in the rms speed of the gas molecules is

(a) 5 (b) 10

(c) 15 (d) 20

13. The rms speed of oxygen and room temperature is about 500 ms^{-1}. The rms speed of hydrogen at the same temperature is about

(a) 125 m s^{-1} (b) 2000 m s^{-1}

(c) 8000 m s^{-1} (d) 500 m s^{-1}

14. At what temperature an oxygen molecule has the same r.m.s velocity as the hydrogen molecule has at 20 K?

(a) 160 K (b) 320 K (c) 293 K (d) 347 K

15. The respective speeds of the five molecules are 1, 2, 3, 4 and 5 kms^{-1}. Then, the ratio of their rms velocity and the average velocity will be

(a) $\sqrt{11}:3$ (b) $3:\sqrt{11}$

(c) 1 : 2 (d) 3 : 4

16. In an ideal gas, if the masses of all molecules are doubled and their speeds are halved, then the ratio of initial and final pressure of the gas is

(a) 2 : 1 (b) 1 : 2

(c) 4 : 1 (d) 1 : 4

17. RMS velocity of oxygen molecules at NTP is 0.5 km/s. The RMS velocity for the hydrogen molecule at NTP is

(a) 4 km/s (b) 2 km/s

(c) 3 km/s (d) 1 km/s

18. What will be the effect on the root mean square velocity of oxygen molecules if the temperature is doubled and oxygen molecule dissociates into atomic oxygen?

(a) The velocity of atomic oxygen remains same

(b) The velocity of atomic oxygen doubles

(c) The velocity of atomic oxygen becomes half

(d) The velocity of atomic oxygen becomes four times

19. When a gas is in thermal equilibrium, its molecules

(a) have the same average kinetic energy of molecules

(b) have different energies which remain constant

(c) have a certain constant energy

(d) do not collide with one another

20. If the rms speed of oxygen molecules at 0°C is 160 m/s, find the rms speed of hydrogen molecules at 0°C.

(a) 640 m/s (b) 40 m/s

(c) 80 m/s (d) 332 m/s

21. In a mixture of gases at a fixed temperature

(a) heavier molecule has higher average speed

(b) lighter molecule has lower average speed

(c) heavier molecule has lower average speed

(d) None of these

22. The average kinetic energy per molecule of any ideal gas is always equal to

(a) $\frac{2}{3}k_BT$ (b) $\frac{3}{4}k_BT$

(c) $\frac{3}{2}k_BT$ (d) $3k_BT$

23. The average kinetic energy of gas molecules depends upon which of the following factor?

(a) Nature of the gas

(b) Temperature of the gas

(c) Volume of the gas

(d) Both (b) & (c)

24. Let v denote the rms speed of the molecules in an ideal diatomic gas at absolute temperature T.

The mass of a molecule is 'm' neglecting vibrational energy terms, the false statement is

(a) a molecule can have a speed greater than $\sqrt{2}v$

(b) v is proportional to $\sqrt{T}$

(c) the average rotational K.E. of a molecule is $\frac{1}{4}mv^2$

(d) the average K.E. of a molecule is $\frac{5}{6}mv^2$

25. The temperature of a gas is a measure of

(a) the average kinetic energy of the gaseous molecules

(b) the average potential energy of the gaseous molecules

(c) the average distance between the molecules of the gas

(d) the size of the molecules of the gas

26. If the rms speeds of helium and oxygen are equal, then the ratio of the temperatures of helium and oxygen is

(a) 1:8 (b) 2:1 (c) 1:4 (d) 4:1

27. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will.

(a) increase

(b) decrease

(c) remains the same

(d) decrease for some and increase for others

28. At a given temperature which of the following gases possesses maximum r.m.s. velocity?

(a) Hydrogen (b) Oxygen

(c) Nitrogen (d) Carbon dioxide

29. The root mean square speed of a group of n gas molecules, having speed $v_1, v_2, v_3, ..., v_n$ is

(a) $\frac{1}{n}\sqrt{(v_1+v_2+v_3+...+v_n)^2}$

(b) $\frac{1}{n}\sqrt{(v_1^2+v_2^2+v_3^2+...+v_n^2)}$

(c) $\sqrt{\frac{1}{n}(v_1^2+v_2^2+v_3^2+...+v_n^2)}$

(d) $\sqrt{\left[\frac{(v_1+v_2+v_3+...\ v_n)^2}{n}\right]}$

30. If E is the translational kinetie energy, then which of the following relation holds good?

(a) $PV = E$ (b) $PV = \frac{3}{2}E$

(c) $PV = 3E$ (d) $PV = \frac{2}{3}E$

31. The temperature at which oxygen molecules have the same root mean square speed as that of hydrogen molecules at 300 K is

(a) 600 K (b) 2400 K

(c) 4800 K (d) 300 K

32. Find the temperature at which the Vrms for O_2 molecule is 483 ms^{-1}

(a) 300 K (b) 400 K

(c) 500 K (d) 600 K

33. The r.m.s. velocity of oxygen molecule at 16ºC is 474 m/sec. The r.m.s. velocity in m/s of hydrogen molecule at 127ºC is

(a) 1603 (b) 1896

(c) 2230.59 (d) 2730

34. The root mean square velocity of hydrogen molecules at 300 K is 1930 metre/sec. Then the r.m.s velocity of oxygen molecules at 1200 K will be

(a) 482.5 metre/sec (b) 965 metre/sec

(c) 1930 metre/sec (d) 3860 metre/sec

35. At what temperature the mean speed of the molecule of hydrogen gas (H_2) equals the escape speed from the earth?

(a) 11800 K (b) 1500 K

(c) 1800 K (d) 2000 K

36. A flask contains a monoatomic and a diatomic gas in the ratio of 4 : 1 by mass at a temperature of 300 K. The ratio of average kinetic energy per molecule of the two gases is

(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) 1 : 4

37. The temperature at which protons in hydrogen gas would have enough energy to overcome Coulomb barrier of 4.14×10^{-14} J is

(Boltzmann constant = 1.38×10^{-23} JK^{-1})

(a) 2×10^9 K (b) 10^9 K

(c) 6×10^9 K (d) 3×10^9 K

38. One kg of a diatomic gas is at a pressure of $8 \times 10^4 N/m^2$. The density of the gas is $4kg/m^3$. What is the energy of the gas due to its thermal motion?

(a) 5×10^4 J (b) 6×10^4 J

(c) 7×10^4 J (d) 3×10^4 J

39. The ratio of kinetic energy of a diatomic gas molecule at a high temperature to that of NTP is

(a) $\frac{3}{2}$ (b) $\frac{5}{3}$

(c) $\frac{5}{7}$ (d) $\frac{7}{5}$

40. An ideal gas is kept in a cylinder of volume $3m^3$ at a pressure of 3×10^5 Pa. The energy of the gas is

(a) 13.5×10^6 J (b) 1.35×10^5 J

(c) 13.5×10^5 J (d) 135×10^6 J

41. The energy (in eV) possessed by a neon atom at 77 °C is (Blotzmann constant, $K_B = 1.38 \times 10^{-23}$ $J K^{-1)}$

(a) 1.32×10^{-3} (b) 3.20×10^{-4}

(c) 4.52×10^{-2} (d) 3.88×10^{-2}

42. If the average kinetic energy of a gas molecule at 27 °C is 3.3×10^{-20} J, then the average kinetic energy of the gas molecules at 127 °C is

(a) 15×10^{-20} J (b) 0.68×10^{-20} J

(c) 4.4×10^{-20} J (d) 10.3×10^{-21} J

43. The relation between the pressure (P), volume (V) and average kinetic energy (E) of a gas is

(a) $P = \frac{E}{2V}$ (b) $P = \frac{3}{2}\frac{E}{V}$

(c) $P = \frac{E}{3V}$ (d) $P = \frac{2}{3}\frac{E}{V}$

44. A vessel of volume 10 liters is filled with H_2 gas. The total average translational kinetic energy of its molecules is 4.5×10^5 J. The pressure of hydrogen in the vessel is

(a) 3×10^6 Nm^{-2} (b) 30×10^6 Nm^{-2}

(c) 30×10^4 Nm^{-2} (d) 3×10^4 Nm^{-2}

45. The pressure of a gas is proportional to

(a) the sum of kinetic and potential energies

(b) potential energy

(c) kinetic energy

(d) None of the above

46. The average kinetic energy of H_2 molecules at 300 K is E. At the same temperature the average kinetic energy of O_2 molecule is

(a) E (b) $\frac{E}{4}$

(c) $\frac{E}{16}$ (d) 16 E

47. The average translational kinetic energy of a molecule in a gas becomes equal to 0.69 eV at temperature about, [Boltzmann's constant = 1.38×10^{-23} J K^{-1}]

(a) 3370°C (b) 3388°C

(c) 5333°C (d) 5060°C

48. A flask contains argon and chlorine in the ratio of 2 : 1 by mass. The temperature of the mixture is 27° C. The ratio of average kinetic energies of two gases per molecule is

(a) 1 : 1 (b) 2 : 1

(c) 3 : 1 (d) 6 : 1

3.2 Law of Equipartition of Energy, Degree of Freedom, Specific Heat Capacity

49. The ratio of the molar specific heat capacities of monatomic and diatomic gases at constant pressure is

(a) 1 : 7 (b) 5 : 7

(c) 3 : 7 (d) 2 : 7

50. A mixture of gasses consists of 16 g of Helium and 16 g of Oxygen. The ratio of specific heats of the mixture is nearly

(a) 1.33 (b) 1.4

(c) 1.56 (d) 1.62

51. The specific heat capacity of a monatomic gas at constant volume is x% of its specific heat capacity at constant pressure. Then x =

(a) 40 (b) 50

(c) 60 (d) 75

52. The number of rotational degrees of freedom of a monatomic molecule is

(a) 2 (b) 1

(c) 0 (d) 3

53. When some amount of heat energy is supplied to a monatomic gas, the percentage of heat energy used for increasing the internal energy of the gas ($\gamma = 5/3$) is

(a) 60 (b) 40

(c) 20 (d) 80

54. In non-rigid diatomic molecule with an additional vibrational mode

(a) $81\,C_v^2 = 49\,C_P^2$ (b) $49\,C_v^2 = 25\,C_P^2$

(c) $49\,C_v^2 = 81\,C_P^2$ (d) $25\,C_v^2 = 49\,C_P^2$

55. The number of vibrational degrees of freedom of a diatomic molecule is

(a) 0 (b) 1

(c) 2 (d) 3

56. What is the number of degrees of freedom for an oscillating simple pendulum?

(a) One (b) Two

(c) Three (d) More than three

57. If a gas has n degrees of freedom, then the ratio of $\frac{C_P}{C_V}$ is

(a) $\frac{n+2}{n}$ (b) $\frac{2n+1}{n}$

(c) $\frac{n+2}{2n}$ (d) $\frac{n+4}{2n}$

58. Under standard conditions, the density of a gas is $\frac{1400}{1089}$ kg - m^{-3} and the speed of sound propagation in it is 330 ms^{-1}, then the number of degrees of freedom of the gas molecules is

(a) 2 (b) 7

(c) 5 (d) 3

59. Ratio of translational degrees of freedom to rotational degrees of freedom of a polyatomic linear gas molecule is

(a) 1 : 1 (b) 1 : 2

(c) 2 : 3 (d) 3 : 2

60. A gas has n degrees of freedom. The ratio of specific heat of gas at constant volume to the specific heat of gas at constant pressure will be :

(a) $\frac{n}{n+2}$ (b) $\frac{n+2}{n}$

(c) $\frac{n}{2n+2}$ (d) $\frac{n}{n-2}$

61. As per the law of equi-partition of energy each vibrational mode gives how many degrees of freedom?

(a) 1 (b) 2

(c) 3 (d) 0

62. A fly moving in a room has ...X... degree of freedom. Here, *X* refers to

(a) one (b) two

(c) three (d) four

63. According to law of equipartition of energy the molar specific heat of a diatomic gas at constant volume where the molecule has one additional vibrational mode is :-

(a) $\frac{9}{2}R$ (b) $\frac{5}{2}R$

(c) $\frac{3}{2}R$ (d) $\frac{7}{2}R$

64. The total number of degree of freedom of a CO_2 gas molecule is

(a) 3 (b) 6

(c) 5 (d) 4

65. The degree of freedom of a molecule of a triatomic gas is

(a) 2 (b) 4

(c) 6 (d) 8

66. How many degrees of freedom are associated with 2 grams of He at NTP ?

(a) 3 (b) 3.01×10^{23}

(c) 9.03×10^{23} (d) 6

67. A cylinder rolls without slipping down an inclined plane, the number of degrees of freedom it has, is

(a) 2 (b) 3

(c) 5 (d) 1

68. The specific heat of a gas

(a) has only two values c_p and c_v

(b) has a unique value at a given temperature

(c) can have any value between 0 and ∞

(d) depends upon the mass of the gas

69. The specific heats at constant pressure is greater than that of the same gas at constant volume because

(a) at constant pressure work is done in expanding the gas

(b) at constant volume work is done in expanding the gas

(c) the molecular attraction increases more at constant pressure

(d) the molecular vibration increases more at constant pressure

70. The total internal energy of one mole of rigid diatomic gas is

(a) $\frac{3}{2}RT$ (b) $\frac{7}{2}RT$

(c) $\frac{5}{2}RT$ (d) $\frac{9}{2}RT$

71. For hydrogen gas $C_p - C_v = a$ and for oxygen gas $C_p - C_v = b$. So, the relation between a and b is given by

(a) $a = 16\,b$ (b) $16\,a = b$

(c) $a = 4\,b$ (d) $a = b$

72. The ratio of molar specific heat at constant pressure C_P, to molar specific heat at constant volume C_v for a monoatomic gas is

(a) $\frac{C_P}{C_V} = \frac{3}{5}$ (b) $\frac{C_P}{C_V} = \frac{5}{3}$

(c) $\frac{C_P}{C_V} = \frac{7}{9}$ (d) $\frac{C_P}{C_V} = \frac{9}{7}$

73. If a gas has 'n' degrees of freedom, the ratio of the specific heats γ of the gas is

(a) $\frac{1+n}{2}$ (b) $1+\frac{n}{2}$

(c) $1+\frac{n}{1}$ (d) $1+\frac{2}{n}$

74. P-V diagram of a diatomic gas is a straight line passing through origin. The molar heat capacity of the gas in the process will be

(a) 4 R (b) 2.5 R

(c) 3 R (d) $\frac{4R}{3}$

75. The molar specific heat at constant pressure of an ideal gas is (9/2)R. The ratio of specific heat at constant pressure to that at constant volume is

(a) 1.58 (b) 1.82

(c) 1.28 (d) 1.44

76. If γ be the ratio of specific heats of a perfect gas, the number of degrees of freedom of a molecule of the gas is

(a) $\frac{25}{2}(\gamma - 1)$

(b) $\frac{3\gamma - 1}{2\gamma - 1}$

(c) $\frac{9}{2}(\gamma - 1)$

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

77. The number of translational degrees of freedom for a diatomic gas is

(a) 2 (b) 3

(c) 5 (d) 6

78. If for a gas, $\frac{R}{C_v} = 0.67$, the gas is made up of molecules which are

(a) diatomic

(b) mixture of diatomic and polyatomic molecules

(c) monoatomic

(d) polyatomic

79. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$. For this gas

(a) $C_V = 3R/J$ (b) $C_P = 3R/J$

(c) $C_P = 5R/J$ (d) $C_V = 5R/J$

3.3 Absorption, Reflection and Transmission of Heat Radiation, Perfect Black Body, Kirchhoff's Law of Heat Radiation, Spectral Distribution of Black Body Radiation & Stefan-Boltzmann Law of Radiation

80. Good absorbers of heat are

(a) poor emitters

(b) non-emitters

(c) good emitters

(d) highly polished

81. Three bodies A, B and C have equal area which are painted red, yellow and black respectively. If they are at same temperature, then

(a) emissive power of A is maximum.

(b) emissive power of B is maximum.

(c) emissive power of C is maximum.

(d) emissive power of A, B and C are equal.

82. Sweet makers do not clean the bottom of cauldron because

(a) emission power of black and bright surface is more.

(b) absorption power of black and bright surface is more.

(c) black and rough surface absorbs more heat.

(d) transmission power of black and rough surface is more.

83. At temperature T, the emissive power and absorption power of a body for certain wavelength are e_λ and a_λ respectively, then

(a) $e_\lambda = a_\lambda$

(b) $e_\lambda > a_\lambda$

(c) $e_\lambda < a_\lambda$

(d) no difinite relation between e_λ and a_λ

84. Which of the following is used as a coolent in automobile radiator as well as a heater in hot water bags?

(a) Ice

(b) Sand

(c) Water

(d) All of these

85. An ideal black body at room temperature is thrown into a furnace. It is observed that

(a) initially it is the darkest body and at later times the brightest

(b) it is the darkest body at all times

(c) it cannot be distinguished at all times

(d) initially it is the darkest body and at later times it cannot be distinguished

86. With the increases of temperature of a black body the peak of the spectral energy distribution of the radiation shift towards lower wavelength. This is given by

(a) Kirchoff's law

(b) Wein's displacement law

(c) Stefan's law

(d) Rayleigh-Jeans law

87. The temperature of the sun can be found out by using

(a) Wien's displacement law

(b) Kepler's law of motion

(c) Stefan's Boltzmann law

(d) Planck's law

88. Three objects coloured black, gray and white can withstand hostile conditions up to 2800°C. These objects are thrown into a furnace where each of them attains a temperature of 2000°C. Which object will glow brightest

(a) the white object

(b) the black object

(c) all glow with equal brightness

(d) gray object

89. Which of the following is the example of ideal black body

(a) Kajal

(b) Black board

(c) A pin hole in a box

(d) None of these

90. According to wien's law

(a) $\lambda_m T = \text{constant}$

(b) $\frac{\lambda_m}{T} = \text{constant}$

(c) $\frac{T}{\lambda_m} = \text{constant}$

(d) $T + \lambda_m = \text{constant}$

91. Relation between the colour and the temperature of a star is given by

(a) Wien's displacement law

(b) Planck's law

(c) Hubble's law

(d) Fraunhoffer diffraction law

92. The amount of radiation emitted by a perfectly black body is proportional to

(a) temperature on ideal gas scale

(b) fourth root of temperature on ideal gas scale

(c) fourth power of temperature on ideal gas scale

(d) source of temperature on ideal gas scale

93. The rate of radiation of a black body at 0°C is E J/s. The rate of radiation of this black body at 273°C will be

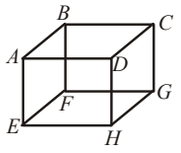
(a) 16 E (b) 8 E

(c) 4 E (d) E

Exercise 2 : ACCELERATOR
Topic-wise MCQs

3.1 Ideal Gas and Real Gas, Mean Free Path, Pressure of Ideal Gas, Root Mean Square (RMS) Speed

1. 1 mole of an ideal gas is contained in a cubical volume V, $ABCDEFGH$ at 300K (figure).



One face of the cube ($EFGH$) is made up of a material which totally absorbs any gas molecule incident on it. At any given time,

(a) the pressure on $EFGH$ would be zero
(b) the pressure on all the faces will the equal
(c) the pressure of $EFGH$ would be double the pressure on $ABCD$
(d) the pressure on $EFGH$ would be half that on $ABCD$

2. A cubic vessel (with face horizontal + vertical) contains an ideal gas at NTP. The vessel is being carried by a rocket which is moving at a speed of 500 m s^{-1} in vertical direction. The pressure of the gas inside the vessel as observed by us on the ground

(a) remains the same because 500 ms^{-1} is very much smaller than v_{rms} of the gas
(b) remains the same because motion of the vessel as a whole does not affect the relative motion of the gas molecules and the walls
(c) will increase by a factor equal to $(v_{rms}^2 + (500)^2)/v_{rms}^2$ where v_{rms} was the original mean square velocity of the gas
(d) will be different on the top wall and bottom wall of the vessel

3. A vessel contains 14 g of nitrogen gas at a temperature of 27°C. The amount of heat to be transferred to the gas to double the r.m.s speed of its molecules will be :
Take R = 8.32 J mol^{-1} k^{-1}.
(a) 2229 J (b) 5616 J (c) 9360 J (d) 13.104 J

4. Consider a sample of oxygen behaving like an ideal gas. At 300 K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be : (Molecular weight of oxygen is 32 g/mol; R = 8.3 J K^{-1} mol^{-1})

(a) $\sqrt{\frac{8\pi}{3}}$ (b) $\sqrt{\frac{3}{3}}$
(c) $\sqrt{\frac{8}{3}}$ (d) $\sqrt{\frac{3\pi}{8}}$

5. The mean free path of molecules of a certain gas at STP is 1500d, where d is the diameter of the gas molecules. While maintaining the standard pressure, the mean free path of the molecules at 373 K is approximately :
(a) 1098d (b) 2049d
(c) 750d (d) 1500d

6. The temperature, at which the root mean square velocity of hydrogen molecules equals their escape velocity from the earth, is closest to :
[Boltzmann Constant $k_B = 1.38 \times 10^{-23}$ J/K
Avogadro Number $N_A = 6.02 \times 10^{26}$ /kg
Radius of Earth : 6.4×10^6 m
Gravitational acceleration on Earth = 10 ms^{-2}]
(a) 800 K (b) 3×10^5 K
(c) 10^4 K (d) 650 K

7. The rms speed of oxygen molecule in a vessel at particular temperature is $\left(1+\frac{5}{x}\right)^{\frac{1}{2}} \upsilon$, where υ is the average speed of the molecule. The value of x will be: (Take $\pi = \frac{22}{7}$)
(a) 28 (b) 27
(c) 8 (d) 4

8. Calculate the value of mean free path (λ) for oxygen molecules at temperature 27°C and pressure 1.01×10^5 Pa. Assume the molecular diameter 0.3 nm and the gas is ideal. ($k = 1.38 \times 10^{-23}$ JK^{-1})
(a) 86 nm (b) 32 nm
(c) 58 nm (d) 102 nm

9. Two gases-argon (atomic radius 0.07 nm, atomic weight 40) and xenon (atomic radius 0.1 nm, atomic weight 140) have the same number density and are at the same temperature. The ratio of their respective mean free times is closest to:
(a) 3.67 (b) 1.83
(c) 2.3 (d) 4.67

10. At 0 K, which of the following properties of a gas will be zero?
(a) Kinetic energy
(b) Potential energy
(c) Density
(d) Mass

11. The temperature of a gas is raised from 27°C to 927°C. The root mean square speed is

(a) $\sqrt{(927/27)}$ times the earlier value

(b) remain the same

(c) gets halved

(d) get doubled

12. If the r.m.s. speed of chlorine molecule is 490 m/s at 27°C, the r.m.s. speed of argon molecules at the same temperature will be (Atomic mass of argon = 39.9 u, molecular mass of chlorine = 70.9 u)

(a) 751.7 m/s (b) 451.7 m/s

(c) 651.7 m/s (d) 551.7 m/s

13. An ideal gas is enclosed in a cylinder at pressure of 2 atm and temperature, 300 K. The mean time between two successive collisions is 6×10^{-8} s. If the pressure is doubled and temperature is increased to 500 K, the mean time between two successive collisions wiil be close to:

(a) 2×10^{-7} s (b) 4×10^{-8} s

(c) 0.5×10^{-8} s (d) 3×10^{-6} s

14. Two boxes are at the same temperature. The first box contains gas with molecular mass m_1 and rms speed v_1. The second box contains gas with molecular mass m_2 and average speed v_2. If $v_1 = 1.5\ v_2$, then $\frac{m_1}{m_2}$ is

(a) 1.25 (b) 0.74

(c) 0.52 (d) 0.26

15. At what temperature is the root mean square (rms) speed of Neon gas atoms is equal to the rms speed of Helium gas atom at –33 °C?

(Atomic mass of Ne = 2.02 u, and that of He = 4.0 u)

(a) 1208 K (b) 1210 K

(c) 1212 K (d) 1220 K

16. Consider an ideal gas in a closed container at 300 K. The container is then heated, so that the average velocity of a particles of the gas increases by a factor of 4. What would be the final temperature?

(a) 4500°C (b) 4527°C

(c) 4617°C (d) 4600°C

17. Uranium has two isotopes of masses 235 and 238 units. If both of them are present in uranium hexafluoride gas, find the percentage ratio of difference in rms velocities of two isotopes to the rms velocity of heavier isotope.

(a) 1.64 (b) 0.064

(c) 0.64 (d) 6.4

18. In the isothermal expansion of 10g of gas from volume V to 2V the work done by the gas is 575J. What is the root mean square speed of the molecules of the gas at that temperature?

(a) 398m/s (b) 520m/s

(c) 499m/s (d) 532m/s

19. Consider a sample of oxygen behaving like an ideal gas. At 300 K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be : (Molecular weight of oxygen is 32 g/mol; R = 8.3 J K^{-1} mol^{-1})

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

(c) $\sqrt{\frac{8}{3}}$ (d) $\sqrt{\frac{3\pi}{8}}$

20. The root mean sqaure velocity of the molecules in a sample of helium is 5/7 th that of the molucules in a sample of hydrogen. If the temperature of hydrogen sample is 0°C, that of helium sample is about

(a) 0 °C (b) 283 K

(c) 0K (d) 100 °C

21. For the given concentration, if the ratio of the diameters of the molecules of two gases is 1 : 2, then the ratio of their mean free paths is

(a) 4 : 1 (b) 2 : 1

(c) 1 : 1 (d) 1 : 2

22. A molecule is travelling in air at 300K and 1 atm, and the radius of the molecule is 0.6×10^{-10} m. Calculate the approx, mean free path of the molecule. (The number density is 2.44×10^{25} molecules/m^3)

(a) $\frac{0.2}{\pi} \times 10^{-5}$ m (b) $\frac{0.3}{\pi} \times 10^{-5}$ m

(c) $\frac{0.4}{\pi} \times 10^{-5}$ m (d) $\frac{0.1}{\pi} \times 10^{-5}$ m

23. The mean free path for a gas at temperature 300 K and pressure 600 torr is 10^{-7} m. The mean free path of the gas at a temperature 400 K and pressure 200 torr will be

(a) 2.5×10^{-8} m (b) 4.4×10^{-8} m

(c) 3.3×10^{-8} m (d) 4×10^{-7} m

24. Consider an ideal gas at pressure *p*, volume *V* and temperature *T*. The mean free path for molecules of the gas is *L*. If the radius of gas molecules, as well as pressure, volume and temperature of the gas are doubled, then the mean free path will be

(a) $\frac{5L}{2}$ (b) $\frac{L}{4}$

(c) $\frac{L}{8}$ (d) 2L

25. For a molecule of an ideal gas, the number density is $2\sqrt{2} \times 10^8\ cm^{-3}$ and the mean free path is $\frac{10^{-2}}{\pi}$ cm. The diameter of the gas molecule is

(a) 5×10^{-4}cm (b) 0.5×10^{-4}cm

(c) 2.5×10^{-4}cm (d) 4×10^{-4}cm

26. How is the mean free path (λ) in a gas related to the interatomic distance ?

(a) λ is 10 times the interatomic distance

(b) λ is 100 times the interatomic distance

(c) λ is 1000 times the interatomic distance

(d) λ is $\frac{1}{10}$ times of the interatomic distance

27. Mean free path of a gas molecule is

(a) inversely proportional to number of molecules per unit volume

(b) inversely proportional to diameter of the molecule

(c) directly proportional to the square root of the absolute temperature

(d) directly proportional to the molecular mass

28. The number of collisions per second suffered by a molecule in a sample of hydrogen at S.T.P is

[Mean free path = 1.38×10^{-5} cm]

(a) 10^{15}

(b) 8.3×10^{12}

(c) 1.1×10^{6}

(d) 1.23×10^{10}

29. Calculate the value of mean free path (λ) for oxygen molecules at temperature 27°C and pressure 1.01×10^5 Pa. Assume the molecular diameter 0.3 nm and the gas is ideal. ($k = 1.38 \times 10^{-23}$ JK^{-1})

(a) 86 nm (b) 32 nm

(c) 58 nm (d) 102 nm

30. A flask contains Hydrogen and Argon in the ratio 2 : 1 by mass. The temperature of the mixture is 30°C. The ratio of average kinetic energy per molecule of the two gases (K argon/K hydrogen) is:

(Given: Atomic Weight of Ar = 39.9)

(a) 1 (b) 2

(c) $\frac{39.9}{2}$ (d) 39.9

3.2 Law of Equipartition of Energy, Degree of Freedom, Specific Heat Capacity

31. One mole of an ideal gas is taken through an adiabatic process where the temperature rises from 27°C to 37°C. If the ideal gas is composed of polyatomic molecule that has 4 vibrational modes, which of the following is true?

[$R = 8.314$ J mol^{-1} k^{-1}]

(a) work done by the gas is close to 332 J

(b) work done on the gas is close to 582 J

(c) work done by the gas is close to 582 J

(d) work done on the gas is close to 332 J

32. Two ideal polyatomic gases at temperatures T_1 and T_2 are mixed so that there is no loss of energy. If F_1 and F_2, m_1 and m_2, n_1 and n_2 be the degrees of freedom, masses, number of molecules of the first and second gas respectively, the temperature of mixture of these two gases is:

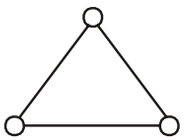
(a) $\frac{n_1F_1T_1 + n_2F_2T_2}{F_1 + F_2}$

(b) $\frac{n_1T_1 + n_2T_2}{n_1 + n_2}$

(c) $\frac{n_1F_1T_1 + n_2F_2T_2}{n_1 + n_2}$

(d) $\frac{n_1F_1T_1 + n_2F_2T_2}{n_1F_1 + n_2F_2}$

33. Consider a gas of triatomic molecules. The molecules are assumed to be triangular and made of massless rigid rods whose vertices are occupied by atoms. The internal energy of a mole of the gas at temperature T is :



(a) $\frac{5}{2}RT$ (b) $\frac{3}{2}RT$

(c) $\frac{9}{2}RT$ (d) $3RT$

34. A 25×10^{-3} m^3 volume cylinder is filled with 1 mol of O_2 gas at room temperature (300 K) . The molecular diameter of O_2, and its root mean square speed, are found to be 0.3 nm and 200 m/s, respectively. What is the average collision rate (per second) for an O_2 molecule?

(a) $\sim 10^{12}$ (b) $\sim 10^{11}$

(c) $\sim 10^{10}$ (d) $\sim 10^{13}$

35. A monoatomic gas of mass 4.0 u is kept in an insulated container. Container is moving with velocity 30 m/s. If container is suddenly stopped then change in temperature of the gas (R = gas constant) is $\frac{x}{3R}$. Value of x is

(a) 3600 (b) 4200 (c) 5200 (d) 6400

36. In a process, temperature and volume of one mole of an ideal monoatomic gas are varied according to the relation $VT = K$, where K is a constant. In this process the temperature of the gas is increased by ΔT. The amount of heat absorbed by gas is (R is gas constant) :

(a) $\frac{1}{2}R\Delta T$ (b) $\frac{1}{2}KR\Delta T$

(c) $\frac{3}{2}R\Delta T$ (d) $\frac{2K}{3}\Delta T$

37. A 15 g mass of nitrogen gas is enclosed in a vessel at a temperature 27°C. Amount of heat transferred to the gas, so that rms velocity of molecules is doubled, is about: [Take R = 8.3 J/K mole]

(a) 0.9 kJ (b) 6 kJ

(c) 10 kJ (d) 14 kJ

38. To raise the temperature of a certain mass of gas by 50°C at a constant pressure, 160 calories of heat is required. When the same mass of gas is cooled by 100°C at constant volume, 240 calories of heat is released. How many degrees of freedom does each molecule of this gas have (assume gas to be ideal)?

(a) 5 (b) 6

(c) 3 (d) 7

39. When heat Q is supplied to a diatomic gas of rigid molecules, at constant volume its temperature increases by ΔT. The heat required to produce the same change in temperature, at a constant pressure is :

(a) $\frac{2}{3}Q$ (b) $\frac{5}{3}Q$

(c) $\frac{7}{5}Q$ (d) $\frac{3}{2}Q$

40. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v, respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to

(a) $\frac{R}{(\gamma-1)}$ (b) $\frac{(\gamma-1)}{R}$

(c) γR (d) $\frac{1+\gamma}{1-\gamma}$

41. If c_p and c_v denote the specific heats (per unit mass) of an ideal gas of molecular weight M

(a) $C_p - C_v = R/M^2$

(b) $C_p - C_v = R$

(c) $C_p - C_v = R/M$

(d) $C_p - C_v = MR$

Where R is the molar gas constant

42. The molar specific heat at constant pressure of an ideal gas is (7/2) R. The ratio of specific heat at constant pressure to that at constant volume is

(a) 8/7 (b) 5/7

(c) 9/7 (d) 7/5

43. A diatomic gas, having $C_p = \frac{7}{2}R$ and $C_v = \frac{5}{2}R$, is heated at constant pressure. The ratio dU : dQ : dW :

(a) 5 : 7 : 2 (b) 3 : 5 : 2

(c) 3 : 7 : 2 (d) 5 : 7 : 3

44. The internal energy (U), pressure (P) and volume (V) of an ideal gas are related as U = 3PV + 4. The gas is

(a) diatomic only

(b) either monoatomic or diatomic

(c) polyatomic only

(d) monoatomic only

45. One mole of a monoatomic gas is mixed with three moles of a diatomic gas. The molecular specific heat of mixture at constant volume is $\frac{\alpha^2}{4}R$ J/mol K; then the value of α will be (Assume that the given diatomic gas has no vibrational mode).

(a) 3 (b) 5

(c) 7 (d) 9

46. A vessel contains hydrogen and nitrogen gases in the ratio 2 : 3 by mass. If the temperature of the mixture of the gases is 30°C, then the ratio of the average kinetic energies per molecule of hydrogen and nitrogen gases is (Molecular mass of hydrogen = 2 and molecular mass of nitrogen = 28)

(a) 3 : 7 (b) 2 : 3

(c) 1 : 1 (d) 1 : 14

47. If the average translational kinetic energy of a molecule in a gas is equal to the kinetic energy of an electron accelerating from rest through 10 V, then the temperature of the gas molecule is

(Boltzmann constant = 1.38×10^{-23} JK^{-1})

(a) 7.73×10^3 K

(b) 730 K

(c) 73.7 K

(d) 77.3×10^3 K

48. One mole of a gas having $\gamma = \frac{7}{5}$ is mixed with one mole of a gas having $\gamma = \frac{4}{3}$. The value of γ for the mixture is (γ is the ratio of the specific heats of the gas)

(a) $\frac{5}{11}$ (b) $\frac{11}{15}$

(c) $\frac{15}{11}$ (d) $\frac{5}{13}$

49. A gas mixture contains n_1 moles of a monoatomic gas and n_2 moles of gas of rigid diatomic molecules. Each molecule in monoatomic and diatomic gas has 3 and 5 degree of freedom respectively. If the adiabatic exponent $\left(\frac{C_p}{C_v}\right)$ for this gas mixture is 1.5, then the ratio $\frac{n_1}{n_2}$ will be

(a) 1 (b) 1.5
(c) 2 (d) 2.5

50. The total internal energy of 2 moles of a monotomic gas at a temperature 27 °C is U. The total internal energy of 3 moles of a diatomic gas at a temperature 127 °C is

(a) U (b) $\frac{10U}{3}$
(c) 2U (d) $\frac{2U}{3}$

51. A poly atomic gas with n degrees of freedom has a mean kinetic energy per molecule given by (if N is Avogadro's number)

(a) $\frac{nKT}{N}$ (b) $\frac{nKT}{2N}$
(c) $\frac{nKT}{2}$ (d) $\frac{3KT}{2}$

52. When 100 J of heat is supplied to a gas, the increase in the internal energy of the gas is 60 J. Then the gas is/can

(a) be triatomic or diatomic gas
(b) Triatomic gas
(c) Monoatomic gas
(d) Diatomic gas

53. The molar specific heat capacity of a diatomic gas at constant pressure is C. The molar specific heat capacity of a monoatomic gas at constant volume is

(a) $\frac{2C}{7}$ (b) $\frac{3C}{7}$
(c) $\frac{C}{7}$ (d) $\frac{4C}{7}$

54. The total internal energy of 4 moles of a diatomic gas at a temperature of 27°C is (Universal gas constant = 8.31 J mol^{-1} K^{-1})

(a) 13.47 kJ (b) 4.98 kJ
(c) 24.93 kJ (d) 14.96 kJ

3.3 Absorption, Reflection and Transmission of Heat Radiation, Perfect Black Body, Kirchhoff's Law of Heat Radiation, Spectral Distribution of Black Body Radiation & Stefan-Boltzmann Law of Radiation

55. On observing light from three different stars P, Q and R, it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperature of P, Q and R, then it can be concluded from the above observations that

(a) $T_P > T_R > T_Q$
(b) $T_P < T_R < T_Q$
(c) $T_P < T_Q < T_R$
(d) $T_P > T_Q > T_R$

56. A sphere and a cube of same material and same volume are heated upto same temperature and allowed to cool in the same surroundings. The ratio of the amounts of radiations emitted will be

(a) 1 : 1 (b) $\frac{4\pi}{3}:1$
(c) $\left(\frac{\pi}{6}\right)^{1/3}:1$ (d) $\frac{1}{2}\left(\frac{4\pi}{3}\right)^{2/3}:1$

57. A black body is at a temperature of 2880 K. The energy of radiation emitted by this object with wavelength between 499 nm and 500 nm is U_1, between 999 nm and 1000 nm is U_2 and between 1499 nm and 1500 nm is U_3. Wien's constant b = 2.88×10^6 nm-K. Then

(a) $U_1 = 0$ (b) $U_2 = 0$
(c) $U_1 = U_2$ (d) $U_2 > U_1$

58. A metal ball of surface area 200 square cm, temperature 527ºC is surrounded by a vessel at 27ºC. If the emissivity of the metal is 0.4, then the rate of loss of heat from the ball is approximately $\left[\sigma = 5.67\times10^{-8}\frac{\text{joule}}{m^2\times\text{sec}\times K^2}\right]$

(a) 108 joule (b) 168 joule
(c) 182 joule (d) 192 joule

59. The rectangular surface of area 8 cm × 4 cm of a black body at temperature 127°C emits energy E per second. If the length and breadth are reduced to half of the initial value and the temperature is raised to 327°C, the rate of emission of energy becomes

(a) $\frac{3}{8}$E (b) $\frac{81}{16}$E
(c) $\frac{9}{16}$E (d) $\frac{81}{64}$E

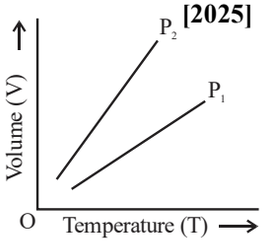
60. Assuming the sun to have a spherical outer surface of radius r, radiating like a black body at temperature t°C, the power received by a unit surface, (normal to the incident rays) at a distance R from the centre of the sun is

(a) $\frac{r^2\sigma(t+273)^4}{4\pi R^2}$ (b) $\frac{16\pi^2r^2\sigma t^4}{R^2}$
(c) $\frac{r^2\sigma(t+273)^4}{R^2}$ (d) $\frac{4\pi r^2\sigma t^4}{R^2}$

where σ is the Stefan's constant.

Exercise 3 : PREVIOUS YEARS MCQs

1. For a perfect gas, two pressures P_1 and P_2 are shown in figure. The graph shows: **[2025]**



(a) $P_1 > P_2$

(b) $P_1 < P_2$

(c) $P_1 = P_2$

(d) Insufficient data to draw any conclusion

2. According to law of equipartition of energy the molar specific heat of a diatomic gas at constant volume where the molecule has one additional vibrational mode is :- **[2025]**

(a) $\frac{9}{2}R$ (b) $\frac{5}{2}R$

(c) $\frac{3}{2}R$ (d) $\frac{7}{2}R$

3. Mean free path of a gas molecule is **[2025]**

(a) inversely proportional to number of molecules per unit volume

(b) inversely proportional to diameter of the molecule

(c) directly proportional to the square root of the absolute temperature

(d) directly proportional to the molecular mass

4. At which temperature the r.m.s. velocity of a hydrogen molecule equal to that of an oxygen molecule at 47° C? **[2024]**

(a) 80 K (b) – 73 K

(c) 4 K (d) 20 K

5. Two vessels A and B are of the same size and are at same temperature. A contains 1g of hydrogen and B contains 1g of oxygen. P_A and P_B are the pressures of the gases in A and B respectively, then $\frac{P_A}{P_B}$ is: **[2024]**

(a) 8 (b) 16

(c) 32 (d) 4

6. If n is the number density and d is the diameter of the molecule, then the average distance covered by a molecule between two successive collisions (i.e. mean free path) is represented by: **[2024]**

(a) $\frac{1}{\sqrt{2}n\pi d^2}$ (b) $\sqrt{2}n\pi d^2$

(c) $\frac{1}{\sqrt{2}n\pi d^2}$ (d) $\frac{1}{\sqrt{2}n^2\pi^2 d^2}$

7. A mixture of one mole of monoatomic gas and one mole of a diatomic gas (rigid) are kept at room temperature (27°C). The ratio of specific heat of gases at constant volume respectively is: **[2024]**

(a) $\frac{7}{5}$ (b) $\frac{3}{2}$

(c) $\frac{3}{5}$ (d) $\frac{5}{3}$

8. A vessel contains a mixture of 1 mole of oxygen and two moles of nitrogen at 300 K. The ratio of the average rotational kinetic energy per O_2 molecule to that per N_2 molecule is **[2023]**

(a) 1 : 1

(b) 1 : 2

(c) 2 : 1

(d) depends on the moment of inertia of the two molecules

9. What will be the effect on the root mean square velocity of oxygen molecules if the temperature is doubled and oxygen molecule dissociates into atomic oxygen? **[2022]**

(a) The velocity of atomic oxygen remains same

(b) The velocity of atomic oxygen doubles

(c) The velocity of atomic oxygen becomes half

(d) The velocity of atomic oxygen becomes four times

10. A flask contains argon and oxygen in the ratio of 3 : 2 in mass and the mixture is kept at 27°C. The ratio of their average kinetic energy per molecule respectively will be **[2022]**

(a) 3 : 2 (b) 9 : 4

(c) 2 : 3 (d) 1 : 1

11. If two vessels A and B contain the same gas but the volume of vessel A is twice that of B and temperature and pressure of gas A is twice that of gas in B, then the ratio of gas molecules in A and B is **[2021]**

(a) 1 : 2 (b) 1 : 4

(c) 4 : 1 (d) 2 : 1

12. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v, respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to **[2021]**

(a) $\frac{R}{(\gamma-1)}$ (b) $\frac{(\gamma-1)}{R}$

(c) γR (d) $\frac{1+\gamma}{1-\gamma}$

13. If one mole of monoatomic gas $\left(\gamma=\frac{5}{3}\right)$ is mixed with one mole of diatomic gas $\left(\gamma=\frac{7}{5}\right)$, the value of γ for the mixture is **[2020]**

(a) 1.40 (b) 1.50

(c) 1.53 (d) 3.07

14. If 'C_p' and C_v are molar specific heats of an ideal gas at constant pressure and volume respectively, 'γ' is ratio of two specific heats and 'R' is univeral gas constant then 'C_p' is equal to **[2019]**

(a) $\frac{R\gamma}{\gamma-1}$ (b) γR

(c) $\frac{1+\gamma}{1-\gamma}$ (d) $\frac{R}{\gamma-1}$

15. The molar specific heat of an ideal gas at constant pressure and constant volume is 'C_p' and 'C_V' respectively. If 'R' is the universal gas constant and the ratio of 'C_p' to 'C_v' is 'γ' then C_V= **[2018]**

(a) $\frac{1-\gamma}{1+\gamma}$ (b) $\frac{1+\gamma}{1-\gamma}$

(c) $\frac{\gamma-1}{R}$ (d) $\frac{R}{\gamma-1}$

16. Heat energy is incident on the surface at the rate of 1000 J/min. If coefficient of absorption is 0.8 and coefficient of reflection is 0.1 then heat energy transmitted by the surface in 5 minutes is **[2018]**

(a) 100 J (b) 500 J

(c) 700 J (d) 900 J

17. For a rigid diatomic molecule, universal gas constant $R = nC_{p,}$ where 'C_P' is the molar specific heat at constant pressure and 'n' is a number. Hence 'n' is equal to **[2017]**

(a) 0.2257 (b) 0.4

(c) 0.2857 (d) 0.3557

18. An ideal gas has pressure 'p' volume 'V' and absolute temperature 'T'. If 'm' is the mass of each molecules and 'K' is the Boltzmann constant, then density of the gas is **[2017]**

(a) $\frac{pm}{KT}$ (b) $\frac{KT}{pm}$

(c) $\frac{Km}{pT}$ (d) $\frac{pK}{Tm}$

19. For a gas $\frac{R}{C_V} = 0.4$, where R is the universal gas constant and C_V is molar specific heat at constant volume. The gas is made up of molecules which are **[2016, 2013]**

(a) rigid diatomic

(b) monoatomic

(c) non-rigid diatomic

(d) polyatomic

20. A sample contains mixture of helium and oxygen gas. The ratio of root mean square speed of helium and oxygen in the sample, is : **[2015]**

(a) $\frac{1}{32}$ (b) $\frac{2\sqrt{2}}{1}$

(c) $\frac{1}{4}$ (d) $\frac{1}{2\sqrt{2}}$

21. A mixture of one mole of monoatomic gas and one mole of a diatomic gas (rigid) are kept at room temperature (27°C). The ratio of specific heat of gases at constant volume respectively is: **[2014]**

(a) $\frac{7}{5}$ (b) $\frac{3}{2}$

(c) $\frac{3}{5}$ (d) $\frac{5}{3}$

22. The ratio of vapour densities of two gases at the same temperature is $\frac{4}{25}$, then the ratio of r.m.s. velocities will be : **[2012]**

(a) $\frac{25}{4}$ (b) $\frac{2}{5}$

(c) $\frac{5}{2}$ (d) $\frac{4}{25}$

23. The mean free path and the average speed of oxygen molecules at 300 K and 1 atm are 3×10^{-7} m and 600 m/s, respectively. Find the frequency of its collisions. **[2011]**

(a) 2×10^{10}/s (b) 9×10^{5}/s

(c) 2×10^{9}/s (d) 5×10^{8}/s

24. If the temperature of a gas is increased from 127°C to 527°C, then the rms speed of the gas molecules **[2010]**

(a) increases by 4 times

(b) becomes $\sqrt{2}$ times

(c) becomes half

(d) decreases by $\sqrt{2}$ times

25. If the rms speed of the molecules of a gas at a temperature of 77 °C is 50 ms^{-1}, then the rms speed of the same gas molecules at a temperature of 150.5 °C is **[2009]**

(a) 65 ms^{-1} (b) 35 ms^{-1}

(c) 55 ms^{-1} (d) 45 ms^{-1}

26. If the heat required to increase the rms speed of 4 moles of a diatomic gas from v to $\sqrt{3}v$ is 83.1 kJ, then the initial temperature of the gas is **[2008]**

(Universal gas Constant = 8.31 J mol^{-1} K^{-1})

(a) 377°C (b) 327°C

(c) 227°C (d) 277°C

27. If the internal energy of 3 moles of a gas at a temperature of 27 °C is 2250R, then the number of degrees of freedom of the gas is **[2007]**

(R – Universal gas constant)

(a) 3 (b) 5

(c) 4 (d) 6

28. The internal energy of one mole of a rigid diatomic gas at absolute temperature T is **[2006]**

(a) $3RT$ (b) $\frac{5}{2}RT$

(c) $\frac{3}{2}RT$ (d) $\frac{1}{2}RT$

29. If the degrees of freedom of a gas molecule is 6, then the total internal energy of the gas molecule at a temperature of 47°C (in eV) is **[2005]**

(Boltzmann constant = 1.38×10^{-23} JK^{-1})

(a) 414×10^{-4} (b) 828×10^{-4}

(c) 927×10^{-4} (d) 572×10^{-4}

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(c)	**11**	(a)	**21**	(c)	**31**	(c)	**41**	(c)	**51**	(c)	**61**	(b)	**71**	(d)	**81**	(c)	**91**	(a)
2	(d)	**12**	(d)	**22**	(c)	**32**	(a)	**42**	(c)	**52**	(c)	**62**	(c)	**72**	(b)	**82**	(c)	**92**	(c)
3	(d)	**13**	(b)	**23**	(b)	**33**	(c)	**43**	(d)	**53**	(a)	**63**	(d)	**73**	(d)	**83**	(a)	**93**	(a)
4	(b)	**14**	(b)	**24**	(c)	**34**	(b)	**44**	(b)	**54**	(a)	**64**	(c)	**74**	(c)	**84**	(c)		
5	(b)	**15**	(a)	**25**	(a)	**35**	(a)	**45**	(c)	**55**	(b)	**65**	(c)	**75**	(c)	**85**	(a)		
6	(None)	**16**	(a)	**26**	(a)	**36**	(a)	**46**	(a)	**56**	(b)	**66**	(c)	**76**	(c)	**86**	(b)		
7	(a)	**17**	(b)	**27**	(c)	**37**	(a)	**47**	(d)	**57**	(a)	**67**	(a)	**77**	(b)	**87**	(c)		
8	(d)	**18**	(b)	**28**	(a)	**38**	(a)	**48**	(a)	**58**	(c)	**68**	(c)	**78**	(c)	**88**	(b)		
9	(a)	**19**	(a)	**29**	(c)	**39**	(d)	**49**	(b)	**59**	(d)	**69**	(a)	**79**	(b)	**89**	(c)		
10	(d)	**20**	(a)	**30**	(d)	**40**	(c)	**50**	(d)	**60**	(a)	**70**	(c)	**80**	(c)	**90**	(a)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(d)	**7**	(a)	**13**	(b)	**19**	(d)	**25**	(a)	**31**	(b)	**37**	(c)	**43**	(a)	**49**	(a)	**55**	(a)
2	(b)	**8**	(d)	**14**	(c)	**20**	(a)	**26**	(b)	**32**	(d)	**38**	(b)	**44**	(c)	**50**	(b)	**56**	(c)
3	(c)	**9**	(None)	**15**	(c)	**21**	(a)	**27**	(a)	**33**	(d)	**39**	(c)	**45**	(a)	**51**	(c)	**57**	(d)
4	(d)	**10**	(a)	**16**	(b)	**22**	(a)	**28**	(d)	**34**	(c)	**40**	(a)	**46**	(c)	**52**	(c)	**58**	(c)
5	(b)	**11**	(d)	**17**	(c)	**23**	(d)	**29**	(d)	**35**	(a)	**41**	(c)	**47**	(d)	**53**	(b)	**59**	(d)
6	(c)	**12**	(c)	**18**	(c)	**24**	(b)	**30**	(a)	**36**	(a)	**42**	(d)	**48**	(c)	**54**	(c)	**60**	(c)
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(a)	**4**	(d)	**7**	(c)	**10**	(None)	**13**	(b)	**16**	(b)	**19**	(a)	**22**	(c)	**25**	(c)	**28**	(b)
2	(d)	**5**	(b)	**8**	(a)	**11**	(d)	**14**	(a)	**17**	(c)	**20**	(b)	**23**	(c)	**26**	(c)	**29**	(b)
3	(a)	**6**	(c)	**9**	(b)	**12**	(a)	**15**	(d)	**18**	(a)	**21**	(c)	**24**	(b)	**27**	(b)		

4 Thermodynamics

TOPIC 4.1 : THERMAL EQUILIBRIUM, ZEROTH LAW OF THERMODYNAMICS, HEAT, INTERNAL ENERGY AND WORK, FIRST LAW OF THERMODYNAMICS, THERMODYNAMIC STATE VARIABLES AND EQUATION OF STATE

Basic Definitions

Thermodynamic state : The state of a system can be described completely by (i) composition (ii) temperature (iii) volume and (iv) pressure. These parameters are called the **thermodynamic parameters** or **variables** of the system.

THERMAL EQUILIBRIUM

Two systems are said to be in thermal equilibrium with each other, if they have the same temperature.

ZEROTH LAW OF THERMODYNAMICS

If objects A and B are separately in thermal equilibrium with a third object C then objects A and B are in thermal equilibrium with each other.

Concept of temperature : Zeroth law of thermodynamics implies that temperature is a physical quantity which has the same value for all systems which are in thermal equilibrium with each other.

HEAT, INTERNAL ENERGY AND WORK

Heat

It is energy in transit between two objects or system due to temperature difference between them.

Internal Energy

Internal energy of a system is the energy possessed by the system due to molecular motion and molecular configuration. Internal energy in the absence of inter-molecular forces is simply the function of temperature and state only, it is independent of path followed. $dU = U_f - U_i$

where U_i and U_f are internal energies in initial and final states.

Work

Work is energy transfer brought about by other means, such as moving the piston of a cylinder containing the gas, by raising or lowering some weight connected to it etc.

Sign conventions for the study of thermodynamic processes:

The following sign conventions are adopted in the study of thermodynamic process :

(i) Heat gained by a system is taken as positive while that lost by a system is taken as negative.

(ii) The work done by a system is taken as positive while that done on the system is taken as negative.

(iii) Increase in the internal energy of a system is taken as positive. Decrease in the internal energy of system is taken as negative.

FIRST LAW OF THERMODYNAMICS

According to **first law of thermodynamics**, *if some quantity of heat is supplied to a system capable of doing external work, then the quantity of heat absorbed by the system is equal to the sum of the increase in the internal energy of the system and the external work done by the system. i.e.,* $\delta Q = \delta U + \delta W$

Hence, $\delta U = \delta Q - \delta W$

This equ^{n}. is known as the **first law of thermodynamics.**

The first law of thermodynamics is essentially a restatement of the law of conservation of energy, i.e., energy can neither be created nor be destroyed but may be converted from one form to another.

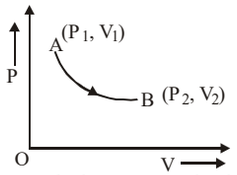
THERMODYNAMIC STATE VARIABLES AND EQUATION OF STATE

A thermodynamic process is said to occur if the thermodynamic variables of a system undergo a change with time.

Extensive variables – *internal energy, volume and total mass* and **intensive variables –** *pressure, temperature and density*

Indicator diagram or P-V diagram :

The equation of state of a gas is $PV = \mu RT$. Out of the three variables P, V and T, if any two are known, the third one can be calculated.

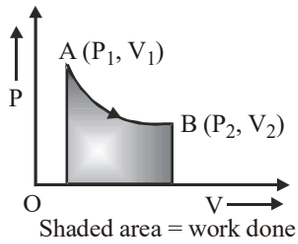


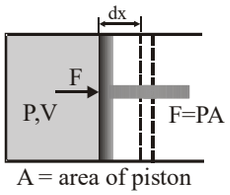
The indicator diagram helps us to calculate the amount of work done by the gas or on the gas during expansion or compression.

TOPIC 4.2 : WORK DONE BY THERMODYNAMIC SYSTEM, THERMODYNAMIC PROCESSES

WORK DONE BY THERMODYNAMIC SYSTEM

A gas in a cylinder with a movable piston is a simple example of a thermodynamic system.





For a finite change in volume from V_i to V_f, this equation is then integrated between V_i to V_f to find the net work

$$W = \int dW = \int_{V_i}^{V_f} PdV$$

The work done by a gas is also equal to the area under P-V graph.

THERMODYNAMIC PROCESSES

Isochoric or Isometric Process:

It is a thermodynamic process that takes place at constant volume of the system, but pressure and temperature varies for change in state of the system.

This is the process in which volume remains constant i.e. $\Delta V = 0$ therefore, work done $\Delta W = \int_{V_i}^{V_f} PdV = 0$

Form of first law of thermodynamics in isochoric process : $\delta Q = \delta U$

Whole of heat supplied is utilized for change in internal energy of the system. $\delta Q = \delta U = \mu\, C_v\, dT$

Isobaric Process :

It is a thermodynamic process that takes place at constant pressure, but volume and temperature varies for change in state of the system.

In an isobaric process, P is fixed. Work done by the gas is

$$W = P(V_2 - V_1) = \mu R (T_2 - T_1)$$

Equation of state : V = const. × T

This is the process in which pressure remains constant, i.e. $\Delta P = 0$

$$\therefore \quad \text{Work done } W = \int_{V_i}^{V_f} PdV = P(V_f - V_i)$$

Form of first law of thermodynamics in isobaric process: $\delta Q = \delta U + P(V_f - V_i)$ or $\mu C_p\, dT = \mu C_v\, dT + P(V_f - V_i)$

Isothermal Process :

It is a thermodynamic process in which the pressure and volume of system change but temperature remains constant.

A process has to be extremely slow to be isothermal.

Equation of state : $PV = constant = \mu RT$ (*since T is constant*)

$$\text{Work done } (W) = 2.303 \mu RT \log_{10}\left[\frac{P_1}{P_2}\right] \quad [\because P_1 V_1 = P_2 V_2]$$

Form of first law of thermodynamics in isothermal process :

Since there is no change in temperature and internal energy of the system, so, $dU = 0$

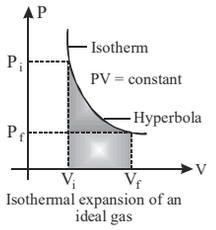
$$\delta Q = 2.303\, \mu RT \log_{10}\left[\frac{V_2}{V_1}\right]$$

Slope of the isothermal curve : For an isothermal process, PV = constant

Differentiating, $PdV + VdP = 0$

or $VdP = -PdV$

or $\frac{dP}{dV} = -\frac{P}{V}$



Isothermal expansion of an ideal gas

$$\therefore \quad \text{Slope of isothermal P-V curve, } \left(\frac{dP}{dV}\right)_{iso} = -\frac{P}{V}$$

Adiabatic Process

It is that thermodynamic process in which pressure, volume and temperature of the system change but there is no exchange of heat between the system and the surroundings.

Equation of state : $PV = \mu RT$

Equation for adiabatic process PV^{γ} = constant

$$\text{Work done } W = \int_{V_1}^{V_2} PdV \text{ or } W = \frac{1}{(\gamma - 1)}[P_1V_1 - P_2V_2]$$

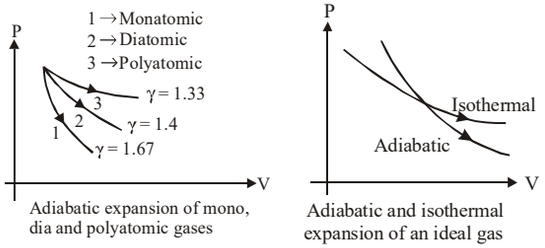
$$W = \frac{\mu R}{(\gamma - 1)}(T_1 - T_2) \quad (\because PV = \mu RT)$$

Form of first law of thermodynamics in adabatic process:

$$\delta U = -\delta W$$

Slope of the adiabatic curve :

Slope of adiabatic curve, $\left(\frac{dP}{dV}\right)_{adia} = -\frac{\gamma P}{V}$



Adiabatic expansion of mono, dia and polyatomic gases

Adiabatic and isothermal expansion of an ideal gas

$$\left(\frac{dP}{dV}\right)_{adia} = \gamma\left(-\frac{P}{V}\right) = \gamma\left(\frac{dP}{dV}\right)_{iso}$$

$$\frac{Slope\ of\ adiabatic\ changes}{Slope\ of\ isothermal\ changes} = \gamma$$

But γ is always greater than one.

So, slope of adiabatic is greater than the slope of isothermal.

Adiabatic Relation Between P and V for Ideal Gas

$\therefore \quad PV^{\gamma} = constant$

Adiabatic Relation Between V and T for Ideal Gas

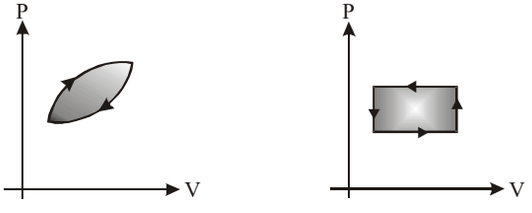
$TV^{\gamma - 1} = constant$

Adiabatic Relation Between P and T for Ideal Gas

$T^{\gamma} P^{1-\gamma} = constant$

Cyclic Process

It is a process in which the system returns to its initial state.

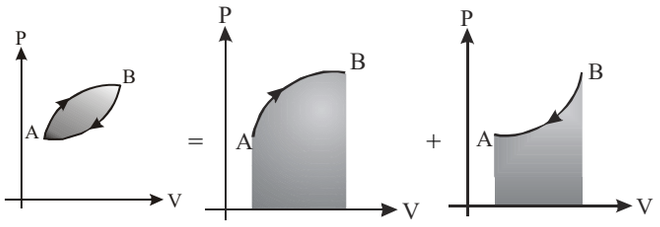


(a) (b)

$W_{clockwise\ cycle}$ = + shaded area

$W_{anticlockwise\ cycle}$ = – shaded area

Work done in clockwise cycle

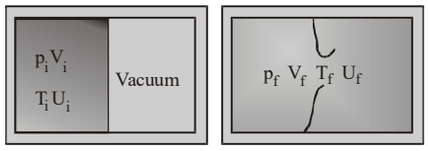


W_{AB} – positive W_{BA} – negative

$W_{cyclic} = W_{AB}$ Positive + W_{BA} Negative

= area of closed path

Free Expansion



(a) (b)

For ideal gas :

$(\delta W)_{ext.}$ = work done against external atmosphere

$= P\,dV = 0\ (\because P = 0)$

$(\delta W)_{int.}$ = work done against internal molecular forces = 0

$0 = \delta U + 0 \qquad (\delta Q = \delta U + \delta W)$

Therefore, the internal energy does not change. $dU = 0$

$U \rightarrow$ constant $\quad T \rightarrow$ constant

The internal energy U(T) of an ideal gas depends only on the temperature.

For real gas :

$\delta Q = 0$, $(\delta W)_{ext.} = 0 \qquad (\because P = 0)$

$(\delta W)_{int.} \neq 0$

(intermolecular forces are present in real gases)

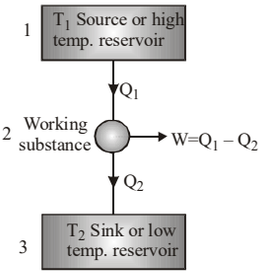
$0 = \delta U + (\delta W)_{int.}$

$\delta U = -(\delta W)_{int.} \qquad U \downarrow\ T \downarrow$

TOPIC 4.3 : HEAT ENGINE, REFRIGERATORS AND HEAT PUMPS, REVERSIBLE & IRREVERSIBLE PROCESSES, CARNOT ENGINE AND SECOND LAW OF THERMODYNAMICS

HEAT ENGINE

➢ *Heat engine is a device which converts heat energy into work.* A heat engine, in general, consists of three parts :



(1) A source or high temperature reservoir at temperature T_1.

(2) A working substance.

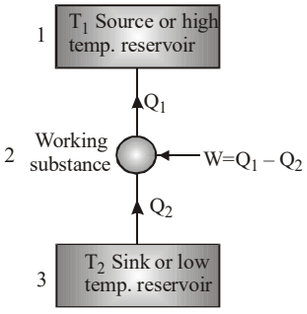
(3) A sink or low temperature reservoir at temperature T_2.

Efficiency of heat engine, $\eta = \dfrac{\text{Work done } (W)}{\text{Heat taken from soruce } (Q_1)}$

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

REFRIGERATORS AND HEAT PUMPS

A refrigerator is the reverse of a heat engine. A heat pump is the same as a refrigerator.



The coefficient of performance of a refrigerator or heat pump

$$\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} \quad [\because W = Q_1 - Q_2]$$

REVERSIBLE & IRREVERSIBLE PROCESSES

Reversible Process

Any process which can be made to proceed in the reverse direction by variation in its conditions such that any change occurring in any part of the direct process is exactly reversed in the corresponding part of reverse process is called a reversible process.

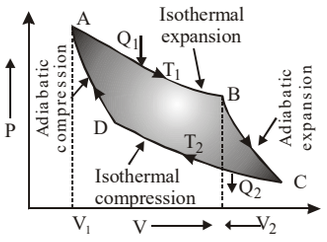
A complete reversible process is an idealised concept as it can never be realised because dissipative forces cannot be completely eliminated.

Irreversible Process

Any process which cannot be retraced in the reverse direction exactly is called an irreversible process. Most of the processes occurring in the nature are irreversible processes.

CARNOT ENGINE

Carnot devised an ideal engine which is based on a reversible cycle of four operations in succession : *isothermal expansion, adiabatic expansion, isothermal compression and adiabatic compression.*



Carnot Cycle

The percentage efficiency of Carnot's engine,

$$\eta = \frac{T_1 - T_2}{T_1} \times 100\% \text{ or, } \eta = \frac{Q_1 - Q_2}{Q_1} \times 100\%$$

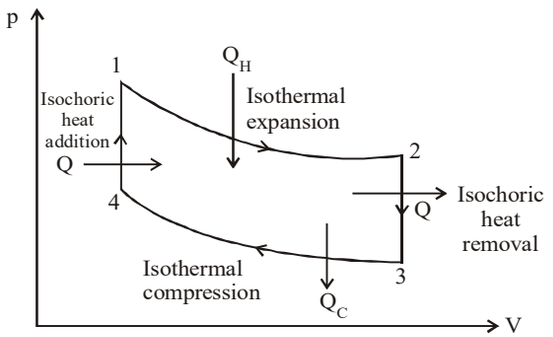
In a Carnot cycle, $\dfrac{Q_2}{Q_1} = \dfrac{T_2}{T_1}$ or $\dfrac{Q_1}{T_1} = \dfrac{Q_2}{T_2}$.

Sterling Cycle

➢ It is a thermodynamic cycle known for its high efficiency.

➢ The ideal sterling cycle consists of 4 processes :

1. Isothermal expansion (heat addition)
2. Isochoric heat removal (regeneration)
3. Isothermal compression (heat rejection)
4. Isochoric heat addition (regeneration)



SECOND LAW OF THERMODYNAMICS

1. **Kelvin-Planck statement :** It is impossible for an engine working between a cyclic process to extract heat from a reservoir and convert completely into work. In other words, 100% conversion of heat into work is impossible.
2. **Claussius statement :** It is impossible for a self-acting machine, unaided by any external agency to transfer heat from a cold to hot reservoir. In other words heat itself cannot flow from a colder to a hotter body.

CHAPTER AT A GLANCE

- Two systems are said to be in thermal equilibrium with each other, if they have the same temperature.
- Internal energy in the absence of inter-molecular forces is simply the function of temperature and state only, it is independent of path followed. $dU = U_f - U_i$

  where U_i and U_f are internal energies in initial and final states.
- According to first law of thermodynamics, $\delta Q = \delta u + \delta w = \delta u + p\delta v$
- The thermodynamic state of a system is characterised by its internal energy, not heat.
- In thermodynamics, heat and work are not state variables. These are the modes of energy transfer to a system resulting in the change in its internal energy.
- Work done during the expansion or compression of a gas is equal to the area enclosed between the p-v curve and the volume axis.
- Work done per cycle = area of the loop representing the cycle.
- Equation of isothermal process PV = constant or $P_1V_1 = P_2V_2$
- Work done when 1 mole of a gas expands isothermally

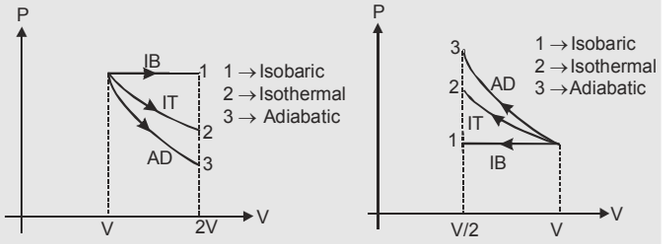
  $W_{iso} = 2.303\ RT \log \frac{V_2}{V_1}$; $W_{iso} = 2.303\ RT \log \frac{P_1}{P_2}$
- Equation for adiabatic process

  (i) $P_1V_1^{\gamma} = P_2V_2^{\gamma} = \text{constant}$

  (ii) $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1} = \text{constant}$

  (iii) $\frac{P_1^{\gamma-1}}{T_1^{\gamma}} = \frac{P_2^{\gamma-1}}{T_2^{\gamma}} = \text{constant}$ where $\gamma = C_p/C_v$
- Work done when 1 mole of a gas expands adiabatically

  $W_{adi} = \frac{R}{\gamma-1}[T_1 - T_2]$; $W_{adi} = \frac{1}{\gamma-1}[P_1V_1 - P_2V_2]$
- When a gas expands its volume increases, then final pressure is less for adiabatic expansion. But, when a gas compresses its volume decreases, then the final pressure is more in case of adiabatic compression.



- Efficiency of a heat engine $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$
- The coefficient of performance of a refrigerator or heat pump

  $\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$ $[\because W = Q_1 - Q_2]$
- Carnot theorem: It states that (i) no engine working between two given temperatures can have efficiency greater than that of the carnot engine working between the same two temperatures and (ii) the efficiency of the carnot engine is independent of the nature of the working substance.
- Effeciency of a carnot's engine $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

Exercise 1 : WARM-UP
Topic-wise MCQs

4.1 Thermal Equilibrium, Zeroth Law of Thermodynamics, Heat, Internal Energy and Work, First Law of Thermodynamics, Thermodynamic State Variables and Equation of State

1. Which of the following macroscopic variable is not measurable?
(a) Pressure (b) Volume
(c) Mass (d) None of these

2. Thermodynamics is concerned in part with transformations
(a) different forms of heat energy
(b) internal energy at various temperatures
(c) one form of mechanical energy into other forms
(d) heat, internal energy and mechnical work

3. If there is no net flow to beat between two systems when they are is contact, then they are said to be in
(a) thermal equilibrium
(b) stable equilibrium
(c) unstable equilibrium
(d) None of these

4. The variable defined by Zeroth law of thermodynamics is
(a) temperature (b) internal energy
(c) work (d) All of these

5. Which of the following is a state variable?
(a) Heat (b) Work
(c) Internal energy (d) All of these

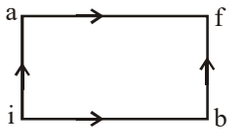
6. The internal energy of an ideal gas depends upon
(a) specific volume
(b) pressure
(c) temperature
(d) density

7. Energy transfer brought about by moving the piston of a cylinder containing the gas is known as
(a) work (b) heat
(c) pressure (d) temperature

8. At a given temperature the internal energy of a substance
(a) in liquid state is equal to that in gaseous state.
(b) in liquid state is less than that in gaseous state.
(c) in liquid state is more than that in gaseous state.
(d) is equal for the three states of matter.

9. A gas is compressed from a volume of $2m^3$ to a volume of $1\,m^3$ at a constant pressure of $100\ N/m^2$. Then it is heated at constant volume by supplying 150 J of energy. As a result, the internal energy of the gas:
(a) increases by 250 J
(b) decreases by 250 J
(c) increases by 50 J
(d) decreases by 50 J

10. When a system is taken from state i to state f along the path iaf, it is found that Q =50 cal and W = 20 cal. Along the path ibf Q = 36 cal. W along the path ibf is



(a) 14 cal (b) 6 cal
(c) 16 cal (d) 66 cal

11. In thermodynamics, heat and work are :
(a) Point functions
(b) Extensive thermodynamic state variables
(c) Path functions
(d) Intensive thermodynamic state variables

12. First law of thermodynamics states that
(a) system can do work
(b) system has temperature
(c) system has pressure
(d) heat is a form of energy

13. The first law of thermodynamics expresses
(a) law of conservation of momentum
(b) law of conservation of energy
(c) law of conservation of mass
(d) All of the above

14. In changing the state of thermodynamics from A to B state, the heat required is Q and the work done by the system is W. The change in its internal energy is
(a) Q + W (b) Q – W
(c) Q (d) $\frac{Q-W}{2}$

15. Which of the following is incorrect regarding first law of thermodynamics?

(a) It is a restatement of principle of conservation of energy.
(b) It is applicable to cyclic processes
(c) It introduces the concept of entropy
(d) It introduces the concept of internal energy

16. The change in internal energy of a thermodynamical system which has absorbed 2 kcal of heat and done 400 J of work is (1 cal = 4.2 J)
(a) 2 kJ (b) 8 kJ
(c) 3.5 kJ (d) 5.5 kJ

17. If the amount of heat given to a system is 35 J and the amount of work done on the system is 15 J, then the change in internal energy of the system is
(a) –50 J (b) 20 J
(c) 30 J (d) 50 J

18. The heat energy supplied to a diatomic gas at constant pressure is 210 J, then the work done by the gas is
(a) 60 J (b) 150 J
(c) 90 J (d) 210 J

19. Two systems in thermal equilibrium with a third system separately are in thermal equilibrium with each other. The above statement is
(a) First law of thermodynamics
(b) Second law of thermodynamics
(c) Third law of thermodynamics
(d) Zeroth law of thermodynamics

20. A gas absorbs 18 J of heat and work done on the gas is 12 J, Then the change in internal energy of the gas
(a) 24 J (b) 36 J
(c) 6 J (d) 30 J

21. A system is said to be in thermal equilibrium if
(a) the macroscopic variables do not change in time
(b) the microscopic variables do not change in time
(c) the macroscopic variables change in time
(d) the microscopic variables change in time

4.2 Work done by Thermodynamic System, Thermodynamic Processes

22. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is
(a) isothermal
(b) isobaric
(c) adiabatic
(d) equal in all cases

23. Choose the incorrect statement related to an isobaric process.
(a) $\frac{V}{T}$ = constant
(b) $W = P\Delta V$
(c) Heat given to a system is used up in raising the temperature only.
(d) $\Delta Q > W$

24. A monoatomic gas at pressure P and volume V is suddenly compressed to one eights of its original volume. The final pressure at constant entropy will be :
(a) P (b) 8 P
(c) 32 P (d) 64 P

25. During isothermal expansion, the slope of *P-V* graph
(a) decreases
(b) increases
(c) remains same
(d) may increase or decrease

26. When heat is given to a gas in an isothermal change, the result will be
(a) external work done
(b) rise in temperature
(c) increase in internal energy
(d) external work done and also rise in temperature

27. The work done in an adiabatic change in a particular gas depends only upon
(a) change in volume
(b) change in temperature
(c) change in pressure
(d) None of these

28. Which one of the following is an isoentropic process?
(a) Isothermal (b) Adiabatic
(c) Isochoric (d) Isobaric

29. Which of the following processes is adiabatic ?
(a) Melting of ice
(b) Bursting of tyre
(c) Motion of piston of an engine with constant speed
(d) None of these

30. Which process will increase the temperature of the system without heating it?
(a) Adiabatic compression
(b) Adiabatic expansion
(c) Isothermal compression
(d) Isothermal expansion

31. The slopes of isothermal and adiabatic curves are related as
(a) isothermal curve slope = adiabatic curve slope
(b) isothermal curve slope = $\gamma \times$ adiabatic curve slope
(c) adiabatic curve slope = $\gamma \times$ isothermal curve slope
(d) adiabatic curve slope = $\frac{1}{2} \times$ isothermal curve slope

32. A mass of diatomic gas ($\gamma = 1.4$) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in final state is

(a) 28 atm (b) 68.7 atm

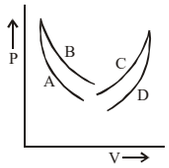
(c) 256 atm (d) 8 atm

33. A diatomic gas initially at 18ºC is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(a) 18ºC (b) 668.4ºK

(c) 395.4ºC (d) 144ºC

34. Four curves A, B, C and D are drawn in the figure for a given amount of a gas. The curves which represent adiabatic and isothermal changes are



(a) C and D respectively

(b) D and C respectively

(c) A and B respectively

(d) B and A respectively

35. A sample of monoatomic gas is taken at inital pressure of 75 kPa. The volume of the gas is then compressed from 1200 cm^3 to 150 cm^3 adiabatically. In this process, the value of workdone on the gas will be:

(a) 79 J (b) 405 J

(c) 4050 J (d) 9590 J

36. The pressure inside a tyre is 4 times that of atmosphere. If the tyre bursts suddenly at temperature 300 K, what will be the new temperature?

(a) $300\,(4)^{7/2}$ (b) $300\,(4)^{2/7}$

(c) $300\,(2)^{7/2}$ (d) $300\,(4)^{-2/7}$

37. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true?

(a) $\Delta U = -W$ in an adiabatic process

(b) $\Delta U = W$ in an isothermal process

(c) $\Delta U = -W$ in an isothermal process

(d) $\Delta U = W$ in an adiabatic process

38. Which of the following holds good for an isochoric process?

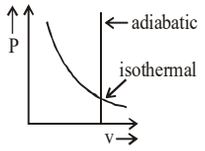
(a) No work is done on the gas

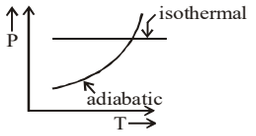
(b) No work is done by the gas

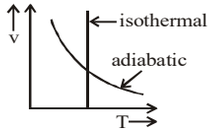
(c) Both (a) and (b)

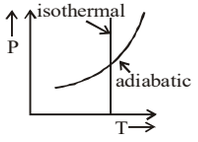
(d) None of these

39. Which one is the correct option for the two different thermodynamic processes?

(1) 

(2) 

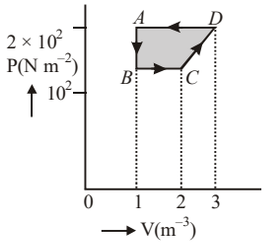
(3) 

(4) 

(a) (3) and (4) (b) (1) only

(c) (3) and (1) (d) (2) and (3)

40. The *P-V* diagram of a gas system undergoing cyclic process is shown here. The work done during isobaric compression is



(a) 100 J (b) 200 J

(c) 600 J (d) 400 J

41. Which of the following statements about a thermodynamic process is wrong ?

(a) For an adiabatic process $\Delta E_{int} = -W$

(b) For a constant volume process $\Delta E_{int} = +Q$

(c) For a cyclic process $\Delta E_{int} = 0$

(d) For free expansion of a gas $\Delta E_{int} > 0$

42. In a cyclic process, work done by the system is

(a) zero

(b) equal to heat given to the system

(c) more than heat given to the system

(d) independent of heat given to the system

43. A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as :

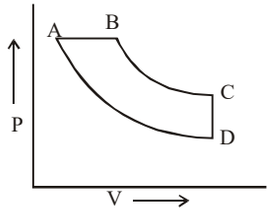
(a) irreversible isothermal

(b) irreversible adiabatic

(c) reversible adiabatic

(d) reversible isothermal

44. In pressure-volume diagram, the isochoric, isothermal, isobaric and iso-entropic parts respectively, are



(a) BA, AD, DC, CB

(b) DC, CB, BA, AD

(c) AB, BC, CD, DA

(d) CD, DA, AB, BC

4.3 Heat Engine, Refrigerators and Heat Pumps, Reversible & Irreversible Processes, Carnot Engine and Second Law of Thermodynamics

45. Heat engine is a device by which a system is made to undergo a ...*X*... process that result in conversion of ...*Y*... into work.

Here, *X* and *Y* refer to

(a) isothermal and heat

(b) cyclic and heat

(c) cyclic and work

(d) adiabatic and heat

46. A steam engine takes 0.1 kg of steam at 100°C per minute and cools it down to 20°C. What is the heat rejected by the steam engine per second? [Latent heat of vaporization of steam = 540 cal g^{-1}]

(a) 6.2×10^4 cal/sec

(b) 1.03×10^3 cal/sec

(c) 62×10^3 cal/sec

(d) None of these

47. Air conditioner is based on the principle of

(a) Carnot cycle

(b) refrigerator

(c) first law of thermodynamics

(d) None of these

48. The correct relation between coefficient of performance and efficiency of refrigerator is

(a) $\beta = \frac{1+\eta}{\eta}$ (b) $\beta = \frac{1-\eta}{\eta}$

(c) $\beta = 1 + \eta$ (d) None of these

49. A refrigerator is a

(a) heat engine

(b) an electric motor

(c) heat engine working in backward direction

(d) air cooler

50. The coefficient of performance of a refrigerator is given by

(a) $\frac{\theta_2}{\theta_1 - \theta_2}$ (b) $\frac{\theta_1}{\theta_1 - \theta_2}$

(c) $\frac{\theta_1 - \theta_2}{\theta_2}$ (d) $\frac{\theta_1 - \theta_2}{\theta_1}$

51. If an air conditioner is put in the middle of a room and started working

(a) the room can be cooled slightly

(b) the temperature of the room will not change

(c) the room will become slightly warmer

(d) the same temperature will be attained in the room as by putting it on the window in the standard position

52. A refrigerator with coefficient of performance $\frac{1}{3}$ releases 200 J of heat to a hot reservoir. Then the work done on the working substance is

(a) $\frac{100}{3}$ J (b) 100 J

(c) $\frac{200}{3}$ J (d) 150 J

53. If the co-efficient of performance of a refrigerator is 5 and operates at the room temperature 27°C, the temperature inside the refrigerator is

(a) 240 K (b) 250 K

(c) 230 K (d) 260 K

54. "Heat cannot by itself flow from a body at lower temperature to a body at higher temperature" is a statement or consequence of

(a) second law of thermodynamics

(b) conservation of momentum

(c) conservation of mass

(d) first law of thermodynamics

55. Which of the following processes is reversible?

(a) Transfer of heat by conduction

(b) Transfer of heat by radiation

(c) Isothermal compression

(d) Electrical heating of a nichrome wire

56. Which of the following processes is irreversible?

(a) Transfer of heat by radiation

(b) Adiabatic changes performed slowly

(c) Extremely slow extension of a spring

(d) Isothermal changes performed slowly

57. The first operation involved in a Carnot cycle is
(a) isothermal expansion
(b) adiabatic expansion
(c) isothermal compression
(d) adiabatic compression

58. Which of the following statements is incorrect?
(a) All reversible cycles have same efficiency
(b) Reversible cycle has more efficiency than an irreversible one
(c) Carnot cycle is a reversible one
(d) Carnot cycle has the maximum efficiency in all cycles

59. A Carnot engine works between a source and a sink maintained at constant temperatures T_1 and T_2. For efficiency to be the greatest
(a) T_1 and T_2 should be high
(b) T_1 and T_2 should be low
(c) T_1 should be low and T_2 should be high
(d) T_1 should be high and T_2 should be low

60. The efficiency of a Carnot engine operating between the temperatures of 100ºC and –23ºC will be
(a) $\frac{100+23}{100}$ (b) $\frac{100-23}{100}$
(c) $\frac{373+250}{373}$ (d) $\frac{373-250}{373}$

61. The temperature of source and sink of a heat engine are 127ºC and 27ºC respectively. An inventor claims its efficiency to be 26%, then:
(a) it is impossible
(b) it is possible with high probability
(c) it is possible with low probability
(d) data are insufficient.

62. Even Carnot engine cannot give 100% efficiency because we cannot
(a) prevent radiation
(b) find ideal sources
(c) reach absolute zero temperature
(d) eliminate friction

63. If the temperatures of source and sink of a Carnot engine having efficiency η are each decreased by 100 K, then the efficiency
(a) remains constant
(b) becomes 1
(c) decreases
(d) increases

64. A Carnot engine takes 3×10^6 cal. of heat from a reservoir at 627°C, and gives it to a sink at 27°C. The work done by the engine is
(a) 4.2×10^6 J (b) 8.4×10^6 J
(c) 16.8×10^6 J (d) zero

65. A Carnot's engine working between 400 K and 800 K has a work output of 1200 J per cycle. The amount of heat energy supplied to the engine from the source in each cycle is:
(a) 1800 J (b) 3200 J
(c) 1600 J (d) 2400 J

Exercise 2 : ACCELERATOR
Topic-wise MCQs

4.1 Thermal Equilibrium, Zeroth Law of Thermodynamics, Heat, Internal Energy and Work, First Law of Thermodynamics, Thermodynamic State Variables and Equation of State

1. A perfect gas goes from a state A to another state B by absorbing 8×10^5 J of heat and doing 6.5×10^5 J of external work. It is now transferred between the same two states in another process in which it absorbs 10^5 J of heat. In the second process
(a) work done by gas is 10^5 J
(b) work done on gas is 10^5 J
(c) work done by gas is 0.5×10^5 J
(d) work done on the gas is 0.5×10^5 J

2. In a thermodynamic process, pressure of a fixed mass of gas is changed in such a manner that the gas molecules gives out 30 joules of heat and 10 J of work is done on the gas. If the initial internal energy of the gas was 40J, then final internal energy will be
(a) zero (b) 80 J
(c) 20 J (d) –20 J

3. Unit mass of a liquid with volume V_1 is completely changed into a gas of volume V_2 at a constant external pressure P and temperature T. If the latent heat of evaporation for the given mass is L, then the increase in the internal energy of the system is
(a) Zero (b) $P(V_2 - V_1)$
(c) $L - P(V_2 - V_1)$ (d) L

4. 1 gm of water at a pressure of 1.01×10^5 Pa is converted into steam without any change of temperature. The volume of 1 g of steam is 1671 cc and the latent heat of evaporation is 540 cal. The change in internal energy due to evaporation of 1 gm of water is

(a) ≈167 cal

(b) ≈500 cal

(c) 540 cal

(d) 581 cal

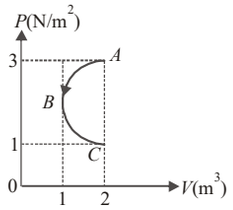
5. 1 g of H_2O changes from liquid to vapour phase at constant pressure at 1 atm. The pressure increases from 1 cc to 1671 cc. The heat of vaporization at this pressure is 540 cal/g. The increase in internal energy of water is

(a) 2099 J (b) 3000 J

(c) 992 J (d) 2122 J

4.2 Work done by Thermodynamic System, Thermodynamic Processes

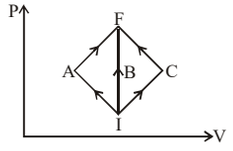
6. In *P-V* diagram shown in figure *ABC* is a semicircle. The work done in the process *ABC* is



(a) 4 J (b) $\frac{-\pi}{2}$ J

(c) $\frac{\pi}{2}$ J (d) zero

7. In the P-V diagram, I is the initial state and F is the final state. The gas goes from I ot F by (i) IAF, (ii) IBF, (iii) ICF. The heat absorbed by the gas is



(a) the same in all three processes

(b) the same in (i) and (ii)

(c) greater in (i) than in (ii)

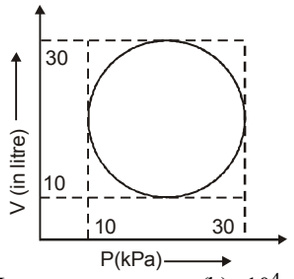
(d) the same in (i) and (iii)

8. A closed system undergoes a process $1 \rightarrow 2$ for which the values $W_{1\text{-}2}$ and $Q_{1\text{-}2}$ are 50 kJ and –20 kJ respectively. If the system is returned to state 1 and $Q_{2\rightarrow1}$ is + 10 kJ the work done $W_{2\rightarrow1}$ is

(a) 40 kJ (b) 50 kJ

(c) –60 kJ (d) –50 kJ

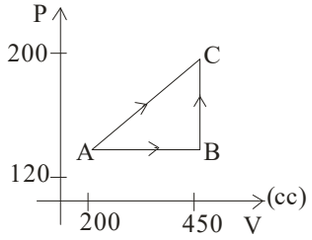
9. Heat energy absorbed by a system in going through a cyclic process shown in the given figure is



(a) $10^7\ \pi$ J (b) $10^4\ \pi$ J

(c) $10^2\ \pi$ J (d) $10^{-3}\ \pi$ J

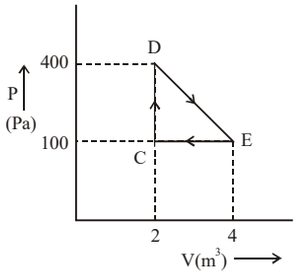
10. Calculate the work done by the gas in the statediagram shown.



(a) 30 J (b) 20 J

(c) – 20 J (d) – 10 J

11. A thermodynamic system is taken through cyclic process. The total work done in the process is :

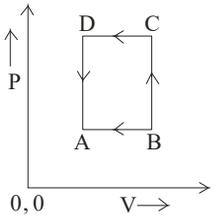


(a) 100 J (b) 300 J

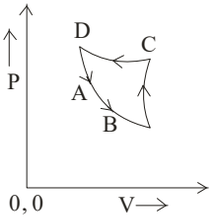
(c) Zero (d) 200 J

12. In following figs. (1) to (4). Variation of volume by change of pressure is shown in Fig. A gas is taken along the path ABCDA. The change in internal energy of the gas will be:

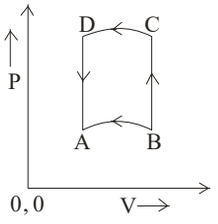
(1)



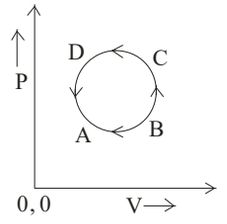
(2)



(3)



(4)



(a) Positive in al cases from (1) to (4)
(b) Positive in cases (1), (2) and (3) but zero in case (4)
(c) Negative in case (1), (2) and (3) but zero in case (4)
(d) zero in all the four cases

13. In thermodynamic processes which of the following statements is not true?
(a) In an isochoric process pressure remains constant
(b) In an isothermal process the temperature remains constant
(c) In an adiabatic process PV^{γ} = constant
(d) In an adiabatic process the system is insulated from the surroundings

14. A monatomic gas at 630 K expands adiabatically to 27 times its initial volume. The final temperature of the gas is
(a) 30 K (b) 130 K
(c) 170 K (d) 70 K

15. The condition $dw = dq$ holds good in the following process
(a) Adiabatic process (b) Isothermal process
(c) Isochoric process (d) Isobaric process

16. Choose the correct statement regarding isobaric process
(a) pV = constant.
(b) Heat absorbed by the gas goes partly to increase internal energy and partly to do work.
(c) The system returns to its initial state.
(d) Both (a) and (b)

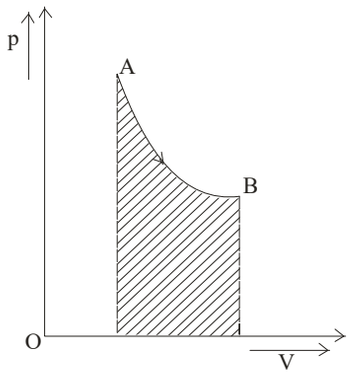
17. In a particular experiment an ideal gas undergoes adiabatic expansion satisfying the equation VT^3 = constant. The ratio of specific heats γ is
(a) 1.5 (b) 3
(c) $\frac{5}{3}$ (d) $\frac{4}{3}$

18. An ideal gas is compressed to half its initial volume by means of several process. Which of the process results in the maximum work done on the gas?
(a) Adiabatic (b) Isobaric
(c) Isochoric (d) Isothermal

19. A monoatomic gas at a pressure p, having a volume V expands isothermally to a volume 2V and then adiabatically to a volume 16V. The final pressure of the gas is $\left(\text{take } \gamma = \frac{5}{3}\right)$
(a) 64p (b) 32p
(c) $\frac{p}{64}$ (d) 16p

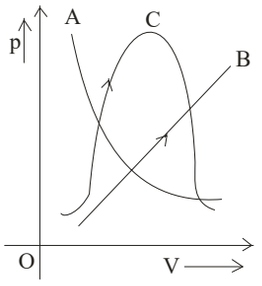
20. When heat is given to a gas in an isothermal change, the result will be
(a) increase in internal energy
(b) rise in temperature
(c) external work done by the gas
(d) external work done as well as increase in internal energy

21. For the given isothermal process A → B of an ideal gas, area under the graph is 20 J, then



(a) $\Delta Q = 0$ (b) $\Delta Q = +20$ J
(c) $\Delta U = -20$ J (d) $\Delta U = 20$ J

22. Among given curves, which one could represent isothermal process?



(a) Curve A (b) Curve B (c) Curve C
(d) None of the curves could represent isothermal process

23. The slopes of isothermal and adiabatic curves are related as
(a) $\left(\frac{dp}{dV}\right)_{iso} = \left(\frac{dp}{dV}\right)_{ad}$ (b) $\left(\frac{dp}{dV}\right)_{iso} = \gamma\left(\frac{dp}{dV}\right)$
(c) $\left(\frac{dp}{dV}\right)_{ad} = \frac{3}{2}\left(\frac{dp}{dV}\right)_{iso}$ (d) $\left(\frac{dp}{dV}\right)_{ad} = \gamma\left(\frac{dp}{dV}\right)_{iso}$

24. For an isothermal expansion or compression, (where ΔW_1 and ΔW_2 are the net work for expansion and compression, respectively)
(a) $\Delta W_1 = -$ve ; $\Delta W_2 = +$ ve
(b) $\Delta W_1 = \Delta W_2$; $\Delta W_2 = -$ ve
(c) $\Delta W_1 = +$ve ; $\Delta W_2 = -$ ve
(d) $\Delta W_1 = \Delta W_2$, at every stage

25. If work is done on the system in an adiabatic process,
(a) $T_f < T_i$
(b) $T_f = T_i$
(c) $T_f > T_i$
(d) Information is insufficient

26. The temperature of an ideal gas increases to 2 times when compressed adiabatically to half of its volume. Its equation of state can be written as
(a) $pV^{3/2}$ = constant (b) $pV^{4/3}$ = constant
(c) $pV^{1/2}$ = constant (d) pV^2 = constant

27. A gas is taken from V_i to V_f by two processes, one is isothermal and other is adiabatic.
Choose the correct option regarding the p-V diagram for two processes.
(a) $(\text{Slope})_{\text{isothermal}} = (\text{Slope})_{\text{adiabatic}}$
(b) $(\text{Slope})_{\text{isothermal}} > (\text{Slope})_{\text{adiabatic}}$
(c) $(\text{Slope})_{\text{isothermal}} < (\text{Slope})_{\text{adiabatic}}$
(d) Information is insufficient

28. In an isothermal reversible expansion, the volume of 128 g of oxygen at 25°C is increased from 75 L 150 L. The amount of work done by the gas is
(a) $2.3 \times 900\ R \log_{10} 2$ (b) $R \log_{10} 2$
(c) $2.3 \times 1192\ R \log_{10} 2$ (d) $900\ R \log_{10} 2$

29. One mole of an ideal gas at temperature T_0 expands according to the law $\frac{p}{V^2}$ = constant. The work done by the gas till the temperature of gas becomes $2T_0$ is
(a) $\frac{1}{2}RT_0$ (b) $\frac{1}{3}RT_0$
(c) $\frac{2}{3}RT_0$ (d) $\frac{1}{3}R(5T_0)$

30. In an isobaric process, the work done by a diatomic gas is 10 J, the heat given to the gas will be [C_p for diatomic gas = $\frac{7}{2}R$]
(a) 35 J (b) 30 J
(c) 45 J (d) 60 J

31. An ideal gas at a pressure of 1 atm and temperature of 27°C is compressed adiabatically until its pressure becomes 8 times the initial pressure, then the final temperature is $\left(\gamma = \frac{3}{2}\right)$
(a) 627° C (b) 527°C
(c) 427°C (d) 327°C

32. Diatomic gas at pressure 2 atm is compressed adiabatically, so that its temperature rises from 25°C to 919°C. The pressure of the gas in its final state is ($\gamma = 1.4$)
(a) 68.7 atm (b) 256 atm
(c) 8 atm (d) 225 atm

33. A gas is compressed adiabatically, which one of the following statement is not true?
(a) There is no heat supplied to the system
(b) The temperature of the gas increases.
(c) There is no change in the internal energy
(d) The change in the internal energy is equal to the work done on the gas.

34. The relation between volume (V) and absolute temperature (T) of a gas in an adiabatic process is
(a) TV^{γ} = constant
(b) VT^{γ} = constant
(c) $TV^{1-\gamma}$ = constant
(d) $TV^{\gamma-1}$ = constant

35. The relation between absolute temperature (T) and pressure (P) of a gas in an adiabatic process is
(a) $p^{\gamma} T^{1-\gamma}$ = constant (b) $p^{1-\gamma} T^{\gamma}$ = constant
(c) $p^{\gamma-1} T^{\gamma}$ = constant (d) $p^{\gamma} T^{\gamma-1}$ = constant

36. A work of 166.28 J is done to adiabatically compress one mole of a gas. If the increase in the temperature of the gas is 8 °C, the gas is
($R = 8.314\ J\ mol^{-1}\ K^{-1}$)
(a) monatomic
(b) diatomic
(c) polyatomic
(d) mixture of diatomic and polyatomic

37. The work done by a gas is maximum when it expands from a volume V_1 to V_2, then the expansion is
(a) Isothermal expansion
(b) Adiabatic expansion
(c) Isobaric expansion
(d) Free expansion

38. A monatomic gas at 630 K expands adiabatically to 27 times its initial volume. The final temperature of the gas is
(a) 30 K (b) 130 K
(c) 170 K (d) 70 K

39. A monatomic gas of volume 'V' and pressure 'P' expands isothermally to a volume '27V' and then compressed adiabatically to a volume 'V'. The final pressure of the gas is
(a) 3P (b) 2P
(c) 9P (d) 4P

40. An ideal gas at 127 °C is compressed suddenly to $\frac{8}{27}$ of its initial volume. If $\gamma = \frac{5}{3}$ for an ideal gas, then rise in its temperature is

(a) 450 K (b) 500 K

(c) 225 K (d) 405 K

4.3 Heat Engine, Refrigerators and Heat Pumps, Reversible & Irreversible Processes, Carnot Engine and Second Law of Thermodynamics

41. Two Carnot engines A and B are operated in series. The first one, A receives heat at T_1 (= 600 K) and rejects to a reservoir at temperature T_2. The second engine B receives heat rejected by the first engine and in turn, rejects to a heat reservoir at T_3 (= 400 K). Calculate the temperature T_2 if the work outputs of the two engines are equal:

(a) 600 K (b) 400 K

(c) 300 K (d) 500 K

42. A Carnot engine whose heat sinks at 27°C, has an efficiency of 25%. By how many degrees should the temperature of the source be changed to increase the efficiency by 100% of the original efficiency ?

(a) Increases by 18 °C

(b) Increase by 200 °C

(c) Increase by 120 °C

(d) Increase by 73 °C

43. A Carnot's engine working between 400 K and 800 K has a work output of 1200 J per cycle. The amount of heat energy supplied to the engine from the source in each cycle is:

(a) 1800 J (b) 3200 J

(c) 1600 J (d) 2400 J

44. A reversible engine has an efficiency of $\frac{1}{4}$. If the temperature of the sink is reduced by 58°C, its efficiency becomes double. Calculate the temperature of the sink :

(a) 174°C

(b) 280°C

(c) 180.4°C

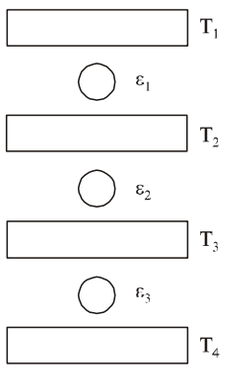
(d) 382°C

45. A heat engine is involved with exchange of heat of 1915 J, – 40 J, +125 J and – *Q* J, during one cycle achieving an efficiency of 50.0%. The value of *Q* is :

(a) 640 J (b) 40 J

(c) 980 J (d) 400 J

46. Three Carnot engines operate in series between a heat source at a temperature T_1 and a heat sink at temperature T_4 (see figure). There are two other reservoirs at temperature T_2 and T_3, as shown, with $T_1 > T_2 > T_3 > T(4)$ The three engines are equally efficient if:



(a) $T_2 = (T_1 T_4)^{1/2}$; $T_3 = (T_1^2 T_4)^{1/3}$

(b) $T_2 = (T_1^2 T_4)^{1/3}$; $T_3 = (T_1 T_4^2)^{1/3}$

(c) $T_2 = (T_1 T_4^2)^{1/3}$; $T_3 = (T_1^2 T_4)^{1/3}$

(d) $T_2 = (T_1^3 T_4)^{1/4}$; $T_3 = (T_1 T_4^3)^{1/4}$

47. Two Carnot engines *A* and *B* are operated in series. The engine *A* receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature *T*. The second engine *B* receives the heat at temperature *T* and rejects to its sink at temperature T_2. For what value of *T* the efficiencies of the two engines are equal?

(a) $\frac{T_1 + T_2}{2}$ (b) $\frac{T_1 - T_2}{2}$

(c) $T_1 T_2$ (d) $\sqrt{T_1 T_2}$

48. A Carnot engine absorbs 1000 J of heat energy from a reservoir at 127°C and rejects 600 J of heat energy during each cycle. The efficiency of engine and temperature of sink will be:

(a) 20% and – 43°C (b) 40% and – 33°C

(c) 50% and – 20°C (d) 70% and – 10°C

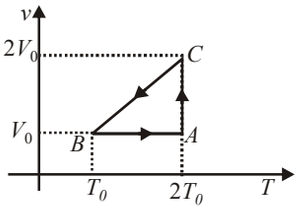
49. The efficiency of an ideal gas with adiabatic exponent 'γ' for the shown cyclic process would be

(a) $\frac{(2\ln 2 - 1)}{\gamma/(\gamma - 1)}$

(b) $\frac{(1 - 2\ln 2)}{\gamma/(\gamma - 1)}$

(c) $\frac{(2\ln 2 + 1)}{\gamma/(\gamma - 1)}$

(d) $\frac{(2\ln 2 - 1)}{\gamma/(\gamma + 1)}$



50. In a Carnot engine, the temperature of reservoir is 927°C and that of sink is 27°C. If the work done by the engine when it transfers heat from reservoir to sink is 12.6×10^6 J, the quantity of heat absorbed by the engine from the reservoir is

(a) 16.8×10^6 J (b) 4×10^6 J

(c) 7.6×10^6 J (d) 4.2×10^6 J

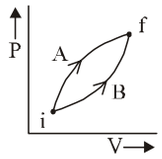
Exercise 3 : PREVIOUS YEARS MCQs

1. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest when the expansion is **[2025]**

(a) isothermal (b) isobaric

(c) adiabatic (d) equal in all cases

2. Following figure shows two processes A and B for a gas. If ΔQ_A and ΔQ_B are the amount of heat absorbed by the system in two cases, and ΔU_A and ΔU_B are changes in internal energies, respectively, then: **[2025]**



(a) $\Delta Q_A < \Delta Q_B, \Delta U_A < \Delta U_B$

(b) $\Delta Q_A > \Delta Q_B, \Delta U_A > \Delta U_B$

(c) $\Delta Q_A > \Delta Q_B, \Delta U_A = \Delta U_B$

(d) $\Delta Q_A = \Delta Q_B; \Delta U_A = \Delta U_B$

3. With same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1, if the process is isothermal, W_2 if isobaric and W_3 if adiabatic, then **[2025]**

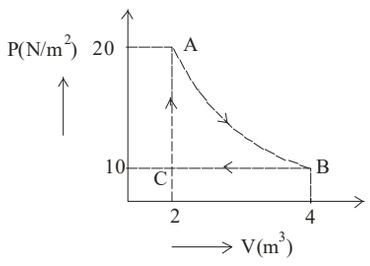
(a) $W_2 > W_1 > W_3$

(b) $W_2 > W_3 > W_1$

(c) $W_1 > W_2 > W_3$

(d) $W_1 > W_3 > W_2$

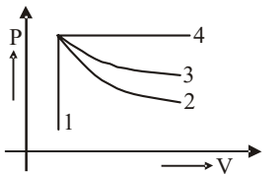
4. A real gas within a closed chamber at 27°C undergoes the cyclic process as shown in figure. The gas obeys $PV^3 = RT$ equation for the path A to B . The net work done in the complete cycle is (assuming R = 8J/molK): **[2024]**



(a) 225 J (b) 205 J

(c) 20 J (d) – 20 J

5. An ideal gas undergoes four different processes from the same initial state as shown in p-V diagram. Four processes are adiabatic, isothermal, isobaric, isochoric. The processes 1, 2, 3 4 respectively are **[2024]**



(a) istothermal, isochoric, isobaric, adiabatic

(b) adiabatic, isobaric, isochoric, isothermal

(c) isochoric, adiabatic, isothermal, isobaric

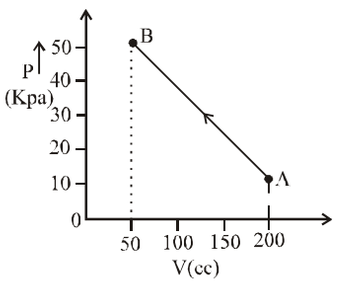
(d) isobaric, isothermal, adiabatic, isochoric

6. A diatomic ideal gas is used in Carnot engine as a working substance. If during the adiabatic expansion part of the cycle, the volume of the gas increases from V to 32V, the efficiency of the engine is **[2024]**

(a) 0.25 (b) 0.50

(c) 0.75 (d) 0.90

7. The pressure of a gas changes linearly with volume from A to B as shown in figure. If no heat is supplied to or extracted from the gas then change in the internal energy of the gas will be **[2023]**



(a) 6 J (b) Zero

(c) –4.5 J (d) 4.5 J

8. A gas is compressed at a constant pressure of 50 N/m^2 from a volume of 10 m^3 to a volume of 4 m^3. Energy of 100 J is then added to the gas by heating. Its internal energy is **[2023]**

(a) increased by 400 J

(b) increased by 200 J

(c) increased by 100 J

(d) decreased by 100 J

9. A gas at normal temperature is suddenly compressed to one-fourth of its original volume. If $\frac{C_P}{C_V} = \gamma = 1.5$, then the increase in its temperature is **[2023]**

(a) 273 K

(b) 373 K

(c) 473 K

(d) 573 K

10. Let η_1 is the efficiency of an engine at $T_1 = 447°C$ and $T_2 = 147°C$ while η_2, is the efficiency at $T_1 = 947°C$ and $T_2 = 47°C$. The ratio $\frac{\eta_1}{\eta_2}$ will be: **[2022]**

(a) 0.41

(b) 0.56

(c) 0.73

(d) 0.70

11. V cc volume of a gas having g = 5/2 is suddenly compressed to $\left(\frac{V}{4}\right)$ cc. The initial pressure of the gas is p. The final pressure of the gas will be **[2022]**

(a) 32p

(b) 16p

(c) $\frac{p}{32}$

(d) $\frac{p}{16}$

12. In an adiabatic process, the state of a gas is changed from p_1, V_1, T_1 to p_2, V_2, T_2 out of the following relations, the correct one is **[2022]**

(a) $p_1V_1^{\gamma} = p_2T_2^{\gamma}$

(b) $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

(c) $p_1V_1^{\gamma-1} = p_2V_2^{\gamma-2}$

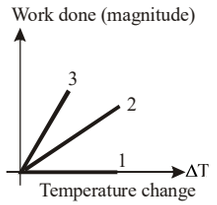
(d) $rT_1V_1^{\gamma} = T_2V_2^{\gamma}$

13. In an isochoric process, if $t_1 = 27°C$ and $t_2 = 127°C$, then $\frac{p_1}{p_2}$ will be equal to [p_1 and p_2 are the pressure at t_1 °C and t_2 °C, respectively] **[2022]**

(a) 4/3 (b) 9/59

(c) 2/3 (d) 3/4

14. For an ideal gas graph is shown for three processes. Process 1, 2 and 3 are respectively. **[2021, 2014]**



(a) Isobaric, adiabatic, isochoric

(b) Adiabatic, isobaric, isochoric

(c) Isochoric, adiabatic, isobaric

(d) Isochoric, isobaric, adiabatic

15. A Carnot engine operating between temperatures T_1 and T_2 has efficiency 0.2. When T_2 is reduced by 50 K, its efficiency increases to 0.4. Then T_1 and T_2 are respectively **[2021, 2008]**

(a) 200 K, 150 K

(b) 250 K, 200 K

(c) 300 K, 250 K

(d) 300 K, 200 K

16. Which one of the following is not a true statement for an isothermal process? **[2020, 2007]**

(a) Temperature of process remains constatn

(b) The process is very fast

(c) The equation of state is pV = constant

(d) There is no change in internal energy of the system

17. A Carnot engine whose low temperature reservoir is at 7°C has an efficiency of 50%. It is desired to increase the efficiency to 70%. By how many degrees should the temperature of the high temperature reservoir be increased? **[2019]**

(a) 840 K

(b) 280 K

(c) 560 K

(d) 380 K

18. An ideal gas at 27°C is compressed adiabatically to (8/27) of its original volume. If ratio of specific heat, $\gamma = 5/3$, then the rise in termperature of the gas is **[2018]**

(a) 500 K (b) 125 K

(c) 250 K (d) 375 K

19. If ΔQ is the amount of heat supplied to n moles of a diatomic gas at constant pressure, ΔU is the change in internal energy and ΔW is the work done, then

$\Delta W = \Delta U : \Delta Q$ **[2017]**

(a) 1 : 2 : 3
(b) 2 : 5 : 7
(c) 2 : 3 : 4
(d) 5 : 7 : 9

20. For a heat engine operating between temperatures t_1°C and t_2°C, its efficiency will be **[2015]**

(a) $\frac{t_1 - t_2}{t_2}$

(b) $\frac{t_1 - t_2}{t_1 + 273}$

(c) $\frac{t_1}{t_2}$

(d) $\frac{t_2}{t_1}$

21. If α is the coefficient of performance of a refrigerator and Q_1 is heat released to the hot reservoir, then the heat extraced from the cold reservoir Q_2 is **[2013]**

(a) $\frac{\alpha Q_1}{\alpha - 1}$ (b) $\frac{\alpha Q_1}{1 + \alpha}$

(c) $\frac{1 + \alpha}{\alpha} Q_1$ (d) $\frac{\alpha - 1}{\alpha} Q_1$

22. The coefficient of performance of a refrigerator is 5. If the inside temperature of freezer is –20°C, then the temperature of the surroundings to which it rejects heat is **[2011]**

(a) 41°C
(b) 11°C
(c) 21°C
(d) 31°C

23. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas? **[2006]**

(a) Isobaric
(b) Isochoric
(c) Isothermal
(d) Adiabatic

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(d)	**8**	(b)	**15**	(c)	**22**	(a)	**29**	(b)	**36**	(d)	**43**	(b)	**50**	(a)	**57**	(a)	**64**	(b)
2	(d)	**9**	(a)	**16**	(b)	**23**	(c)	**30**	(a)	**37**	(a)	**44**	(d)	**51**	(c)	**58**	(a)	**65**	(d)
3	(d)	**10**	(b)	**17**	(d)	**24**	(c)	**31**	(c)	**38**	(c)	**45**	(b)	**52**	(d)	**59**	(d)		
4	(a)	**11**	(c)	**18**	(a)	**25**	(a)	**32**	(c)	**39**	(a)	**46**	(b)	**53**	(b)	**60**	(d)		
5	(c)	**12**	(d)	**19**	(d)	**26**	(a)	**33**	(b)	**40**	(d)	**47**	(b)	**54**	(a)	**61**	(a)		
6	(c)	**13**	(b)	**20**	(d)	**27**	(b)	**34**	(c)	**41**	(a)	**48**	(b)	**55**	(c)	**62**	(c)		
7	(a)	**14**	(b)	**21**	(a)	**28**	(a)	**35**	(b)	**42**	(b)	**49**	(c)	**56**	(a)	**63**	(d)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(d)	**6**	(c)	**11**	(b)	**16**	(b)	**21**	(b)	**26**	(d)	**31**	(d)	**36**	(b)	**41**	(d)	**46**	(b)
2	(c)	**7**	(c)	**12**	(d)	**17**	(d)	**22**	(a)	**27**	(c)	**32**	(b)	**37**	(c)	**42**	(b)	**47**	(d)
3	(c)	**8**	(c)	**13**	(a)	**18**	(a)	**23**	(d)	**28**	(c)	**33**	(c)	**38**	(d)	**43**	(d)	**48**	(b)
4	(b)	**9**	(c)	**14**	(d)	**19**	(c)	**24**	(c)	**29**	(b)	**34**	(d)	**39**	(c)	**44**	(a)	**49**	(a)
5	(a)	**10**	(d)	**15**	(b)	**20**	(c)	**25**	(c)	**30**	(a)	**35**	(b)	**40**	(b)	**45**	(c)	**50**	(a)
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(a)	**4**	(b)	**7**	(d)	**10**	(b)	**13**	(d)	**16**	(b)	**19**	(b)	**22**	(d)				
2	(c)	**5**	(c)	**8**	(a)	**11**	(a)	**14**	(d)	**17**	(d)	**20**	(b)	**23**	(d)				
3	(a)	**6**	(c)	**9**	(a)	**12**	(b)	**15**	(b)	**18**	(d)	**21**	(b)						

5 Oscillations

TOPIC 5.1 : PERIODIC MOTION, SIMPLE HARMONIC MOTION (S.H.M.), DISPLACEMENT, VELOCITY AND ACCELERATION IN S.H.M., AMPLITUDE, PERIOD AND FREQUENCY OF S.H.M., REFERENCE CIRCLE METHOD AND PHASE IN S.H.M., GRAPHICAL REPRESENTATION OF S.H.M., COMBINATION OF TWO PARALLEL S.H.M.s HAVING SAME PERIOD AND ALONG SAME LINE

PERIODIC MOTION

Any motion which repeats itself after regular interval of time is called **periodic motion or harmonic motion**. The constant interval of time after which the motion is repeated is called time period.

Examples of periodic motion :

(i) Motion of planets around the sun.

(ii) Motion of the pendulum of wall clock.

The motion of a body is said to be **oscillatory** or **vibratory motion** if it moves back and forth (to-and-fro) about a fixed point after regular interval of time.

SIMPLE HARMONIC MOTION (S.H.M.)

Simple harmonic motion is the simplest form of vibratory or oscillatory motion.

S.H.M. are of two types :

(i) In linear S.H.M. : The restoring force (or acceleration) acting on the particle should always be proportional to the displacement of the particle and directed towards the equilibrium position.

i.e., $F \propto x$ or $a \propto -x$

Negative sign shows that direction of force and acceleration is towards equilibrium position and x is displacement of particle from equilibrium position.

(ii) In angular S.H.M. : The restoring torque (or angular acceleration) acting on the particle should always be proportional to the angular displacement of the particle and directed towards the equilibrium position.

i.e., $\tau \propto -\theta$ or $\alpha \propto -\theta$

Differential Equation of Linear S.H.M.

Restoring force $F = -kx$ ..... (1)

Here k = force constant and x is displacement of body from mean position.

According to newton's second laws of motion,

$$F = ma$$

$$F = m\frac{d^2x}{dt^2} \quad \text{..... (2)}$$

From, equation (1) and equation (2)

$$m\frac{d^2x}{dt^2} = -kx$$

$$\frac{d^2x}{dt^2} + \frac{k}{m}x = 0$$

Let $\frac{k}{m} = \omega^2$

$$\frac{d^2x}{dt^2} + \omega^2 x = 0$$

DISPLACEMENT, VELOCITY AND ACCELERATION IN S.H.M.

Displacement in S.H.M.

The displacement of a particle executing linear S.H.M. at any instant is defined as the distance of the particle from the mean position at that instant.

It can be given by relation,

$$x = A \sin \omega t$$

Velocity in S.H.M.

It is defined as the time rate of change of the displacement of the particle at the given instant.
Velocity in S.H.M. is given by

$$\Rightarrow \quad v = \frac{dx}{dt} = \frac{d}{dt}(A\sin\omega t) \Rightarrow v = A\omega\cos\omega t$$

$$v = \pm A\omega\sqrt{1-\sin^2\omega t}) \Rightarrow v = \pm A\omega\sqrt{1-\frac{x^2}{A^2}}$$

$$= \pm\omega\sqrt{(A^2-x^2)} \qquad [\because x = A\sin\omega t]$$

Squaring both sides we get,

$$v^2 = \omega^2(A^2 - x^2)$$

Maximum velocity $v = \omega\sqrt{A^2-x^2}$
At mean position $x = 0$

$$V_{max} = A\omega$$

Minimum velocity at extreme position $x = \mp A$
so $V_{min} = 0$

Acceleration in S.H.M.

Acceleration, $a = \omega^2 x$.

AMPLITUDE, PERIOD AND FREQUENCY OF S.H.M.

Amplitude (A) : The maximum (positive or negative) value of displacement of particle from its mean position is defined as amplitude.

Time period (T) : The least time taken to complete one oscillation or vibration is defined as time period.

It is given by,

$T = \frac{2\pi}{\omega} = \frac{1}{n}$ where ω is angular frequency and n is frequency.

SI Unit : Second (s); **Dimension :** $[M^0L^0T]$

Frequency (n or f) : The number of oscillations executed by particles per second is defined as frequency.

It is given by $n = \frac{1}{T}$ or, $n = \frac{\omega}{2\pi}$

SI unit : hertz (Hz), 1 hertz = 1 cycle per second

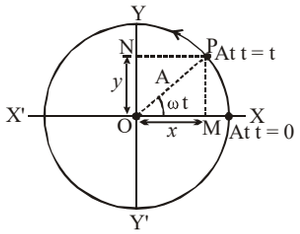
Dimension: $[M^0L^0T^{-1}]$

REFERENCE CIRCLE METHOD AND PHASE IN S.H.M.

If a particle is moving with uniform speed along the circumference of a circle then the straight line motion of the foot of perpendicular drawn from the particle on the diameter of the circle is called Simple Harmonic Motion.

Description of SHM based on circular motion :

Draw a circle of radius A equal to the amplitude of the particle performing SHM. Suppose particle is moving with constant angular velocity ω along the circle. Perpendicular from particle position on vertical and horizontal diameter shows SHM. After time t radius vector turns by ωt.



So, if the projection of P is taken on y-axis then from the figure

$$y = a\sin\omega t = a\sin\frac{2\pi}{T}t = a\sin 2\pi nt$$

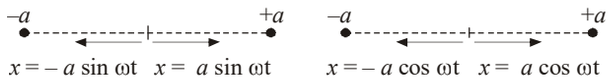
(i) $y = a\sin\omega t$ when the time is noted from the instant when the vibrating particle is at mean position.

(ii) $y = a\cos\omega t$ when the time is noted from the instant when the vibrating particle is at extreme position.

(iii) $y = a\sin(\omega t \pm \phi)$ when the vibrating particle is ϕ phase leading or lagging from the mean position.

If the projection of P is taken on X-axis then equations of S.H.M. can be given as

$$x = a\cos(\omega t \pm \phi) = a\cos\left(\frac{2\pi}{T}t \pm \phi\right) = a\cos(2\pi nt \pm \phi)$$



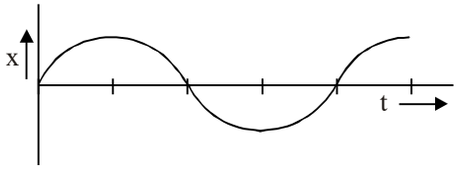
Direction of displacement is always taken away from the equilibrium position, particle either is moving away from or is coming towards the equilibrium position.

Phase: The phase of a vibrating particle at any instant is the state of the vibrating particle regarding its position and direction of vibration at that particular instant.

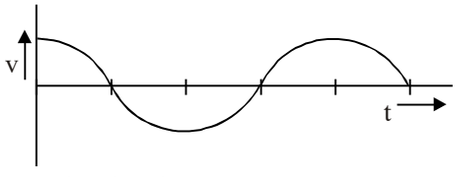
In the equation $x = A\sin(\omega t + \phi)$
where $(\omega t + \phi)$ is the phase of the particle.

GRAPHICAL REPRESENTATION OF S.H.M.

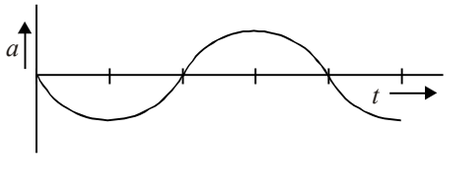
(i) Displacement-time



(ii) Velocity-time



(iii) Acceleration-time



COMBINATION OF TWO PARALLEL S.H.M.s HAVING SAME PERIOD AND ALONG SAME LINE

Let two SHMs are

$x_1 = A_1 \sin(\omega t + \phi_1)$ and

$x_2 = A_2 \sin(\omega t + \phi_2)$

The resultant SHM is

$x = x_1 + x_2$

$x = \sin\omega t (A_1 \cos\phi_1 + A_2 \cos\phi_2) + \cos\omega t (A, \sin\phi_1 + A_2 \sin\phi_2)$

Let $A_1\cos\phi_1 + A_2\cos\phi_2 = A\cos\phi$ and $A_1\sin\phi_1 + A_2\sin\phi_2 = A\sin\theta$

Then, $x = A\sin(\omega t + \theta)$

Thus, amplitude of SHM

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\phi_1 - \phi_2)}$$

and Epoch of SHM

$$\tan\theta = \frac{A_1\sin\phi_1 + A_2\sin\phi_2}{A_1\cos\phi_1 + A_2\cos\phi_2}$$

If $A_1 = A_2 = A$ and $\phi_1 - \phi_2 = \phi$

then $\tan\theta = \dfrac{\sin\phi}{1+\cos\phi}$

Maximum and minimum amplitude

If $\phi_1 - \phi_2$ 0° and $A_1 = A_2$

$A = A_1 + A_2$

$A = 2A_1$ (Maximum)

If $\phi_1 - \phi_2 = \pi$ and $A_1 = A_2$

$A = A_1 - A_2$

$A = 0$ (Minimum)

TOPIC 5.2 : ENERGY OF A PARTICLE IN S.H.M.

ENERGY OF A PARTICLE IN S.H.M.

Potential Energy (U)

(i) In terms of displacement

The potential energy is related to force by the relation

$$F = -\frac{dU}{dx} \Rightarrow \int dU = -\int F\,dx$$

For S.H.M., $F = -kx$

So, $\int dU = -\int(-kx)\,dx = \int \lambda x\,dx$

$$\Rightarrow \quad U = \frac{1}{2}kx^2 + C$$

At $x = 0$, $U = U_0$

$$\Rightarrow \quad C = U_0 \quad \therefore \quad U = \frac{1}{2}kx^2 + U_0$$

where the potential energy at equilibrium position = U_0

When $U_0 = 0$ then, $U = \dfrac{1}{2}kx^2$

(ii) In terms of time

Since $X = A\sin(\omega t + \phi)$, $U = \dfrac{1}{2}kA^2\sin^2(\omega t + \phi)$

If initial phase (ϕ) is zero then

$$U = \frac{1}{2}kA^2\sin^2\omega t = \frac{1}{2}m\omega^2A^2\sin^2\omega t$$

Kinetic Energy (K)

(i) In terms of displacement

If mass of the particle executing S.H.M. is m and its velocity is v then kinetic energy at any-instant

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\omega^2(A^2 - \omega^2) = \frac{1}{2}k(A^2 - x^2)$$

(ii) In terms of time

$v = A\omega\cos(\omega t + \phi)$

$$K = \frac{1}{2}m\omega^2A^2\cos^2(\omega t + \phi)$$

If initial phase ϕ is zero then,

$$K = \frac{1}{2}m\omega^2A^2\cos^2\omega t$$

Total Energy (E)

Total energy in S.H.M. is given by;

E = potential energy + kinetic energy = U + K

(i) **In terms of displacement**

$$E = \frac{1}{2}kx^2 + \frac{1}{2}k(A^2 - x^2)$$

$$E = \frac{1}{2}kA^2 = constant$$

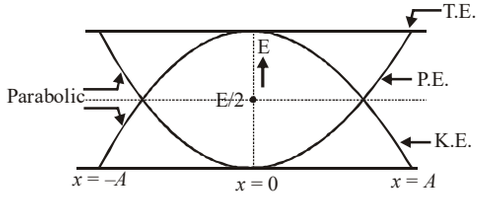
(ii) **In terms of time**

$$E = \frac{1}{2}m\omega^2A^2\sin^2\omega t + \frac{1}{2}m\omega^2A^2\cos^2\omega t$$

$$= \frac{1}{2}m\omega^2A^2(\sin^2\omega t + \cos^2\omega t)$$

$$E = \frac{1}{2}m\omega^2A^2 = \frac{1}{2}kA^2 = constant$$

Graphical representation of P.E., K.E. and T.E. :

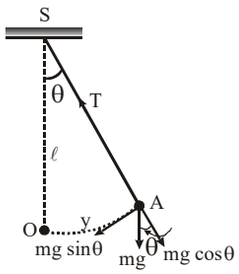


TOPIC 5.3 : SIMPLE PENDULUM, SPRING PENDULUM, ANGULAR S.H.M., MAGNET VIBRATING IN UNIFORM MAGNETIC FIELD, FREE, FORCED AND DAMPED OSCILLATION

SIMPLE PENDULUM

Simple Pendulum

If a heavy point mass is suspended by a weightless, inextensible and perfectly flexible string from a rigid support, then this arrangement is called a simple pendulum.



Expression for time period :

If displacement is small then simple pendulum performs S.H.M. with time period

$$\therefore \quad T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{\ell}{g}} = 2\pi\sqrt{\frac{\textit{effective length}}{\textit{acceleration due to gravity}}}$$

1. If angular amplitude (θ_0) is large ($\theta_0 > 15°$) then time period is given by

$$T = 2\pi\sqrt{\frac{\ell}{g}}\left[1+\frac{\theta_0^2}{16}\right] \text{ here } \theta_0 \text{ is in radian.}$$

2. If a simple pendulum of density ρ is made to oscillate in a liquid of density σ then its time period will increase as compare to that of air and is given by

$$T = 2\pi\sqrt{\frac{\ell}{\left[1-\frac{\sigma}{\rho}\right]g}}$$

Second's Pendulum

If the time period of a simple pendulum is 2 second then it is called second's pendulum. Second's pendulum take one second to go from one extreme position to other extreme position.

For second's pendulum, time period

$$T = 2 = 2\pi\sqrt{\frac{\ell}{g}}$$

At the surface of earth $g = 9.8\ m/s^2 \approx \pi^2\ m/s^2$,

So length of second pendulum at the surface of earth

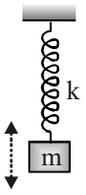
$\ell \approx 1$ metre.

SPRING PENDULUM

(i) When a small mass is suspended from a massless spring then this arrangement is known as spring pendulum.

For small linear displacement the motion of spring pendulum is simple harmonic.

(ii) For a spring pendulum

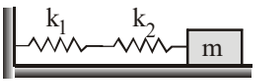


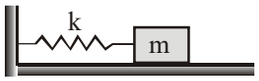
Time period $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

Frequency $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Various Spring Arrangements

(i) Series combination of springs : In series combination same restoring force exerts in all springs but extension will be different.





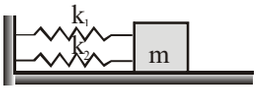
$$k_s = \frac{k_1 k_2}{k_1 + k_2}$$

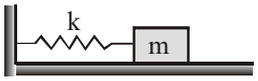
Time period, $T = 2\pi\sqrt{\frac{m}{k_s}} = 2\pi\sqrt{\frac{m\,(k_1+k_2)}{k_1 k_2}}$

Frequency, $n = \frac{1}{2\pi}\sqrt{\frac{k_s}{m}}$

Angular frequency, $\omega = \sqrt{\frac{k_s}{m}}$

(ii) Parallel combination of springs : In parallel combination displacement on each spring is same but restoring force is different.





$$k_p = k_1 + k_2$$

Time period, $T = 2\pi\sqrt{\frac{m}{k_p}} = 2\pi\sqrt{\frac{m}{k_1+k_2}}$

Frequency, $n = \frac{1}{2\pi}\sqrt{\frac{k_p}{m}}$

Angular frequency, $\omega = \sqrt{\frac{k_1+k_2}{m}}$

ANGULAR S.H.M.

Differential Equation for Angular SHM

$$\Rightarrow \quad I\frac{d^2\theta}{dt^2} + C\theta = 0 \Rightarrow \frac{d^2\theta}{dt^2} + \left(\frac{C}{I}\right)\theta = 0$$

Since, $\frac{d^2\theta}{dt^2} + \omega^2\theta = 0 \Rightarrow \omega = \sqrt{\left(\frac{C}{I}\right)}$

where C = restoring torque constant

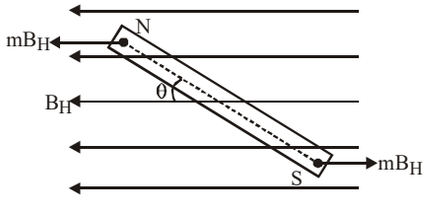
I = moment of inertia

Time period, $T = \frac{2\pi}{\omega}$ $\because$ where $\omega = \sqrt{\frac{C}{I}}$

$T = 2\pi\sqrt{\frac{I}{C}}$

MAGNET VIBRATING IN UNIFORM MAGNETIC FIELD

It is an instrument used to compare magnetic moments of two bar magnets, comparison of horizontal components of earth's magnetic field at two places and for measuring the horizontal component of earth's magnet field.



Principle : When a bar magnet suspended freely in a uniform magnetic field and is displaced from its equilibrium position it starts executing simple harmonic motion about the equilibrium position.

The **torque** acting on magnet is

$$\tau = -mB_H(2\ell\sin\theta) = -MB_H\sin\theta \quad [\because m \times 2\ell = M]$$

–ive sign shows that torque acts in the direction of decreasing θ. If θ is small, $\tau = -MB_H\theta$.

If α is angular acceleration of magnet and I is moment of inertia of magnet about axis of suspension, then $I\alpha = -MB_H\theta$

Time period $T = 2\pi\sqrt{\frac{angular\ \ displacement}{angular\ \ acceleration}} = 2\pi\sqrt{\frac{I}{MB_H}}$

FREE, FORCED AND DAMPED OSCILLATION

Free Oscillation

If a given body is once set into oscillation and then let free to vibrate with its own natural frequency, the oscillations are said to be free oscillations. The natural frequency of free oscillations depends on the nature and structure of the body and in ideal situation, the amplitude, frequency and the energy of the vibrating body remain constant.

Forced Oscillation

The vibrations in which a body oscillates under the effect of an external periodic force, whose frequency is different from the natural frequency of oscillating body are called forced oscillations. The amplitude of oscillator would have decrease due to damping forces but on account of the energy gained from the external source it remains constant.

The solution of this equation gives $x = x_0 \sin(\omega_d t + \phi)$ with amplitude $x_0 = \frac{F_0/m}{\sqrt{(\omega_0^2 - \omega_d^2) + \left(\frac{b\omega}{m}\right)^2}}$

$$\phi = \tan^{-1}\left[\frac{\omega_d\, b/m}{(\omega_0^2 - \omega_d^2)}\right]$$

and $\omega_0 = \sqrt{\frac{k}{m}}$ = natural frequency of oscillator

Resonant Vibrations

It is a special case of forced vibrations in which frequency of external force is exactly same as the natural frequency of oscillator. As a result the oscillating body begins to vibrate with a large amplitude leading to the **resonance** phenomenon to occur.

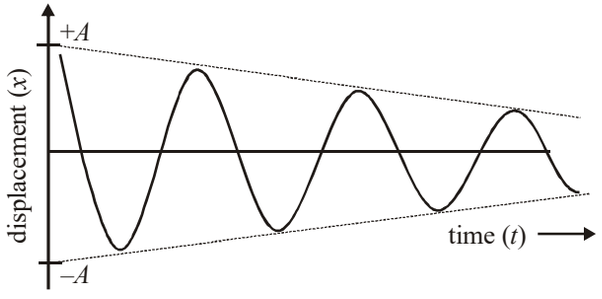
Damped Oscillation

When a body is set in free vibrations, generally there is a dissipation of energy due to dissipative causes like viscous drag of a fluid, frictional force, hysteresis, electromagnetic damping force, etc, and as a result amplitude of vibration regularly decreases with time, such vibrations of continuously falling amplitudes are called damped vibrations.

Displacement of a damped oscillator

$$x = x_m e^{-bt/2m}\sin(\omega' t + \phi)$$

$x = x_m e^{-bt/2m}$ is the amplitude of the damped harmonic oscillations. Amplitude decreases with time exponentially as shown in displacement time graph.



Displacement time graph

The angular frequency $\omega' = \sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}$

Period of oscillation $T = \frac{2\pi}{\sqrt{\frac{k}{m} - \left(\frac{b}{2m}\right)^2}}$

For a damped oscillator if the damping is small then the mechanical energy decreases exponentially with time as

$$E = \frac{1}{2}kx_m^2 e^{-bt/m}$$

CHAPTER AT A GLANCE

- Any motion which repeats itself after regular interval of time is called **periodic motion or harmonic motion**.
- Differential equation of S.H.M., $\frac{d^2x}{dt^2} + \omega^2 x = 0$
- Displacement, $x = A\cos(\omega t + \phi_0)$
- Velocity of SHM $v = -A\omega \sin(\omega t + \phi_0) = -\omega\sqrt{A^2 - x^2}$
  Maximum velocity, $V_{max} = \omega A$
- Acceleration $a = -\omega^2 A\cos(\omega t + \phi_0) = -\omega^2 x$
  Maximum acceleration $a_{max} = \omega^2 A$
- Restoring force, $F = -kx = -m\omega^2 x$
- Angular frequency, $\omega = 2\pi f = \frac{2\pi}{T}$
- Amplitude of two parallel S.H.M. having same period and along same line. $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos(\phi_1 - \phi_2)}$
- Potential energy (P.E.) at displacement y from the mean position

$$E_p = \frac{1}{2}ky^2 = \frac{1}{2}m\omega^2y^2 = \frac{1}{2}m\omega^2A^2\sin^2\omega t$$

- Kinetic energy (K.E.) at displacement y form the mean position

$$E_k = \frac{1}{2}k(A^2 - y^2) = \frac{1}{2}m\omega^2(A^2 - y^2)$$

$$= \frac{1}{2}m\omega^2A^2\cos^2\omega t$$

- Total energy of S.H.M. at any point

$$E = \frac{1}{2}KA^2 = \frac{1}{2}m\omega^2A^2 = 2\pi^2mA^2v^2$$

- Time-period of simple pendulum is given by,

$$T = 2\pi\sqrt{\left(\frac{\ell}{g}\right)}$$

- For second's pendulum, time period

$$T = 2 = 2\pi\sqrt{\frac{\ell}{g}}$$

- For a spring pendulum

Time period $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$

Frequency $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

- $T = 2\pi\sqrt{\frac{angular\ \ displacement}{angular\ \ acceleration}} = 2\pi\sqrt{\frac{I}{MB_H}}$
- If a given body is once set into oscillation and then let free to vibrate with its own natural frequency, the oscillations are said to be free oscillations.
- The vibrations in which a body oscillates under the effect of an external periodic force, whose frequency is different from the natural frequency of oscillating body are called forced oscillations.
- Displacement of damped oscillator,

$x(t) = Ae^{-bt/2m}\cos(\omega t + \phi)$

- Angular frequency of damped oscillator, $\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$
- Mechanical energy of the oscillator, $E(t) = \frac{1}{2}KA^2e^{-bt/m}$

Exercise 1 : WARM-UP
Topic-wise MCQs

5.1 Periodic Motion, Simple Harmonic Motion (S.H.M.), Displacement, Velocity and Acceleration in S.H.M., Amplitude, Period and Frequency of S.H.M., Reference Circle Method and Phase in S.H.M., Graphical Representation of S.H.M., Combination of Two Parallel S.H.M.s Having Same Period and along

1. Which one of the following is both periodic and oscillatory?
(a) A freely suspended bar magnet displaced from its N-S direction and released
(b) The piston in steam engine moves back and forth inside a cylinder
(c) Rotation of the earth about its axis
(d) An arrow released from a bow

2. Motion of a ball bearing inside a smooth curved bowl when released from a point slightly above the lower point, is
(a) simple harmonic motion (SHM)
(b) non-periodic motion
(c) parabolic
(d) periodic but not SHM

3. In SHM, the acceleration is directly proportional to
(a) time
(b) linear velocity
(c) displacement
(d) frequency

4. For a body executing simple harmonic motion, which parameter comes out to be non-periodic ?
(a) Displacement
(b) Velocity
(c) Acceleration
(d) None of these

5. The displacement of a particle is given by $\vec{r} = A(\vec{i}\cos\omega t + \vec{j}\sin\omega t)$. The motion of the particle is
(a) simple harmonic
(b) on a straight line
(c) on a circle
(d) with constant acceleration.

6. Which of the following quantities are always negative in a simple harmonic motion ?
(a) $\vec{F}.\vec{r}$. (b) $\vec{v}.\vec{r}$.
(c) $\vec{a}.\vec{r}$. (d) Both (a) & (c)

7. The graph plotted between the velocity and displacement from mean position of a particle executing SHM is
(a) circle (b) ellipse
(c) parabola (d) straight line

8. The displacement of a particle is given by $x = k \sin^2 \omega t$. The motion of the particle corresponds to
(a) SHM of frequency $\frac{\omega}{\pi}$
(b) SHM of frequency $\frac{3\omega}{2\pi}$
(c) non-simple harmonic motion
(d) SHM of frequency $\frac{\omega}{2\pi}$

9. Which of the following expressions does not represent simple harmonic motion?
(a) $x = A\cos\omega t + B\sin\omega t$
(b) $x = A\cos(\omega t + \alpha)$
(c) $x = B\sin(\omega t + \beta)$
(d) $x = A\sin\omega t\cos^2\omega t$

10. Which of the following is not a characteristics of simple harmonic motion?
(a) The motion is periodic
(b) The motion is along a straight line about the mean position
(c) The oscillations are responsible for the energy conversion
(d) The acceleration of the particle is directed towards the extreme position

11. The phase difference between the instantaneous velocity and acceleration of a particle executing simple harmonic motion is
(a) π (b) $0.707\ \pi$
(c) zero (d) 0.5π

12. A particle is moving in a circle with uniform speed. Its motion is

(a) not periodic

(b) periodic and simple harmonic

(c) periodic but not simple harmonic

(d) none of the above

13. A particle executing S. H. M. of amplitude 4 cm and T = 4 sec. The time taken by it to move from positive extreme position to half the amplitude is

(a) 1 sec

(b) 1/3 sec

(c) 2/3 sec

(d) $\sqrt{3/2}$ sec

14. Two simple harmonic motions with the same frequency act on a particle at right angles i.e., along x and y axis. If the two amplitudes are equal and the phase difference is $\pi/2$, the resultant motion will be

(a) a circle

(b) an ellipse with the major axis along y-axis

(c) an ellipse with the major axis along x-axis

(d) a straight line inclined at 45° to the x-axis

15. A particle perform oscillatory motion with amplitude 4 cm. If the time period of particle is 1s, then time taken by the particle to reach 2 cm from the mean position is given by

(a) (1/2) s (b) (1/4) s

(c) (1/12) s (d) (1/6) s

16. Displacement of a particle in periodic motion is expressed as $x(t) = 20 \cos \omega t$. If the time period of particle is 4s, then displacement of the particle in 1 s will be

(a) 10 m (b) 15 m

(c) 0 (d) 20 m

17. The displacement of a particle varies according to the relation $x = 4 (\cos \pi t + \sin \pi t)$

The amplitude of the particle is

(a) 8 (b) –4

(c) 4 (d) $4\sqrt{2}$

18. Two particles A and B execute simple harmonic motion according to the equations $y_1 = 3 \sin \omega t$ and $y_2 = 4 \sin \left(\omega t + \frac{\pi}{2}\right) + 3 \sin \omega t$. The phase difference between them is

(a) $\frac{\pi}{2}$ (b) $\tan^{-1}\left(\frac{4}{3}\right)$

(c) $\tan^{-1}\left(\frac{3}{4}\right)$ (d) None of these

19. Two S. H. Ms. s_1 = a sin ωt and s_2 = b sin ωt are superimposed on a particle. The s_1 and s_2 are along the directions which make angle 37° with each other.

(a) the particle will perform S. H. M.

(b) the particle will not perform S. H. M.

(c) the particle will perform periodic motion but not S. H. M.

(d) The motion will not be oscillatory.

20. A particle executes simple harmonic motion with an amplitude of 4 cm. At the mean position the velocity of the particle is 10 cm/s. The distance of the particle from the mean position when its speed becomes 5 cm/s is

(a) $\sqrt{3}$ cm (b) $\sqrt{5}$ cm

(c) $2(\sqrt{3})$cm (d) $2(\sqrt{5})$cm

21. A piston is performing S.H.M. in the vertical direction with a frequency of 0.5 Hz. A block of 10 kg is placed on the piston. The maximum amplitude of the system such that the block remains in contact with the piston is

(a) 1.5 m (b) 1 m

(c) 0.1 m (d) 0.5 m

22. For a particle executing simple harmonic motion (SHM), at its mean position

(a) Velocity is zero and acceleration is maximum

(b) Velocity is maximum and acceleration is zero

(c) Both velocity and acceleration are maximum

(d) Both velocity and acceleration are zero

23. The displacement of a particle executing SHM is given by $x = 3 \sin \left(2\pi t + \frac{\pi}{4}\right)$ where 'x' is in metres and 't' is in seconds. The amplitude and maximum speed of the particle is

(a) 3 m, 6π m s^{-1}

(b) 3 m, 2π m s^{-1}

(c) 3 m, 8π m s^{-1}

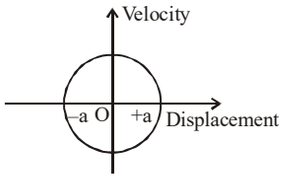
(d) 3 m, 4π m s^{-1}

24. A particle executing SHM has maximum speed of 0.5 m s^{-1} and maximum acceleration of 1.0 m s^{-2}. The angular frequency of oscillation is

(a) 2 rad s^{-1} (b) 0.5 rad s^{-1}

(c) 2π rad s^{-1} (d) 0.5π rad s^{-1}

25. The graph shown in figure represents



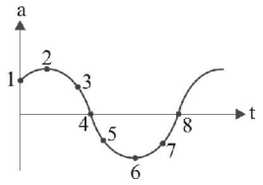
(a) S.H.M.

(b) circular motion

(c) rectillinear motion

(d) uniform circular motion

26. The acceleration of a particle undergoing SHM is graphed in figure. At point 2 the velocity of the particle is



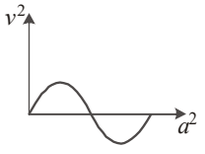
(a) zero

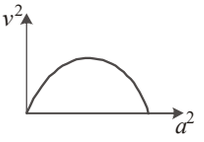
(b) negative

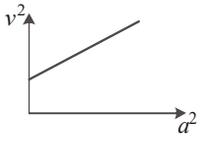
(c) positive

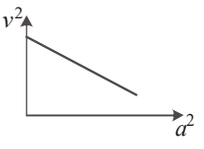
(d) None of these

27. A graph of the square of the velocity against the square of the acceleration of a given simple harmonic motion is

(a) 

(b) 

(c) 

(d) 

28. A body executing linear simple harmonic motion has a velocity of 3 m/s when its displacement is 4 cm and a velocity of 4 m/s when its displacement is 3 cm. What is the amplitude of oscillation?

(a) 5 cm (b) 7.5 cm

(c) 10 cm (d) 12.5 cm

29. The displacement of a particle in SHM is $x = 10\sin\left(2t - \frac{\pi}{6}\right)$ metre. When its displacement is 6 m, the velocity of the particle (in m s^{-1}) is

(a) 8 (b) 24

(c) 16 (d) 10

30. If the maximum velocity and acceleration of a particle executing SHM are equal in magnitude, the time period will be

(a) 1.57 sec (b) 3.14 sec

(c) 6.28 sec (d) 12.56 sec

31. The maximum velocity of a particle, executing simple harmonic motion with an amplitude 7 mm, is 4.4 m/s. The period of oscillation is

(a) 0.01 s (b) 10 s

(c) 0.1 s (d) 100 s

32. A body is executing S.H.M. When its displacement from the mean position are 4 cm and 5 cm, it has velocities 10 cm s^{-1} and 8 cm s^{-1} respectively. Its periodic time is

(a) $\pi/2$ s (b) π s

(c) $3\pi/2$ s (d) 2π s

33. The displacement of an object attached to a spring and executing simple harmonic motion is given by $x = 2 \times 10^{-2} \cos \pi t$ metre. The time at which the maximum speed first occurs is

(a) 0.25 s (b) 0.5 s

(c) 0.75 s (d) 0.125 s

34. The equation of a particle executing simple harmonic motion is given by $x = \sin\pi\left(t + \frac{1}{3}\right)$ m. At t = 1s, the speed of particle will be (Given : $\pi = 3.14$)

(a) 0 cm s^{-1} (b) 157 cm s^{-1}

(c) 272 cm s^{-1} (d) 314 cm s^{-1}

35. A particle of mass 1 kg is moving in S.H.M. with an amplitude 0.02 and a frequency of 60 Hz. The maximum force acting on the particle is

(a) $144\ \pi^2$ (b) $188\ \pi^2$

(c) $288\ \pi^2$ (d) None of these

36. A particle moves in a circular path with a uniform speed. Its motion is

(a) periodic

(b) oscillatory

(c) simple harmonic

(d) angular simple harmonic

37. A system exhibiting SHM must possess
(a) inertia only
(b) elasticity as well as inertia
(c) elasticity, inertia and an external force
(d) elasticity only

38. The motion which is not simple harmonic is
(a) vertical oscillations of a spring
(b) motion of simple pendulum
(c) motion of a planet around the Sun
(d) oscillation of liquid column in a U-tube

39. A particle moves on the X-axis according to the equation $x = A\cos(\omega t + kx) + B\sin(\omega t + kx)$. The motion is simple harmonic with amplitude
(a) A (b) B
(c) $A + B$ (d) $\sqrt{A^2 + B^2}$

40. For a particle moving according to the equation $x = a\cos \pi t$, the displacement in 3 s is
(a) 0 (b) $0.5a$
(c) $1.5a$ (d) $2a$

41. A body oscillates with SHM according to the equation (in SI units), $x = 5\cos\left(2\pi t\frac{\pi}{4}\right)$.

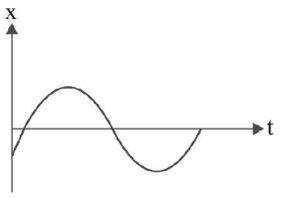
Its instantaneous displacement at $t = 1$ second is
(a) $\frac{\sqrt{2}}{5}$m (b) $\frac{1}{\sqrt{3}}$m
(c) $\frac{5}{\sqrt{2}}$m (d) $\frac{1}{2}$m

42. The equation of SHM is $y = a\sin(2\pi nt + \alpha)$, then its phase at time 't' is
(a) α (b) $2\pi nt$
(c) $2\pi nt + \alpha$ (d) $2\pi t$

43. The displacement of a particle in simple harmonic motion in one time period is [A = amplitude]
(a) A (b) 2 A
(c) 4 A (d) Zero

44. Which of the following is a simple harmonic motion?
(a) Particle moving through a string fixed at both ends.
(b) Wave moving through a string fixed at both ends.
(c) Earth spinning about its axis.
(d) Ball bouncing between two rigid vertical walls.

45. The displacement vs time of a particle executing SHM is shown in figure. The initial phase ϕ is



(a) $-\pi < \phi < -\frac{\pi}{2}$ (b) $\pi < \phi < \frac{3\pi}{2}$
(c) $-\frac{3\pi}{2} < \phi < -\pi$ (d) $\frac{\pi}{2} < \phi < \pi$

46. If a particle takes 0.5 sec to reach position of minimum velocity from previous such position, then
(a) T = 6 sec, ν = 1/6 Hz
(b) T = 2 sec, ν = 1 Hz
(c) T = 3 sec, ν = 3 Hz
(d) T = 1 sec, ν = 1 Hz

47. A simple harmonic motion has an amplitude A and time period T. The time required by it to travel from x = A to x = A/2 is
(a) T/6 (b) T/4
(c) T/3 (d) T/2

48. A particle executes simple harmonic motion between x = – A and x = + A. The time taken for it to go from O to A/2 is T_1 and T_1 and to go from A/2 to A is T_2. Then
(a) $T_1 < T_2$ (b) $T_1 > T_2$
(c) $T_1 = T_2$ (d) $T_1 = 2T_2$

49. A particle executing simple harmonic motion covers a distance equal to half of its amplitude in one second. Then the time period of the simple harmonic motion is
(a) 4 s (b) 6 s
(c) 8 s (d) 12 s

50. A particle is subjected to two mutually perpendicular simple harmonic motions such that its x and y coordinates are given by $x = 2\sin\omega t$; $y = 2\sin\left(\omega t + \frac{\pi}{4}\right)$

The path of the particle will be
(a) a straight line
(b) a circle
(c) an ellipse
(d) a parabola

51. Which of the following expressions does not represent simple harmonic motion?

(a) $x = A\cos(\omega t + \delta)$

(b) $x = B\cos(\omega t + \phi)$

(c) $x = A\tan(\omega t + \phi)$

(d) $x = A\sin\omega t\cos\omega t$

52. A particle executing simple harmonic motion along y-axis has its motion described by the equation $y = A\sin(\omega t) + B$. The amplitude of the simple harmonic motion is

(a) A (b) B

(c) A + B (d) $\sqrt{A+B}$

53. A simple harmonic oscillator has a period of 0.01 sec and an amplitude of 0.2 m The magnitude of the velocity in $msec^{-1}$ at the centre of oscillation is

(a) 20π (b) 100

(c) 40π (d) 100π

54. The average acceleration in one time period in a simple harmonic motion is

(a) $A\omega^2$ (b) $A\omega^2/2$

(c) $A\omega^2/\sqrt{2}$ (d) zero

55. The motion of a particle is given by $x = A\sin\omega t + B\cos\omega t$. The motion of the particle is

(a) not simple harmonic

(b) simple harmonic with amplitude (A–B)/2

(c) simple harmonic with amplitude (A + B)/2

(d) simple harmonic with amplitude $\sqrt{A^2+B^2}$

56. A particle moving along the X-axis, executes simple harmonic motion then the force acting on it is given by (Where, A and k are positive constants).

(a) $-Akx$

(b) A cos (kx)

(c) A exp (– kx)

(d) Akx

57. If the displacement equation of a particle be represented by $y = A\sin PT + B\cos PT$, the particle executes

(a) a uniform circular motion

(b) a uniform elliptical motion

(c) a S.H.M.,

(d) a rectilinear motion

58. Two mutually perpendicular simple harmonic vibrations have same amplitude, frequency and phase. When they superimpose, the resultant form of vibration will be

(a) a circle (b) an ellipse

(c) a straight line (d) a parabola

59. The motion of a particle varies with time according to the relation $y = a(\sin\omega t + \cos\omega t)$, then

(a) the motion is oscillatory but not S.H.M.

(b) the motion is S.H.M. with amplitude a

(c) the motion is S.H.M. with amplitude $a\sqrt{2}$

(d) the motion is S.H.M. with amplitude $2a$

5.2 Energy of a Particle in S.H.M.

60. When the displacement of a particle executing SHM is one-fourth of its amplitude, what fraction of the total energy is the kinetic energy?

(a) $\frac{16}{15}$ (b) $\frac{15}{16}$

(c) $\frac{5}{4}$ (d) $\frac{3}{4}$

61. A system containing a ball is oscillating on a frictionless horizontal plane. The position of the mass when its potential energy and its kinetic energy both are equal, is (let A is the amplitude of oscillation)

(a) A (b) $\frac{A}{\sqrt{2}}$

(c) $\frac{A}{2}$ (d) $\frac{A}{\sqrt{3}}$

62. A block attached to a spring is executing SHM. Let the time period of variation of velocity is T_1 and time period of variation of kinetic energy is T_2. The relation between T_1 and T_2 is

(a) $T_1 = T_2$

(b) $T_1 = 2T_2$

(c) $T_1 = T_2/2$

(d) $T_1 = 4T_2$

63. A particle is vibrating simple harmonically with an amplitude 'a'. The displacement of the particle when its energy is half kinetic and half potential is

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

(c) a / 4 (d) zero

64. A particle executing simple harmonic motion with time period T. The time period with which its kinetic energy oscillates is

(a) T (b) $2T$

(c) $4T$ (d) $T/2$

65. The total mechanical energy of a particle executing simple harmonic motion is E. When the displacement is half the amplitude its kinetic energy will be

(a) $\frac{3E}{4}$ (b) E

(c) $\frac{E}{2}$ (d) $\frac{E}{4}$

66. A particle is executing SHM. At a point x = A/3, kinetic energy of the particle is K, where A is the amplitude. At a point x = 2A/3, kinetic energy of the particle will be:

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

(c) $\frac{5}{8}K$ (d) $\frac{5}{3}K$

67. The mass of a particle is 1 kg and it is moving along x-axis. The period of its small oscillation is $\frac{\pi}{2}$. Find its potential energy

(a) –4 sin 2x (b) – 16 sin x

(c) – 16 cos x (d) – 4 cos 2x

68. The displacement of a particle of mass 2 g executing simple harmonic motion is $x = 8\cos\left(50t + \frac{\pi}{12}\right)m$, where t is time in second. The maximum kinetic energy of the particle is

(a) 160 J (b) 80 J

(c) 40 J (d) 20 J

69. The mass of a particle is 1 kg and it is moving along x- axis. The period of its oscillation is $\frac{\pi}{2}$. Its potential energy at a displacement of 0.2 m is

(a) 0.24 J

(b) 0.48 J

(c) 0.32 J

(d) 0.16 J

70. The potential energy of a particle of mass 10 g as a function of displacement x is $(50\ x^2 + 100)$J. The frequency of oscillation is

(a) $\frac{10}{\pi}s^{-1}$ (b) $\frac{5}{\pi}s^{-1}$

(c) $\frac{100}{\pi}s^{-1}$ (d) $\frac{50}{\pi}s^{-1}$

71. A mass of 4 kg suspended from a spring of force constant 800 N m^{-1} executes simple harmonic oscillations. If the total energy of the oscillator is 4 J, the maximum acceleration (in m s^{-2}) of the mass is

(a) 5 (b) 15

(c) 45 (d) 20

72. A particle of mass m executes simple harmonic motion with amplitude a and frequency ν. The average kinetic energy during its motion from the position of equilibrium to the end is

(a) $2\pi^2ma^2\nu^2$

(b) $\pi^2ma^2\nu^2$

(c) $\frac{1}{4}ma^2\nu^2$

(d) $4\pi^2ma^2\nu^2$

73. The total energy of the particle executing simple harmonic motion of amplitude A is 100 J. At a distance of 0.707 A from the mean position, its kinetic energy is

(a) 25 J (b) 50 J

(c) 100 J (d) 12.5 J

74. A particle undergoing simple harmonic motion has time dependent displacement given by $x(t) = A\sin\frac{\pi t}{90}$. The ratio of kinetic to potential energy of this particle at t = 210s will be :

(a) $\frac{1}{9}$ (b) 1

(c) 2 (d) $\frac{1}{3}$

75. At a given point of time the value of displacement of a simple harmonic oscillator is given as $y = A\cos(30°)$. If amplitude is 40 cm and kinetic energy at that time is 200 J, the value of force constant is 1.0×10^x Nm^{-1}. The value of x is

(a) 2 (b) 4

(c) 6 (d) 8

76. The total energy of a particle executing S.H.M. is proportional to

(a) displacement from equilibrium position

(b) frequency of oscillation

(c) velocity in equilibrium position

(d) square of amplitude of motion

77. The potential energy of a particle (U_x) executing S.H.M. is given by

(a) $U_x = \frac{k}{2}(x-a)^2$

(b) $U_x = k_1x + k_2x^2 + k_3x^3$

(c) $U_x = Ae^{-bx}$

(d) U_x = a constant

78. If *a* is the amplitude of SHM, then K.E. is equal to the P.E. at ..... distance from the mean position.

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

(c) $\frac{a}{4}$ (d) a

79. Which of the following is true about total mechanical energy of SHM ?

(a) It is zero at mean position.

(b) It is zero at extreme position.

(c) It is always zero.

(d) It is never zero.

80. The total mechanical energy of a harmonic oscillator is given as

(a) $\frac{1}{4}m\omega^2A^2$ (b) $\frac{1}{4}m^2\omega^2A^2$

(c) $\frac{1}{2}m\omega^2A^2$ (d) $\frac{1}{2}m^2\omega^2A^2$

81. Starting from the origin a body oscillates simple harmonically with a period of 2 s. After what time will its kinetic energy be 75% of the total energy?

(a) $\frac{1}{6}$s (b) $\frac{1}{4}$s

(c) $\frac{1}{3}$s (d) $\frac{1}{12}$s

82. The expression for displacement of an object in SHM is x = A cos ωt. The potential energy at t = T/4 is

(a) $\frac{1}{2}KA^2$ (b) $\frac{1}{8}KA^2$

(c) $\frac{1}{4}KA^2$ (d) Zero

83. The potential energy of a particle executing SHM changes from maximum to minimum in 5s. Then the time period of SHM is:

(a) 5 s (b) 10 s

(c) 15 s (d) 20 s

84. Frequency of vibration of kinetic energy of simple harmonic motion of frequency n is

(a) 2n (b) n

(c) n/2 (d) 3n

85. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is

(a) E/2

(b) 2E/3

(c) E/8

(d) E/4

where E is the total energy

86. A particle executes S.H.M. having time period T, then the time period with which the potential energy changes is

(a) T (b) 2 T

(c) T/2 (d) ∞

87. The average total energy in one time period of a particle of mass *m* executive SHM of amplitude *a* and angular velocity ω is

(a) $\frac{1}{2}m\omega^2a^2$

(b) $\frac{1}{4}m\omega^2a^2$

(c) 0

(d) $m\omega^2a^2$

88. The potential energy of a particle executing S.H.M. is 2.5 J, when its displacement is half of amplitude. The total energy of the particle is

(a) 18 *J*

(b) 10 *J*

(c) 12 *J*

(d) 2.5 *J*

89. A particle is executing simple harmonic motion with frequency *f*. The frequency at which its kinetic energy change into potential energy is

(a) $f/2$

(b) f

(c) $2f$

(d) $4f$

90. A body of mass 1 *kg* is executing simple harmonic motion. Its displacement *y* (*cm*) at *t* seconds is given by $y = 6\sin(100 + \pi/4)$. It maximum kinetic energy is

(a) 6 *J*

(b) 18 *J*

(c) 24 *J*

(d) 36 *J*

91. There is a body having mass *m* and performing S.H.M. with amplitude *a*.There is a restoring force $F = -Kx$, where *x* is the displacement. The total energy of body depends upon

(a) *K, x*

(b) *K, a*

(c) *K, a, x*

(d) *K, a, v*

5.3 Simple Pendulum, Spring Pendulum, Angular S.H.M., Magnet Vibrating in Uniform Magnetic Field, Free, Forced and Damped Oscillation

92. What is the effect on the time period of a simple pendulum if the mass of the bob is doubled ?

(a) Halved

(b) Doubled

(c) Becomes 8 times

(d) No effect

93. A mass *m* is vertically suspended from a spring of negligible mass; the system oscillates with a frequency *n*. What will be the frequency of the system, if a mass 4 *m* is suspended from the same spring?

(a) n/4

(b) 4n

(c) n/2

(d) 2n

94. The time period of a simple pendulum is 2 seconds. If its length is increased by 4-times, then its period becomes

(a) 16 s

(b) 12 s

(c) 8 s

(d) 4 s

95. A 10 kg metal block is attached to a spring of spring constant 1000 N m^{-1}. A block is displaced from equilibrium position by 10 cm and released. The maximum acceleration of the block is

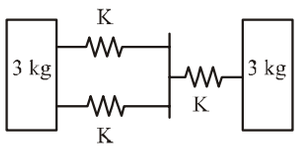
(a) 200 m s^{-2}

(b) 10 m s^{-2}

(c) 0.1 m s^{-2}

(d) 100 m s^{-2}

96. In a spring block system as shown in figure, if the spring constant $K = 9\pi^2 Nm^{-1}$, then the time period of oscillation is



(a) 1s

(b) 3.14s

(c) 1.414s

(d) 0.5s

97. A mass m is suspended from a two coupled springs, connected in series. The force constant for springs are k_1 and k_2. The time period of the suspended mass will be

(a) $T = 2\pi\sqrt{\dfrac{m}{k_1 - k_2}}$

(b) $T = 2\pi\sqrt{\dfrac{mk_1k_2}{k_1 + k_2}}$

(c) $T = 2\pi\sqrt{\dfrac{m}{k_1 + k_2}}$

(d) $T = 2\pi\sqrt{\dfrac{m(k_1 + k_2)}{k_1k_2}}$

98. A simple pendulum is suspended from the roof of a trolley which moves in a horizontal direction with an acceleration a, then the time period is given by $T = 2\pi\sqrt{(l/g)}$, where g is equal to

(a) g

(b) g – a

(c) g + a

(d) $\sqrt{(g^2 + a^2)}$

99. If a simple harmonic oscillator has got a displacement of 0.02 m and acceleration equal to 2.0 m/s^2 at any time, the angular frequency of the oscillator is equal to

(a) 10 rad/s

(b) 0.1 rad/s

(c) 100 rad/s

(d) 1 rad/s

100. If the length of a simple pendulum is increased by 2%, then the time period

(a) increases by 2%

(b) decreases by 2%

(c) increases by 1%

(d) decreases by 1 %

101. The period of oscillation of a mass M suspended from a spring of negligible mass is T. If along with it another mass M is also suspended, the period of oscillation will now be

(a) T

(b) $T/\sqrt{2}$

(c) 2T

(d) $\sqrt{2}$T

102. A forced oscillator is acted upon by a force $F = F_0 \sin \omega t$. The amplitude of oscillation is given by $\frac{55}{\sqrt{2\omega^2 - 36\omega + 9}}$.

The resonant angular frequency is

(a) 2 units

(b) 9 units

(c) 18 units

(d) 36 units

103. A wall clock uses a vertical spring-mass system to measure the time. Each time the mass reaches an extreme position, the clock advances by a second. The clock gives correct time at the equator. If the clock is taken to the poles it will

(a) run slow

(b) run fast

(c) stop working

(d) give correct time

104. A child swinging on a swing in sitting position, stands up, then the time period of the swing will

(a) increase

(b) decrease

(c) remains same

(d) increases of the child is long and decreases if the child is short

105. A lightly damped oscillator with a frequency ν is set in motion by a harmonic driving force of frequency ν', when $\nu' < \nu$ then response of the oscillator is controlled by

(a) spring constant

(b) inertia of the mass

(c) oscillator frequency

(d) damped coefficient

106. The ratio of frequencies of two pendulums are 2 : 3, then their lengths are in ratio

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

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

(c) $\frac{4}{9}$

(d) $\frac{9}{4}$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

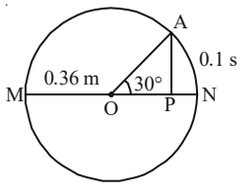
5.1 Periodic Motion, Simple Harmonic Motion (S.H.M.), Displacement, Velocity and Acceleration in S.H.M., Amplitude, Period and Frequency of S.H.M., Reference Circle Method and Phase in S.H.M., Graphical Representation of S.H.M., Combination of Two Parallel S.H.M.s Having Same Period and along

1. The amplitude of a particle executing SHM is 4 cm. At the mean position the speed of the particle is 16 cm/sec. The distance of the particle from the mean position at which the speed of the particle becomes $8\sqrt{3}$ cm/s, will be

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

(c) $1\,cm$ (d) $2\,cm$

2. The point A moves with a uniform speed along the circumference of a circle of radius 0.36 m and covers 30° in 0.1 s. The perpendicular projection 'P' from 'A' on the diameter MN represents the simple harmonic motion of 'P'. The restoration force per unit mass when P touches M will be



(a) 9.87 N

(b) 50 N

(c) 100 N

(d) 0.49 N

3. A simple harmonic motion along the x-axis has the following properties : amplitude = 0.5 m, the time to go from one extreme position to other is 2 s and x = 0.3 m at t = 0.5 s. The general equation of the simple harmonic motion is

(a) $x = (0.5\text{ m})\sin\left[\frac{\pi t}{2} + 8^o\right]$

(b) $x = (0.5\text{ m})\sin\left[\frac{\pi t}{2} - 8^o\right]$

(c) $x = (0.5\text{ m})\cos\left[\frac{\pi t}{2} + 8^o\right]$

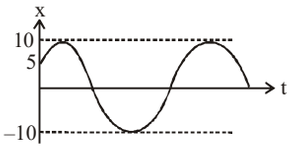
(d) $x = (0.5\text{ m})\cos\left[\frac{\pi t}{2} - 8^o\right]$

4. A particle executes linear simple harmonic motion with an amplitude of 2 cm. When the particle is at 1 cm from the mean position the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is

(a) $\frac{1}{2\pi\sqrt{3}}$ (b) $2\pi\sqrt{3}$

(c) $\frac{2\pi}{\sqrt{3}}$ (d) $\frac{\sqrt{3}}{2\pi}$

5. The figure shows a position time graph of a particle executing SHM. If the time period of SHM is 2 sec, then the equation of SHM is



(a) $x = 10\cos \pi t$

(b) $x = 5\sin\left(\pi t + \frac{\pi}{3}\right)$

(c) $x = 10\sin\left(\pi t + \frac{\pi}{3}\right)$

(d) $x = 10\sin\left(\pi t + \frac{\pi}{6}\right)$

6. Two simple harmonic motions are represented by $y_1 = 4\sin(4\pi t + \frac{\pi}{2})$ and $y_2 = 3\cos(4\pi t)$. The resultant amplitude is

(a) 7 (b) 1

(c) 5 (d) $2+\sqrt{3}$

7. A particle executes simple harmonic motion according to the equation $x(t) = A\sin^2(\alpha t)$. If the time period of the SHM is 0.2 s, then the value of α (in units o rad/s) is

(a) 2π (b) 10π

(c) 5π (d) 2.5π

8. The position, velocity and acceleration of a particle executing simple harmonic motion are found to have magnitudes of 4 m, 2 ms^{-1} and 16 ms^{-2} at a certain instant. The amplitude of the motion is $\sqrt{x}$ m where x is

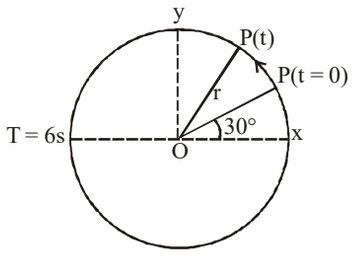
(a) 13 (b) 17

(c) 21 (d) 29

9. A particle executes simple harmonic motion between x = –A and x = +A. If time taken by particle to go from x = 0 to $\frac{A}{2}$ is 2s; then time taken by particle in going from x = $\frac{A}{2}$ to A is:

(a) 3 s (b) 2 s (c) 1.5 s (d) 4 s

10. For particle P revolving round the centre O with radius of circular path r and angular velocity ω, as shown in below figure, the projection of OP on the x-axis at time t is



(a) $x(t) = r\cos\left(\omega t + \frac{\pi}{6}\right)$

(b) $x(t) = r\cos(\omega t)$

(c) $x(t) = r\sin\left(\omega t + \frac{\pi}{6}\right)$

(d) $x(t) = r\cos\left(\omega t - \frac{\pi}{6}\omega\right)$

11. Two particles are oscillating along two close parallel straight lines side by side, with the same frequency and amplitudes. They pass each other, moving in opposite directions when their displacement is half of the amplitude. The mean positions of the two particles lie on a straight line perpendicular to the paths of the two particles. The phase difference is

(a) 0 (b) 2π/3 (c) π (d) π/6

12. The function $\sin^2(\omega t)$ represents

(a) a simple harmonic motion with a period 2π/ω

(b) a simple harmonic motion with a period π/ω

(c) a periodic but not simple harmonic motion with a period 2π/ω

(d) a periodic but not simple harmonic motion with a period π/ω

13. The function log ωt

(a) is a periodic function

(b) is a non-periodic function

(c) could represents oscillatory motion

(d) can represents circular motion

14. Choose the periodic function from the following.

(a) $A\sin^3(\omega t)^2$

(b) $\sin\omega t + \cos\omega t$

(c) $\tan(\omega t)^3$

(d) $e^{\omega t}$

15. A body executing simple harmonic motion has a periodic time of 3 s. After how much time from t = 0, its displacement will be half of its amplitude?

(a) $\left(\frac{1}{8}\right)$s (b) $\left(\frac{1}{6}\right)$s

(c) $\left(\frac{1}{4}\right)$s (d) $\left(\frac{1}{3}\right)$s

16. If x, v and a represent the displacement, the velocity and the acceleration of a particle executing simple harmonic motion of time period T, then which of the following does not change with time?

(a) $\frac{aT}{v}$

(b) $aT + 2\pi v$

(c) $\frac{aT}{x}$

(d) $a^2T + 4\pi^2v^2$

17. The equation of a simple harmonic motion is given by y = 3 sin (50t – x), where x and y are in metres and t is in seconds, the maximum particle velocity (in ms^{-1}) is

(a) 3 (b) 50

(c) 150 (d) 25

18. The piston in the cylinder head of a locomotive has a stroke (twice the amplitude) of 2.0 m. If the piston moves with simple harmonic motion with an angular frequency of 100 rad min^{-1}, what is its maximum speed?

(a) 50 m min^{-1}

(b) 100 m min^{-1}

(c) 200 m min^{-1}

(d) 75 m min^{-1}

19. Two simple harmonic motions of angular frequency 100 $rads^{-1}$ and 1000 $rads^{-1}$ have the same displacement amplitude. The ratio of their maximum accelerations is

(a) 1 : 10

(b) $1 : 10^2$

(c) $1 : 10^3$

(d) $1 : 10^4$

20. In an SHM, x is the displacement and a is the acceleration at time t. The plot of a against x for one complete oscillation will be

(a) a straight line

(b) a circle

(c) an ellipse

(d) a sinusoidal curve

21. The displacement of an object attached to a spring and executing SHM is given by equation $x = 2 \cos(2\pi t)$, where x is in cm and t in second. The time at which maximum speed occurs is

(a) 0.2 s

(b) 0.25 s

(c) 0.3 s

(d) 0.4 s

22. The displacement of a particle executing simple harmonic motion is $y = A\sin(2t + \phi)$ m, where t is time in second and ϕ is phase angle. At time $t = 0$, the displacement and velocity of the particle are 2 m and 4 ms^{-1}. The phase angle, ϕ =

(a) 60° (b) 30°

(c) 45° (d) 90°

23. The time taken by a particle performing SHM on a straight line to pass from point A to B where its velocities are same is 2 seconds. After another 2 seconds it returns to B. The time period of oscillation is (in seconds)

(a) 2 (b) 4

(c) 6 (d) 8

24. For a particle executing simple harmonic motion, determine the ratio of average acceleration of particle from extreme position to equilibrium position to the maximum acceleration.

(a) $\frac{4}{\pi}$ (b) $\frac{2}{\pi}$

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

25. Two simple harmonic motions are represented by equations

$y_1 = 4 \sin(10t + \phi) \Rightarrow y_2 = 5 \cos 10t$

What is the phase difference between their velocities?

(a) ϕ (b) $-\phi$

(c) $\left(\phi + \frac{\pi}{2}\right)$ (d) $\left(\phi - \frac{\pi}{2}\right)$

26. A particle undergoes SHM with a time period of 2 seconds. In how much time will it travel from its mean position to a displacement equal to half of its amplitude?

(a) 1/2 sec (b) 1/3 sec

(c) 1/4 sec (d) 1/6 sec

27. The displacement of a particle from its mean position (in metre) is given by $y = 0.2 \sin(10\pi t + 1.5\ \pi) \cos(10\ \pi t + 1.5\ \pi)$. The motion of particle is

(a) Periodic but not S. H. M.

(b) Non - Periodic

(c) Simple harmonic motion with period 0.1 s

(d) Simple harmonic motion with period 0.2 s

28. The displacement of a particle varies with time as $x = 12 \sin \omega t - 16 \sin^3 \omega t$ (in cm). If its motion is S. H. M., then its maximum acceleration is

(a) $12\omega^2$ (b) $36\omega^2$

(c) $133\ \omega^2$ (d) $\sqrt{192}\omega^2$

29. A particle is acted simultaneously by mutually perpendicular simple harmonic motion $x = a \cos \omega t$ and $y = a \sin \omega t$. The trajectory of motion of the particle will be

(a) an ellipse

(b) a parabola

(c) a circle

(d) a straight line

30. If displacement x and velocity v are related as $4v^2 = 25 - x^2$ in a SHM Then time period of given SHM is (considered SI units)

(a) π (b) 2π

(c) 4π (d) 6π

31. A particle is executing a motion in which its displacement as a function of time is given by

$x = 3 \sin(5\pi t + \pi/3) + \cos(5\pi t + \pi/3)$ where x is in m and t is in s. Then the motion is

(a) simple harmonic with time period 0.2 s

(b) simple harmonic with time period 0.4 s

(c) simple harmonic with amplitude 3m

(d) not a simple harmonic but a periodic motion

32. Three simple harmonic motions of equal amplitudes A and equal time periods along the same line combine. The phase of the second motion is 60° ahead of the first and phase of the third motion is 60° ahead of the second. The amplitude of resultant motion is

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

(c) $\sqrt{3}A$ (d) 2A

33. A simple harmonic oscillator has an amplitude A and time period 6π second. Assuming the oscillation starts from its mean position, the time required by it to travel from $x = A$ to $x = \frac{\sqrt{3}}{2}A$ will be $\frac{\pi}{x}$ s, where x =

(a) 2 (b) 4

(c) 8 (d) 16

34. A particle of mass 0.50 kg executes simple harmonic motion under force $F = -50(Nm^{-1})x$. The time period of oscillation is $\frac{x}{35}$ s . The value of x is (Given $\pi = \frac{22}{7}$)

(a) 6 (b) 12

(c) 18 (d) 22

35. A particle executing simple harmonic motion covers a distance equal to half of its amplitude in one second. Then the time period of the simple harmonic motion is

(a) 4 s (b) 6 s

(c) 8 s (d) 12 s

36. An object undergoing SHM takes 0.5 s to travel from one point of zero velocity to the next such point. The distance between those points is 50 cm. The period, frequency and amplitude of the motion is :

(a) 1s, 1Hz, 25 cm

(b) 2s, 1Hz, 50 cm

(c) 1s, 2Hz, 25 cm

(d) 2s, 2Hz, 50 cm

37. A block is resting on a piston which is moving vertically with S.H.M. of period 1.0 s. At what amplitude of motion will the block and piston separate?

(a) 0.2 m (b) 0.25 m

(c) 0.3 m (d) 0.35 m

38. Two particles are executing simple harmonic motion of the same amplitude A and frequency ω along the *x*-axis. Their mean position is separated by distance $X_0 (X_0 > A)$. If the maximum separation between them is $(X_0 + A)$, the phase difference between their motion is

(a) $\frac{\pi}{3}$ (b) $\frac{\pi}{4}$

(c) $\frac{\pi}{6}$ (d) $\frac{\pi}{2}$

39. Two simple harmonic motions with the same frequency act on a particle at right angles i.e., along x and y axis. If the two amplitudes are equal and the phase difference is π/2, the resultant motion will be

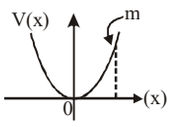
(a) a circle

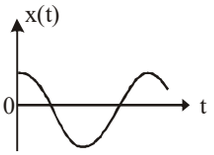
(b) an ellipse with the major axis along y-axis

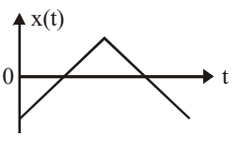
(c) an ellipse with the major axis along x-axis

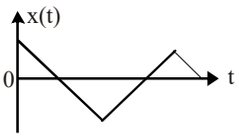
(d) a straight line inclined at 45° to the x-axis

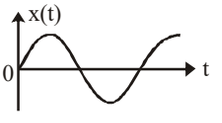
40. A particle of mass m is released from rest and follows a parabolic path as shown. Assuming that the displacement of the mass from the origin is small, which graph correctly depicts the position of the particle as a function of time



(a) 

(b) 

(c) 

(d) 

5.2 Energy of a Particle in S.H.M.

41. A body executes simple harmonic motion have amplitude A. The potential energy (P.E.), the kinetic energy (K.E.) and total energy (T.E.) are measured as a function of displacement x. Which of the following statement is true?

(a) P.E. is maximum when $x = 0$.

(b) K.E. = P.E. at $x = \pm\frac{A}{\sqrt{2}}$

(c) T.E. is zero when $x = \pm A$.

(d) K.E. is maximum when $x = A$

42. A particle of mass 10 gm is describing S.H. M. along a straight line with period of 2 sec and amplitude of 10 cm. Its kinetic energy (in ergs) when it is at 5 cm from its equilibrium position is

(a) $37.5\ \pi^2$ (b) $3.75\ \pi^2$

(c) $375\ \pi^2$ (d) $0.375\ \pi^2$

43. The total energy of a particle executing S.H. M. is 80 J. What is the potential energy when the particle is at a distance of 3/4 of amplitude from the mean position?

(a) 60 J (b) 10 J

(c) 40 J (d) 45 J

44. In a simple harmonic oscillator, at the mean position

(a) kinetic energy is minimum, potential energy is maximum

(b) both kinetic and potential energies are maximum

(c) kinetic energy is maximum, potential energy is minimum

(d) both kinetic and potential energies are minimum

45. The amplitude of a particle executing SHM is made three fourth keeping its time period constant. Its total energy will be

(a) $\frac{E}{2}$

(b) $\frac{3}{4}E$

(c) $\frac{9}{16}E$

(d) None of these

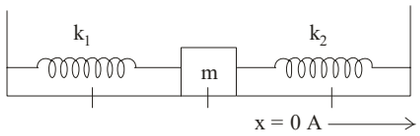
46. The displacement of a particle in simple harmonic motion (SHM) is given by $y = \sqrt{3\pi}\sin\left(\frac{100}{\pi}t + \frac{\pi}{4}\right)$. What will be the displacement of the particle from the mean position, when its kinetic energy is eight times that of its potential energy?

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

(c) $\sqrt{\pi}$ (d) $\sqrt{3\pi}$

5.3 Simple Pendulum, Spring Pendulum, Angular S.H.M., Magnet Vibrating in Uniform Magnetic Field, Free, Forced and Damped Oscillation

47. In the figure shown, the block is moved side ways by a distance A. The magnitude of net force on the block is



(a) $(k_1 - k_2)A$ (b) $(k_2 - k_1)A$

(c) $(k_1 + k_2)A$ (d) $\left(\frac{k_1 + k_2}{2}\right)A$

48. A particle, with restoring force proportional to displacement and resisting force proportional to velocity is subjected to a force F sin ωt. If the amplitude of the particle is maximum for $\omega = \omega_1$ and the energy of the particle is maximum for $\omega = \omega_2$, then

(a) $\omega_1 = \omega_0$ and $\omega_2 \neq \omega_0$

(b) $\omega_1 = \omega_0$ and $\omega_2 = \omega_0$

(c) $\omega_1 \neq \omega_0$ and $\omega_2 = \omega_0$

(d) $\omega_1 \neq \omega_0$ and $\omega_2 \neq \omega_0$

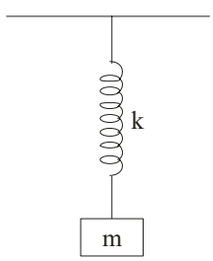
49. A block is left in the equilibrium position as shown in the figure. If now it is stretched by $\frac{mg}{k}$, the net stretch of the spring is

(a) $\frac{mg}{k}$

(b) $\frac{mg}{2k}$

(c) $\frac{2mg}{k}$

(d) $\frac{mg}{4k}$

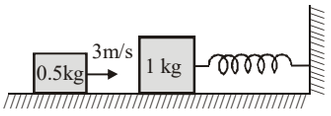


50. A mass M attached to a spring oscillates with a period of 2s. If the mass is increased by 2 kg, then the period increases by 2s. Find the initial mass M assuming that Hooke's law is obeyed.

(a) $\frac{2}{3}$kg (b) $\frac{1}{3}$kg

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

51. A 1 kg mass is attached to a spring of force constant 600 N/m and rests on a smooth horizontal surface with other end of the spring tied to wall as shown in figure. A second mass of 0.5 kg slides along the surface towards the first at 3m/s. If the masses make a perfectly inelastic collision, then find amplitude and time period of oscillation of combined mass.



(a) 5cm, $\frac{\pi}{10}$s (b) 5cm, $\frac{\pi}{5}$s

(c) 4cm, $\frac{2\pi}{5}$s (d) 4cm, $\frac{\pi}{3}$s

52. An electric motor of mass 40 kg is mounted on four vertical springs each having spring constant of 4000 Nm^{-1}. The period with which the motor vibrates vertically is

(a) 0.314 s (b) 3.14 s

(c) 0.628 s (d) 0.157 s

53. A body of mass 500 g is attached to a horizontal spring of spring constant $8\pi^2$ Nm^{-1}. If the body is pulled to a distance of 10 cm from its mean position, then its frequency of oscillation is

(a) 2 Hz (b) 4 Hz

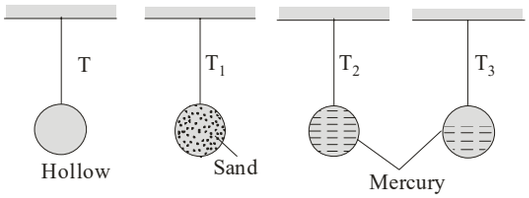
(c) 8 Hz (d) 0.5 Hz

54. A particle at the end of a spring executes simple harmonic motion with a period t_1, while the corresponding period for another spring is t_2. If the period of oscillation with the two springs in series is T, then

(a) $T = t_1 + t_2$ (b) $T^2 = t_1^2 + t_2^2$

(c) $T^{-1} = t_1^{-1} + t_2^{-1}$ (d) $T^{-2} = t_1^{-2} + t_2^{-2}$

55. The period of a simple pendulum, whose bob is a hollow metallic sphere, is T. The period is T_1 when the bob is filled with sand, T_2 when it is filled with mercury and T_3 when it is half filled with mercury. Which of the following is true?



(a) $T = T_1 = T_2 > T_3$ (b) $T_1 = T_1 = T_3 > T$

(c) $T > T_3 > T_1 = T_2$ (d) $T = T_1 = T_2 < T_3$

56. A simple pendulum attached to the ceiling of a stationary lift has a time period T. The distance y covered by the lift moving upwards varies with time t as $y = t^2$ where y is in metres and t in seconds. If g = 10 m/s^2, the time period of pendulum will be

(a) $\sqrt{\frac{4}{5}}T$ (b) $\sqrt{\frac{5}{6}}T$

(c) $\sqrt{\frac{5}{4}}T$ (d) $\sqrt{\frac{6}{5}}T$

57. The amplitude of a pendulum executing damped simple harmonic motion falls to 1/3 the original value after 100 oscillations. The amplitude falls to S times the original value after 200 oscillations, where S is

(a) 1/9 (b) 1/2

(c) 2/3 (d) 1/6

58. In damped oscillations, the amplitude of oscillations is reduced to one-third of its inital value a_0 at the end of 100 oscillations. When the oscillator completes 200 oscillations, its amplitude must be

(a) $a_0/2$ (b) $a_0/4$

(c) $a_0/6$ (d) $a_0/9$

59. The amplitude of a damped oscillator decreases to 0.9 times its original magnitude in 5s. In another 10s it will decrease to α times its original magnitude, where α equals

(a) 0.7 (b) 0.81

(c) 0.729 (d) 0.6

60. Two simple pendulums of length 1 m and 4 m respectively are both given small displacement in the same direction at the same instant. They will be again in phase after the shorter pendulum has completed number of oscillations equal to :

(a) 2 (b) 7

(c) 5 (d) 3

Exercise 3 : PREVIOUS YEARS MCQs

1. A simple pendulum performs SHM about $x = 0$ with an amplitude a and time period T. What is the speed of the pendulum at $x = a/2$? **[2025]**

(a) $\frac{a\pi\sqrt{3}}{T}$ (b) $\frac{a^2\pi^2\sqrt{3}}{T^2}$

(c) $\frac{a}{T}$ (d) $\frac{a\pi}{T}$

2. A particle is executing Simple Harmonic Motion (SHM). The ratio of potential energy and kinetic energy of the particle when its displacement is half of its amplitude will be: **[2024]**

(a) 1 : 1 (b) 2 : 1

(c) 1 : 4 (d) 1 : 3

3. A particle performs simple harmonic motion with amplitude A. Its speed is tripled at the instant that it is at a distance $\frac{2A}{3}$ from equilibrium position. The new amplitude of the motion is : **[2023]**

(a) $A\sqrt{3}$ (b) $\frac{7A}{3}$

(c) $\frac{A}{3}\sqrt{41}$ (d) 3A

4. A particle is executing simple harmonic motion with amplitude A. When the ratio of its kinetic energy to the potential energy is $\frac{1}{4}$, its displacement from its mean position is **[2021]**

(a) $\frac{2}{\sqrt{5}}A$ (b) $\frac{\sqrt{3}}{2}A$

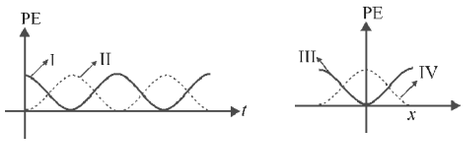
(c) $\frac{3}{4}A$ (d) $\frac{1}{4}A$

5. Two simple harmonic motions are represented by the equations $y_1 = 0.1 \sin\left(100\pi t + \frac{\pi}{3}\right)$ and $y_1 = 0.1 \cos \pi t$. The phase difference of the velocity of particle 1 with respect to the velocity of particle 2 is **[2020]**

(a) $\frac{\pi}{3}$ (b) $\frac{-\pi}{6}$

(c) $\frac{\pi}{6}$ (d) $\frac{-\pi}{3}$

6. For a particle executing SHM the displacement x is given by $x = A \cos \omega t$. Identify the graph which represents the variation of potential energy (P.E.) as a function of time t and displacement x. **[2020]**



(a) I, III (b) II, IV

(c) II, III (d) I, IV

7. The quantity which *does not* vary periodically for a particle performing S.H.M. is **[2019]**

(a) acceleration

(b) total energy

(c) displacement

(d) velocity

8. A particle executes the simple hormonic motion with an amplitude 'A'. The distance travelled by it in one periodic time is **[2019]**

(a) $\frac{A}{2}$ (b) A

(c) 2 A (d) 4 A

9. The path length of oscillation of simple pendulum of length 1 meter is 16 cm. Its maximum velocity is ($g = \pi^2$ m/s^2)

(a) 2π cm/s (b) 4π cm/s **[2018]**

(c) 8π cm/s (d) 16π cm/s

10. For a particle performing linear S.H.M., its average speed over one oscillation is (a = amplitude of S.H.M., n = frequency of oscillation) **[2018]**

(a) 2 an (b) 4 an (c) 6 an (d) 8 an

11. A mass is suspended from a vertical spring which is executing S.H.M. of frequency 5 Hz. The spring is unstretched at the highest point of oscillation. Maximum speed of the mass is [acceleration due to gravity g = 10 m/s^2] **[2018]**

(a) 2π m/s (b) π m/s

(c) $\frac{1}{2\pi}$ m/s (d) $\frac{1}{\pi}$ m/s

12. A particle performing SHM starts equilibrium position and its time period is 16 seconds. After 2 seconds its velocity is π m/s. Amplitude of oscillation is $\left(\cos 45° = \frac{1}{\sqrt{2}}\right)$ **[2017]**

(a) $2\sqrt{2m}$ (b) $4\sqrt{2m}$

(c) $6\sqrt{2m}$ (d) $8\sqrt{2m}$

13. A particle is executing simple harmonic motion with amplitude A. The ratio of the kinetic energies of the particle when it is at displacements of $\frac{A}{4}$ and $\frac{A}{2}$ from the mean position is **[2016]**

(a) 4 : 1 (b) 2 : 1

(c) 5 : 4 (d) 9 : 16

14. The time period of a simple pendulum on the surface of the earth is T. If the pendulum is taken to a height equal to half of the radius of the earth, then its time period is **[2015]**

(a) $\frac{T}{2}$ (b) $\frac{3T}{2}$

(c) 2 T (d) 3 T

15. When the mass attached to a spring is increased from 4 kg to 9 kg, the time period of oscillation increases by 0.2π s. Then the spring constant of the spring is **[2014]**

(a) 80 N m^{-1} (b) 200 N m^{-1}

(c) 50 N m^{-1} (d) 100 N m^{-1}

16. The angular frequency of a block of mass 0.1 kg oscillating with the help of a spring of force constant 2.5 N m^{-1} is **[2013]**

(a) 0.2 rad s^{-1} (b) 5 rad s^{-1}

(c) 10 rad s^{-1} (d) 2 rad s^{-1}

17. For a particle executing simple harmonic motion, the ratio of kinetic and potential energies at a point where displacement is one half of the amplitude is **[2012]**

(a) 3 : 1 (b) 1 : 3

(c) 2 : 1 (d) 1 : 2

18. A child swinging on a swing in sitting position, stands up, then the time period of the swing will **[2011]**

(a) increase

(b) decrease

(c) remains same

(d) increases if the child is long and decreases if the child is short

19. T_0 is the time period of a simple pendulum at a place. If the length of the pendulum is reduced to $\frac{1}{16}$ times of its initial value, the modified time period is : **[2010]**

(a) T_0 (b) $8\pi T_0$

(c) $4T_0$ (d) $\frac{1}{4}T_0$

20. The total energy of a particle, executing simple harmonic motion is **[2009]**

(a) independent of x (b) $\propto x^2$

(c) $\propto x$ (d) $\propto x^{1/2}$

where x is the displacement from the mean position, hence total energy is independent of x.

21. Time period of a simple pendulum is T inside a lift when the lift is stationary. If the lift moves upwards with an acceleration g/2, the time period of pendulum will be : **[2008]**

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

(c) $\sqrt{\frac{3}{2}}T$ (d) $\frac{T}{\sqrt{3}}$

22. The length of a simple pendulum executing simple harmonic motion is increased by 21%. The percentage increase in the time period of the pendulum of increased length is **[2008]**

(a) 11% (b) 21%

(c) 42% (d) 10%

23. The equation of a particle executing simple harmonic motion is given by $x = \sin\pi\left(t + \frac{1}{3}\right)$ m. At t = 1s, the speed of particle will be (Given : $\pi = 3.14$) **[2007]**

(a) 0 cm s^{-1} (b) 157 cm s^{-1}

(c) 272 cm s^{-1} (d) 314 cm s^{-1}

24. In a simple harmonic oscillator, at the mean position **[2006]**

(a) kinetic energy is minimum, potential energy is maximum

(b) both kinetic and potential energies are maximum

(c) kinetic energy is maximum, potential energy is minimum

(d) both kinetic and potential energies are minimum

25. If a simple harmonic motion is represented by $\frac{d^2x}{dt^2} + \alpha x = 0$, its time period is` **[2005]**

(a) $\frac{2\pi}{\sqrt{\alpha}}$ (b) $\frac{2\pi}{\alpha}$

(c) $2\pi\sqrt{\alpha}$ (d) $2\pi\alpha$

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs

1	(b)	**12**	(c)	**23**	(a)	**34**	(b)	**45**	(a)	**56**	(a)	**67**	(c)	**78**	(a)	**89**	(c)	**100**	(c)
2	(a)	**13**	(c)	**24**	(a)	**35**	(c)	**46**	(d)	**57**	(c)	**68**	(a)	**79**	(d)	**90**	(b)	**101**	(d)
3	(c)	**14**	(a)	**25**	(a)	**36**	(a)	**47**	(a)	**58**	(c)	**69**	(c)	**80**	(c)	**91**	(b)	**102**	(b)
4	(d)	**15**	(c)	**26**	(a)	**37**	(b)	**48**	(a)	**59**	(c)	**70**	(d)	**81**	(a)	**92**	(d)	**103**	(d)
5	(c)	**16**	(c)	**27**	(d)	**38**	(c)	**49**	(d)	**60**	(b)	**71**	(d)	**82**	(d)	**93**	(c)	**104**	(b)
6	(d)	**17**	(d)	**28**	(a)	**39**	(d)	**50**	(c)	**61**	(b)	**72**	(b)	**83**	(d)	**94**	(d)	**105**	(a)
7	(b)	**18**	(b)	**29**	(c)	**40**	(d)	**51**	(c)	**62**	(b)	**73**	(b)	**84**	(a)	**95**	(b)	**106**	(d)
8	(c)	**19**	(a)	**30**	(c)	**41**	(c)	**52**	(a)	**63**	(b)	**74**	(d)	**85**	(d)	**96**	(c)		
9	(d)	**20**	(c)	**31**	(a)	**42**	(c)	**53**	(c)	**64**	(d)	**75**	(b)	**86**	(c)	**97**	(d)		
10	(d)	**21**	(b)	**32**	(b)	**43**	(d)	**54**	(d)	**65**	(a)	**76**	(d)	**87**	(a)	**98**	(d)		
11	(d)	**22**	(b)	**33**	(b)	**44**	(b)	**55**	(d)	**66**	(c)	**77**	(a)	**88**	(b)	**99**	(a)		

Exercise 2 : ACCELERATOR Topic-wise MCQs

1	(d)	**7**	(c)	**13**	(b)	**19**	(b)	**25**	(d)	**31**	(b)	**37**	(b)	**43**	(d)	**49**	(c)	**55**	(d)
2	(a)	**8**	(b)	**14**	(b)	**20**	(a)	**26**	(d)	**32**	(d)	**38**	(a)	**44**	(c)	**50**	(a)	**56**	(b)
3	(b)	**9**	(d)	**15**	(c)	**21**	(b)	**27**	(c)	**33**	(a)	**39**	(a)	**45**	(c)	**51**	(a)	**57**	(a)
4	(c)	**10**	(a)	**16**	(c)	**22**	(c)	**28**	(b)	**34**	(d)	**40**	(a)	**46**	(a)	**52**	(a)	**58**	(d)
5	(d)	**11**	(b)	**17**	(c)	**23**	(d)	**29**	(c)	**35**	(d)	**41**	(b)	**47**	(c)	**53**	(a)	**59**	(c)
6	(a)	**12**	(d)	**18**	(b)	**24**	(b)	**30**	(c)	**36**	(a)	**42**	(c)	**48**	(c)	**54**	(b)	**60**	(a)

Exercise 3 : PREVIOUS YEARS MCQs

1	(a)	**4**	(a)	**7**	(b)	**10**	(b)	**13**	(c)	**16**	(b)	**19**	(d)	**22**	(d)	**25**	(a)		
2	(d)	**5**	(b)	**8**	(d)	**11**	(d)	**14**	(b)	**17**	(a)	**20**	(a)	**23**	(b)				
3	(b)	**6**	(a)	**9**	(c)	**12**	(d)	**15**	(d)	**18**	(b)	**21**	(a)	**24**	(c)				

6 Superposition of Waves

TOPIC 6.1 : WAVE AND WAVE MOTION, PROGRESSIVE WAVES, REFLECTION OF WAVES & SUPERPOSITION OF WAVES

WAVE AND WAVE MOTION

Wave motion is a type of motion in which the disturbance travels from one point of the medium to another but the particles of the medium do not travel from one point to another. The pattern of disturbance which move as a whole is called wave. In a wave, information and energy transfer but not motion of matter as a whole through a medium.

PROGRESSIVE WAVES

It can also be written in the following forms :

$$y(x,t) = A\sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right)$$

or $$y(x,t) = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) \quad \ldots \text{(i)}$$

$$= A\sin\frac{2\pi}{T}\left(t - \frac{x}{\lambda}T\right)$$

But $\frac{\lambda}{T} = v$ $\quad\therefore\quad y(x,t) = A\sin\frac{2\pi}{T}\left(t - \frac{x}{v}\right)$

Also $$y(x,t) = A\sin\frac{2\pi}{\lambda}\left(\frac{\lambda}{T}t - x\right) \quad \ldots\text{(ii)}$$

or $$y(x,t) = A\sin\frac{2\pi}{\lambda}(vt - x) \quad \ldots \text{(iii)}$$

Equations (i), (ii) and (iii) are the various forms of plane progressive wave. If the initial phase of the particle at O is ϕ_0, then the equation of wave motion will be

$$\overbrace{y(x,t)}^{\text{Displacement}} = \overbrace{A}^{\text{Amplitude}} \overbrace{\sin(\omega t - kx + \phi_0)}^{\text{Phase}}$$

- ω : Angular frequency
- t : Time
- k : Angular wave number
- x : Position
- ϕ_0 : Initial phase angle

A harmonic wave travelling along negative direction of X-axis can be written as

$$y(x,t) = A\sin(\omega t + kx + \phi_0)$$

Phase, Phase Difference and Path Difference

Phase : Phase is a quantity which contains all information related to any vibrating particle in a wave.

For equation $y = A\sin(\omega t - kx)$, $(\omega t - kx)$ is the phase.

Phase difference and path difference : At any instant t, if ϕ_1 and ϕ_2 are the phase of two particles whose distances from the origin are x_1 and x_2 respectively, then

$$\phi_1 = (\omega t - kx_1) \text{ and } \phi_2 = (\omega t - kx_2)$$

$$\Rightarrow \phi_1 - \phi_2 = k(x_2 - x_1)$$

$$\Rightarrow \textit{ phase difference } \Delta\phi = \frac{2\pi}{\lambda}(\textit{Path difference } \Delta x)$$

Relation between phase difference, path difference and time period :

$$\Rightarrow \frac{\Delta\phi}{2\pi} = \frac{\Delta\lambda}{\lambda} = \frac{\Delta T}{T}$$

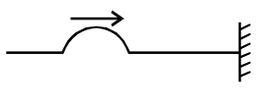
$$\Rightarrow \textit{ Path difference } = \left(\frac{\lambda}{2\pi}\right) \textit{ Phase difference}$$

REFLECTION OF WAVES

When energy travelling in a homogeneous medium meets a boundary of some other medium or some sudden discontinuity (change in density) it has a tendency to travel in opposite direction. This is called reflection of a wave.

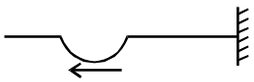
Reflection from rigid end : Equation of wave propagating in +ve x-axis

Incident wave : $y_1 = a\sin(\omega t - kx)$

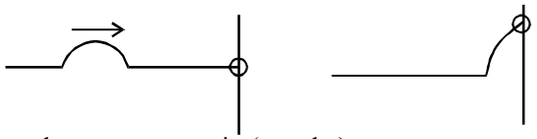


Reflected wave : $y_2 = a \sin(\omega t + kx + \pi)$

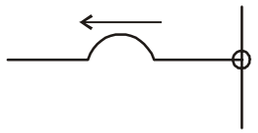
or $y_2 = -a \sin(\omega t + kx)$



Reflection from free end : Incident wave: $y_1 = a \sin(\omega t - kx)$



Reflected wave: $y_2 = a \sin(\omega t + kx)$



SUPERPOSITION OF WAVES

The phenomenon of intermixing of two or more waves to produce a new wave is called ***superposition of waves***.

If $\vec{y}_1, \vec{y}_2, \vec{y}_3$..... are the displacement of particle at a particular time due to individual waves, then the resultant displacement is given by $\vec{y} = \vec{y}_1 + \vec{y}_2 + \vec{y}_3 + ...$

Intensity of Wave

The amount of energy flowing per unit area and per unit time is called the intensity of wave.

It is represented by I.

Its **SI unit** is J/m^2s or $watt/meter^2$.

$I = 2\pi^2 f^2 A^2 \rho v$ i.e. $I \propto f^2$ and $I \propto A^2$

Interference of Waves

When two waves of equal frequency and nearly equal amplitude travelling in same direction having same state of polarisation in medium superimpose, then intensity is different at different points. At some points intensity is large, whereas at other points it is nearly zero.

Consider two waves

$y_1 = A_1 \sin(\omega t - kx)$ and $y_2 = A_2 \sin(\omega t - kx + \phi)$

By principle of superposition

$y = y_1 + y_2 = A \sin(\omega t - kx + \delta)$

where, $A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos\phi$,

and $\tan\delta = \dfrac{A_2 \sin\phi}{A_1 + A_2 \cos\phi}$

As intensity $I \propto A^2$

So, resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

For constructive interference (maximum intensity):

Phase difference, $\phi = 2n\pi$ or path difference $= n\lambda$

where n = 0, 1, 2, 3, ...

$\Rightarrow A_{max} = A_1 + A_2$ and $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

$= (\sqrt{I_1} + \sqrt{I_2})^2$

For destructive interference (minimum intensity) :

Phase difference, $\phi = (2n + 1)\pi$,

or path difference $= (2n-1)\dfrac{\lambda}{2}$; where n = 0, 1, 2, 3, ...

$\Rightarrow A_{min} = A_1 - A_2$ and $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$

$= (\sqrt{I_1} - \sqrt{I_2})^2$

TOPIC 6.2 : STATIONARY WAVES, BEATS AND MUSICAL INSTRUMENTS

STATIONARY WAVES

A stationary or standing wave is formed when two identical waves travelling in the opposite directions along a straight line interfere. The superposition of the two waves will give rise to a stationary wave.

Formation of stationary wave is possible only in bounded medium.

Analytical method for stationary waves

(i) From rigid end : We know equation for progressive wave in positive x-direction

$y_1 = a \sin(\omega t - kx)$

After reflection from rigid end,

$y_2 = a \sin(\omega t + kx + \pi)$

$y_2 = -a \sin(\omega t + kx)$

By principle of superposition,

$y = y_1 + y_2$

$y = a \sin(\omega t - kx) - a \sin(\omega t + kx)$

or, $y = -2a \sin kx \cos \omega t$

This is equation of stationary wave reflected from rigid end.

(1) At node : $x = 0, \dfrac{\lambda}{2}, \lambda$ .....

$A = 0$; $V_p = 0$

Strain $\rightarrow$ max, change in pressure $\rightarrow$ max

Position of nodes $\rightarrow$ $0, \dfrac{\lambda}{2}, \lambda$ .....

(2) At antinode $x = \dfrac{\lambda}{4}, \dfrac{3\lambda}{4}$ .....

$A \rightarrow$ max ; $V_p \rightarrow$ max

Strain = 0 ; amplitude change in pressure = 0

Position of antinodes $\rightarrow$ $\dfrac{\lambda}{4}, \dfrac{3\lambda}{4}, \dfrac{5\lambda}{4}$ .....

(ii) From free end : We know equation for progressive wave in positive x-direction,

$y_1 = a \sin(\omega t - kx)$

After reflection from free end

$y_2 = a \sin(\omega t + kx)$

By Principle of superposition,

$y = y_1 + y_2$

$y = a \sin(\omega t - kx) + a \sin(\omega t + kx)$

or, $y = 2a \sin \omega t \cos kx$

This is the equation of stationary wave reflected from free end.

(1) At node : $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$.....

Amplitude $A = 0$

Wave velocity $\frac{dy}{dt} = 0$

Strain $\to$ max ; $dp \to$ max

Position of nodes $\frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}$.....

(2) At antinode : $x = 0, \frac{\lambda}{2}, \lambda$.....

$A \to$ max

$V_p \to \frac{dy}{dt} \to$ max

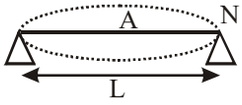
Strain = 0 ; $dp = 0$

Position of antinodes $\to 0, \frac{\lambda}{2}\lambda$ ....

Stationary Transverse Waves in Strings

In this waves ends are always nodes

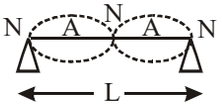
First harmonic



$\frac{\lambda}{2} = L \Rightarrow \lambda = 2L$

(a)

Second harmonic or first overtone



$\frac{2\lambda}{2} = L \Rightarrow \lambda = L$

(b)

Third harmonic or second overtone

$\frac{3\lambda}{2} = L \Rightarrow \lambda = \frac{2L}{3}$

(c)

For p^{th} harmonic or $(p-1)$ overtone $\frac{p\lambda}{2} = L \Rightarrow \lambda = \frac{2L}{p}$

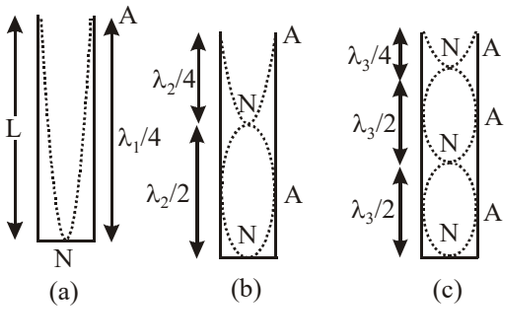
For n^{th} mode, $V = \left(n + \frac{1}{2}\right)\frac{V}{2L}, n = 0, 1, 2, 3.....$

Stationary Longitudinal Waves in Air Columns

When two longitudinal waves of same frequency and amplitude travel in a medium in opposite directions then by superposition, standing waves are produced.

These waves are produced in air columns in cylindrical tube of uniform diameter. These sound producing tubes are called **organ pipes.**

1. Vibration of air column in closed organ pipe : *The tube which is closed at one end and open at the other end is closed called organ pipe.*



Case (a) $L = \frac{\lambda}{4} \Rightarrow \lambda = 4L \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{4L}$

Fundamental frequency or first harmonic.

Case (b) $L = \frac{3\lambda}{4} \Rightarrow \lambda = \frac{4L}{3} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{3v}{4L}$

First overtone or third harmonic

Case (c) $L = \frac{5\lambda}{4} \Rightarrow \lambda = \frac{4L}{5} \Rightarrow n_3 = \frac{v}{\lambda} = \frac{5v}{4L}$

Second overtone or fifth harmonic.

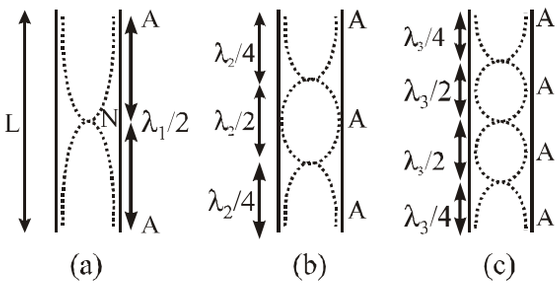
When closed organ pipe vibrate in m^{th} overtone then

$$L = (2m+1)\frac{\lambda}{4} \text{ so, } \lambda = \frac{4L}{(2m+1)} \Rightarrow n = (2m+1)\frac{v}{4L}$$

Hence frequency of overtones is given by

$n_1 : n_2 : n_3$.....$= 1 : 3 : 5$....

2. Vibration of air column in open organ pipe :



Case (a)

$L = \frac{\lambda}{2} \Rightarrow \lambda = 2L \Rightarrow n_1 = \frac{v}{\lambda} = \frac{v}{2L}$

Fundamental frequency or first harmonic.

Case (b)

$$L = \frac{2\lambda}{2} \Rightarrow \lambda = \frac{2L}{2} \Rightarrow n_2 = \frac{v}{\lambda} = \frac{2v}{2L}$$

First overtone or second harmonic.

Case (c)

$$L = \frac{3\lambda}{2} \Rightarrow \lambda = \frac{2L}{3} \Rightarrow n_3 = \frac{v}{\lambda} = \frac{3v}{2L}$$

Second overtone or third harmonic.

Hence frequency of overtones are given by the relation

$n_1 : n_2 : n_3$ .....= 1 : 2 : 3.....

When open organ pipe vibrate in m^{th} overtone then

$$L = (m+1)\frac{\lambda}{4} \quad \text{so,} \quad \lambda = \frac{4L}{m+1}$$

$$\Rightarrow n = (m+1)\frac{v}{2L}$$

End Correction

Due to finite momentum of air molecules in organ pipes reflection takes place not exactly at open end but somewhat it so in an organ pipe antinode is not formed exactly at free-end but above it at a **distance e = 0.6r called end correction** or **Rayleigh correction** with r being the radius of pipe. So for closed organ pipe $L \rightarrow L + 0.6r$ while for open organ pipe

$L \rightarrow L + 2 \times 0.6r$ (as both ends are open) so that,

$$f_C = \frac{v}{4(L+0.6r)} \text{ while, } f_0 = \frac{v}{2(L+1.2r)}$$

This is why for a given v and L narrower the pipe higher will the frequency or pitch and shriller will be the sound.

Free and Forced Vibrations

When a body vibrates with its own natural frequency, the vibrations are **free** or **natural vibrations**.

If there is no damping, the total energy or amplitude of vibrations remains constant.

In case of damping, amplitude decrease exponentially, energy also decreases.

Forced vibrations: When an external force which vibrates periodically with frequency (p) acts on a body of natural freq. (n), the body vibrates with the freq. of the force (p). In such case the vibrations of the body are forced vibrations.

If the difference ($p \approx n$) in large, the amplitude of vibrating body is small.

There is a phase difference between the force and the body

Resonance

When the frequency of the force (p) is equal to the natural frequency (n) of the body, resonance occurs.

At resonance n = p

The amplitude of the body is maximum. Damping limits this amplitude at resonance. There is a phase difference of $\pi/2$ between the force and vibrating body.

Sonometer

If the length of the wire between the two bridges is *l*, then the frequency of vibration is $n = \frac{1}{2l}\sqrt{\frac{T}{m}} = \sqrt{\frac{T}{\pi r^2 d}}$

(*r* = Radius of the wire, d = Density of material of wire) m = mass per unit length of the wire)

Resonance : When a vibrating tuning fork is placed on the box, and if the length between the bridges is property adjusted then if $(n)_{fork} = (n)_{string} \rightarrow$ rider is thrown off the wire.

BEATS

When two sound waves of nearly same frequency are produced simultaneously, then the intensity of resultant sound wave increases and decreases with time. This change in the intensity of sound is called as the phenomenon of 'beats'.

The time interval between two successive beats is called **beat period** and the number of beats per second is called the **beat frequency.**

If f_1 and f_2 are the frequencies ($f_1 > f_2$) of the two waves, then the beat frequency

$$b = f_1 - f_2$$

MUSICAL INSTRUMENTS

A musical instrument is a device created or adapted to make musical sounds and it can be classified into four types.

(1) Stringed instruments (2) Wind instruments (3) Percussion instruments (4) Solid instruments

1. **Stringed instruments :** The instruments in which sound is produced by plucking of strings. Examples :
   (1) Sitar, veena, guitar, tanpura are instruments in which string is plucked by a finger.
   (2) Pianoforte, santoor are instruments in which string is stuck by a hammer.
2. **Wind instruments :** The instruments in which sound produced by setting vibration of air columns.

Examples :

(a) **Flutes:** The flute is simple wind instrument consisting of a cylindrical pipe of either metal or bamboo closed at one end and open at the other end.

(b) **Harmonium :** It is reed instrument without pipe. It is wind musical instrument. It consists of a keyboard in which air is set into vibrations by means of thin metal reeds. Each key is tuned to its appropriate pitch.

(c) **Bugle :** It is pipe instrument without reeds. When flute is played softly, it produces almost pure sound note free from any overtone. The frequency of the sound produced by a flute (pipe) depends on its length.

(d) **Bassoon :** It is pipe instruments with reeds.

3. **Percussion instruments :** The instruments in which sound produced by setting vibrations in a stretched membrane. **Drums, tabla,** mridangam etc. are examples of percussion instrument.

4. **Solid instruments:** Musical instrument in which a vibrating solid material is used to produce sound. Example: Electric guitar, electric bass etc.

CHAPTER AT A GLANCE

- Plane progressive wave equation,

  $y = A \sin (wt - kx)$

  $y = A \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

  $y = A \sin \frac{2\pi}{\gamma} (vt - x)$

- If the wave equation has $f(vt + x)$ or $f(\omega t + kx)$, the wave is propagating along the negative x-direction. If the wave equation has $f(vt - x)$ or $f(\omega t - kx)$, it is propagating along the positive x-direction.

- When energy travelling in a homogeneous medium meets a boundary of some other medium or some sudden discontinuity (change in density) it has a tendency to travel in opposite direction. This is called reflection of a wave.

- Intensity of wave, $I = 2\pi^2 f^2 A^2 \rho v$

- In interference resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\phi$

- **For constructive interference (maximum intensity):**

  Phase difference, $\phi = 2n\pi$ or path difference $= n\lambda$

  where $n = 0, 1, 2, 3, ...$

  $A_{max} = A_1 + A_2$ and $I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$

  $= (\sqrt{I_1} + \sqrt{I_2})^2$

- **For destructive interference (minimum intensity) :**

  Phase difference, $\phi = (2n + 1)\pi$,

  or path difference $= (2n - 1)\frac{\lambda}{2}$; where $n = 0, 1, 2, 3, ...$

  $A_{min} = A_1 - A_2$ and $I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$

  $= (\sqrt{I_1} - \sqrt{I_2})^2$

- The stationary wave formed by the superposition

  $y = y_1 + y_2 = \pm 2a \cos\frac{2\pi x}{\lambda} \sin\frac{2\pi t}{T}$

- Fundamental frequency of string vibrates in p loops, $f_p = \frac{p}{2L}\sqrt{\frac{T}{m}}$

- In an organ pipe closed at one end, only odd harmonics 1, 3, 5, ... are present.

  Fundamental or first harmonic frequency, $f_1 = \frac{V}{4L}$

- In an organ pipe open at both ends, both odd and even harmonics are present,

  Fundamental or first harmonic, $f_1 = \frac{V}{2L}$

- If L_1 and L_2 are the first and second resonance lengths with a tuning fork of frequency f, then the speed of sound.

  $V = 4f(L_1 + 0.3D)$ or, $V = 2f(L_2 - L_1)$

  End correction $= 0.3\,D = \frac{L_2 - 3L_1}{2}$

- Beat frequency = Number of beats per second = Difference in frequencies of two sources

  or, $b = (f_1 - f_2)$ or $(f_2 - f_1)$

- In stringed instruments sound is produced by plucking of strings.

- In wind instruments sound produced by setting vibration of air columns.

Exercise 1 : WARM-UP
Topic-wise MCQs

6.1 Wave and Wave Motion, Progressive Waves, Reflection of Waves & Superposition of Waves

1. In the given progressive wave equation $y = 0.5 \sin (10\ \pi t - 5x)$ where x, y in cm and t in second. The maximum velocity of the particle is:

(a) 5 cm/s (b) $5\ \pi$ cm/s

(c) 10 cm/s (d) 10.5 cm/s

2. A plane progressive wave is given by $y = 2 \cos 2\pi(330\,t - x)$ m. The frequency of the wave is :

(a) 165 Hz (b) 330 Hz

(c) 660 Hz (d) 340 Hz

3. A travelling harmonic wave is represented by the equation $y(x, t) = 10^{-3} \sin(50t + 2x)$, where x and y are in meter and t is in seconds. Which of the following is a correct statement about the wave?

(a) The wave is propagating along the negative x-axis with speed 25 ms^{-1}.

(b) The wave is propagating along the positive x-axis with speed 100 ms^{-1}.

(c) The wave is propagating along the positive x-axis with speed 25 ms^{-1}.

(d) The wave is propagating along the negative x-axis with speed 100 ms^{-1}.

4. The equation of plane progressive wave motion is $y = a \sin \frac{2\pi}{\lambda}(vt - x)$. Velocity of the particle is

(a) $y\frac{dv}{dx}$ (b) $v\frac{dy}{dx}$

(c) $-y\frac{dv}{dx}$ (d) $-v\frac{dy}{dx}$

5. The equation $y = a \sin \frac{2\pi}{\lambda}(vt - x)$ is expression for

(a) stationary wave of single frequency along x-axis

(b) a simple harmonic motion

(c) a progressive wave of single frequency along x-axis

(d) the resultant of two SHMs of slightly different frequencies

6. Two waves of equal amplitude A and equal frequency travel in the same direction in a medium having phase difference of ϕ. The amplitude of the resultant wave is

(a) 0 (b) A

(c) 2A (d) between 0 to 2A

7. When a wave is reflected normally from a rigid boundary, the reflected wave suffers a phase change of (assuming no absorption)

(a) $\frac{\pi}{2}$ (b) $\frac{\pi}{4}$

(c) π (d) 2π

8. If a propagating wave meets a boundary which is not completely rigid or is an interface between two different elastic media, then which of the statement is correct?

(a) A part of the incident wave is reflected and a part is transmitted into the second medium.

(b) The incident wave is completely reflected from the boundary.

(c) Only a part of the wave is reflected and the remaining part disappears.

(d) None of the above

9. Two waves are propagating to the point P along a straight line produced by two sources A and B of simple harmonic and of equal frequency. The amplitude of every wave at P is 'a' and the phase of A is ahead by $\frac{\pi}{3}$ than that of B and the distance AP is greater than BP by 50 cm. Then the resultant amplitude at the point P will be , if the wavelength is 1 meter

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

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

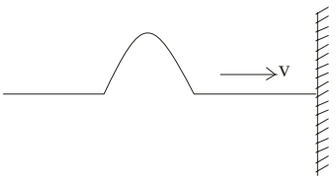
10. There are 10 sound sources each producing intensity I at a point independently. They are incoherent. Average intensity of sound at that point will be:

(a) I (b) 10 I (c) 100 I (d) 0

11. Two coherent sources of different intensities send waves which interfere. The ratio of the maximum intensity to the minimum intensity is 25. The intensities are in the ratio:

(a) 25 : 1 (b) 5 : 1 (c) 9 : 4 (d) 625 : 1

12. When a wave pulse travelling in a string is reflected from a rigid wall to which string is tied as shown in figure. For



this situation two statement are given below.

(1) Th reflected pulse will be in same orientation of incident pulse due to a phase change of π radians

(2) During reflection the wall exert a force on string in upward direction

For the above given two statements choose the correct option given below.

(a) Only (1) is true (b) Only (2) is true

(c) Both are true (d) Both are wrong

13. When a wave is reflected from a denser medium, the change in phase is

(a) 0 (b) π (c) 2 π (d) 3 π

14. A progressive wave y = A sin(kx – ωt) is reflected by a rigid wall at x = 0. Then the reflected wave can be represented by

(a) y = A sin(kx + ωt) (b) y = A cos(kx + ωt)

(c) y = –A sin(kx – ωt) (d) y = –A sin(kx + ωt)

15. A string is clamped at both the ends and it is vibrating in its 4th harmonic. The equation of the stationary wave is Y = 0.3 sin(0.157x) cos(200ωt). The length of the string is: (All quantities are in SI units.)

(a) 20 m (b) 80 m

(c) 40 m (d) 60 m

16. Which of the following changes at an antinode in a stationary wave?

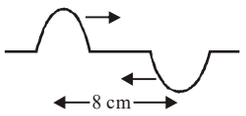
(a) Density only

(b) Pressure only

(c) Both pressure and density

(d) Neither pressure nor density

17. Two pulses in a stretched string whose centres are initially 8 cm apart are moving towards each other as shown in the figure. The speed of each pulse is 2 cm/s. After 2 s, the total energy of the pulses will be



(a) Zero

(b) Purely kinetic

(c) Purely potential

(d) Partly kinetic and partly potential

18. Two sound waves travel in the same direction in a medium. The amplitude of each wave is A and the phase difference between the two waves is 120°. The resultant amplitude will be

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

(c) 3A (d) A

19. The minimum intensity of sound is zero at a point due to two sources of nearly equal frequencies, when

(a) Two sources are vibrating in opposite phase

(b) The amplitude of two sources are equal

(c) At the point of observation, the amplitudes of two S. H. M. produced by two sources are equal and both the S. H. M. are along the same straight line

(d) Both the sources are in the same phase

20. Equation of motion in the same direction is given by $y_1 = A \sin(\omega t - kx)$, $y_2 = A \sin(\omega t - kx - \theta)$. The amplitude of the medium particle will be

(a) $2A\cos\frac{\theta}{2}$

(b) $2A\cos\theta$

(c) $\sqrt{2}A\cos\frac{\theta}{2}$

(d) 1.2f, 1.2λ

21. Two waves having equations $x_1 = a \sin(\omega t + \varphi_1)$, $x_2 = a \sin(\omega t + \varphi_2)$

If in the resultant wave the frequency and amplitude remain equal to those of superimposing waves. Then phase difference between them is

(a) $\frac{\pi}{6}$ (b) $\frac{2\pi}{3}$

(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{3}$

22. As the wave propagates, choose the incorrect statement.

(a) the wave intensity remains constant for a plane curve

(b) the wave intensity decreases as the inverse of the distance from the source for a spherical wave

(c) the wave intensity decreases as the inverse square of the distance from the source for a spherical wave

(d) the wave intensity decreases as the inverses of the distance for a line source

23. The amplitude of a wave represented by displacement equation $y = \frac{1}{\sqrt{a}}\sin\omega t \pm \frac{1}{\sqrt{b}}\cos\omega t$ will be

(a) $\frac{a+b}{ab}$ (b) $\frac{\sqrt{a}+\sqrt{b}}{ab}$

(c) $\frac{\sqrt{a}\pm\sqrt{b}}{ab}$ (d) $\sqrt{\frac{a+b}{ab}}$

24. Two waves are said to be coherent, if they have

(a) same phase but different amplitude

(b) same frequency but different amplitude

(c) same frequency and phase

(d) different frequency, phase and amplitude

25. An incident wave is represented by y (x,t) = 20 sin (2x–4t). The expression for reflected wave from an open boundary is

(a) 20 sin (2x + 4t)

(b) –20 sin (2x + 4t)

(c) 10 sin (x + 2t)

(d) 10 cos (x + 2t)

26. When a wave is reflected from a denser medium, the change in phase is

(a) 0 (b) π

(c) 2 π (d) 3 π

27. A progressive wave y = A sin(kx – ωt) is reflected by a rigid wall at x = 0. Then the reflected wave can be represented by

(a) y = A sin(kx + ωt)

(b) y = A cos(kx + ωt)

(c) y = –A sin(kx – ωt)

(d) y = –A sin(kx + ωt)

28. When a sound wave is reflected from a wall, the phase difference between the reflected and incident pressure wave is

(a) 0

(b) π

(c) π/2

(d) π/4

6.2 Stationary Waves, Beats and Musical Instruments

29. The equation of the vibration of a string fixed at both end, vibrating in its third harmonic is given by y = 2 cm sin [0.6 cm^{-1})x] cos [500πs^{-1})t]

The length of the string is:

(a) 24.6 cm (b) 12.5 cm

(c) 20.6 cm (d) 15.7 cm

30. Two wires are kept tight between the same pair of supports. The tensions in the wires are in the ratio 2 : 1, the radii are in the ratio 3 :1 and the densities are in the ratio 1 : 2. The ratio of their fundamental frequencies is

(a) 2 : 3 (b) 2 : 4

(c) 2 : 5 (d) 2 : 6

31. A closed organ pipe and an open organ pipe are tuned to the same fundamental frequency. What is the ratio of lengths?

(a) 1 : 2 (b) 2 : 1

(c) 2 : 3 (d) 4 : 3

32. A tuning fork of frequency 340 Hz is vibrated just above the tube of 120 cm height. Water is poured slowly in the tube. What is the minimum height of water necessary for the resonance (speed of sound in the air = 340 m/sec)?

(a) 15 cm (b) 25 cm

(c) 30 cm (d) 45 cm

33. An organ pipe is closed at one end had fundamental frequency of 1500 Hz. The maximum number of overtones generated by this pipe which a normal person can hear is:

(a) 14 (b) 13

(c) 6 (d) 9

34. An open organ pipe of length L resonates at fundamental frequency with closed organ pipe. Find the length of closed organ pipe.

(a) 2L (b) L /2

(c) $L\sqrt{2}$ (d) $L\sqrt{3}/2$

35. If the fundamental frequency of a pipe closed at one end is 512 Hz. The fundamental frequency of a pipe of the same dimensions but open at both ends will be:

(a) 1024 Hz (b) 512 Hz

(c) 256 Hz (d) 128 Hz

36. When two sound waves are superimposed, beats are produced when they have different

(a) amplitudes and phases

(b) velocities

(c) phases

(d) frequencies

37. An organ pipe P_1 closed at one vibrating in its first overtone and another pipe P_2 open at both ends vibrating in third overtone are in resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is

(a) 8/3 (d) 3/8

(c) 1/2 (d) 1/3

38. An open pipe is suddenly closed with the result that the second overtone of the closed pipe is observed to be higher in frequency by 100 Hz than the first overtone of the original pipe. The fundamental frequency of the open pipe will be

(a) 100 Hz (b) 300 Hz

(c) 150 Hz (d) 200 Hz

39. In a resonance tube experiment, the first two resonances are observed at length 10.5 cm and 29.5 cm. The third resonance is observed at the length

(a) 47.5 cm (b) 58.5 cm

(c) 48.5 cm (d) 82.8 cm

40. A closed organ pipe had length 'λ'. The air in it is vibrating in 3rd overtone with maximum amplitude 'a'. The amplitude at a distance of λ/7 from closed end of the pipe.

(a) a (b) a/2

(c) $\frac{\sqrt{3}}{2}a$ (d) $\frac{1}{\sqrt{2}}a$

41. An organ pipe of length L is open at one end and closed at other end. The wavelengths of the three lowest resonating frequencies that can be produced by this pipe are

(a) 4L, 2L, L (b) 2L, L, L/2

(c) 2L, L, 2L/3 (d) 4L, 4L/3, 4L/5

42. A string of length 1.5 m with its two ends clamped is vibrating in fundamental mode. Amplitude at the centre of the string is 4 mm. Minimum distance between the two points having amplitude 2 mm is:

(a) 1 m (b) 75 cm

(c) 60 cm (d) 50 cm

43. The second overtone of an open pipe A and a closed pipe B have the same frequencies at a given temperature. Both pipes contain air. The ratio of fundamental frequency of A to the fundamental frequency of B is:

(a) 3 : 5 (b) 5 : 3

(c) 5 : 6 (d) 6 : 5

44. In a stationary wave all the particles

(a) On either side of a node vibrate in same phase

(b) In the region between two nodes vibrate in same phase

(c) In the region between two antinodes vibrate in same phase

(d) Of the medium vibrate in same phase

45. When a stationary wave is formed then its frequency is

(a) Same as that of the individual waves

(b) Twice that of the individual waves

(c) Half that of the individual waves

(d) None of the above

46. At a certain instant a stationary transverse wave is found to have maximum kinetic energy. The appearance of string at that instant is

(a) Sinusoidal shape with amplitude A/3

(b) Sinusoidal shape with amplitude A/2

(c) Sinusoidal shape with amplitude A

(d) Straight line

47. Which two of the given transverse waves will give stationary waves when get superimposed?

(A) $z_1 = a \cos(kx - \omega t)$

(B) $z_2 = a \cos(kx + \omega t)$

(C) $z_3 = a \cos(ky - \omega t)$

(a) A and B (b) A and C

(c) B and C (d) Any two

48. For the stationary wave $y = 4 \sin\left(\frac{\pi x}{15}\right) \cos(96\ \pi t)$, the distance between a node and the next antinode is

(a) 7.5 (b) 15 (c) 22.5 (d) 30

49. A wave represented by the given equation $y = a \cos(kx - \omega t)$ is superposed with another wave to form a stationary wave such that the point x = 0 is a node. The equation for the other wave is

(a) $y = a \sin(kx + \omega t)$ (b) $y = -a \cos(kx + \omega t)$

(c) $y = -\cos(kx - \omega t)$ (d) $y = -a \sin(kx - \omega t)$

50. A standing wave pattern is formed on a string. One of the waves is given by equation $y_1 = a \cos\left(\omega t - kx + \frac{\pi}{3}\right)$ then the equation of the other wave such that at x = 0 a node is formed.

(a) $y_2 = a \sin\left(\omega t + kx + \frac{\pi}{3}\right)$

(b) $y_2 = a \cos\left(\omega t + kx + \frac{\pi}{3}\right)$

(c) $y_2 = a \cos\left(\omega t + kx + \frac{2\pi}{3}\right)$

(d) $y_2 = a \cos\left(\omega t + kx + \frac{4\pi}{3}\right)$

51. Two waves are approaching each other with a velocity of 20 m/s and frequency n. The distance between two consecutive nodes is

(a) $\frac{20}{n}$ (b) $\frac{10}{n}$

(c) $\frac{5}{n}$ (d) $\frac{n}{10}$

52. The equation of a stationary wave is given by y = 6 sin (πx/3) cos 40πt where y and x are given in cm and time t in second, then the amplitude of progressive wave is:
(a) 6 cm (b) 3 cm
(c) 12 cm (d) 2 cm

53. Equation of a standing wave is generally expressed as y = 2A sin ωt cos kx. In the equation, quantity $\frac{\omega}{k}$ represents
(a) the transverse speed of the particles of the string
(b) the speed of either of the component waves
(c) the speed of the standing wave
(d) a quantity that is independent of the properties of the string

54. A string of length of 2m is fixed at both ends. If this string vibrates in its fourth normal mode with a frequency of 500 Hz then the waves would travel on it is with a velocity of
(a) 125 m/s (b) 250 m/s
(c) 500 m/s (d) 10 m/s

55. The first overtone of a stretched string of given length is 320 Hz. The first harmonic is
(a) 320 Hz (b) 640 Hz
(c) 160 Hz (d) 480 Hz

56. A guitar string of length L has a fundamental frequency. Where should it be pressed to produced another fundamental frequency, if the ratio of two fundamental frequencies is f?
(a) $\frac{L}{f}$ (b) fL
(c) $\frac{l}{f^2}$ (d) $\frac{L}{f^{1/2}}$

57. A wire having a linear mass density 5.0×10^3 kg/m is stretched between two rigid supports with a tension of 450 N. The wire resonates at a frequency of 420 Hz. The next higher frequency at which the same wire resonates is 480 Hz. The length of the wire is
(a) 2.0 m (b) 2.1 m
(c) 2.5 m (d) 3 m

58. The equation of a stationary wave is $y = 2 \sin\left(\frac{\pi x}{15}\right) \cos$ (48 πt). The distance between a node and its next antinode is
(a) 22.5 units (b) 7.5 units
(c) 30 units (d) 1.5 units

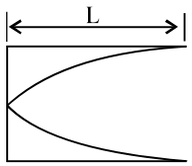
59. First overtone frequency of a closed pipe of length l_1 is equal to the 2nd harmonic frequency of an open pipe of length l_2. The ratio l_1/l_2 =
(a) 3/4 (b) 4/3
(c) 3/2 (d) 2/3

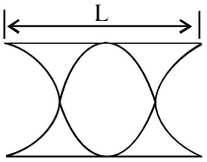
60. The waves set up in a closed pipe are
(a) longitudinal and progressive
(b) longitudinal and stationary
(c) transverse and stationary
(d) transverse and progressive.

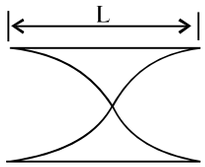
61. A stretched string is vibrating in the second overtone, then the number of nodes and antinodes between the ends of the string are respectively
(a) 3 and 2 (b) 2 and 3
(c) 4 and 3 (d) 3 and 4

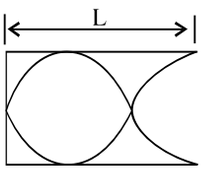
62. A pipe of 30 cm long and open at both the ends produces harmonics. Which harmonic mode of pipe resonates a 1.1 kHz source? Given speed of sound in air = 330 m s^{-1}.
(a) Third harmonic (b) Fifth harmonic
(c) Second harmonic (d) Fourth harmonic

63. The vibrations of four air columns are shown below. The ratio of frequencies is

(1) 

(2) 

(3) 

(4) 

(a) 1 : 2 : 3 : 4 (b) 1 : 3 : 2 : 4
(c) 1 : 4 : 3 : 2 (d) 1 : 4 : 2 : 3

64. A pipe with 30 cm Length is open at both ends, which harmonic mode of the pipe resonates a 1.65 kHz source? (Velocity of sound in air= 330 ms^{-1})
(a) 2 (b) 3
(c) 3.5 (d) 2.5

65. A closed organ pipe (closed at one end) is excited to support the third overtone. It is found that air in the pipe has
(a) three nodes and three antinodes
(b) three nodes and four antinodes
(c) four nodes and three antinodes
(d) four nodes and four antinodes

66. A string 2.0 m long and fixed at its ends is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is:
(a) 180 m/s, 80 Hz
(b) 320 m/s, 80 Hz
(c) 320 m/s, 120 Hz
(d) 180 m/s, 120 Hz

67. If n_1, n_2 and n_3 are the fundamental frequencies of three segments into which a string is divided, then the original fundamental frequency n of the string is given by

(a) $\frac{1}{n}=\frac{1}{n_1}+\frac{1}{n_2}+\frac{1}{n_3}$

(b) $\frac{1}{\sqrt{n}}=\frac{1}{\sqrt{n_1}}+\frac{1}{\sqrt{n_2}}+\frac{1}{\sqrt{n_3}}$

(c) $\sqrt{n}=\sqrt{n_1}+\sqrt{n_2}+\sqrt{n_3}$

(d) $n=n_1+n_2+n_3$

68. Tube *A* has both ends open while tube *B* has one end closed, otherwise they are identical. The ratio of fundamental frequency of tube *A* and *B* is

(a) 1 : 2 (b) 1 : 4

(c) 2 : 1 (d) 4 : 1

69. If the length of a stretched string is shortened by 40% and the tension increased by 44% then the ratio of the final and initial fundamental frequencies is

(a) 3 : 4 (b) 4 : 3

(c) 1 : 3 (d) 2 : 1

70. The number of possible natural oscillation of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are : (velocity of sound = 340 ms^{-1})

(a) 4 (b) 5 (c) 7 (d) 6

71. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is

(a) 100 cm (b) 120 cm

(c) 140 cm (d) 80 cm

72. An organ pipe P_1 closed at one end vibrating in its first overtone and another pipe P_2 open at both ends vibrating in third overtone are in resonance with a given tuning fork. The ratio of the length of P_1 to that of P_2 is

(a) 8/3 (b) 3/8

(c) 1/2 (d) 1/3

73. Length of a sonometer wire between two fixed ends is 110 cm. If the fundamental frequencies are in the ratio of 1 : 2 : 3, then what is the ratio of lengths of these segments of the wire?

(a) 3 : 2 : 1 (b) 6 : 3 : 2

(c) 6 : 2 : 3 (d) 2 : 3 : 6

74. A sonometer wire supports a 4 kg load and vibrates in fundamental mode with a tuning fork of frequency 416 Hz. The length of the wire between the bridges is now doubled. In order to maintain fundamental mode, the load should be changed to

(a) 1 kg (b) 2 kg

(c) 4 kg (d) 16 kg

75. A stretched wire 60 cm long is vibrating with its fundamental frequency of 256 Hz. If the length of the wire is decreased to 15 cm and the tension remains the same. Then the fundamental freuqency of the vibration of the wire will be

(a) 1024 (b) 572 (c) 256 (d) 64

76. The fundamental frequency of an open organ pipe is 300 Hz. The first overtone of this pipe has same frequency as first overtone of a closed organ pipe. If speed of sound is 330 m/s, then the length of closed organ pipe is

(a) 41 cm (b) 37 cm

(c) 31 cm (d) 80 cm

77. Two identical piano wires kept under the same tension T have a fundamental frequency of 600 Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats/s when both the wires oscillate together would be

(a) 0.02 (b) 0.03

(c) 0.04 (d) 0.01

78. A wire of density 8×10^3 kg/m^3 is stretched between two clamps 0.5 m apart. The extension developed in the wire is 3.2×10^{-4} m. If $Y = 8 \times 10^{10}$ N/m^2, the fundamental frequency of vibration in the wire will be

(a) 20 Hz (b) 40 Hz

(c) 80 Hz (d) 160 Hz

79. A string fixed at both ends is vibrating in two segments. The wavelength of the corresponding wave is

(a) $\ell/4$ (b) $\ell/2$

(c) ℓ (d) 2ℓ

80. If vibrations of a string are to be increased by a factor of two, then tension in the string must be made

(a) half (b) twice

(c) four times (d) eight times

81. The fundamental frequency of a closed end organ pipe is n. Its length is doubled and radius is halved. Its frequency will become nearly

(a) n/2 (b) n/3 (c) n (d) 2n

82. The fundamental frequency of an organ pipe is 512 Hz. If its length is increased, then frequency will

(a) decrease (b) increase

(c) remains same (d) cannot be predicted

83. What is the effect of increase in temperature on the frequency of sound produced by an organ pipe?

(a) increases (b) decreases

(c) no effect (d) erratic change

84. Frequencies of sound produced from an organ pipe open at both ends are

(a) only fundamental note

(b) only even harmonics

(c) only odd harmonics

(d) even and odd harmonics

85. The fifth harmonic for vibrations of a stretched string is shown in figure. How many nodes are present here?

(a) 4 (b) 6
(c) 5 (d) 10

86. If two tuning forks A and B are sounded together, they produce 4 beats per second. A is then slightly loaded with wax, they produce 2 beats when sounded again. The frequency of A is 256. The frequency of B will be
(a) 250 (b) 252
(c) 260 (d) 262

87. The frequency of tuning forks A and B are respectively 3% more and 2% less than the frequency of tuning fork C. When A and B are simultaneously excited, 5 beats per second are produced. Then the frequency of the tuning fork 'A' (in Hz) is
(a) 98 (b) 100
(c) 103 (d) 105

88. When beats are produced by two progressive waves of nearly the same frequency, which one of the following is correct?
(a) The particle vibrate simple harmonically, with the frequency equal to the difference in the component frequencies.
(b) The amplitude of vibration at any point changes simple harmonically with a frequency equal to the difference in the frequencies of the two waves.
(c) The frequency of beats depends upon the position, where the observe is.
(d) The frequency of beats changes as the time progresses.

89. Two open organ pipes give 4 beats/s when sounded together in their fundamental mode. If the length of the pipes are 100 cm and 102.5 cm respectively, then the velocity of sound is
(a) 496 m/s (b) 328 m/s
(c) 49600 m/s (d) 32800 m/s

90. Two tuning forks of frequencies n_1 and n_2 produce n beats per second. If n_2 and n are known, n_1 may be given by
(a) $\frac{n_2}{n} + n_2$ (b) $n_2 n$
(c) $n_2 \pm n$ (d) $\frac{n_2}{n} - n_2$

91. If three sources of sound of frequencies $(n - 1)$, n and $(n + 1)$ are vibrated together, the number of beats produced and heard per second respectively are
(a) 4 and 2 (b) 4 and 4 (c) 2 and 2 (d) 2 and 4

92. A tuning fork arrangement (pair) produces 4 beats/sec with one fork of frequency 288 cps. A little wax is placed on the unknown fork and it then produces 2 beats/sec. The frequency of the unknown fork is
(a) 286 cps (b) 292 cps
(c) 294 cps (d) 288 cps

93. The musical interval between two tones of frequencies 320 Hz and 240 Hz is:
(a) 80 (b) (4/3)
(c) 560 (d) 320 × 240

94. When two sound waves are superimposed, beats are produced when they have different
(a) amplitudes and phases
(b) velocities
(c) phases
(d) frequencies

95. Beats are produced by two waves
$Y_1 = a \sin 100 \pi t$ and $y_2 = a \sin 998 \pi t$
The number of beats heard/sec is:
(a) 0 (b) 2
(c) 1 (d) 4

96. Two tones of frequencies n_1 and n_2 are sounded together. The beats can be heard distinctly when
(a) $10 < (n_1 - n_2) < 20$ (b) $5 < (n_1 - n_2) > 20$
(c) $5 < (n_1 - n_2) < 20$ (d) $0 < (n_1 - n_2) < 10$

97. A string 2.0 m long and fixed at its ends is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is
(a) 180 m/s, 80 Hz (b) 320 m/s, 80 Hz
(c) 320 m/s, 120 Hz (d) 180 m/s, 120 Hz

98. An open tube is in resonance with string. If tube is dipped in water, so that 75% of length of tube is inside water, then the ratio of the frequency v_0 of tube to string is
(a) 1 (b) 2
(c) $\frac{2}{3}$ (d) $\frac{3}{2}$

99. The fundamental frequency of a closed organ pipe is same as the first overtone frequency of the open pipe. The length of open pipe is 50 cm. The length of closed pipe is
(a) 25 cm (b) 100 cm
(c) 200 cm (d) 12.5 cm

100. The fundamental frequency of a string stretched with a weight of 4 kg is 256 Hz. The weight required to produce its octave is (Neglect change in linear mass density)
(a) 4 kg-wt (b) 12 kg-wt
(c) 16 kg-wt (d) 24 kg-wt

101. An organ pipe open on both ends in the nth harmonic is in resonance with a source of 1000 Hz. The length of pipe is 16.6 cm and speed of sound in air is 332 m/s, the find the value of n.
(a) 3 (b) 2 (c) 1 (d) 4

102. If the speed of sound in air is 330 m/s, then find the number of tones present in an open organ pipe of length 1 m whose frequency is ≤ 1000 Hz.

(a) 2 (b) 4

(c) 8 (d) 6

103. A stretched string of length ℓ, fixed at both ends can sustain stationary waves of wavelength λ, given by (n = no. of loops)

(a) $\lambda = \frac{n^2}{2\ell}$ (b) $\lambda = \frac{2\ell}{n}$

(c) $\lambda = \ell^2 / 2n$ (d) $\lambda = 2\ell n$

104. The fundamental frequency of an organ pipe is 512Hz. If its length is increased, then frequency will

(a) decrease (b) increase

(c) remains same (d) cannot be predicted

105. The ratio of fundamental frequency of an organ pipe opened at both ends to that of the organ pipe closed at one end is

(a) 1 : 1 (b) 1.5 : 1

(c) 2 : 1 (d) 3 : 1

106. Which of the following statements related to organ pipe is/incorrect ?

(a) In a closed organ pipe closed at one end the maximum possible wavelength is 4 ℓ

(b) In a closed organ pipe only odd harmonics are present.

(c) The harmonics which are present in a pipe, open at both ends are odd harmonics only.

(d) In open organ pipe ratio of overtones 2 : 3 : 4 : 5....

107. Two waves of wavelengths 2 m and 2.02 m respectively, moving with the same velocity and superimpose to produce 2 beats per second. The velocity of the waves is

(a) 400 m/s (b) 402 m/s

(c) 404 m/s (d) 406 m/s

108. A tuning fork P is sounded with another tuning fork Q of frequency 500 Hz and 4 beats is observed. Now P is slightly loaded and 100% increased beat frequency is observed. The original frequency of P is

(a) 504 Hz (b) 508 Hz

(c) 496 Hz (d) 492 Hz

109. Two vibrating tuning forks produce progressive waves given by $y_1 = 4 \sin 500 \pi t$ and $y_2 = 2\sin 506 \pi t$. Number of beats produced per minute is

(a) 360 (b) 180

(c) 3 (d) 60

110. At a point, beats frequency of n Hz is observed. It means:

(a) medium particles, at the point, are vibrating with frequency n Hz

(b) amplitude of vibrations changes simple harmonically with frequency n Hz at the point only

(c) at that, zero intensity 2n times per second

(d) none of the above

111. An unknown frequency x produces 8 beats per seconds with a frequency of 250 Hz and 12 beats with 270 Hz source, then x is

(a) 258 Hz (b) 242 Hz

(c) 262 Hz (d) 282 Hz

112. Two waves of lengths 50 cm and 51 cm produce 12 beats per sec. The velocity of sound is

(a) 306 m/s (b) 331 m/s

(c) 340 m/s (d) 360 m/s

113. For production of beats the two sources must have

(a) different frequencies and same amplitude

(b) different frequencies

(c) different frequencies, same amplitude and same phase

(d) different frequencies and same phase

114. A wave has S.H.M whose period is 4 seconds while another wave which also possess SHM has its period 3 seconds. If both are combined, then the resultant wave will have the period equal to

(a) 4 seconds (b) 5 seconds

(c) 12 seconds (d) 3 seconds

115. Beats are produced by frequencies υ_1 and υ_2 ($\upsilon_1 > \upsilon_2$). The duration of time between two successive minima is

(a) $\frac{1}{\upsilon_1 + \upsilon_2}$ (b) $\frac{2}{\upsilon_1 - \upsilon_2}$

(c) $\frac{2}{\upsilon_1 + \upsilon_2}$ (d) $\frac{1}{\upsilon_1 - \upsilon_2}$

116. A tuning fork 'A' of frequency 250 Hz and another tuning fork 'B' of frequency 'x' produced 5 beats per second when vibrated together. If the fork 'B' is waxed and vibrated together with 'A', then 3 beats per second are produced. Then x =

(a) 255 Hz (b) 245 Hz

(c) 247 Hz (d) 253 Hz

Exercise 2 : ACCELERATOR
Topic-wise MCQs

6.1 Wave and Wave Motion, Progressive Waves, Reflection of Waves & Superposition of Waves

1. The equations of two waves are given by :

$y_1 = 5\sin 2\pi (x - vt)$ cm

$y_2 = 3\sin 2\pi (x - vt + 1.5)$ cm

These waves are simultaneously passing through a string. The amplitude of the resulting wave is

(a) 2 cm (b) 4 cm (c) 5.8 cm (d) 8 cm

2. **Assertion :** Velocity of particles, while crossing mean position in case of stationary waves varies from maximum at antinodes to zero at nodes.

Reason : Amplitude of vibration at antinodes is maximum and at nodes, the amplitude is zero, and all particles between two successive nodes cross the mean position together.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

3. In the wave equation $y = 0.5\sin\frac{2\pi}{\lambda}(400t - x)$ m the velocity of the wave will be :

(a) 200 m/s (b) $200\sqrt{2}$ m/s

(c) 400 m/s (d) $400\sqrt{2}$ m/s

4. If the incident travelling wave is given by y (x, t) = a sin(kx – ωt), the match the Column I (condition) with Column II (equation of displacement).

	Column I		Column II
A.	Reflected wave from rigid boundary	1.	a sin(kx – ωt)
B.	Reflected wave from open boundary	2.	a sin (kx – ωt)
C.	The resultant displacement at the rigid boundary	3.	2a sin (kx – ωt)
D.	The resultant displacement at the open boundary	4.	0

Choose the correct answer from the options given below.

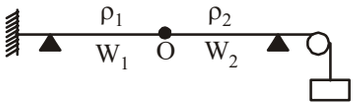
	A	B	C	D		A	B	C	D
(a)	2	1	4	3	(b)	1	2	3	4
(c)	2	1	3	4	(d)	1	2	4	3

5. In a standing wave experiment, a 1.2 kg horizontal rope is fixed in place at its two ends (x = 0 and x = 2.0 m) and made to oscillate up and down in the fundamental mode, at frequency 5.0 Hz. At t = 0, the point at x = 1.0 m has zero displacement and is moving upward in the positive direction of y axis with a transverse velocity 3.14 m/s. Tension in the rope is

(a) 60 N (b) 100 N

(c) 120 N (d) 240 N

6. Two wires W_1 and W_2 have the same radius r and respective densities ρ_1 and ρ_2 such that $\rho_2 = 4\rho_1$. They are joined together at the point O, as shown in the figure. The combination is used as a sonometer wire and kept under tension T. The point O is midway between the two bridges. When a stationary waves is set up in the composite wire, the joint is found to be a node. The ratio of the number of antinodes formed in W_1 to W_2 is :



(a) 1 : 1 (b) 1 : 2

(c) 1 : 3 (d) 4 : 1

7. **Assertion :** In the case of a stationary wave, a person hear a loud sound at the nodes as compared to the antinodes.

Reason : In a stationary wave all the particles of the medium vibrate in phase.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

8. **Assertion :** It is not possible to have interference between the waves produced by two violins.

Reason : For interference of two waves the phase difference between the waves must remain constant.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

9. Three harmonic waves having equal frequency ν and same intensity I_0, have phase angles 0, $\frac{\pi}{4}$ and $-\frac{\pi}{4}$ respectively. When they are superimposed the intensity of the resultant wave is close to:

(a) 5.8 I_0 (b) 0.2 I_0
(c) 3 I_0 (d) I_0

10. The equation of wave is given by

$$Y = 10^{-2} \sin 2\pi\left(160t - 0.5x + \frac{\pi}{4}\right)$$

Where x and Y are in m and t in s. The speed of the wave is

(a) 432 Kmh^{-1} (b) 864 Kmh^{-1}
(c) 1152 Kmh^{-1} (d) 2562 Kmh^{-1}

11. Two waves of intensity ratio 1 : 9 cross each other at a point. The resultant intensities at that point, when (a) Waves are incoherent is I_1 (b) Waves are coherent is I_2 and differ in phase by 60°. If $\frac{I_1}{I_2} = \frac{10}{x}$ then x =

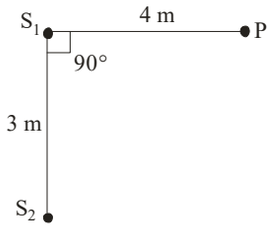
(a) 11 (b) 13
(c) 23 (d) 27

12. Two waves are simultaneously passing through a string and their equations are :

$y_1 = A_1 \sin k(x–vt)$, $y_2 = A_2 \sin k(x–vt + x_0)$. Given amplitudes $A_1 = 12$ mm and $A_2 = 5$ mm, $x_0 = 3.5$ cm and wave number $k = 6.28$ cm^{-1}. The amplitude of resulting wave will be

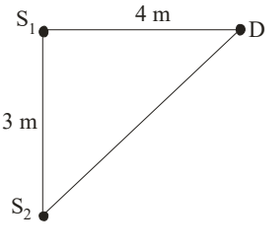
(a) 7 mm (b) 14 mm
(c) 21 mm (d) 28 mm

13. S_1 and S_2 are two coherent sources of sound of frequency 110 Hz each. They have no initial phase difference. The intensity at a point P due to S_1 is I_0 and due to S_2 is $4I_0$. If the velocity of sound is 330 m/s then the resultant intensity at P is



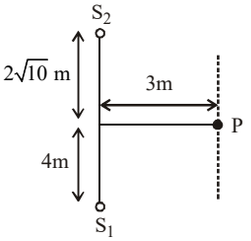
(a) I_0 (b) $9I_0$
(c) $3I_0$ (d) $8I_0$

14. In the figure the intensity of waves arriving at D from two coherent sources S_1 and S_2 is I_0. The wavelength of the wave is λ = 4m. Resultant intensity at D will be:



(a) $4I_0$ (b) I_0
(c) $2I_0$ (d) zero

15. Two sound sources S_2 and S_1 emit pure sinusoidal coherent waves in phase. If the speed of sound is 340 m/s, then find out the frequencies for which constructive interference occurs at P.



(a) 170 Hz (b) 340 Hz
(c) 510 Hz (d) All of these

16. In a large room, a person receives direct sound waves from a source 120 m away from him. He also receives waves from the same source which reach him, being reflected from the 25 m high celling at a point halfway between them. The two waves interfere constructively for wavelength of

(a) 20, $\frac{20}{3}$, $\frac{20}{5}$ etc
(b) 10, 5, 2.5 etc
(c) 10, 20, 30 etc
(d) 15, 25, 35 etc

17. The displacement equations of two interfering waves are given by

$$y_1 = 10\sin\left(\omega t + \frac{\pi}{3}\right)\text{cm}, \quad y_2 = 5\left[\sin(\omega t) + \sqrt{3}\cos\omega t\right]\text{cm}$$

respectively. The amplitude of the resultant wave is

(a) 20 cm (b) 25 cm

(c) 30 cm (d) 35 cm

6.2 Stationary Waves, Beats and Musical Instruments

18. The ratio of frequencies of fundamental harmonic produced by an open pipe to that of closed pipe having the same length is

(a) 1 : 2 (b) 2 : 1

(c) 1 : 3 (d) 3 : 1

19. In a guitar, two strings A and B made of same material are slightly out of tune and produce beats of frequency 6 Hz. When tension in B is slightly decreased, the beat frequency increases to 7 Hz. If the frequency of A is 530 Hz, the original frequency of B will be

(a) 524 Hz (b) 536 Hz

(c) 537 Hz (d) 523 Hz

20. The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20 cm, the length of the open organ pipe is

(a) 13.2 cm (b) 8 cm

(c) 16 cm (d) 12.5 cm

21. The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system?

(a) 20 Hz (b) 30 Hz

(c) 40 Hz (d) 10 Hz

22. **Statement I:** Sound produced by an open organ pipe is richer than the sound produced by a closed organ pipe.

Statement II: Outside air can enter the pipe from both ends, in case of open organ pipe.

(a) Both statement I and II are correct.

(b) Both statement I and II are incorrect.

(c) Statement I is correct but statement II is incorrect.

(d) Statement II is correct but statement I is incorrect.

23. The length of the wire between two ends of a sonometer is 100 cm. What should be the positions of two bridges below the wire so that the three segments of the wire have their fundamental frequencies in the ratio of 1 : 3 : 5?

(a) $\frac{1500}{23}$ cm, $\frac{2000}{23}$ cm (b) $\frac{1500}{23}$ cm, $\frac{500}{23}$ cm

(c) $\frac{1500}{23}$ cm, $\frac{300}{23}$ cm (d) $\frac{300}{23}$ cm, $\frac{1500}{23}$ cm

24. Two open organ pipes of length 60 cm and 90 cm resonate at 6^{th} and 5^{th} harmonics respectively. The difference of frequencies for the given modes is

(Velocity of sound in air = 333 m/s)

(a) 240Hz (b) 360Hz (c) 740Hz (d) 860Hz

25. **Assertion :** Superposition of two harmonic waves, one of frequency 11 Hz and the other of frequency 9 Hz give rise to beats of frequency 2 Hz.

Reason : Harmonic waves of nearly equal frequencies interfere to give rise to beat having beat frequency, $v_{beat} = |v_1 - v_2|$.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

26. Considering the length of the vibrating air column (which is closed at one end) as L, the possible wavelengths of the standing waves as λ, wave velocity as v and the normal nodes or the natural frequencies of the system as v. Match the Column (characteristics) with Column II (respective value).

	Column I		**Column II**
A.	v	1.	$\frac{2L}{\left(n+\frac{1}{2}\right)}$; n = 0, 1, 2, 3...
B.	λ	2.	$\left(n+\frac{1}{2}\right)\frac{v}{2L}$; n = 0,1,2, 3..
C.	v_0 (fundamental mode)	3.	v/4L
D.	Longest wavelength	4.	4L

Choose the correct answer from the options given below.

	A	B	C	D		A	B	C	D
(a)	2	1	3	4	(b)	4	2	3	1
(c)	3	4	2	1	(d)	2	3	1	4

27. A wire of length 2L, is made by joining two wires A and B of same length but different radii r and $2r$ and made of the same material. It is vibrating at a frequency such that the joint of the two wires forms a node. If the number of antinodes in wire A is p and that in B is q then the ratio $p : q$ is :

(a) 3 : 5 (b) 4 : 9

(c) 1 : 2 (d) 1 : 4

28. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between then. The wavelength of the standing wave is

(a) 1.21 Å (b) 2.42 Å (c) 6.05 Å (d) 3.63 Å

29. A string of length 1 m and mass 5 g is fixed at both ends. The tension in the string is 8.0 N. The string is set into vibration using an external vibrator of frequency 100 Hz. The separation between successive nodes on the string is close to:

(a) 10.0 cm (b) 33.3 cm

(c) 16.6 cm (d) 20.0 cm

30. A tuning fork of known frequency 256 Hz makes 5 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per second when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was

(a) (256 + 2) Hz (b) (256 – 2) Hz

(c) (256 – 5) Hz (d) (256 + 5) Hz

31. A tuning fork 'A' of frequency 250 Hz and another tuning fork 'B' of frequency 'x' produced 5 beats per second when vibrated together. If the fork 'B' is waxed and vibrated together with 'A', then 3 beats per second are produced. Then x =

(a) 255 Hz (b) 245 Hz

(c) 247 Hz (d) 253 Hz

32. The frequency of fifth harmonic of a closed pipe is equal to the frequency of third harmonic of an open pipe. If the length of the open pipe is 72 cm. then the length of the closed pipe is

(a) 60 cm (b) 45 cm

(c) 30 cm (d) 75 cm

33. The fundamental frequency of an open pipe is 100 Hz. If the bottom end of the pipe is closed and $\frac{1}{3}$ rd of the pipe is filled with water, then the fundamental frequency of the pipe is

(a) 200 Hz (b) 100 Hz

(c) 75 Hz (d) 150 Hz

34. The tension applied to a metal wire of one metre length produces an elastic strain of 1%. The density of the metal is 8000 kgm^{-3} and Young's modulus of the metal is 2×10^{11} Nm^{-2}. The fundamental frequency of the transverse waves in the metal wire is

(a) 500 Hz (b) 375 Hz

(c) 250 Hz (d) 125 Hz

35. Two closed pipes when sounded simultaneously in their fundamental modes produce 6 beats per second. If the length of the shorter pipe is 150 cm, then the length of the longer pipe is (Speed of sound in air = 336 ms^{-1})

(a) 168 cm (b) 184 cm

(c) 176 cm (d) 192 cm

36. The difference between the fundamental frequencies of an open pipe and a closed pipe of same length is 100 Hz. The difference between the frequencies of the second harmonic of the open pipe and the third harmonic of the closed pipe is

(a) 100 Hz (b) 150 Hz

(c) 200 Hz (d) 250 Hz

37. The speed of a transverse wave in a stretched string '*A*' is '*v*'. Another string '*B*' of same length and same radius is subjected to same tension. If the density of the material of the string '*B*' is 2% more than that of '*A*', then the speed of the transverse wave in string '*B*' is

(a) $\sqrt{1.04}$ v (b) $\sqrt{1.02}$ v

(c) $\frac{v}{\sqrt{1.04}}$ (d) $\frac{v}{\sqrt{1.02}}$

38. Equation of travelling wave on a stretched string of linear density 5 g/m is y = 0.03 sin (450 t – 9x) where distance and time are measured in SI units. The tension in the string is:

(a) 10 N (b) 7.5 N

(c) 12.5 N (d) 5 N

39. A string 2.0 m long and fixed at its ends is driven by a 240 Hz vibrator. The string vibrates in its third harmonic mode. The speed of the wave and its fundamental frequency is:

(a) 180 m/s, 80 Hz (b) 320 m/s, 80 Hz

(c) 320 m/s, 120 Hz (d) 180 m/s, 120 Hz

40. A string is clamped at both the ends and it is vibrating in its 4^{th} harmonic. The equation of the stationary wave is Y = 0.3 sin(0.157x) cos(200ωt). The length of the string is: (All quantities are in SI units.)

(a) 20 m (b) 80 m

(c) 40 m (d) 60 m

41. A closed organ pipe has a fundamental frequency of 1.5 kHz. The number of overtones that can be distinctly heard by a person with this organ pipe will be: (Assume that the highest frequency a person can hear is 20,000 Hz)

(a) 6 (b) 4

(c) 7 (d) 5

42. The velocity of sound in a gas in which two wavelengths 4.08m and 4.16m produce 40 beats in 12s, will be :

(a) 2.828 ms^{-1} (b) 175.5 ms^{-1}

(c) 353.6 ms^{-1} (d) 707.2 ms^{-1}

43. A tuning fork A of unknown frequency produces 5 beats/s with a fork of known frequency 340 Hz. When fork A is filed, the beat frequency decreases to 2 beats/s. What is the frequency of fork A?

(a) 335 Hz (b) 338 Hz

(c) 345 Hz (d) 342 Hz

44. The fundamental frequency of vibration of a string stretched between two rigid support is 50 Hz. The mass of the string is 18 g and its linear mass density is 20 g/m. The speed of the transverse waves so produced in the string is

(a) 18 m/s (b) 36 m/s

(c) 45 m/s (d) 90 m/s

45. For a certain organ pipe, the first three resonance frequencies are in the ratio of 1 : 3 : 5 respectively. If the frequency of fifth harmonic is 405 Hz and the speed of sound in air is 324 ms^{-1} the length of the organ pipe is

(a) 0.5 m (b) 1 m

(c) 4 m (d) 9 m

46. An organ pipe 40cm long is open at both ends. The speed of sound in air is 360ms^{-1}. The frequency of the second harmonic is

(a) 180Hz (b) 360Hz

(c) 450Hz (d) 900Hz

47. A guitar string of length 90 cm vibrates with a fundamental frequency of 120 Hz. The length of the string producing a fundamental frequency of 180 Hz will be

(a) 15 cm (b) 30 cm

(c) 45 cm (d) 60 cm

48. In a closed organ pipe, the frequency of fundamental note is 30 Hz. A certain amount of water is now poured in the organ pipe so that the fundamental frequency is increased to 110 Hz. If the organ pipe has a cross - sectional area of 2 cm^2, the amount of water poured in the organ tube is (Take speed of sound in air is 330 m/s)

(a) 200g (b) 400g

(c) 600g (d) 800g

49. A tuning fork resonated with a sonometer wire of length 1 m stretched with a tension of 6N. When the tension in the wire is changed to 54 N, the same tuning fork produces 12 beats per second with it. The frequency of the tuning fork is

(a) 2Hz (b) 4Hz

(c) 6Hz (d) 8Hz

50. A closed and an open organ pipe have same lengths. If the ratio of frequencies of their seventh overtones is $\left(\frac{a-1}{a}\right)$ then the value of a is

(a) 12 (b) 16

(c) 48 (d) 94

51. A closed organ pipe of length L and an open organ pipe contain gases of densities ρ_1 and ρ_2 respectively. The compressibility of gases are equal in both the pipes. Both the pipes are vibrating in their first overtone with same frequency. The length of the open pipe is $\frac{x}{3}L\sqrt{\frac{\rho_1}{\rho_2}}$ where x is

(a) 4 (b) 8 (c) 16 (d) 32

52. Which of the following statements related to organ pipe is/are correct ?

I. In a closed organ pipe closed at one end longitudinal standing waves are present.

II. In a closed organ pipe only odd harmonics are present.

III. The harmonics which are present in a pipe, open at both ends are odd harmonics only.

IV. The fundamental frequency of an open pipe increases as the temperature is increased.

(a) I and IV (b) II and III

(c) I, II and IV (d) I, II and III

53. A sonometer wire of length 1.5 m is made of steel. The tension in it produces an elastic strain of 1%. What is the fundamental frequency of steel if density and elasticity of steel are 7.7×10^3 kg/m^3 and 2.2×10^{11} N/m^2 respectively ?

(a) 188.5 Hz (b) 178.2 Hz

(c) 200.5 Hz (d) 770 Hz

54. A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. Then, the lowest resonant frequency for this string is

(a) 105 Hz (b) 1.05 Hz

(c) 1050 Hz (d) 10.5 Hz

55. In the sonometer experiment, a tuning fork of frequency 256 Hz is in resonance with 0.4 m length of the wire when the iron load attached to free end of wire is 2 kg. If the load is immersed in water, the length of the wire in resonance would be (specific gravity of iron = 8)

(a) 0.37 m (b) 0.43 m (c) 0.31 m (d) 0.2 m

56. **Statement I:** To hear distinct beats, the difference in frequencies of the sounding bodies should be less than 10 Hz.

Statement II: The persistence of hearing of sound os 01 s, so the ear cannot distinguish between sounds of frequency more than 10 Hz.

(a) Both statement I and II are correct.

(b) Both statement I and II are incorrect.

(c) Statement I is correct but statement II is incorrect.

(d) Statement II is correct but statement I is incorrect.

57. The fundamental frequency of vibration of a string stretched between two rigid support is 50 Hz. The mass of the string is 18 g and its linear mass density is 20 g/m. The speed of the transverse waves so produced in the string is

(a) 45 m/s (b) 90 m/s (c) 135 m/s (d) 180 m/s

58. In an experiment with sonometer when a mass of 180 g is attached to the string, it vibrates with fundamental frequency of 30 Hz. When a mass m is attached, the string vibrates with fundamental frequency of 50 Hz. The value of m is

(a) 250 g (b) 500 g

(c) 750 g (d) 900 g

59. Tuning fork F_1 has a frequency of 256 Hz and it is observed to produce 6 beats/second with another tuning fork F_2. When F_2 is loaded with wax, it still produces 6 beats/second with F_1. The frequency of F_2 before loading was

(a) 253 Hz (b) 262 Hz

(c) 250 Hz (d) 259 Hz

60. Two sitar strings A and B playing the note 'Dha' are slightly out of tune and produce beats of frequency 5 Hz. The tension of the string B is slightly increased and the beat frequency is found to decrease to 3 Hz. The original frequency of B, if the frequency of A is 427 Hz,

(a) 422 Hz (b) 420 Hz

(c) 424 H (d) 419 Hz

61. A source of unknown frequency gives 4 beats/s when sounded with a source of known frequency 250 Hz. The second harmonic of the source of unknown frequency gives 5 beats/s when sounded with a source of frequency 513 Hz. The unknown frequency is

(a) 254 Hz (b) 246 Hz

(c) 240 Hz (d) 260 Hz

62. When two tuning forks (fork 1 and fork 2) are sounded simultaneously, 4 beats/s are heard. Now, some tape is attached on the prong of the fork 2. When the tuning forks are sounded again, 6 beats/s are heard. If frequency of fork 1 is 200 Hz, then what was the original frequency of fork 2?

(a) 200 Hz (b) 202 Hz

(c) 196 Hz (d) 204 Hz

63. When two tuning forks A and B are sounded together, 4 beats per second are heard. The frequency of the fork B is 384 Hz. When one of the prongs of the fork A is filed and sounded with B, the beat frequency increases, then the frequency of the fork A is

(a) 388 Hz (b) 389 Hz

(c) 380 Hz (d) 379 Hz

64. Two stretched strings A and B when vibrated together produce 4 beats per second. If the tension applied to the string A increased, the number of beats produced per second is increased to 7. If the frequency of string B is 480 Hz initially. The frequency of string A is

(a) 473 Hz (b) 476 Hz

(c) 484 Hz (d) 487 Hz

65. The displacement equations of sound waves produced by two sources are given by $y_1 = 5\sin 400\pi t$ and $y_2 = 8\sin 408\pi t$, where 't' is time in seconds. If the waves are produced simultaneously, the number of beats produced per minute is

(a) 4 (b) 8 (c) 120 (d) 240

66. Two tuning forks P and Q when set vibrating, give 4 beats per second. If a prong of the fork P is filled, the beats are reduced to 2/5 what is frequncy of P, if that of Q is 250 Hz?

(a) 246 Hz (b) 250 Hz

(c) 254 Hz (d) 252 Hz

67. The wavelength of two waves are 50 and 51 cm respectively. If the temperature of the room is 20°C then what will be the number of beats produced per second by these waves, when the speed of sound at 0°C is 332 m/s?

(a) 24 (b) 14

(c) 10 (d) none of these

68. A source of sound gives 5 beats per second when sounded with another source of frequency 100 per second. The second harmonic of the source, together with a source of frequency 205 per second gives 5 beats per second. What is the frequency of the source?

(a) 95 Hz (b) 100 Hz (c) 105 Hz (d) 205 Hz

69. A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per sec when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was

(a) 510 Hz (b) 514 Hz (c) 516 Hz (d) 508 Hz

70. A set of 20 tuning forks is arranged in a series of increasing frequencies. If each fork gives 4 beats with respect to the preceding fork and the frequency of the last fork is twice the frequency of the first, then the frequency of last fork is

(a) 36 Hz (b) 72 Hz (c) 108 Hz (d) 152 Hz

Exercise 3 : PREVIOUS YEARS MCQs

1. The speed of a stationary wave represented by the equation $y = 0.7\sin\left(\frac{7\pi}{4}x\right)\cos(350\pi t)$ is (In the given equation x and y are in metre and t is in second) **[2025]**

(a) 100 ms^{-1} (b) 150 ms^{-1}
(c) 160 ms^{-1} (d) 200 ms^{-1}

2. In a closed organ pipe, the number of nodes formed in fifth and ninth harmonics are respectively **[2025]**

(a) 5, 9 (b) 3, 5
(c) 5, 7 (d) 2, 4

3. If two progressive sound waves represented by $y_1 = 3 \sin 250\ \pi t$ and $y_2 = 2 \sin 260\ \pi t$ (where displacement is in metre and time is in second) superimpose, then the time interval between two successive maximum intensities is **[2024]**

(a) 0.1 s (b) 0.4 s
(c) 0.5 s (d) 0.2 s

4. An air column in a tube of length 50 cm, closed at one end is vibrating in its fifth harmonic. The phase difference between a particle at the open end and a particle at 42 cm from the open end is **[2024]**

(a) 90° (b) 180°
(c) 0° (d) 270°

5. If the lengths of the open and closed pipes are in the ratio of 2 : 3, then the ratio of the frequencies of the third harmonic of the open pipe and the fifth harmonic of the closed pipe is: **[2023]**

(a) 3 : 5 (b) 9 : 5
(c) 2 : 3 (d) 4 : 9

6. Two tuning forks of frequencies 320 Hz and 323 Hz are vibrated together. The time interval between a maximum sound and its adjacent minimum sound heard by an observer is **[2022]**

(a) $\frac{1}{6}$s (b) $\frac{1}{3}$s (c) $\frac{1}{12}$s (d) $\frac{1}{9}$s

7. Two sound waves each of intensity I are superimposed. If the phase difference between the waves is $\frac{\pi}{2}$, then the intensity of the resultant wave is **[2021]**

(a) 2 I (b) 3 I (c) 4 I (d) I

8. In an experiment with a closed organ pipe, it is filled with water by $\left(\frac{1}{5}\right)$th of its volume. The frequency of the fundamental note will change by **[2020]**

(a) 25% (b) 20% (c) –20% (d) –25%

9. The amplitude and phase of a wave that is formed by the superposition of two harmonic travelling waves, $y_1(x, t) = 4 \sin (kx - \omega t)$ and $y_2(x, t) = 2 \sin (kx - \omega t + \frac{2\pi}{3})$, are: (Take the angular frequency of initial waves same as ω) **[2019]**

(a) $\left[6, \frac{2\pi}{3}\right]$ (b) $\left[6, \frac{\pi}{3}\right]$ (c) $\left[\sqrt{3}, \frac{\pi}{6}\right]$ (d) $\left[2\sqrt{3}, \frac{\pi}{6}\right]$

10. A closed organ pipe (closed at one end) is excited to support the third overtone. It is found that air in the pipe has **[2018]**

(a) three nodes and three antinodes
(b) three nodes and four antinodes
(c) four nodes and three antinodes
(d) four nodes and four antinodes

11. Fundamental frequency of pipe is 100 Hz and other two frequencies are 300 Hz and 500 Hz then **[2017]**

(a) Pipe is open at both the ends
(b) Pipe is closed at both the ends
(c) One end open and another end is closed
(d) None of the above

12. Two sound waves travel in the same direction in a medium. The amplitude of each wave is A and the phase difference between the two waves is 120º. The resultant amplitude will be **[2016]**

(a) A (b) 2A (c) 3A (d) 4A

13. Two tuning forks have frequencies 450 Hz and 454 Hz respectively. On sounding these forks together, the time interval between successive maximum intensities will be **[2015]**

(a) 1/4 s (b) 1/2 s
(c) 1 s (d) 2 s

14. When two waves of almost equal frequencies f_1 and f_2 reach at a point simultaneously, the time interval between successive maxima is **[2014]**

(a) $f_1 + f_2$ (b) $f_1 - f_2$ (c) $\frac{1}{f_1 + f_2}$ (d) $\frac{1}{f_1 - f_2}$

15. A standing wave is represented by y = Asin (100t) cos (0.01x), where y and A are in millimetre, t in seconds and x is in metre. Velocity of wave is **[2013]**

(a) 10^4 m/s
(b) 1 m/s
(c) 10^{-4} m/s
(d) Not derivable from above data

16. In stationary waves **[2012]**

(a) Energy is uniformly distributed

(b) Energy is minimum at nodes and maximum at antinodes

(c) Energy is maximum at nodes and minimum at antinodes

(d) Alternating maximum and minimum energy producing at nodes and antinodes

17. A small speaker delivers 2 W of audio output. At what distance from the speaker will one detect 120 dB intensity sound ? **[2011]**

[Given reference intensity of sound as $10^{-12}W/m^2$]

(a) 40 cm (b) 20 cm (c) 10 cm (d) 30 cm

18. The velocity of waves in a string fixed at both ends is 2 *m/s*. The string form standing waves with nodes 5.0 cm apart. The frequency of vibration of the string in *Hz* is **[2010]**

(a) 40 (b) 30 (c) 20 (d) 10

19. Two periodic waves of intensities I_1 and I_2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is **[2009]**

(a) $(\sqrt{I_1}-\sqrt{I_2})^2$ (b) $2(I_1+I_2)$

(c) I_1+I_2 (d) $(\sqrt{I_1}+\sqrt{I_2})^2$

20. The fundamental frequencies of an open and a closed tube, each of same length L with v as the speed of sound in air, respectively are **[2008]**

(a) $\frac{v}{2L}$ and $\frac{v}{L}$ (b) $\frac{v}{L}$ and $\frac{v}{2L}$

(c) $\frac{v}{2L}$ and $\frac{v}{4L}$ (d) $\frac{v}{4L}$ and $\frac{v}{2L}$

21. If the velocity of sound in air is 350 m/s. The fundamental frequency of an open organ pipe of length 50 *cm*, will be **[2007]**

(a) 350 *Hz* (b) 175 *Hz* (c) 300 *Hz* (d) 750 *Hz*

22. Find the fundamental frequency of a closed pipe, if the length of then air column is 42 *m*. (speed of sound in air = 332 *m*/sec) **[2006]**

(a) 2 *Hz* (b) 4 *Hz* (c) 7 *Hz* (d) 9 *Hz*

23. Air is blown at the mouth of an open tube of length 25 *cm* and diameter 2*cm*, If the velocity of sound in air is 330 ms^{-1}, then emitted frequencies are (in *Hz*) **[2005]**

(a) 660, 1320, 2640 (b) 660, 1000, 3300

(c) 302, 664, 1320 (d) 330, 990, 1990

24. In open organ pipe, if fundamental frequency is *n* then the other frequencies are **[2005]**

(a) $n, 2n, 3n, 4n$ (b) $n, 3n, 5n$

(c) $n, 2n, 4n, 8n$ (d) None of these

25. In one metre long open pipe what is the harmonic of resonance obtained with a funing fork of frequency 480 *Hz* **[2005]**

(a) First (b) Second

(c) Third (d) Fourth

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(b)	**13**	(b)	**25**	(a)	**37**	(b)	**49**	(b)	**61**	(c)	**73**	(b)	**85**	(a)	**97**	(b)	**109**	(b)
2	(b)	**14**	(d)	**26**	(b)	**38**	(d)	**50**	(d)	**62**	(c)	**74**	(d)	**86**	(b)	**98**	(b)	**110**	(d)
3	(a)	**15**	(b)	**27**	(d)	**39**	(c)	**51**	(b)	**63**	(d)	**75**	(a)	**87**	(c)	**99**	(d)	**111**	(a)
4	(d)	**16**	(d)	**28**	(a)	**40**	(a)	**52**	(b)	**64**	(b)	**76**	(a)	**88**	(b)	**100**	(c)	**112**	(a)
5	(c)	**17**	(b)	**29**	(d)	**41**	(d)	**53**	(b)	**65**	(d)	**77**	(a)	**89**	(d)	**101**	(c)	**113**	(b)
6	(d)	**18**	(d)	**30**	(a)	**42**	(a)	**54**	(c)	**66**	(b)	**78**	(c)	**90**	(c)	**102**	(d)	**114**	(c)
7	(c)	**19**	(c)	**31**	(a)	**43**	(b)	**55**	(c)	**67**	(a)	**79**	(c)	**91**	(a)	**103**	(b)	**115**	(d)
8	(a)	**20**	(a)	**32**	(d)	**44**	(b)	**56**	(b)	**68**	(c)	**80**	(b)	**92**	(b)	**104**	(a)	**116**	(b)
9	(d)	**21**	(b)	**33**	(c)	**45**	(a)	**57**	(b)	**69**	(d)	**81**	(a)	**93**	(d)	**105**	(c)		
10	(b)	**22**	(b)	**34**	(b)	**46**	(d)	**58**	(b)	**70**	(d)	**82**	(a)	**94**	(d)	**106**	(c)		
11	(c)	**23**	(d)	**35**	(a)	**47**	(a)	**59**	(a)	**71**	(b)	**83**	(a)	**95**	(c)	**107**	(c)		
12	(d)	**24**	(c)	**36**	(d)	**48**	(a)	**60**	(b)	**72**	(b)	**84**	(d)	**96**	(d)	**108**	(c)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(a)	**8**	(a)	**15**	(a)	**22**	(a)	**29**	(d)	**36**	(a)	**43**	(a)	**50**	(b)	**57**	(b)	**64**	(c)
2	(a)	**9**	(a)	**16**	(a)	**23**	(a)	**30**	(c)	**37**	(d)	**44**	(d)	**51**	(a)	**58**	(b)	**65**	(d)
3	(c)	**10**	(c)	**17**	(a)	**24**	(c)	**31**	(b)	**38**	(c)	**45**	(b)	**52**	(c)	**59**	(d)	**66**	(a)
4	(a)	**11**	(b)	**18**	(b)	**25**	(a)	**32**	(a)	**39**	(b)	**46**	(d)	**53**	(b)	**60**	(a)	**67**	(b)
5	(d)	**12**	(a)	**19**	(a)	**26**	(a)	**33**	(c)	**40**	(b)	**47**	(d)	**54**	(a)	**61**	(a)	**68**	(c)
6	(b)	**13**	(c)	**20**	(a)	**27**	(c)	**34**	(c)	**41**	(a)	**48**	(b)	**55**	(a)	**62**	(c)	**69**	(d)
7	(c)	**14**	(c)	**21**	(a)	**28**	(a)	**35**	(a)	**42**	(d)	**49**	(c)	**56**	(a)	**63**	(a)	**70**	(d)
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(d)	**4**	(c)	**7**	(a)	**10**	(d)	**13**	(a)	**16**	(b)	**19**	(b)	**22**	(a)	**25**	(c)		
2	(b)	**5**	(b)	**8**	(a)	**11**	(c)	**14**	(d)	**17**	(a)	**20**	(c)	**23**	(a)				
3	(d)	**6**	(a)	**9**	(d)	**12**	(a)	**15**	(a)	**18**	(c)	**21**	(a)	**24**	(a)				

7 Wave Optics

TOPIC 7.1 : NATURE OF LIGHT, HUYGEN'S PRINCIPLE, POLARISATION

NATURE OF LIGHT

Newton's Corpuscular Theory

(1) Light consists of extremely small, very light weighed material particles called corpuscles.

(2) The corpuscles travel with the velocity of light.

(3) When the corpuscles strike out retina, they produce the sensation of vision.

(4) This theory explains the phenomenon of reflection, rectilinear propagation of light etc.

This theory fails to explain the following :

(1) According to this theory, velocity of light is more in denser medium rather than rarer medium, which is wrong.

(2) It fails to explain the phenomenon of interference, diffraction, and polarisation of light.

(3) Corpuscles of different colours are of different sizes.

(4) In one medium, corpuscles of one colour travel with uniform velocity and when it enters in another medium it travels with different uniform velocity.

Wave model of light

- In 1678, the wave model of light was proposed by Dutch physicist, Christian Huygens. It predicted that on refraction if the wave bends towards the normal, then the speed of light would be less in the second medium. This is in contradiction to the prediction made by using the corpuscular model of light.
- Maxwell propounded that light must be an electromagnetic wave. According to Maxwell, electromagnetic waves are coupled time-varying electric and magnetic fields that propagates in space.

Dual nature of light : At present we assume that light has dual nature. It behaves like waves in phenomena like interference and diffraction. While in photoelectric effect, it behaves like a particle.

HUYGEN'S PRINCIPLE

Wavefront

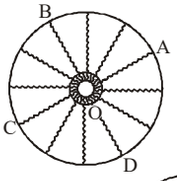
The locus of all particles vibrating in the same phase is called wavefront.

(i) Each point of wavefront is considered as source of secondary wavelets.

(ii) The ray of light is considered in the outward direction normal to the wavefront.

Types of Wavefront

(i) Spherical wavefront is due to Point light source.



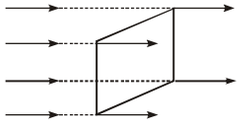
(ii) Cylindrical wavefront is due to Linear light source.

(iii) Plane wavefront :

(a) Light source is at large distance.

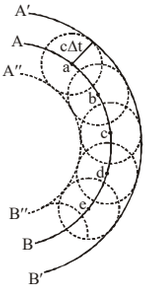
(b) Effective distance should be at infinite.

(c) Intensity and amplitude does not depend on distance.

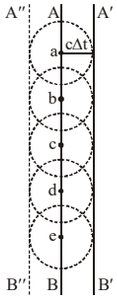


Huygen's Principle

Huygens proposed the wave theory of light. Light travels in the form of wavefront in the medium. According to this principle, energy is emitted in the form of waves from light source. It need medium for propagation of light, that is why a universal hypothetical medium called ether is proposed.



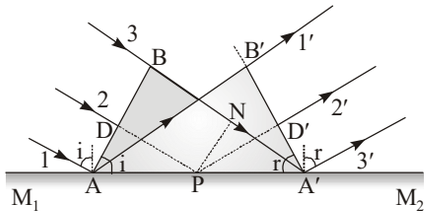
(a)



(b)

Reflection of Light at a Plane Surface

According to Huygen's principle, every point on AB is a source of secondary wavelets.

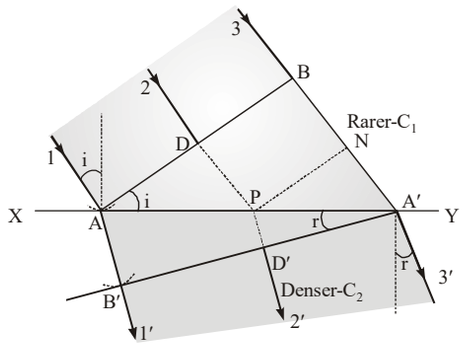


$\angle BAA' = \angle B'A'A$, *i.e.*, $\angle i = \angle r$

Which is the ***first law of reflection***.

Incident ray, normal to the mirror M_1M_2 and reflected ray all lie in the plane of the paper. This is ***second law of reflection***.

Refraction of Light at a Plane Boundary between Two Media



In $\Delta AA'B$, $\sin i = \dfrac{BA'}{AA'} = \dfrac{c_1 \times t}{AA'}$

In $\Delta AA'B'$, $\sin r = \dfrac{AB'}{AA'} = \dfrac{c_2 \times t}{AA'}$

Hence, $\mu = \dfrac{\sin i}{\sin r}$

which proves *Snell's law of refraction*.

It is clear from fig. that the incident rays, normal to the interface XY and refracted rays, all lie in the same plane (i.e., in the plane of the paper). This is the second law of refraction.

- If λ_0 is the wavelength of light in vacuum and n is the refractive index of another medium then, $\lambda = \dfrac{\lambda_0}{n}$
- Frequency of light remains unchanged while going from one medium to another.

POLARISATION

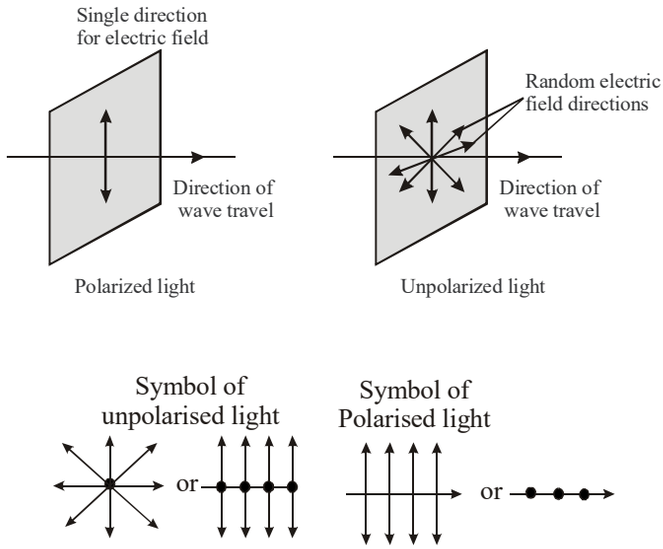
The phenomenon of polarisation has helped to establish beyond doubt that light waves are transverse waves.

Unpolarised Light

The resultant electromagnetic wave is a superposition of waves produced by the individual atomic source and it is called **unpolarised light**. In ordinary or unpolarised light, the vibrations of the electric vector occur symmetrically in all possible directions in a plane perpendicular to the direction of propagation of light.

Polarisation of Light

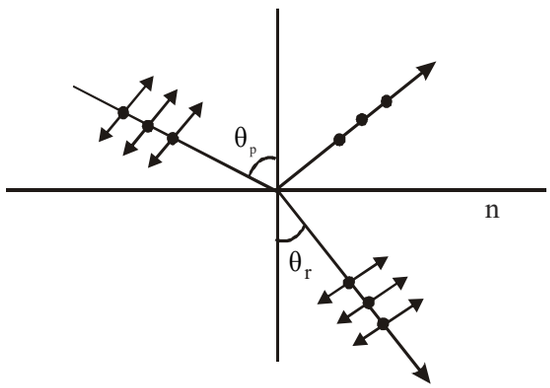
The phenomenon of restricting the vibration of light (electric vector) in a particular direction perpendicular to the direction of propagation of wave is called polarisation of light.



Brewster's Law

When unpolarised light strikes at polarising angle θ_p on an interface, separating a rarer medium from a denser medium of refractive index μ, such that

$$\mu = \tan \theta_p$$



This relation $\mu = \tan \theta_p$ is known as **Brewster's law**.

Law of Malus

When a completely plane polarised light beam is incident on an analyser, then intensity of emergent light varies as the square of cosine of the angle between the planes of transmission of the analyser and the polarizer.

$I \propto \cos^2\theta \Rightarrow I = I_0 \cos^2\theta$

Polarisation by Scattering : When sunlight strikes air molecules or dust particles in the atmosphere, it changes its direction. This is called scattering. The scattered sunlight is partially polarised. The scattered light reaching as from different direction is polarised to different degrees.

TOPIC 7.2 : INTERFERENCE OF LIGHT, YOUNG'S DOUBLE SLIT EXPERIMENT

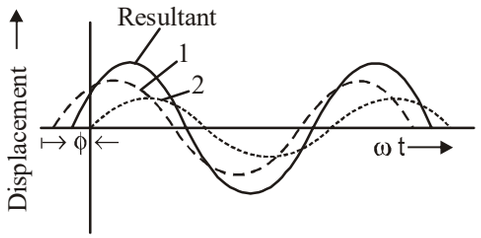
INTERFERENCE OF LIGHT

The phenomenon of redistribution of light energy in a medium on account of superposition of light waves from two coherent sources is called interference.

Let a_1 and a_2 be the amplitudes of the waves at that point be y_1 and y_2 then,

$y_1 = a_1 \sin \omega t$ .... (i)

and $y_2 = a \sin(\omega t + \phi)$ .... (ii)



Resultant Amplitude (R)

$R^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$

resultant intensity I is given by

$I \propto (a_1^2 + a_2^2 + 2a_1a_2 \cos\phi)$ and

$$\text{phase angle } \phi = \tan^{-1}\frac{a_2 \sin\phi}{a_1 + a_2\cos\phi}$$

Thus the resultant intensity at any point depends upon the phase difference ϕ between the two waves at that point.

Comment : If phase difference ϕ is equivalent to path difference x or Δt time difference, then

$$\frac{\phi}{2\pi} = \frac{x}{\lambda} = \frac{\Delta t}{T}$$

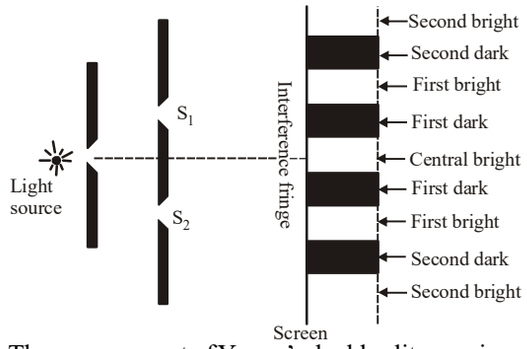
Types of Interference

(i) Constructive interference (ii) Destructive interference

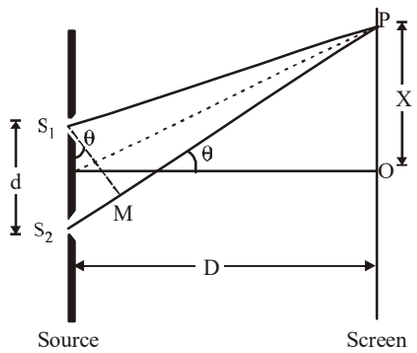
Comparative Study of Constructive and Destructive Interference

S.No.	Constructive interference $\{I > (I_1 + I_2)\}$	Destructive interference $\{I < (I_1 + I_2)\}$
1.	The phase difference between two waves is an even multiple of π. i.e., $\delta = 2n\pi$ *where* $n = 0, 1, 2, ...$	The phase difference between two waves is an odd multiple of π. i.e., $\delta = (2n-1)\pi$ *where* $n = 0, 1, 2, ...$
2.	The path difference between two waves is an even multiple of $\lambda/2$. $\Delta x = 2n(\lambda/2)$ *where* $n = 0, 1, 2, ...$	The path difference between two waves is an odd multiple of $\lambda/2$. $\Delta x = (2n-1)\lambda/2$, *where* $n = 1, 2, ...$
3.	The time interval between two waves is an even multiple of T/2 $\Delta t = (2n)T/2$, $n = 0, 1, 2$	The time interval between two waves is an odd multiple of T/2 $\Delta t = (2n-1)T/2$, $n = 1, 2, 3$
4.	The resultant amplitude of wave is equal to the sum of amplitudes of individual waves $A = a_1 + a_2$ *If* $\phi = 0, 2\pi, 4\pi, ... 2n\pi$	The resultant amplitude of wave is equal to the difference of amplitudes of two waves $A = a_1 - a_2$ *If* $\phi = \pi, 3\pi, 5\pi, ... (2n-1)\pi$
5.	The resultant intensity is more than the sum of intensities of individual waves. $I = I_1 + I_2 + 2\sqrt{I_1I_2} \Rightarrow (\sqrt{I_1} + \sqrt{I_2})^2$	The resultant intensity is less than the sum of intensities of individual waves. $I = I_1 + I_2 - 2\sqrt{I_1I_2} \Rightarrow (\sqrt{I_1} - \sqrt{I_2})^2$

YOUNG'S DOUBLE SLIT EXPERIMENT



The arrangement of Young's double slit experiment.



Bright fringes:

Distance between central fringe and n^{th} bright fringe :

$$X_n = \frac{n\lambda D}{d}$$

Dark fringes :

Distance between central fringe and n^{th} dark fringe.

$$X_n = \frac{(2n-1)\lambda D}{2d}$$

In interference, fringe width of dark and bright fringes are same $\beta = \frac{\lambda D}{d}$

Angular width of fringe :

$$\alpha = \beta/D = \frac{\lambda}{d}$$

Conditions for Sustained Interference Pattern

- The source of light must be monochromatic.
- Two sources of light must be coherent.
- Frequencies of two waves must be same.
- The amplitudes of two waves must be nearly equal.
- The distance between two light sources must be small or narrow.
- The two coherent sources must be narrow.
- If the two light waves are polarized then their state of polarizations must be same.
- The two light waves must travel in the same direction.
- The vibrations of two waves must be in the same direction.
- The distance between the source and the screen must be large.

Lloyd's mirror : The light from a source is made to fall at a grazing angle on a plane mirror. Some light falls directly on the screen, some light falls on the mirror and the light reflected from the mirror falls on the screen. The reflected light appears to come from virtual source and thus we get two coherent sources.

Fresnel biprism : In Fresnel's biprism, two coherent sources (s_1 and s_2) are obtained from the same source by reflection.

Optical path = n × (distance travelled in the medium)

Here, n = refractive index

TOPIC 7.3 : DIFFRACTION OF LIGHT, RAYLEIGH'S CRITERION OF RESOLUTION, RESOLVING POWER (R.P.) OF AN OPTICAL INSTRUMENT

DIFFRACTON OF LIGHT

The phenomenon of bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacle or aperture is defined as diffraction of light.

Types of Diffraction

Fresnel diffraction : Fresnel diffraction which involves non-plane (spherical) wavefronts, so that the source and the point p (where diffraction effect is to be observed) are to be at a finite distance from the diffracting obstacle.

Fraunhofer diffraction : Fraunhofer diffraction deals with wavefronts that are plane on arrival and source and screen are at infinite distances from diffracting system.

For diffraction maxima :

$$a \sin\theta = (2n+1)\lambda/2$$

For diffraction minima :

$$a \sin\theta = n\lambda$$

Linear width of the central maximum

$$W = \frac{2f\lambda}{a}$$

f = focal length of convex lens

a = width of slit

Angular width $= \frac{2\lambda}{a}$

Difference between Interference and Diffraction

	Interference	Diffraction
1.	Two coherent sources are necessary	One coherent source is necessary
2.	All fringes have same width	Fringes have unequal width
3.	Width of bright fringes is equal to other fringes	Width of first bright fringe is just doubled to second bright fringe
4.	All bright fringes have equal intensity	As order of bright fringes increases, intensity goes down
5.	For bright fringe :	For bright fringe :
	(a) Path difference $D = n\lambda$	$D = (2n-1)\lambda/2$
	(b) Phase difference $\delta = 2n\pi$	$\delta = (2n-1)\pi$
6.	For dark fringe :	For dark fringe :
	(a) Path difference $D = (2n-1)\lambda/2$	$D = 2n\lambda/2$
	(b) Phase difference $\delta = (2n-1)\pi$	$\delta = 2n\pi$

RAYLEIGH'S CRITERION OF RESOLUTION

According to Rayleigh, two images of two objects are said to be just resolved when central maxima of one diffraction pattern falls on first minima of other.

RESOLVING POWER (R.P.) OF AN OPTICAL INSTRUMENT

Resolving power (R.P.) of an optical instrument is its ability to distinguish two neighbouring points.

R.P. of Telescope :

Limit of resolution, $\theta = \sin^{-1}\dfrac{1.22\lambda}{a}$;

where a = aperture of objective.

For small angle, $\theta = \dfrac{1.22\lambda}{a}$

$$\textit{Resolving power} = \frac{1}{\textit{limit of resolution}} = \frac{a}{1.22\lambda}$$

R.P. of Microscope :

Limit of resolution (the smallest distance between two objects)

$$x_{min} = \frac{\lambda}{2\mu\sin\theta}$$

$$R.P. = \frac{2\mu\sin\theta}{\lambda}$$

CHAPTER AT A GLANCE

- Wavefront : The locus of all particles in a medium, vibrating in the same phase is called wavefront.
  - (i) When the light source is point source then the wavefront is spherical.
  - (ii) When the light source is linear source then the wavefront is cylindrical.
  - (iii) When the light source is at large distance then the wavefront appears to be plane.
- Polarization : Symmetry to asymmetry of vibrations of optic vector is called polarisation.

  When natural light falls on polariser, its intensity become half the incident.
- Malus law : $I = I_0 \cos^2\theta$
- Brewster's law : $\mu = \tan i_p$ where i_p = polarising angle.
- Interference: When two or more coherent waves travels in same direction, nearly in a line, they superpose and give interference.

  For two waves of amplitudes a_1 and a_2

  $A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\varphi$

  or $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\varphi$ and $\tan\theta = \dfrac{a_2\sin\varphi}{a_1 + a_2\cos\varphi}$

  (i) **Constructive interference :**

  $A_{max} = a_1 + a_2$ for $\varphi = 2n\pi$, n = 0, 1, 2, ...

  or $\Delta x = n\lambda$

  (ii) **Destructive interference :**

  $A_{min} = a_1 - a_2$ for $\varphi = (2n-1)\pi$, n = 0, 1, 2, ...

  or $x = (2n-1)\lambda/2$
- Young's double slits experiment :

  (i) For constructive interference

  $$y_n = n\frac{D\lambda}{d}$$

$$\beta = \frac{D\lambda}{d}$$

Angular fringe width: $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$.

(ii) For destructive interference

$$y_n = \frac{(2n-1)}{2}\frac{D\lambda}{d}$$

$$\beta = \frac{D\lambda}{d}.$$

- Diffraction of light : The phenomena of bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacle or aperture and their encroachment in the geometrical shadow of obstacle or aperture is defined as diffraction of light.
- Fraunhoffer diffraction at single slit : Diffraction occurs due to super position between the wavelets originated from same wave front. For diffraction, size of aperture is order of wavelength of wave.

$a \sin\theta = \lambda$, for first order minima

Width of principal maxima $= 2\theta = 2\sin^{-1}(\lambda/a)$

- Resolving Power : Resolving power of an optical instrument is its ability to distinguish two neighbouring points.

Linear R.P. $= \frac{d}{\lambda D}$ Angular R.P. $= \frac{d}{\lambda}$

D = observed distance and d = distance between two points

- R.P of Telescope:

Limit of resolution, $\theta = \sin^{-1}\frac{1.22\lambda}{a}$

where a = aperature of objective

For small angle, $\theta = \frac{1.22\lambda}{a}$

Resolving power $= \frac{1}{\text{limit of resolution}} = \frac{a}{1.22\lambda}$

- R.P. of Microscope:

Limit of resolution, $x_{min} = \frac{\lambda}{2\mu\sin\theta}$

R.P. $= \frac{2\mu\sin\theta}{\lambda}$

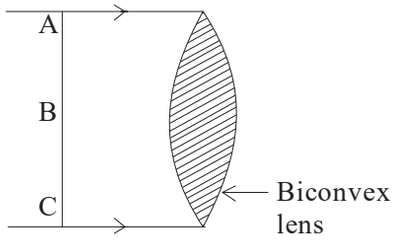
Exercise 1 : WARM-UP
Topic-wise MCQs

7.1 Nature of Light, Huygen's Principle, Polarisation

1. When light propagates through a given homogeneous medium, the velocities of
(a) primary wavefronts are lesser than those of secondary wavelets.
(b) primary wavefronts are greater than or equal to those of secondary wavelets.
(c) primary wavefront and wavelets are equal.
(d) primary wavefront are larger than those of secondary wavelets.

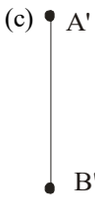
2. Position of secondary wavefront at later time t can be obtained by drawing
(a) a sphere of diameter of 2vt at each point of primary wavefront.
(b) a sphere of diameter 2t at each point of primary wavefront.
(c) a circle of diameter vt at each point of primary wavefront.
(d) a plane at a distance vt from the primary wavefront.

3. If ABC is incident wavefront in the figure shown below, then refracted wavefront is



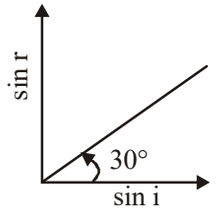
(a)

(b)

(c) 

(d)

4. A transparent medium shows relation between i and r as shown. If the speed of light in vacuum is c, the Brewster's angle for the medium is



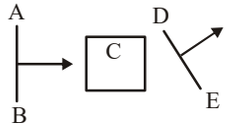
(a) 60° (b) 30°
(c) 90° (d) 45°

5. A polaroid is placed at 45° to an incoming light of intensity I. Now the intensity of light after polarisation would be
(a) I (b) I/2
(c) $I/\sqrt{2}$ (d) zero

6. Unpolarised light is incident on a dielectric of refractive index $\sqrt{3}$. What is the angle of incidence if the reflected beam is completely polarised?
(a) 30° (b) 45°
(c) 60° (d) 75°

7. Which of the following is correct for light diverging from a point source?
(a) The intensity decreases in proportion for the distance squared.
(b) The wavefront is parabolic.
(c) The intensity at the wavelength does depend of the distance.
(d) None of these.

8. A wavefront AB passing through a system C emerges as DE. The system C could be



(a) a slit
(b) a biprism
(c) a prism
(d) a glass slab

9. On a hot summer night, the refractive index of air is smallest near the ground and increases with height from the ground. When a light beam is directed horizontally, the Huygens' principle leads us to conclude that as it travels, the light beam :

(a) bends downwards

(b) bends upwards

(c) becomes narrower

(d) goes horizontally without any deflection

10. When light suffers reflection at the interface between water and glass, the change of phase in the reflected wave is

(a) zero (b) π

(c) $\pi/2$ (d) 2π

11. At which angle, the intensity of transmitted light is maximum when a polaroid sheet is rotated between two crossed polaroids?

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$

(c) $\frac{\pi}{3}$ (d) π

12. The refractive index of a medium is 1. If the unpolarised light is incident on it at the polarising angle of the medium, the angle of refraction is

(a) 60° (b) 45°

(c) 30° (d) 0°

13. When unpolarised light beam is incident from air onto glass (n = 1.5) at the polarising angle

(a) Reflected beam is polarised 100 percent

(b) Reflected and refracted beams are partially polarised

(c) The reason for (a) is that almost all the light is reflected

(d) All of the above

14. In a system of two crossed polarisers, it is found that the intensity of light from the second polariser is half from that of first polariser. The angle between their pass axes is

(a) 30° (b) 0°

(c) 45° (d) 60°

15. The angle of polarisation for a medium with respect to air is 60°. The critical angle of this medium with respect to air is

(a) $\sin^{-1}\sqrt{3}$ (b) $\tan^{-1}\sqrt{3}$

(c) $\cos^{-1}\sqrt{3}$ (d) $\sin^{-1}\frac{1}{\sqrt{3}}$

16. The Brewster angle for air to glass transition of light is (Refractive index of glass = 1.5)

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

(c) $\tan^{-1}\left(\frac{3}{2}\right)$ (d) $\cos^{-1}\left(\frac{2}{3}\right)$

17. When unpolarized light is incident at an angle of 60° on a transparent medium from air. The reflected ray is completely polarized. The angle of refraction in the medium is

(a) 30° (b) 60°

(c) 90° (d) 45°

18. When a polaroid sheet is rotated between two crossed polaroids then the transmitted light intensity will be maximum for a rotation of :

(a) 60° (b) 30°

(c) 90° (d) 45°

19. In the propagation of light waves, the angle between the plane of vibration and plane of polarisaiton is

(a) 0° (b) 90°

(c) 45° (d) 80°

20. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refractive index n), is

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

(c) $\sin^{-1}(n)$ (d) $\tan^{-1}(n)$

21. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is

(a) $\frac{1}{4}I_0$ (b) $\frac{1}{2}I_0$

(c) I_0 (d) zero

22. An unpolarised beam of intensity $2a^2$ passes through a thin polaroid. Assuming zero absorption in the polaroid, the intensity of emergent plane polarised light will be

(a) $2a^2$ (b) a^2

(c) $\sqrt{2}\,a^2$ (d) $\frac{a^2}{\sqrt{2}}$

23. When the angle of incidence is 60° on the surface of a glass slab, it is found that the reflected ray is completely polarised. The velocity of light in glass is

(a) $\sqrt{2}\times10^{8}\,ms^{-1}$

(b) $\sqrt{3}\times10^{8}\,ms^{-1}$

(c) $2\times10^{8}\,ms^{-1}$

(d) $3\times10^{8}\,ms^{-1}$

24. By Huygen's wave theory of light, we cannot explain the phenomenon of

(a) interference

(b) diffraction

(c) photoelectric effect

(d) polarisation

25. Light waves travel in vacuum along the y-axis. Which of the following may represent the wave-front?

(a) x = constant

(b) y = constant

(c) z = constant

(d) x + y + z = constant

26. In Huygens's wave theory, the locus of all points in the same state of vibration is called

(a) a half period zone

(b) oscillator

(c) a wave-front

(d) a ray

27. If the light is polarised by reflection, then the angle between reflected and refracted light is

(a) 180° (b) 90°

(c) 45° (d) 36°

28. A polaroid is placed at 45° to an incoming light of intensity I. Now the intensity of light after polarisation would be

(a) I (b) I/2

(c) $I/\sqrt{2}$ (d) zero

29. Unpolarised light is incident on a dielectric of refractive index $\sqrt{3}$. What is the angle of incidence if the reflected beam is completely polarised?

(a) 30° (b) 45°

(c) 60° (d) 75°

30. The angle of polarisation for any medium is 60°. The critical angle for this is

(a) $\sin^{-1}\frac{1}{\sqrt{3}}$ (b) $\cos^{-1}\sqrt{3}$

(c) $\sin^{-1}\sqrt{3}$ (d) $\tan^{-1}\sqrt{3}$

31. Light is incident on a glass surface at polarising angle of 57.5°. Then the angle between the incident ray and the refracted ray is

(a) 57.5°

(b) 115°

(c) 65°

(d) 205°

7.2 Interference of Light, Young's Double Slit Experiment

32. In Young's double slit experiment, when two light waves form third minimum, they have

(a) Phase difference of 3π

(b) Phase difference of $5\pi/2$

(c) Path difference of 3λ

(d) Path difference of $5\lambda/2$

33. In the Young's double slit experiment, if the phase difference between the two waves interfering at a point is ϕ, the intensity at that point can be expressed by the expression

(a) $I=\sqrt{A^2+B^2\cos^2\phi}$

(b) $I=\frac{A}{B}\cos\phi$

(c) $I=A+B\cos\frac{\phi}{2}$

(d) $I = A + B\cos\phi$

34. The ratio of the intensity at the centre of a bright fringe to the intensity at a point one - quarter of the distance between two fringe from the centre is

(a) 2

(b) 1/2

(c) 4

(d) 16

35. In Young's double slit experiment, intensity of light at a point on the screen where the path difference becomes λ is I. The intensity at a point on the screen where the path difference becomes $\frac{\lambda}{3}$ is,

(a) $\frac{I}{4}$ (b) $\frac{I}{3}$

(c) $\frac{2I}{3}$ (d) 3I

36. The ratio of intensities at two points P and Q on a screen in young's double slit experiment when waves from sources S_1 and S_2 have phase difference of (a) 0° and (b) $\pi/2$ respectively, is

(a) 1 : 4 (b) 4 : 1

(c) 1 : 2 (d) 2 : 1

37. In YDSE, how many maximas can be obtained on a screen including central maxima in both sides of the central fringe if $\lambda = 3000Å$, $d = 5000Å$

(a) 2 (b) 5

(c) 3 (d) 1

38. Distance between screen and source is decreased by 25%. Then the percentage change in fringe width is

(a) 20% (b) 31%

(c) 75% (d) 25%

39. In a Young's double slit experiment, the separation of the two slits is doubled. To keep the same spacing of fringes, the distance D of the screen from the slits should be made

(a) $\frac{D}{2}$ (b) $\frac{D}{\sqrt{2}}$

(c) $2D$ (d) $4D$

40. The Young's double slit experiment is performed with blue and with green light of wavelengths 4360Å and 5460Å respectively. If x is the distance of 4th maxima from the central one, then

(a) x (blue) = x (green)

(b) x (blue) > x (green)

(c) x (blue) < x (green)

(d) $\frac{x(blue)}{x(green)} = \frac{5460}{4360}$

41. In a double slit experiment, instead of taking slits of equal widths, one slit is made twice as wide as the other. Then, in the interference pattern

(a) the intensities of both the maxima and the minima increases

(b) the intensity of the maxima increases and the minima has zero intensity.

(c) the intensity of the maxima decreases and that of the minima increases

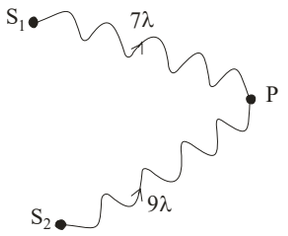
(d) the intensity of the maxima decreases and the minima has zero intensity.

42. The ratio of intensities of two waves is 9 : 1. They are producing interference. The ratio of maximum and minimum intensities will be

(a) 10 : 8 (b) 9 : 1

(c) 4 : 1 (d) 2 : 1

43. Let S_1 and S_2 are two sources and if wave from S_1 reaches some common point P by covering seven time of wavelength λ and from S_2 by covering nine times of wavelength λ.



Which of the following statement is incorrect?

(a) $S_2P - S_1P = 2\lambda$

(b) Waves from S_1 arrives exactly two cycles earlier than waves from S_2.

(c) At point P, waves from S_1 and S_2 are in phase.

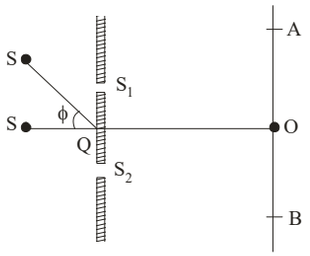
(d) At point P, waves from S_1 and S_2 are out of phase.

44. If the 5th order maxima of wavelength 400 nm in YDSE coincides with nth order maxima of the wavelength 5000Å, then the value of n is

(a) 3 (b) 4

(c) 5 (d) 6

45. In Young's double slit experiment, if source S is shifted by an angle ϕ as shown in figure. Then, central bright fringe will be shifted by angle ϕ towards



(a) end A of screen

(b) end B of screen

(c) does not shift at all

(d) Either end A and B depending on extra phase difference caused by shifting of source

46. If the intensities of the two interferring beams in Young's double slit experiment be I_1 and I_2, then the contrast between the maximum and minimum intensity is good when

(a) I_1 is much greater than I_2

(b) I_2 is smaller than I_2

(c) $I_1 = I_2$

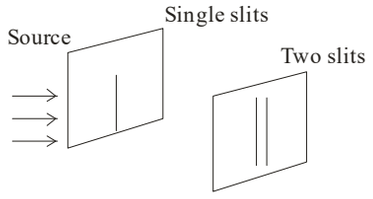
(d) Either $I_1 = 0$ or $I_2 = 0$

47. In Young's double slit experiment, let S_1 and S_2 be the two slits and C be the centre of the screen. If the $\angle S_1CS_2 = \theta$ and λ is the wavelength, then fringe width will be

(a) $\frac{\lambda}{\theta}$ (b) $\lambda\theta$

(c) $\frac{2\lambda}{\theta}$ (d) $\frac{\lambda}{2\theta}$

48. In young's double slit experiment, if the point sources are replaced by slits as shown below, then the intensity pattern observed have



(a) point fringes with decreasing intensity

(b) point fringes with increasing intensity

(c) straight line fringes with decreasing intensities

(d) straight line fringes with increasing intensities

49. The maximum intensity of fringes in Young's experiment is *I*. If one of the slit is closed, then the intensity at that place becomes I_o. Which of the following relation is true?

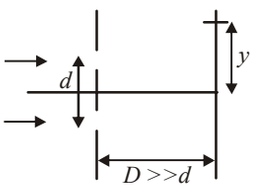
(a) $I = I_o$

(b) $I = 2I_o$

(c) $I = 4I_o$

(d) there is no relation between *I* and I_o

50. Consider the YDSE arrangement shown in figure. If $d = 10\lambda$ then position of 8th maxima is



(a) $y = \frac{D}{10}$ (b) $y = \frac{D}{3}$

(c) $y = \frac{4}{5}D$ (d) $y = \frac{4D}{3}$

51. A double slit arrangement produces fringes for $\lambda = 5890$ Å that are 0.4° apart. What is the angular width if the entire arrangement is immersed in water ? ($\mu_w = 4/3$)

(a) 0.3° (b) 2.3°

(c) 0.8° (d) 1.3°

52. Young's double slit experiment is made in a liquid. The 10th bright fringe lies in liquid where 6th dark fringe lies in vacuum. The refractive index of the liquid is approximately

(a) 1.8 (b) 1.5

(c) 1.3 (d) 1.6

53. The ratio of intensities at two points P and Q on the screen in a Young's double slit experiment where phase difference between two wave of same amplitude are $\frac{\pi}{3}$ and $\frac{\pi}{2}$, respectively are

(a) 1 : 3 (b) 3 : 1

(c) 3 : 2 (d) 2 : 3

54. The width of fringe is 2 mm on the screen in a double slits experiment for the light of wavelength of 400 nm. The width of the fringe for the light of wavelength 600 nm will be:

(a) 4 mm

(b) 1.33 mm

(c) 3 mm

(d) 2 mm

55. Two beams of light of intensity I_1 and I_2 interfere to give an interference pattern. If the ratio of maximum intensity to that of minimum intensity is 25/9, then I_1/I_2 is

(a) 5/3 (b) 4

(c) 81/625 (d) 16

56. Two coherent sources of light interfere. The intensity ratio of two sources is 1 : 4. For this interference pattern if the value of $\frac{I_{max} + I_{min}}{I_{max} - I_{min}}$ is equal to $\frac{2\alpha + 1}{\beta + 3}$, then $\frac{\alpha}{\beta}$ will be:

(a) 1.5 (b) 2

(c) 0.5 (d) 1

57. A point p is situated 90.50 and 90.58 cm away from two coherent sources. The nature of illumination of the point 'p' if the wavelength of light is 4000 Å, is

(a) bright

(b) dark

(c) neither bright nor dark

(d) none of these

58. The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength.

(a) 6000×10^{-10} cm

(b) 6000 Å

(c) 6000×10^{-8} mm

(d) None of these

59. Find the minimum thickness of a film which will strongly reflect the light of wavelength 598 nm. The refractive index of the material of the film is 1.25.

(a) 118 nm (b) 120 nm

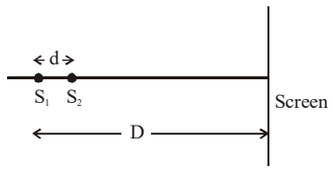
(c) 218 m (d) 225 mm

60. The path difference between two wavefronts emitted by coherent sources of wavelength 5460Å is 2.1 micron. The phase difference between the wavefronts at that point is

(a) 7.692 (b) $7.692\ \pi$

(c) $\frac{7.692}{\pi}$ (d) $\frac{7.692}{3\pi}$

61. Two coherent point sources S_1 and S_2 are separated by a small distance 'd' as shown in figure. The fringes obtained on the screen will be



(a) points

(b) straight lines

(c) semi-circles

(d) concentric circles

62. In Young's double slit experiment, the minimum amplitude is obtained when the phase difference of super-imposing waves is (where n = 1, 2, 3, ...)

(a) zero (b) $(2n - 1)\ \pi$

(c) $n\ \pi$ (d) $(n + 1)\ \pi$

63. In Young's double slit experiment with sodium vapour lamp of wavelength 589 nm and the slits 0.589 mm apart, the half angular width of the central maximum is

(a) $\sin^{-1}(0.01)$ (b) $\sin^{-1}(0.0001)$

(c) $\sin^{-1}(0.001)$ (d) $\sin^{-1}(0.1)$

64. If the intensities of the two interfering beams in Young's double-slit experiment are I_1 and I_2, then the contrast between the maximum and minimum intensities is good when

(a) $|I_1$ and $I_2|$ is large

(b) $|I_1$ and $I_2|$ is small

(c) either I_1 or I_2 is zero

(d) $I_1 = I_2$

65. In the Young's Double slit experiment, when we place a converging lens after the slits and place the screen at the focus of the lens, it

(a) introduces an extra path difference in the parallel beam.

(b) introduces no path difference in the parallel beam.

(c) introduces an extra phase difference in the parallel beam.

(d) introduces an extra fringe in the diffraction pattern.

66. Consider an Young's double slit experiment that has different slits width as a result, amplitudes of waves from two slits are I_0 and $4I_0$, then the intensity at a point on screen, where phase difference between waves is $\frac{2\pi}{3}$, is

(a) I_0 (b) $2\ I_0$

(c) $3\ I_0$ (d) $4\ I_0$

67. Two identical light sources S_1 and S_2 emit light of same wavelength λ. These light rays will exhibit interference if

(a) their phase difference remain constant

(b) their phases are distributed randomly

(c) their light intensities remain constant

(d) their light intensities change randomly

68. If yellow light emitted by sodium lamp in Young's double slit experiment is replaced by a monochromatic blue light of the same intensity

(a) fringe width will decrease

(b) finge width will increase

(c) fringe width will remain unchanged

(d) fringes will become less intense

69. In Young's double slit experiment, the slits are 3 mm apart. The wavelength of light used is 5000 Å and the distance between the slits and the screen is 90 cm. The fringe width in mm is

(a) 1.5 (b) 0.015

(c) 2.0 (d) 0.15

70. In Young's double slit experiment, if d, D and λ represent, the distance between the slits, the distance of the screen from the slits and wavelength of light used respectively, then the band width is inversely proportional to

(a) λ (b) d

(c) D (d) λ^2

71. If the separation between slits in Young's double slit experiment is reduced to $\frac{1}{3}rd$, the fringe width becomes n times. The value of n is

(a) 3 (b) $\frac{1}{3}$

(c) 9 (d) $\frac{1}{9}$

72. In young's double slit experiment, the wavelength of the light used to doubled and distane between two slits is half of initial distance, the resultant fringe width becomes.

(a) 2 times (b) 3 times (c) 4 times (d) 1/2 times

73. In a Young's double slit experiment, the slit separation is 0.2 *cm*, the distance between the screen and slit is 1*m*. Wavelength of the light used is 5000 Å. The distance between two consecutive dark fringes (in *mm*) is

(a) 0.25 (b) 0.26

(c) 0.27 (d) 0.28

74. Young's double slit experiment is carried out by using green, red and blue light, one color at a time. The fringe widths recorded are β_G, β_R and β_B, respectively. Then

(a) $\beta_G > \beta_B > \beta_R$

(b) $\beta_B > \beta_G > \beta_R$

(c) $\beta_R > \beta_B > \beta_G$

(d) $\beta_R > \beta_G > \beta_B$

75. Two slits, 4 *mm* apart, are illuminated by light of wavelength 6000 Å. What will be the fringe width on a screen placed 2*m* from the slits

(a) 0.12 *mm* (b) 0.3 *mm*

(c) 3.0 *mm* (d) 4.0 *mm*

76. An interference pattern was made by using red light. If the red light changes with blue light, the fringes will become

(a) wider (b) narrower

(c) fainter (d) brighter

7.3 Diffraction of Light, Rayleigh's Criterion of Resolution, Resolving Power (R.P.) of an Optical Instrument

77. A slit of width a is illuminated by red light of wavelength 6500 Å. If the first diffraction minimum falls at 30°, then the value of a is

(a) 6.5×10^{-4} mm

(b) 1.3 micron

(c) 3250 Å

(d) 2.6×10^{-4} cm

78. In a Fraunhoffer diffraction at a single slit, if yellow light illuminating the slit is replaced by blue light, then diffraction bands

(a) remain unchanged

(b) become wider

(c) disappear

(d) become narrower

79. A plane wavefront of wavelength λ is incident on a single slit of width a. The angular width of principal maximum is

(a) $\frac{\lambda}{a}$ (b) $\frac{2\lambda}{a}$

(c) $\frac{a}{\lambda}$ (d) $\frac{a}{2\lambda}$

80. A beam of light of wavelength 600nm from a distant source falls on a single slit 1.00mm wide and the resulting diffraction pattern is observed on a screen 2m away. The width of the central maximum is

(a) 1.2 cm (b) 1.2 mm

(c) 2.4 cm (d) 2.4 mm

81. If a converging lens of focal length f is placed after the slit and the fringes are obtained on screen placed at the focus of lens in single-slit diffraction, then the size of screen is

(a) $\frac{\lambda}{a}$ (b) $f\frac{\lambda}{a}$

(c) $\frac{a}{\lambda}$ (d) $f\frac{a}{\lambda}$

82. A narrow slit of width 1 mm is illuminated by monochromatic light of wavelength 600 nm. The distance between the first minima on either side of a screen at a distance of 2 m is

(a) 1.2 cm

(b) 1.2 mm

(c) 2.4 cm

(d) 2.4 mm

83. The ratio of intensities of consecutive maxima in the diffraction pattern due to a single slit is

(a) 1 : 4 : 9

(b) 1 : 2 : 3

(c) $1:\frac{4}{9\pi^2}:\frac{4}{25\pi^2}$

(d) $1:\frac{1}{\pi^2}:\frac{9}{\pi^2}$

84. Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. The angular width of central maxima in the diffraction pattern is (measured from minimum to minimum)

(a) 6×10^{-3} rad

(b) 4×10^{-3} rad

(c) 2.4×10^{-3} rad

(d) 4.5×10^{-3} rad

85. A microwave of wavelength 2.0 cm falls normally on a slit of width 4.0 cm. The angular spread of the central maxima of the diffraction pattern obtained on a screen 1.5 m away from the slit, will be:

(a) 60° (b) 45°

(c) 15° (d) 30°

86. The condition for observing Fraunhoffer diffraction from a single slit is that the light wavefront incident on the slit should be

(a) spherical

(b) cylindrical

(c) plane

(d) elliptical

87. In case of diffraction if 'a' is a slit width and λ is the wavelength of the incident light, then the required condition for diffraction to take place is

(a) $\frac{a}{\lambda} = 1000$ (b) $\frac{a}{\lambda} \leq 1$

(c) $a < 1$ (d) $a > 1$

88. The diameter of the objective of a telescope is 3.6 m. The limit of resolution of the telescope for a light of wavelength 540 nm is

(a) 1.22×10^{-7}- rad

(b) 1.83×10^{-7} rad

(c) 0.61×10^{-7} rad

(d) 3.76×10^{-7} rad

89. Diameter of the objective lens of a telescope is 250 cm. For light of wavelength 600 nm, coming from a distant object, the limit of resolution of the telescope is close to

(a) 1.5×10^{-7} rad

(b) 2.0×10^{-7} rad

(c) 3.0×10^{-7} rad

(d) 4.5×10^{-7} rad

90. A diffraction pattern is being formed at the screen. Firstly yellow light was used for it. If yellow light is replaced by the X-rays, then the central maxima

(a) becomes wider

(b) becomes narrower

(c) no change

(d) None of these

91. Wavelength of light used in an optical instrument are $\lambda_1 = 4000$ Å and $\lambda_2 = 5000$ Å, then ratio of their respective resolving powers (corresponding to λ_1 and λ_2) is

(a) 16 : 25 (b) 9 : 1

(c) 4 : 5 (d) 5 : 4.

92. Red light is generally used to observe diffraction pattern from single slit. If blue light is used instead of red light, then diffraction pattern will

(a) be more clear

(b) contract

(c) expand

(d) not be visualized

Exercise 2 : ACCELERATOR
Topic-wise MCQs

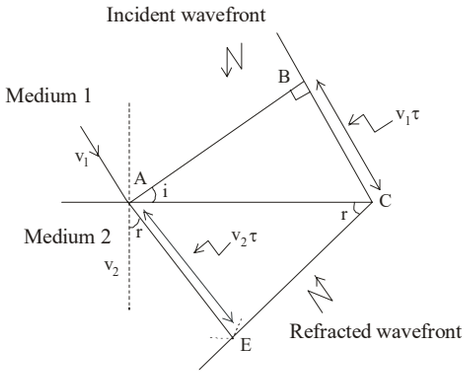
7.1 Nature of Light, Huygen's Principle, Polarisation

1. '*n*' polarizing sheets are arranged such that each makes an angle 45° with the preceding sheet. An unpolarized light of intensity I is incident into this arrangement. The output intensity is found to be I/64. The value of *n* will be:

(a) 6 (b) 3

(c) 5 (d) 4

2. In the given figure, light passes from denser medium 1 to rarer medium 2.



When $i > i_c$ (critical angle of incidence), then wavefront EC is

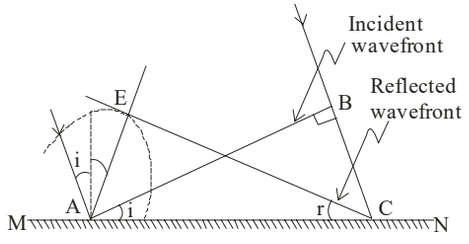
(a) formed further deep in medium 2

(b) formed closer to surface line AC

(c) formed perpendicular to AC

(d) formed in medium 1 (on the same side of AB)

3. In the given figure, a plane wave AB incident at an angle i on a reflecting surface MN.



The reflected wavefront is obtained by (take, v be the speed of light and t be the time taken by it from B to C)

(a) drawing a sphere of radius vt from point A

(b) drawing a sphere of radius vt from point C

(c) drawing a perpendicular from point A

(d) drawing a perpendicular from point C

4. An unpolarised light of intensity I is passed through two polaroids kept one after the other with their planes parallel to each other. The intensity of light emerging from second polaroid is $\frac{1}{4}$. The angle between the pass axes of the polaroids is

(a) 0° (b) 60°

(c) 30° (d) 45°

5. A polarized light of intensity I_0 is passed through another polarizer whose pass axis makes an angle of 60° with the pass axis of the former. What is the intensity of emergent polarized light from second polarizer?

(a) $I = \frac{I_0}{5}$ (b) $I = I_0$

(c) $\frac{I_0}{4}$ (d) $I = \frac{I_0}{6}$

6. A light whose electric field vectors are completely removed by using a good Polaroid, allowed to incident on the surface of the prism at Brewster's angle. Choose the most suitable option for the phenomenon related to the prism.

(a) Reflected and refracted rays will be perpendicular to each other

(b) Wave will propagate along the surface of prism

(c) No refraction, and there will be total reflection of light.

(d) No reflection and there will be total transmission of light.

7. In refraction, light waves are bent on passing from one medium to the second medium, because, in the second medium

(a) the frequency is different

(b) the coefficient of elasticity is different

(c) the speed is different

(d) the amplitude is smaller

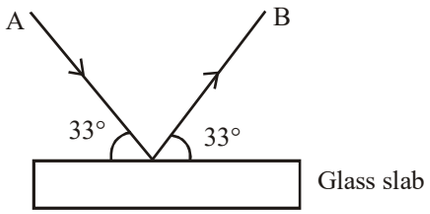
8. Unpolarized light is incident on a plane sheet on water surface. The angle of incidence for which the reflected and refracted rays are perpendicular to each other is

$\left(\mu \text{ of water} = \frac{4}{3}\right)$

(a) $\sin^{-1}\left(\frac{4}{3}\right)$ (b) $\tan^{-1}\left(\frac{3}{4}\right)$

(c) $\tan^{-1}\left(\frac{4}{3}\right)$ (d) $\sin^{-1}\left(\frac{1}{3}\right)$

9. A beam of light is incident on a glass slab ($\mu = 1.54$) in a direction as shown in the figure. The reflected light is analysed by a polaroid prism. On rotating the polaroid, (tan 57° = 1.54)



(a) the intensity remains unchanged

(b) the intensity is reduced to zero and remains at zero

(c) the intensity gradually reduces to zero and then again increase

(d) the intensity increases continuously

10. When unpolarised light is incident on a plane glass plate at Brewster's angle, then which of the following statements is correct?

(a) Reflected and refracted rays are completely polarised with their planes of polarization parallel to each other

(b) Reflected and refracted rays are completely polarised with their planes of polarization perpendicular to each other

(c) Reflected light is plane polarised but transmitted light is partially polarised

(d) Reflected light is partially polarised but refracted light is plane polarised

11. The Brewster angle for the glass-air interface is 54.74°. If a ray of light going from air to glass strikes at an angle of incidence 45°, then the angle of refraction is

(Hint : $\tan 54.74° = \sqrt{2}$)

(a) 60° (b) 30°

(c) 25° (d) 54.74°

12. A plane wavefront showers its energy perpendicular to a glass surface. The energy continues to move inside the medium as

(a) Plane wavefront

(b) (Spherical) concave wavefront

(c) Convex wavefront

(d) Rays and not as wavefronts

13. The wave normals drawn on a wavefront at various points on the wavefront are diverging from a point. The wavefront is

(a) plane

(b) spherical

(c) cylindrical

(d) elliptical

7.2 Interference of Light, Young's Double Slit Experiment

14. If the intensity ratio of two coherent sources is 49 : 1, then the ratio between the maximum and minimum intensities in the interference pattern is

(a) 1 : 9 (b) 9 : 16

(c) 25 : 16 (d) 16 : 9

15. n identical waves each of intensity I_0 interfere with each other. The ratio of maximum intensities if the interference is (i) coherent and (ii) incoherent is :

(a) n^2 (b) $\frac{1}{n}$

(c) $\frac{1}{n^2}$ (d) n

16. If the amplitude ratio of two sources producing interference is 3 : 5, the ratio of intensities at maxima and minima is

(a) 25 : 16 (b) 5 : 3

(c) 16 : 1 (d) 25 : 9

17. For constructive interference to take place between two monochromatic light waves of wavelength λ, the path difference should be

(a) $(2n-1)\frac{\lambda}{4}$ (b) $(2n-1)\frac{\lambda}{2}$

(c) $n\lambda$ (d) $(2n+1)\frac{\lambda}{2}$

18. Two sources of same intensity interfere at a point and produced resultant I. When one source is removed, the intensity at that point will be

(a) I (b) $I/2$

(c) $I/4$ (d) $I/3$

19. If two waves represented by $y_1 = 4 \sin \omega t$ and $y_2 = 3\sin\left(\omega t + \frac{\pi}{3}\right)$ interfere at a point, the amplitude of the resulting wave will be about

(a) 7 (b) 6
(c) 5 (d) 3.5

20. Two coherent sources of intensitites, I_1 and I_2 produce an interference pattern. The maximum intensity in the interference pattern will be

(a) $I_1 + I_2$ (b) $I_1^2 + I_2^2$
(c) $(I_1 + I_2)^2$ (d) $\left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

21. Sodium light $(\lambda = 6\times10^{-7}\,\text{m})$ is used to produce interference pattern. The observed fringe width is 0.12 mm. The angle between two interfering wave trains, is

(a) 1×10^{-3} rad (b) 1×10^{-2} rad
(c) 5×10^{-3} rad (d) 5×10^{-2} rad

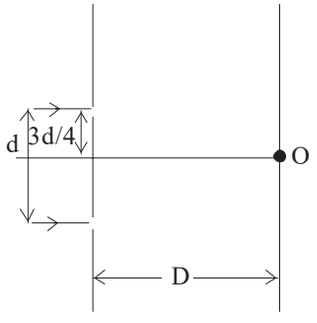
22. In an interference experiment, the spacing between successive maxima or minima is

(a) λd/D (b) λD/d
(c) dD/λ (d) λd/4D

23. With a monochromatic light, the fringe-width obtained in a Young's double slit experiment is 0.133 cm. The whole set-up is immersed in water of refractive index 1.33, then the new fringe-width is

(a) 0.133 cm (b) 0.1 cm
(c) 1.33×1.33 cm (d) $\frac{1.33}{2}$ cm

24. In the figure shown, if a parallel beam of white light is incident on the plane of the slits then the distance of the nearest white spot on the screen from O is $\frac{d}{A}$. Find the value of A. (Assume d << D)



(a) 3 (b) 5
(c) 6 (d) 4

25. In a Young's double slit experiment, d = 1 mm and D = 200 cm. It is found that 7th bright fringe is at a distance of 6.5 mm from 1st dark fringe of fringe pattern. The wavelength of light used is

(a) 4000 Å (b) 5200 Å
(c) 5000 Å (d) 2000 Å

26. In the Young's double slit experiment with sodium light, the slits are 0.589 m apart. The angular separation of the third maximum from the central maximum will be (given λ = 589 mm)

(a) $\sin^{-1}(0.33 \times 10^{8})$
(b) $\sin^{-1}(0.33 \times 10^{-6})$
(c) $\sin^{-1}(3 \times 10^{-8})$
(d) $\sin^{-1}(3 \times 10^{-6})$

27. In Young's double slit experiment, the 8th maximum with wavelength λ_1 is at a distance d_1 from the central maximum and the 6th maximum with a wavelength λ_2. is at a distance d_2. Then (d_1/d_2) is equal to

(a) $\frac{4}{3}\left(\frac{\lambda_2}{\lambda_1}\right)$ (b) $\frac{4}{3}\left(\frac{\lambda_1}{\lambda_2}\right)$
(c) $\frac{3}{4}\left(\frac{\lambda_2}{\lambda_1}\right)$ (d) $\frac{3}{4}\left(\frac{\lambda_1}{\lambda_2}\right)$

28. Two coherent sources of equal intensity produce maximum intensity of 100 units at a point. If the intensity of one of the sources is reduced by 36% reducing its width then the intensity of light at the same point will be

(a) 90 (b) 89
(c) 67 (d) 81

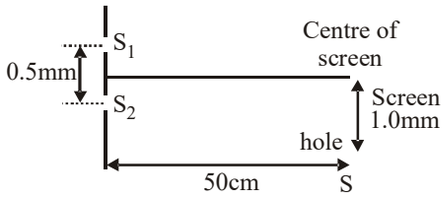
29. A double slit arrangement produces interference fringes for sodium light (λ = 589 nm) that have an angular separation of 3.50×10^{-3} radian. For what wavelength would the angular separation be 10% greater?

(a) 527 nm (b) 648 nm
(c) 722 nm (d) 449 nm

30. Monochromatic light of wavelength 400 nm and 560 nm are incident simultaneously and normally on double slits apparatus whose slits separation is 0.1 mm and screen distance is 1m. Distance between areas of total darkness will be

(a) 4 mm (b) 5.6 mm
(c) 14 mm (d) 28 mm

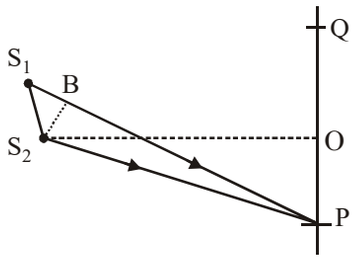
31. In Young's double slit experiment shown in figure S_1 and S_2 are coherent sources and S is the screen having a hole at a point 1.0mm away from the central line. White light (400 to 700nm) is sent through the slits. Which wavelength passing through the hole has strong intensity?



(a) 400 nm (b) 700 nm

(c) 500 nm (d) 667 nm

32. In figure, Young's double slit experiment Q is the position of the first bright fringe on the right side of O. P is the 11^{th} fringe on the other side, as measured from Q. If $\lambda = 6000$ Å, then S_1B will be equal to



(a) 6×10^{-6} m (b) 6.6×10^{-6} m

(c) 3.318×10^{-7} m (d) 3.144×10^{-7} m

33. Two identical light waves, propagating in the same direction, have a phase difference δ. After they superpose, the intensity of the resulting wave will be proportional to

(a) $\cos\delta$ (b) $\cos(\delta/2)$

(c) $\cos^2(\delta/2)$ (d) $\cos^2\delta$

34. Two sources of light of wavelengths 2500 Å and 3500 Å are used in Young's double slit expt. simultaneously. Which orders of fringes of two wavelength patterns coincide?

(a) 3^{rd} order of 1^{st} source and 5^{th} of the 2^{nd}

(b) 7^{th} order of 1^{st} and 5^{th} order of 2^{nd}

(c) 5^{th} order of 1^{st} and 3^{rd} order of 2^{nd}

(d) 5^{th} order of 1^{st} and 7^{th} order of 2^{nd}

35. In Young's double slit experiment, the intensity of light at a point on the screen where the path difference is λ is K units. What is the intensity of light at a point where the path difference is $\lambda/3$; λ being the wavelength of light used?

(a) K/4 (b) K/3 (c) K/2 (d) K

36. Interference was observed in an interference chamber when air was present. Now, the chamber is evacuated and if the same light is used, a careful observation will show

(a) no interference

(b) interference with bright bands

(c) interference with dark bands

(d) interference in which breadth of the fringe will be slightly increased

37. In Young's double slit experiment with a separation d, a monochromatic light of wavelength λ is used. The angular separation of the fringe is

(a) $\frac{d}{\lambda}$ (b) $\frac{\lambda}{d}$

(c) $\frac{2\lambda}{d}$ (d) $\frac{\lambda}{2d}$

38. Two coherent monochromatic light beams of intensities i and 4I are superposed. The maximum and minimum possible intensities in the resulting beam are

(a) 5 I and I (b) 5I and 3I

(c) 9I and I (d) 9I and 3I

39. In a YDSE : D = 1m, d = 1 mm and $\lambda = 5000$ nm. The distance of 100^{th} maxima from the central maxima is $\frac{1}{\sqrt{X}}$ m then find the value of X.

(a) 5 m (b) 4 m

(c) 3 m (d) 7 m

40. In YDSE, phase difference between the interfering waves, so that at any point on screen the resulting intensity becomes less than the average intensity, may be

(1) $\frac{\pi}{4}$ (2) $\frac{2\pi}{3}$

(3) π (4) $\frac{7\pi}{8}$

Choose the correct options

(a) 1 and 2 (b) 1, 2 and 3

(c) 2 and 3 (d) 2, 3 and 4

41. In Young's double slit experiment, $\lambda = 500$nm, d = 1mm, D = 1m. Minimum distance from the central maximum for which intensity is half of the maximum intensity is

(a) 2.5×10^{-4} m

(b) 1.25×10^{-4} m

(c) 0.625×10^{-4} m

(d) 0.3125×10^{-4} m

42. In an experiment the two slits are 0.5 mm apart and the fringes are observed to 100 cm from the plane of the slits. The distance of the 11th bright fringe from the Ist bright fringe is 9.72 mm. Calculate the wavelength used.

(a) 4.85×10^{-5} cm

(b) 4.85×10^{-5} m

(c) 4.86×10^{-7} m

(d) 4.86×10^{-5} cm

43. If an interference pattern has maximum and minimum intensities in 36 : 1 ratio then what will be the ratio of ampitudes

(a) 5 : 7 (b) 7 : 4

(c) 4 : 7 (d) 7 : 5

44. In Youngs double slit experiment, angular width of fringes is 0.40° for sodium light of wavelength 5890 Å. If complete system is dipped in water, then angular width of fringes becomes

(a) 0.11° (b) 0.15°

(c) 0.22° (d) 0.30°

45. In Young's double slit experiment, when two light waves form third minimum, they have

(a) Phase difference of 3π (b) Phase difference of $\frac{5\pi}{2}$

(c) Path difference of 3λ (d) Path difference of $\frac{5\lambda}{2}$

7.3 Diffraction of Light, Rayleigh's Criterion of Resolution, Resolving Power (R.P.) of an Optical Instrument

46. When the diffraction pattern from a certain slit illuminated with laser light ($\lambda = 6330$ Å) is projected on a screen 150 cm from the slit, the second minima on each side are separated by 8 cm. This tells us that:

(a) the slit is approximately 0.005 cm wide

(b) the slit is approximately 0.05 cm wide

(c) a / λ is approximately 7.5 (a is the slit width)

(d) a / λ is approximately 750

47. In a single slit diffraction experiment, the width of the slit is made double its original width. Then the central maxima of the diffraction pattern will become

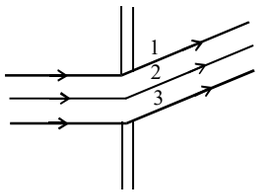
(a) narrower and fainter

(b) narrower and brighter

(c) broader and fainter

(d) broader and brighter

48. The adjacent figure shows Fraunhoffer's diffraction due to a single slit. If first minimum is obtained in the direction shown, then the path difference between rays 1 and 3 is



(a) 0

(b) $\lambda / 4$

(c) $\lambda / 2$

(d) λ

49. If we observe the single slit Fraunhofer diffraction with wavelength λ and slit width b, the width of the central maxima is 2θ. On decreasing the slit width for the same λ

(a) θ increases

(b) θ remains unchanged

(c) θ decreases

(d) θ increases or decreases depending on the intensity of light

50. A narrow slit of width 2 mm is illuminated with a monochromatic light of wavelength 500 nm. If the distance between the slit and the screen is 1m, then first minima are separated by a distance of

(a) 5 mm (b) 0.5 mm

(c) 1 mm (d) 10 mm

51. Angular width of central maximum of a diffraction pattern due to a single slit does not depend upon

(a) Distance between slit and source

(b) Wavelength of light used

(c) Width of the slit

(d) Frequency of light used

52. In a single slit diffraction, the slit is illuminated with light of wavelength 6000 Å. If the slit were illuminated by a light of wavelength l the angular width of the central maximum decreases by 30%. Then l is

(a) 6000 Å (b) 4200 Å

(c) 3000 Å (d) 1800 Å

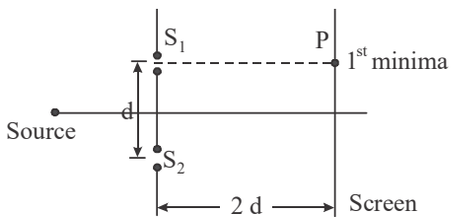
Exercise 3 : PREVIOUS YEARS MCQs

1. In a Young's double slit experiment, the slits are separated by 0.2 mm. If the slits separation is increased to 0.4 mm, the percentage change of the fringe width is: **[2025]**

(a) 0% (b) 100%

(c) 50% (d) 25%

2. Consider a Young's double slit experiment as shown in figure. What should be the slit separation d in terms of wavelength λ such that the first minima occurs directly in front of the slit (S_1)? **[2025]**



(a) $\frac{\lambda}{2\left(\sqrt{5}-2\right)}$ (b) $\frac{\lambda}{\left(\sqrt{5}-2\right)}$

(c) $\frac{\lambda}{2\left(5-\sqrt{2}\right)}$ (d) $\frac{\lambda}{\left(5-\sqrt{2}\right)}$

3. Light emerges out of a convex lens when a source of light kept at its focus. The shape of wavefront of the light is:

(a) Both spherical and cylindrical **[2024]**

(b) Cylindrical

(c) Spherical

(d) Plane

4. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is **[2023]**

(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$

(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

5. The interference pattern is obtained with two coherent light sources of intensity ratio 4 : 1. And the ratio $\frac{I_{max}+I_{min}}{I_{max}-I_{min}}$ is $\frac{5}{x}$. Then, the value of x will be equal to : **[2022]**

(a) 3 (b) 4

(c) 2 (d) 1

6. In Young's double slit experiment, the fringe width is 12 mm. If the entire arrangement is placed in water of refractive index $\frac{4}{3}$, then the fringe width becomes (in mm) : **[2022]**

(a) 16 (b) 9

(c) 48 (d) 12

7. In a Young's double-slit experiment, let β be the fringe width, and let I_0 be the intensity at the central bright fringe. At a distance x from the central bright fringe, the intensity will be **[2021]**

(a) $I_0 \cos\left(\frac{x}{\beta}\right)$ (b) $I_0 \cos^2\left(\frac{x}{\beta}\right)$

(c) $I_0 \cos^2\left(\frac{\pi x}{\beta}\right)$ (d) $\left(\frac{I_0}{4}\right)\cos^2\left(\frac{\pi x}{\beta}\right)$

8. The width of a slit is 0.012 mm. Monochromatic light is incident on it. The angular position of first bright line is 5.2°. The wavelength of incident light is [sin 5.2° = 0.0906]. **[2020]**

(a) 6040 Å (b) 4026 Å

(c) 5890 Å (d) 7248 Å

9. The fringe width in a Young's double slit experiment can be increased if we decrease **[2020]**

(a) width of slits

(b) separation of slits

(c) wavelength of light used

(d) distance between slits and screen

10. A telescope has large diameter of the objective. Then its resolving power is **[2019]**

(a) independent of the diameter of the objective

(b) low

(c) zero

(d) high

11. In biprism experiment, the distance between source and eyepiece is 1.2 m, the distance between two virtual sources is 0.84 mm. Then the wavelength of light used if eyepiece is to be moved transversely through a distance of 2.799 cm to shift 30 fringes is **[2019]**

(a) 6533 Å (b) 6537 Å

(c) 6535 Å (d) 6351 Å

12. Two light waves of intensities 'I_1' and 'I_2' having same frequency pass through same medium at a time in same direction and interface. The sum of the minimum and maximum intensities is **[2018]**

(a) $(I_1 + I_2)$ (b) $2(I_1 + I_2)$

(c) $(\sqrt{I_1} + \sqrt{I_2})$ (d) $(\sqrt{I_1} - \sqrt{I_2})$

13. If numerical aperture of a microscope is increased then its

(a) resolving power remains constant **[2018]**

(b) resolving power becomes zero

(c) limit of resolution is decreased

(d) limit of resolution is increased

14. In Fraunhofer diffraction pattern, slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000Å, then the distance between the first minimum on either side of the central maximum is (θ is small and measured in radian) **[2017]**

(a) 10^{-1}m (b) 10^{-2}m

(c) 2×10^{-2}m (d) 2×10^{-1}m

15. The polarising angle for transparent medium is 'θ' and 'v' is the speed of light in that medium. Then relation between 'θ' and 'v' is **[2017]**

(c = velocity if light in air)

(a) $\theta = \tan^{-1}\left(\frac{v}{c}\right)$ (b) $\theta = \cot^{-1}\left(\frac{v}{c}\right)$

(c) $\theta = \sin^{-1}\left(\frac{v}{c}\right)$ (d) $\theta = \cos^{-1}\left(\frac{v}{c}\right)$

16. Two identical light waves having phase difference 'ϕ' propagate in same direction.When they superpose, the intensity of resultant wave is proportional to **[2017]**

(a) $\cos^2 \phi$ (b) $\cos^2\left(\frac{\phi}{2}\right)$

(c) $\cos^2\left(\frac{\phi}{3}\right)$ (d) $\cos^2\left(\frac{\phi}{4}\right)$

17. Interference fringes are produced on a screen by using two light sources of intensities I and 9I. The phase difference between the beams is $\frac{\pi}{2}$ at point P and π at point Q on the screen. The difference between the resultant intensities at point P and Q is **[2016]**

(a) 2I (b) 4I

(c) 6I (d) 8I

18. From Brewster's law, except for polished metallic surfaces, the polarising angle **[2015]**

(a) depends on wavelength and is different for different colours

(b) independent of wavelength and is different for different colours

(c) independent of wavelength and is same for different colours

(d) depends on wavelength and is same for different colours

19. Resolving power of telescope increases when **[2014]**

(a) wavelength of light decreases

(b) wavelength of light increases

(c) focal length of eye-piece increases

(d) focal length of eye-piece decreases

20. A monochromatic light of wavelength 6000 Å is incident on the single slit of width 0.01 mm. If the diffraction pattern is formed at the focus of the convex lens of focal length 20 cm, the linear width of the central maximum is: **[2013]**

(a) 60 mm (b) 24 mm

(c) 120 mm (d) 12 mm

21. A microwave of wavelength 2.0 cm falls normally on a slit of width 4.0 cm. The angular spread of the central maxima of the diffraction pattern obtained on a screen 1.5 m away from the slit, will be: **[2012]**

(a) 60° (b) 45°

(c) 15° (d) 30°

22. In Young's double slit experiment, if the distance between the slits is increased to 3 times initial distance, then the ratio of initial and final fringe widths is **[2011]**

(a) 1 : 9

(b) 9 : 1

(c) 3 : 1

(d) 1 : 3

23. In Young's double slit experiment, the wavelength of monochromatic light is increased by 20% and the distance between the two slits is decreased by 25%. If the initial fringe width is 0.3 mm, then the final fringe width is **[2009]**

(a) 0.72 mm (b) 0.60 mm

(c) 0.16 mm (d) 0.48 mm

24. In an experiment, two polariods are arranged such that the intensity of the polarised light emerged from the second polaroid is 37.5% of the intensity of the unpolarised light incident on the first polaroid. Then the angle between the axes of the two polaroids is **[2007]**

(a) 60° (b) 90°

(c) 45° (d) 30°

25. An unpolarised beam of light incidents on a group of three polarising sheets arranged such that the angle between the axes of any two adjacent sheets is 30°. The ratio of the intensities of polarised light emerging from the second and third sheets is **[2005]**

(a) 1 : 1 (b) 2 : 1

(c) 4 : 3 (d) 3 : 2

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(c)	**11**	(a)	**21**	(b)	**31**	(d)	**41**	(a)	**51**	(a)	**61**	(d)	**71**	(a)	**81**	(b)	**91**	(d)
2	(a)	**12**	(b)	**22**	(b)	**32**	(d)	**42**	(c)	**52**	(a)	**62**	(b)	**72**	(c)	**82**	(d)	**92**	(b)
3	(b)	**13**	(a)	**23**	(b)	**33**	(d)	**43**	(d)	**53**	(c)	**63**	(c)	**73**	(a)	**83**	(c)		
4	(a)	**14**	(c)	**24**	(c)	**34**	(a)	**44**	(b)	**54**	(c)	**64**	(d)	**74**	(d)	**84**	(a)		
5	(b)	**15**	(d)	**25**	(b)	**35**	(a)	**45**	(b)	**55**	(d)	**65**	(b)	**75**	(b)	**85**	(a)		
6	(c)	**16**	(c)	**26**	(c)	**36**	(d)	**46**	(c)	**56**	(b)	**66**	(c)	**76**	(b)	**86**	(c)		
7	(a)	**17**	(a)	**27**	(b)	**37**	(c)	**47**	(a)	**57**	(a)	**67**	(a)	**77**	(b)	**87**	(b)		
8	(c)	**18**	(d)	**28**	(b)	**38**	(d)	**48**	(d)	**58**	(b)	**68**	(a)	**78**	(d)	**88**	(b)		
9	(b)	**19**	(b)	**29**	(c)	**39**	(c)	**49**	(c)	**59**	(a)	**69**	(d)	**79**	(b)	**89**	(c)		
10	(b)	**20**	(d)	**30**	(a)	**40**	(c)	**50**	(d)	**60**	(b)	**70**	(b)	**80**	(d)	**90**	(b)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(a)	**7**	(c)	**13**	(b)	**19**	(b)	**25**	(c)	**31**	(c)	**37**	(b)	**43**	(d)	**49**	(a)		
2	(d)	**8**	(c)	**14**	(d)	**20**	(d)	**26**	(d)	**32**	(a)	**38**	(c)	**44**	(d)	**50**	(b)		
3	(a)	**9**	(c)	**15**	(d)	**21**	(c)	**27**	(b)	**33**	(c)	**39**	(d)	**45**	(d)	**51**	(a)		
4	(d)	**10**	(c)	**16**	(c)	**22**	(b)	**28**	(d)	**34**	(b)	**40**	(d)	**46**	(a)	**52**	(b)		
5	(c)	**11**	(c)	**17**	(c)	**23**	(b)	**29**	(b)	**35**	(a)	**41**	(b)	**47**	(b)				
6	(d)	**12**	(a)	**18**	(c)	**24**	(d)	**30**	(d)	**36**	(d)	**42**	(d)	**48**	(c)				
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(c)	**4**	(c)	**7**	(c)	**10**	(d)	**13**	(c)	**16**	(b)	**19**	(a)	**22**	(c)	**25**	(c)		
2	(a)	**5**	(b)	**8**	(d)	**11**	(None)	**14**	(b)	**17**	(c)	**20**	(b)	**23**	(d)				
3	(d)	**6**	(b)	**9**	(b)	**12**	(b)	**15**	(b)	**18**	(a)	**21**	(a)	**24**	(d)				

8 Electrostatics

TOPIC 8.1 : ELECTRIC FLUX, GAUSS'S LAW & ITS APPLICATIONS, CONDUCTORS & INSULATORS

ELECTRIC FLUX (ϕ)

The total number of electric lines of force through a given area is called the electric flux.

- Electric flux $d\phi$ through a small area element $d\mathbf{S}$ due to an electric field $\mathbf{E}$ at an angle θ with $d\mathbf{S}$ is
  $d\phi = \mathbf{E} \cdot d\mathbf{S} = E\, d\mathbf{S} \cos\theta$
  which is proportional to the number of field lines cutting the area element.
- Total electric flux ϕ over the surface $\mathbf{S}$ due to an electric field E is

$$\phi = \oint_S \mathbf{E} \cdot d\mathbf{S} = \oint_S E\, dS \cos\theta$$

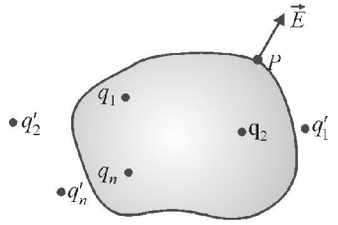
Electric flux is a scalar quantity
The **S.I. unit** of electric flux is V m or $N m^2/C$
Dimensions : $[ML^3 T^{-3} A^{-1}]$

GAUSS'S LAW OR GAUSS'S THEOREM

According to this law, *the total flux of the net electric field through a closed surface (Gaussian surface) equals the net charge enclosed by the surface divided by* ϵ_0. Thus if q_{in} is the total charge inside the closed surface, then

$$\oint \vec{E}.d\vec{A} = \frac{1}{\epsilon_0}\sum_{i=1}^{n} q_i = \frac{q_{enclosed}}{\epsilon_0}.$$

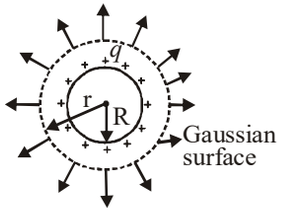
where $q_{enclosed} = q_1, q_2, q_3 ____ q_n$



Applications of Gauss's Law

Gauss's law helps to determine the electric field intensity.

(i) Electric field intensity due to charged spherical shell or hollow sphere :

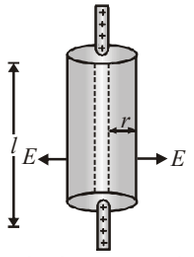


Case I: $E_{inside} = 0$ (r < R)

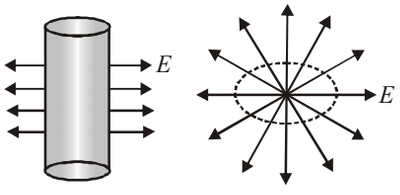
Case II: $E_{surface} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$ (r = R)

Case III: $E_{outside} = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$ (r > R)

(ii) Electric field intensity due to an infinitely long straight charged wire (or due to an infinitely long charge conducting cylinder)



Hence, we can apply the Gauss's law as,



$$\therefore \quad E(2\pi rl) = \frac{\lambda l}{\varepsilon_0} \qquad \therefore \quad E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

This is the electric field intensity at at point outside a charged conducting cylinder.

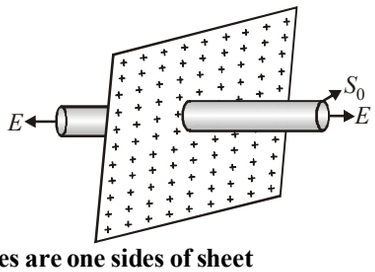
i.e., $E \propto \frac{1}{r}$

Case I: At a point on the surface of cylinder then r = R therefore,

$$E_{surface} = \frac{1}{2\pi\varepsilon_0} \cdot \left(\frac{\lambda}{R}\right)$$

Case II: At a point lies inside charged cylinder then, q = 0 therefore E = 0.

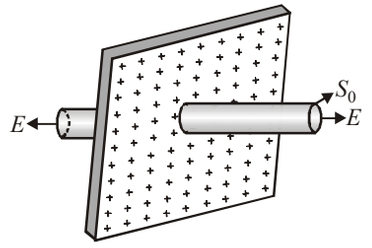
(iii) Electric field due to a charged infinite plane sheet



When charges are one sides of sheet

$$\text{or, } E = \frac{\sigma}{2\varepsilon_0}$$

When charges are on both sides of sheet



$$\text{or, } E = \frac{\sigma}{\varepsilon_0}$$

CONDUCTORS & INSULATORS

- *The materials which allow electric charge (or electricity) to flow freely through them are called* **conductors**. Metals are very good conductors of electric charge. Silver, copper and aluminium are some of the best conductors of electricity.
- *The materials which do not allow electric charge to flow through them are called* **nonconductors** *or* **insulators dielectric**.
  Insulators can be charged but do not conduct electric charge. Insulators do not have '*free electrons*' that is why insulators do not conduct electricity.

FREE CHARGES AND BOUND CHARGES INSIDE MATERIALS:

- The electrical behaviour of conductors and insulators can be understood on the basis of free and bound charges. In metallic conductors, the electrons in the outermost shells of the atoms are loosely bound to the nucleus and hence can easily get detached and move freely inside the metal.
- In insulators, the electrons are tightly bound to the nucleus and are thus not available for conductions and hence are poor conductors of electricity. There are no free charges since all the charges are bound to the nucleus.

TOPIC 8.2 : DIELECTRICS & ELECTRIC POLARISATION, CAPACITORS & CAPACITANCE, PARALLEL PLATE CAPACITOR AND COMBINATION OF CAPACITORS

DIELECTRICS AND ELECTRIC POLARISATION

The insulators in which microscopic local displacement of charges takes place in presence of electric field are known as ***dielectrics***. Dielectrics are non-conductors upto certain value of field depending on its nature. If the field exceeds this limiting value called dielectric strength they lose their insulating property and begin to conduct.

Dielectric strength *is defined as the maximum value of electric field that a dielectric can tolerate without breakdown.*

The **SI unit** of dielectric strength is volt/metre.

Dimensions $[MLT^{-3}A^{-1}]$.

Polar Dielectrics

(i) In absence of external field the centre of positive and negative charge do not coincide-due to asymmetric shape of molecules.

(ii) Each molecule has permanent dipole moment.

(iii) In presence of external field dipoles tends to align in direction of field.

Ex. water, alcohol, N_2O, HCl, NH_3 etc.

Non-polar Dielectrics

(i) In absence of external field the centre of positive and negative charge coincides in these atoms or molecules because they are symmetric.

(ii) The dipole moment is zero in normal state.

(iii) In presence of external field they acquire induced dipole moment.

Ex. nitrogen, oxygen, benzene, methane etc.

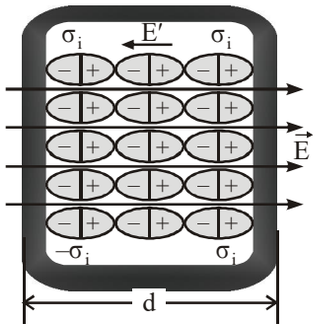
Polarisation :

The alignment of dipole moments of permanent or induced dipoles in the direction of applied electric field is called ***polarisation***.

Polarisation vector $\vec{P}$: This is a vector quantity which describes the extent to which molecules of dielectric become polarized by an electric field or oriented in direction of field.

$\vec{P}$ = dipole moment per unit volume of dielectric = n $\vec{p}$

where n is number of atoms per unit volume of dielectric and p is dipole moment of an atom or molecule.



The **SI unit** of polarisation vector $\vec{P}$ is C/m^2
Dimensions are $[M^0L^{-2}TA]$

CAPACITORS AND CAPACITANCE

A capacitor or condenser *is a device that stores electrical energy.*
The symbol of a capacitor is ⊣|⊢ or ⊣(⊢
The net charge on a capacitor is zero.
Capacitance or **capacity** *of a capacitor is a measure of ability of the capacitor to store charge on it.*

i.e., $Q \propto V$ or $Q = CV$ or, $C = \frac{Q}{V}$

The constant C is known as the **capacitance of the conductor.**
Capacitance is a scalar quantity.

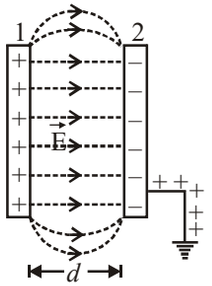
Dimensions of capacitance are $[M^{-1} L^{-2} T^4 A^2]$
Its **SI unit** is farad (F) or coulomb/volt

Capacitance of the conductor depends upon :
(i) Size of conductor
(ii) Surrounding medium
(iii) Presence of other conductors nearby

Capacitance of the conductor is independent of :
(a) Charge on conductor
(b) Potential of conductor
(c) Nature of material and thickness of the conductor

THE PARALLEL PLATE CAPACITOR

The capacitor has two parallel metallic plates of any shape each of surface area A. Both these plates are separated by a distance d. Plate 1 is given a positive charge so that equal negative charge is induced on the plate 2 which is earthed from outside.



The capacitance is given by, $C = \frac{K\varepsilon_0 A}{d}$
where K is the dielectric constant of the medium in between the plates.

Special cases : Effect of dielectric on capacitance

(i) When medium between the plates is air (K ≃ 1)

$$C = \frac{\varepsilon_0 A}{d}$$

(ii) When the space between the capacitor is partly filled with the dielectric,

$$C = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}} = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$$

(iii) When a metallic sheet of thickness t (t < d) is introduced between the plates, then

$$C = \frac{\varepsilon_0 A}{d - t}$$

(iv) When the space between the plates is filled with a dielectric medium which linearly varies as such its value near one plate is K_1, and that near the other plate is K_2, then

$$C = \frac{\varepsilon_0 A(K_2 - K_1)}{\log_e(K_2 / K_1)}$$

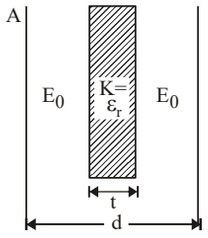
(v) If the space between the plates of a parallel plate capacitor is filled with two dielectric medium of thicknesses d_1 and d_2 ($d = d_1 + d_2$) having dielectric constants K_1 and K_2 then

the capacitance will be, $C = \frac{\varepsilon_0 A}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$

Capacity of Capacitor of Different Configuration

If a parallel plate capacitor is partially filled with dielectric of thickness t (t < d)

If no slab is introduced between the plates of the capacitor, then a field E_0 given by $E_0 = \frac{\sigma}{\varepsilon_0}$, exists in a space d.



On inserting the slab of thickness t, a field $E = \frac{E_0}{\varepsilon_r}$ exists inside the slab of thickness t and a field E_0 exists in remaining space (d – t). If V is total potential then

$$\Rightarrow \quad C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{\varepsilon_r}\right)} \qquad \text{....(1)}$$

If medium is fully present between the space.
$\because$ t = d
Now from equation (1)

$$C_{medium} = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

If capacitor is partially filled by a conducting slab of thickness t (t< d).

$\because$ $\varepsilon_r = \infty$ for conductor

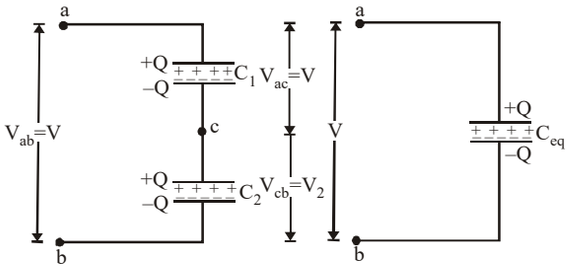
$$C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{\infty}\right)}$$

$$C = \frac{\varepsilon_0 A}{(d - t)}$$

COMBINATION OF CAPACITORS

Capacitors in Series:

In this arrangement of capacitors the charge has no alternative path(s) to flow.

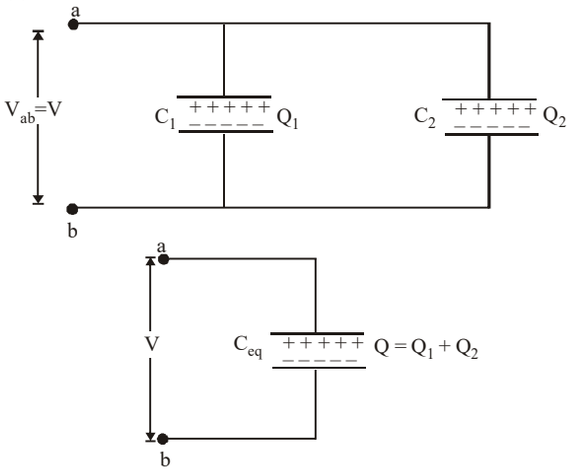


If there are n numbers of capacitors are joined in series then,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_n}$$

Capacitors in Parallel :

In such arrangement of capacitors the charge has an alternative path(s) to flow.



If there are 'n' number of capacitors are joined in parallel then, $C_{eq} = C_1 + C_2 + C_3 + ... + C_n$

TOPIC 8.3 : ENERGY STORED IN A CAPACITOR, ENERGY DENSITY AND VAN de GRAFF GENERATOR

ENERGY STORED IN A CAPACITOR

Let C is the capacitance of a conductor. On being connected to a battery. It charges to a potential V from zero potential. If q is charge on the conductor at that time, then q = CV

Energy stored in a charged capacitor,

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

ENERGY DENSITY

Energy density defined as energy stored per unit volume of space.

Energy density of electric field (μ) = $(1/2)\varepsilon_0 E^2$

Displacement Current

- A displacement current (i_d) exists at any point in space where time-varying electric field (E) exists $\left(\text{i.e.,} \frac{dE}{dt} \neq 0\right)$.
- The rate of change of electric field $\left(\frac{dE}{dt}\right)$ across the capacitor is directly proportional to the current (i_c) flowing in the corresponding part of the circuit.

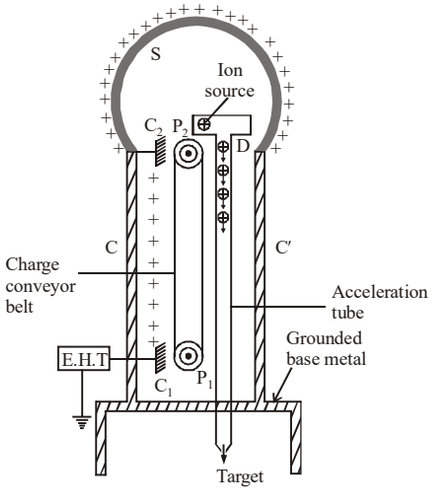
VAN de GRAFF GENERATOR (HIGH VOLTAGE GENERATOR)

R.J. Van de Graff in 1931 designed an electrostatic generator capable of generating very high potential of the order of 5×10^6 V, which was then made use of an accelerating charged particles so as to carry out nuclear reactions.

Principle : It is based on the following two electrostatic phenomena

(i) The electric discharge takes place in air or gases readily at pointed conductors.

(ii) If a hollow conductor is in contact with an other conductor, then as charge is supplied to the conductor, the hollow conductor continues accepting the charge irrespective of the fact, howsoever large its potential may grow.



TOPIC 8.4 : ELECTROSTATIC POTENTIAL & POTENTIAL ENERGY AND EQUIPOTENTIAL SURFACES

ELECTROSTATIC POTENTIAL

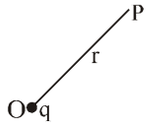
➢ Electrostatic potential at a point is analytically defined as a scalar function of position whose (–ve) gradient at that point gives electric field intensity $\vec{E}$.

i.e., $\vec{E} = -grad\, V \Rightarrow \vec{E} = -\frac{dv}{dr}\hat{n}$

so, $dv = -\vec{E} \cdot d\vec{r}$

i.e., $V = -\int_{\infty}^{r} \vec{E}.d\vec{r}$ i.e. $E = -\frac{dv}{dr}$

It is a scalar quantity.



Its **SI unit** is volt or joule coulomb^{-1}, **dimensions :** $[M L^2 T^{-3} A^{-1}]$

Electrostatic potential due to a point charge and system of charges

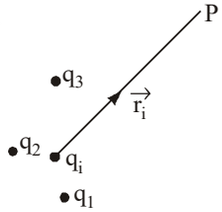
Electrostatic potential produced by a point charge, $V = \frac{kq}{r}$

(i) For discrete distribution of charge

– principle of superposition is valid.

$V = V_1 + V_2 + ... + V_n$

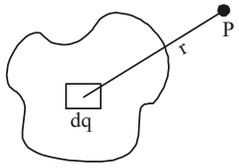
$= \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i}$



(ii) For continuous charge distribution, treating the element as a point.

$dv = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$

$\Rightarrow V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r}$



Where k is the dielectric constant of the medium.

Potential Difference

➢ *The potential difference between two points in an electric field is defined as the amount of work done in bringing a unit positive charge from one point to the other against the electric field.*

The potential difference between any two points A and B is given by

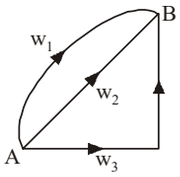
$V_B - V_A = \frac{W_{AB}}{q_0} \qquad V_{AB} = -\int_{A}^{B}\vec{E}(r)\cdot d\vec{r}$

Its **SI unit** is joule/coulomb and **dimensions** are $[ML^2T^{-3}A^{-1}]$

Its value does not depend on the frame of reference, hence it is an absolute quantity.

➢ As the electric field is **conservative**, work done and hence *potential difference between two points is path independent* and depends only on the position of points.

i.e., $W_1 = W_2 = W_3$.

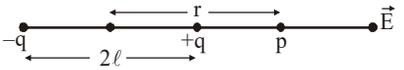


Electric potential is theoretically zero at infinite and practically zero at earth's surface.

POTENTIAL DUE TO AN ELECTRIC DIPOLE

Electric dipole *is a system formed by two equal and opposite charges placed at a short distance apart. Electric dipole moment* $\vec{p} = q \times 2\vec{\ell}$

(i) **End on or axial position**

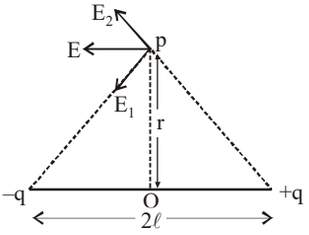


$V_{max.} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{P}{r^2}$ and $E_{max.} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{2P}{r^3}$

(ii) **Broad on or equatorial position**

$V = 0$

and $E_{min.} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{P}{r^3}$



Potential due to a dipole varies with distance, as $V \propto (1/r^2)$ and field $E \propto (1/r^3)$

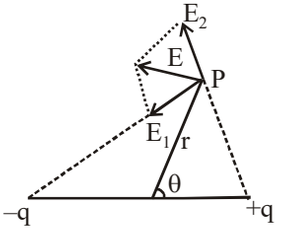
$V_{max.} = \frac{kP}{r^2}$ $(\theta = 0^o)$, $V = \frac{kP}{r^3}$ $(\theta = 90^o)$,

$E_{max.} = \frac{2kP}{r^3}$ $(\theta = 0^o)$, $E_{min.} = \frac{kP}{r^3}$ $(\theta = 90^o)$

➢ If the point 'p' lies on the line making an angle 'θ' with the axis of the dipole, then intensity at point p

$E = \frac{p}{4\pi\varepsilon_0 r^3}\sqrt{(3\cos^2\theta + 1)}$

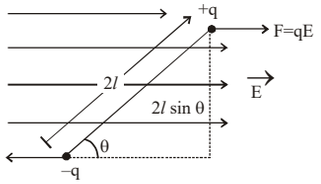
$V = \frac{1}{4\pi\varepsilon_0}\frac{P\cos\theta}{r^2}$



Electric Dipole in a Field

When an electric dipole is placed in an uniform electric field, a torque acts on it which subjects the dipole to rotatory motion.

$\vec{F}_{net} = [q\vec{E} + (-q\vec{E})] = 0$



Torque $\vec{\tau} = q\vec{E} \times 2\vec{\ell} \sin\theta$

$\Rightarrow \quad \vec{\tau} = \vec{P} \times \vec{E}$

There is no net force acting on the dipole in a uniform electric field.

Work done in rotating an electric dipole from θ_1 to θ_2 (uniform field)

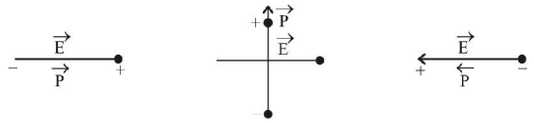
$$dw = \tau d\theta \Rightarrow w = \int dw = \int \tau\, d\theta$$

$$\Rightarrow \quad W = \int_{\theta_1}^{\theta_2} P E \sin\theta\, d\theta = PE(\cos\theta_1 - \cos\theta_2)$$

e.g. $W_{0 \to 180^\circ} = PE(1 - (-1)] = 2PE$

$W_{0 \to 90^\circ} = PE(1 - 0) = PE$

- **If a dipole is rotated from field direction ($\theta = 0$) to θ, then $W = PE(1 - \cos\theta)$**



τ = min = 0	τ = max. = PE	τ = min = 0
W = min = 0	W = PE	W = max. = 2PE

Relation Between Electric Field E and Electric Potential V

$$E = -\frac{\Delta V}{\Delta x}$$

For small changes, above expression may be written as $E_x = \frac{-dV}{dx}$

Thus, electric field intensity E is the negative gradient of potential. This means that decrease in potential is along the direction of E. The **SI unit** of E is therefore, volt per metre (Vm^{-1}).

POTENTIAL ENERGY (PE) IN AN EXTERNAL FIELD

In case of dipole (in uniform electric field) *potential energy of dipole is defined as work done in rotating a dipole from direction perpendicular* ($\perp$) *to the field to the given direction.*

i.e., $U = W_0 - W_{90^\circ} = PE(1 - \cos\theta) - PE = -PE\cos\theta.$

$\Rightarrow \quad U = -\vec{P}.\vec{E}$

$\vec{E}$ is a conservative field. So whatever work is done in rotating a dipole from θ_1 to θ_2 is just equal to change in electrostatic P.E.

$$W_{\theta_1 \to \theta_2} = U_{\theta_2} - U_{\theta_1} = PE(\cos\theta_1 - \cos\theta_2)$$

Dipole in a Uniform Electric Field

(a) If $\theta = 0^\circ$, i.e. $\vec{P} \parallel \vec{E}$, $\vec{\tau} = 0$ and U = – PE,

$\Rightarrow$ Dipole is in the minimum potential energy state and no torque acting on it and hence it is in the stable equilibrium state.

(b) For $\theta = 180^\circ$, i.e. $\vec{P}$ and $\vec{E}$ are in opposite direction then $\tau = 0$ but U = PE which is maximum potential energy state. Although it is in equilibrium, but it is not a stable state and a slight perturbation can disturb it.

Dipole in a Non-Uniform Electric Field

If dipole is placed in a Non-uniform electric field, it performed rotatory as well as translatory motion, because now a net force also acts on the dipole along with the torque.

- Torque τ on dipole in electric field $\vec{E}$ is given by $\vec{\tau} = \vec{P} \times \vec{E}$
- Potential energy of electric dipole in external electric field $U = -\vec{P}.\vec{E} = -PE\cos\theta = -PE\cos 180^\circ$

When angle between $\vec{E}$ and $\vec{P}$ is 180°

$\therefore$ U = +PE

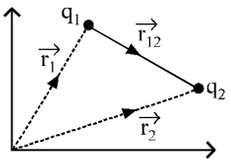
On moving towards right electric field strength decrease

$\therefore$ U decreases.

ELECTROSTATIC POTENTIAL ENERGY (EPE) OF A SYSTEM OF CHARGES

The electrostatic potential energy of a system of point charges is defined as the work done in assembling this system of charges from an infinite distance apart from one another.

$$U_{12} = \frac{kq_1q_2}{r_{12}} = q_1 V_2$$



By definition $V = \frac{U}{q_1} \Rightarrow U = q_1 V$

If the field is produced by a point charge q_2 which is at distance r_{12} from q_1, then

$$U = q_1\left(\frac{kq_2}{r_{12}}\right) = \frac{kq_1q_2}{r_{12}}$$

Due to discrete distribution of charges, (EPE) : $U = \frac{K}{2}\sum_{i \neq g}\frac{q_i q_j}{r_{ij}}$

(1/2 is used as each term in summation will appear twice).

Due to continuous distribution of charges :

$$dU = dq.\, V \Rightarrow U = \int V.dq$$

EQUIPOTENTIAL SURFACES (EPS)

For a given charge distribution, locus of all points having same potential is called equipotential surfaces.

Regarding equipotential surfaces, it is worth noting that :

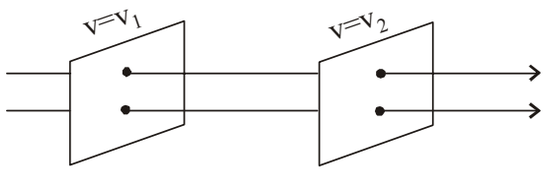
(i) EPS can never cross each other (otherwise potential at a point will have two values which is not possible)

(ii) EPS are always $\perp$ to ELF (electric line of force)

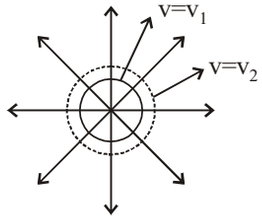
(iii) If a charge is moved from one point to other over an EPS work–done will be zero, as

$$W_{AB} = -V_{AB} = q(V_B - V_A) = 0 \; [\because V_A = V_B]$$

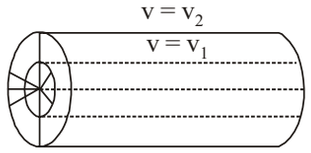
(iv) Shape of EPS in an uniform electric field is planar.



(v) Equipotential surface due to an isolated point charge is spherical.



(vi) Equipotential surface due to a line charge is cylindrical.



(vii) The intensity of electric field along an EPS is always zero.

CHAPTER AT A GLANCE

- Electric flux over an area is equal to the total number of electric field lines crossing this area.
  Electric flux through small area element ds is given by $\phi_E = E.ds$
- Gauss's theorem: The electric flux over any closed surface is $\frac{1}{\varepsilon_0}$ times the total charge enclosed by that surface,
  i.e., $\phi_E = \oint_s E.ds = \frac{1}{\varepsilon_0}\sum q$
- Electric field due to a charged spherical shell
  (i) At an extreme point (r > R); $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
  (ii) At the surface of a shell (r = R); $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$
  (iii) At an internal point (r < R); E = 0
- Electric field at a distance r from a long straight wire of uniform linear charge density λ, $E = \frac{\lambda}{2\pi\varepsilon_0 r}$
- Electric field of an infinite plane sheet of uniform surface charge density σ, $E = \frac{\sigma}{2\varepsilon_0}$
- Electric field of two equally and oppositely charged parallel plates,
  $E = 0$ (For outside points)
  $E = \frac{\sigma}{\varepsilon_0}$ (For inside points)
- The phenomenon of displacement of centres of positive and negative charges of a non-polar dielectric in the presence of external field is called dielectric polarisation.
  It is found that the induced dipole moment $\vec{p}$ is proportional to the electric field $\vec{E}$.
  It can be expressed as $\vec{p} = \alpha \in_0 \vec{E}$, where α is proportionality constant. It is known as atomic polarizability.
  The above equation can be in scalar form, as $p = \alpha \in_0$ or $\alpha = \frac{p}{\in_0 E}$
- Induced charge on the faces of dielectric due to dielectric polarisation is $q' = q[1 - (1/K)]$.
- Capacitance of a capacitor $C = \frac{Q}{V}$
- Capacitance of a parallel plate capacitor filled with air $C = \frac{\varepsilon_0 A}{d}$
- If condensers are connected in series then equivalent capacitance $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + ... \frac{1}{C_n}$
- If n identical condensers, each of capacity C are connected in series, then the effective capacitance of the system is C/n.
- In case of condensers connected in parallel, equivalent capacitance of the system will be $C = C_1 + C_2 + ...+C_n$
- If n identical capacitors each of capacity C are connected in parallel, then the effective capacitance of the system is nC.
- Energy stored in a capacitor, $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$
- Energy density of a charged capacitor, $u = \frac{1}{2}\varepsilon_0 E^2$

- Electric potential is the amount of work done in bringing a unit positive charge from infinity to the point in electrostatic field.

  Electric potential, $V = \frac{W}{q}$

- Electric potential due to a point charge $V = \frac{kq}{r}$
- Electric potential at a point due to a dipole,

  $V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{\vec{p}.\vec{r}}{r^3}$
- Electric potential difference

  $V_B - V_A = \frac{W_{AB}}{q} = -\int_A^B \vec{E}.\vec{d\ell} = kq\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$
- Relation between potential gradient and electric field,

  $\vec{E} = -\frac{dv}{dx}$ where, $\frac{dv}{dx}$ is the potential gradient
- Electrostatic potential energy, $u = \frac{kq_1q_2}{r}$
- Electric potential energy of a system of N point charges.

  $U = \frac{1}{4\pi\varepsilon_0}\sum_{\text{all pairs}}\cdot\frac{q_jq_k}{r_{jk}}$
- Potential energy of an electric dipole in a uniform electric field, $U = -pE(\cos\theta_2 - \cos\theta_1)$
- An equipotential surface is a surface with a constant value of potential at all points on the surface.
- σ due to dipole

Exercise 1 : WARM-UP
Topic-wise MCQs

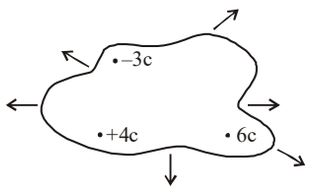
8.1 Electric Flux, Gauss's Law & its Applications, Conductors & Insulators

1. Gauss's law is valid for
(a) any closed surface
(b) only rectangular close surfaces
(c) any open surface
(d) only irregular open surface

2. A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will
(a) increase four times (b) be reduced to half
(c) remain the same (d) be doubled

3. Change of motion within the Gaussain surface gives
(a) electric field (b) electric flux
(c) charge (d) gaussain surface area

4. A closed surface is shown in the figure in an electric field. Total normal electric induction over the closed surface is equal to
(a) 13 c
(b) 7 c
(c) 72 c
(d) 12 c



5. Electric intensities due to a cylindrical conductor at two points at a distance x_1 and x_2 from its axis and outside the conductor are E_1 and E_2. Then
(a) $E_1/E_2 = x_1/x_2$
(b) $E_1/E_2 = x_2/x_1$
(c) $E_1/E_2 = x_1^2/x_2^2$
(d) $E_1/E_2 = x_2^2/x_1^2$

6. E is an intensity of electric field at a point and u is energy density at the same point. If the intensity is doubled, the energy density will be
(a) 2u (b) u/2
(c) 4u (d) 1/4u.

7. A charge q is placed at the center of one of the surface of a cube. The flux linked with the cube is :
(a) $\frac{q}{4\epsilon_0}$ (b) $\frac{q}{2\epsilon_0}$
(c) $\frac{q}{8\epsilon_0}$ (d) Zero

8. An electric field is given by $\left(6\hat{i}+5\hat{j}+3\hat{k}\right)N/C$. The electric flux through a surface area $30\hat{i}$ m^2 lying in YZ-plane (in SI unit) is ;
(a) 180 (b) 90
(c) 150 (d) 60

9. The electric field intensity at a point located at distance *r* ($r < R$) from the centre of a hollow spherical conductor (radius *R*) having charged *Q* will be

(a) $\frac{kQR}{r^3}$ (b) $\frac{kQR}{R^3}$

(c) $\frac{kQ}{r^2}$ (d) zero

10. A non-conducting sphere of radius R is uniformly charged. The electric field due to sphere at a distance r ($r < R$) from the centre is related to r as

(a) $E = 0$ (b) $E \propto \frac{1}{r^2}$

(c) $E \propto \frac{1}{r}$ (d) $E \propto r$

11. If same charge q is placed inside a sphere and cube having radius lm and side 2 m, respectively. What will be the ratio of flux passing through them?

(a) 1 : 1 (b) 1 : 8 (c) 8 : 1 (d) 1 : 2

12. A point charge +q is placed at mid point of a cube of side 'L'. The electric flux emerging from the cube is

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{6qL^2}{\varepsilon_0}$

(c) $\frac{q}{6L^2\varepsilon_0}$ (d) zero

13. It is not convenient to use a spherical Gaussian surface to find the electric field due to an electric dipole using Gauss's theorem because

(a) Gauss's law fails in this case
(b) This problem does not have spherical symmetry
(c) Coulomb's law is more fundamental than Gauss's law
(d) Spherical Gaussian surface will alter the dipole moment

14. The electric flux due to an electric field $\vec{E} = (8\hat{i} + 13\hat{j})\ \text{NC}^{-1}$ through an area 3 m^2 lying in the XZ plane is

(a) 39 Wb (b) 24 Wb
(c) 63 Wb (d) 15 Wb

15. If the electric flux entering and leaving an enclosed surface respectively is ϕ_1 and ϕ_2, the electric charge inside the surface will be

(a) $2(\phi_2 + \phi_1) \times \varepsilon_o$ (b) $2(\phi_1 - \phi_2) \times \varepsilon_o$
(c) $(\phi_1 + \phi_2) \times \varepsilon_o$ (d) $(\phi_2 - \phi_1) \times \varepsilon_o$

16. Two parallel large thin metal sheets have equal surface charge densities ($\sigma = 26.4 \times 10^{-12}\ \text{C/m}^2$) of same signs. The electric field between these sheets is

(a) 1.5 N/C (b) 1.5×10^{-10} N/C
(c) zero (d) 3×10^{-10} N/C

17. The electric field intensity (E) at a distance of 3 m from a uniform long straight wire of linear charge density 0.2 m Cm^{-1} is

(a) $1.2 \times 10^3\ \text{Vm}^{-1}$ (b) $0.6 \times 10^3\ \text{Vm}^{-1}$
(c) $1.8 \times 10^3\ \text{Vm}^{-1}$ (d) $2.4 \times 10^3\ \text{Vm}^{-1}$

18. The total electric flux through a closed spherical surface of radius 'r' enclosing an electric dipole of dipole moment 2 aq is (Give ε_0 = permittivity of free space)

(a) Zero (b) $\frac{q}{\varepsilon_0}$

(c) $\frac{2q}{\varepsilon_0}$ (d) $\frac{8\pi r^2 q}{\varepsilon_0}$

19. Electric field at a point varies as r^0 for

(a) an electric dipole
(b) a point charge
(c) a plane infinite sheet of charge
(d) a line charge of infinite length

20. If there is only one type of charge in the universe, then ($\vec{E} \rightarrow$ Electric field, $d\vec{s} \rightarrow$ Area vector)

(a) $\oint \vec{E} \cdot d\vec{s} \neq 0$ on any surface

(b) $\oint \vec{E} \cdot d\vec{s}$ could not be defined

(c) $\oint \vec{E} \cdot d\vec{s} = \infty$ if charge is inside

(d) $\oint \vec{E} \cdot d\vec{s} = 0$ if charge is outside, $= \frac{q}{\varepsilon_0}$ if charge is inside

21. The Gaussian surface

(a) can pass through a continuous charge distribution.
(b) cannot pass through a continuous charge distribution.
(c) can pass through any system of discrete charges.
(d) can pass through a continuous charge distribution. as well as any system of discrete charges.

22. Which statement is true for Gauss law-

(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.
(b) Electric flux depends upon the geometry of the gaussian surface.
(c) Gauss theorem can be applied to non-uniform electric field.
(d) The electric field over the gaussian surface remains continuous and uniform at every point.

23. The total electric flux emanating from a closed surface enclosing an α-particle is (e-electronic charge)

(a) $\frac{2e}{\varepsilon_0}$ (b) $\frac{e}{\varepsilon_0}$

(c) $e\varepsilon_0$ (d) $\frac{\varepsilon_0 e}{4}$

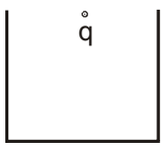
24. For a given surface the Gauss's law is stated as $\oint \vec{E}.d\vec{A} = 0$. From this we can conclude that

(a) E is necessarily zero on the surface
(b) E is perpendicular to the surface at every point
(c) the total flux through the surface is zero
(d) the flux is only going out of the surface

25. The electric field inside a spherical shell of uniform surface charge density is

(a) zero
(b) constant different from zero
(c) proportional to the distance from the curve
(d) None of the above

26. A charge q is placed at the centre of the open end of a cylindrical vessel. The flux of the electric field through the surface of the vessel is



(a) zero
(b) q/ε_o
(c) $q/2\varepsilon_o$
(d) $2q/\varepsilon_o$

27. At the centre of a cubical box + Q charge is placed. The value of total flux that is coming out a wall is

(a) Q/ε_o (b) $Q/3\varepsilon_o$
(c) $Q/4\varepsilon_o$ (d) $Q/6\varepsilon_o$

28. An electric dipole is put in north-south direction in a sphere filled with water. Which statement is correct?

(a) Electric flux is coming towards sphere.
(b) Electric flux is coming out of sphere.
(c) Electric flux entering into sphere and leaving the sphere are same.
(d) Water does not permit electric flux to enter into sphere.

29. A cylinder of radius r and length l is placed in an uniform electric field parallel to the axis of the cylinder. The total flux for the surface of the cylinder is given by-

(a) zero (b) πr^2
(c) $E\pi r^2$ (d) $2E\pi r^2$

30. A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will

(a) increase four times (b) be reduced to half
(c) remain the same (d) be doubled

31. A sphere encloses an electric dipole with charges $\pm 3 \times 10^{-6}$ C. What is the total electric flux across the sphere?

(a) 6×10^{-6} Nm^2/C (b) -3×10^{-6} Nm^2/C
(c) Zero (d) 3×10^{-6} Nm^2/C

32. A hollow insulated conduction sphere is given a positive charge of 10 mC. What will be the electric field at the centre of the sphere if its radius is 2 metres?

(a) zero (b) 5 mCm^{-2}
(c) 20 mCm^{-2} (d) 8 mCm^{-2}

33. A uniformly charged conducting sphere of 4.4 m diameter has a surface charge density of 60 μC m^{-2}. The charge on the sphere is

(a) $7.3 \times 10^{-3} C$ (b) 3.7×10^{-6} C
(c) $7.3 \times 10^{-6} C$ (d) $3.7 \times 10^{-3} C$

34. A cylinder of radius R and length ℓ is placed in a uniform electric field E parallel to the axis of the cylinder. The total flux over the curved surface of the cylinder is

(a) zero (b) $\pi R^2 E$
(c) $2\pi R^2 E$ (d) $E/\pi R^2$

35. Positive electric flux indicates that electric lines of force are directed

(a) outwards (b) inwards
(c) either (a) or (b) (d) None of these

36. Electric flux over a surface in an electric field may be

(a) positive (b) negative
(c) zero (d) All of these

37. A surface has the area vector $\vec{A} = \left(2\hat{i} + 3\hat{j}\right) m^2$. The flux of an electric field through it if the field is $\vec{E} = 4\hat{i}\,\frac{V}{m}$:

(a) 8 V-m (b) 12 V-m
(c) 20 V-m (d) zero

38. If the electric field is given by $(5\hat{i} + 4\hat{j} + 9\hat{k})$. The electric flux through a surface of area 20 units lying in the Y-Z plane will be

(a) 100 units (b) 80 units
(c) 180 units (d) 20 units

8.2 Dielectrics & Electric Polarisation, Capacitors & Capacitance, Parallel Plate Capacitor and Combination of Capacitors

39. The capacitance of a parallel plate capacitor is C. If one of its plates is removed, then capacitance of the isolated plate will be

(a) C (b) $2C$
(c) infinite (d) zero

40. The capacitance of the two identical capacitors placed in series is $2C$. Their capacitance when they are placed in parallel is :

(a) C (b) $2C$

(c) $4C$ (d) $8C$

41. A capacitor C can store a maximum charge Q while another capacitor 2C can store a maximum charge Q/2. What maximum charge can be stored by a parallel combination of the two capacitors ?

(a) 3Q/4 (b) Q/4

(c) Q/2 (d) Q

42. A dielectric slab is inserted between the plates of an isolated charged capacitor. Which of the following quantities remain unchanged ?

(a) The charge on the capacitor

(b) The stored energy in the capacitor

(c) The potential difference between the plates

(d) The electric field in the capacitor

43. The capacity of the conductor does not depend upon

(a) charge (b) voltage

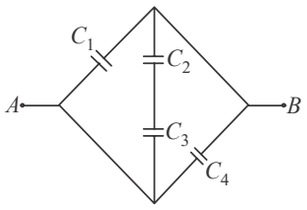
(c) nature of the material (d) All of these

44. Capacitors are used in electrical circuits where appliances need more

(a) current (b) voltage

(c) watt (d) resistance

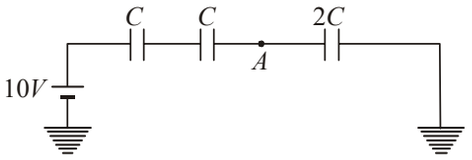
45. In a given network the equivalent capacitance between A and B is $[C_1 = C_4 = 1\ \mu F, C_2 = C_3 = 2\mu F$



(a) $3\ \mu F$ (b) $6\ \mu F$

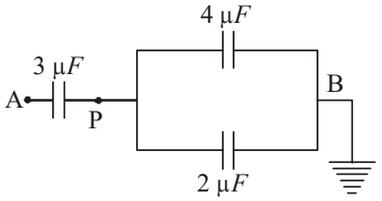
(c) $4.5\ \mu F$ (c) $2.5\ \mu F$

46. In circuit shown in the figure, what is potential of point A?



(a) 2V (b) 5V (c) 8V (d) 4V

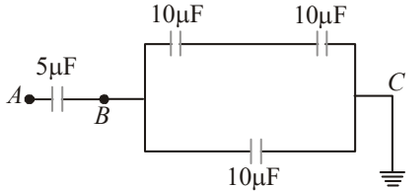
47. In the figure a potential of + 1200 V is given to point A and point B is earthed, what is the potential at the point P



(a) 100 V (b) 200 V

(c) 400 V (d) 600 V

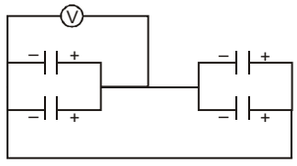
48. In the given circuit if point C is connected to the earth and a potential of +2000V is given to the point A, the potential at B is



(a) 1500V (b) 1000 V

(c) 500 V (d) 400 V

49. The four capacitors, each of 25 μ F are connected as shown in fig. The dc voltmeter reads 200 V. The charge on each plate of capacitor is



(a) $\pm 2\times10^{-3}$ C

(b) $\pm 5\times10^{-3}$ C

(c) $\pm 2\times10^{-2}$ C

(d) $\pm 5\times10^{-2}$ C

50. Capacitance (in F) of a spherical conductor with radius 1 m is

(a) 1.1×10^{-10} (b) 10^6

(c) 9×10^{-9} (d) 10^{-3}

51. The capacity of parallel plate condenser depends on

(a) the type of metal used

(b) the thickness of plates

(c) the potential applied across the plates

(d) the separation between the plates

52. A capacitor of capacitance 15 nF having dielectric slab of $\varepsilon_r = 2.5$, dielectric strength = 30 MV/m and potential difference = 30 V. Calculate the area of the plate.

(a) $6.7 \times 10^{-4}\ m^2$ (b) $4.2 \times 10^{-4}\ m^2$

(c) $8.0 \times 10^{-4}\ m^2$ (d) $9.85 \times 10^{-4}\ m^2$

53. Eight drops of mercury of equal radii combine to form a big drop. The capacitance of a bigger drop as compared to each smaller drop is

(a) 2 times (b) 8 times

(c) 4 times (d) 16 times

54. A 20 μF capacitor is connected to 45 V battery through a circuit whose resistance is 2000 Ω. What is the final charge on the capacitor?

(a) 9×10^{-4} C (b) 9.15×10^{-4}C

(c) 9.8×10^{-4} C (d) None of these

55. On decreasing the distance between the plates of a parallel plate capacitor, its capacitance
(a) remains unaffected
(b) decreases
(c) first increases then decreases.
(d) increases

56. If in a parallel plate capacitor, which is connected to a battery, we fill dielectrics in whole space of its plates, then which of the following increases?
(a) Q and V (b) V and E
(c) E and C (d) Q and C

57. A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential and capacitance respectively are
(a) increases, decreases, decreases
(b) constant, increases, decreases
(c) constant, decreases, decreases
(d) constant, decreases, increases.

58. A parallel plate capacitor is charged by connecting a 2 V battery across it. It is then disconnected from the battery and a glass slab is introduced between plates. Which of the following pairs of quantities decrease?
(a) Energy stored and capacitance.
(b) Charge and potential difference.
(c) Capacitance and charge.
(d) Potential difference and energy stored.

59. The capacitance of a spherical condenser is 1 μF. If the spacing between the two spheres is 1 mm, then the radius of the outer sphere is
(a) 30 cm (b) 6m
(c) 5 cm (d) 3m

60. If the dielectric constant and dielectric strength be denoted by K and x, respectively, then a material suitable for use as a dielectric in a capacitor must have
(a) high K and high x (b) high K and low x
(c) low K and low x (d) low K and high x

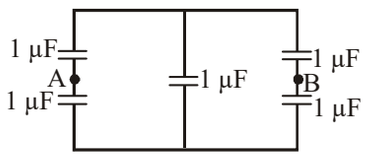
61. A capacitor is kept connected to the battery and a dielectric slab is inserted between the plates. During this process
(a) No work is done
(b) Work is done at the cost of the energy already stored in the capacitor before the slab is inserted.
(c) Work is done at the cost of the battery
(d) Work is done at the cost of both the capacitor and the battery.

62. When air in a capacitor is replaced by a medium of dielectric constant K, the capacity
(a) decreases K times (b) increases K times
(c) increases K^2 times (d) remains constant

63. Capacitiors are used in electrical circuits where applicances need more
(a) voltage (b) current
(c) resistance (d) power

64. Three parallel plate capacitors of capacitances 4 μF, 6 μF and 12 μF are first connected in series and then in parallel. The ratio of the effective capacitances in the two cases is
(a) 1 : 11 (b) 5 : 8 (c) 3 : 7 (d) 4 : 9

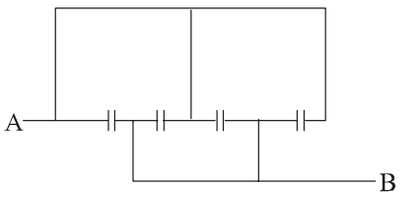
65. Five capacitors each of value 1μF are connected as shown in the figure. The equivalent capacitance between A and B is



(a) 1 μF (b) 2 μF
(c) 5 μF (d) 3 μF

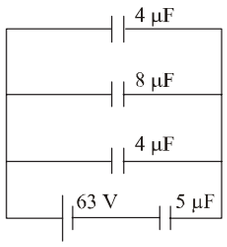
66. The difference between equivalent capacitances of two identical capacitors connected in parallel to that in series is 6 μF. The value of capacitance of each capacitor is
(a) 4 μF (b) 6 μF
(c) 2 μF (d) 3 μF

67. Four condensers each of capacitance 8 μF are joined as shown in the figure. The equivalent capacitance between the points A & B will be



(a) 32 μF (b) 2 μF (c) 8 μF (d) 16 μF

68. In the given circuit, the potential difference across 5 μF capacitor is



(a) 48 V
(b) 24 V
(c) 63 V
(d) 21 V

69. The capacitors of capacity C_1 and C_2 are connected in parallel, then the equivalent capacitance is

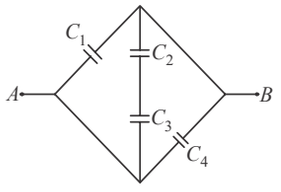
(a) $C_1 + C_2$ (b) $\frac{C_1C_2}{C_1+C_2}$

(c) $\frac{C_1}{C_2}$ (d) $\frac{C_2}{C_1}$

70. Three capacitors each of 4 μF are to be connected in such a way that the effective capacitance is 6μF. This can be done by connecting them :

(a) all in series
(b) all in parallel
(c) two in parallel and one in series
(d) two in series and one in parallel

71. In a given network the equivalent capacitance between *A* and *B* is [$C_1 = C_4 = 1$ μF, $C_2 = C_3 = 2$μF



(a) 3 μ*F* (b) 6 μ*F*
(c) 4.5 μ*F* (d) 2.5 μ*F*

72. The minimum value of effective capacitance that can be obtained by combining 3 capacitors of capacitances 1 pF, 2 pF and 4 pF is

(a) $\frac{7}{4}$pF (b) $\frac{4}{7}$pF

(c) 1pF (d) 2pF

73. A capacitor of capacitance *C* charged by an amount *Q* is connected in parallel with an uncharged capacitor of capacitance 2*C*. The final charges on the capacitors are

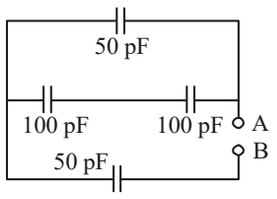
(a) $\frac{Q}{3}, \frac{2Q}{3}$ (b) $\frac{Q}{2}, \frac{Q}{2}$

(c) $\frac{Q}{5}, \frac{4Q}{5}$ (d) $\frac{Q}{4}, \frac{3Q}{4}$

74. Two capacitors of 10 pF and 20 pF are connected to 200 V and 100 V sources respectively. If they are connected by the wire, what is the common potential of the capacitors?

(a) 300 volt (b) 133.3 volt
(c) 400 volt (d) 150 volt

75. The equivalent capacitance between *A* and *B* is,



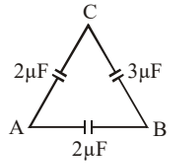
(a) 150 pF (b) 50 pF
(c) 300 pF (d) $\frac{100}{3}$pF

76. Three capacitors 2 μF, 3 μF and 6 μF are joined in series with each other. The equivalent capacitance is-

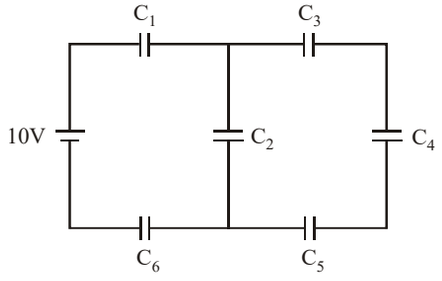
(a) 1/2 μF (b) 1 μF
(c) 2 μF (d) 11 μF

77. Three capacitors are connected in the arms of a triangle ABC as shown in figure 5 V is applied between A and B. The voltage between B and C is

(a) 2V
(b) 1V
(c) 3V
(d) 1.5V



78. In the given circuit, $C_1 = 2$ μF, $C_2 = 0.2$ μF, $C_3 = 2$ μF, $C_4 = 4$ μF, $C_5 = 2$ μF, $C_6 = 2$ μF, the charge stored on capacitor C_4 is



(a) 2 μC (b) 4 μC
(c) 6 μC (d) 8 μC

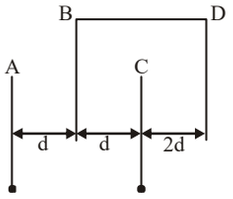
79. Two capacitors of capacitances C_1 and C_2 are connected in series, assume that $C_1 < C_2$. The equivalent capacitance of this arrangement is *C*, where

(a) $C < C_1/2$
(b) $C_1/2 < C < C_2/2$
(c) $C_1 < C < C_2$
(d) $C_2 < C < 2C_2$

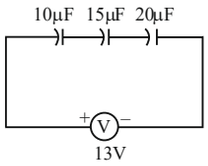
80. Four identical square plates of side *a* are arranged as shown. The equivalent capacity between A and C

(a) $\frac{3\varepsilon_0 a^2}{2d}$ (b) $\frac{3\varepsilon_0 a^2}{5d}$

(c) $\frac{3\varepsilon_0 a^2}{3d}$ (d) $\frac{5\varepsilon_0 a^2}{3d}$



81. The charge on capacitor of capacitance 15μF in the figure given below is :



(a) 60 μc (b) 130 μc

(c) 260 μc (d) 585 μc

82. From a supply of identical capacitors rated 8 mF, 250V, the minimum number of capacitors required to form a composite 16 mF, 1000V is

(a) 2 (b) 4

(c) 16 (d) 32

83. The resultant capacitance of n condenser of capacitances $C_1, C_2 .... C_n$ connected in series is given by

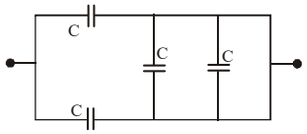
(a) $C_s = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}$

(b) $\frac{1}{C_s} = \frac{1}{C_1} + ... + \frac{1}{C_n}$

(c) $C_s = C_1 + C_2 + ... + C_n$

(d) $C_s = C_1 - C_2 + ... - C_n$

84. The equivalent capacitance of the combination shown is



(a) $\frac{C}{2}$ (b) 4C (c) 2C (d) $\frac{5}{3}C$

85. The resultant capacity of n condensers of capacitances $C_1, C_2 .... C_n$ connected in parallel is

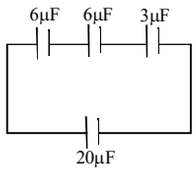
(a) $C_p = C_1 + C_2 + ... + C_n$

(b) $C_p = C_1 - C_2 - C_3 ..... - C_n$

(c) $\frac{1}{C_p} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}$

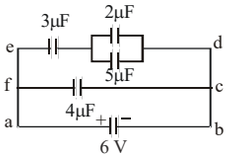
(d) $C_p = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}$

86. The capacitor, whose capacitance is 6, 6 and 3μF respectively are connected in series with 20 volt line. Find the charge on 3μF.



(a) 30 μc (b) 60 μF (c) 15 μF (d) 90 μF

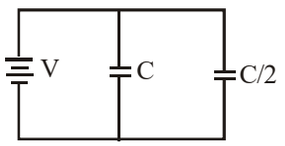
87. In the circuit given below, the charge in μC, on the capacitor having capacitance 5 μF is



(a) 4.5 (b) 9 (c) 7 (d) 15

8.3 Energy Stored in a Capacitor, Energy Density and Van de Graff Generator

88. Two condensers, one of capacity C and other of capacity C/2 are connected to a V-volt battery, as shown.
The work done in charging fully both the condensers is



(a) $\frac{1}{4}CV^2$ (b) $\frac{3}{4}CV^2$

(c) $\frac{1}{2}CV^2$ (d) $2CV^2$.

89. Two positive point charges of 12 μC and 8 μC are 10 cm apart. The work done is bringing them 4 cm closer is

(a) 5.8 J (b) 5.8 eV (c) 13 J (d) 13 eV

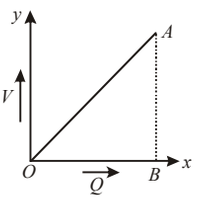
90. Charge Q on a capacitor varies with voltage V as shown in the figure, where Q is taken along the X-axis and V along the Y-axis. The area of triangle OAB represents

(a) capacitance

(b) capacitive reactance

(c) magnetic field between the plates

(d) energy stored in the capacitor



91. A capacitor is charged to store an energy U. The charging battery is disconnected. An identical capacitor is now connected to the first capacitor in parallel. The energy in each of the capacitors is

(a) 3 U/2 (b) U

(c) U/4 (d) U/2

92. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved further apart by means of insulating handles, then

(a) the charge on the capacitor increases

(b) the voltage across the plates decreases

(c) the capacitance increases

(d) the electrostatic energy stored in the capacitor increases.

93. Work done by an external agent in separating the parallel plate capacitor is

(a) CV (b) $\frac{1}{2}C^2V$

(c) $\frac{1}{2}CV^2$ (d) none of these

94. A one microfarad capacitor of a TV is subjected to 4000 V potential difference. The energy stored in capacitor is

(a) 8 J (b) 16 J

(c) 4×10^{-3} J (d) 2×10^{-3} J

95. A system of 2 capacitors of capacitance 2 μF and 4 μF is connected in series across a potential difference of 6 V. The electric charge and energy stored in the system are

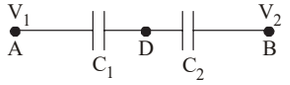
(a) 1 μC and 3 μJ

(b) 8 μC and 24 μJ

(c) 10 μC and 30 μJ

(d) 36 μC and 108 μJ

96. Two condensers C_1 & C_2 in a circuit are joined as shown in the figure. The potential of point A is V_1 and that of point B is V_2. The potential at point D will be



(a) $\frac{1}{2}(V_1 + V_2)$ (b) $\frac{C_2V_1 + C_1V_2}{C_1 + C_2}$

(c) $\frac{C_1V_1 + C_2V_2}{C_1 + C_2}$ (d) $\frac{C_2V_2 - C_1V_2}{C_1 + C_2}$

97. Energy of a parallel plate capacitor, when dielectric of dielectric constant k is introduced keeping battery remains connected becomes

(a) decreased

(b) remains constant

(c) increased by a factor of k

(d) increased by a factor of k^2

98. If a capacitor 900 μF is charged to 100 V and its total energy is transferred to a capacitor of capacitance 100 μF then its potential is

(a) 200 V (b) 30 V

(c) 300 V (d) 400 V

99. n identical condensers are joined in parallel and are charged to potential V. Now they are separated and joined in series. Then the

(a) Total energy and potential difference remain same

(b) Total energy remains same and potential difference becomes nV

(c) Total energy increases n times and potential difference becomes nV

(d) Total energy increases n times and potential difference remains same

100. A capacitor of capacitance C and potential V has energy E. It is connected to another capacitor of capacitance 2C and potential 2V. Then the loss of energy is $\frac{x}{3}$E, where x is

(a) 9 (b) 11 (c) 2 (d) 3

101. Two identical capacitors are joined in parallel and charged to a potential V. Now these are separated and connected in series. i.e., the positive plate of one is connected to negative of the other, while open plates are kept open ended

(a) The charges on the plates connected together finally become zero

(b) The charges on the free plates are enhanced

(c) The energy stored in the system increases

(d) The potential difference between the free plates becomes $2V$

102. While a capacitor remains connected to a battery and dielectric slab is applied between the plates, then

(a) Potential difference between the plates is changed.

(b) Charge flows from the battery to the capacitor

(c) Electric field between the plates increases

(d) Energy stored in the capacitor decreases

103. A conductor carries a certain charge. When it is connected to another uncharged conductor of finite capacity, then the energy of the combined system is

(a) more than that of the first conductor

(b) less than that of the first conductor

(c) equal to that of the first conductor

(d) uncertain

104. The energy stored in a condenser of capacity C which has been raised to a potential V is given by

(a) $u = \frac{1}{2} CV$ (b) $u = \frac{1}{2} CV^2$

(c) $u = CV$ (d) $u = \frac{1}{2VC}$

105. The work done in placing a charge of 8×10^{-18} coulomb on a condenser of capacity 100 micro-farad is

(a) 3.1×10^{-26} joule
(b) 4×10^{-10} joule
(c) 32×10^{-32} joule
(d) 16×10^{-32} joule

106. A capacitor with capacitance 5μF is charged to 5 μC. If the plates are pulled apart to reduce the capacitance to 2 μF, how much work is done?

(a) 6.25×10^{-6} J (b) 3.75×10^{-6} J
(c) 2.16×10^{-6} J (d) 2.55×10^{-6} J

8.4 Electrostatic Potential & Potential Energy and Equipotential Surfaces

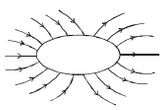
107. In a region, the electric field is $(30\bar{i} + 40\bar{j})NC^{-1}$. If the electric potential at the origin is zero, the electric potential at the point (1 m, 2 m) is

(a) –60 V (b) –75 V
(c) –55 V (d) –110 V

108. A cube of a metal is given a positive charge Q. For this system, which of the following statements is true?

(a) Electric potential at the surface of the cube is zero
(b) Electric potential within the cube is zero
(c) Electric field is normal to the surface of the cube
(d) Electric field varies within the cube

109. Figure below shows a hollow conducting body placed in an electric field. Which of the quantities are zero inside the body?



(a) Electric field and potential
(b) Electric field and charge density
(c) Electric potential and charge density.
(d) Electric field, potential and charge density.

110. The potential at a point x (measured in μm) due to some charges situated on the x-axis is given by $V(x) = 20/(x^2 - 4)$ volt. The electric field E at $x = 4$ μm is given by

(a) (10/9) volt/μm and in the +ve x direction
(b) (5/3) volt/μm and in the –ve x direction
(c) (5/3) volt/μm and in the +ve x direction
(d) (10/9) volt/μm and in the –ve x direction

111. The expression $E = -\frac{dv}{dr}$ implies, that electric field is in that direction in which

(a) increase in potential is steepest.
(b) decrease in potential is steepest.
(c) change in potential is minimum.
(d) None of these

112. The electric potential at a point (x, y) in the x – y plane is given by V = –kxy. The field intensity at a distance r from the origin varies as

(a) r^2 (b) r

(c) $\frac{1}{r}$ (d) $\frac{1}{r^2}$

113. If the electric potential at any point (x, y, z) m in space is given by $V = 3x^2$ volt. The electric field at the point (1, 0, 3) m will be :

(a) 3 Vm^{-1}, directed along positive x-axis.
(b) 3 Vm^{-1}, directed along negative x-axis.
(c) 6 Vm^{-1}, directed along positive x-axis.
(d) 6 Vm^{-1}, directed along negative x-axis.

114. What is an instantaneous rate of change of voltage for displacement current of 10A current in the space between the parrallel plate of 1μF capacitor?

(a) 10^5 Vs^{-1} (b) 10^6 Vs^{-1}
(c) 10^{-6} Vs^{-1} (d) 10^7 Vs^{-1}

115. The charge of a parallel plate capacitor in varying as $q = q_0 \sin 2\pi ft$. The plates are very large and close together (area = A, separation = d). Neglecting edge effects, the displacement current through the capacitor is

(a) $\frac{d}{A\varepsilon_0}$

(b) $\frac{d}{\varepsilon_0} \sin 2\pi ft$

(c) $2\pi f q_0 \cos 2\pi ft$

(d) $\frac{2\pi f q_0}{\varepsilon_0} \cos 2\pi ft$

Exercise 2 : ACCELERATOR
Topic-wise MCQs

8.1 Electric Flux, Gauss's Law & its Applications, Conductors & Insulators

1. A charged conductor of area ds is placed in electric field of strength E. The force acting on unit area of the conductor is

(a) $\frac{\epsilon_0 kE^2}{2}$ (b) $\frac{\epsilon_0 k}{2E}$ (c) $\frac{E^2}{2\epsilon_0 k}$ (d) $\epsilon_0 kE^2$

2. A metal surface of area 1 m^2 is charged with $\sqrt{8.85}\mu C$ in air. The mechanical force acting on it is

(a) 1 N (b) 0.5 N (c) 10 N (d) 50 N

3. The mechanical force acting on a unit area of a charged conductor is

(a) $f = \frac{\sigma^2}{2\epsilon_0 k}$ (b) $f = \frac{\sigma}{2\epsilon_0 k}$

(c) $f = \frac{\sigma^2}{\epsilon_0 k}$ (d) $f = \frac{\sigma}{\epsilon_0 k}$

4. A force of 2.25 N acts on a charge of 15 × 10–4C. The intensity of the electric field at the point is

(a) 375 N/C (b) 1500 N/C
(c) 1666 N/C (d) 2000 N/C

5. A cylinder of length L has a charge of magnitude q. The electric intensity at a point at a distance r from the axis of the cylinder is

(a) $E = \frac{1}{4\pi\epsilon_0 k}.\frac{q}{r^2}$ (b) $E = \frac{1}{2\pi\epsilon_0 k}.\frac{q}{rL}$

(c) $E = \sigma / \epsilon_0 k$ (d) none of these

6. A conductor having a charge density of 120 $\mu C/m^2$ is surrounded by a medium of dielectric constant 4. The electric intensity at a point very near the charged conductor is

(a) 9.33×10^6 N/C (b) 3.39×10^8 N/C
(c) 9.33×10^8 N/C (d) 3.389×10^6 N/C

7. A metal sphere of radius 10 cm is given a charge of 12 μC. The force acting on unit area of its surface is

(a) 5.151×10^2 N/m^2 (b) 5.15×10^3 N/m^2
(c) 515×10^{-2} N/m^2 (d) 5.15×10^{-3} N/m^2

8. Which of the following is correct?

(a) Gauss's law is valid only for symmetrical charge distributions.
(b) Gauss's law is valid only for charge placed in vacuum.
(c) The electric field calculated by Gauss's law is the field due to the charges outside the Gaussian surface.
(d) The flux of the electric field through a closed surface due to all the charges is equal to the flux due to the charges enclosed by the surface.

9. The inward and outward electric flux for a closed surface in units of N-m^2/C are respectively 8×10^3 and 4×10^3. Then the total charge inside the surface is [where ε_0 = permittivity constant]

(a) $4 \times 10^3 C$ (b) $-4 \times 10^3 C$

(c) $\frac{(-4 \times 10^3)}{\varepsilon} C$ (d) $-4 \times 10^3 \varepsilon_0 C$

10. For a given surface the Gauss's law is stated as $\oint E.ds = 0$. From this we can conclude that

(a) E is necessarily zero on the surface
(b) E is perpendicular to the surface at every point
(c) the total flux through the surface is zero
(d) the flux is only going out of the surface

11. Three charges +4q, Q and q are placed in a straight line of length l at points distant, 0, l/2 and l respectively. What should be Q in order to make the net force on q to be zero?

(a) Q = – q (b) Q = q
(c) $Q = q^2$ (d) Q = 2q

12. Two charges of 5Q and –2Q are situated at the points (3a, 0) and (–5a, 0) respectively. The electric flux through a sphere of radius '4a' having center at origin is:

(a) $\frac{3Q}{\varepsilon_0}$ (b) $\frac{5Q}{\varepsilon_0}$ (c) $\frac{7Q}{\varepsilon_0}$ (d) $\frac{2Q}{\varepsilon_0}$

13. An electric field, $\vec{E} = \frac{2\hat{i} + 6\hat{j} + 8\hat{k}}{\sqrt{6}}$ passes through the surface of 4 m^2 area having unit vector $\hat{n} = \left(\frac{2\hat{i} + \hat{j} + \hat{k}}{\sqrt{6}}\right)$. The electric flux for that surface is

(a) 12 Vm (b) 14 Vm
(c) 16 Vm (d) 18 Vm

14. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 17.0×10^{-22} Cm^{-2}. What is *E* in the outer region of the first plate?

(a) 17×10^{-22} N/C (b) 1.5×10^{-15} N/C
(c) 1.9×10^{-10} N/C (d) Zero

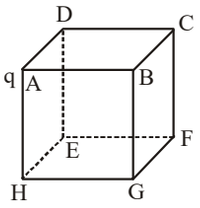
15. An electric field given by $\vec{E} = 4\hat{i} + 3(y^2 + 2)\hat{j}$ pierces Gaussian cube of side 1 m placed at origin such that its three sides represents x, y and z axes. The net charge enclosed within the cube is

(a) $4\varepsilon_0$ (b) $3\varepsilon_0$ (c) $5\varepsilon_0$ (d) zero

16. A point charge q is placed at the corner of a cube of side a as shown in the figure. What is the electric flux through the face $ABCD$?

(a) $\frac{q}{6\varepsilon_0}$ (b) $\frac{q}{72\varepsilon_0}$

(c) 0 (d) $\frac{q}{24\varepsilon_0}$



17. If an area is tilted in the direction of field such that normal to plane of area makes θ angle with the direction of field, then number of field lines passing through the area is

(a) equal to $E\Delta S \times 4$
(b) proportional to $E\Delta S \cos\theta$
(c) equal to $E\Delta S \cos\Delta$
(d) proportional to $E\Delta S \cos\theta/r^2$

18. In a region of space having a uniform electric field E, a hemispherical bowl of radius r is placed. The electric flux ϕ through the bowl is

(a) $2\pi RE$ (b) $4\pi R^2E$ (c) $2\pi R^2E$ (d) πR^2E

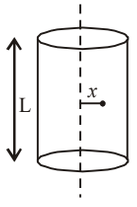
19. A charge +q is at a distance L/2 above a square of side L. Then what is the flux linked with the surface?

(a) $\frac{q}{4\varepsilon_0}$ (b) $\frac{2q}{3\varepsilon_0}$ (c) $\frac{q}{6\varepsilon_0}$ (d) $\frac{6q}{\varepsilon_0}$

20. A loop of diameter d is rotated in a uniform electric field until the position of maximum electric flux is found. The flux in this position is measured to be ϕ. What is the electric field strength ?

(a) $\frac{4\phi}{\pi d^2}$ (b) $\frac{2\phi}{\pi d^2}$ (c) $\frac{\phi}{\pi d^2}$ (d) $\frac{\pi\phi d^2}{4}$

21. A long cylindrical volume contains a uniformly distributed charge of density ρ Cm^{-3}. The electric field inside the cylindrical volume at a distance $x = \frac{2\varepsilon_0}{\rho}$ m from its axis is



(a) $1\ Vm^{-1}$ (b) $3\ Vm^{-1}$ (c) $5\ Vm^{-1}$ (d) $7\ Vm^{-1}$

22. The electric field in a region is given by $\vec{E} = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$ with $E_0 = 4.0\times10^3 \frac{N}{C}$. The flux of this field through a rectangular surface area 0.4 m^2 parallel to the Y – Z plane is

(a) $240\ Nm^2C^{-1}$ (b) $540\ Nm^2C^{-1}$
(c) $640\ Nm^2C^{-1}$ (d) $740\ Nm^2C^{-1}$

23. A rod of length 2.4 m and radius 4.6 mm carries a negative charge of 4.2×10^{-7} C spread uniformly over it surface. The electric field near the mid–point of the rod, at a point on its surface is

(a) $-8.6 \times 10^5\ N\ C^{-1}$ (b) $8.6 \times 10^4\ N\ C^{-1}$
(c) $-6.7 \times 10^5\ N\ C^{-1}$ (d) $6.7 \times 10^4\ N\ C^{-1}$

24. The number of electric lines of force that radiate outwards from one coulomb of charge in vacuum is

(a) 1.13×10^{11} (b) 1.13×10^{10}
(c) 0.61×10^{11} (d) 0.61×10^9

25. The electric field in a region of space is given by, $\vec{E} = E_o\hat{i} + 2E_o\hat{j}$ where $E_o = 100$ N/C. The flux of the field through a circular surface of radius 0.02 m parallel to theY-Z plane is nearly:

(a) $0.125\ Nm^2/C$ (b) $0.02\ Nm^2/C$
(c) $0.005\ Nm^2/C$ (d) $3.14\ Nm^2/C$

26. If electric field in a region is radially outward with magnitude $E = Ar$, the charge contained in a sphere of radius r centred at the origin is

(a) $\frac{1}{4\pi\varepsilon_o}Ar^3$ (b) $4\pi\varepsilon_oAr^3$

(c) $\frac{1}{4\pi\varepsilon_o}\frac{A}{r^3}$ (d) $\frac{4\pi\varepsilon_oA}{r^3}$

27. A uniform electric field $E = 3 \times 10^5\ NC^{-1}$ is acting along the positive Y-axis. The electric flux through a rectangle of area 10 cm × 30 cm whose plane is parallel to the Z-X plane is

(a) $12 \times 10^3\ Vm$ (b) $9 \times 10^3\ Vm$
(c) $15 \times 10^3\ Vm$ (d) $18 \times 10^3\ Vm$

28. The inward and outward electric flux for a closed surface in units of N-m^2/C are respectively 8×10^3 and 4×10^3. Then the total charge inside the surface is [where ε_0= permittivity constant]

(a) $4 \times 10^3\ C$ (b) $-4 \times 10^3\ C$

(c) $\frac{(-4\times10^3)}{\varepsilon}C$ (d) $-4 \times 10^3\varepsilon_0C$

8.2 Dielectrics & Electric Polarisation, Capacitors & Capacitance, Parallel Plate Capacitor and Combination of Capacitors

29. When two identical capacitors are charged individually to different potentials and then connected in parallel, after disconnecting from the source

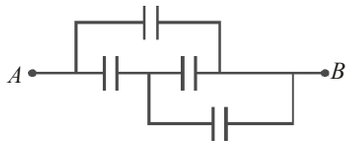
(a) net charge = sum of initial charges
(b) net potential difference ≠ sum of individual initial potential difference
(c) net energy stored < sum of individual intial energy
(d) all of these

30. By keeping the charge on a capacitor unchanged, the energy of capacitor can be decreased by

(a) increasing dielectric constant of the medium between the plates
(b) decreasing dielectric constant of the medium between the plates
(c) making the dielectric constant zero
(d) none of these

31. A capacitor is connected to a battery of 20 V, so that a charge of 100 μC is obtained at the plates. The capacitance of the capacitor is
(a) 6 μF (b) 5 μF (c) 9.5 μF (d) 10 μF

32. In the circuit shown in figure, each capacitor has a capacity of 3μF. The equivalent capacitance between *A* and *B* is



(a) $\frac{3}{4}\mu F$ (b) 3μF (c) 6μF (d) 5μF

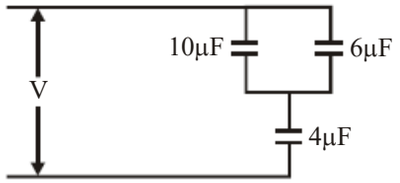
33. A 20 μF capacitor is connected to 45 V battery through a circuit whose resistance is 2000 Ω. What is the final charge on the capacitor?
(a) 9×10^{-4} C (b) 9.15×10^{-4}C
(c) 9.8×10^{-4} C (d) None of these

34. A parallel plate condenser with oil between the plates (dielectric constant of oil K = 2) has a capacitance C. If the oil is removed, then capacitance of the capacitor becomes

(a) $\sqrt{2}C$ (b) 2C (c) $\frac{C}{\sqrt{2}}$ (d) $\frac{C}{2}$

35. A parallel plate air capacitor has a capacitance of 100 μF. The plates are at a distance *d* apart. If a slab of thickness *t* ($t < d$) and dielectric constant 5 is introduced between the parallel plates, then the capacitance will be
(a) 50 μF (b) 100 μF
(c) 200 μF (d) 500 μF

36. The equivalent capacitance of the combination of the capacitors is



(a) 3.20 μF (b) 7.80 μF
(c) 3.90 μF (d) 2.16 μF

37. An unchanged parallel plate capacitor filled with a dielectric constant K is connected to an air filled identical parallel capacitor charged to potential V_1. If the common potential is V_2, the value of K is

(a) $\frac{V_1 - V_2}{V_1}$ (b) $\frac{V_1}{V_1 - V_2}$ (c) $\frac{V_2}{V_1 - V_2}$ (d) $\frac{V_1 - V_2}{V_2}$

38. Three capacitors each of capacitance C and of breakdown voltage V are joined in series. The capacitance and breakdown voltage of the combinatioin will be

(a) $3C, \frac{V}{3}$ (b) $\frac{C}{3}, 3V$ (c) 3C, 3V (d) $\frac{C}{3}, \frac{V}{3}$

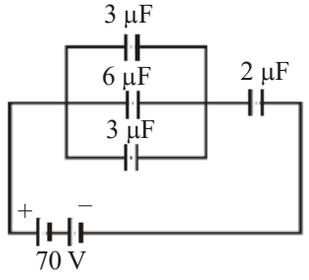
39. A capacitor having capacitance 1μF with air is filled with two dielectrics as shown. How many times capacitance will increase ?

(a) 12 (b) 6 (c) 8/3 (d) 3

40. A parallel plate capacitor is charged to a potential difference of 50V. It is discharged through a resistance. After 1 second, the potential difference between plates becomes 40 V. Then,
(a) fraction of stored energy after 1 second is 18/25
(b) potential difference between the plates after 2 second, will be 32 V
(c) potential difference between the plates after 2 seconds will be 20 V
(d) fraction of stored energy after 1 second is 4/5

41. To obtain 3 μF capacity from three capacitors of 2 μF each, they will be arranged.
(a) all the three in series
(b) all the three in parallel
(c) two capacitors in series and the third in parallel with the combinatioin of first two
(d) two capacitors in parallel and the third in series with the combinatioin of first two

42. The p.d. across the capacitance of 2 μF in the figure is



(a) 10V (b) 60V (c) 28V (d) 56V

43. A capacitor C_1 is charged to p.d.V. The charging battery is then removed and the capacitor is connected to an uncharged capacitor C_2. the final p.d. across the combination is

(a) $V\frac{C_1}{C_1 + C_2}$ (b) $V\frac{C_2}{C_1 + C_2}$

(c) $V\frac{C_1 C_2}{C_1 + C_2}$ (d) $\frac{V}{C_1 + C_2}$

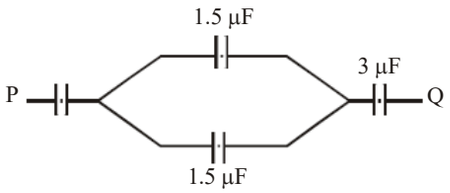
44. Two identical capacitors are joined in parallel, charged to a potential V, separated and they are connected in series i.e., the positive plate of one is connected to the negative of the other. Then,
(a) charges on the free plates connected together are destroyed.
(b) the charges on the free plates are enhanced
(c) the energy stored in the system increases
(d) the potential difference between the free plates becomes 2V.

45. A 200 V battery is connected across the combination of capacitors of capacities 5 μF and 10 μF in series. The charge on each capacitor is
(a) 2.667×10^{-4} C (b) 6.667×10^{-4} C
(c) $2 \times 10{-}4$ C (d) 3×10^{-4} C

46. An uncharged capacitor with a solid dielectric is connected to a similar air capacitor charged to a potential of V_0. If the common potential after sharing of charges becomes V, then the dielectric constant of the dielectric must be

(a) $\frac{V_0 - V}{V}$ (b) $\frac{V_0 + V}{V}$ (c) $\frac{V_0}{V}$ (d) $\frac{V_0}{2V}$

47. The capacitance between the points P and Q in the following circuit is



(a) 3.5 μF (b) 3 μF (c) 2 μF (d) 1 μF

48. In a parallel plate capacitor with air, the distance between the plates is reduced to half and the space is filled with dielectric of constant 4. If initial capacity of capacitor is 2 μF, the final value of
(a) 4 μF (b) 8 μF (c) 16 μF (d) 2 μF

49. Each plate of a parallel plate condenser has surface area of 5 cm^2. The distance between the plates is 2mm. The dielectric constant for the medium between the plates is 5. Then the capacity of the condenser is
($\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$)
(a) 0.5 pF (b) 0.25 pF
(c) 0.75 pF (d) 11 pF

50. Two capacitors of capacitances C_1 and C_2 are connected in parallel across a battery. If Q_1 and Q_2 respectively be the charges on the capacitors, then $\frac{Q_1}{Q_2}$ will be equal to

(a) $\frac{C_2}{C_1}$ (b) $\frac{C_1}{C_2}$ (c) $\frac{C_1^2}{C_2^2}$ (d) $\frac{C_2^2}{C_1^2}$

51. Two conducting plates X and Y each of area A are placed parallel to each other at a small separation d. X is given a charge 3q and Y is given a charge q. The potential difference between the plates is

(a) $\frac{qd}{2\varepsilon_0 A}$ (b) $\frac{qd}{\varepsilon_0 A}$ (c) $\frac{3qd}{2\varepsilon_0 A}$ (d) $\frac{2qd}{\varepsilon_0 A}$

52. The capacity of a parallel plate condenser is 10 μF, when the distance between its plates is 8 cm. If the distance between the plates is reduced to 4 cm, then the capacity of this parallel plate condenser will be
(a) 5 μF (b) 10 μF (c) 20 μF (d) 40 μF

53. A parallel plate air capacitor has a capacitance 18 μF. If the distance between the plates is tripled and a dielectric medium is introduced, the capacitance becomes 72 μF. The dielectric constant of the medium is
(a) 4 (b) 9 (c) 12 (d) 2

54. The space between the plates of a parallel plate capacitor is halved and a dielectric medium of relative permittivity 10 is introduced between the plates. The ratio of the final and initial capacitances of the capacitor is

(a) 20 (b) 10 (c) $\frac{1}{10}$ (d) $\frac{1}{20}$

55. When a parallel plate capacitor is charged up to 95 V, its capacitance is C. If a dielectric slab of thickness 2 mm is inserted between plates and distance between the plates is increased by 1.6 mm such that the same potential difference is maintained. The dielectric constant of the material (slab) is
(a) 2.4 (b) 4.5 (c) 5.0 (d) 9.0

56. Two identical metal plates are given positive charges Q_1 and Q_2 ($< Q_1$) respectively. If they are now brought close together to form a parallel plate capacitor with capacitance C, the potential difference between them is

(a) $\frac{Q_1 + Q_2}{2C}$ (b) $\frac{Q_1 + Q_2}{C}$

(c) $\frac{Q_1 - Q_2}{C}$ (d) $\frac{Q_1 - Q_2}{2C}$

57. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. Calculate the capacitance if the distance between the plates is reduced by half and the space between them is filled with a substance of dielectric constant. (k = 6)
(a) 72 pF (b) 81 pF (c) 84 pF (d) 96 pF

58. An air capacitor of capacity C = 10 μF is connected to a constant voltage battery of 12 volt. Now the space between the plates is filled with a liquid of dielectric constant 5. The (additional) charge that flows now from battery to the capacitor is
(a) 120 μC (b) 600 μC
(c) 480 μC (d) 24 μC

59. A voltmeter reads 4 V when connected to a parallel plate capacitor with air as a dielectric. When a dielectric slab is introduced between plates for the same configuration, voltmeter reads 2 V. What is the dielectric constant of the material?
(a) 8 (b) 0.5 (c) 10 (d) 2

60. A parallel plate capacitor has 1μF capacitance. One of its two plates is given + 2μC charge and the other plate, +4μC charge. The potential difference developed across the capacitor is :
(a) 3V (b) 1V (c) 5V (d) 2V

61. A parallel plate capacitor of capacitance C_1 with a dielectric slab in between its plates is connected to a battery. It has potential difference V_1 across its plates. When the dielectric potential difference are C_2 and V_2 respectively. Then,
(a) $V_1 > V_2, C_1 > C_1$ (b) $V_1 < V_2, C_1 > C_1$
(c) $V_1 = V_2, C_1 > C_1$ (d) $V_1 = V_2, C_1 < C_1$

62. Two metal spheres of capacitance C_1 and C_2 carry some charges. They are put in contact and then separated. The final charges Q_1 and Q_2 on them will satisfy

(a) $\frac{Q_1}{Q_2} < \frac{C_1}{C_2}$ (b) $\frac{Q_1}{Q_2} = \frac{C_1}{C_2}$

(c) $\frac{Q_1}{Q_2} > \frac{C_1}{C_2}$ (d) $\frac{Q_1}{Q_2} < \frac{C_2}{C_1}$

63. A capacitor when filled with a dielectric K = 3 has charge Q_0, voltage V_0 and field E_0. If the dielectric is replaced with another one having K = 9, the new values of charge, voltage and field will respectively be

(a) $3Q_0, 3V_0, 3E_0$ (b) $Q_0, 3V_0, 3E_0$

(c) $Q_0, \frac{V_0}{3}, 3E_0$ (d) $Q_0, \frac{V_0}{3}, \frac{E_0}{3}$

64. A capacitor plates are charged by a battery with 'V' volts. After charging battery is disconnected and a dielectric slab with dielectric constant 'K' is inserted between its plates, the potential across the plates of a capacitor will become

(a) Zero (b) V/2

(c) V/K (d) KV

65. Two capacitors of 3 μF and 6 μF are connected in series and a potential difference of 900 V is applied across the combination. They are then disconnected and reconnected in parallel. The potential difference across the combination is

(a) zero (b) 100 V

(c) 200 V (d) 400 V

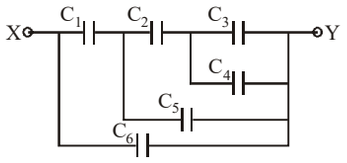
66. In the given network of capacitors as shown in Fig. given that $C_1 = C_2 = C_3 = 400$ pF and $C_4 = C_5 = C_6 = 200$ pF. The effective capacitance of the circuit between X and Y is

(a) 810 pF

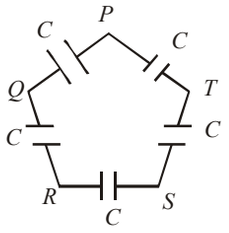
(b) 205 pF

(c) 600 pF

(d) 410 pF



67. Five capacitors, each of capacitance value *C* are connected as shown in the figure. The ratio of capacitance between *P* and *R*, and the capacitance between *P* and *Q*, is



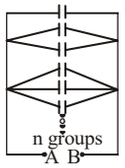
(a) 3 : 1 (b) 5 : 2

(c) 2 : 3 (d) 1 : 1

68. A number of capacitors each of equal capacitance C, are arranged as shown in Fig. The equivalent capacitance between A and B is

(a) n^2 C (b) (2n + 1) C

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



69. An air capacitor of capacity C = 10 μF is connected to a constant voltage battery of 12 volt. Now the space between the plates is filled with a liquid of dielectric constant 5. The (additional) charge that flows now from battery to the capacitor is

(a) 120 μC (b) 600 μC

(c) 480 μC (d) 24 μC

70. A 900 pF capacitor is charged by 100 V battery, then which of the following statement is correct?

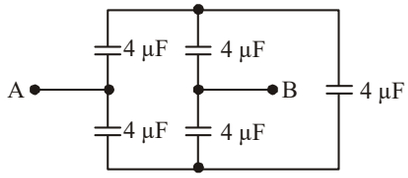
(a) The charge on the capacitor is 4.5×10^{-8} C.

(b) The energy stored by the capacitor is 9×10^{-6} J.

(c) If capacitor is disconnected from the battery and connected to another 900 pF capacitor, then energy stored by the system is 225×10^{-6} J.

(d) None of the above

71. For the arrangement of capacitors as shown in the circuit, the effective capacitance between the points *A* and *B* is (capacitance of each capacitor is 4 μF)



(a) 4 μF (b) 2 μF (c) 1 μF (d) 8 μF

8.3 Energy Stored in a Capacitor, Energy Density and Van de Graff Generator

72. A capacitor is charged to store an energy U. The charging battery is disconnected. An identical capacitor is now connected to the first capacitor in parallel. The energy in each of the capacitors is

(a) U / 2 (b) 3U / 2

(c) U (d) U / 4

73. When three identical capacitors are connected in series, their equivalent capacitance is 2 μF. Now they are connected in parallel across a source of e.m.f. 200 V. The total energy stored is

(a) 0.36 J (b) 0.48 J (c) 0.16 J (d) 0.08 J

74. A string is compressed by 2 mm by a force of 8 N and a condenser is charged through a potential difference of 200 N possess a charge of 80 μC. The ratio of the energy stored in the two bodies is

(a) 1 (b) 3/2 (c) 2 (d) 1/2

75. A 100 volt battery is connected across the series combination of the two capacitors of 4 μF and 8 μF. The energy stored in the series combination is

(a) $\frac{3}{4}\times10^{-2}$ J (b) $\frac{4}{3}\times10^{-2}$ J

(c) 0.5 J (d) 1 J

76. Two condensers of capacity 3 μF and 6 μF respectively are connected in series. The combination is connected across a potential of 6V. The ratio of the energies stored by the condensers will be

(a) $\frac{1}{2}$ (b) $\frac{2}{1}$ (c) $\frac{1}{4}$ (d) $\frac{4}{1}$

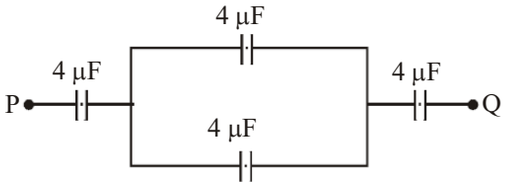
77. Two insulated metallic spheres of capacitances 3μF and 5μF are charged to 300 V and 500 V respectively. The energy loss when they are connected by a wire is

(a) 0.375 J (b) 0.0375 J

(c) 0.735 J (d) 0.0735 J

78. Four condensers each of capacity 4 μF are connected as shown in the adjoining figure.

If $V_P - V_Q = 15V$, the energy stored in the system



(a) 2.4 ergs (b) 1.8 ergs

(c) 3.6 ergs (d) 5.4 ergs

79. A parallel plate condenser has a uniform electric field E(V/m) in the space between the plates. If the distance between the plates is d(m) and area of each plate is A(m^2) the energy stored (in joules) in the condenser is

(a) E^2Ad/ϵ_0 (b) $\frac{1}{2}\epsilon_0 E^2$

(c) ϵ_0 EAd (d) $\frac{1}{2}\epsilon_0 E^2Ad$

80. A 5.0 μF capacitor is charged to a potential difference of 800 V and discharged through a conductor. The energy given to the conductor during the discharge is

(a) 1.6×10^{-2} joule (b) 3.2 joule

(c) 1.6 joule (d) 4.2 joule

81. A parallel plate capacitor is connected to a 5V battery and charged. The battery is then disconnected and a glass slab is introduced between the plates, then the quantities that decrease are

(a) charge and potential difference

(b) charge and capacitance

(c) capacitance and potential difference

(d) energy stored and potential difference

82. Two capacitors of capacitances 1 μF and 2 μF can separately withstand potentials of 6 kV and 4 kV respectively. The total potential, they together can withstand when they are connected in series is

(a) 9kV (b) 4kV

(c) 6kV (d) 2kV

83. Two identical capacitors are joined in parallel, charged to a potential V and then separated and then connected in series i.e. the positive plate of one is connected to negative of the other. Then

(a) The charges on the free plates connected together are destroyed

(b) The charges on the free plates are enhanced

(c) The energy stored in the system increases

(d) The potential difference across the free plates becomes 2 V

84. Three capacitors of capacitance 1 μF, 2 μF and 3 μF are connected in series and a potential difference of 11V is applied across the combination. Then the potential difference across the plates of 1 μF capacitor is

(a) 2V (b) 4V

(c) 1V (d) 6V

85. Two identical capacitors have some capacitance C. One of them is charged to the potential V and other to the potential 2V. The negative ends of both are connected together. When the positive ends are also joined together, the decrease in energy of the combined system is:

(a) $\frac{1}{4}CV^2$ (b) $2CV^2$

(c) $\frac{1}{2}CV^2$ (d) $\frac{3}{4}CV^2$

86. Three capacitors of capacitances 25 μF, 30 μF and 45 μF are connected in parallel to a supply of 100 V. Energy stored in the above combination is E. When these capacitors are connected in series to the same supply, the stored energy is $\frac{9}{x}$E . The value of x is

(a) 89 (b) 98

(c) 49 (d) 58

87. A parallel plate capacitor is charged and the charging battery is then disconnected. If the plates of the capacitor are moved further apart by means of insulating handles. then which of the following statement is correct?

(a) The charge on the capacitor increases.

(b) The voltage across the plates increases.

(c) The capacitance increases.

(d) The electrostatic energy stored in the capacitor decreases

88. A parallel plate capacitor of capacity C_0 is charged to a potential V_0.

(i) The energy stored in the capacitor when the battery is disconnected and the separation is doubled E_1.

(ii) The energy stored in the capacitor when the charging battery is kept connected and the separation between the capacitor plates is doubled is E_2.

Then E_1 / E_2 value is

(a) 4/1 (b) 3/2

(c) 2/1 (d) 1/2

8.4 Electrostatic Potential & Potential Energy and Equipotential Surfaces

89. Electric field and potential inside hollow charged conducting sphere are respectively

(a) $0, 0$ (b) $0, \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

(c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}, 0$ (d) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}, \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

90. A charge $2Q$ is placed at each corner of a cube of side a. The potential at the centre of the cube is

(a) $\frac{8Q}{\pi\varepsilon_0 a}$ (b) $\frac{4Q}{4\pi\varepsilon_0 a}$ (c) $\frac{8Q}{\sqrt{3}\pi\varepsilon_0 a}$ (d) $\frac{2Q}{\pi\varepsilon_0 a}$

91. An infinite number of charges each equal to Q are placed along the X-axis at $x = 1, 2, 4, 8$ ..... The potential at the point $x = 0$ due to this set of charges is

(a) $\frac{Q}{4\pi\varepsilon_0}$ (b) $\frac{2Q}{4\pi\varepsilon_0}$ (c) $\frac{3Q}{4\pi\varepsilon_0}$ (d) $\frac{Q}{\pi\varepsilon_0}$

92. Four charges $+3\mu C, -1\mu C, +5\mu C$ and $-7\mu C$ are arranged on the circumference of a circle of radius 0.5 m. The potential at the centre is

(a) zero
(b) 18×10^4 V
(c) -18×10^4 V
(d) 288×10^3 V

93. A hollow metal sphere of radius 5 cm is charged so that the potential on its surface is 10 V. The potential at the centre of the sphere is

(a) 0V
(b) 10V
(c) same as at point 5 cm away from the surface
(d) same as at point 25 cm away from the surface

94. The electric potential inside a conducting sphere

(a) increases from centre to surface
(b) decreases from centre of surface
(c) remains constant from centre to surface
(d) is zero at every point inside

95. Concentric, thin metallic spheres of radii r_1 and $r_2 (r_1 > r_2)$ carry charges q_1 and q_2, respectively. Then the electric potential at a distance $r (r_2 < r < r_1)$ will be $\frac{1}{4\pi\varepsilon_0}$ times

(a) $\frac{q_1 + q_2}{r}$ (b) $\frac{q_1}{r_1} + \frac{q_2}{r}$

(c) $\frac{q_1}{r_2} + \frac{q_2}{r_2}$ (d) $\frac{q_1}{r_2} + \frac{q_2}{r_1}$

96. The electric potential at a point (x, y, z) is given by $V = -x^2 y - xz^3 + 4$
The electric field $\vec{E}$ at that point is

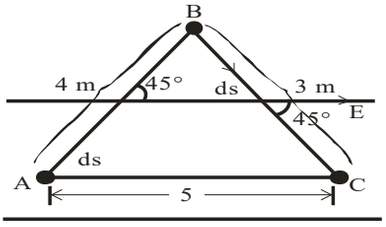
(a) $\vec{E} = \hat{i}(2xy + z^3) + \hat{j}\,x^2 + \hat{k}3xz^2$

(b) $\vec{E} = \hat{i}2\,xy + \hat{j}(x^2 + y^2) + \hat{k}(3xz - y^2)$

(c) $\vec{E} = \hat{i}z^3 + \hat{j}\,xyz + \hat{k}\,z^2$

(d) $\vec{E} = \hat{i}(2xy - z^3) + \hat{j}\,xy^2 + \hat{k}3z^2x$

97. Consider a uniform electric field in a region as shown below.



Then, potential difference between points A and C is given by

(a) $V_A - V_C = -\int_{AB} E\,ds\cos 45° - \int_{BC} E\,ds\cos 45°$

(b) $V_A - V_C = -\int_{AB} E\,ds\cos 45° - \int_{BC} E\,ds\cos 45°$

(c) $V_A - V_C = 5E$
(d) $V_C - V_A = 5E$

98. If four charges $q_1 = +1 \times 10^{-8}$ C, $q_2 = -2 \times 10^{-8}$ C, $q_3 = +3 \times 10^{-8}$ C and $q_4 = +2 \times 10^{-8}$ C are kept at the four corners of a square of side 1 m, then the electric potential at the centre of the square is

(a) 300V (b) 200V
(c) 510V (d) 410V

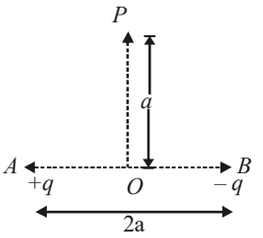
99. 125 identical charged small spheres coalesce to form a big charged sphere, If the electric potential on each small sphere is 60 mV then the electric potential on the bigger sphere formed is

(a) 30V (b) 15V
(c) 1.5V (d) 3V

100. In the figure given below, O is the centre of line joining AB. Two charges of opposite nature and same magnitude are placed at points A and B, respectively.
The potential at point P is

(a) $\frac{2kq}{a\sqrt{2}}$ (b) Zero

(c) $\frac{kq}{a\sqrt{2}}$ (d) $\frac{kq}{2a}$



Exercise 3 : PREVIOUS YEARS MCQs

1. The capacity of a parallel plate air capacitor is C_0 and the distance of separation of the plates is d. A dielectric slab of thickness $\frac{4d}{5}$ is introduced between the plates and the new capacity is C. The ratio $C : C_0$ is **[2022, 2025]**

(a) $5K : (K+4)$ (b) $4K : (K+5)$

(c) $(K+4) : 5K$ (d) $5K : 4$

2. Two concentric sphere kept in air have radii R and r. They have similar charge and equal surface density σ. The elelctric potential at their common centre is **[2025]**

(a) $\sigma\left(\frac{R+r}{\varepsilon_0}\right)$ (b) $\sigma\frac{(R-r)}{\varepsilon_0}$

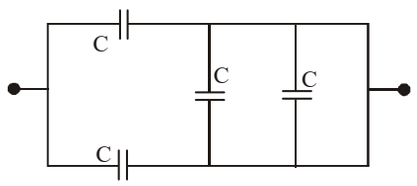
(c) $\sigma\frac{(R+r)}{2\varepsilon_0}$ (d) $\frac{\alpha(R+r)}{4\varepsilon_0}$

3. A metal sphere of radius 10 cm is given a charge of 12 μC. The force acting on unit area of its surface is **[2024]**

(a) 5.151×10^2 N/m^2 (b) 5.15×10^3 N/m^2

(c) 515×10^{-2} N/m^2 (d) 5.15×10^{-3} N/m^2

4. The equivalent capacitance of the combination shown is **[2023]**



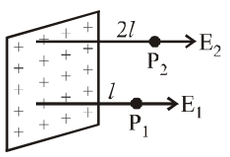
(a) $\frac{C}{2}$ (b) 4C (c) 2C (d) $\frac{5}{3}$C

5. Two identical thin metal plates has charge q_1 and q_2 respectively such that $q_1 > q_2$. The plates were brought close to each other to form a parallel plate capacitor of capacitance C. The potential difference between them is: **[2022]**

(a) $\frac{(q_1+q_2)}{C}$ (b) $\frac{(q_1-q_2)}{C}$

(c) $\frac{(q_1-q_2)}{2C}$ (d) $\frac{2(q_1-q_2)}{C}$

6. In the figure, a very large plane sheet of positive charge is shown. P_1 and P_2 are two points at distance l and $2l$ from the charge distribution. If σ is the surface charge density, then the magnitude of electric fields E_1 and E_2 at P_1 and P_2 respectively are : **[2019, 2022]**



(a) $E_1 = \sigma/\varepsilon_0$, $E_2 = \sigma/2\varepsilon_0$

(b) $E_1 = 2\sigma/\varepsilon_0$, $E_2 = \sigma/\varepsilon_0$

(c) $E_1 = E_2 = \sigma/2\varepsilon_0$

(d) $E_1 = E_2 = \sigma/\varepsilon_0$

7. Which statement is true for Gauss law- **[2021]**

(a) All the charges whether inside or outside the gaussian surface contribute to the electric flux.

(b) Electric flux depends upon the geometry of the gaussian surface.

(c) Gauss theorem can be applied to non-uniform electric field.

(d) The electric field over the gaussian surface remains continuous and uniform at every point.

8. A rod of length 2.4 *m* and radius 4.6 *mm* carries a negative charge of 4.2×10^{-7} C spread uniformly over it surface. The electric field near the mid–point of the rod, at a point on its surface is **[2021]**

(a) -8.6×10^5 N C^{-1} (b) 8.6×10^4 N C^{-1}

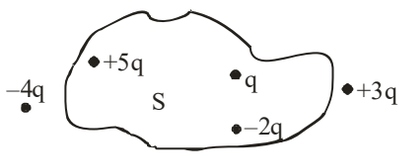
(c) -6.7×10^5 N C^{-1} (d) 6.7×10^4 N C^{-1}

9. Energy of a charged condenser is given by **[2020]**

(a) $E = \frac{CV^2}{2}$ (b) $E = \frac{Q^2}{2C}$

(c) $E = \frac{QV}{2}$ (d) all of these

10. Five charges +q, +5q, –2q, +3q and –4q are situated as shown in the figure. The electric flux due to this configuration through the surface S is : **[2019]**



(a) $\frac{5q}{\epsilon_0}$ (b) $\frac{4q}{\epsilon_0}$ (c) $\frac{3q}{\epsilon_0}$ (d) $\frac{q}{\epsilon_0}$

11. σ is the uniform surface charge density of a thin spherical shell of radius R. The electric field at any point on the surface of the spherical shell is : **[2017, 2019]**

(a) $\frac{\sigma}{\epsilon_0 R}$ (b) $\frac{\sigma}{2\epsilon_0}$ (c) $\frac{\sigma}{\epsilon_0}$ (d) $\frac{\sigma}{4\epsilon_0}$

12. If the charge on a capacitor is increased by 2 C, the energy stored in it increases by 44%. The original charge on the capacitor is (in C) : **[2018]**

(a) 10 (b) 20 (c) 30 (d) 40

13. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be : **[2017]**

(a) 4 : 1 (b) 2 : 1 (c) 1 : 4 (d) 1 : 2

14. A capacitor C is fully charged with voltage V_0. After disconnecting the voltage source, it is connected in parallel with another uncharged capacitor of capacitance $\frac{C}{2}$. The energy loss in the process after the charge is distributed between the two capacitors is : **[2016]**

(a) $\frac{1}{2}CV_0^2$ (b) $\frac{1}{3}CV_0^2$ (c) $\frac{1}{4}CV_0^2$ (d) $\frac{1}{6}CV_0^2$

15. A capacitor $C_1 = 4\mu F$ is connected in series with another capacitor $C_2 = 1\mu F$. The combination is connected across DC source of 200 V. The ratio of potential across C_2 to C_1 is **[2013, 2015]**

(a) 2 : 1 (b) 4 : 1 (c) 8 : 1 (d) 16 : 1

16. The difference in the effective capacity of two similar capacitors when joined in series and then in parallel is 6μF. The capacity of each capacitor is **[2015]**

(a) 2μF (b) 4μF (c) 8μF (d) 16μF

17. Two charges of equal magnitude q are placed in air at a distance 2a apart and third charge –2q is placed at mid-point. The potential energy of the system is (ε_0 = permittivity of free space) **[2014]**

(a) $-\frac{q^2}{8\pi\varepsilon_0 a}$ (b) $-\frac{3q^2}{8\pi\varepsilon_0 a}$

(c) $-\frac{5q^2}{8\pi\varepsilon_0 a}$ (d) $-\frac{7q^2}{8\pi\varepsilon_0 a}$

18. Three particles, each having a charge of 10μC are placed at the corners of an equilateral triangle of side 10 cm. The electrostatic potential energy of the system is

$\left(\text{Given, } \frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ N-m}^2\text{C}^{-2}\right)$ **[2011]**

(a) zero (b) ∞ (c) 27 J (d) 100 J

19. If σ is the surface charge density of a charge for charged sphere of radius R kept in a medium of dielectric constant K, then electric intensity at a distance r from its centre is ($r > R$, ε_0 = permittivity of free space) **[2010]**

(a) $\frac{\sigma r^2}{\varepsilon_0 KR^2}$ (b) $\frac{\sigma r}{\varepsilon_0 KR}$ (c) $\frac{\sigma R^2}{\varepsilon_0 Kr^2}$ (d) $\frac{\sigma R}{\varepsilon_0 Kr}$

20. The charge on 48 μF capacitor is increased from 0.1C to 0.5C. The energy stored in the capacitor increases by **[2008, 2010]**

(a) 242×10^{-6} J (b) 250 J
(c) 2500 J (d) 2.5×10^6 J

21. A charge q is placed at the corner of a cube of side a. The electric flux through the cube is **[2007]**

(a) $\frac{q}{\varepsilon_0}$ (b) $\frac{q}{3\varepsilon_0}$ (c) $\frac{q}{6\varepsilon_0}$ (d) $\frac{q}{8\varepsilon_0}$

22. Unit of electric flux is **[2005]**

(a) Vm (b) N-m/C
(c) V/m (d) C/N-m

ANSWER KEYS

Exercise 1 : WARM-UP Topic-wise MCQs																			
1	(a)	**13**	(b)	**25**	(a)	**37**	(a)	**49**	(b)	**61**	(c)	**73**	(a)	**85**	(a)	**97**	(c)	**109**	(b)
2	(c)	**14**	(a)	**26**	(a)	**38**	(a)	**50**	(a)	**62**	(b)	**74**	(b)	**86**	(a)	**98**	(c)	**110**	(a)
3	(a)	**15**	(d)	**27**	(d)	**39**	(d)	**51**	(d)	**63**	(b)	**75**	(d)	**87**	(b)	**99**	(b)	**111**	(b)
4	(b)	**16**	(c)	**28**	(c)	**40**	(d)	**52**	(a)	**64**	(a)	**76**	(b)	**88**	(b)	**100**	(c)	**112**	(b)
5	(b)	**17**	(a)	**29**	(a)	**41**	(a)	**53**	(a)	**65**	(a)	**77**	(a)	**89**	(a)	**101**	(d)	**113**	(d)
6	(c)	**18**	(a)	**30**	(c)	**42**	(a)	**54**	(a)	**66**	(a)	**78**	(b)	**90**	(d)	**102**	(b)	**114**	(d)
7	(b)	**19**	(c)	**31**	(c)	**43**	(d)	**55**	(d)	**67**	(a)	**79**	(b)	**91**	(c)	**103**	(b)	**115**	(c)
8	(a)	**20**	(d)	**32**	(a)	**44**	(a)	**56**	(d)	**68**	(a)	**80**	(c)	**92**	(d)	**104**	(b)		
9	(d)	**21**	(a)	**33**	(d)	**45**	(a)	**57**	(b)	**69**	(a)	**81**	(a)	**93**	(c)	**105**	(c)		
10	(d)	**22**	(d)	**34**	(a)	**46**	(a)	**58**	(d)	**70**	(d)	**82**	(d)	**94**	(a)	**106**	(b)		
11	(a)	**23**	(a)	**35**	(a)	**47**	(c)	**59**	(d)	**71**	(a)	**83**	(b)	**95**	(b)	**107**	(d)		
12	(a)	**24**	(c)	**36**	(d)	**48**	(c)	**60**	(a)	**72**	(b)	**84**	(c)	**96**	(c)	**108**	(d)		
Exercise 2 : ACCELERATOR Topic-wise MCQs																			
1	(a)	**11**	(a)	**21**	(a)	**31**	(b)	**41**	(c)	**51**	(b)	**61**	(c)	**71**	(a)	**81**	(d)	**91**	(b)
2	(b)	**12**	(b)	**22**	(c)	**32**	(d)	**42**	(b)	**52**	(c)	**62**	(b)	**72**	(a)	**82**	(a)	**92**	(a)
3	(a)	**13**	(a)	**23**	(c)	**33**	(a)	**43**	(a)	**53**	(c)	**63**	(d)	**73**	(a)	**83**	(d)	**93**	(b)
4	(b)	**14**	(d)	**24**	(a)	**34**	(d)	**44**	(d)	**54**	(a)	**64**	(c)	**74**	(a)	**84**	(d)	**94**	(c)
5	(b)	**15**	(b)	**25**	(a)	**35**	(c)	**45**	(b)	**55**	(c)	**65**	(d)	**75**	(b)	**85**	(a)	**95**	(b)
6	(d)	**16**	(c)	**26**	(b)	**36**	(a)	**46**	(a)	**56**	(d)	**66**	(d)	**76**	(b)	**86**	(a)	**96**	(a)
7	(a)	**17**	(c)	**27**	(b)	**37**	(d)	**47**	(d)	**57**	(d)	**67**	(c)	**77**	(b)	**87**	(b)	**97**	(c)
8	(d)	**18**	(c)	**28**	(d)	**38**	(b)	**48**	(d)	**58**	(c)	**68**	(d)	**78**	(b)	**88**	(a)	**98**	(c)
9	(d)	**19**	(c)	**29**	(d)	**39**	(b)	**49**	(d)	**59**	(d)	**69**	(c)	**79**	(d)	**89**	(b)	**99**	(c)
10	(c)	**20**	(a)	**30**	(a)	**40**	(b)	**50**	(b)	**60**	(b)	**70**	(c)	**80**	(c)	**90**	(c)	**100**	(b)
Exercise 3 : PREVIOUS YEARS MCQs																			
1	(a)	**4**	(c)	**7**	(d)	**10**	(b)	**13**	(c)	**16**	(b)	**19**	(c)	**22**	(a)				
2	(a)	**5**	(c)	**8**	(c)	**11**	(c)	**14**	(d)	**17**	(d)	**20**	(c)						
3	(a)	**6**	(c)	**9**	(d)	**12**	(a)	**15**	(b)	**18**	(c)	**21**	(d)						

SOLUTIONS

Chapter-1 : Rotational Dynamics

Scan QR Code to get detailed solutions of all exercises

Chapter-2 : Mechanical Properties of Fluids

Scan QR Code to get detailed solutions of all exercises

Chapter-3 : Kinetic Theory of Gases and Radiation

Scan QR Code to get detailed solutions of all exercises

Chapter-4 : Thermodynamics

Scan QR Code to get detailed solutions of all exercises

Chapter-5 : Oscillations

Scan QR Code to get detailed solutions of all exercises

Chapter-6 : Superposition of Waves

Scan QR Code to get detailed solutions of all exercises

Chapter-7 : Wave Optics

Scan QR Code to get detailed solutions of all exercises

Chapter-8 : Electrostatics

Scan QR Code to get detailed solutions of all exercises