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Concept Of The Month

Geometrical Intrepretation of Collisions

Power Drive

Centre of Mass, Linear Momentum & Collisions, Fluid Mechanics

Previous Year Questions (NEET/NTSE/NSEJS)

OCTOBER 2019

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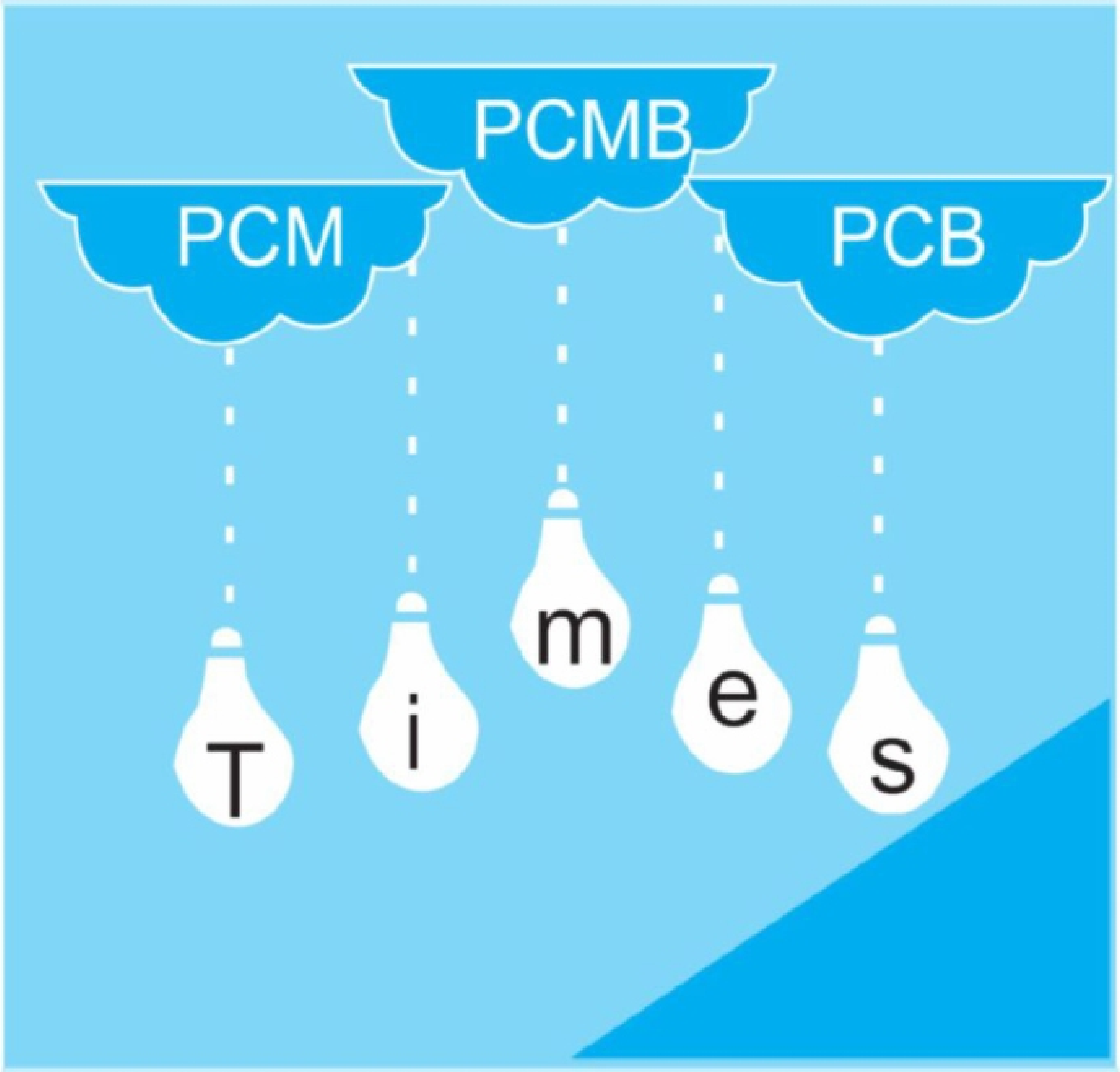
VOL-V



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Geometrical Interpretation of Collisions

Concept of the month

This column is aimed at preparing students for all competitive exams like JEE ADVANCED, BITSAT, NEET etc. Every concept has been designed by highly qualified faculty to cater to the needs of the students by discussing the most complicated and confusing concepts in Physics.

By: ESWAR REDDY ALLA (Bangalore)
ARUP BHATTACHARYA (Kolkata)

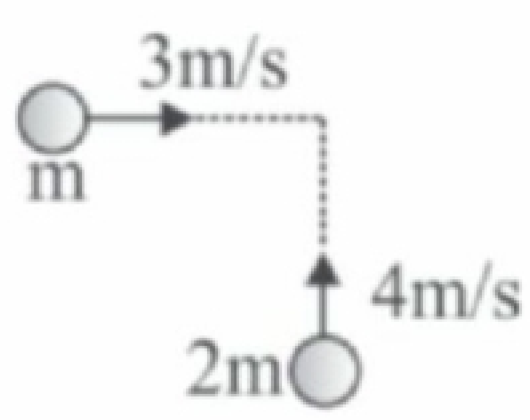
Introduction

In march-2017 and may -2017 we published two parts of an article, **geometrical interpretation of collisions**. This month article is also based on the same concept. In this article we have discussed two methods of solving a probelm on collisions .

1. Algebraic Method
2. Geometrial Method

In geometrical method we represent the linear momentum of the bodies as a vector. When linear momentum is conserved then the initial resultant momentum vector must be equal to final resultant momentum vector. Some of the solved examples are given as follows.

1. A particle of mass m moving along x-axis with velocity 3 m/s collides with another particle of mass 2m moving along y-axis with velocity 4 m/s at the origin. The impact is completely inelastic. What is the angle between the velocity vector of the combined mass and x-axis after the collision?



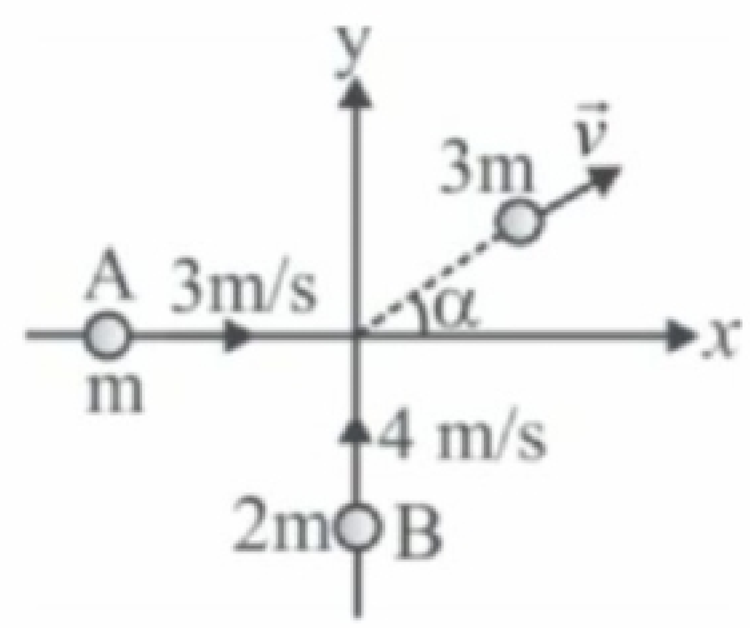
(1) $\tan^{-1}\left(\frac{8}{3}\right)$ (2) $\tan^{-1}\left(\frac{4}{3}\right)$

(3) $\tan^{-1}\left(\frac{3}{2}\right)$ (4) $\tan^{-1}\left(\frac{6}{5}\right)$

1. 1

1.Sol: Method I

Conserving momentum along x and y-axes respectively.



$$3mv\cos\alpha = 3m \quad (1)$$

$$3mv\sin\alpha = 8m \quad (2)$$

From eq's 1 & 2 we get

$$\tan\alpha = \frac{8}{3} \Rightarrow \alpha = \tan^{-1}\left(\frac{8}{3}\right)$$

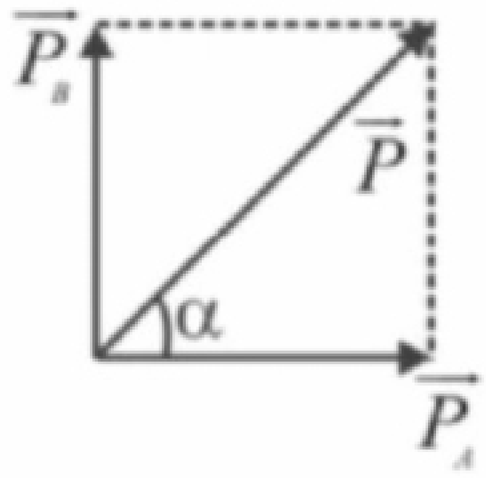
Method II

Let the momentum of the combined mass after the collision be $\vec{P}$. Initial momentums of A and B are $\vec{P}_A$ and $\vec{P}_B$.

From conservation of linear momentum

$\vec{P} = \vec{P}_A + \vec{P}_B$

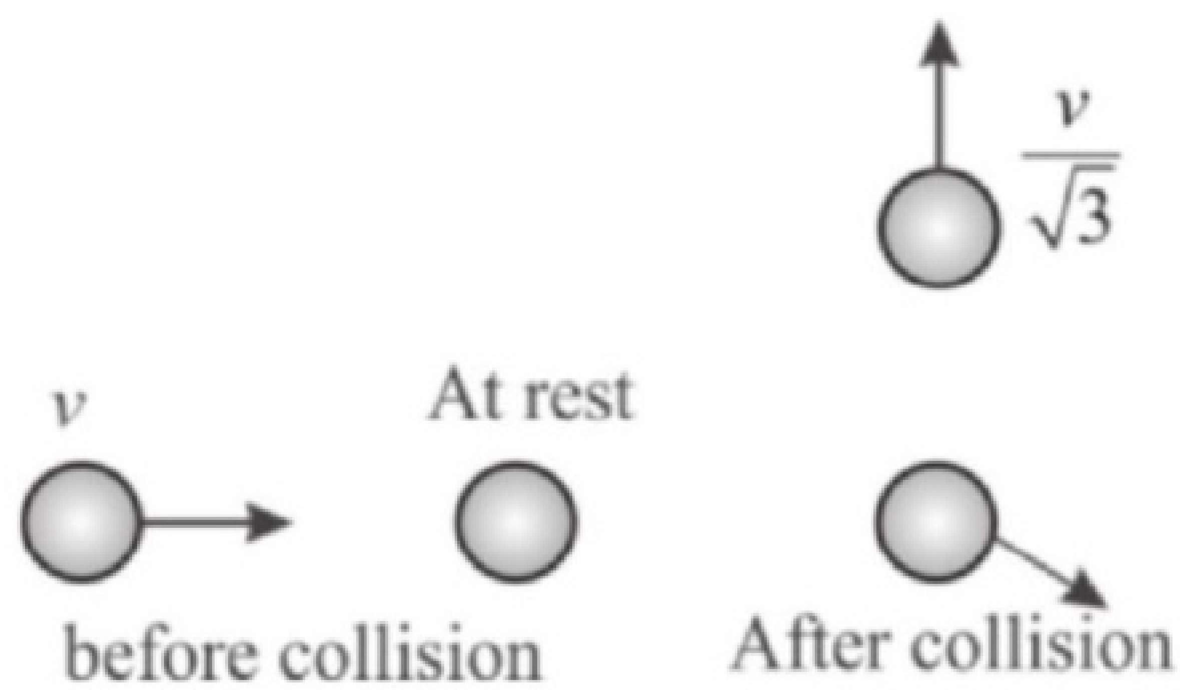
The vector diagram is shown in the figure



$$\tan\alpha = \frac{P_B}{P_A} = \frac{8m}{3m} = \frac{8}{3}$$

$$\Rightarrow \quad \alpha = \tan^{-1}\left(\frac{8}{3}\right)$$

2. A mass 'm' moves with a velocity v and collides with another identical mass. After collision the 1st mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the intial direction of motion. Find the speed of the 2nd mass after collision.

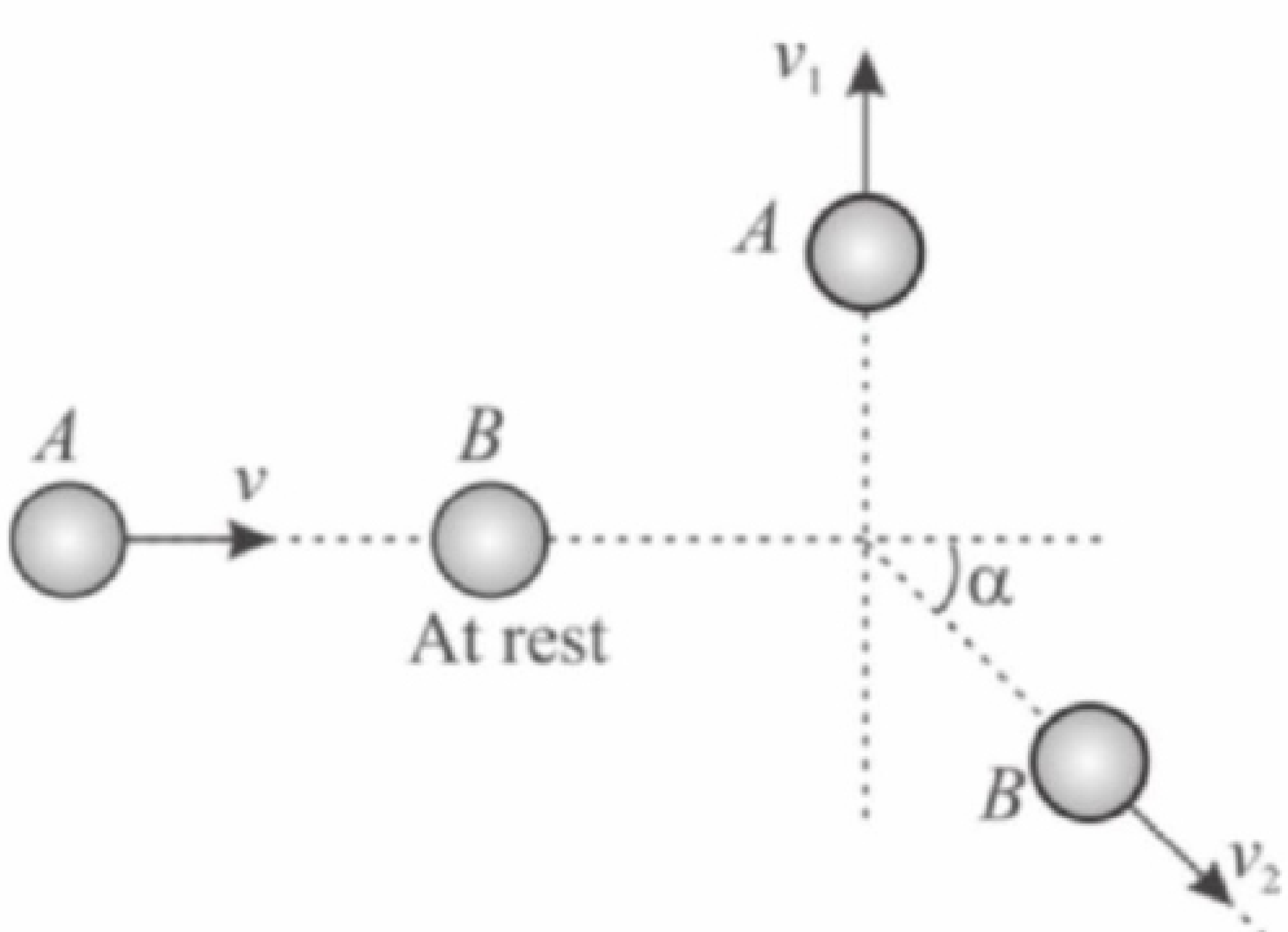


(1) $\frac{v}{\sqrt{3}}$ (2) $\frac{2}{\sqrt{3}}v$ (3) $\sqrt{3}\,v$ (4) v

2. 2

2.Sol: Method 1

Let mass A moves with a velocity v and collides inelastically with mass B, which is at rest.



Let the mass B moves at angle α with the horizontal with a velocity v_2.

$$P_i = mv \qquad (1)$$

$$P_f = mv_2\cos\alpha \qquad (2)$$

$$\Rightarrow mv = mv_2\cos\alpha$$

$$v = v_2\cos\alpha \qquad (3)$$

From the conservation of vertical linear momentum

$$mv_1 - mv_2\sin\alpha = 0 \Rightarrow \frac{v}{\sqrt{3}} = v_2\sin\alpha \qquad (4)$$

By solving (3) and (4)

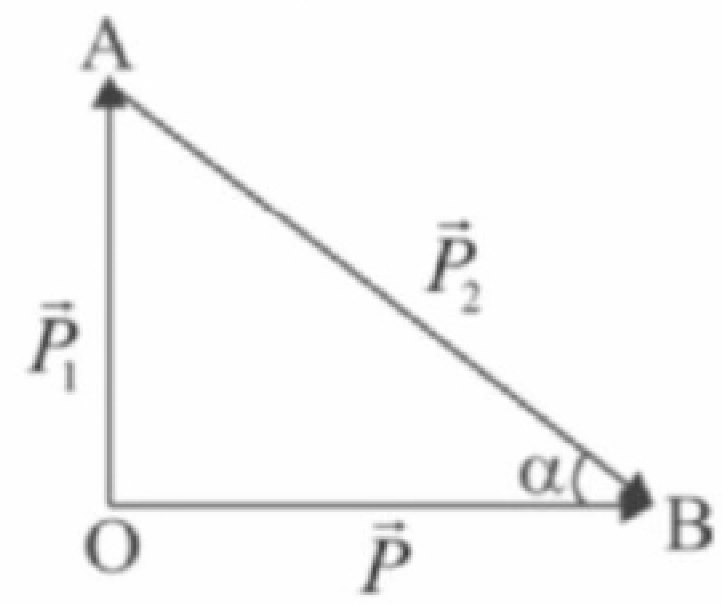
$$v^2 + \frac{v^2}{3} = v_2^2\,(\sin^2\alpha + \cos^2\alpha)$$

$$\Rightarrow \frac{4v^2}{3} = v_2^2 \Rightarrow v_2 = \frac{2}{\sqrt{3}}v$$

Method 2

Let P be the initial momentum of the moving sphere. After collision P_1 and P_2 are the momentums.

$$\vec{P} = \vec{P}_1 + \vec{P}_2$$

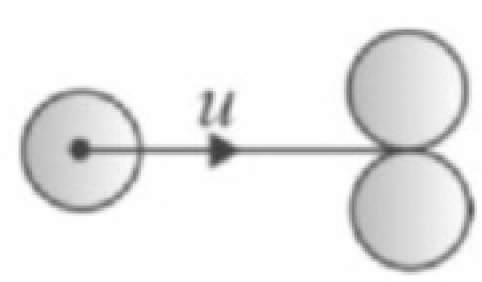


$$OA = m\frac{v}{\sqrt{3}}, \quad OB = mv$$

$$P_2 = AB = \sqrt{(OA)^2 + (OB)^2} = m\sqrt{\frac{v^2}{3} + v^2}$$

$$P_2 = \frac{2mv}{\sqrt{3}} \Rightarrow v_2 = \frac{2v}{\sqrt{3}}$$

3. Two identical frictionless spheres are in contact on a frictionless table. A third identical sphere strikes them simultaneously and remains at rest after the impact. The coefficient of restitution is



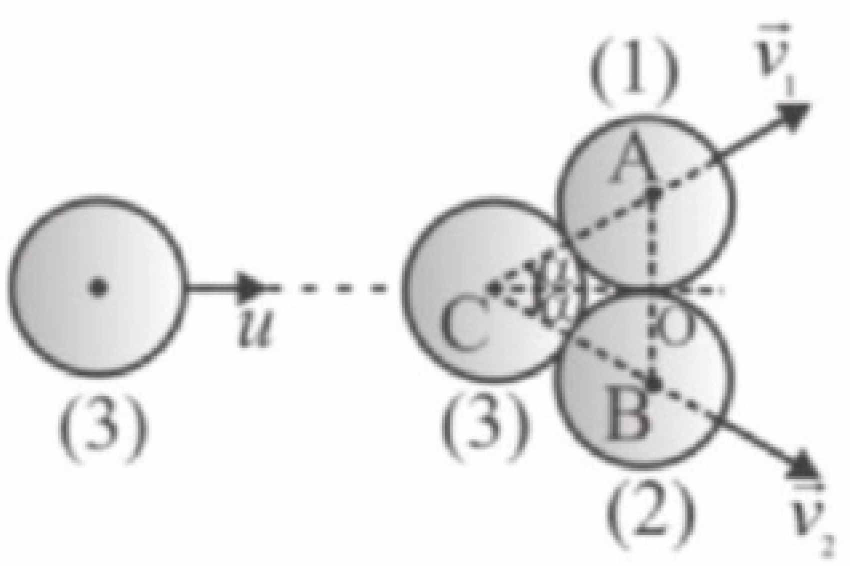
(1) $\frac{3}{5}$ (2) 1

(3) $\frac{1}{3}$ (4) $\frac{2}{3}$

3. 4

3.Sol: Method I

The three spheres are shown in the figure.



From the symmetry of the figure

$$\angle ACO = \angle BCO = \alpha = 30^\circ$$

Conserving momentum along x and y axes

$$mu = mv_1 \cos\alpha + mv_2 \cos\alpha$$

$$\frac{2u}{\sqrt{3}} = v_1 + v_2 \quad (1)$$

$$0 = mv_1 \sin 30^\circ - mv_2 \sin 30^\circ$$

$$\Rightarrow \quad v_1 = v_2 \quad (2)$$

From 1 & 2

$$v_1 = v_2 = \frac{u}{\sqrt{3}}$$

The coefficient of restitution is

$$e = \frac{v_1 - 0}{u\cos 30^\circ - 0} = \frac{2v_1}{\sqrt{3}u} = \frac{2}{3}$$

Method II

From symmetry of the system, it is clear that some impact force N acts on spheres 1 and 2 and duration of impact of 3 with 1 and 2 are also the same.

For sphere's 1 or 2

$$\int_0^t Ndt = mv_1 = mv_2 \quad (1)$$

For sphere 3

$$2\int(-N\cos\alpha)dt = 0 - mu$$

$$\int Ndt = \frac{mu}{\sqrt{3}} \quad (2)$$

From eq's 1 & 2 we get

$$v_1 = v_2 = \frac{u}{\sqrt{3}}$$

Now $\quad e = \frac{v_1}{u\cos\alpha} = \frac{2}{3}$

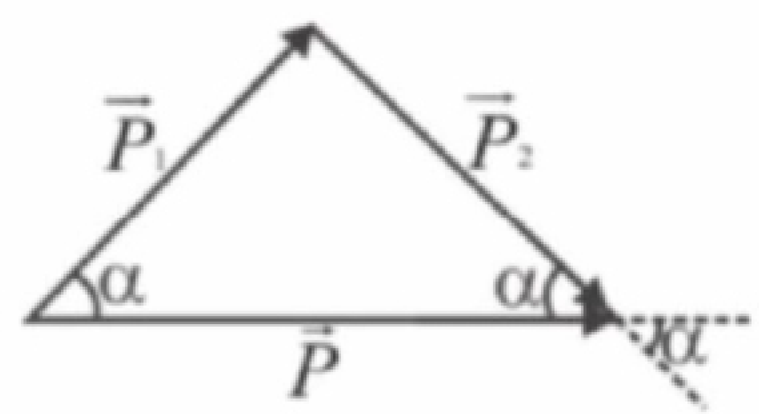
Method III

From symmetry it is evident that spheres 1 and 2 acquire the same magnitude of momentum each being equal to P.

Conserving momentum

$$\vec{P}_1 + \vec{P}_2 = \vec{P}$$

where $\quad P_1 = P_2$



From the vector triangle

$$P_1\cos\alpha + P_2\cos\alpha = P$$

$$P_1 = \frac{P}{2\cos\alpha} \quad (P_1 = P_2)$$

Now $\quad e = \frac{P_1}{P\cos\alpha} = \frac{P}{P\,2\cos^2\alpha} = \frac{2}{3}$

4. When two spheres of equal masses undergo glancing elastic collision with one of them at rest, after collision they will move:

(1) In the same direction

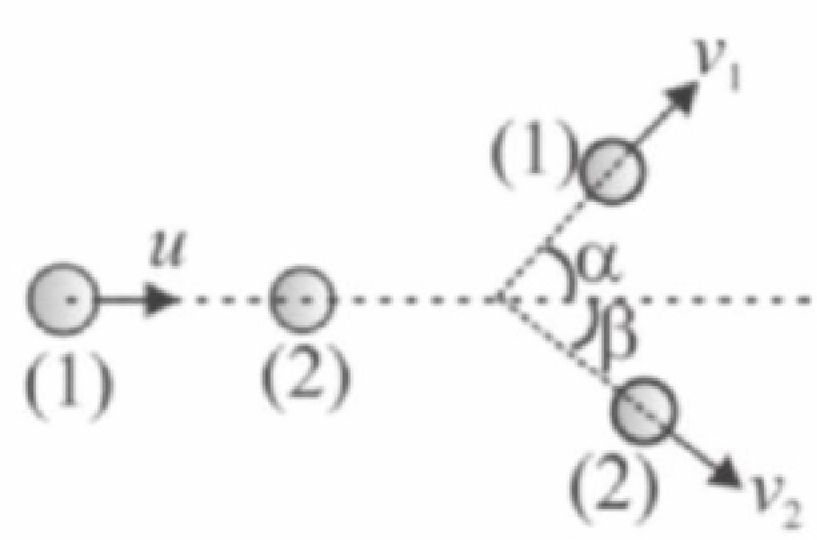
(2) Opposite to one another

(3) At right angle to each other

(4) Together

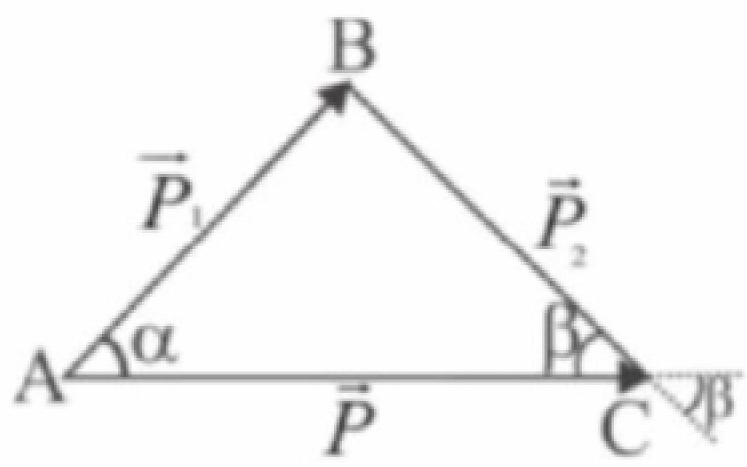
4. 3

4.Sol: It is a case of elastic oblique collision between identical objects.



Let p be the initial momentum of the moving sphere, P_1 and P_2 be the momentums of both spheres after collision.

$$\vec{P} = \vec{P}_1 + \vec{P}_2$$



Here $m_1 = m_2 = m$

Since K.E is conserved

$$K \cdot E_\lambda = K \cdot E_f$$

$$\frac{P^2}{2m} + 0 = \frac{P_1^2}{2m} + \frac{P_2^2}{2m}$$

$$P^2 = P_1^2 + P_2^2$$

The above equation indicates that $\angle ABC$ is a right angle triangle

$\Rightarrow \quad \alpha + \beta + 90° = 180° \Rightarrow \alpha + \beta = 90°$

5. A sphere A moving with linear momentum P collides obliquely with another stationary sphere B and after collision the direction of motion of A makes an angle of α with its initial direction of motion. What minimum momentum can be transferred to sphere B?

(1) P $\tan\alpha$

(2) P $\cos\alpha$

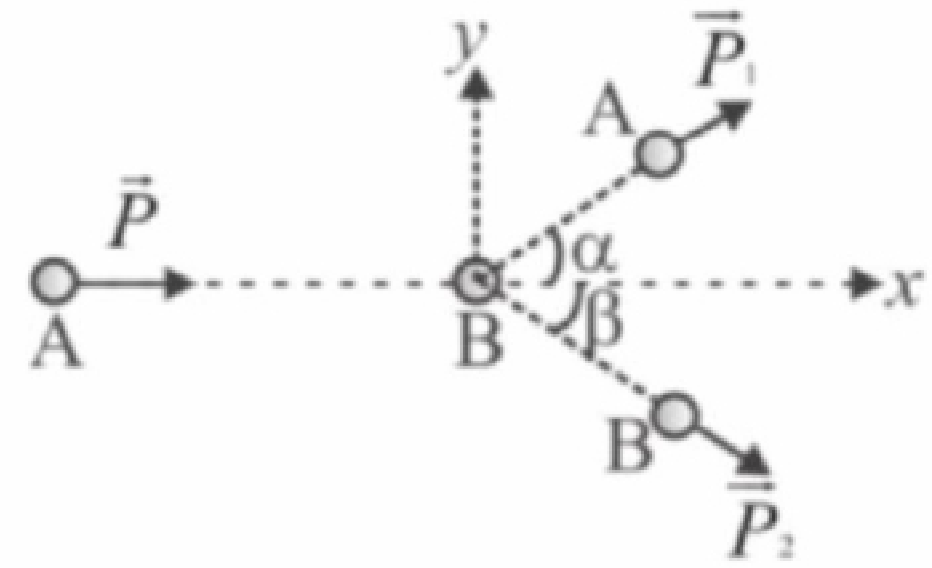
(3) P $\sin\alpha$

(4) Zero

5. 3

5.Sol: Method I

Let α and β are the angles made by the momentums of spheres A and B after collision.



Conserving momentum along x-axis and y-axis,

$$P_1 \cos\alpha + P_2 \cos\beta = P \qquad (1)$$

$$P_1 \sin\alpha = P_2 \sin\beta \qquad (2)$$

From eq's 1 & 2

$$P_2 = \frac{P\sin\alpha}{\sin(\alpha+\beta)}$$

P_2 is minimum when $\sin(\alpha+\beta) = 1$

i.e., when $\alpha + \beta = 90°$

$$P_{2\,min} = P\sin\alpha$$

Method II

Since momentum is conserved

$$\vec{P}_1 + \vec{P}_2 = \vec{P} \qquad (1)$$

The vector diagram is as shown in the figure

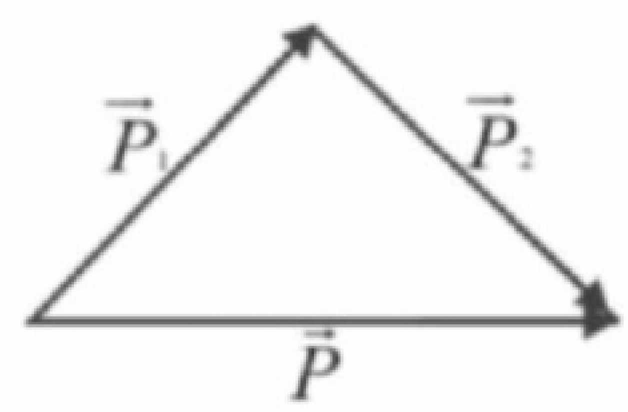


Fig-(a)

It is clear that $\vec{P}_2$ will be minimum when it is perpendicular to $\vec{P}_1$. The modified vector triangle is as shown in the figure b

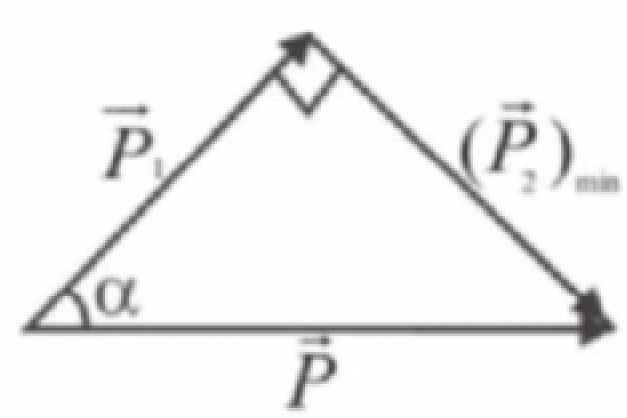
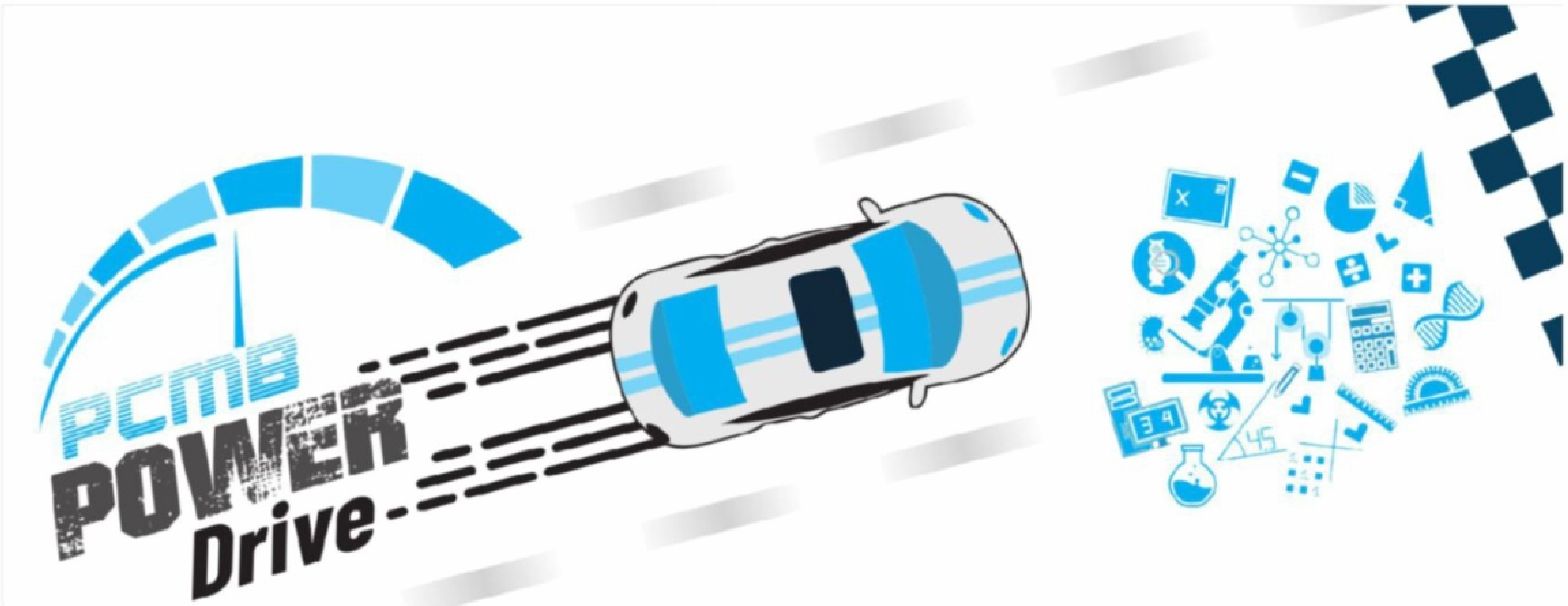


Fig-(b)

$$(P_2)_{min} = P\sin\alpha$$

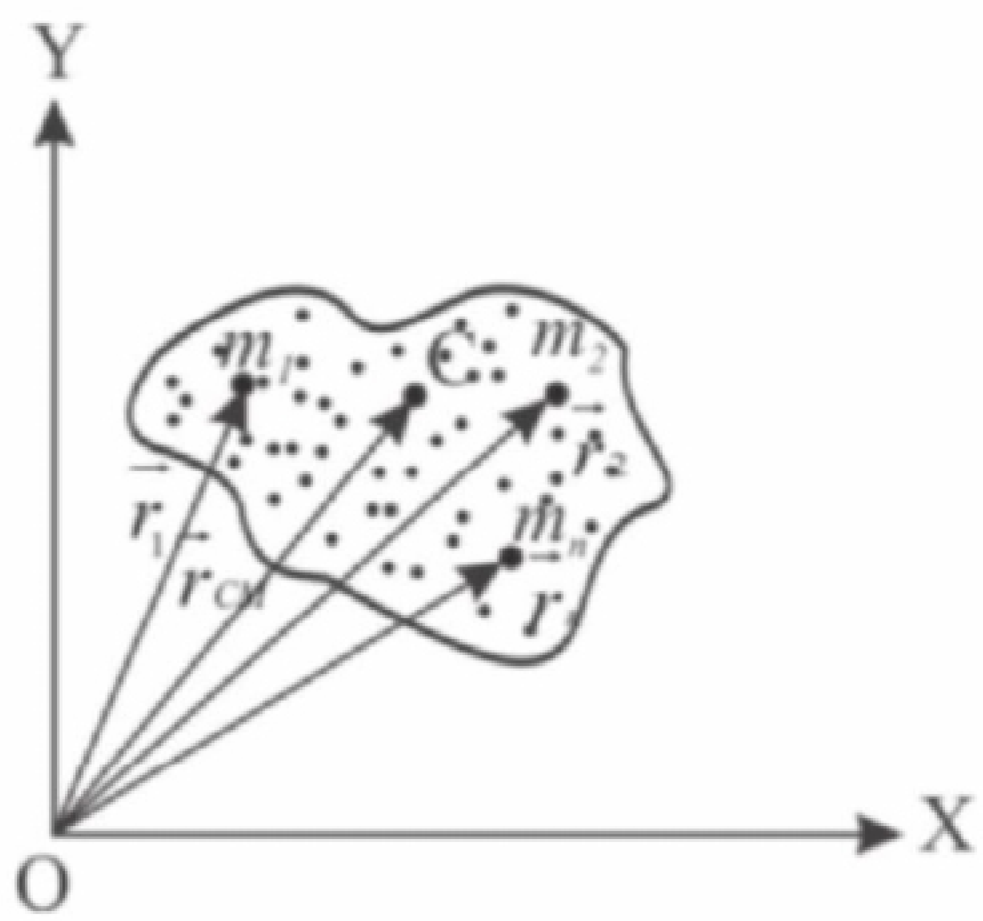


CENTRE OF MASS, LINEAR MOMENTUM & COLLISIONS

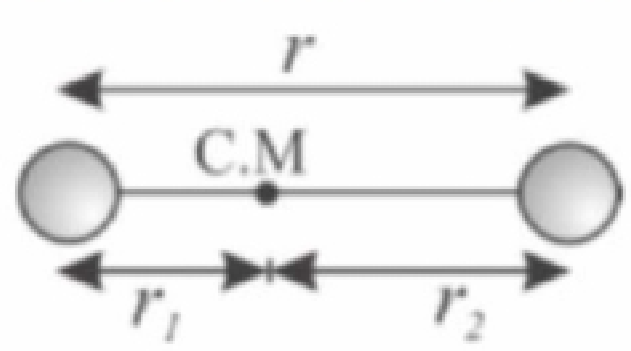
1. Centre of Mass(CM)

- Consider a system of N point masses m_1, m_2, m_3, ... m_n whose position vectors from origin O are given by $\vec{r}_1, \vec{r}_2, \vec{r}_3, ...\vec{r}_n$ respectively. Then the position vector of the centre of mass C of the system is given by.

$$\vec{r}_{CM} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + ... + m_n\vec{r}_n}{m_1 + m_2 + ... + m_n};$$



2. Position of C.M of two Particles



$$m_1 r_1 = m_2 r_2$$

$$r_1 = \left(\frac{m_2}{m_2 + m_1}\right) r \quad \text{and} \quad r_2 = \left(\frac{m_1}{m_1 + m_2}\right) r$$

3. Centre of mass of a continuous mass distribution

For continuous mass distribution the centre of mass can be located by replacing summation sign with an integral sign.

$$x_{CM} = \frac{\int x\,dm}{\int dm},\ y_{CM} = \frac{\int y\,dm}{\int dm},\ z_{CM} = \frac{\int z\,dm}{\int dm}$$

$\int dm = M$ (mass of the body)

$$\vec{r}_{CM} = \frac{1}{M}\int \vec{r}\,dm.$$

4. Velocity of centre of mass of a system

$$\vec{v}_{CM} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3 .... + m_n\vec{v}_n}{M}$$

5. Acceleration of centre of mass of system

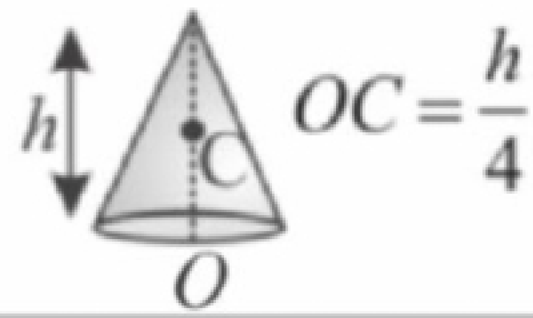
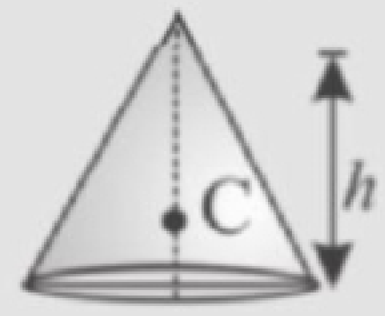
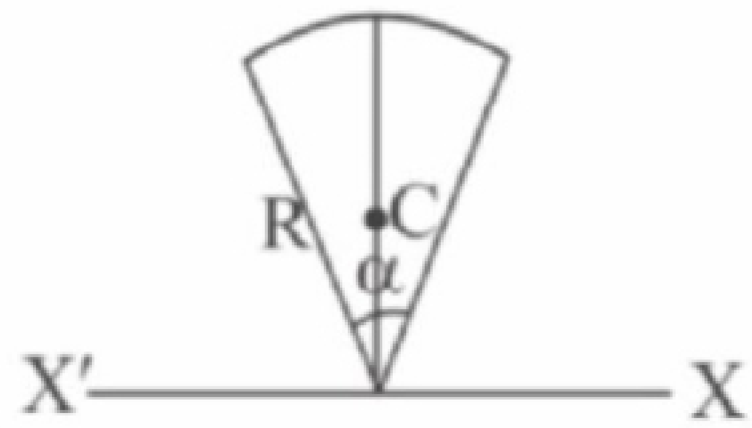
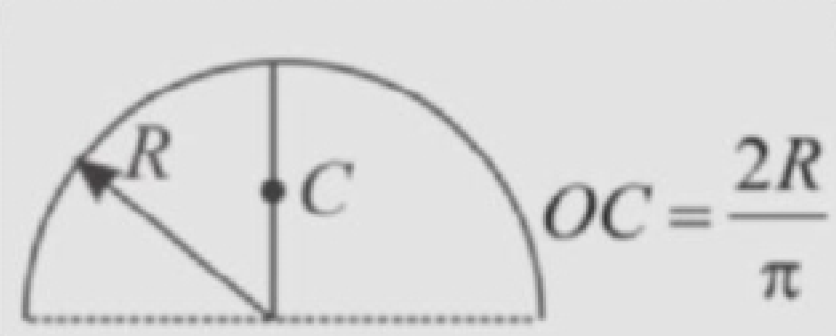
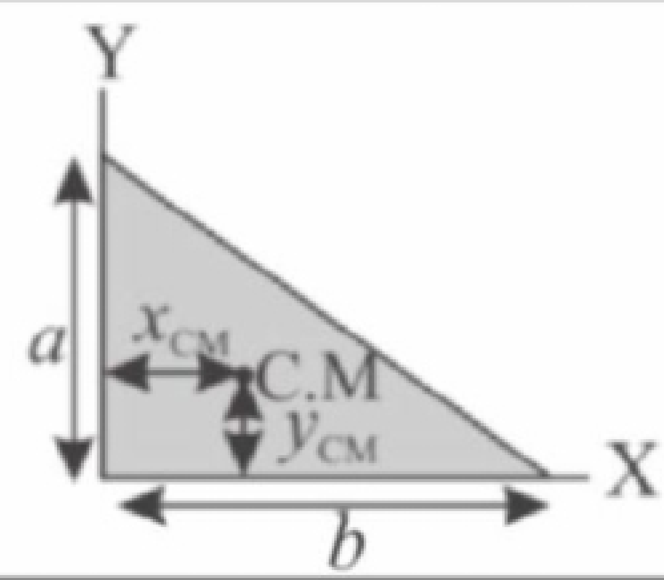
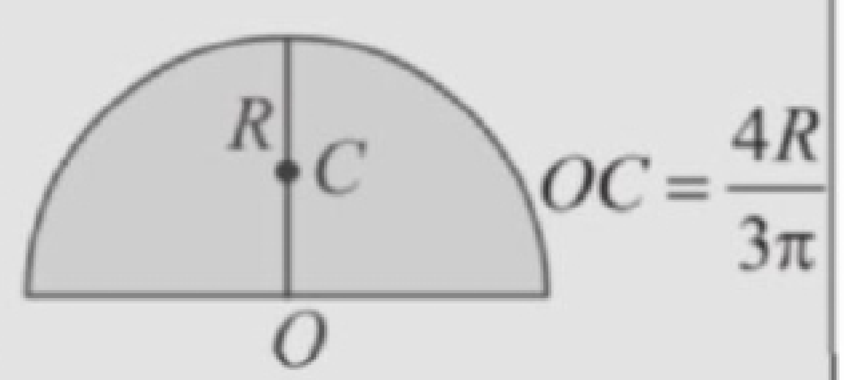
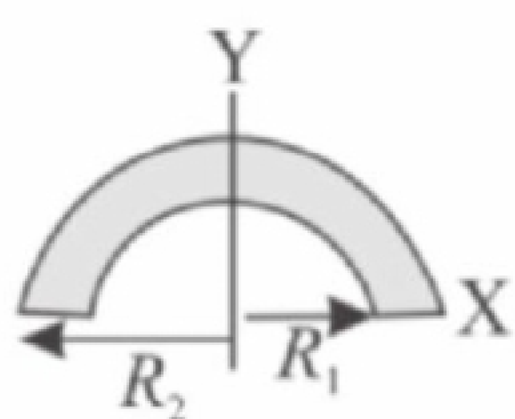
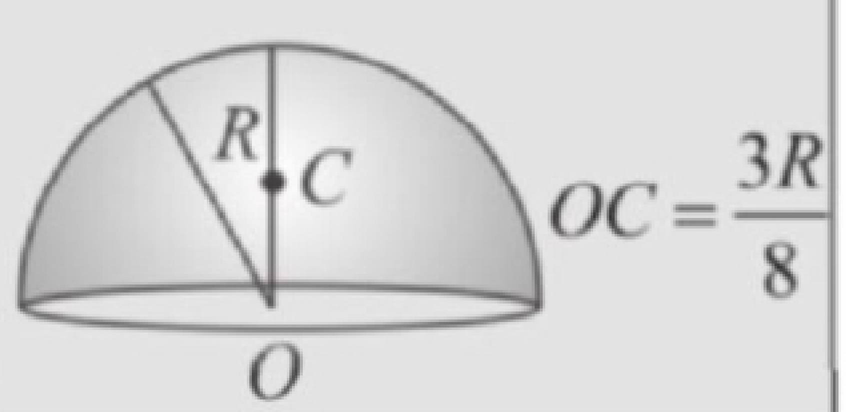
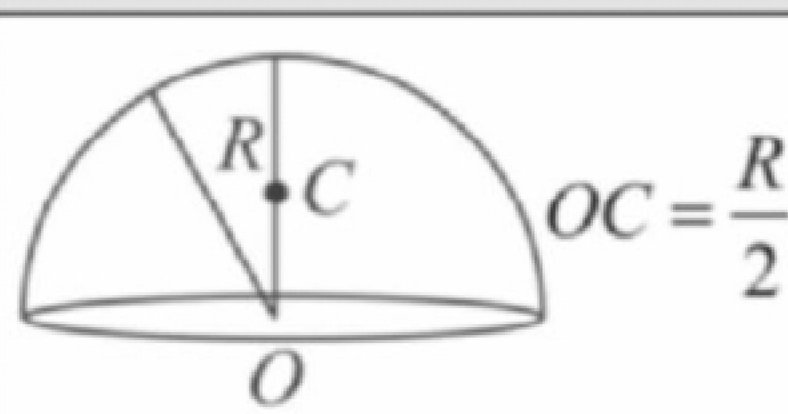
$$\vec{a}_{CM} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2 + m_3\vec{a}_3 .... + m_n\vec{a}_n}{M}$$

6. Shift in the position of centre of mass

(I) Addition of mass

- Due to addition of mass, the C.M of a system generally shifts towards or into the region where mass is added. If C_1 is C.M before addition and C_2 is the C.M of added mass and $C_1C_2 = d$, then

$$\Delta X_{shift} = \left[\frac{m_{added} \times d}{M_{initial} + m_{added}}\right],$$ C.M shifts towards the side of added mass.

Centre of mass of Some Common Systems			
S.No	**Shape of the body**	**Position of centre of mass**	**Figure**
1	Solid cone	At a height of $\frac{h}{4}$ from the base	
2	A circular cone (hollow)	$y_c = \frac{h}{3}$	
3	An arc of radius R subtend an angle α at its centre	At a distance of $\frac{2R}{\alpha}\sin\left(\frac{\alpha}{2}\right)$ from its centre of curvature on the axis of symmetry	
4	A Semi-circular ring of radius 'R'	At a distance of $\frac{2R}{\pi}$ from its centre on the axis of symmetry	
5	A right angle triangular plate	$x_{CM} = \frac{b}{3}$ $y_{CM} = \frac{a}{3}$	
6	Semi-circular disc	At a distance of $\frac{4R}{3\pi}$ from its centre 'O' on the axis of symmetry	
7	Semi circular plate with inner radius R_1 and outer R_2	$y_{CM} = \frac{4(R_2^3 - R_1^3)}{3\pi(R_2^2 - R_1^2)}$	
8	Solid hemi-sphere	At a distance of $\frac{3R}{8}$ from its centre 'O' on the axis of symmetry	
9	Hollow hemi-sphere	At a distance of $\frac{R}{2}$ from its centre 'O' on the axis of symmetry	

(II) Removal of mass

- Due to removal of mass the C.M of a system shifts away from the region where mass is removed. If C_1 is C.M of the body before removal and C_2 is the C.M of the removed part and $C_1C_2 = d$ then

$$\Delta X_{shift} = \left[\frac{-m_{removed} \times d}{M_{initial} - m_{removed}}\right]$$

'–' indicates CM shifts opposite to the side of removed mass

7. Conservation of momentum

$$\vec{F}_{ext} = \frac{d\vec{P}}{dt}$$

If $\vec{F}_{ext} = 0 \Rightarrow \frac{d\vec{P}}{dt}; \vec{P} = \text{constant}$

$$\vec{P}_1 + \vec{P}_2 + \vec{P} + \text{.........} + \vec{P}_n = \text{constant.}$$

8. Collision

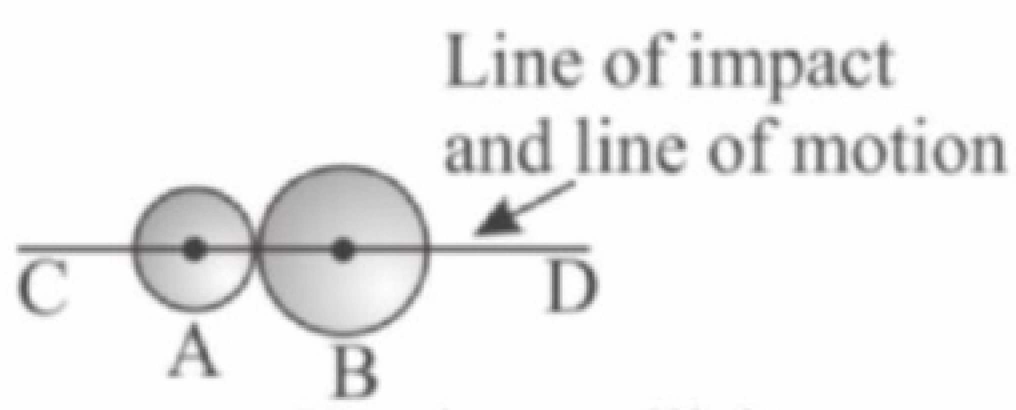
- Collision is an event in which a strong force acts between two or more bodies for a short time, which results in change of their velocities.

9. Line of Impact

- The line passing through the common normal to the surfaces in contact during impact is called line of impact. The force during collision acts along this line on both the bodies.

Line of impact in different collisions

(i) Two balls A and B are approaching each other such that their centres are moving along line CD.



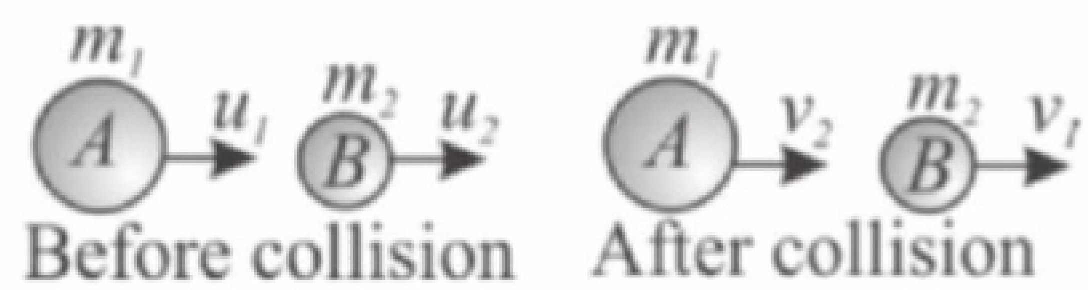
Head on collision

10. Elastic collision

- In an elastic collision, the particle regain their shape and size completely after collision, i.e., no fraction of mechanical energy remains stored as deformation potential energy in the bodies.

Elastic collision in one dimension

The two bodies suffer head on collision and continue moving along the straight line in the same direction as shown in the figure.



$$v_1 = \frac{(m_1 - m_2)u_1}{(m_1 + m_2)} + \frac{2m_2u_2}{m_1 + m_2} \qquad (1)$$

$$v_2 = \frac{2m_1u_1}{m_1 + m_2} + \frac{(m_2 - m_1)}{m_1 + m_2}u_2 \qquad (2)$$

Special cases of elastic collision in one dimension		
Before collision	Condition	After collision
m_1 (A) u_1 → m_2 (B) u_2 →	$m_1 = m_2$	m_1 (A) u_2 → m_2 (B) u_1 →
m_1 (A) u_1 → m_2 (B)	$m_1 = m_2$	m_1 (A) m_2 (B) u_1 →
m_1 (A) u_1 → m_2 (B)	$m_1 >> m_2$	m_1 (A) u_1 → m_2 (B) $2u_1$ →
m_1 (A) u_1 → m_2 (B)	$m_1 << m_2$	← u_1 m_1 (A) m_2 (B)

11. Inelastic collision

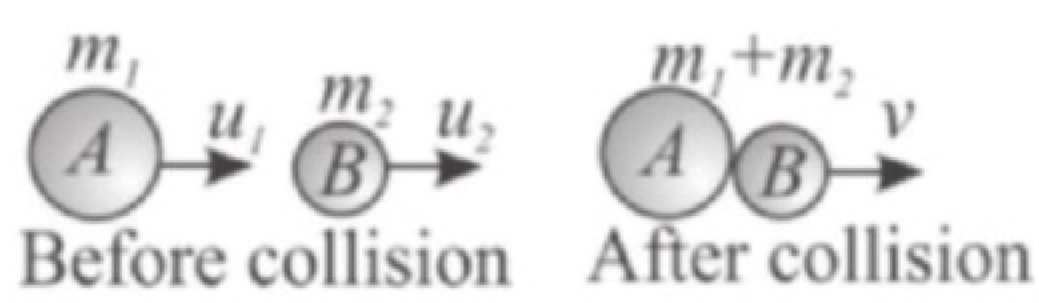
- In an inelastic collision, particles do not regain their shape and size completely after collision.

12. Perfectly inelastic collision

- Collision is said to be perfectly inelastic if both the particles stick together after collision and move with same velocity,

Perfectly inelastic collision in one dimension: Two bodies A and B of masses m_1 and m_2 moving with velocities

u_1 and u_2 $(u_2 < u_1)$ respectively along the same line collide head on and after collision they have same common velocity v.



$$v = \frac{m_1u_1 + m_2u_2}{(m_1 + m_2)}$$

Loss in kinetic energy

$$\Delta K = \frac{1}{2}\frac{m_1m_2}{(m_1 + m_2)}(u_1 - u_2)^2$$

13. Coefficient of restitution (e)

$$e = \frac{\text{Velocity of separation along line of impact}}{\text{Velocity of approach along line of impact}}$$

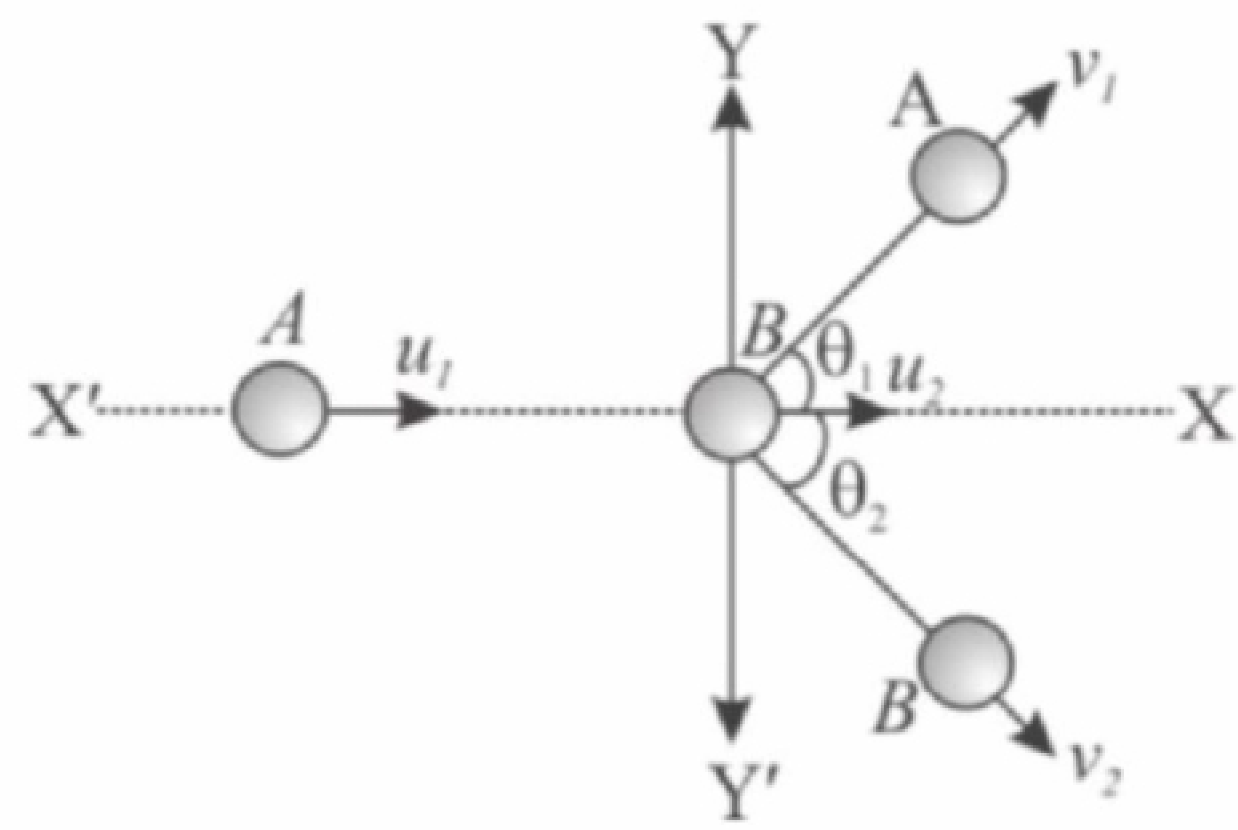
$$= \frac{v_2 - v_1}{u_1 - u_2}$$

u_1 & u_2 are components of velocities of 1 & 2 along normal direction before collision.

v_1 & v_2 are components of velocities of 1 & 2 along normal direction after collision.

- e = 1 $\Rightarrow$ Kinetic Energy is conserved $\Rightarrow$ Elastic collision.
- e = 0 $\Rightarrow$ Kinetic Energy is not conserved $\Rightarrow$ Perfectly Inelastic collision.
- 0 < e < 1 $\Rightarrow$ Kinetic Energy is not conserved $\Rightarrow$ Partial elastic or inelastic collision.

Elastic collision in two dimensions or oblique collision: Let us consider two bodies A and B of masses m_1 and m_2 moving along X-axis with velocities u_1 and u_2 respectively. When $u_1 > u_2$, the two bodies collide. After collision, body A moves with velocity v_1 at an angle θ_1 with X-axis and body B move with a velocity v_2 at an angle θ_2 with X- axis as shown in the figure.



Since the collision is elastic, kinetic energy is conserved.

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \quad (1)$$

Also momentum along X-axis before collision = momentum after collision along X-axis

$$\Rightarrow m_1u_1 + m_2u_2 = m_1v_1\cos\theta_1 + m_2v_2\cos\theta_2$$

Similarly along Y-axis

$$0 = m_1v_1\sin\theta_1 - m_2v_2\sin\theta_2 \quad (2)$$

Thus from these three equations (1), (2) and (3) we can find the required quantities.

14. Collision of a ball to a horizontal surface

- A ball of mass m hits a floor with a speed v_0 making an angle of incidence α with the normal. The coefficient of restitution is e.
- After collision components of velocity are $v_0\sin\alpha$ and $ev_0\cos\alpha$

$$\therefore v' = \sqrt{(v_0\sin\alpha)^2 + (ev_0\cos\alpha)^2} \quad \text{and}$$

$$\Rightarrow \tan\beta = \frac{\tan\alpha}{e}$$

For elastic collision, e = 1 $v' = v_0$ and $\beta = \alpha$

15. Impulse

Impulse of a force F acting on a body is defined as

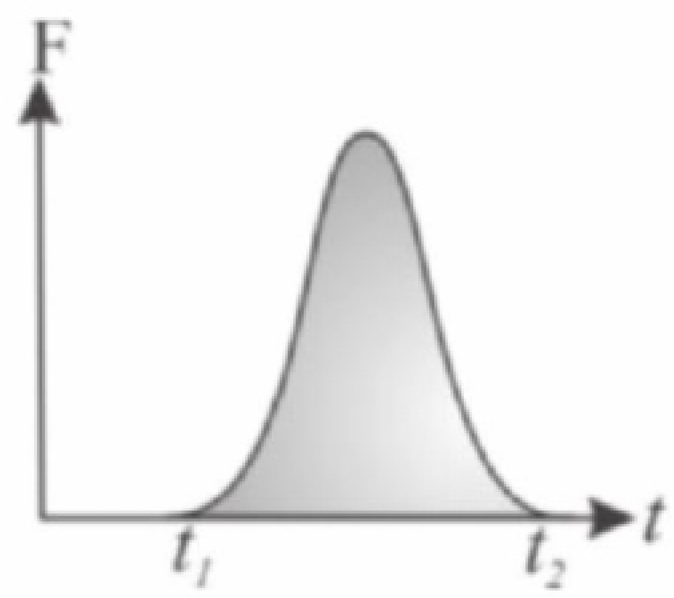
$$\vec{J}=\int \vec{f}dt=\int m\frac{\vec{dv}}{dt}dt=\int m\vec{dv}$$

$$J=m(\vec{v}_2-\vec{v}_1)$$

It is also defined as change in momentum

$$\vec{J}=\Delta\vec{P}$$

Instantaneous Impulse



$$\vec{J}=\int \vec{F}\,dt=\Delta\vec{P}=\vec{P}_f-\vec{P}_i$$

Impulse on a body for a time interval is equal to the area under force time (F-t) graph in the same time interval.

- It is a vector quantity.
- Magnitude is equal to area under the F-t. graph.
- $J=\int Fdt=Fav\int dt=F_{ev}\Delta t$

16. Variable Mass system

If a mass is added or ejected from a system, at rate μ kg/s and relative velocity $\vec{v}_{rel}$ (w.r.t. the system), then the thrust force F_{Th} exerted by this mass on the system has magnitude $\mu|\vec{v}_{rel}|$.

$$\vec{F}_{th}=\vec{v}_{rel}\left(\frac{dm}{dt}\right)$$

We can use another form of Newton's 2^{nd} law, i.e.,

$$\sum\vec{F}_{ext}+\vec{F}_{Th}=m\vec{a}$$

Where $\vec{F}_{Th}=\vec{v}_r\frac{dm}{dt}$

Where $\vec{v}_r$ is the relative velocity of incoming mass or ejected mass w.r.t. the main body.

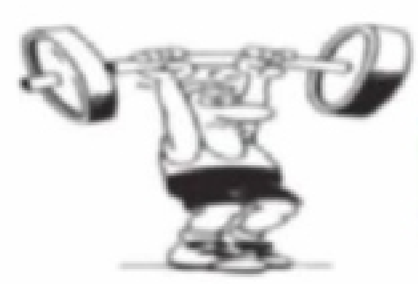
17. Rocket Propulsion

A rocket with initial mass m_0 is ejecting the gases with relative velocity v_r. The rate with which the rocket ejects gases is $\mu=\frac{-dm}{dt}$. Initial velocity is u.

$$v=u+v_r\ln\left(\frac{m_0}{m}\right)-gt$$

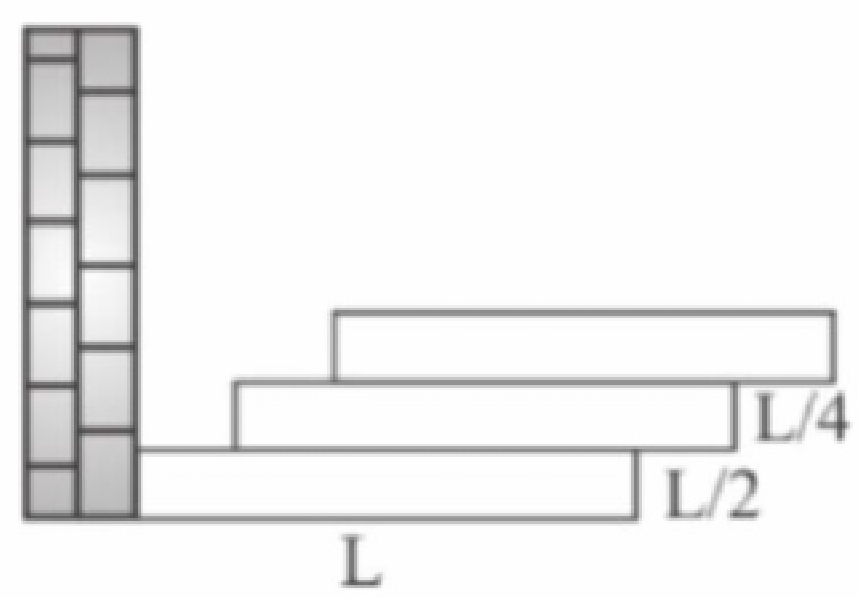
If the rocket is in free space then $g=0$

$$v=u+v_r\ln\left(\frac{m_0}{m}\right)$$



Exercise

1. Three bricks each of length L and mass M are arranged as shown from the wall. The distance of the centre of mass of the system from the wall is



(1) $\frac{L}{4}$ (2) $\frac{L}{2}$ (3) $\frac{11}{12}L$ (4) $\frac{3}{2}L$

2. From a uniform disc of radius R, a circular section of radius $\frac{R}{2}$ is cut out. The centre of the hole is at $\frac{R}{2}$ from the centre of the original disc. Locate the centre of mass of the resulting flat body.

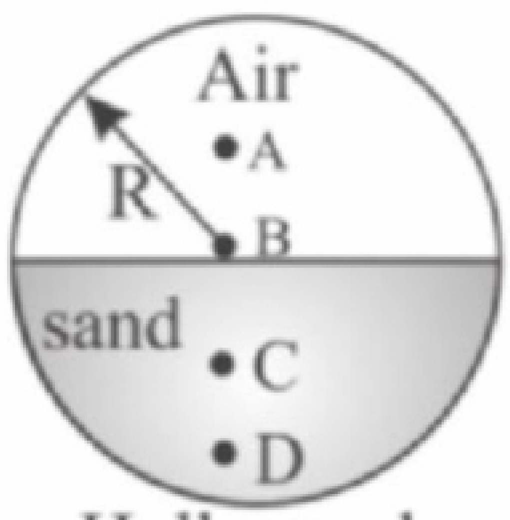
(1) $\frac{R}{6}$ to the right of centre o

(2) $\frac{R}{3}$ to the right of centre o

(3) $\frac{R}{3}$ to the left of centre o

(4) $\frac{R}{6}$ to the left of centre o

3. Which of the following points is the likely position of the centre of mass of the system shown in figure.



Hollow sphere

(1) A (2) B (3) C (4) D

4. Two particles of mass 1kg and 3kg have position vectors $2\hat{i}+3\hat{j}+4\hat{k}$ and $-2\hat{i}+3\hat{j}$ $-4\hat{k}$ respectively. The centre of mass has a position vector

(1) $\hat{i}+3\hat{j}-2\hat{k}$ (2) $-\hat{i}-3\hat{j}-2\hat{k}$

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

5. Three masses of 2kg, 4 kg and 4 kg are placed at the three points (1,0,0) (1,1,0) and (0, 1, 0) respectively. The position vector of its center of mass is

(1) $(3\hat{i}+\hat{j})$ (2) $\frac{3}{5}\hat{i}+\frac{4}{5}\hat{j}$

(3) $\frac{1}{5}\hat{i}+\frac{4}{5}\hat{j}$ (4) $\frac{2}{5}\hat{i}+\frac{4}{5}\hat{j}$

6. Two semicircular rings of linear mass densities λ and 3λ and of radius R each are joined to form a complete ring. The distance of the centre of the mass of complete ring from its geometrical centre is

(1) $\frac{R}{\pi}$ (2) $\frac{2R}{3\pi}$ (3) $\frac{R}{3\pi}$ (4) $\frac{2R}{\pi}$

7. Two identical particles are located at $\vec{x}$ and $\vec{y}$ with reference to the origin of threedimensional co-ordinate system. The position vector of centre of mass of the system is given by

(1) $\frac{\vec{x}+\vec{y}}{2}$ (2) $\vec{x}-\vec{y}$

(3) $\frac{\vec{x}-\vec{y}}{2}$ (4) $(\vec{x}-\vec{y})$

8. A child is sitting at one end of a long trolley moving with a uniform speed v on a smooth horizontal track. If the child starts running towards the other end of the trolley with a speed u (w.r.t trolley), the speed of the centre of mass of the system is

(1) $v - u$ (2) $u + v$

(3) v (4)None of these

9. The figure shows the positions and velocities of two particles. If the particles move under the mutual attraction of each other, then the position of centre of mass at t = 1 s is

(1) x=6cm (2) x=5cm

(3) x=2cm (4) x=3cm

10. Two particles of equal masses have velocity $\vec{v_1}=2\hat{i}\,m/s$ and $\vec{v_2}=2\hat{i}\,m/s$. The first particle has an acceleration $\vec{a_1}=(3\hat{i}+3\hat{j})\,m/s^2$ while the acceleration ofthe other particle is zero. The centre of mass of the two particles moves in a:

(1) Circle (2) Parabola

(3) Straight line (4) Ellipse

11. A boy of mass m is standing on a block ofmass M kept on a rough surface. Assume that block does not slip on the surface. When the boy walks from left to right on the block, the centre of mass (boy+block) of system:

(1) Remains stationary
(2) Shifts towards left
(3) Shift towards right.
(4) Shifts towards right if M > m and towards left if M < m.

12. Two bodies A and B have masses M and m respectively where M>m and they are at a distance d apart. Equal force is applied to them so that they approach each other. The position where they hit each other is
(1) Nearer to A
(2) Nearer to B
(3) Cannot be determined
(4) At equal distance from A and B

13. In a two-particle system with particle masses m_1 and m_2 ,the first particle is pushed towards the centre of mass through a distance d, the distance through which second particle must be moved to keep the centre of mass at the same position is

(1) d (2) $\frac{m_2 d}{m_1}$

(3) $\frac{m_1 d}{m_2}$ (4) $\frac{m_1 d}{(m_1 + m_2)}$

14. A rifle man, who together with his rifle has a mass of 100 kg, stands on a smooth surface fires 10 shots horizontally. Each bullet has a mass 10 gm and a muzzle velocity of 800 m/s. What velocity does rifle man acquire at the end of 10 shots
(1) 0.5 m/s (2) 0.8 m/s
(3) 1.2 m/s (4) 0.3 m/s

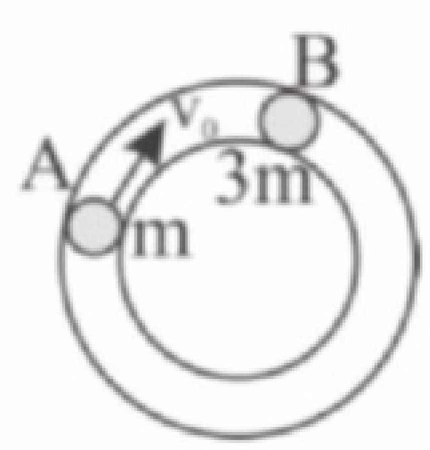
15. Internal forces can change
(1) The KE but not the linear momentum
(2) The linear momentum but bot the KE
(3) Neither the linear momentum nor the KE
(4) Linear momentum as well as KE

16. For a system to follow the law of conservation of linear momentum during a collision, the condition is
(i) Total external force acting on the system is zero.
(ii) Total external force acting on the system is finite and time of collision is negligible.
(iii) Total internal force acting on the system is zero.
(1) Only (ii) (2) Only (i)
(3) Only (i) and (ii) (4) Only (iii)

17. Two identical bodies moving in opposite direction with same speed, collide with each other. If the collision is perfectly elastic then
(1) After the collision both comes to rest
(2) After the collision first body comes to rest
(3) After collision they exchange their velocities
(4) Both 1 and 2

18. During a collision between a closed system of particles, in the absence of external forces.
(1) The total kinetic energy of the system remains constant
(2) The momentum of each particle remains constant
(3) Only momentum and kinetic energy, both are exchanged between different particles.
(4) Momentum is exchanged between different particles

19. In a smooth circular tube of radius R, a particle of mass m moving with speed v_0 hits another particle of mass 3m at rest as shown. The time after which the next collision takes place (assume elastic collision)



(1) $\frac{2\pi R}{v_0}$ (2) $\frac{\pi R}{v_0}$ (3) $\frac{\pi R}{4v_0}$ (4) $\frac{\pi R}{2v_0}$

20. In case of elastic collision, at the time of impact
(1) Total K.E. of colliding bodies increases
(2) Total K.E. of colliding bodies is conserved
(3) Total momentum of colliding bodies decreases
(4) Total K.E. of colliding bodies decreases

21. Two identicals balls A and B moving with velocities +0.5 m/s and -0.3 m/s respectively collide head on elastically. The velocities of the balls A and B after collision will be respectively.
(1) -0.3 m/s and +0.5 m/s
(2) +0.5 m/s and +0.3 m/s
(3) -0.5 m/s and +0.3 m/s
(4) +0.3 m/s amd 0.5 m/s

22. For inelastic collision between two spherical rigid bodies
(1) The total kinetic energy is conserved
(2) The coefficient of restitution is equal to 1
(3) The linear momentum is not conserved
(4) The linear momentum is conserved

23. A pendulum consist of a wooden bob of mass m and length l. A bullet of mass m_1 is fired towards the pendulum with a speed v_1. the bullet emerges out of the bob with a speed $v_1/3$ and the bob just completes motion along a vertical circle. Then v_1 is

(1) $\frac{3}{2}\left(\frac{m}{m_1}\right)\sqrt{5gl}$ (2) $\left(\frac{m}{m_1}\right)\sqrt{5gl}$

(3) $\left(\frac{m_1}{m}\right)\sqrt{gl}$ (4) $\frac{2}{3}\left(\frac{m_1}{m}\right)\sqrt{5gl}$

24. Two solid rubber A and B having masses 200 & 400 gm respectively are moving in opposite direction with velocity of A equal to 0.3 m/sec. After collision the two balls come to rest then the velocity of B is
(1) 0.15 m/sec (2) 1.5 m/sec
(3) -0.15 m/sec (4) None of these

25. Two bodies of masses 0.1 kg and 0.4 kg move towards each other with the velocities 1m/s and 0.1m/s respectively. After collision they stick together. In 10sec the combined mass travels:
(1) 0.12 m (2) 120 m
(3) 1.2 m (4) 12 m

26. A sphere of mass m moving with a constant velocity v hits another stationary sphere of same mass. If e is the coefficient of restitution, then the ratio of velocity of two spheres after collision will be

(1) $\frac{1-e}{1+e}$ (2) $\frac{1+e}{1-e}$ (3) $\frac{e+1}{e-1}$ (4) $\frac{e-1}{e+1}$

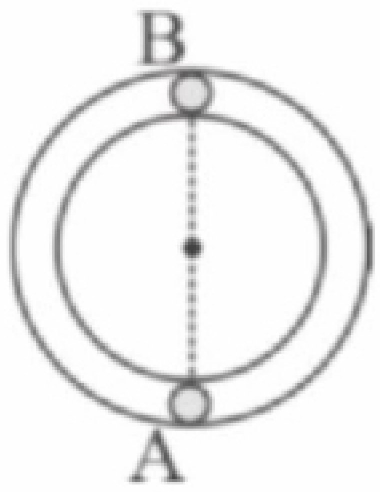
27. A particle of mass m_1 collides head on with a stationary particle of mass m_2. If $\frac{m_1}{m_2} > e$ where e is the coefficient of restitution, then:
(1) m_1 will move in same direction
(2) m_1 will return back
(3) Unpredictable
(4) m_1 will stop

28. A ball is let fall from a height h_0. There are n collisions with the earth. If the velocity of rebound after n collisions is v_n and the ball rises to a height h_n, then coefficient of restituation e is given by

(1) $e^n = \sqrt{\frac{h_0}{h_n}}$ (2) $e^n = \sqrt{\frac{h_n}{h_0}}$

(3) $\sqrt{ne} = \sqrt{\frac{h_n}{h_0}}$ (4) $ne = \sqrt{\frac{h_n}{h_0}}$

29. Two identical spheres A and B lie on a smooth horizontal circular groove at opposite ends of a diameter. A is projected along the groove and at the end of time t, impinges on B. If e is the coefficient of restitution, the second impact will occur after a time.



(1) $\frac{t}{e}$ (2) $\frac{2t}{e}$ (3) $\frac{2\pi t}{e}$ (4) $\frac{\pi t}{e}$

30. Two ice skaters A and B approach each other at right angles. Skater A has a mass 30 kg and velocity 1 m/s and skater B has a mass 20 kg and velocity 2 m/s. They meet and cling together. Their final velocity of the couple is

(1) 2 m/s (2) 1.5 m/s
(3) 1 m/s (4) 2.5 m/s

31. A mass m moving horizontally (along the x-axis) with velocity v collides and sticks to mass of 3m moving vertically doward (along the y-axis) with velocity $2v$. The final velocity of the combination is

(1) $\frac{1}{3}v\hat{i}+\frac{2}{3}v\hat{j}$ (2) $\frac{1}{4}v\hat{i}+\frac{3}{2}v\hat{j}$

(3) $\frac{3}{2}v\hat{i}+\frac{1}{4}v\hat{j}$ (4) $\frac{2}{3}v\hat{i}+\frac{1}{3}v\hat{j}$

32. A man in a boat A pulls a rope with a force 100 N. The other end of the rope is tied to a boat B of mass 200 kg. The total mass of boat A and man is 300 kg, disregard the weight of the rope and the resistance of the water. The power developed by the man by the end of the third second is

(1) 200W (2) 100W
(3) 250W (4) 150W

33. A ball strikes a horizontal floor at 45^o . $\frac{1}{4}th$ of its kinetic energy is lost in collision. Find the coefficient of restitution.

(1) $\frac{1}{\sqrt{2}}$ (2) $\frac{1}{2}$ (3) $\frac{1}{4}$ (4) $\frac{1}{2\sqrt{2}}$

34. Hail storms are observed to strike the surface of the frozen lake at 30^o with the vertical and rebound at 60^o with the vertical. Assume contact to be smooth, the coefficient of restitution is

(1) $e=\frac{1}{3}$ (2) $e=\frac{1}{\sqrt{3}}$

(3) $e=3$ (4) $e=\sqrt{3}$

35. A projectile is fired with a speed u at an angle θ above the horizontal field. The coefficient of restitution between the projectile and field is e. Find the position from the starting point where the projectile will land at its second collision.

(1) $\frac{(1-e^2)u^2\sin\theta}{g}$

(2) $\frac{e^2u^2\sin\theta}{g}$

(3) $\frac{(1+e)u^2\sin 2\theta}{g}$

(4) $\frac{(1-e)u^2\sin\theta\cos\theta}{g}$

36. A molecule of mass m of an ideal gas collides with the wall of a vessel with a velocity v and returns back with the same velocity. The change in linear momentum of molecule is:

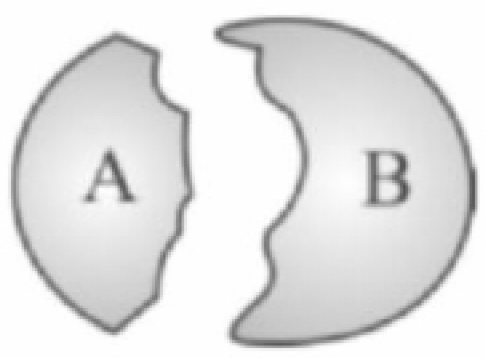
(1) $4mv$ (2) $2mv$ (3) $10mv$ (4) $8mv$

37. A stationary body explodes into two fragmentsofmasses m_1 *and* m_2. If momentum of one fragment is p, the minimum energy ofexplosion is

(1) $\frac{p^2}{2\sqrt{m_1m_2}}$ (2) $\frac{p^2}{2(m_1-m_2)}$

(3) $\frac{p^2}{2(m_1+m_2)}$ (4) $\frac{p^2(m_1+m_2)}{2m_1m_2}$

38. A shell in free space initially at rest explodes into two pieces, A and B, which then move in opposite directions. Piece A has less mass than piece B. Ignore all external forces. Identify correct statement.



(1) Piece B has greater magnitude of momentum after the explosion.
(2) Both have the same momentum after the explosion.
(3) Both have the same kinetic energy after the explosion.
(4) Piece A has greater kinetic energy after the explosion.

39. A shell of mass m moving with velocity v suddenly breaks into 2 pieces. The part having mass $m/3$ remains stationary. The velocity of other part will be

(1) $\frac{2}{3}v$ (2) $\frac{7}{5}v$

(3) $\frac{3}{2}v$ (4) None of these

40. A shell of mass 20kg at rest explodes into two fragments whose masses are in the ratio 2:3. The smaller fragment moves with a velocity of $6ms^{-1}$.The kinetic energy of the large fragment is:
(1) 216J (2) 96J
(3) 360J (4) 144J

41. The area of F-t curve is A, where 'F' is the force acting on one mass due to the other. If one of the colliding bodies of mass M is at rest initially, its speed just after the collision is

(1) M/A(2) $\sqrt{\frac{2A}{M}}$ (3) A/M (4) AM

42. A ball moving with a velocity v strikes a wall moving towards the ball with a velocity u. An elastic impact lasts for t seconds then the mean elastic force acting on the ball is (Mass of the ball is M)

(1) $\frac{M(v+2u)}{t}$ (2) $\frac{2Mv}{t}$

(3) $\frac{M(2v+u)}{t}$ (4) $\frac{2M(v+u)}{t}$

43. A body of mass 5 kg has momentum of 10 kg m/sec. When a force of 0.2N is applied on it for 10 sec in the same direction, the changein its kinetic energy is
(1) 3.3J (2) 4.4J (3)1.1J (4) 5.5J

44. In a rocket of mass 1000kg fuel is consumed at a rate of 40 kg/s. The velocity of the gases ejected from the rocket is $5\times10^4 m/s$. The thrust on the rocket is

(1) $2\times10^9 N$ (2) $2\times10^6 N$

(3) $2\times10^4 N$ (4) $2\times10^3 N$

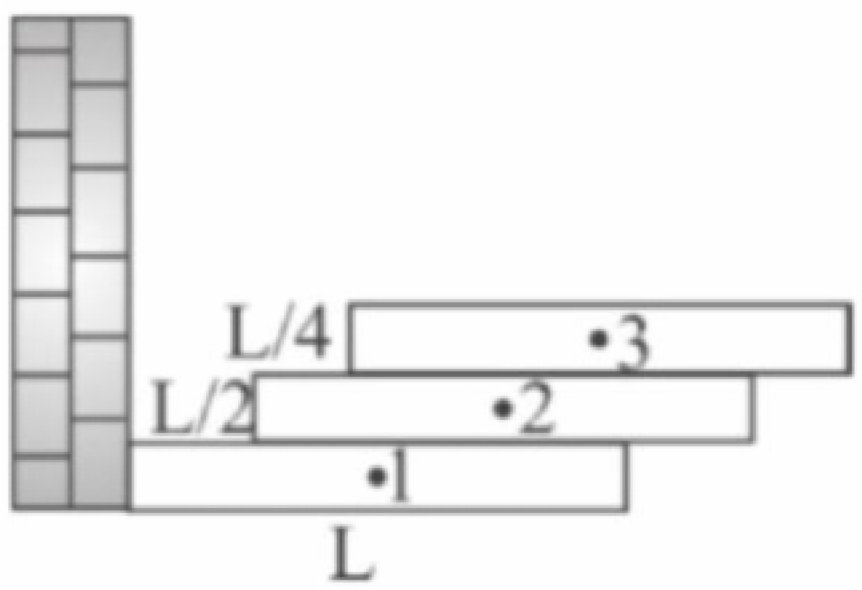
45. If the thrust force on a rocket which is ejecting gases with a relative a velocity of 300 m/s, is 210N. Then rate of combustion of the fuel will be
(1) 10.7 kg/sec (2) 0.7 kg/sec
(3) 1.4 kg/sec (4) 0.07 kg/sec

ANSWER KEY

1. 3	**2.** 4	**3.** 3	**4.** 4	**5.** 2
6. 1	**7.** 1	**8.** 3	**9.** 2	**10.** 3
11. 3	**12.** 1	**13.** 3	**14.** 2	**15.** 1
16. 2	**17.** 3	**18.** 4	**19.** 1	**20.** 4
21. 1	**22.** 4	**23.** 1	**24.** 2	**25.** 3
26. 1	**27.** 1	**28.** 2	**29.** 2	**30.** 3
31. 2	**32.** 3	**33.** 1	**34.** 1	**35.** 3
36. 2	**37.** 4	**38.** 4	**39.** 3	**40.** 2
41. 3	**42.** 4	**43.** 2	**44.** 2	**45.** 2

HINTS & SOLUTIONS

1.Sol:



From figure,

$$x_1 = \frac{L}{2}, x_2 = \frac{L}{2} + \frac{L}{2} = L$$

$$x_3 = \frac{L}{2} + \frac{L}{4} + \frac{L}{2} = \frac{5L}{4}$$

$$\therefore x_{CM} = \frac{M_1x_1 + M_2x_2 + M_3x_3}{M_1 + M_2 + M_3}$$

$$= \frac{M \times \frac{L}{2} + M \times L + M \times \frac{5L}{4}}{M + M + M} = \frac{11L}{12}$$

2.Sol: Let mass per unit area of the disc be σ.

$\therefore$ Mass of the disc $(M) = \pi R^2 \sigma$.

Mass of the portion removed from the disc

$$m = \pi\left(\frac{R}{2}\right)^2 \sigma = \frac{M}{4}$$

The position of centre of mass of the remaining portion is

$$x = \frac{-m\left(\frac{R}{2}\right)}{M - m} = \frac{-\frac{M}{4} \times \frac{R}{2}}{M - \frac{M}{4}} = -\frac{R}{6}$$

3.Sol: The position of the centre of mass of the system shown in figure is likely to be at C. This is because lower part of the sphere containing sand is heavier than upper part of the sphere containing air.

4.Sol: Here, $m_1 = 1kg, m_2 = 3kg$

$$\vec{r_1} = 2\hat{i} + 3\hat{j} + 4\hat{k}, \vec{r_2} = -2\hat{i} + 3\hat{j} - 4\hat{k}$$

The position vector of the centre of mass is

$$\overrightarrow{r_{CM}} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$$

$$= \frac{(1)(2\hat{i} + 3\hat{j} + 4\hat{k}) + (3)(-2\hat{i} + 3\hat{j} - 4\hat{k})}{1+3}$$

$$= \frac{-4\hat{i} + 12\hat{j} - 8\hat{k}}{4} = -\hat{i} + 3\hat{j} - 2\hat{k}$$

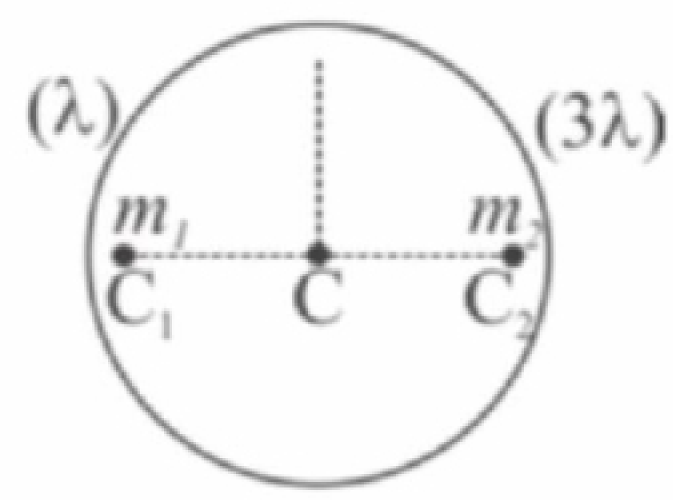
5.Sol: Given that

$$m_1 = 2, m_2 = 4, m_3 = 4$$

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3}{m_1 + m_2 + m_3}$$

$$= \frac{2(\hat{i}) + 4(\hat{i} + \hat{j}) + 4(\hat{j})}{10} = \frac{3}{5}\hat{i} + \frac{4}{5}\hat{j}$$

6.Sol: The distance of CM of a semi circular ring of radius R is $\frac{2R}{\pi}$.



$$m_1 = \lambda(\pi R)$$

$$m_2 = 3\lambda(\pi R)$$

Consider the origin at the centre of the ring. The x position of CM of the ring from C is

$$x = \frac{-m_1\left(\frac{2R}{\pi}\right) + m_2\left(\frac{2R}{\pi}\right)}{m_1 + m_2} = \frac{R}{\pi}$$

7.Sol: $$\vec{r} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2} = \frac{m(\vec{x} + \vec{y})}{2} = \frac{\vec{x} + \vec{y}}{2}$$

8.Sol: Velocity of centre of mass will remain unaffected as no external force acts on a system.

9.Sol: External force on the system is equal to zero. So C.M remains at rest and lies at the mid point.

$$x_{CM} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{1\times2+1\times8}{2}$$

$$x_{CM} = 5cm$$

10.Sol: $$\vec{v}_{cm} = \frac{m2\hat{i} + m2\hat{j}}{m+m} = \hat{i} + \hat{j}$$

$$\vec{a}_{cm} = \frac{m(3\hat{i}+3\hat{j}) + m\times0}{m+m} = \frac{3}{2}\hat{i} + \frac{3}{2}\hat{j}$$

As both vectors make $45°$ with x-axis so both move along a straight line.

11.Sol: As boy walk from left to right on the block, the block will be at rest because of frictional force. Hence the centre of mass of the boy and block will shift towards right.

12.Sol: As net external force on the system is zero therefore position of their centre of mass remains unaffected i.e. they will hit each other at the point of centre of mass . The centre ofmass of the system lies nearer to A because

$M_A > M_B$.

13.Sol: As centre of mass remains at rest

$$\Delta x_{CM} = \frac{m_1\Delta x_1 + m_2\Delta x_2}{m_1 + m_2} = 0$$

$$m_1(-d) + m_2\Delta x_2 = 0$$

$$\Delta x_2 = \left(\frac{m_1}{m_2}\right)d$$

14.Sol: Let m_1 and m_2 be the masses of bullet and the rifleman v_1 and v_2 their respective velocities after the first shot. As external force is zero, momentum of system is constant $= m_1v_1 + m_2v_2$

$$v_2 = \frac{m_1v_1}{m_2} = -\frac{(10\times10^{-3}kg)(800m/s)}{100kg} = -0.08m/s$$

Velocity acquired after 10 shots

$$= 10v_2 = 10\times(-0.08) = -0.8m/s$$

15.Sol: Conceptual

16.Sol: From Newton's second law,

$$F = \frac{dp}{dt}$$

If $\quad F = 0 \Rightarrow \frac{dp}{dt} = 0$

$$\Rightarrow \text{p} = \text{constant}$$

Thus, if total external force acting on the system is zero, then linear momentum of the system remains conserved.

17.Sol: Let u_1 & u_2 be the initial velocities and v_1 & v_2 final velocities after collision.

$$v_1 = \frac{(m_1 - m_2)u_1}{m_1 + m_2} + \frac{2m_2u_2}{m_1 + m_2}$$

$$v_2 = \frac{2m_1u_1}{m_1 + m_2} + \frac{(m_1 - m_2)u_2}{m_1 + m_2}$$

Given that $m_1 = m_2$, $v_1 = u_2$ & $v_2 = u_1$

After collision the bodies exchange their velocities.

18.Sol: Since external forces are absent, so the total momentum of the system remains constant. However, internal forces, may alter the momentum of each particle. Momentum is exchanged among different particles. In the presence of elastic forces K.E of system converts into P.E. So K.E of system changes.

19.Sol: Relative velocity of separation = relative velocity of approach = v

$$\text{Time of next collision} = \frac{2\pi R}{v}$$

20.Sol: In case of elastic collision the two bodies undergoes compression in their shapes and then they regain their shapes. During this process K.E is converted into elastic potential energy.

21.Sol: When the identical balls collide head-on, their velocities are exchanged.

22.Sol: In an inelastic collision, the particle donotregain their shape and size completely after collision. Some fraction of mechanical energy is lost in the form of heat energy. Thus, the kinetic energy of particles is not conserved. However, in the absence of external forces, linear momentum is conserved.

23.Sol: Applying the law of conservation of momentum,

$$m_1v_1 = m_1\frac{v_1}{3} + mv$$

To describe a vertical circle v should be $\sqrt{5gl}$

$$\frac{2m_1v_1}{3m} = \sqrt{5gl} \Rightarrow v_1 = \left(\frac{m}{m_1}\right)\frac{3}{2}\sqrt{5gl}$$

24.Sol:

$m_1 = 0.2kg, m_2 = 0.4kg, u_1 = 0.3m/s, u_2 = ?$

Applying law of conservation of momentum

$$m_1u_1 - m_2u_2 = 0 \Rightarrow u_2 = \frac{0.2\times0.3}{0.4} = 0.15m/s.$$

25.Sol: According to conservation of momentum

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

Where v is common velocity of the two bodies

$m_1 = 0.1kg, \quad m_2 = 0.4kg$

$u_1 = 1m/s, u_2 = -0.1m/s$

$\therefore \quad 0.1\times1 + 0.4\times(-0.1) = (0.1+0.4)v$

$$v = \frac{0.06}{0.5} = 0.12m/s$$

Hence, distance covered $0.12\times10 = 1.2m$

26.Sol: Given, $m_1 = m_2 = m$

$$u_1 = v \text{ and } u_2 = 0$$

$$e = \frac{v_2 - v_1}{v - 0}$$

$$v_2 - v_1 = ev \qquad (1)$$

$$mv + 0 = mv_1 + mv_2$$

$$v = v_1 + v_2 \qquad (2)$$

From eq's (1) & (2)

$$\frac{v_1}{v_2} = \frac{1-e}{1+e}$$

27.Sol: $m_1u = m_1v_1 + m_2v_2 \qquad (1)$

and $v_1 - v_2 = eu \qquad (2)$

From eq's (1) & (2)

$$v_1 = \frac{u(m_1 - em_2)}{(m_1 + m_2)}$$

Given $\frac{m_1}{m_2} > e \Rightarrow v_1 = (+)ve$

So m_1 will move in same direction

28.Sol: In this problem, the velocity of the earth before and after the collision may be assumed zero. Let v_n be the velocity after nth rebounding and v_0 is the velocity with which the ball strikes the earth first time.

Hence, $$e^n = \frac{v_n}{v_0} = \frac{\sqrt{2gh_n}}{\sqrt{2gh_0}}$$

Where h_n is the height to which the ball rises after n^{th} rebounding: Hence,

$$e^n = \frac{v_n}{v_0} = \frac{\sqrt{h_n}}{\sqrt{h_0}}$$

29.Sol: First collision occurs at $t = \frac{\pi R}{u}$

After collision their relative velocity $= eu$

So second collision will occur after

$$\frac{\textit{Relative distance}}{\textit{Relative velocity}} = \frac{2\pi R}{eu} = \frac{2t}{e}$$

30.Sol: Momentum of Skater

$$A = 30\times1 = 30kg\,m/s$$

Momentum of skater

$$B = 20\times2 = 40kgm/s$$

They are at right angles to each other.

Resultant momentum $= p$

$$\Rightarrow p=\sqrt{(30)^2+(40)^2}$$

$$\Rightarrow p=50kg\,m/s$$

$$\therefore Final\,velocity=\frac{p}{Total\,mass}=\frac{50}{(30+20)}=1m/s$$

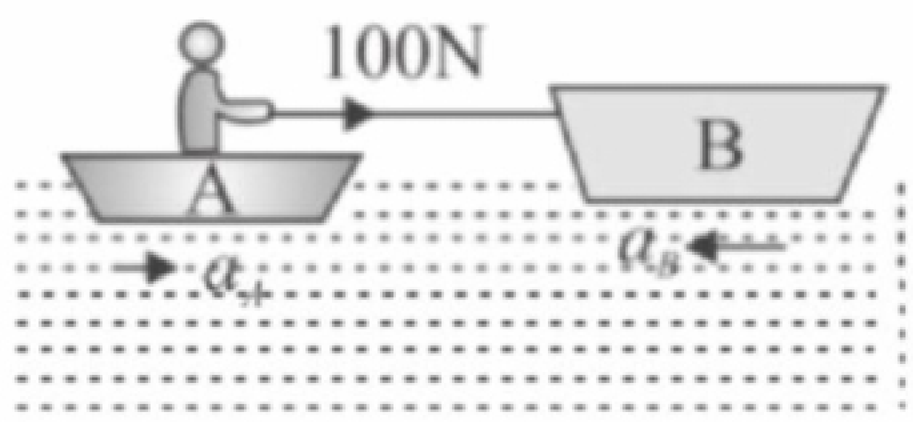
31.Sol: From the law of conservation of linear momentum

$$mv\hat{i}+(3m)(2v)\hat{j}=(4m)\vec{v}'$$

$$mv\hat{i}+6mv\hat{j}=4m\vec{v}'$$

$$\vec{v}'=\frac{1}{4}v\hat{i}+\frac{3}{2}v\hat{j}$$

32.Sol: The situation is shown in the figure.



Given that $m_A=300kg$

$$m_B=200kg$$

$$F=100N$$

As the man in boat A pulls the rope, accelerations produced in boat A and B are

$$a_B=\frac{100}{200}=\frac{1}{2}m/s^2$$

$$a_A=\frac{100}{300}=\frac{1}{3}m/s^2$$

$$v_A=a_At=\frac{1}{3}(3)=1m/s$$

$$v_B=a_Bt=\frac{1}{2}(3)=\frac{3}{2}m/s$$

$$P_{total}=Fv_A+Fv_B$$

$$=100\left(1+\frac{3}{2}\right)=250W$$

33.Sol: Fraction of KE lost in collision

$$\Delta K\%=\frac{\frac{1}{2}mu^2-\frac{1}{2}mv^2}{\frac{1}{2}mu^2}=1-\left(\frac{v}{u}\right)^2=\frac{1}{4}$$

$$\Rightarrow v=u\sqrt{\frac{3}{4}}$$

The ball strikes at 45^o. Component of velocity parallel to wall $(u\cos45^o)$ will not change while component of velocity normal to wall will change.

$$v_x=u\cos45^o=\frac{u}{\sqrt{2}}$$

$$v_y=eu\cos45^o=\frac{eu}{\sqrt{2}}$$

$$v=\sqrt{v_x^2+v_y^2}=\left[\left(\frac{u}{\sqrt{2}}\right)^2+\left(\frac{eu}{\sqrt{2}}\right)^2\right]^{\frac{1}{2}}$$

$$\Rightarrow v=u\left[\frac{1}{2}+\frac{e^2}{2}\right]^{\frac{1}{2}} \quad (2)$$

Solving (1) and (2), we get

$$e=\frac{1}{\sqrt{2}}$$

34.Sol: Components of velocity before and after collision parallel to the plane are equal, so

$$v\sin60^o=u\sin30^o$$

Components of velocity normal to the plane are related to each other

$$v\cos60^o=eu(\cos30^o)$$

$$\Rightarrow \cot60^o=e\cot30^o\Rightarrow e=\frac{\cot60^o}{\cot30^o}$$

$$\Rightarrow e=\frac{\frac{1}{\sqrt{3}}}{\sqrt{3}}\Rightarrow e=\frac{1}{3}.$$

35.Sol: Vertical velocity after first collision $=eu\sin\theta$

New time of flight $T'=\dfrac{2eu\sin\theta}{g}$

New range $R'=u_xT'$ (u_x -remain constant)

$$x=R+R'=\frac{u^2\sin2\theta}{g}(1+e)$$

36.Sol: Initial momentum = mv
Final momentum = $m(-v)$
Change in momentum = mv - m $(-v)$ -$2mv$

37.Sol: As momentum is conserved the momentum of both the particles are equal

$$P = m_1v_1 + m_2v_2$$

Energy of explosion

$$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 = K.E_1 + K.E_2$$

$$= \frac{P^2}{2m_1} + \frac{P^2}{2m_2} = \frac{P^2(m_1+m_2)}{2m_1m_2}$$

38.Sol: In expression the small piece will have more K.E than larger piece

39.Sol: From momentum conservation

$$mv = m/3 \times 0 + \frac{2m}{3}v'$$

$$mv = \frac{2m}{3}v' \Rightarrow v' = \frac{3}{2}v$$

40.Sol: Total mass $= 20kg$

$\therefore$ Large fragment $= 12kg$

$\therefore$ Smaller fragment $= 8kg$

Momentum is conserved

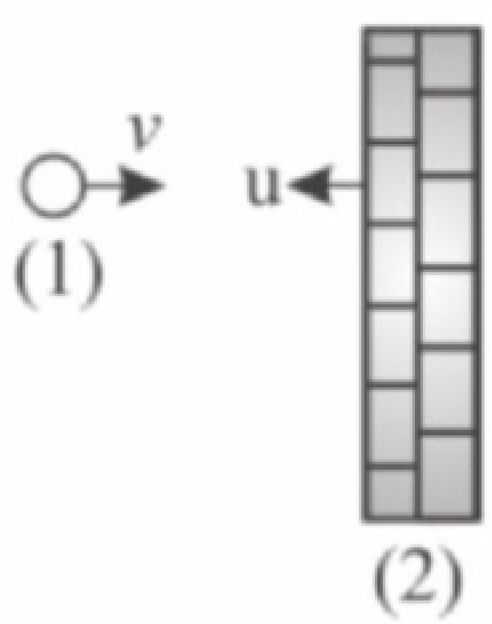
$$\therefore 8 \times 6 + 12 \times v = 0 \Rightarrow v = 4$$

$$\Rightarrow \text{Kinetic energy} = \frac{1}{2}mv^2 = \frac{1}{2} \times 12 \times (4)^2 = 96J$$

41.Sol: The area of the graph drawn between F & t is equal to change in momentum of the body

$$\Delta p = Mv = A \Rightarrow v = \frac{A}{M}$$

42.Sol:



$$e = \frac{v_2 - v_1}{u_1 - u_2} = \frac{-u - v_1}{v - (-u)} = 1$$

$$-u - v_1 = u + v$$

$$\Rightarrow \quad v_1 = -(2u + v)$$

Change in momentum of the ball is

$$\Delta P = Mv_1 - Mv$$

$$= -M[2u + 2v]$$

$$\Rightarrow \quad F = \frac{2M[v+u]}{t}$$

43.Sol: Change in momentum,

$$\Delta p = F \cdot t = 0.2 \times 10 = 2$$

$$v_1 = \frac{10}{5} = 2\,m/\text{sec}$$

$$K.E_i = \frac{1}{2} \times 5 \times 2^2 = 10J$$

$$p_2 = 10 + 2 = 12kg\,m/\text{sec}$$

$$v_2 = \frac{12}{5}m/\text{sec}$$

$$K.E_f = \frac{1}{2} \times 5 \times \left(\frac{12}{5}\right)^2 = 14.4J$$

Change in energy $= 14.4 - 10 = 4.4$ joule

44.Sol: The thrust force on the rocket is

$$F_{Th} = V_r \times \frac{dm}{dt}$$

$$F_{Th} = 5 \times 10^4 \times 40$$

$$F_{Th} = 2 \times 10^6\,N$$

45.Sol: $F_{Thrust} = v_{rel}\frac{dm}{dt} \Rightarrow 210 = 300\frac{dm}{dt}$

$$\Rightarrow \frac{dm}{dt} = 0.7\frac{kg}{\text{Sec}}$$

[2011-12]

1. Let the electrostatic force between to electrons (F_e) be x times the gravitational force (F_g) between them. Then, x is of the order of
   (a) 10^{40} (b) 10^{42} (c) 10^{38} (d) 10^{37}

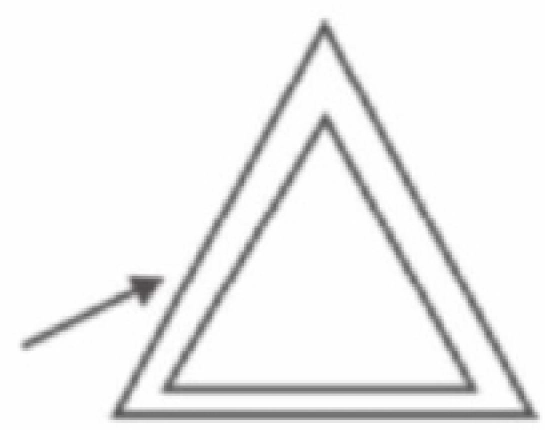
2. An arrow shot vertically upwards loses its initial speed by 60% in 3 Seconds. The maximum height reached by the arrow is $\left(g = 9.8\text{ms}^{-2}\right)$
   (a) 122.5 m (b) 44.1 m
   (c) 100m (d) 45m

3. A certain force applied to a body A gives it an caccelerations of 10 ms^{-2}. The same force applied to body B gives it an acceleration of 15 ms^{-2}. If the two bodies are joined together and same force is applied to the combination, the acceleration will be
   (a) 6 ms^{-2} (b) 25 ms^{-2}
   (c) 12.5 ms^{-2} (d) 9 ms^{-2}

4. A ball is dropped from a height of 7.2 m. It bounces back to 3.2 m after striking the floor. The ball remains in contact with the floor for 20ms. Given that $g = 10\ ms^{-2}$, the average acceleration of the ball during the contact is
   (a)100 ms^{-2} (b 200 ms^{-2}
   (c) 600 ms^{-2} (d)1000 ms^{-2}

5. A loaded bus (mass m_2) and an unloaded bus (mass m_1) are both moving with the same kinetic energy. Brakes are applied to both the buses so as to exert equal retarding force. If S_1 and S_2 are the distances covered by the two buses respectively, before coming to rest, them $\frac{S_1}{S_2}$ is.
   (a) 1 (b) $\frac{m_1}{m_2}$
   (c) $\sqrt{\frac{m_1}{m_2}}$ (d) $\sqrt{\frac{m_1^2}{m_2^2}}$

6. A ray of light is incident on a hollow glass prism as shown. Then the ray will undergo

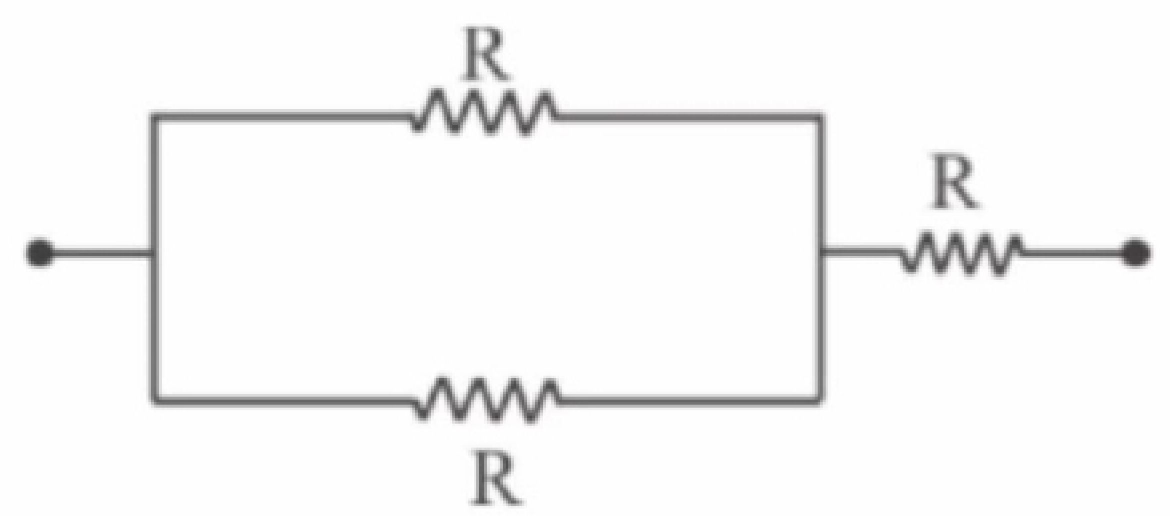


   (a) Deviation and dispersion both
   (b) Deviation but no dispersion
   (c) Dispersion but no deviation
   (d) Neither deviation nor dispersion

7. In a neon discharge tube 2.8×10^{18} Ne^{+} ions move to the right per second. While 1.2×10^{18} electrons move to the left per second. Therefore, the current in the discharge tube is
   (a) 0.64 A towards right

(b) 0.256 A towards right
(c) 0.64 A towards left
(d) 0.256 A towards left f

8. Three equal resistances are connected as shown in the figure. Maximum power that can be dissipated by each resistance is 40 watt. Therefore, the maximum power that can be safely dissipated in the combination is



(a) 120 watt (b) 80watt.
(c) 60 watt (d) 40watt.

9. An object is placed at a distance x_1 from the focus of a concave mirror. Its real image is formed at a distance x_2 from the focus. Hence, the focal length of the mirror is

(a) $\frac{x_1 x_2}{x_1 + x_2}$ (b) $\sqrt{x_1 x_2}$

(c) $\frac{x_1 + x_2}{2}$ (d) $|x_1 - x_2|$

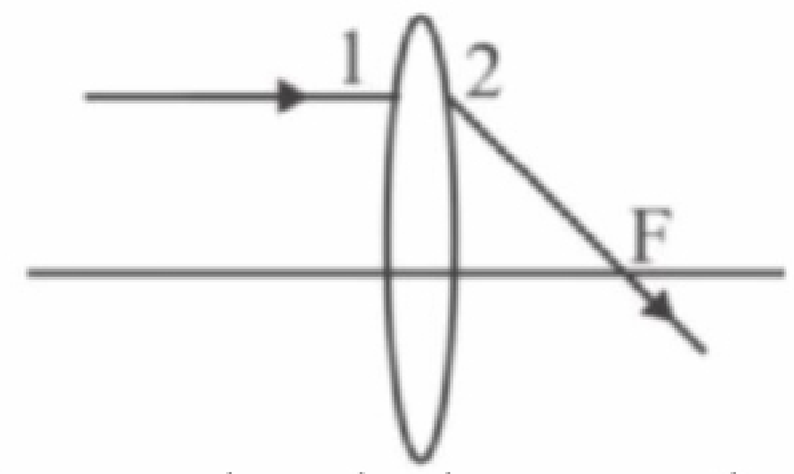
10. How much water should be filled in a container 21 cm in height, so that it appears half filled when viewed from the top of the container?

$$\left[\text{Refractive index of water} = \frac{4}{3}\right]$$

(a) 8 cm. (b) 10.5 cm.
(c)12 cm. (d) 14. cm

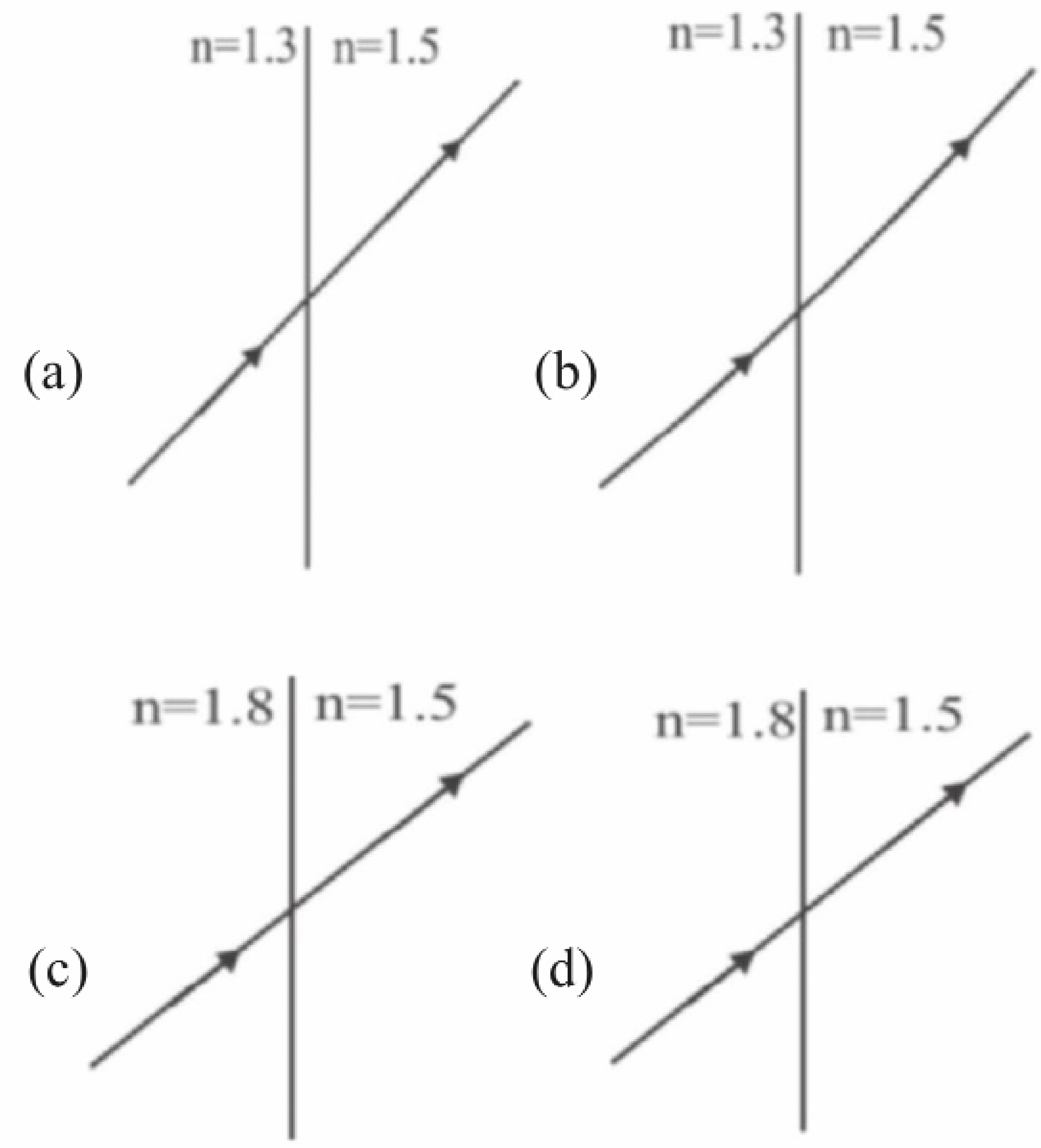
11. An electron moving to the east in a horizontal plane is deflected towards south by a magnetic field. The direction of this magnetic field is
(a) towards north (b)towards west
(c) downwards (d) upwards

12. The figure shows a ray of light incident on a convex lens, parallel to its principal axis. Obviously the emergent ray passes through the principal focus F. Which of the following statements is correct?

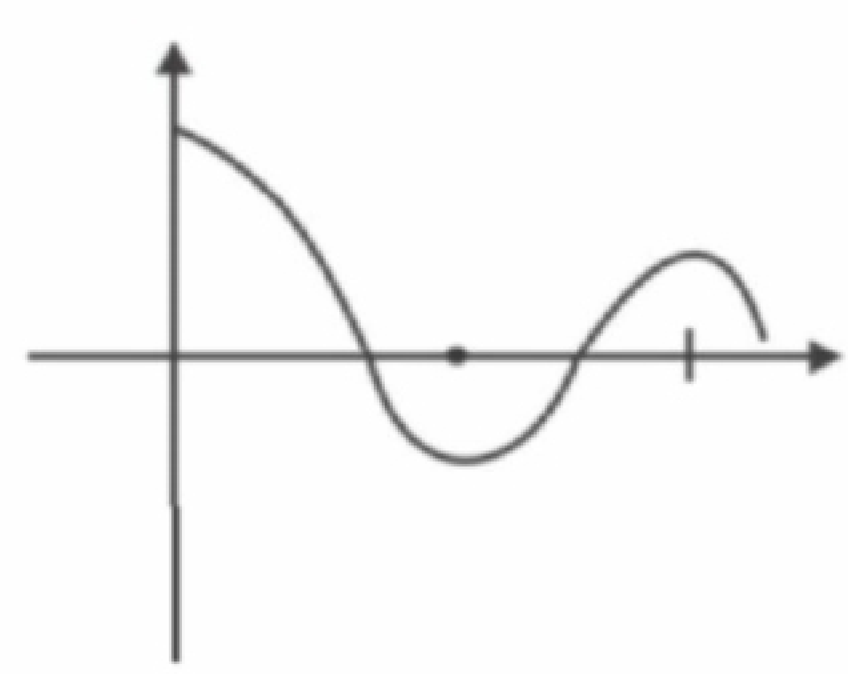


(a)They ray bends downwards only once inside the lens.
(b) The ray bends downwards at each surface.
(c) The ray bends downwards at the first surface and upwards at the second surface.
(d) The ray bends upwards the first surface and downwards at the second surface.

13. Which of the following does NOT represent correct refraction?



14. The figure shows graphical representation of a sound wave. The quantities on X and Y axes respectively are



(a) time and displacement
(b) distance and pressure
(c) distance and change in density
(d) density and pressure

15. A certain amount of heat is required to raise the temperature of x gram of a substance t hrough t_1 °C. The same amount of heat when taken away from y gram of water, it colls through t_2°C. Therefore, the specific heat of the substance is

(a) $\frac{yt_1}{xt_1}$ (b) $\frac{xt_2}{yt_1}$

(c) $\frac{yt_2}{xt_1}$ (d) $\frac{xt_1}{yt_1}$

16. An aeroplane is flying horizontally at height of 3150 m above a horizontal plane ground. At a particular instant it passes another aeroplane vertically below it. At this instant, the angles of elevation of planes from a point on the ground are 30° and 60°.Hence, the distance between the planes at that instant is

(a) 1050 m. (b) 2100 m.
(c)4200 m. (d) 5250 m

17. A boy throws a stone (mass 100g) vertically upwards. It reaches a height of 10m and then falls to the ground. The work done by the boy is $\left(g = 10\text{ms}^{-2}\right)$

(a) 10 J (b) 20J
(c) Zero. (d) -10J.

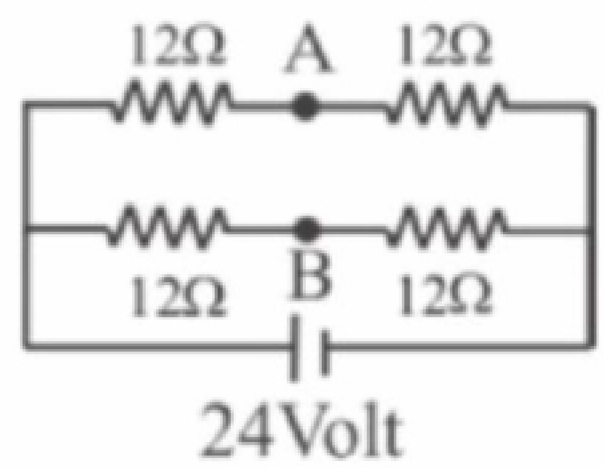
18. A conical vessel of radius 6 cm and height 8 cm is completely filled with water. A metal sphere is now lowered into the water. The size of the sphere is such that when it touches the inner surface, it just gets immersed. The fraction of water that overflows from the conical vessel is

(a) $\frac{3}{8}$ (b) $\frac{5}{8}$ (c) $\frac{7}{8}$ (d) $\frac{5}{16}$

19. Which of the following does NOT involve friction?

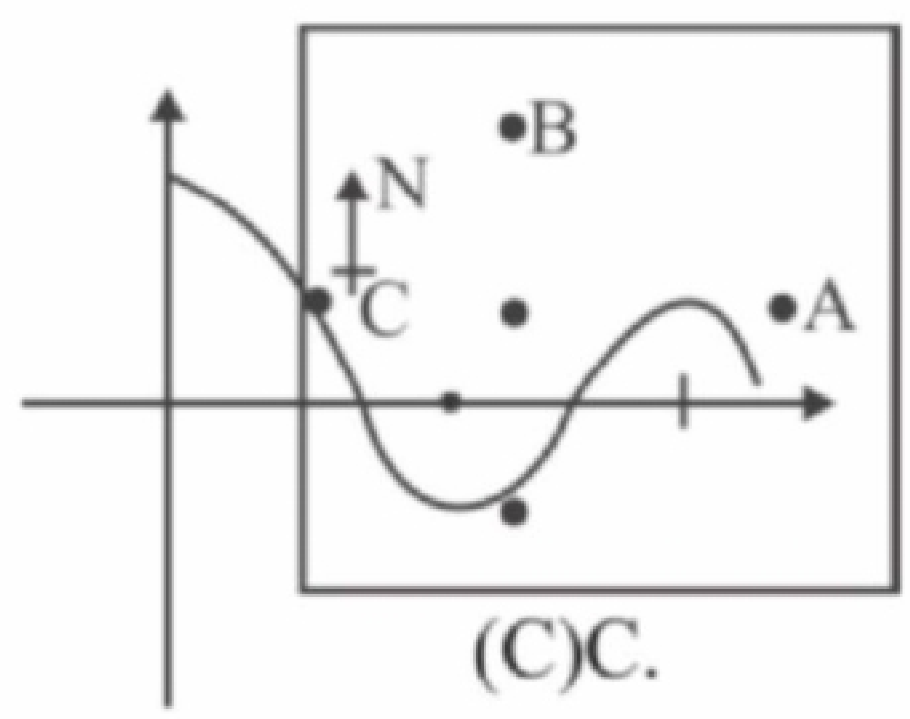
(a) Writing on a paper using a pencil
(b) Turning a car to the left on a horizontal road.
(c) A car at rest parked on a sloping ground.
(d) Motion of a satellite around the earth.

20. In the circuit arrangement shown, if the point A and B are joined by a wire the current in this wire will be



(a) 1A. (b) 2A (c) 4A (d) zero.

21. Consider points A,B,C,D on a horizontal cardboard equidistant from centre O as shown in the figure.Acopper wire perpendicular to the cardboard passes through the centre O and carries an electric current flowing upwards.Deflection of magnetic needle will be maximum when it is kept at the point



(a)A (b) B (c) C (d) 0

22. Two vectors of equal magnitube are inclined to each other at an angle θ.Keeping the direction of one of the fixed the other is rotated throught an eual angle θ.Now, the resultant of these vectors has the same magnitude as each of the two vectors.

(a) 90° (b) 30° (c) 45° (d) 60°

23. Which of the following statements is INCORRECT?

(a) Electric current is a scalar quantity
(b) Electric lines of force are closed curves.
(c) Magnetic lines of induction are closed curves.
(d) Changing magnetic field induces an electric current in a coil

ANSWER KEY

[2011-12]

1. b	**2.** a	**3.** a	**4.** b	**5.** a
6. d	**7.** a	**8.** c	**9.** b	**10.** c
11. c	**12.** b	**13.** b	**14.** c	**15.** c
16. b	**17.** a	**18.** a	**19.** d	**20.** d
21. d	**22.** d	**23.** b		

HINTS & SOLUTIONS

1.Sol: $\frac{F_e}{F_g}=\frac{Ke^2}{GM_e m_e}$

$$=\frac{9\times10^9\times(1.6)^2\times10^{-38}}{6.67\times10^{-11}\times(9.1)^2\times10^{-62}}$$

$$=4.1\times10^{42}$$

2.Sol: Let initial speed be v.

So, after 3 second speed will be $=\left(\frac{2}{5}\right)u$

From equation of motion,

$$\frac{2}{5}u=u-g\times3 \quad \Rightarrow u=5g \qquad (1)$$

From third equation of motion,

$v^2=u^2-2gs$

Since at maximum height, $v=0$

So,V $0=u^2-2gH,\ H=\frac{u^2}{2g}$

From equation (1) $H=\frac{(5g)^2}{2g}=122.5m$

3.Sol: If $m_a=\frac{F}{10}, m_b=\frac{F}{15}$

$$\Rightarrow a=\frac{F}{m_a+m_b}=\frac{F}{\frac{F}{10}+\frac{F}{15}}$$

$$\Rightarrow a=6m/s^2$$

4.Sol: Let m is the mass of the ball. velocities of the ball before and after collision are

$$v_1=\sqrt{2gh_1}=\sqrt{2\times10\times7.2}$$

$$v_1=12\,m/s$$

$$v_1=\sqrt{2gh_2}=\sqrt{2\times10\times3.2}$$

$$v_1=8\,m/s$$

$$a=\frac{v_2-v_1}{t}=\frac{4\,m/s}{20\times103\,s}=200\,m/s^2$$

5.Sol: Given that $m_2>m_1$

$K_2=K_1$

If both comes to rest then,

$\Rightarrow \Delta K_2=\Delta K_1$

$f_2=f_1=f$

From work energy theorem

$W_2=W_1$

$\Rightarrow f\times S_1=f\times S_2$

$\Rightarrow \frac{S_1}{S_2}=1$

6.Sol: As when the light will pass through the arms of hollow prism, the arm will behave like simple glass slab so there will be no dispersion as well no deviation

7.Sol: Net current is defined as rate of flow of positive charge.

$i_{Net}=i_{Ne^+}+i_{e^-}$

$i_{Ne^+}\rightarrow$ towards right

$i_{e^-}\rightarrow$ towards right (conventional)

$i_{Ne^+}=2.8\times10^{18}\times1.6\times10^{-19}=0.45\,A$

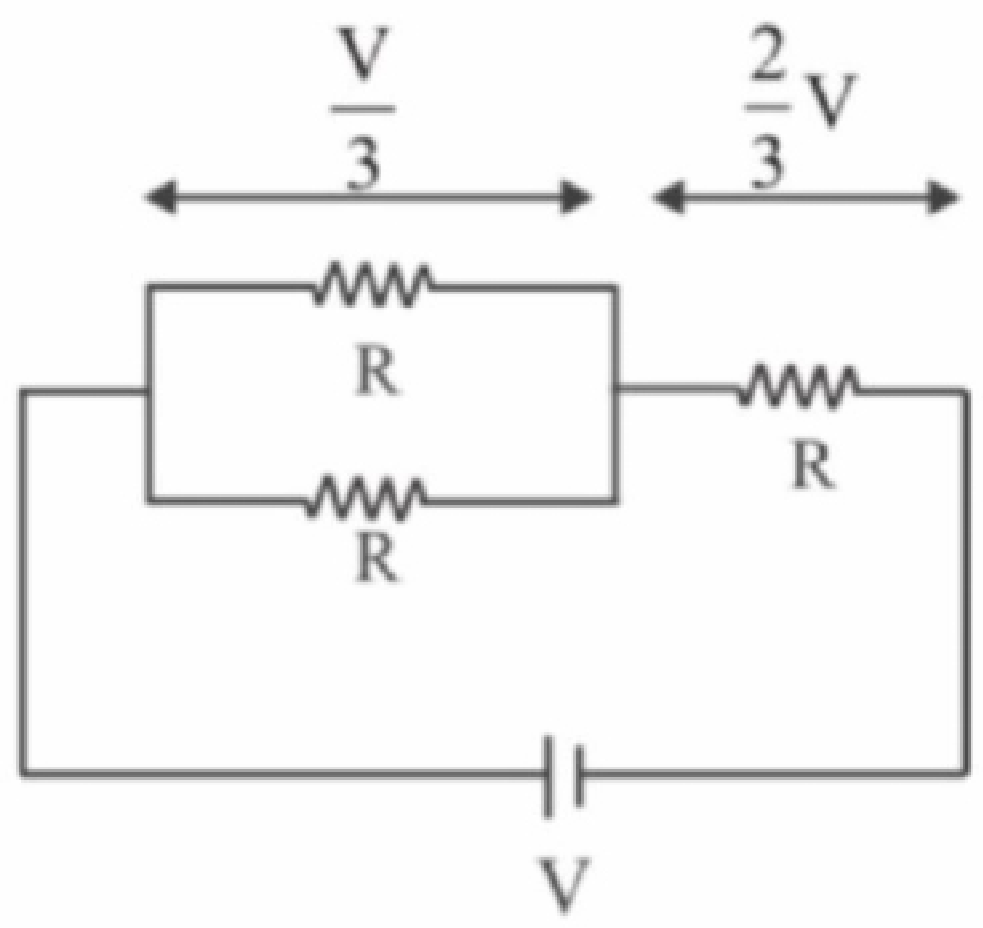
$i_{e^-}=1.2\times10^{18}\times1.6\times10^{-19}=0.19A$

$i_{Net}=0.64A$ (towards right)

8.Sol: The maximum voltage across any resistor

$$40=\frac{V_0^2}{R} \qquad (1)$$

Let V is the em f across the given c ircuit

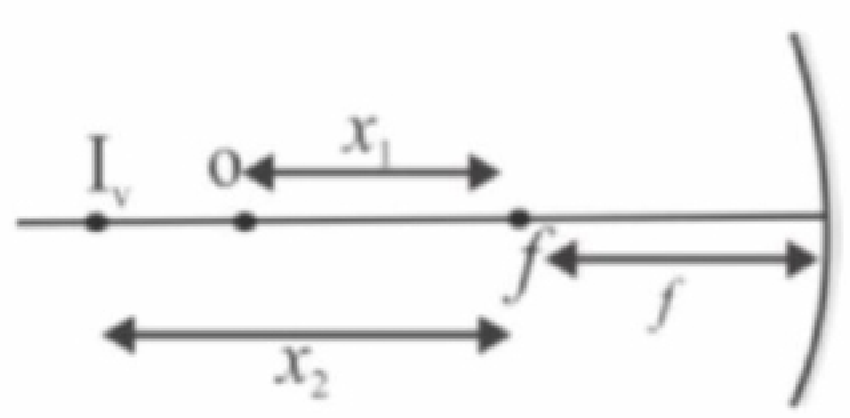


Here $\frac{2}{3}V = V_0$ (For maximum power)

$$P_{total} = \frac{(V/3)^2}{R} + \frac{(V/3)^2}{R} + \frac{\left(\frac{2}{3}V\right)^2}{R}$$

$$= \frac{6V^2}{9R} + \frac{6}{9R}\left(\frac{V_0^2}{4}\right) = 60W$$

9.Sol: Let f is the focal lenth of the concave mirror



$$\frac{1}{u} + \frac{1}{v} = \frac{1}{-f}$$

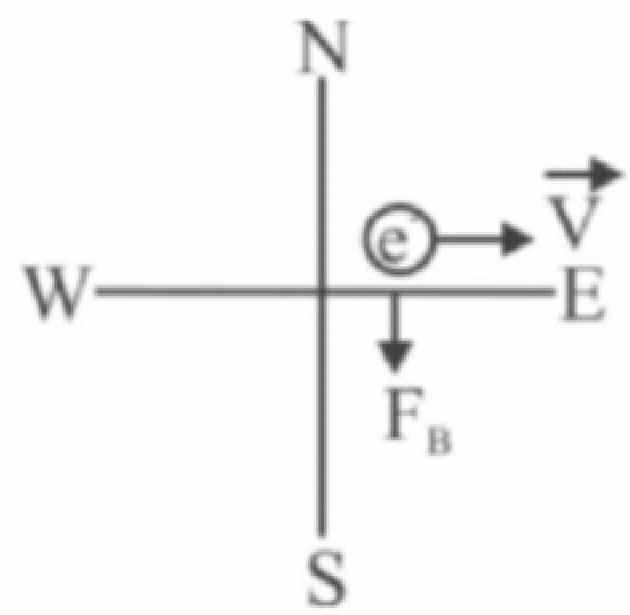
$$\frac{1}{-(x_1+f)} - \frac{1}{(x_2+f)} = \frac{-1}{f}$$

$$\Rightarrow f = \sqrt{x_1 x_2}$$

10.Sol: Let x is the height of the water in the container. The height of empty space is is $(21-x)$ cm If the container looks be half filied then the affarent defth of the container and height of empty space must be equal

$$21 - x = \frac{x}{\mu} \quad \Rightarrow x = 12\,cm$$

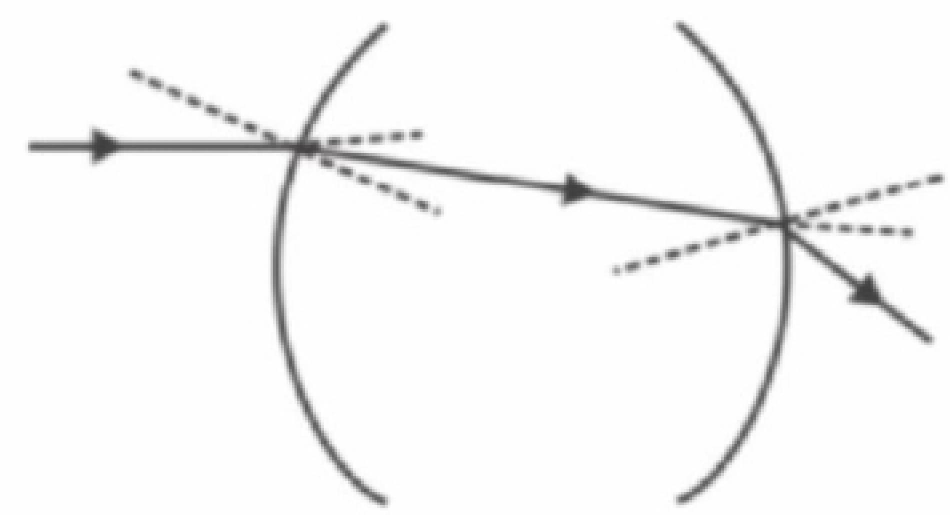
11.Sol: The motion of e^- is shown in the figure



If we apply the force formula $\vec{F} = q\vec{v} \times \vec{B}$

$\overline{B}$ is present in downward direction.

12.Sol: The ray fath is shown in the figure



13.Sol: Because refracted ray in denser midium should move towards the normal.

14.Sol: Conceptual

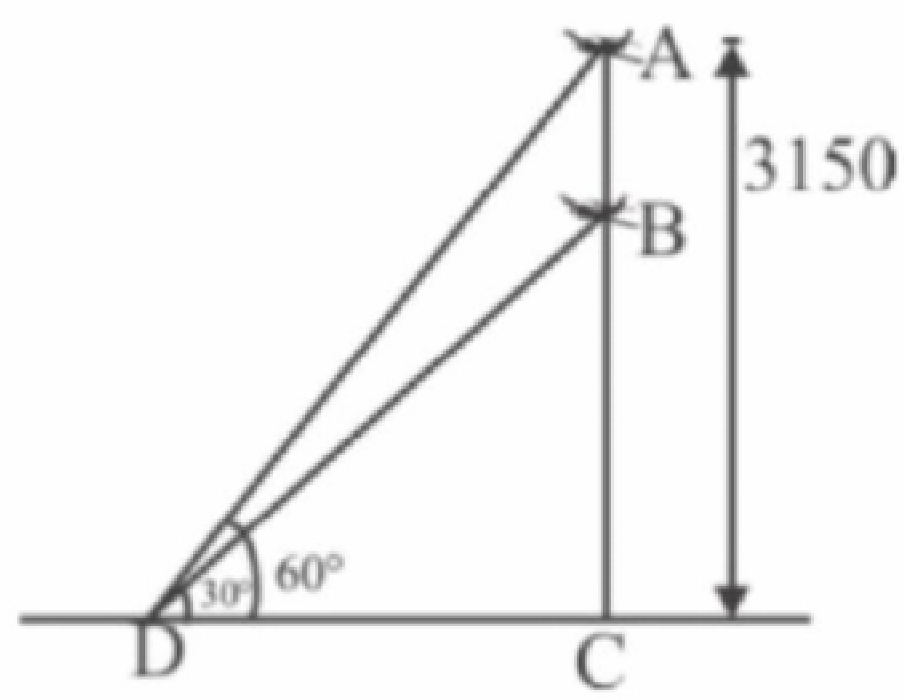
15.Sol: Given

$$Q = xs_1t_1, \; Q = y \times \frac{1cal}{g^oC} t_2$$

$$xs_1t_1 = yt_2$$

$$s_1 = \frac{yt_2}{xt_1}$$

16.Sol:



$$\tan 60^o = \frac{AC}{DC}$$

$$\sqrt{3} = \frac{3150}{DC} \quad \Rightarrow DC = \frac{3150}{\sqrt{3}}$$

$$\Delta DBC$$

$$\tan 30^o = \frac{BC}{DC}$$

$$\frac{1}{\sqrt{3}} = \frac{BC}{\frac{3150}{\sqrt{3}}} \Rightarrow BC = 1050\,m$$

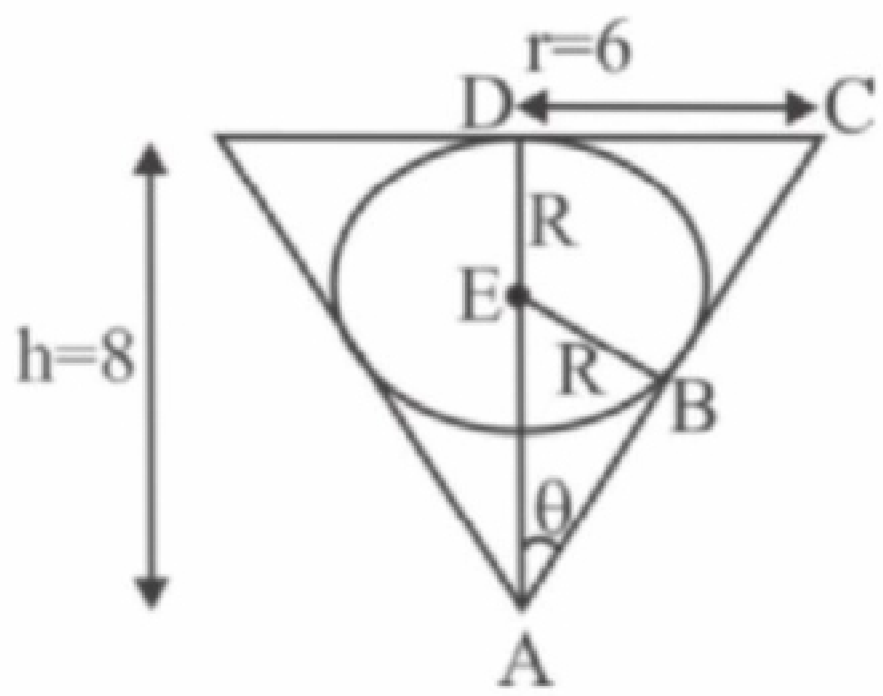
$$AB = AC - BC \;\; = 2100\,m$$

17.Sol: Work is done by the body against the force of gravitation when it moves upwards,

$$W = mgh$$

$$= 0.1 \times 100 = 10\,J$$

18.Sol:



$$AC = \sqrt{8^2 + 6^2} = 100\,m$$

$$\text{Sin}\,\theta = \frac{BF}{AF} = \frac{DC}{AC}$$

$$\frac{R}{AE} = \frac{6}{10} \Rightarrow AE = \frac{5R}{3}$$

$$AD = AE + DE$$

$$8 = \frac{5R}{3} + R$$

$$\Rightarrow R = 3\,cm$$

Fraction of water flow

$$= \frac{\text{volume of sphere}}{\text{volume of cone}}$$

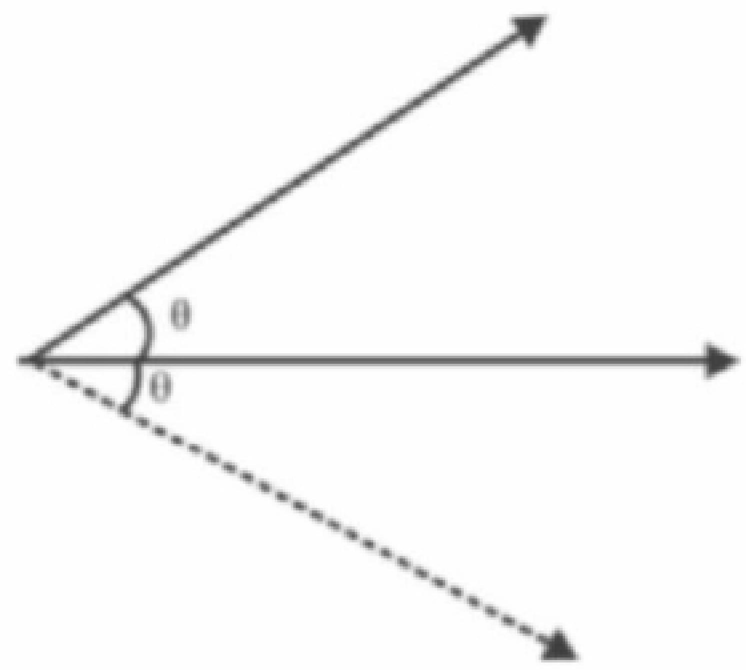
$$= \frac{\frac{4}{3}\pi R^3}{\frac{1}{3}\pi r^2 h} = \frac{4(3)^3}{6^2 \times 8} = \frac{3}{8}$$

19.Sol: Conceptual

20.Sol: In such set up, it becomes wheat stone bridge and A, B have same potentials so no current flows through it.

21.Sol: At point C, the resultant magnetic field will be the greatest as Earth,s magnetic field is in the same direction as of magnetic field due to the wire.

22.Sol:



$$A = \sqrt{A^2 + A^2 + 2A^2\cos(2\theta)}$$

$$A = \sqrt{2A^2 + 2A^2 + \cos(2\theta)}$$

if and only if, cos $2\theta = -\frac{1}{2}$

the $2\theta = -\frac{1}{2}$

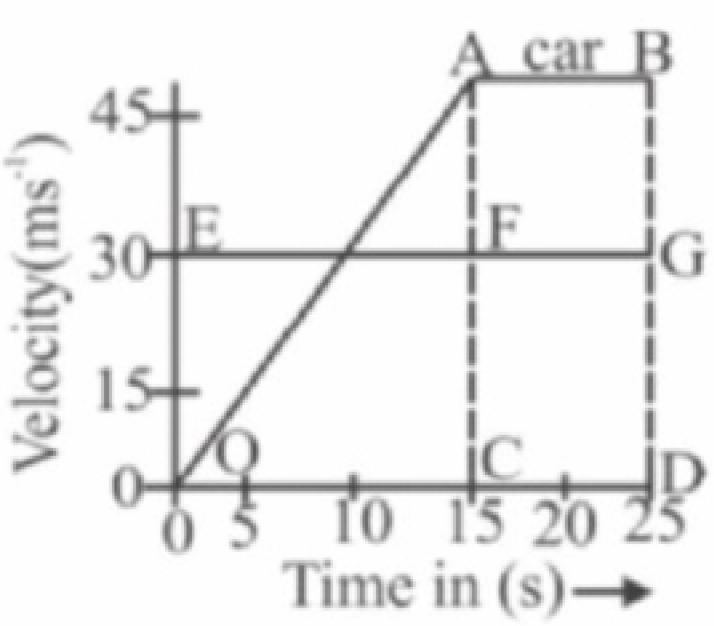
$$\theta = 60°$$

23.Sol: Conceptual

Previous years JEE MAIN Questions

MOTION IN ONE DIMENSION
[ONLINE QUESTIONS]

1. The velocity-time graphs of a car and a scooter are shown in the figure. (i) The difference between the distance travelled by the car and the scooter in 15s and (ii) the time at which the car will catch up with the scooter are, respectively. **[2018]**



(a) 112.5 m and 22.5 s (b) 337.5 m and 25 s
(c) 225.5 m and 10 s (d) 112.5 m and 15 s

2. Which graph corresponds to an object moving with a constant negative acceleration and a positive velocity? **[2017]**

(a) 

(b) 

(c) 

(d) 

3. A car is standing 200 m behind a bus , which is also at rest. The two start moving at the same instant but with different forword accelerations. The bus has acceleration $2\ m/s^2$ and the car has acceleration $4\ m/s^2$. The car will catch up with the bus after at time of **[2017]**

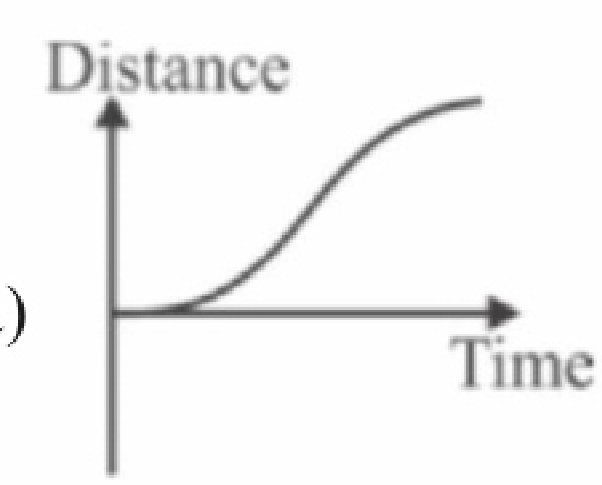
(a) $\sqrt{120}\ s$ (b) 15 s
(c) $\sqrt{110}\ s$ (d) $10\sqrt{2}\ s$

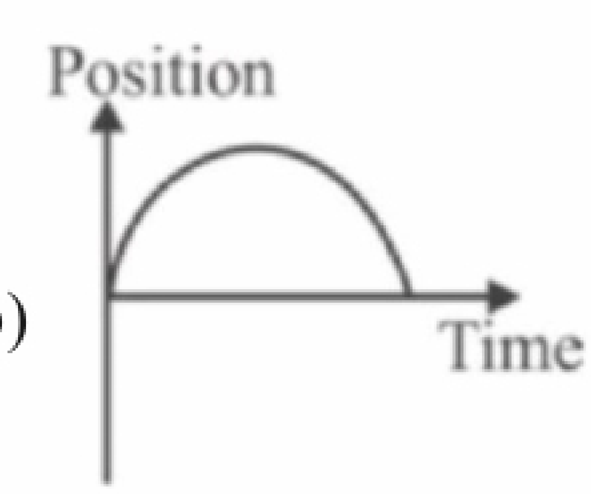
4. A bullet looses $\left(\frac{1}{n}\right)^{th}$ of its velocity passing through one plank. The number of such planks that are required to stop the bullet can be : **[2014]**

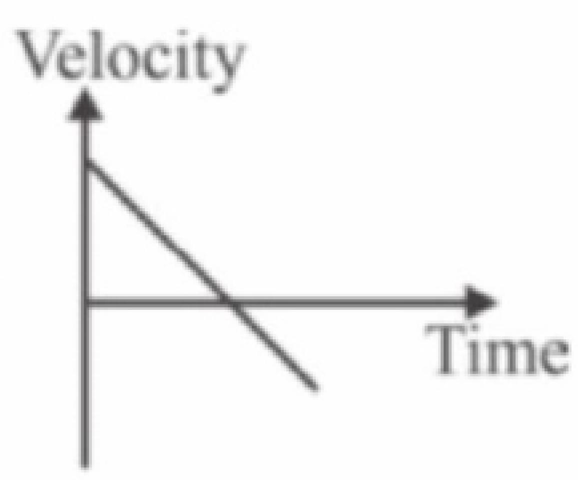
(a) n (b) $\frac{n^2}{2n-1}$ (c) Infinte (d) $\frac{2n^2}{n-1}$

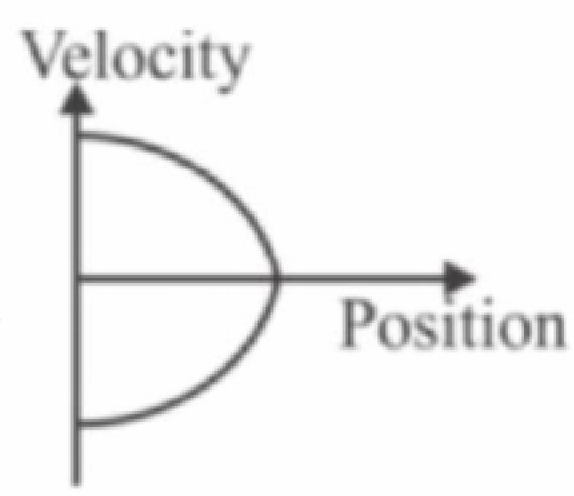
[OFFLINE QUESTIONS]

1. All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up **[2018]**

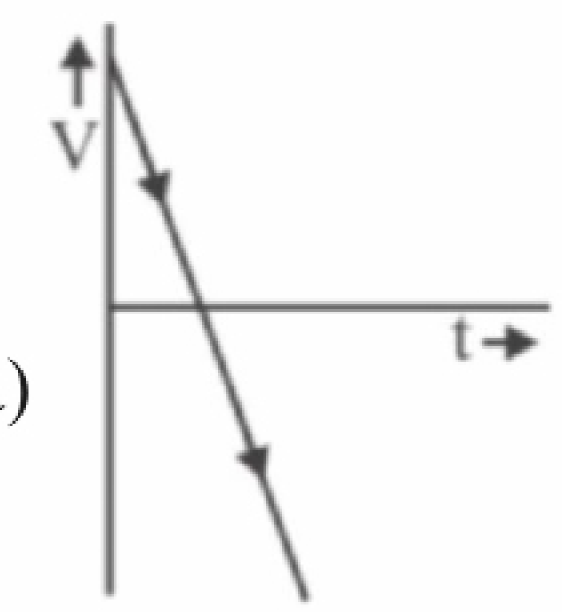
(a) 

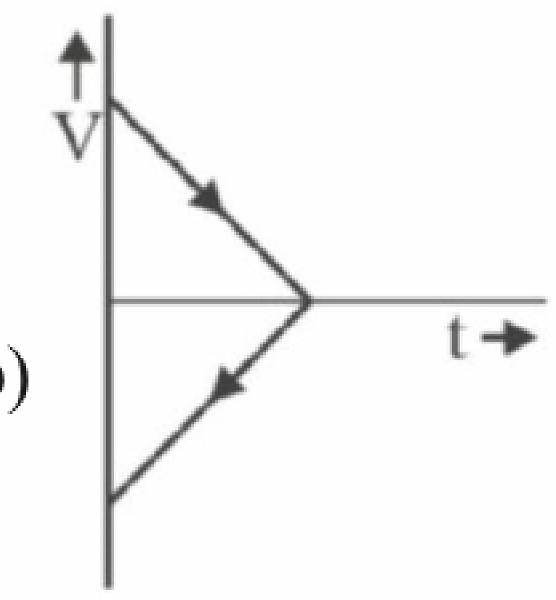
(b) 

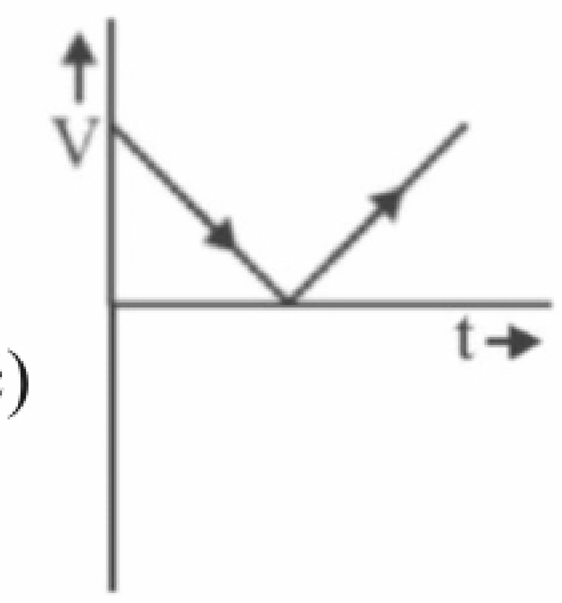
(c) 

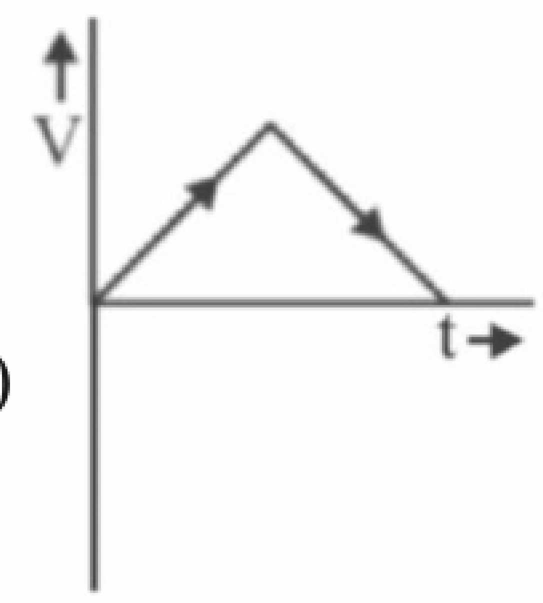
(d) 

2. A body is thrown vertically upwards. Which one of the following graphs correctly represent the velocity vs time ? **[2017]**

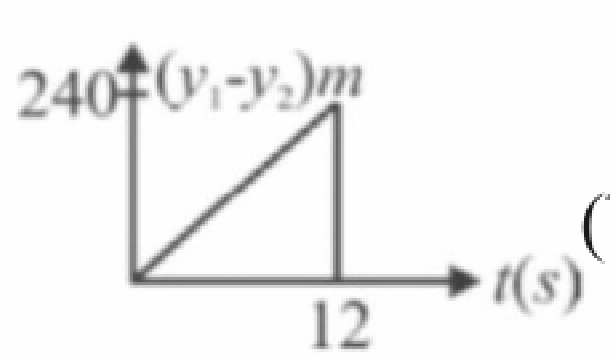
(a) 

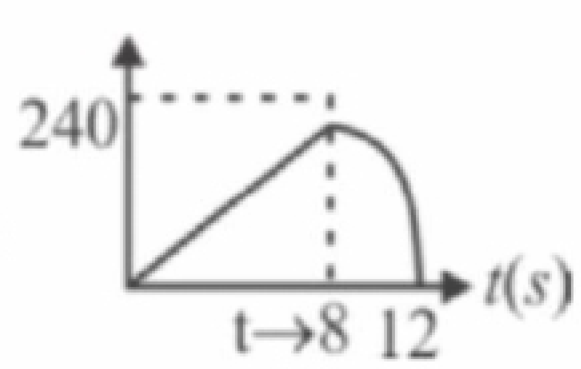
(b) 

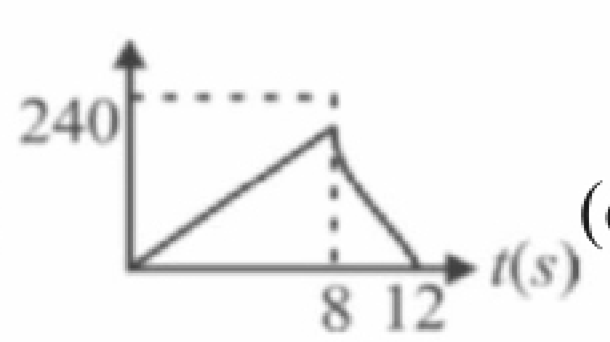
(c) 

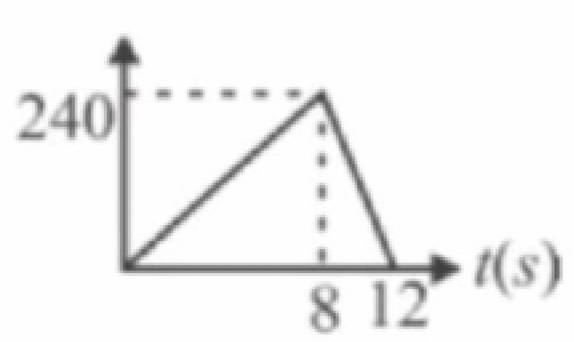
(d) 

3. Two stones are thrown up simultaneously from the edge of a cliff 240 m high with initial speed of 10 m/s and 40 m/s respectively. Which of the following graph best represents the time variation of relative position of the second stone with respect to the first ?(Assume stones do not rebound after hitting the ground and neglect air resistance, take g = 10 m/s2) (The figures are schematic and not drawn to scale) **[2015]**

(a) 

(b) 

(c) 

(d) 

4. From a tower of height H, a particle is thrown vertically upwards with a speed u. The time taken by the particle, to hit the ground, is n times that is taken by it to reach the highest point of its path. The relation between H, u and n is **[2014]**

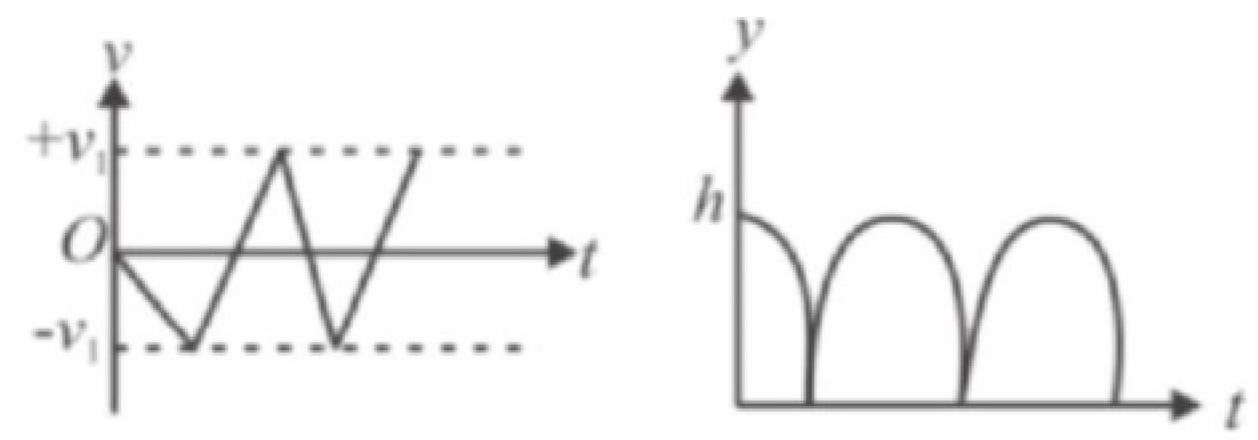
(a) $2gH = nu^2(n-2)$ (b) $gH = (n-2)u^2$

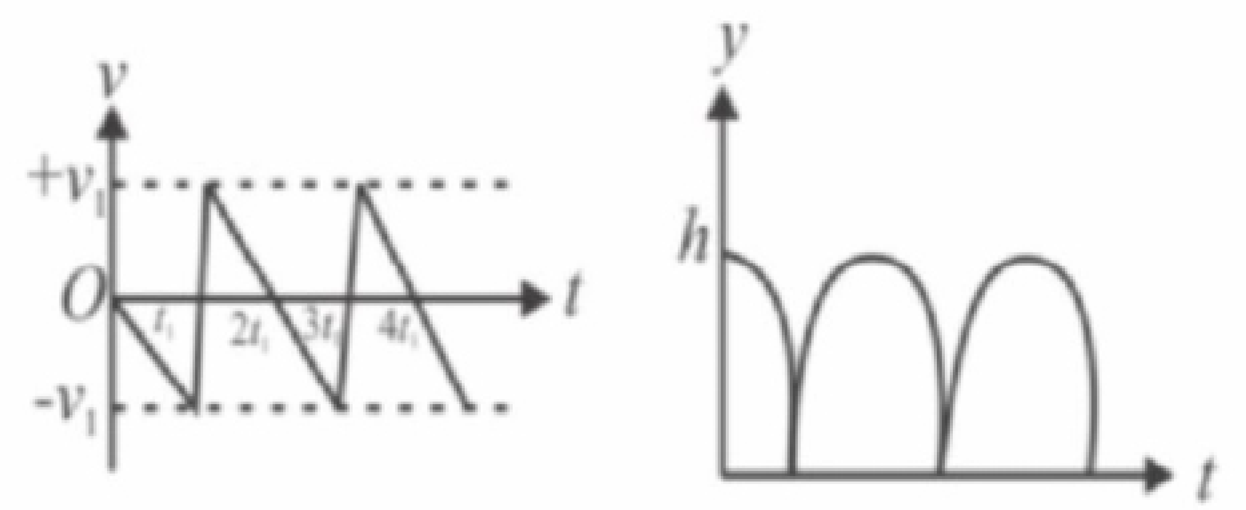
(c) $2gH = n^2u^2$ (d) $gH = (n-2)^2u^2$

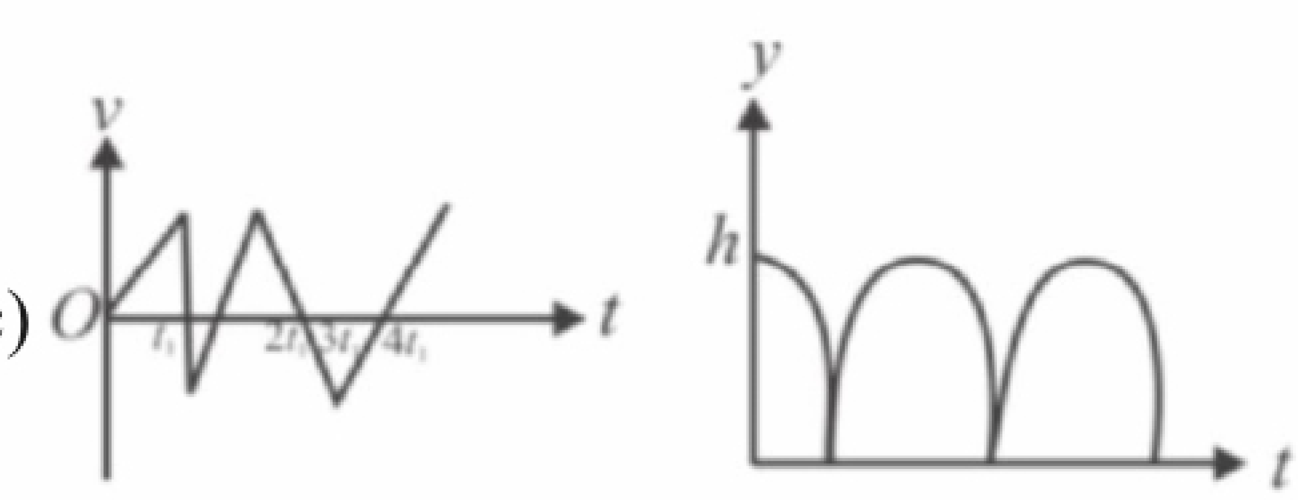
5. An object, moving with a speed of 6.25 m/s, is decelerated at a rate given by $\frac{dv}{dt} = -2.5\sqrt{v}$, where v is the instantaneous speed. The time taken by the object, to come to rest, would be **[2011]**

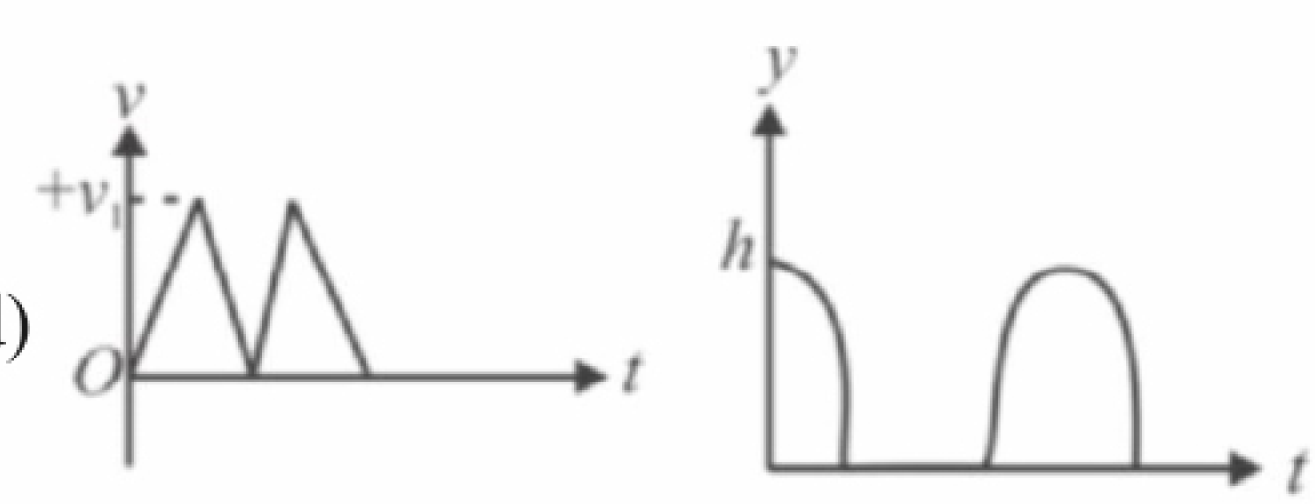
(a) 4s (b) 2s (c) 1s (d) 8s

6. Consider a rubber ball freely falling from a height h = 4.9m onto a horizontal elastic plate. Assume that the duration of collision is negligible and the collision with the plate is totally elastic. Then the velocity as a function of time and the height as a function of time will be **[2009]**

(a) 

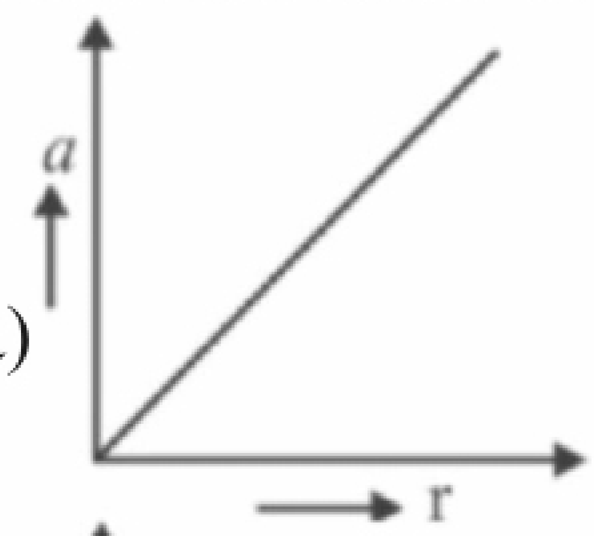
(b) 

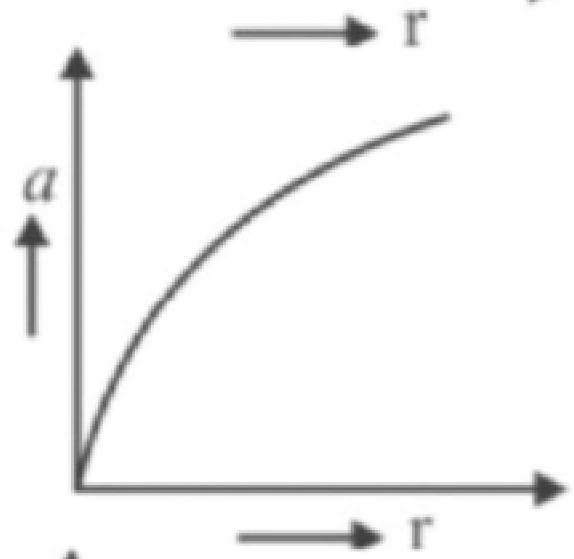
(c) 

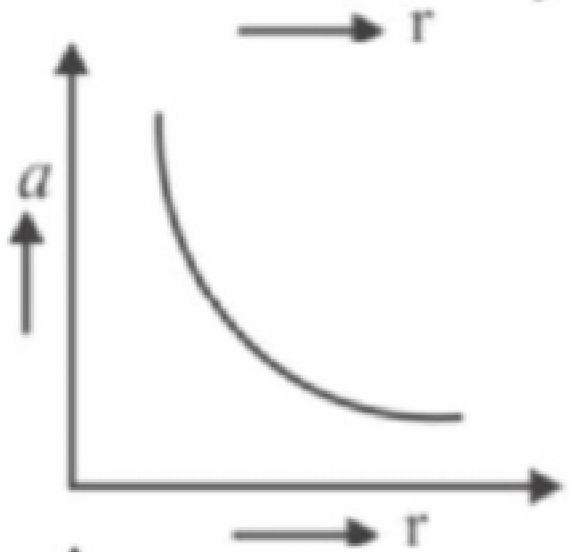
(d) 

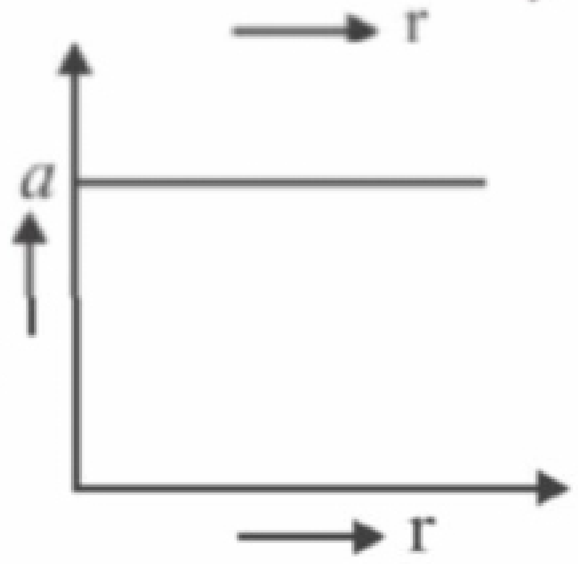
MOTION IN TWO DIMENSION [ONLINE QUESTIONS]

1. If a body moving in circular path maintains constant speed of $10\,ms^{-1}$, then which of the following correctly describes relation between acceleration and radius? **[2015]**

(a)


(b)


(c)


(d)


2. A vector $\vec{A}$ is rotated by a small angle $\Delta\theta$ radian $(\Delta\theta << 1)$ to get a new vector $\vec{B}$. In that case $|\vec{B}-\vec{A}|$ is: **[2015]**

(a) $|\vec{A}|\Delta\theta$ (b) $|\vec{B}|\Delta\theta - |\vec{A}|$

(c) $|\vec{A}|\left(1-\frac{\Delta\theta^2}{2}\right)$ (d) 0

3. The position of a projectile launched from the origin at t = 0 is given by $\vec{r} = (40\hat{i}+50\hat{j})$ m at $t = 2s$. If the projectile was launched at an angle θ from the horizontal, then θ is (take $g = 10\ ms^{-2}$) **[2014]**

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

(c) $\tan^{-1}\frac{2}{3}$ (d) $\tan^{-1}\frac{7}{4}$

4. The initial speed of a bullet fired from a rifle is 630 m/s. The rifle is fired at the centre of a target 700 m away at the same level as the target. How far above is the centre of the target the rifle must be aimed in order to hit the target? **[2014]**

(a) 1.0 m (b) 4.2 m (c) 6.1 m (d) 9.8 m

5. The maximum range of a bullet fired from a toy pistal mounted on a car at rest is $R_0 = 40$ m. What will be the acute angle of inclination of the pistol for maximum range when the car is moving in the direction of firing with uniform velocity v = 20 m/s, on a horizontal surface? $(g = 10 m/s^2)$ **[2013]**

(a) 30° (b) 60° (c) 75° (d) 45°

6. A ball projected from ground at an angle of 45° just clears a wall in front. If point of projection is 4m from the foot of wall and ball strikes the ground at a distance of 6m on the other side of the wall, the height of the wall is: **[2013]**

(a) 4.4 m (b) 2.4 m

(c) 3.6 m (d) 1.6 m

[OFFLINE QUESTIONS]

1. A projectile is given an initial velocity of $(\hat{i}+2\hat{j})$ m/s, where $\hat{i}$ is along the ground and $\hat{j}$ is along the vertical. If $g = 10\,m/s^2$, the equation of its trajectory is : **[2013]**

(a) $y = x - 5x^2$ (b) $y = 2x - 5x^2$

(c) $4y = 2x - 5x^2$ (d) $4y = 2x - 25x^2$

2. A boy can throw a stone up to a maximum height of 10 m. The maximum horizontal distance that the boy can throw the same stone up to will be **[2012]**

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

(c) $10\sqrt{2}\,m$ (d) $20\,m$

3. A water fountain on the ground sprinkles water all around it. If the speed of water coming out of the fountain is v, the total area around the fountain that gets wet is: **[2011]**

(a) $\pi \frac{v^4}{g^2}$ (b) $\frac{\pi}{2}\frac{v^4}{g^2}$

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

4. A particle is moving with velocity $\vec{v} = k(y\hat{i} + x\hat{j})$, where k is a constant. The general equation for its path is **[2010]**

(a) $y = x^2 +$ constant (b) $y^2 = x +$ constant

(c) $xy =$ constant (d) $y^2 = x^2 +$ constant

5. A particle has an initial velocity of $3\hat{i} + 4\hat{j}$ and an acceleration of $0.4\hat{i} + 0.3\hat{j}$. Its speed after 10 s is **[2009]**

(a) $7\sqrt{2}$ units (b) 7 units

(c) 8.5 units (d) 10 units

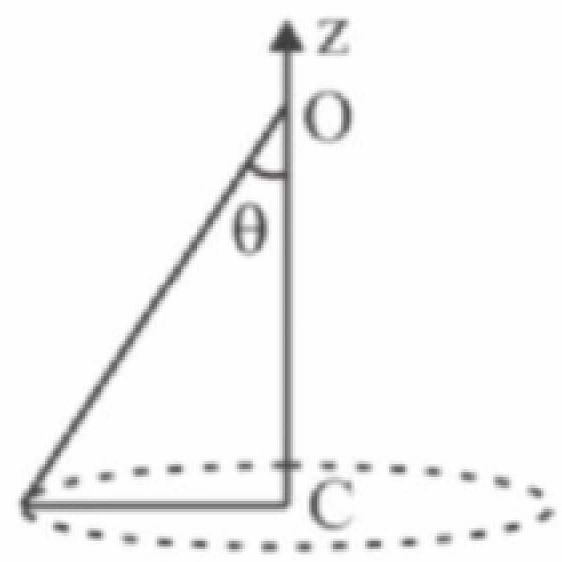
LAWS OF MOTION [ONLINE QUESTIONS]

1. A given object takes n times more time to slide down a 45^0 rough inclined plane as it takes to slide down a perfectly smooth 45^0 incline. The coefficients of kinetic friction between the object and the incline is: **[2018]**

(a) $\sqrt{1-\frac{1}{n^2}}$ (b) $1-\frac{1}{n^2}$

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

2. A conical pendulum of length 1 m makes an angle $\theta = 45^0$ w.r.t. Z-axis and moves in a circle in the XY plane. The radius of the circle is 0.4m and its centre is vertically below O. The speed of the pendulum, in its circular path, will be - (Take $g = 10ms^{-2}$) **[2017]**



(a) 0.2 m/s (b) 0.4m/s

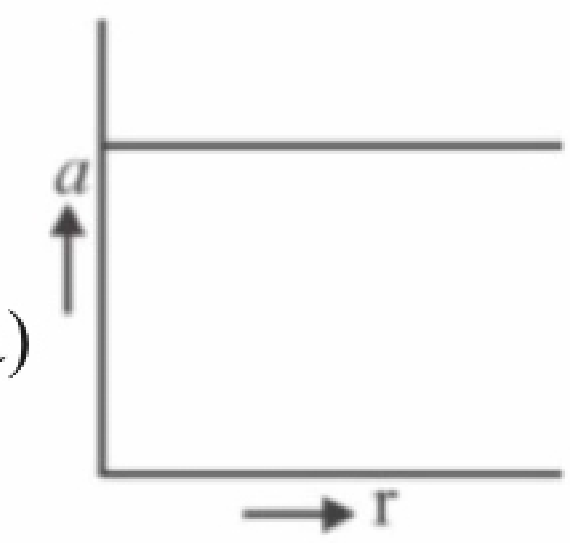
(c) 2 m/s (d) 4m/s

3. A rocket is fired vertically from the earth with an acceleration of 2g, where g is the gravitational acceleration. On an inclined plane inside the rocket, making an angle θ with the horizontal, a point object of mass m is kept. The minimum coefficient of friction μ_{min} between the mass and the inclined surface such that the mass does not move is: **[2016]**

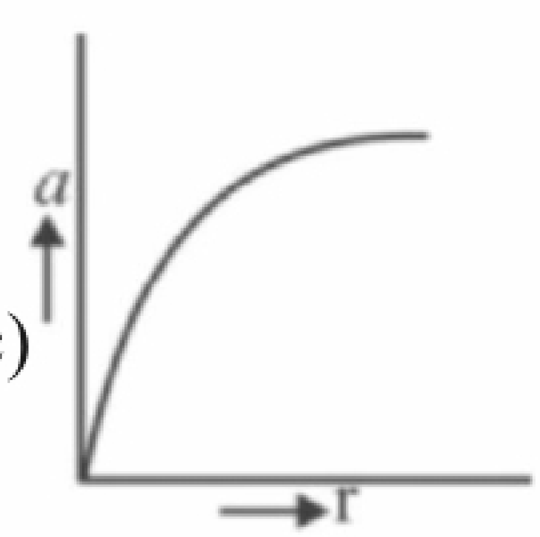
(a) $\tan 2\theta$ (b) $\tan\theta$

(c) $3\tan\theta$ (d) $2\tan\theta$

4. If a body moving in a circular path maintains constant speed of $10\ ms^{-1}$, then which of the following correctly describes relation between acceleration and radius ? **[2015]**

(a) 

(b) 

(c) 

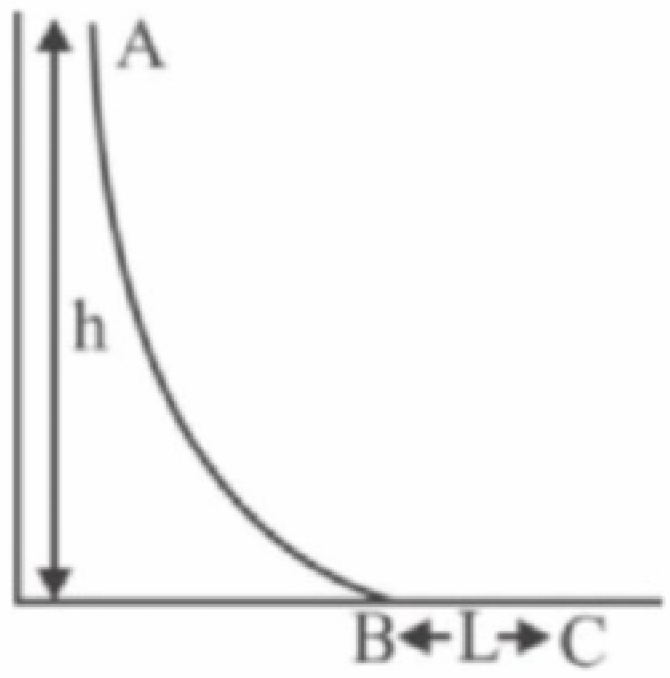
(d) 

5. A body of mass 5 kg under the action of constant force $\vec{F} = F_x\hat{i} + F_y\hat{j}$ has velocity at $t = 0\,s$ as $\vec{v} = (6\hat{i} - 2\hat{j})\,m/s$ and at $t = 10\,s$ as $\vec{v} = +6\hat{j}\,m/s$. The force $\vec{F}$ is: **[2014]**

(a) $(-3\hat{i} + 4\hat{j})N$ (b) $(-\frac{3}{5}\hat{i} + \frac{4}{5}\hat{j})N$

(c) $(3\hat{i} - 4\hat{j})N$ (d) $\left(\frac{3}{5}\hat{i} - \frac{4}{5}\hat{j}\right)N$

6. A small ball of mass m starts at a point A with speed v_0 and moves along a frictionless track AB as shown. The track BC has coefficient of friction μ. The ball becomes to stop at C after travelling a distance L which is: [2014]



(a) $\frac{2h}{\mu} + \frac{v_0^2}{2\mu g}$ (b) $\frac{h}{\mu} + \frac{v_0^2}{2\mu g}$

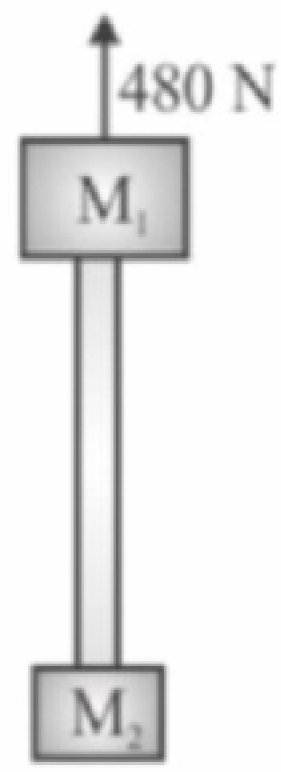
(c) $\frac{h}{2\mu} + \frac{v_0^2}{\mu g}$ (d) $\frac{h}{2\mu} + \frac{v_0^2}{2\mu g}$

7. A heavy box is to be dragged along a rough horizontal floor. To do so, person A pushes it at an angle 30^o from the horizontal and requires a minimum force F_A, while person B pulls the box at an angle 60^o from the horizontal and needs minimum force F_B. If the coefficient of fraction between the box and the floor is $\frac{\sqrt{3}}{5}$, the ratio $\frac{F_A}{F_B}$ is : [2014]

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

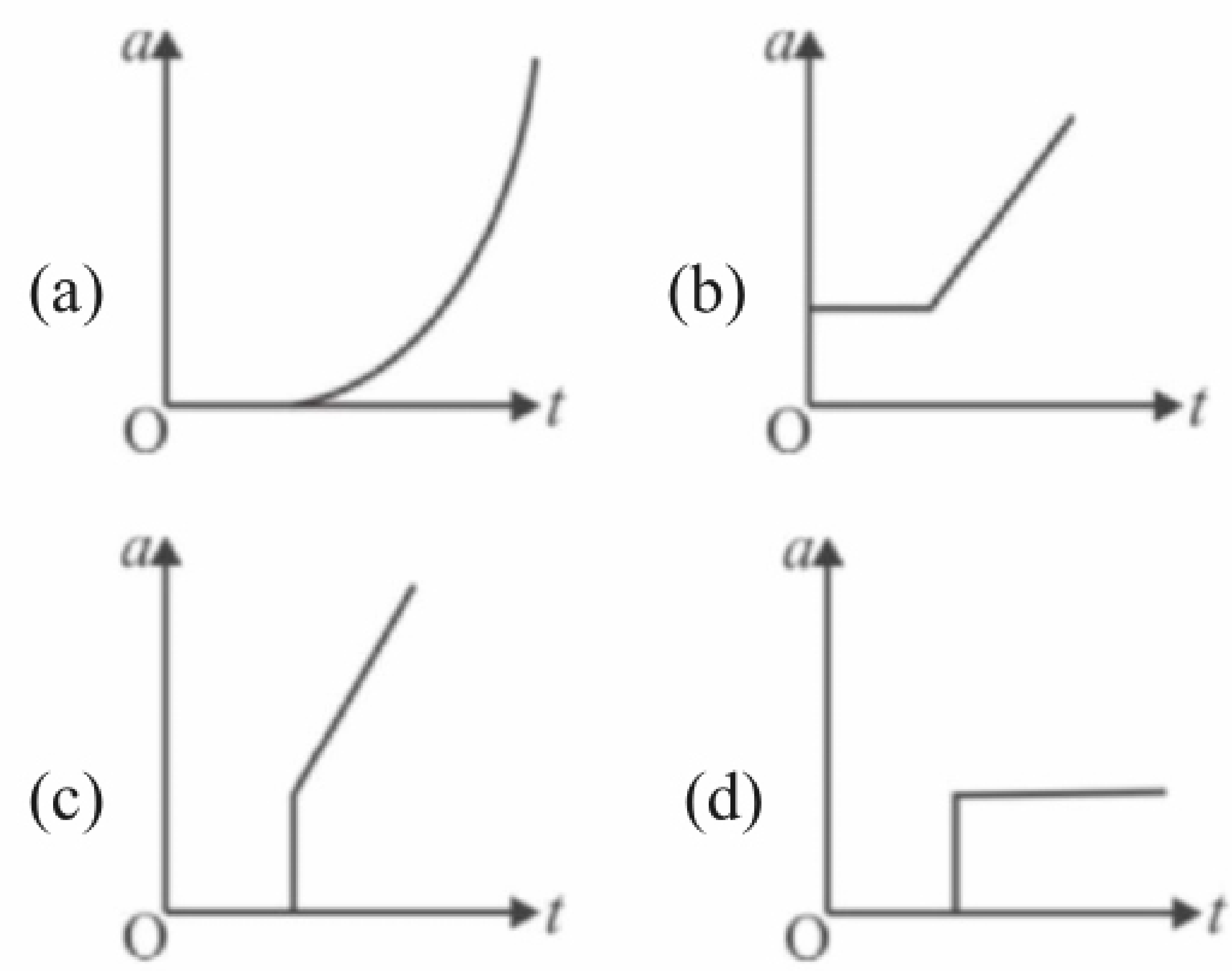
(c) $\frac{5}{\sqrt{3}}$ (d) $\sqrt{3}$

8. Two blocks of mass $M_1 = 20\,kg$ and $M_2 = 12\,kg$ are connected by a metal rod of mass 8 kg. The system is pulled vertically by applying a force of 480 N as shown. The tension at the mid-point of the rod is [2013]



(a) 144 N (b) 96 N (c) 240 N (d) 192 N

9. A block is placed on a rough horizontal plane. A time dependent horizontal force $F = kt$ acts on the block, where k is a positive constant. The acceleration-time graph of the block is: [2013]



10. A body starts from rest on a long inclined plane of slope $45°$. The coefficient of friction between the body and the plane varies as $\mu = 0.3x$, where x is distance travelled down the plane. The body will have maximum speed (for $g = 10\,m/s^2$) when $x =$ [2013]

(a) 9.8 m (b) 27 m
(c) 12 m (d) 3.33 m

11. A body of mass 'm' is tied to one end of a spring and whirled round in a horizontal plane with a constant angular velocity. The elongation in the spring is 1 cm. If the angular velocity is doubled, the elongation in the spring is 5 cm. The original length of the spring is [2013]

(a) 15 cm (b) 12 cm (c) 16 cm (d) 10 cm

ANSWER KEY

MOTION IN ONE DIMENSION
[ONLINE QUESTIONS]

1. a **2.** c **3.** d **4.** b

[OFFLINE QUESTIONS]

1. a **2.** a **3.** b **4.** a **5.** b
6. b

MOTION IN TWO DIMENSION
[ONLINE QUESTIONS]

1. c **2.** a **3.** d **4.** c **5.** b
6. b

[OFFLINE QUESTIONS]

1. b **2.** d **3.** a **4.** d **5.** a

LAWS OF MOTION
[ONLINE QUESTIONS]

1. b **2.** c **3.** b **4.** d **5.** a
6. b **7.** b **8.** d **9.** b **10.** d
11. a

HINTS & SOLUTIONS

MOTION IN ONE DIMENSION
[ONLINE QUESTIONS]

1.Sol: Distance travelled by car in

$15\sec = \frac{1}{2}(45)(15) = \frac{675}{2}m$, Distance travelled by scooter in $15\text{seconds} = 30\times 15 = 450$

Let car catches scooter in time t;

$$\frac{675}{2} + 45(t-15) = 30t$$

$$337.5 + 45t - 675 = 30t \Rightarrow 15t = 337.5$$

$$\Rightarrow t = 22.5\sec$$

2.Sol: $a = - C$

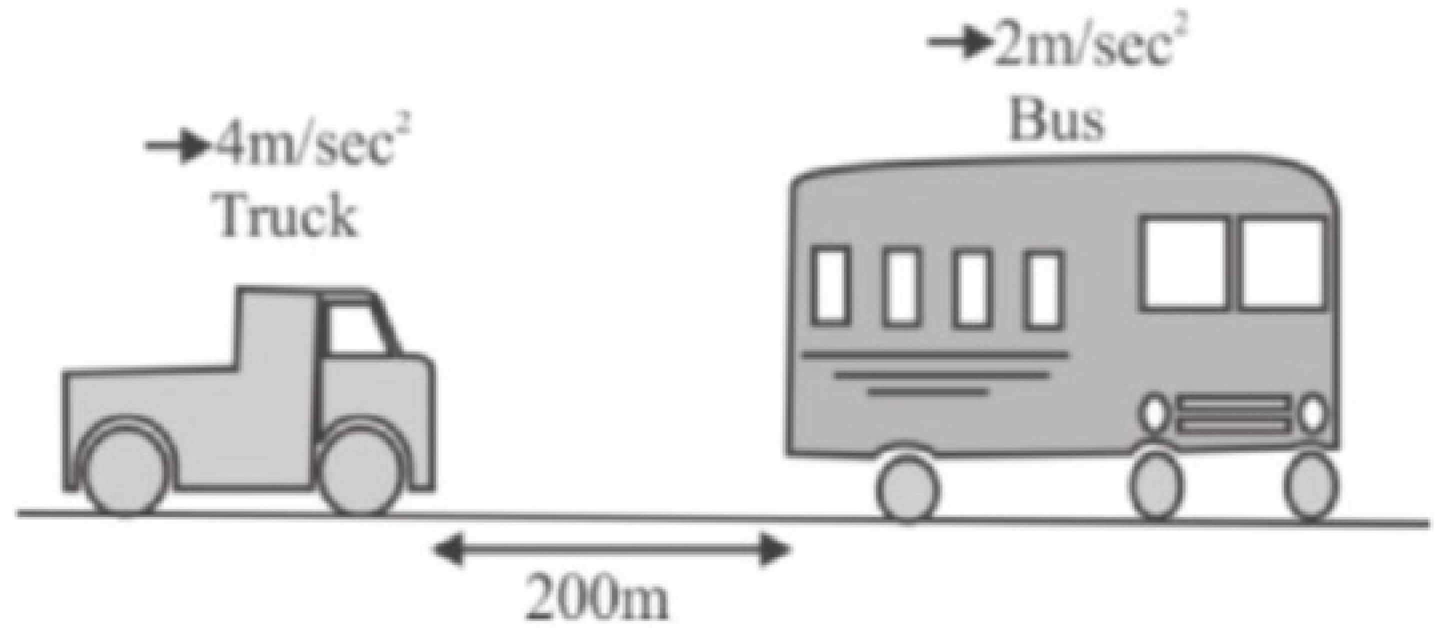
$$\frac{vdv}{dx} = -C$$

$$vdv = -Cdx$$

$$\frac{v^2}{2} = -Cx + K$$

$$x = -\frac{v^2}{2C} + \frac{K}{C}$$

3.Sol:

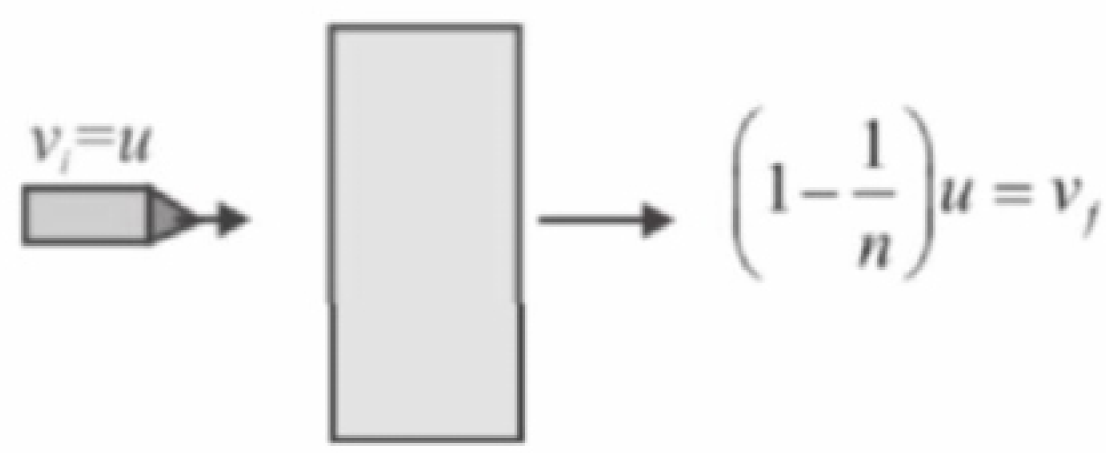


$$a_{CB} = 2m/\sec^2$$

$$200 = \frac{1}{2}\times 2t^2$$

$$t = 10\sqrt{2}\ \text{s}$$

4.Sol:



$$\left(1-\frac{1}{n}\right)^2 u^2 = u^2 - 2as$$

$$2as = u^2\left(1-\left(\frac{n-1}{n}\right)^2\right) = u^2\left(\frac{2n-1}{n^2}\right)$$

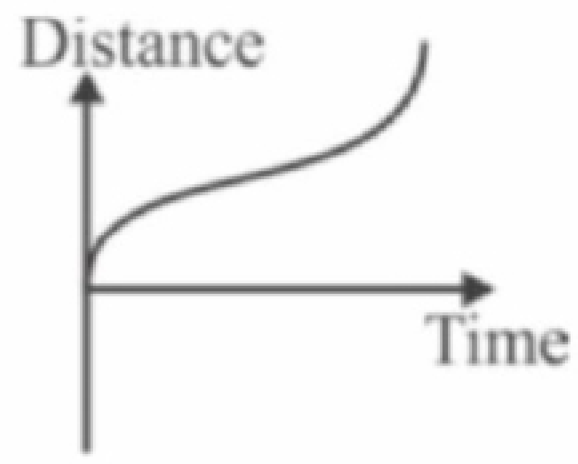
Let n be the number of planks required to stop the bullet.

$$0 = u^2 - 2ans$$

$$n = \frac{u^2}{2as} = \frac{u^2}{u^2\left(\frac{2n-1}{n^2}\right)} = \frac{n^2}{2n-1}$$

[OFFLINE QUESTIONS]

1.Sol: In this question options (b) and (d) are the corresponding position -time graph and velocity-position graph of option (c) and its distance-time graph is given as



Hence incorrect graph is option (a).

2.Sol: Velocity at any time t is given by

$$v = u + at$$

$$v = v_0 - gt$$

$\Rightarrow$ straight line with negative slope. During its return path the velocity should have opposite sign. The correct graph is (a).

3.Sol: $y_1 = 10t - \frac{1}{2}gt^2$

$$y_2 = 40 - \frac{1}{2}gt^2$$

$$y_1 - y_2 = 30t \text{ (straight line)}$$

but stone with 10 m/s speed will fall first and the other stone is still in air. Therefore path will be straight line first and it becomes parabolic till other stone reaches the ground.

4.Sol: Time to reach the maximum height

$$t_1 = \frac{u}{g}$$

If t_2 be the time taken to hit the ground

$$-H = ut_2 - \frac{1}{2}gt_2^2$$

But $t_2 = nt_1$ (given)

$$\Rightarrow -H = \frac{nu^2}{g} - \frac{1}{2}g\frac{n^2u^2}{g^2}$$

$$\Rightarrow 2gH = nu^2(n-2)$$

5.Sol: $\frac{dv}{dt} = -2.5\sqrt{v}$

$$\Rightarrow \frac{dv}{\sqrt{v}} = -2.5\, dt$$

Integrating,

$$\int_{6.25}^{0} v^{-1/2} dv = -2.5\int_0^t dt$$

$$\Rightarrow 2\left[v^{+1/2}\right]_{6.25}^{0} = -2.5[t]_0^t$$

$$\Rightarrow -2(6.25)^{1/2} = -2.5t$$

$$\Rightarrow t = 2 \sec$$

6.Sol: Downward motion

$v = -gt$

The velocity of the rubber ball increases in downward direction and we get a straight line between v and t with a negative slope.

We get $y = h - \frac{1}{2}gt^2$

The graph between y and t is a parabola with $y = h$ at $t = 0$. As time increases y decreases.

Upward motion

The ball suffers elastic collision with the horizontal elastic plate therefore the direction of velocity is reversed and the magnitude remains the same. Here $v = u - gt$, where u is the velocity just after collision.

As t increases, v decreases. We get a straight line between v and t with negative slope.

Also $y = ut - \frac{1}{2}gt^2$

MOTION IN TWO DIMENSION [ONLINE QUESTIONS]

1.Sol: Speed, V = constant (from question)

Centripetal acceleration,

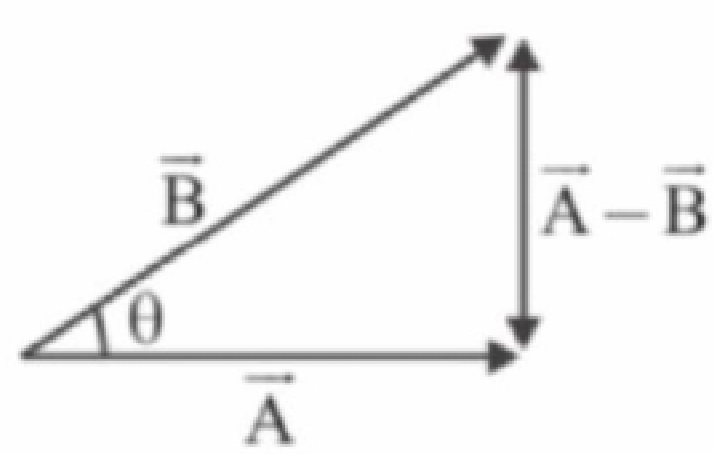
$$a = \frac{V^2}{r}$$

ra = constant

Hence graph (c) correctly describes relation between acceleration and radius.

2.Sol: Arc length = radius × angle

So, $\left|\vec{B} - \vec{A}\right| = \left|\vec{A}\right|\Delta\theta$



3.Sol: $2u_x = 40 \Rightarrow u_x = 20$

$$50 = 2u_y - \frac{1}{2}\times 10\times 2^2 \Rightarrow u_y = 35$$

$$\tan\theta = \frac{u_y}{u_x} = \frac{35}{20} = \frac{7}{4}$$

$$\theta = \tan^{-1}\left(\frac{7}{4}\right)$$

4.Sol: Let 't' be the time taken by the bullet to hit the target.

$$\therefore\ 700\,m = 630\,ms^{-1}t$$

$$\Rightarrow\ t = \frac{700m}{630\,ms^{-1}} = \frac{10}{9}\text{sec}$$

For vertical motion, $u = 0$

$$\therefore\ h = \frac{1}{2}gt^2 = \frac{1}{2}\times 10\times\left(\frac{10}{9}\right)^2 = \frac{500}{81}m = 6.1\,m$$

Therefore, the rifle must be aimed 6.1 m above the centre of the target to hit the target.

5.Sol: $\frac{u^2}{g} = R_{\max} \Rightarrow \frac{u^2}{10} = 40 \Rightarrow u = 20m/s$

$$T = \frac{2\times 20\sin\theta}{10} = 4\sin\theta$$

$$R = u_x\times T = (20+20\cos\theta)\times 4\sin\theta$$

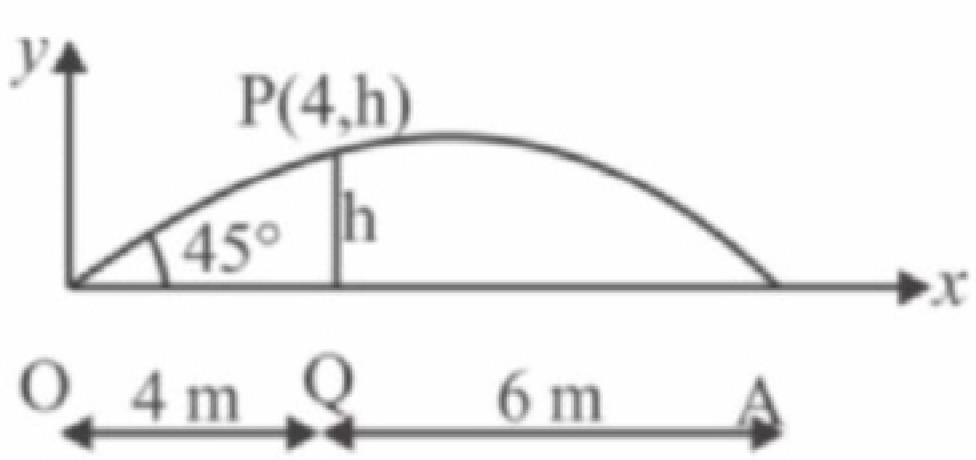
$$= 80(\sin\theta + \sin\theta.\cos\theta)$$

For maximum R, $\frac{dR}{d\theta} = 0$

$$\Rightarrow 2\cos^2\theta + \cos\theta - 1 = 0 \Rightarrow \cos\theta = \frac{1}{2}$$

$$\Rightarrow \theta = 60^\circ$$

6.Sol:



$$y = x\tan\theta\left(1-\frac{x}{R}\right) \Rightarrow h = 4\times 1\left(1-\frac{4}{10}\right)$$

$$h = 2.4m$$

[OFFLINE QUESTIONS]

1.Sol: $\vec{v} = \hat{i} + 2\hat{j}$

$$\Rightarrow\ x = t \qquad ...(i)$$

$$y = 2t - \frac{1}{2}(10t^2) \qquad ...(ii)$$

From (i) and (ii)

$$y = 2x - 5x^2$$

2.Sol: $R = \frac{u^2\sin^2\theta}{g}, H = \frac{u^2\sin^2\theta}{2g}$

$$H_{\max}\ at\ 2\theta = 90^\circ$$

$$H_{\max} = \frac{u^2}{2g}$$

$$\frac{u^2}{2g} = 10 \Rightarrow u^2 = 10g\times 2$$

$$R = \frac{u^2\sin 2\theta}{g} \Rightarrow R_{\max} = \frac{u^2}{g}$$

$$R_{\max} = \frac{10\times g\times 2}{g} = 20\,metre$$

3.Sol: Total area around fountain $A = \pi R_{\max}^2$

Where $R_{\max} = \frac{v^2\sin 2\theta}{g} = \frac{v^2\sin 90^\circ}{g} = \frac{v^2}{g}$

$$\therefore\ A = \pi\frac{v^4}{g^2}$$

4.Sol: $\vec{v} = k(y\hat{i} + x\hat{j})$

x-component of $v = ky$

$$\Rightarrow\ \frac{dy}{dt} = ky \qquad ...(1)$$

y- component of $v = kx$

$$\Rightarrow\ \frac{dy}{dt} = kx \qquad ...(2)$$

From (1) and (2), $\frac{dy}{dx} = \frac{x}{y}$

$$\Rightarrow\ ydy = xdx \Rightarrow y^2 = x^2 + \text{constant}$$

5.Sol: Given $\vec{u} = 3\hat{i} + 4\hat{j}, \vec{a} = 0.4\hat{i} + 0.3\hat{j}, t = 10s$

$$\vec{v} = \vec{u} + \vec{a}t = 3\hat{i} + 4\hat{j} + (0.4\hat{i} + 0.3\hat{j})\times 10 = 7\hat{i} + 7\hat{j}$$

$$\therefore\ |\vec{v}| = \sqrt{7^2 + 7^2} = 7\sqrt{2}\ \text{units}$$

LAWS OF MOTION [ONLINE QUESTIONS]

1.Sol: Time taken to slide along smooth surface

$$S = \frac{1}{2} g \sin 45^0 t_1^2$$

where S is thelrngth of the incline

$$t_1 = \sqrt{\frac{2\sqrt{2}S}{g}}$$

Time taken to slide along rough surface

$$S = \frac{1}{2}(g \sin 45^0 - \mu g \cos 45^0) t_2^2$$

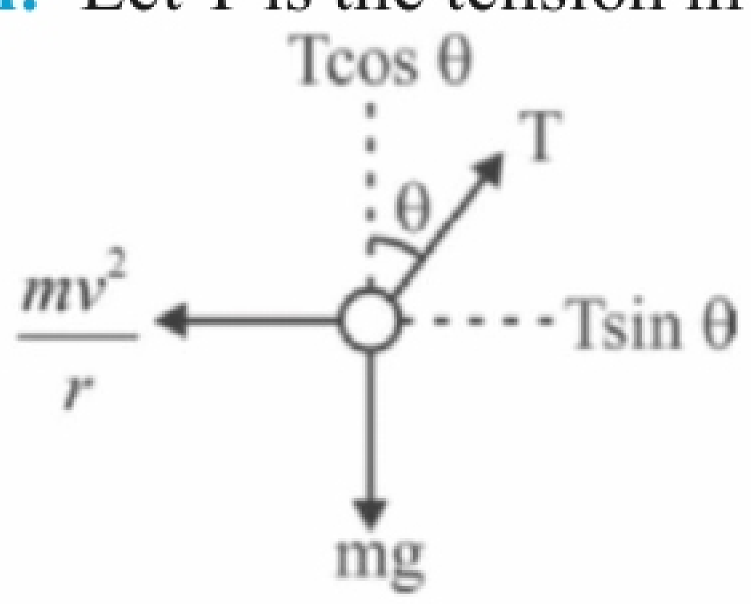
$$t_2 = \sqrt{\frac{2\sqrt{2}S}{g(1-\mu)}}$$

Given that

$$t_2 = nt_1$$

$$\frac{2\sqrt{2}S}{g(1-\mu)} = n^2 \times \frac{2\sqrt{2}S}{g} \Rightarrow 1-\mu = \frac{1}{n^2} \Rightarrow \mu = 1 - \frac{1}{n^2}$$

2.Sol: Let T is the tension in the string

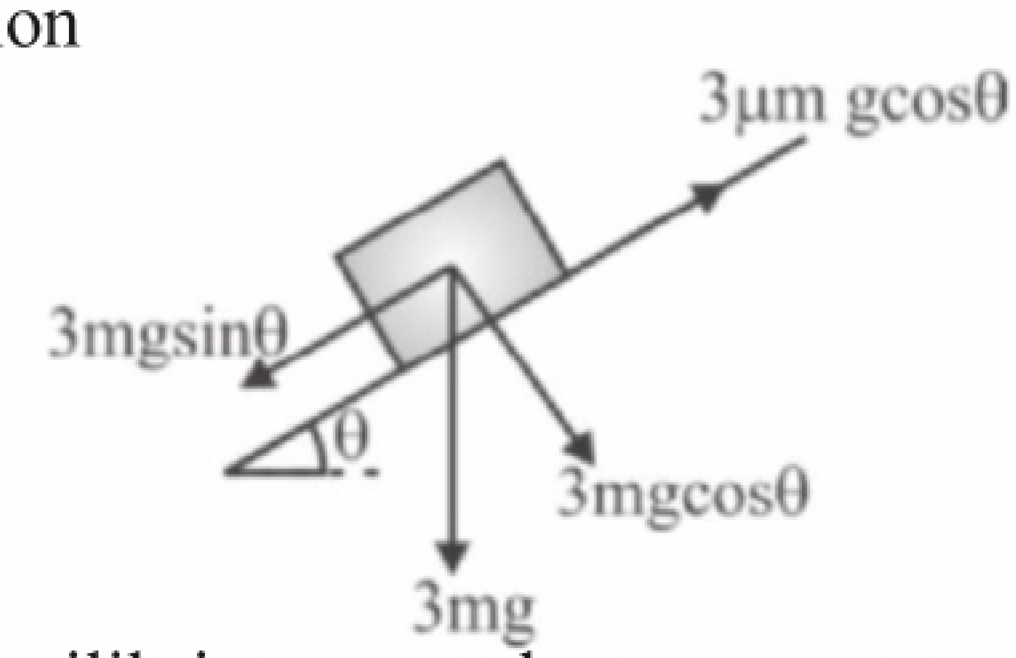


$$T \sin \theta = \frac{mv^2}{r}, T \cos \theta = mg$$

$$\Rightarrow \tan \theta = \frac{v^2}{rg}$$

$$\theta = 45^\circ \Rightarrow v = \sqrt{rg} = \sqrt{0.4 \times 10} = 2 m/s$$

3.Sol: Let μ be the minimum coefficient of friction



At equilibrium mass does not move so,

$$3mg \sin \theta = \mu 3mg \cos \theta$$

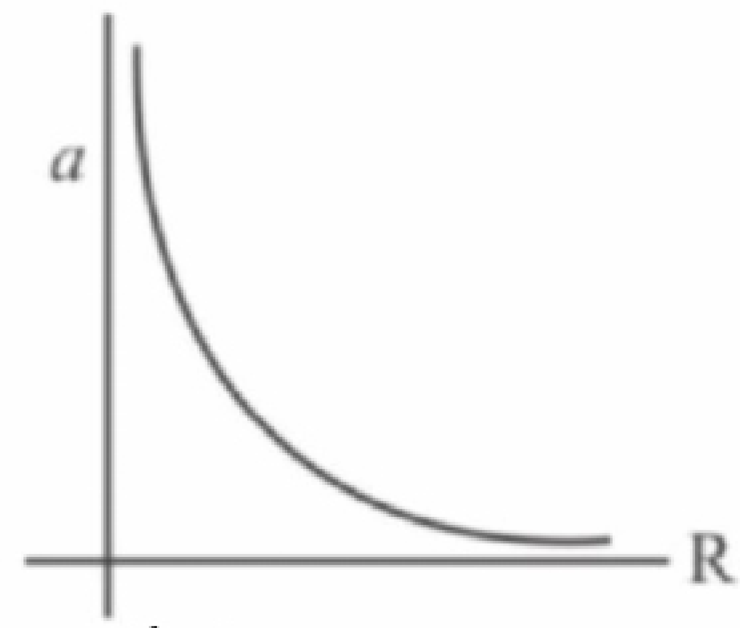
$$\therefore \ \mu_{min} = \tan \theta$$

4.Sol: Speed $v = 10 m/sec$

$$a = \frac{v^2}{R}$$

$$|\vec{v}| = \text{constant}$$

$$a \propto \frac{1}{R}$$



5.Sol: Given that

m = 5 kg

at t = 0s $\vec{v}_1 = 6\hat{i} - 2\hat{j}$

at t = 10s $\vec{v}_2 = 6\hat{i}$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t} = \frac{6\hat{i} - (6\hat{i} - 2\hat{j})}{10} = \frac{-3\hat{i} + 4\hat{j}}{5}$$

F = ma

$$= -3\hat{i} + 4\hat{j}$$

6.Sol: Initial speed at point A, $u = v_0$

Speed at point B, $v = ?$

$$v^2 - u^2 = 2gh$$

$$v^2 = v_0^2 + 2gh$$

Let ball travel distance 'S' before coming to rest

$$S = \frac{v^2}{2\mu g} = \frac{v_0^2 + 2gh}{2\mu g}$$

$$= \frac{v_0^2}{2\mu g} + \frac{2gh}{2\mu g} = \frac{h}{\mu} + \frac{v_0^2}{2\mu g}$$

7.Sol: For pushing

$$N = mg + F_A \sin 30^\circ$$

$$\mu N = F_A \cos 30^\circ$$

$$\mu(mg + F_A \sin 30^\circ) = F_A \cos 30^\circ$$

$$F_A = \frac{\mu mg}{\cos 30^\circ - \mu \sin 30^\circ}$$

For pulling

$$F_B = \frac{\mu mg}{\cos 60^\circ + \mu \sin 60^\circ}$$

$$\Rightarrow \frac{F_A}{F_B} = \frac{2}{\sqrt{3}}$$

8.Sol: Acceleration produced in upward direction

$$a = \frac{F}{M_1 + M_2 + Mass\ of\ metal\ rod}$$

$$= \frac{480}{20+12+8} = 12\, ms^{-2}$$

The tension at the mid point

$$T = \left(M_2 + \frac{Mass\ of\ rod}{2} \right) a$$

$$= (12+4) \times 12 = 192N$$

9.Sol: Until F equals limiting friction $a = 0$ after that a increases linearly with t. The correct graph is (b)

10.Sol: At $x = 0 \Rightarrow \mu = 0$ i.e., the body accelerates down and v increases. When

$\mu = \tan\theta$ where $mg\sin\theta = \mu mg\cos\theta$

The body reaches maximum velocity.

i.e., $0.3x = \tan 45^\circ \Rightarrow x = 3.33m$

Beyond 3.33 m the friction dominates $mg\sin\theta$ and the block decelerates and its velocity decreases.

11.Sol: At equilibrium of the rotatig body

$$Kx = mr\omega^2$$

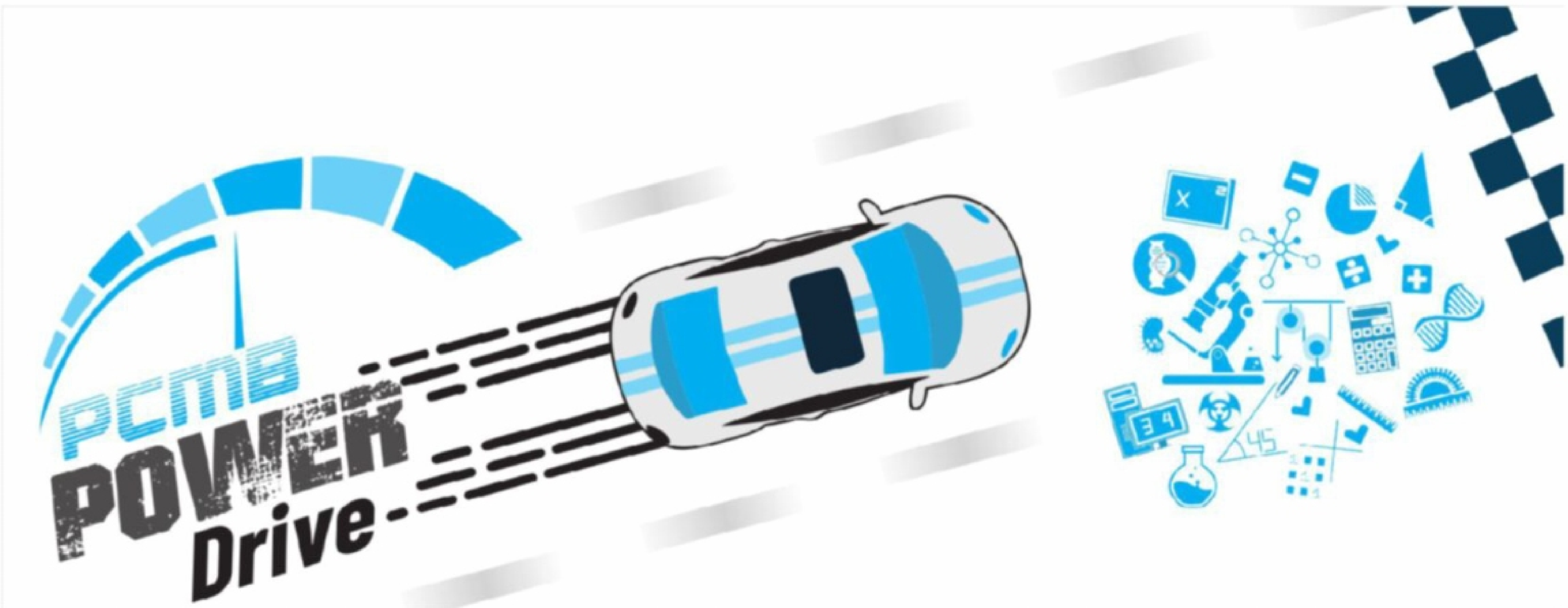
$$Kx = m(l_0 + x)\omega^2$$

$$K(1cm) = m(l_0 + 1cm)\omega^2 \quad \text{(i)}$$

$$K(5cm) = m(l_0 + 5cm)4\omega^2 \quad \text{(ii)}$$

From eq's (i) & (ii)

$$l_0 = 15\text{cm}$$



FLUID MECHANICS (CLASS-XI)

1. Fluid

The term fluid refers to a substance that can flow and does not have a shape of its own. For **e.g** liquids and gases.

2. Pressure in a fluid

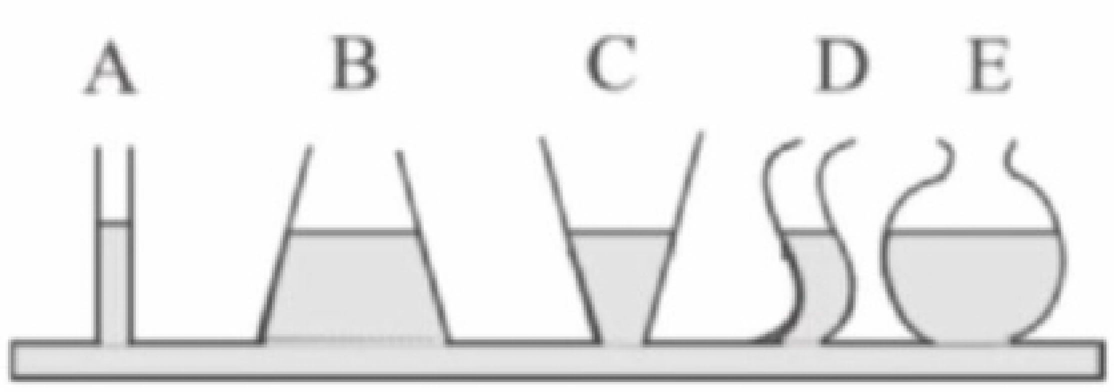
The pressure p is defined as the magnitude of the normal force acting on a unit surface area.

$$P = \frac{F}{A}$$

F = normal force on a surface area A.

3. Hydrostatic paradox

In the figure shown all the containers having different shapes are connected at the base. Even though the containers have different shapes the pressure at the base of all the containers must be same and level of liquid is same.



4. Atmospheric pressure

The atmospheric pressure at any point is numerically equal to the weight of a column of air of unit cross-sectional area extending from that point to the top of the atmosphere.

Atmospheric pressure = 1.013 × 10–5 N-m2

(I) Absolute pressure

Absolute pressure is measured by taking vaccum as the reference point. The absolute pressure of vaccum is zero.

(II) Gauge pressure

- A gauge pressure is used to measure the pressure difference between absolute pressure and atmospheric pressure.
- Conventionally the gauge pressure is defined as positive if the pressure (absolute) is more than atmospheric pressure and it is negative if the pressure (absolute) is less than atmospheric pressure

5. Measurement of atmospheric pressure

(I) Mercury barometer

A barometer in which the weight of a column of mercury in a glass tube with a sealed top is balanced against that of the atmosphere.

$$p_a = h\rho g$$

$$h = 760\ mm\ Hg$$

(II) Water barometer

If water is used in the barometer instead of mercury then the height of the water column is

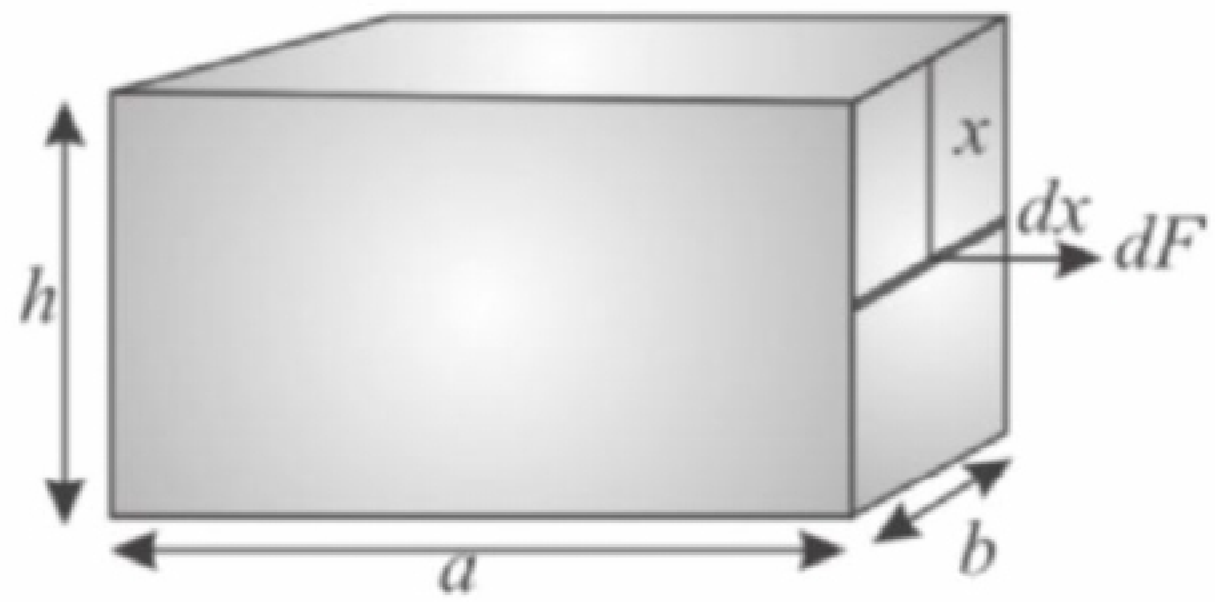
$$h\rho g = 1.013 \times 10^5\ N/m^2$$

$$\Rightarrow h = \frac{1.013 \times 10^5}{\rho g} = 10.3\, m$$

6. Archimede's principle

When a body is immersed partly or wholly in a fluid it loses some weight, which is equal to the weight of the liquid displaced by the body"

7. Force on side wall of a vessel

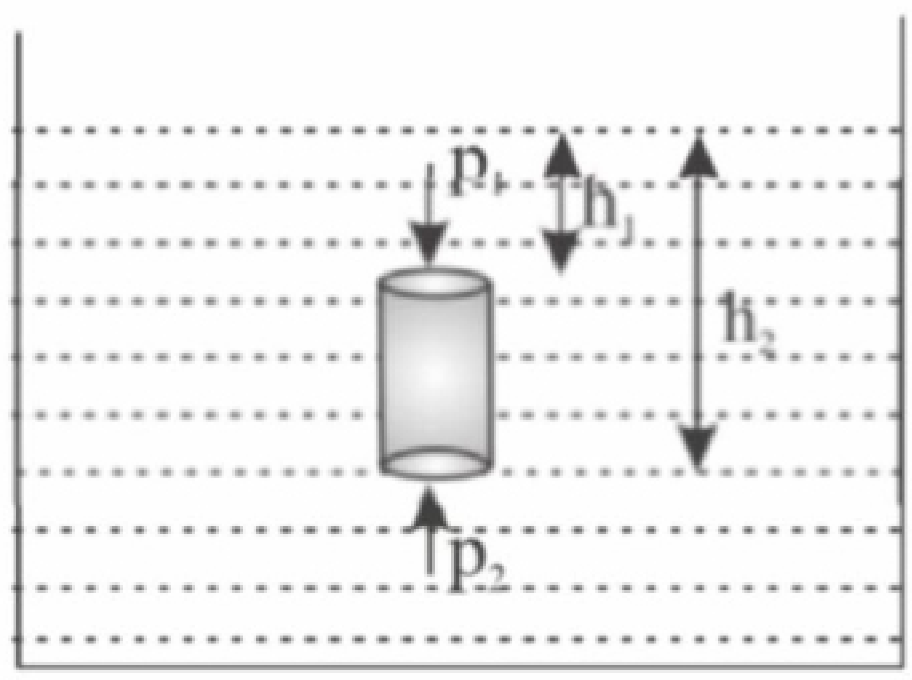


The net pressure force on a surface along a direction (say x direction) is $F_x = P_{CM} \times A$

P_{CM} = is the pressure at the centre of mass of the projected area A - is the projected area of the surface in yz plane. In the above case

$$P_{CM} = \frac{\rho g h}{2} \;\&\; A = hb \quad \Rightarrow F_x = \frac{\rho g h^2 b}{2}$$

8. Buyoancy Force



- Net ***pressure force*** is nothing but ***buoyancy*** force which is equal to the weight of the liquid replaced by a body. This is true even if a body floats or submerged completely.

(I) Relative density (Specific gravity) of solid

$$\text{RD of solid} = \frac{\text{density of the body}}{\text{density of water at } 4^\circ\text{C}}$$

(II) Relative density of a liquid

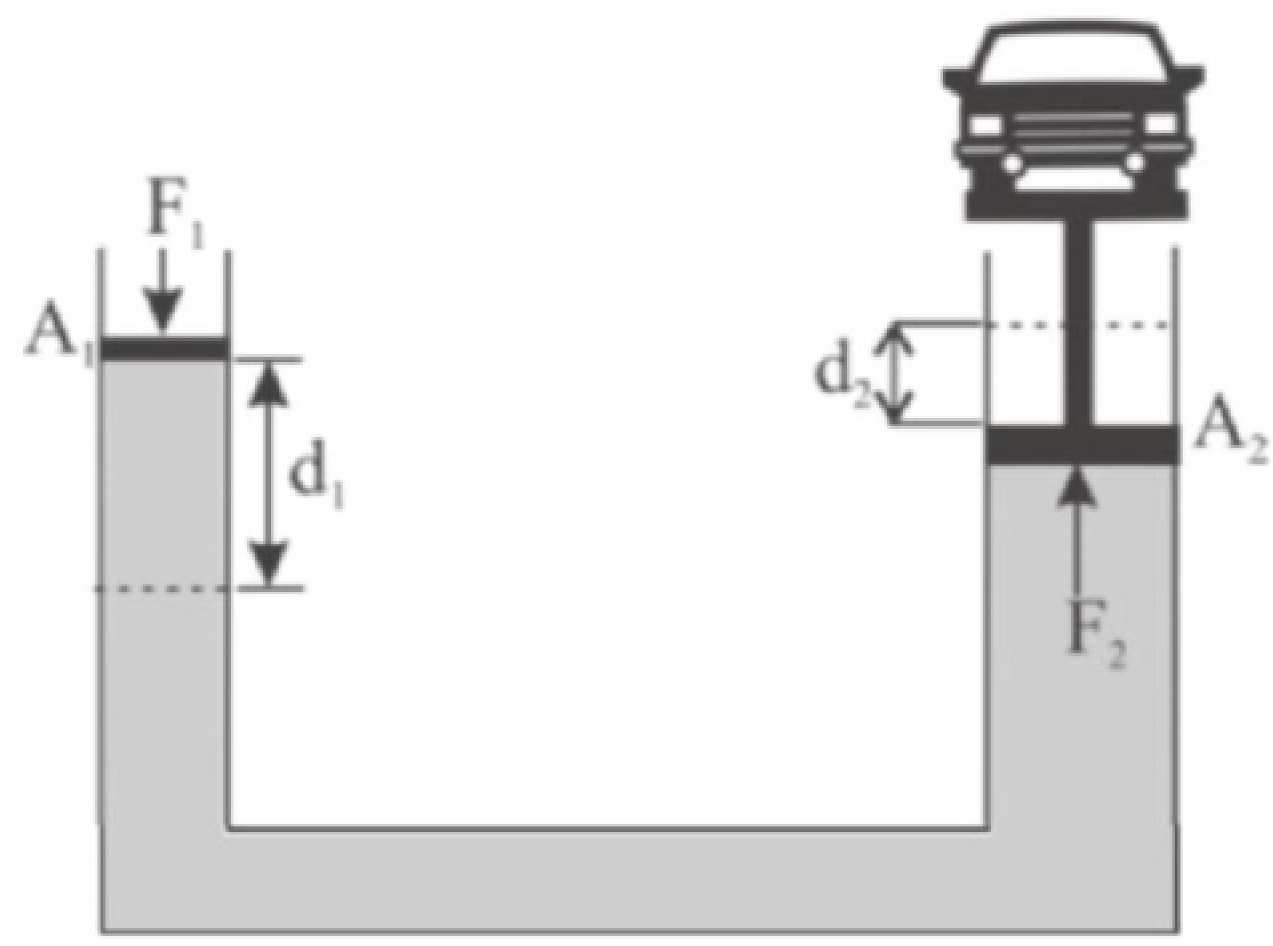
$$\text{RD of liquid} = \frac{\text{Density of the liquid}}{\text{Density of water at } 4^\circ\text{C}}$$

9. Floatation

Law of floatation

- Let F_g and F_b be the weight of a body and the buoyancy force on it.
- If $F_g > F_b$ body sinks,
- If $F_g = F_b$ body is just submerged (body floats with its volume completely under the liquid),
- If $F_g < F_b$ body floats (a part of the body lies outside the liquid).

10. Pascal's law



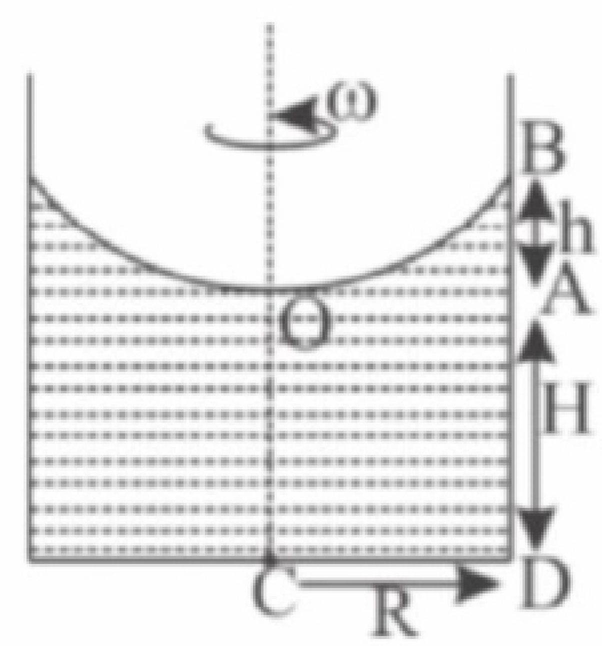
- Consider a hydraulic system in which a car is balanced by an external force F_1.

Let the weight of the car is F_2. As the extra pressure is same at both ends.

$$\Delta P = \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow F_2 = F_1 \frac{A_2}{A_1}$$

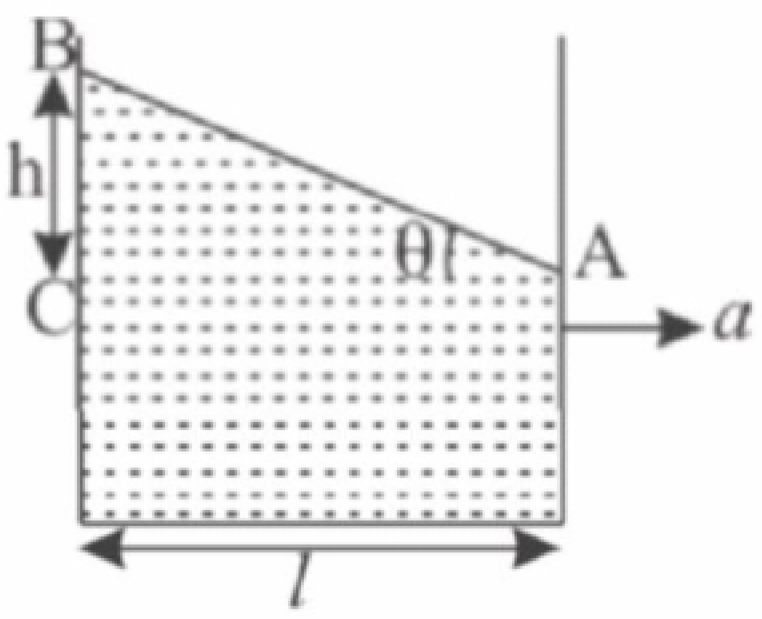
As $A_2 > A_1, F_2$ is magnified.

11. Free surface of a liquid in rotation



$$h = \frac{\omega^2 R^2}{2g} \quad (P_o = P_B)$$

12. Free surface of a liquid in horizontal acceleration



$$\frac{h}{l}=\frac{a}{g}=\mathrm{Tan}\,\theta \Rightarrow \theta=\mathrm{Tan}^{-1}\left(\frac{a}{g}\right)$$

13. Types of fluid flow

(I) Steady flow

Steady flow is defined as the flow in which the fluid characteristics like velocity, pressure and density at a point do not change with time.

(II) Streamline flow

- In a steady flow all the particles passing through a given point follow the same path and hence flow a unique line of flow. This line of path is called a streamline.
- Streamline do not intersect each other

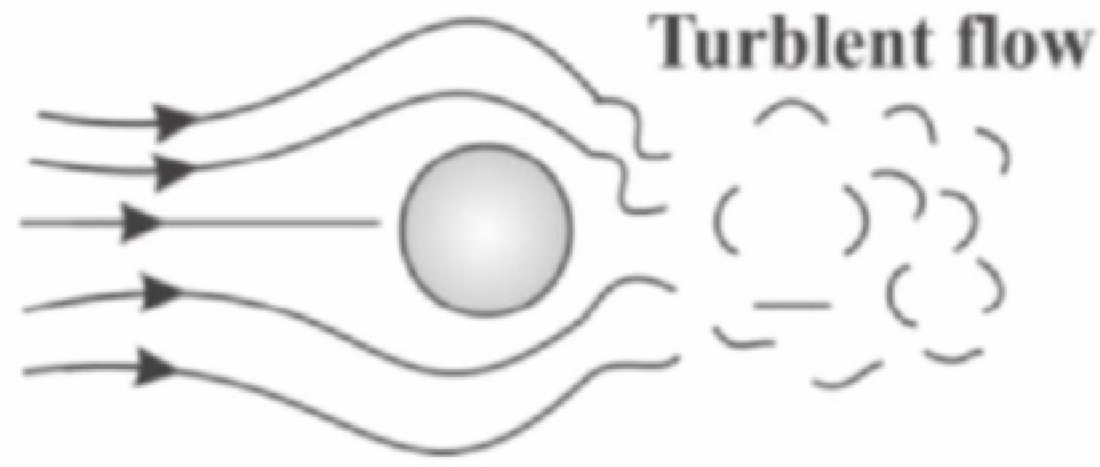
Two stream lines never intersect each other.

(III) Laminar flow

If the liquid flows over a horizontal surface in the form of layers of different velocities, then the flow of liquid is called Laminar flow. The particle of one layer do not go to another layer. In general, Laminar flow is a streamline flow.

(IV) Turbulent flow

The flow of fluid in which velocity of all particles crossing a given point is not same and the motion of the fluid becomes disorderly or irregular is called turbulent flow.



14. Equation of continuity

Av = constant. This is called equation of continuity and states that as the area of cross-section of the tube of flow becomes larger, the liquid's (fluid) speed becomes smaller and vice-versa.

E.g: Velocity of liquid is greater in the narrow tube as compared to the velocity of the liquid in a broader tube.

15. Energy of a liquid

A liquid can possess three types of energies :

(I) Kinetic energy

$$\therefore \text{K.E. per unit volume } = \frac{\frac{1}{2}mv^2}{V}=\frac{1}{2}\rho v^2$$

(II) Potential energy

$$\therefore \text{P.E. per unit volume} = \frac{\text{mgh}}{\text{V}} = \rho\text{gh}.$$

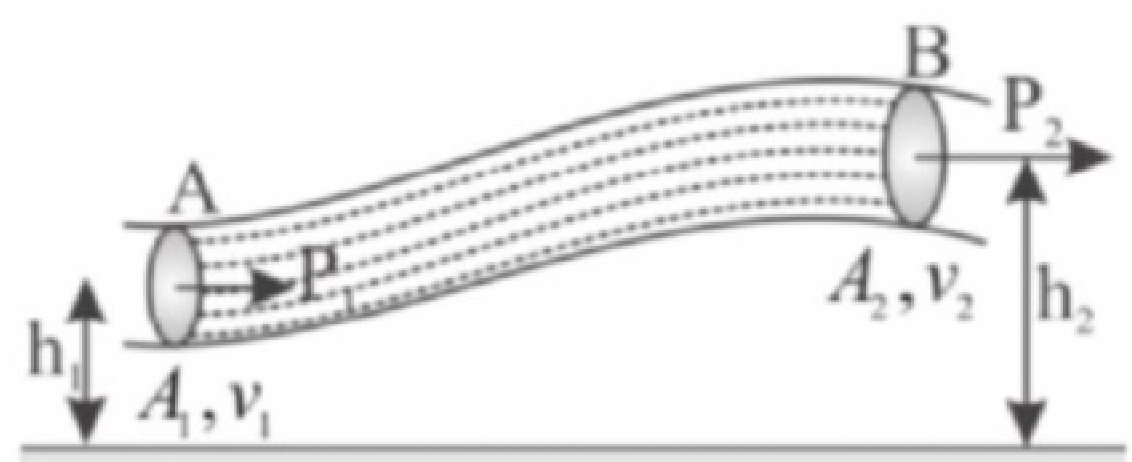
(III) Pressure energy

$\therefore$ Pressure energy per unit volume of the

$$\text{liquid} = \frac{PdV}{dV}=P.$$

16. Bernoulli's theorem

It states that the sum of pressure energy, kinetic energy and potential energy per unit mass or per unit volume is always constant for incompressible and non-viscous fluid having streamline flow.

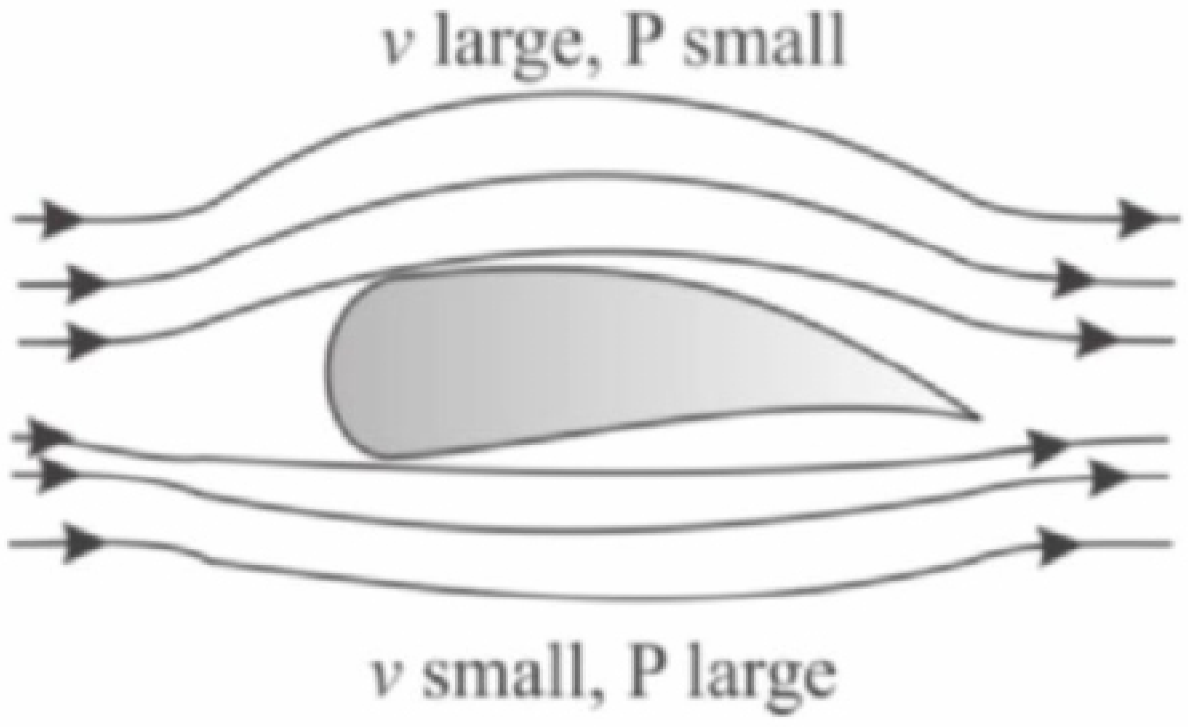


The total energy per unit volume is

i.e., $P+\frac{1}{2}\rho v^2+\rho gh = \text{constant}$

17. Applications of Bernoulli's theorem

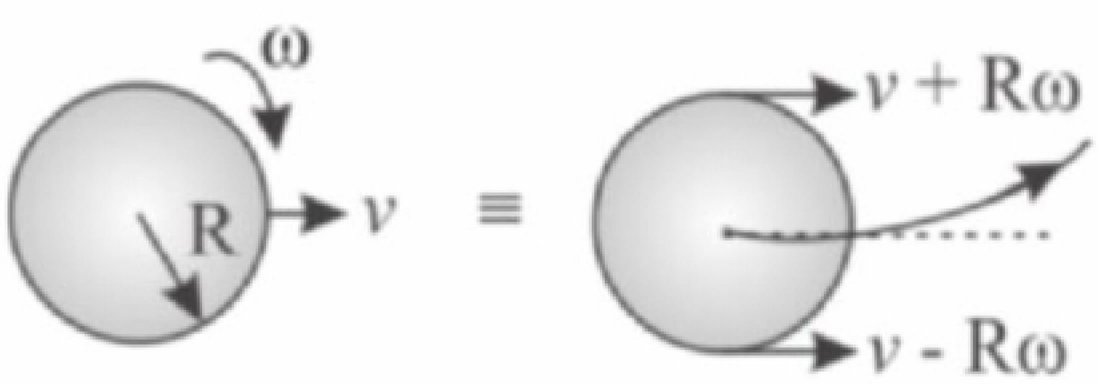
(I) Dynamic lift



- The dynamic lift experienced by a body when it is in motion in air is called aerodynamic lift.

  Pressure force $=(p_1-p_2)A$

(II) Spinning ball: (magnus effect)

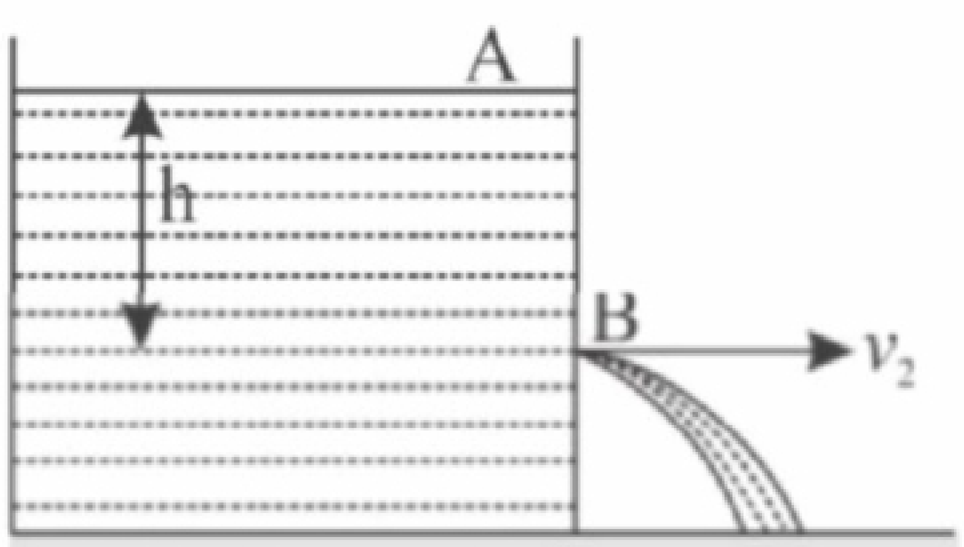


- The resultant velocity on the top is $v+R\omega$ and at the bottom of the ball resultant velocity is $v-R\omega$.
- Therefore, pressure on the top of the ball will be less than that at the bottom. There is a net force F acting on the ball in upward direction.

(III) Torricelli's theorem (speed of efflux)

At point **A** $P_1=P_a$, $v_1=0$ and $h_1=h$

At point **B** $P_2=P_a$, $h=0$



Using Bernoulli's theorem

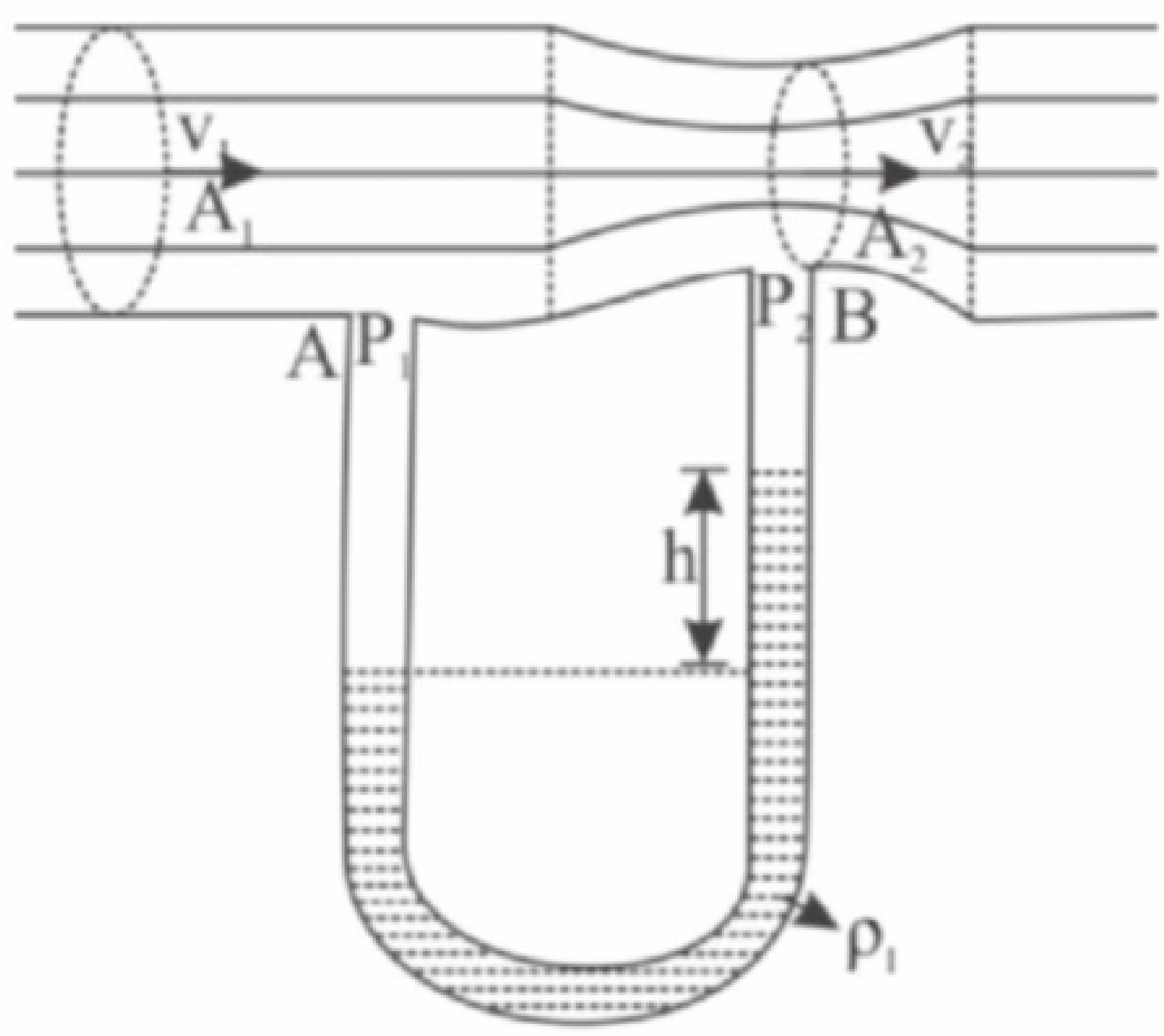
$$P_1+\rho gh_1+\frac{1}{2}\rho v_1^2=P_2+\rho g(0)+\frac{1}{2}\rho v_2^2$$

we have $P_1=P_2=P_a$

$$P+\rho gh=P+\frac{1}{2}\rho v_2^2$$

$$\Rightarrow\frac{1}{2}v_2^2=gh\Rightarrow v_2=\sqrt{2gh}$$

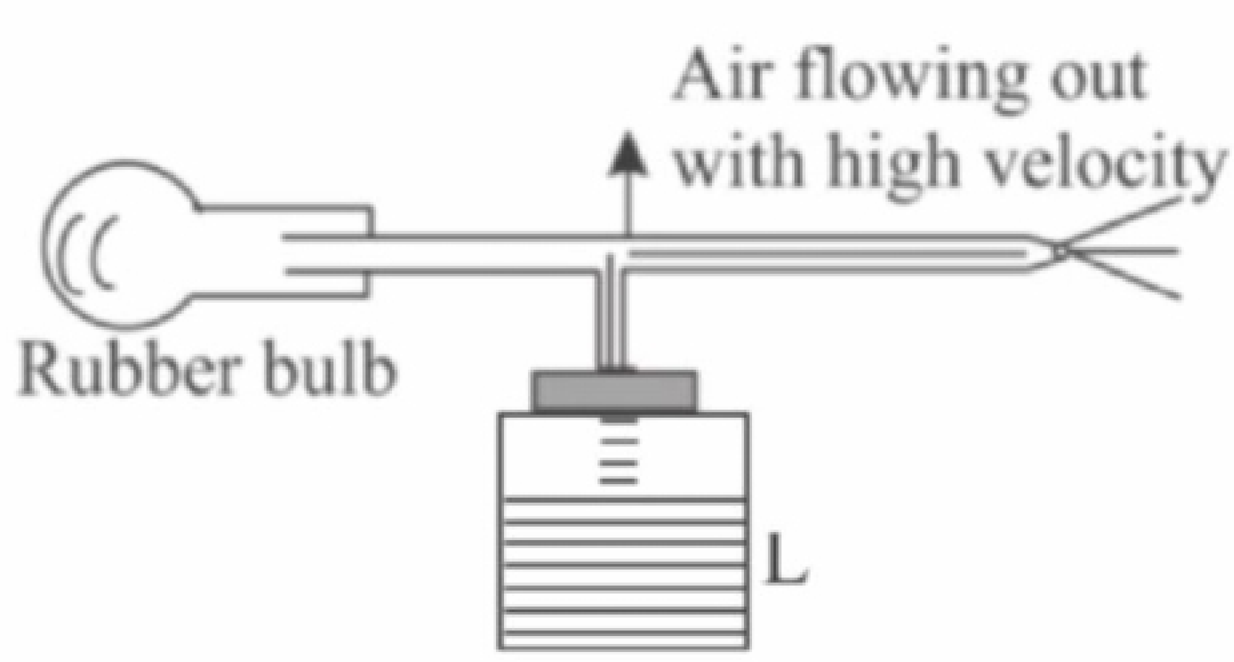
(IV) Venturimeter



- It is a gauge put on a flow pipe to measure the flow of speed of a fluid (Fig). Let the fluid of density ρ be flowing through a pipe of area of cross section A_1. Let A_2 be the area of cross section at the throat and a manometer is attached as shown in the figure.

$$v_1=\sqrt{\frac{2\rho_l gh}{\rho\left[\left(\frac{A_1}{A_2}\right)^2-1\right]}}$$

(V) Action of atomiser or sprayer

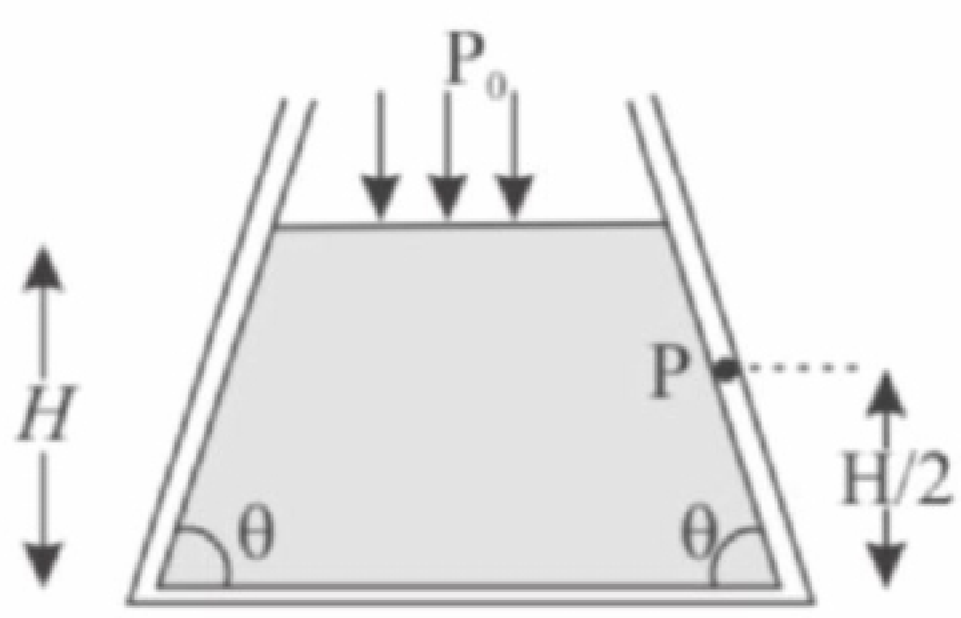


- When we press the rubber bulb then the air move with high velocity in horizontal tube. So the pressure in the horizontal tube decreases as a result the liquid in the bottle rises up and gets mixed up with air and comes out as a spray.

Exercise

1. The height to which a cylindrical vessel be filled with a homogeneous liquid, to make the average force (ignore direction) with which the liquid presses the side of the vessel equal to the force exerted by the liquid on the bottom of the vessel, is equal to
(1) Half of the radius of the vessel
(2) Radius of the vessel
(3) One-fourth of the radius of the vessel
(4) Three-fourth of the radius of the vessel

2. A container shown in figure contains a liquid to a depth H, and of density ρ. The gauge pressure at point P is:



(1) $\dfrac{\rho g H}{2+P_0}$ (2) $\dfrac{\rho g H}{2}$

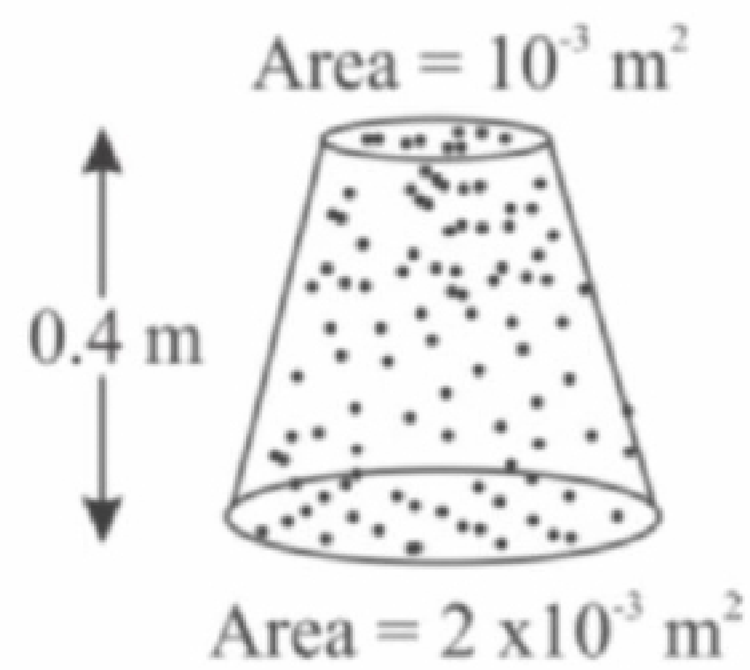
(3) $\dfrac{\rho g H}{2\cos\theta}$ (4) $\dfrac{\rho g H\cos\theta}{2}$

3. The pressure at the bottom of a tank containing a liquid does not depend on:
(1) Height of the liquid column
(2) Acceleration due to gravity
(3) Nature of the liquid
(4) Area of the bottom surface

4. The force acting on a window of area $50cm \times 50cm$ of a submarine at a depth of 200 m in an ocean, interior of which is maintained at sea level atmospherical pressure is (Density of sea water $= 10^3 kgm^3$, $g = 10ms^{-2}$)
(1) $5\times10^5 N$ (2) $10^6 N$
(3) $5\times10^6 N$ (4) $25\times10^6 N$

5. Why the dam of water reservior is thick at the bottom?
(1) Density of water increases with depth
(2) Quantity of water increases with depth
(3) Temperature of water increases with depth
(4) Pressure of water increases with depth

6. A uniformly tapering vessel is filled with a liquid of density $900 kg/m^3$. The force that acts on the base of the vessel due to the liquid is $(g = 10ms^{-2})$



(1) 7.2 N (2) 3.6 N
(3) 9.0 N (4) 14.4 N

7. The diameter of the piston of a hydraulic automobile is D meter. What pressure, in atmosphere is required to lift a car of mass m kg?

(1) $\dfrac{6mg}{\pi D^2}$ (2) $\dfrac{2mg}{\pi D^2}$

(3) $\dfrac{mg}{\pi D^2}$ (4) $\dfrac{4mg}{\pi D^2}$

8. An object weights m_1 in a liquid of density d_1 and that in liquid of density d_2 is m_2. The density d of the object is:

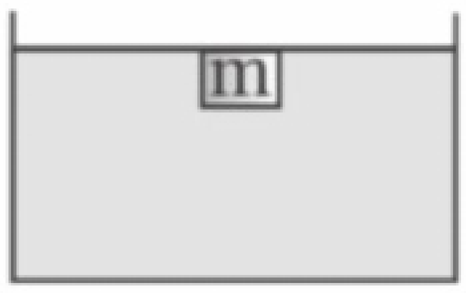
(1) $\dfrac{m_1d_1 - m_2d_2}{m_2 - m_1}$ (2) $\dfrac{m_2d_2 - m_1d_1}{m_2 - m_1}$

(3) $\dfrac{m_1d_2 - m_2d_1}{m_1 - m_2}$ (4) $\dfrac{m_2d_1 - m_1d_2}{m_1 - m_2}$

9. A large ship can float but a steel needle sinks because of:
(1) Viscosity (2) Surface tension
(3) Density (4) None of these

10. A 45kg woman is standing on an ice slab without getting her feet wet. What is the minimum volume of the slab
($\rho_{ice} = 0.92 gcm^{-3}$) ?
(1) $0.562m^3$ (2) $0.5m^3$
(3) $0.812m^3$ (4) None of these

11. A block just floats in a liquid. It is pushed down and released then:



(1) It will rise to original position and stay there
(2) It will oscillate
(3) It will rise to another position and stay there
(4) It will sink

12. A vessel with water is placed on a weighing pan and reads 600g. Now a ball of 40g and density 0.80 g/cc in submerged into the water with a pin as shown in fig. Keeping it sunk. the weighing pan will show a reading
(1) 550 g (2) 600 g
(3) 632 g (4) 650 g

13. Density of ice is ρ and that of water is σ. What will be the decrease in volume when a mass M of ice melts?
(1) $\frac{\sigma-\rho}{M}$ (2) $\frac{M}{\sigma-\rho}$
(3) $\frac{1}{M}\left[\frac{1}{\rho}-\frac{1}{\sigma}\right]$ (4) $M\left[\frac{1}{\rho}-\frac{1}{\sigma}\right]$

14. In order that a floating object be in a stable equilibrium, its centre of buoyancy should be
(1) Below its centre of gravity
(2) Vertically above its centre of gravity
(3) May be anywhere
(4) Horizontally in a line with its centre of gravity

15. A sphere of solid material of specific gravity 8 has a concentric spherical cavity and just sinks in water. The ratio of radius of cavity to that of outer radius of the sphere must be
(1) $\frac{5^{1/3}}{2}$ (2) $\frac{7^{1/3}}{2}$ (3) $\frac{3^{1/3}}{2}$ (4) $\frac{9^{1/3}}{2}$

16. In making an alloy, a substance of specific gravity s_1 and mass m_1 is mixed with another substance of specific gravity s_2 and mass m_2; then the specific gravity of the alloy is :-
(1) $\left(\frac{s_1 s_2}{m_1+m_2}\right)$
(2) $\left(\frac{m_1+m_2}{s_1+s_2}\right)$
(3) $\left[\frac{(m_1/s_1+m_2/s_2)}{m_1+m_2}\right]$
(4) $\left[\frac{m_1+m_2}{(m_1/s_1+m_2/s_2)}\right]$

17. A block of material of specific gravity 0.4 is held submerged at a depth of 1m in a vessel filled with water. The vessel is accelerated upwards with acceleration of $a_o = g/5$. If the block is released at $t=0$, neglecting viscous effects, it will reach the water surface at t equal to ($g = 10\,m/s^2$):
(1) 0.33 s (2) 0.60 s
(3) 1.2 s (4) 3.3 s

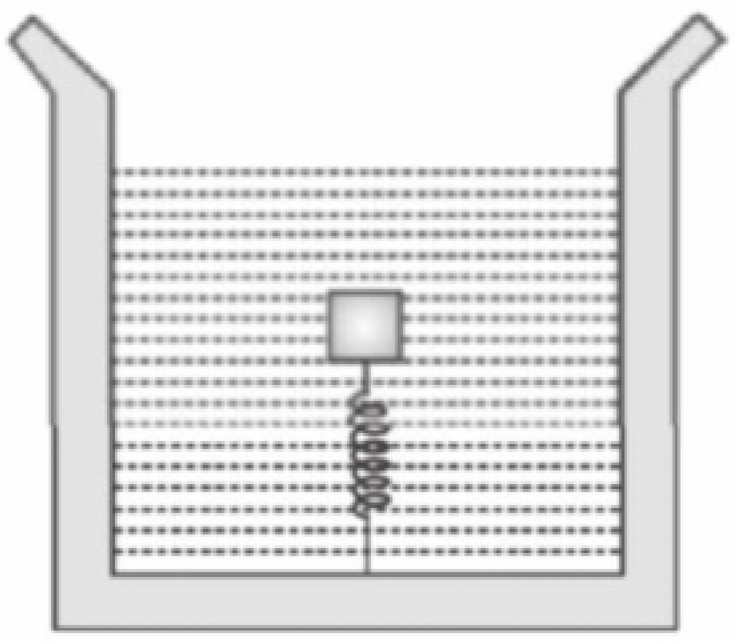
18. When a boat in a river enters the sea water, then it
(1) Sinks a little (2) Rises a little
(3) Remains same (4) Will drawn

19. The force of buoyancy is equal to
(1) Weight of the body
(2) Weight of the liquid displaced by the body
(3) Net pressure force on the body
(4) All the above

20. A boy is carrying a bucket of water in one hand and a piece of plastic in the other. After transferring the plastic piece to the bucket (in which it floats) the boy will carry:

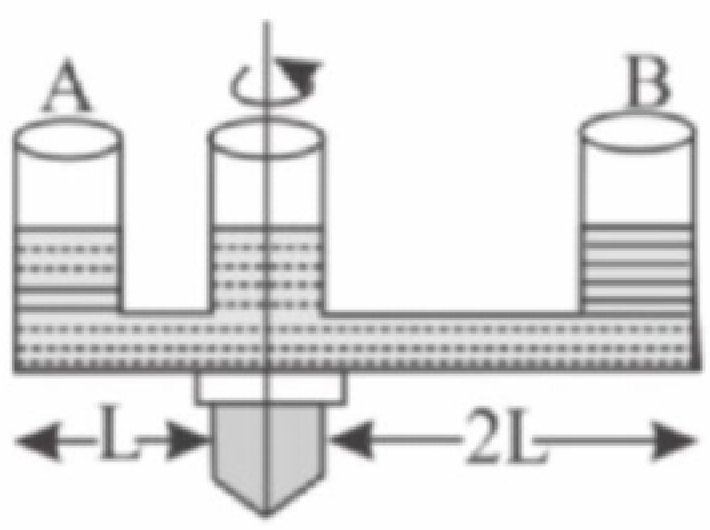
(1) Same load as before
(2) More load as before
(3) Less load as before
(4) Either less or more load, depending on the density of plastic

21. A block is submerged in vessel filled with water by a spring attached to the bottom of the vessel. In equilibrium, the spring is compressed. The vessel now moves downwards with an acceleration $a(<g)$. The spring length



(1) Will decreases but not zero
(2) Will become zero
(3) May increase or decrease or remain constant
(4) Will increase

22. A given shaped glass tube having uniform cross section is filled with water and is mounted on a rotatable shaft as shown in figure. If the tube is rotated with a constant angular velocity ω then



(1) Water levels in both sections A and B go up
(2) Water level in Section A goes up and that in B comes down
(3) Water level in Section A comes down and that in B it goes up
(4) Water levels remains same in both sections

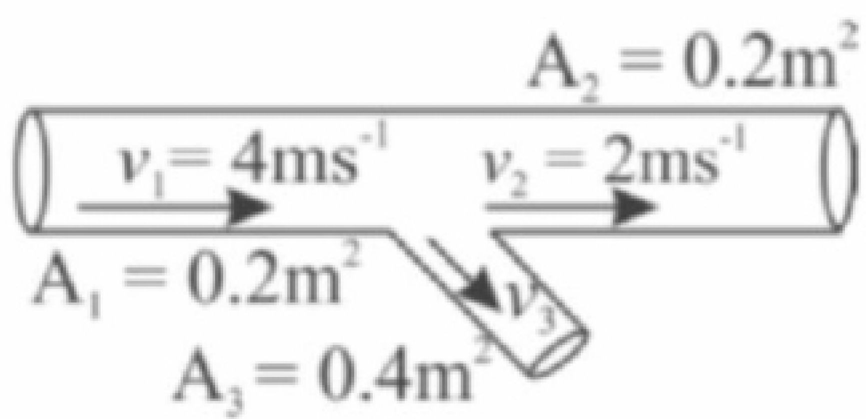
23. An open vessel containing water is accelerating horizontally with a. the angle made by the liquid surface w.r.to horizontal direction is.

(1) $\theta = \tan^{-1}\frac{a}{g}$ (2) $\theta = \cos^{-1}\frac{g}{a}$
(3) $\theta = \tan^{-1}\frac{g}{a}$ (4) $\theta = \sin^{-1}\frac{a}{g}$

24. The liquid flow is most stream lined when
(1) Liquid of high viscosity and high density flowing through a tube of small radius.
(2) Liquid of high viscosity and low density flowing through a tube of small radius
(3) Liquid of low viscosity and low density flowing through a tube of large radius
(4) Liquid of low viscosity and high density flowing through a tube of large radius

25. In turbulent flow, the velocity of the liquid molecules in contact with the walls of the tube.
(1) Is zero
(2) Is maximum
(3) Is equal to critical velocity
(4) May have any value

26. In the figure, the velocity v_3 will be

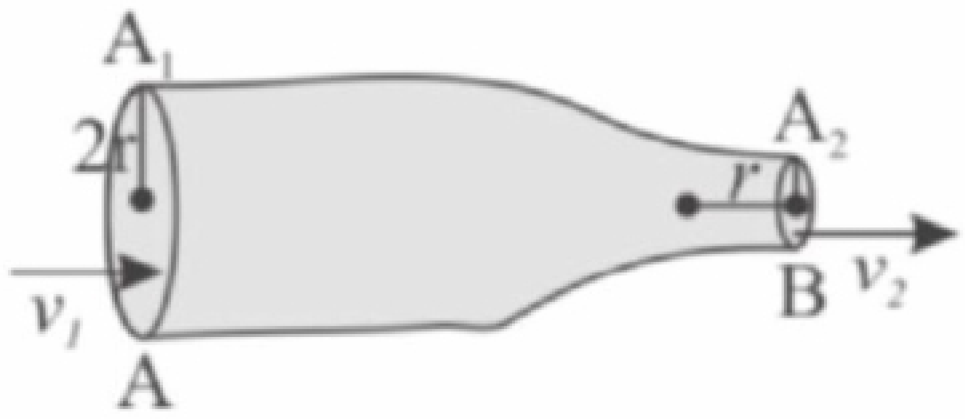


(1) $1\ ms^{-1}$ (2) $4\ ms^{-1}$ (3) Zero (4) $3\ ms^{-1}$

27. Water is flowing continuosly from a tap having an internal diameter $8\times10^{-3}m$. The water velocity as it leaves the tap is $0.4ms^{-1}$. The diameter of the water stream at a distance $2\times10^{-1}m$ below the tap is close to
(1) $5.0\times10^{-3}m$ (2) $3.6\times10^{-3}m$
(3) $9.6\times10^{-3}m$ (4) $7.5\times10^{-3}m$

28. Equation of continuity for the streamline flow of an ideal fluid expresses the law of conservation of
(1) Energy (2) Mass
(3) Angular momentum
(4) Linear momentum

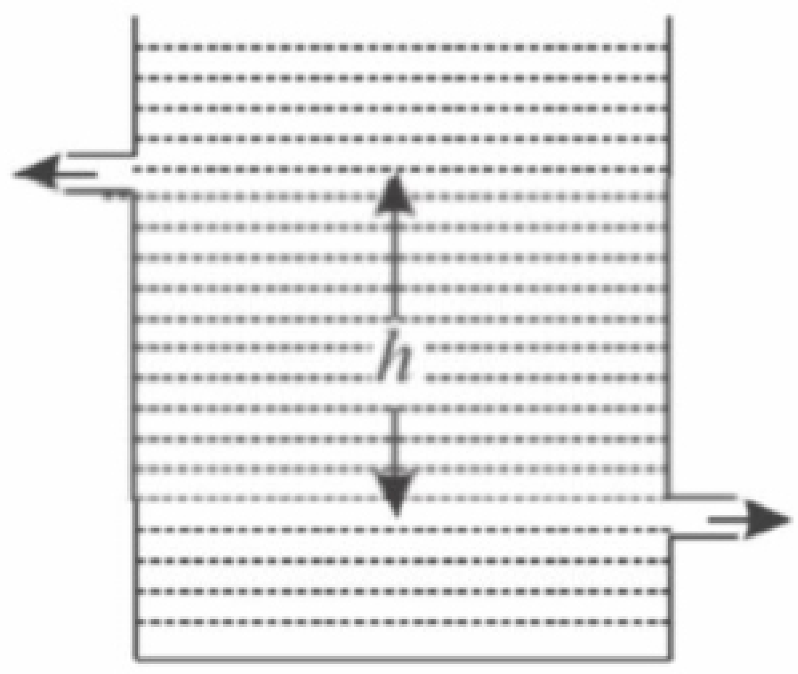
29. An incompressible fluid flows steadily through cylindrical pipe, which has radius 2r at point A and radius r at B further along the flow direction. If the velocity at point A is v, its velocity at point B is



(1) $2v$ (2) v

(3) $v/2$ (4) $4v$

30. There are two identical small holes on the opposite sides of a tank containing a liquid. The tank is open at the top. The difference in height between the two holes is h. As the liquid comes out of the two holes, the tank will experience a net horizontal force proportional to



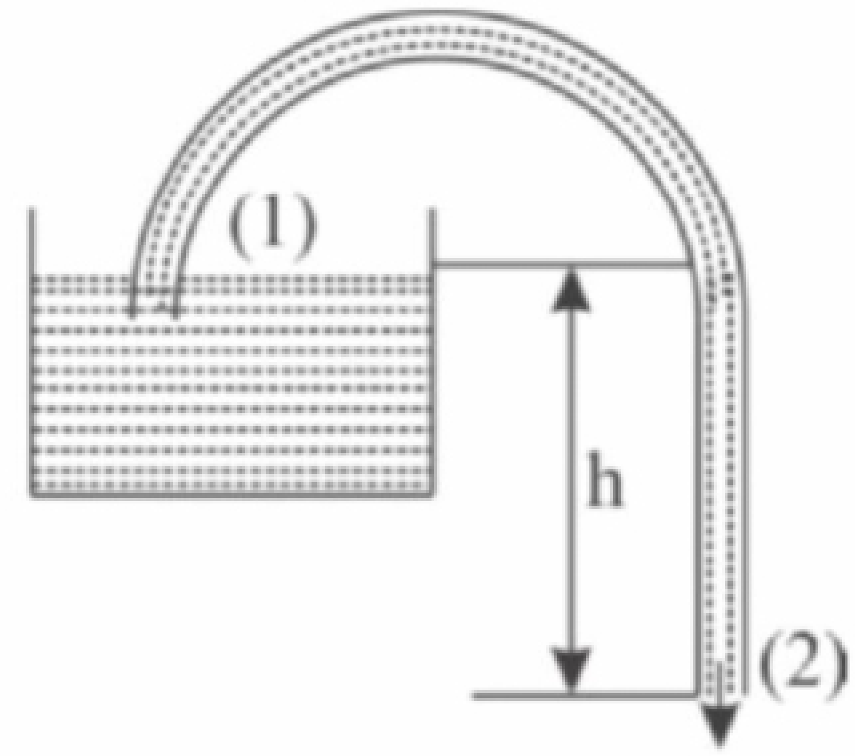
(1) $h^{1/2}$ (2) $h^{3/2}$ (3) h^2 (4) h

31. Water is flowing at a speed of $1 m/s$ through horizontal tube of cross-sectional area $100 cm^2$ and you are trying to stop the flow by your palm. Assuming that the water stops immediately after hitting the palm, the minimum force that you must exert should be (density of water $= 10^3 kgm^{-3}$)

(1) 22.5N (2) 10N

(3) 45N (4) 33.7N

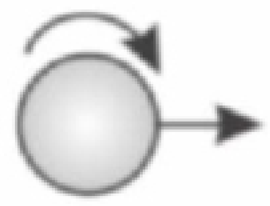
32. In a siphon arrangement the water level in the supply reservoir is above the free end of a pipe as shown in the figure. If the diameter of the pipe is 'd' (constant) what is the rate of the discharge of water.

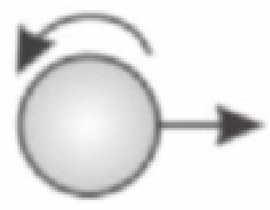


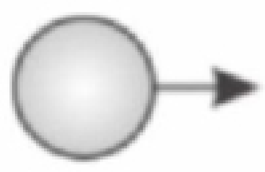
(1) $\pi d^2\sqrt{gh}$ (2) $\pi d^2\sqrt{8gh}$

(3) $\pi d^2\sqrt{\frac{gh}{8}}$ (4) $\pi d^2\sqrt{2gh}$

33. To get the maximum flight a ball must be thrown as:

(1) 

(2) 

(3) 

(4) Any of (1), (2) and (3)

34. Water falls from a tap, down the stream line:

(1) Area increases

(2) Area decreases

(3) Area remains same

(4) Velocity remains same

35. The flow speeds of air on the lower and upper surfaces of the wing of an aero plane are v and $\sqrt{2}v$ respectively. The density of air is ρ and surface area of wing is A. The dynamic lift on the wing is:

(1) $\sqrt{2}\rho v^2 A$ (2) $\rho v^2 A$

(3) $2\rho v^2 A$ (4) $(1/2)\rho v^2 A$

36. 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 $(\rho_1 > \rho_2)$

(1) $\left[2g\left(h_1\rho_1+h_2\rho_2\right)\right]^{1/2}$

(2) $\left[2g\left(h_1+h_2\right)\right]^{1/2}$

(3) $\left[2g\left(h_1+h_2\left(\rho_1/\rho_2\right)\right)\right]^{1/2}$

(4) $\left[2g\left(h_1+h_2\left(\rho_2/\rho_1\right)\right)\right]^{1/2}$

37. A tank has a small hole at its botom of area of cross-section a. Liquid is being poured in the tank at the rate $V\ m^3/s$, the maximum level of liquid in the container will be

(1) $\dfrac{V^2}{2ga^2}$ (2) $\dfrac{V}{ga}$

(3) $\dfrac{V}{2ga}$ (4) $\dfrac{V^2}{ga}$

38. An atomiser is based on the application of
(1) Bernoulli's principle
(2) Torricelli's theorem
(3) Principle of continuity
(4) Archimedes' principle

39. Water flows steadily through a horizontal pipe of variable cross-section. If the pressure of water is p at a point where flow speed is v, the pressure at another point where the flow of speed is $2v$, is (take density of water as ρ)

(1) $p-\dfrac{\rho v^2}{2}$ (2) $p-\dfrac{3\rho v^2}{2}$

(3) $p-\rho v^2$ (4) $p-\dfrac{3\rho v^2}{4}$

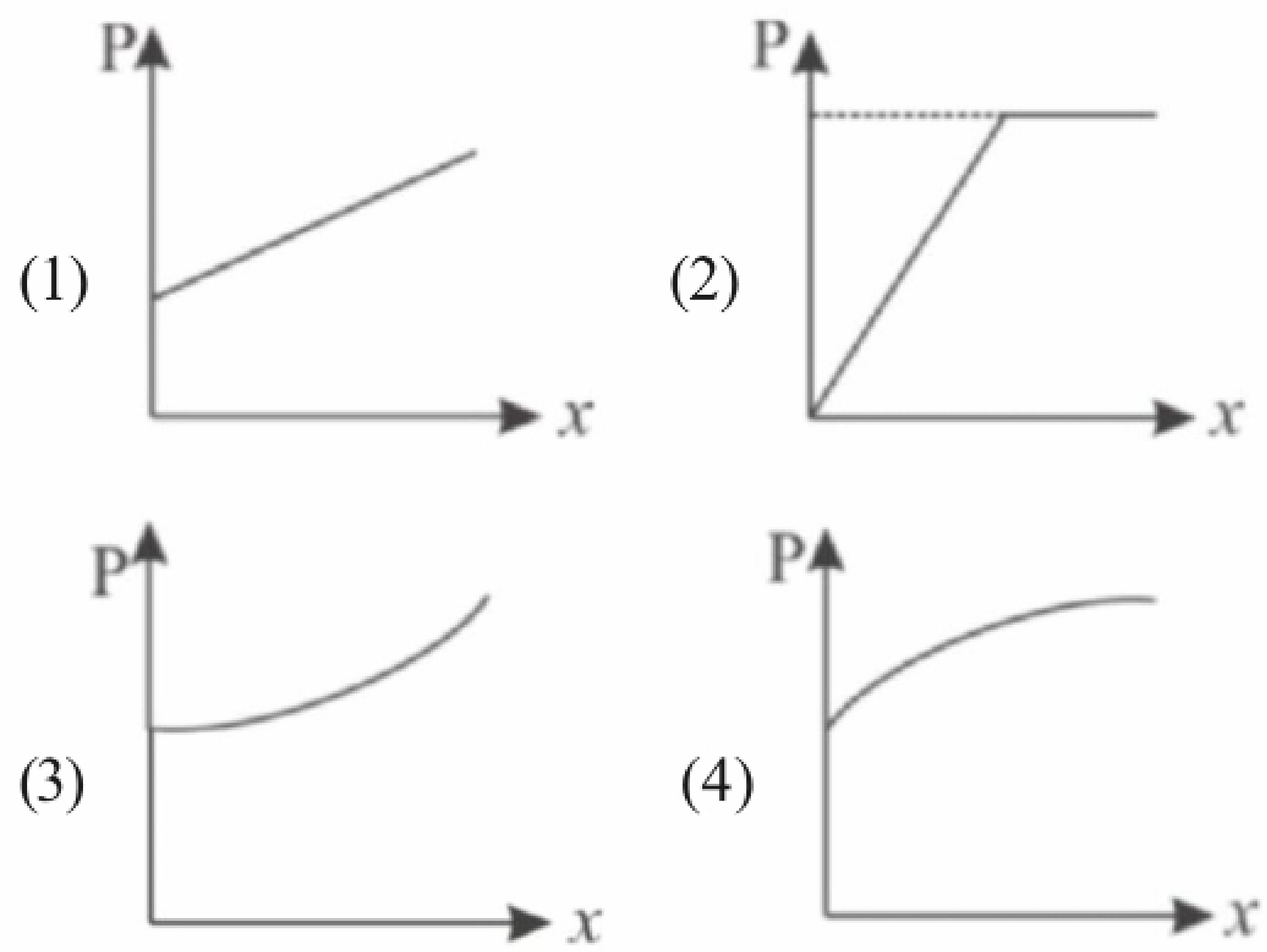
40. A hole is made at the bottom of a tank filled with water (density $=10^3\ kg/m^3$). If the total pressure at the bottom of the tank is 3 atm ($1atm=10^5\ N/m^2$), then the velocity of efflux is

(1) $\sqrt{400}\ m/s$ (2) $\sqrt{200}\ m/s$

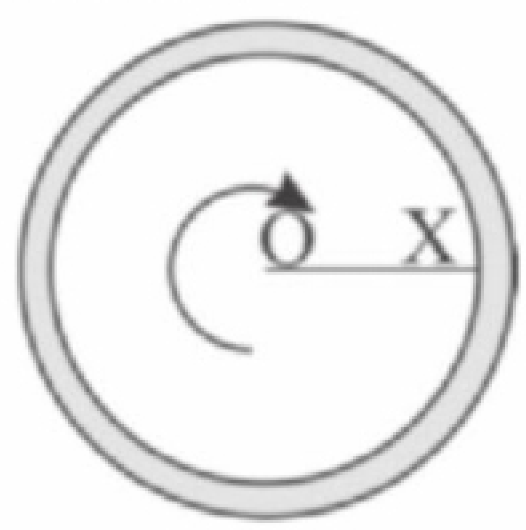
(3) $\sqrt{500}\ m/s$ (4) $\sqrt{600}\ m/s$

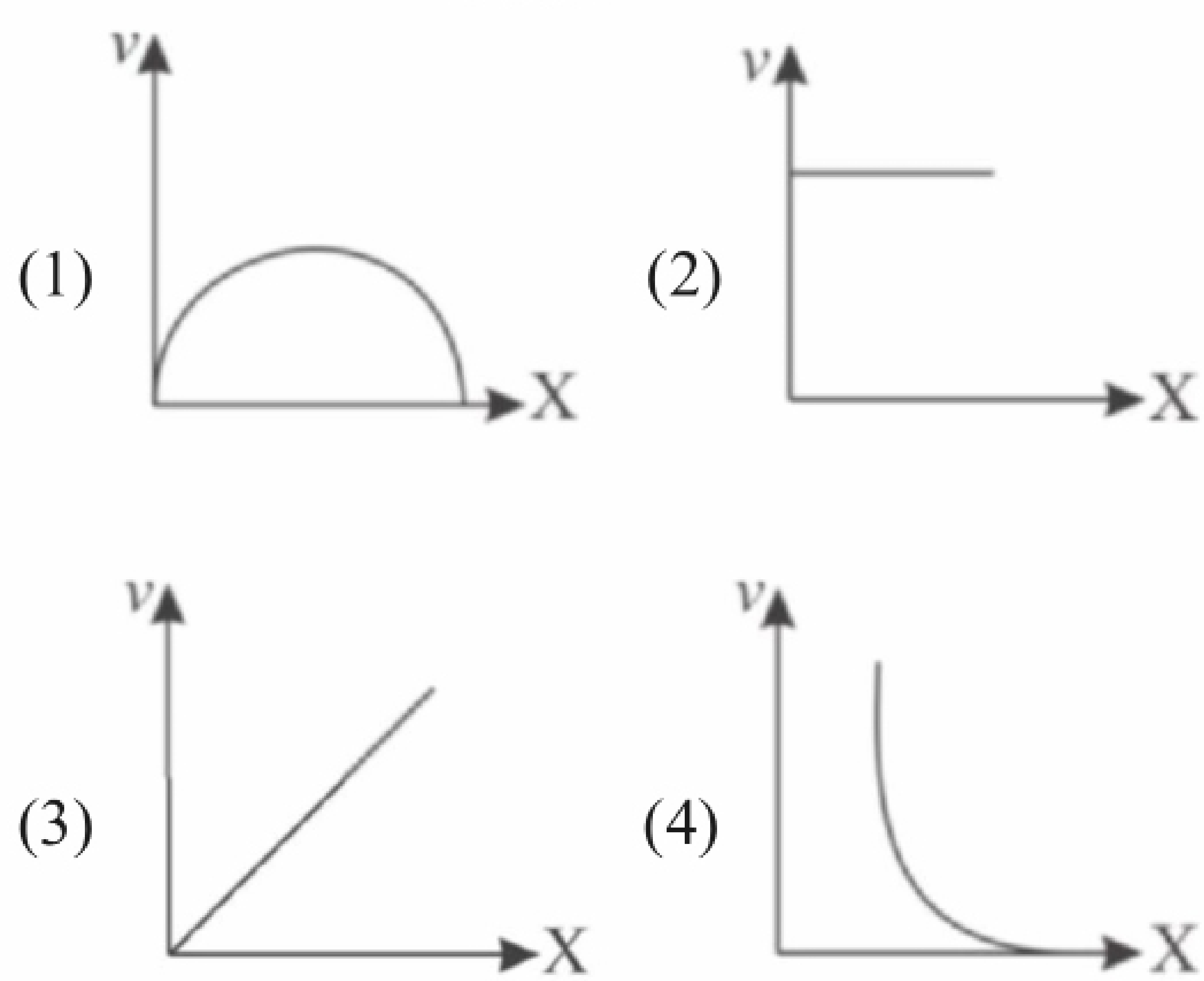
41. Bernoulli's principle is not involved in the working/explanation of
(1) Blades of a kitchen mixer
(2) Movement of spinning ball
(3) Dynamic lift of an aeroplane
(4) Heart attack

42. The cross-sectional area of a horizontal tube increases along its length linearly, as we move in the direction of flow. The variation of pressure, as we move along its length in the direction of flow (x-direction), is best depicted by which of the following graphs?

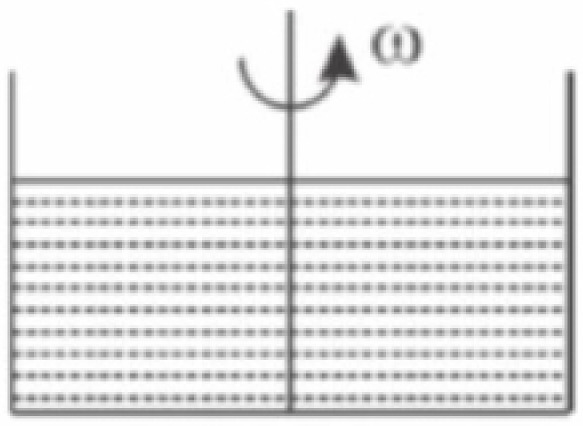


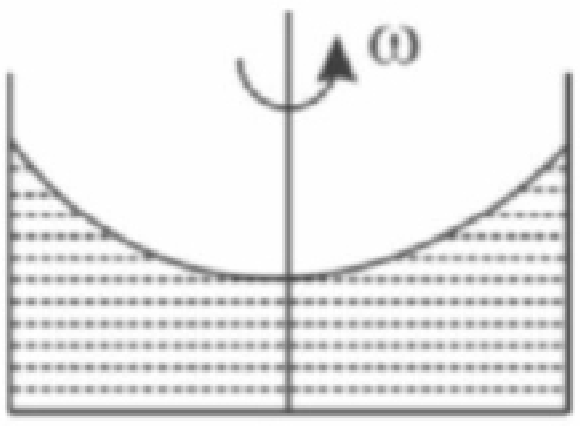
43. The diagram shows a cup of tea seen from above. The tea has been stirred and is now rotating without turbulence. A graph showing the speed v with which the liquid is crossing points at a distance X from O along a radius OX would look like

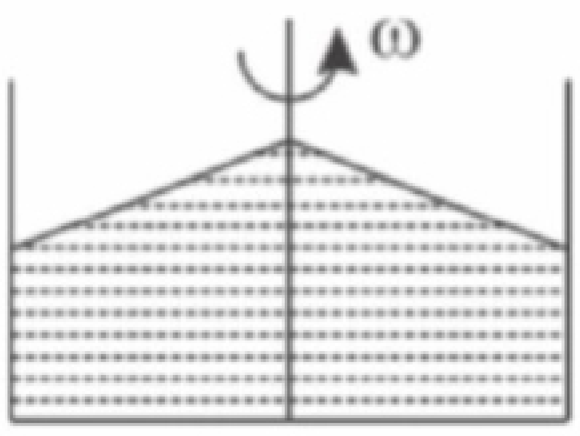


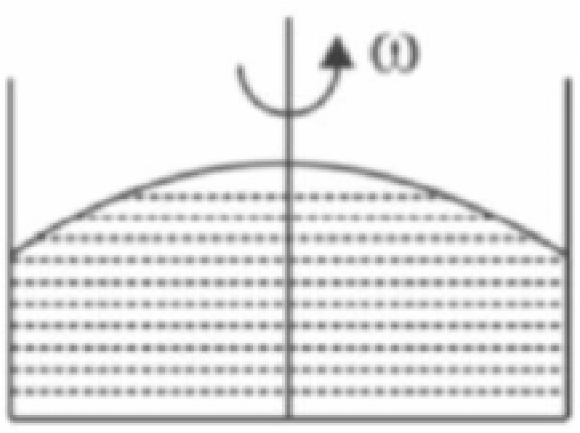


44. A container is filled with non-viscous fluid of density 'ρ'. Initially, the entire system is at rest. Now, the container starts rotating with a constant angular velocity ω about its vertical axis. Choose the appropriate plot from below which depicts the shape of free surface of the fluid after a long time.

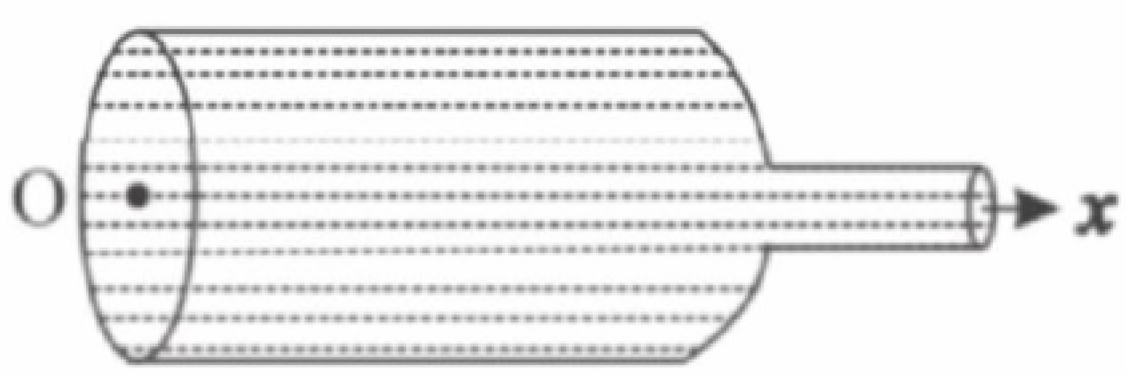
(1)


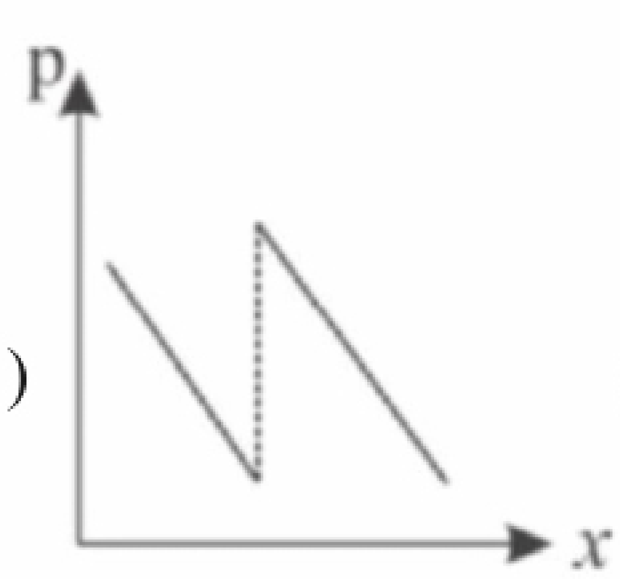
(2)


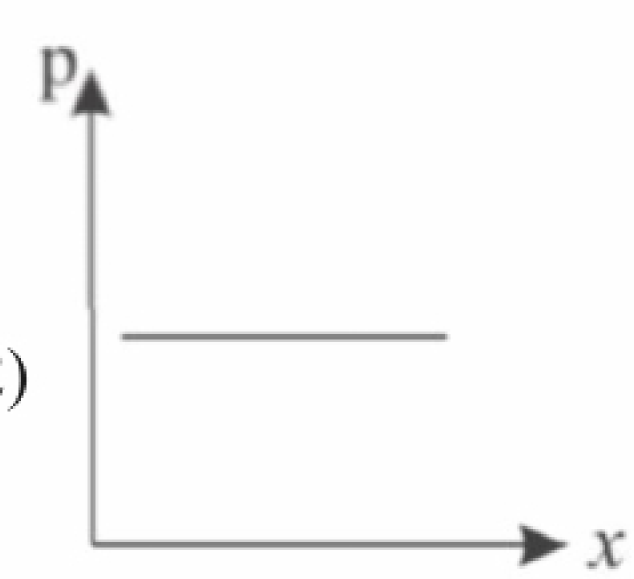
(3)


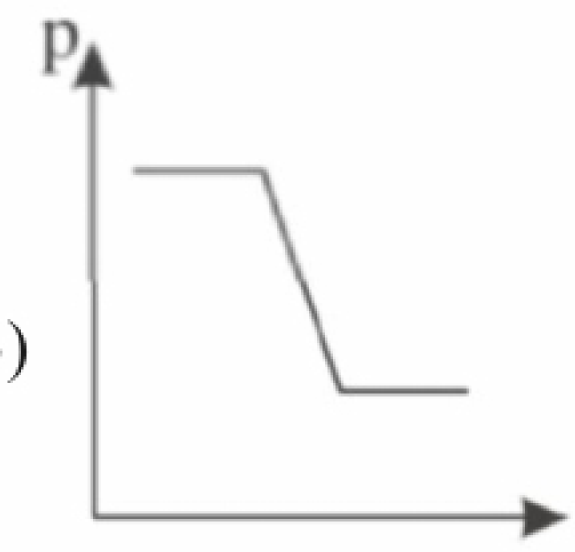
(4)


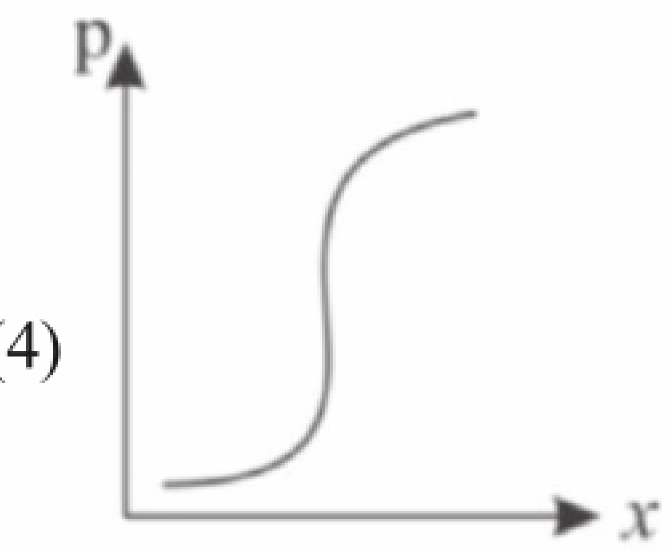
45. A non-viscous liquid is flowing through a frictionless duct, with cross-section varying as shown in figure. Which of the following graph represents the variation of pressure p along the axis of the tube?



(1)


(2)


(3)


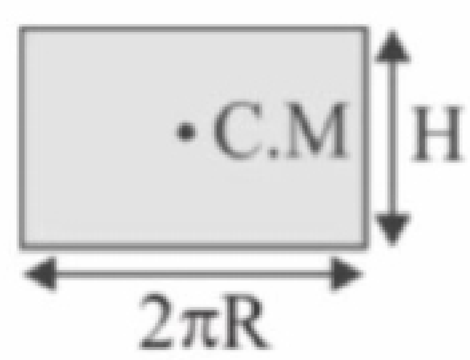
(4)


ANSWER KEY

1. 2	**2.** 2	**3.** 4	**4.** 3	**5.** 4
6. 1	**7.** 4	**8.** 3	**9.** 3	**10.** 2
11. 4	**12.** 4	**13.** 4	**14.** 2	**15.** 2
16. 4	**17.** 1	**18.** 2	**19.** 4	**20.** 1
21. 4	**22.** 1	**23.** 1	**24.** 2	**25.** 4
26. 1	**27.** 2	**28.** 2	**29.** 4	**30.** 4
31. 2	**32.** 3	**33.** 1	**34.** 2	**35.** 4
36. 4	**37.** 1	**38.** 1	**39.** 2	**40.** 1
41. 1	**42.** 4	**43.** 4	**44.** 1	**45.** 3

HINTS & SOLUTIONS

1.Sol: Let R and H be the radius and height of the cylindrical vessel. The average pressure force on a vertical surface is equal to the product of pressure at the C.M and surface area. If we open the cylindrical surface then



$$F = P_{CM}(2\pi RH) = \rho g\left(\frac{H}{2}\right)(2\pi RH)$$

$$F_1 = \rho g H^2 R\pi \qquad (1)$$

The pressure force on the base is

$$F_2 = (\pi R^2)\rho g H \qquad (2)$$

As $F_1 = F_2 \Rightarrow H = R$

2.Sol: Gauge pressure $= h\rho g$

$$h = \frac{H}{2}$$

$\therefore$ Gauge pressure is $\frac{H\rho g}{2}$

3.Sol: $P = h\rho g$ i.e., Pressure does not depend upon the area of bottom surface.

4.Sol: The pressure outside the submarine is

$P = P_o + \rho g h$

Pressure inside the submarine is P_o.

$P_{Net} = \rho g h = 10^3\,kgm^{-3} \times 10ms^{-2} \times 2\times 10^2$

$= 2\times 10^7\,N$

Net pressure acting on the window is

$P_{Net} = \rho g h = 10^3\,kgm^{-3} \times 10ms^{-2} \times 2\times 10^2$

$= 2\times 10^7\,N$

Area of window is

$A = 50cm \times 50cm = 2500\times 10^{-4}\,m^2$

Force on the window is

$F = P_{Net} A = 2\times 10^7\,Pa \times 2500\times 10^{-4}\,m^2$

$= 5\times 10^6\,N$

5.Sol: The dam of water reservoir is made thick at the bottom because the pressure of water is maximum at bottom.

6.Sol: Force acting on the base

$F = P\times A = hdg\ A = 0.4\times 900\times 10\times 2\times 10^{-3}$

$= 7.2N$

7.Sol: $P\times \frac{\pi D^2}{4} = mg \Rightarrow P = \frac{4mg}{\pi D^2}$ pascal

8.Sol: Given that

$V(d-d_1) = m_1$ and $V(d-d_2) = m_2$

Thus, $\frac{d-d_1}{d-d_2} = \frac{m_1}{m_2}$

So, we get $d = \frac{m_1 d_2 - m_2 d_1}{m_1 - m_2}$

9.Sol: A large ship can float but a steel needle sinks, this concept is explanied by Archimedes' Principle.

10.Sol: when the woman is just able to stand on the ice then the weight of the woman and ice will be balanced by buoyancy force.

$45\times 10 + \rho_{ice} Vg = \rho_w Vg$

$\rho_{ice} = 0.92\times 10^3\,kg/m^3$

$\rho_w = 1\times 10^3\,kg/m^3$

$V = \frac{450}{0.08\times 10^3\times 10} = 0.562m^3$

11.Sol: The additional push gives an unbalanced force and according to Newton's first law it will continue to move down and sink.

12.Sol: Upthrust on ball = weight of displaced water

$V_{in} = \frac{40}{0.8}\times 1\times g = 50g$

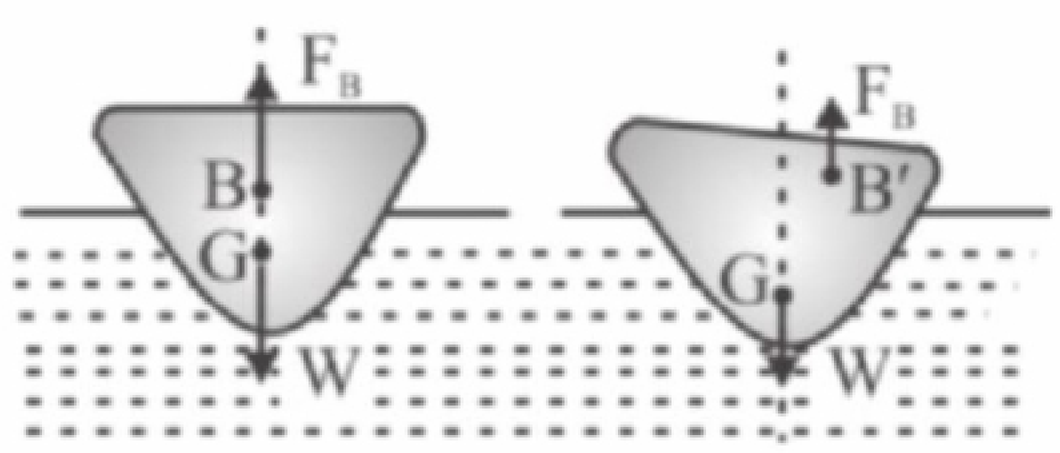
As the ball is sunk into the water with a pin by applying downward force equal to upthrust on it. So reading of weighing pan = weight of water + downward force against upthrust = $600 + 50 = 650$gm

13.Sol: Volume of ice $= \frac{M}{\rho}$

Volume of water $= \frac{M}{\sigma}$

$\therefore$ Change in volume $= \frac{M}{\rho} - \frac{M}{\sigma} = M\left(\frac{1}{\rho} - \frac{1}{\sigma}\right)$

14.Sol: In the tilted position F_B and W produce restoring couple.



15.Sol: Let ρ be the density of the material. ρ_w be the density of water . When the sphere has just started sinking, the weight of the sphere = weight of water displaced.

$\Rightarrow (R^3 - r^3)\rho = R^3\rho_w \Rightarrow \frac{(R^3 - r^3)}{R^3} = \frac{\rho_w}{\rho}$

$\Rightarrow \quad \frac{r}{R} = \frac{(7)^{1/3}}{2}$

16.Sol: $\rho_{mix} = \frac{m_{mix}}{V_{mix}}$

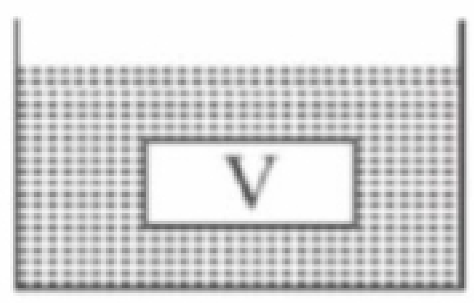
$$m_{mix} = m_1 + m_2\,,\; V_{mix} = \frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}$$

$$\rho_{mix} = \frac{m_1}{s_1\rho_w} + \frac{m_2}{s_2\rho_w}$$

$$\rho_{mix} = \frac{(m_1+m_2)\rho_w}{\left(\frac{m_1}{s_1}+\frac{m_2}{s_2}\right)} = s_{mix}\rho_w$$

$$\Rightarrow s_{mix} = \frac{m_1+m_2}{\frac{m_1}{s_1}+\frac{m_2}{s_2}}$$

17.Sol: $g_{eff.} = 12\,m/s^2\,,\frac{\rho_m}{\rho_w} = \frac{4}{10}$



$$a = \frac{V\rho_w \times 12 - V\rho_m \times 12}{V\rho_m} = 18\,m/s^2$$

$$1m = \frac{1}{2}\times 18t^2, t = \frac{1}{3}s.$$

18.Sol: Sea water is more denser than river water.

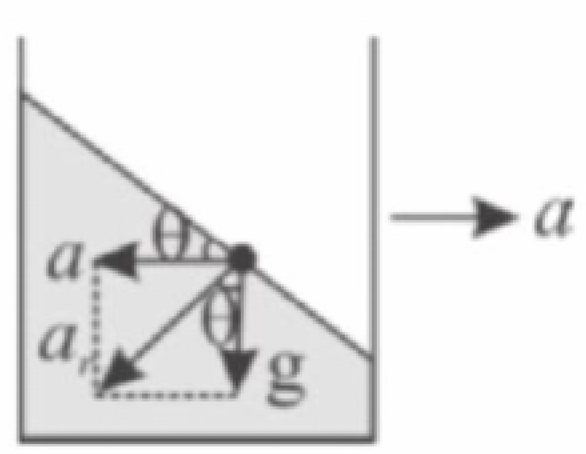
19.Sol: Conceptual

20.Sol: Conceptual

21.Sol: As the vessel is accelerating down then pseudo force acts on the block in the upward direction and hence the spring length increases.

22.Sol: Pressure due to pseudo force causes the rise in level in both the limbs.

23.Sol: As the container accelerates towards right side pseudo force ma acts towards left side.



$$\tan\theta = \frac{a}{g} \Rightarrow \theta = \tan^{-1}\frac{a}{g}$$

24.Sol: Reynold's number is given by

$$R = \frac{v_C\rho D}{\eta}$$

v_C - Critical velocity

D - Diameter of the tube

ρ - Density of the liquid

η - Coefficient of viscosity

If R is small then the motion will be streamlined so η is large & ρ, D & v_C should be small

25.Sol: Conceptual

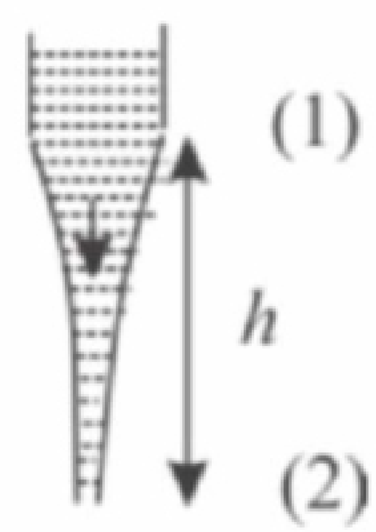
26.Sol: According to equation of continuity

$$A_1v_1 = A_2v_2 + A_3v_3$$

$$\Rightarrow 4\times 0.2 = 2\times 0.2 + 0.4\times v_3 \Rightarrow v_3 = 1\,m/s$$

27.Sol: $v_2^2 = v_1^2 + 2gh$

$$= (0.4)^2 + 2\times 10\times 0.2$$



$$\Rightarrow \quad v_2 = 2.04\,m/s.$$

Again, $\frac{\pi d_2^2}{4}\cdot v_2 = \frac{\pi d_1^2}{4}\times v_1$

$$\Rightarrow d_2 = d_1\cdot\sqrt{\frac{v_1}{v_2}} = 8\times 10^{-3}\times\sqrt{\frac{0.4}{2.04}}\,m$$

$$\Rightarrow d_2 = 3.54\times 10^{-3}\,m \simeq 3.6\times 10^{-3}\,m$$

28.Sol: Equation of continuity expresses the law of conservation of mass.

29.Sol: From continuity equation.

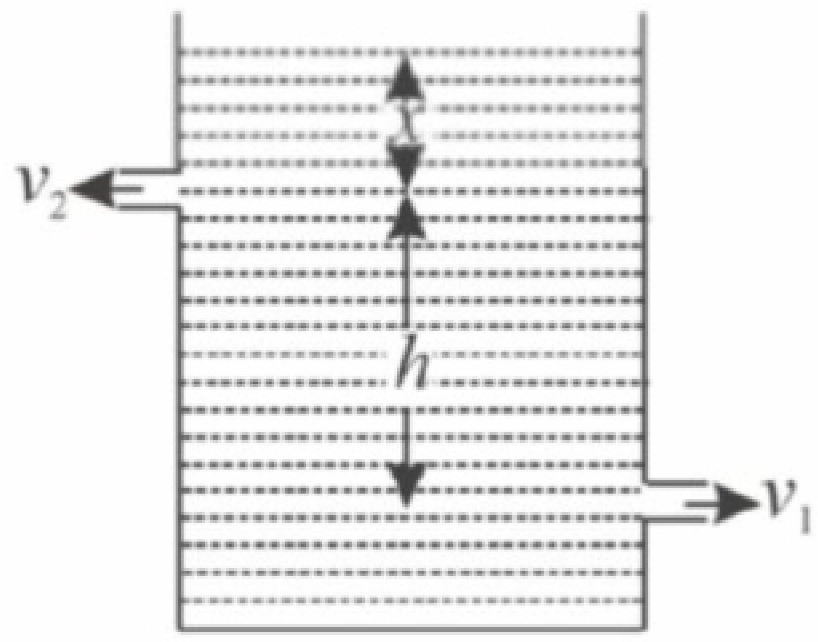
$$A_1v_1 = A_2v_2 \Rightarrow \frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2}$$

$$\Rightarrow v_2 = \frac{r_1^2}{r_2^2}\times v_1 \Rightarrow v_2 = \frac{(2r)^2}{(r)^2}\times v = 4v$$

30.Sol: Here, $v_1 = \sqrt{2g(h+x)}; v_2 = \sqrt{2gx}$

Let, $a =$ area of cross-section of each hole

$\rho =$ density of the liquid



The force exerted on the lower hole towards left $= a\rho v_1^2$

Similarly, the force exerted on the upper hole towards right $= a\rho v_2^2$

Net force on the tank, $F = a\rho\left(v_1^2 - v_2^2\right)$

$$F = a\rho\left[2g(h+x) - 2gx\right] = 2a\rho gh$$

$\Rightarrow F \propto h$

31.Sol: The thrust force exerted by the liquid jet is

$$F = \rho A v^2$$

$\rho = 10^3\, kgm^{-3}, A = 100cm^2,\ v = 1m/s$

$\Rightarrow \quad F = 10N$

32.Sol: Point (1) is on the free surface of water in the supply reservoir and point (2) is just inside the pipe.Applying Bernoulli's equation between (1) and (2),(Taking the reference line at (2))

$$p_1 + \frac{1}{2}\rho(0^2) + \rho gh = p_2 + \frac{1}{2}\rho V_2^2 + \rho g(0)$$

$p_1 = p_2 = p_o$

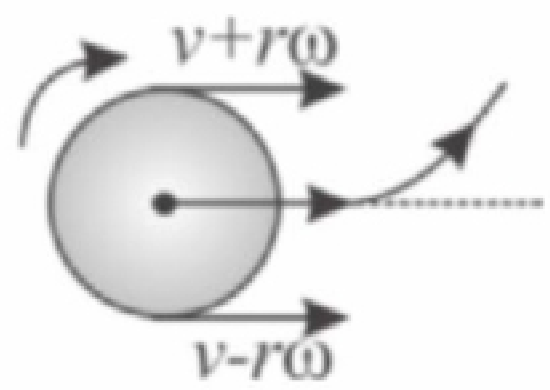
$V_2 = \sqrt{2gh}$

The volume rate of flow through the pipe is $Q = AV_2$

$$A = \frac{\pi d^2}{4} \quad \& \quad V_2 = \sqrt{2gh}$$

$$Q = \pi d^2 \sqrt{\frac{gh}{8}}$$

33.Sol: If a ball is moving from left to right and also spinning about a horizontal axis in clockwise direction which is perpendicular to the direction of motion then relative to the ball air will be moving from right to left.



The resultant velocity of air above the ball will be $(v + r\omega)$ while below it $(v - r\omega)$. So in accordance with Bernoulli's principle, pressure above the ball will be less than below it. Due to this difference of pressure an upward force will act on the ball as shown in the figure.

34.Sol: Equation of continuity

35.Sol: Apply Bernoulli's equation below and above the wing.

$$\frac{1}{2}\rho v_1^2 + P_1 = \frac{1}{2}\rho v_2^2 + P_2\ (h = \text{constant})$$

$$P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$F = \left(P_1 - P_2\right)A = \frac{1}{2}\rho A\left(v_2^2 - v_1^2\right)$$

$$F = \frac{1}{2}\rho A\left(2v^2 - v^2\right) = \frac{1}{2}\rho A v^2$$

36.Sol: Apply the Bernoulli's equation at the free surface and at the position where water comes out.

$$P_o + \frac{1}{2}\rho_1 v_1^2 + 0 = P_o + \frac{1}{2}\rho_2 v_2^2 + \left(\rho_1 g h_1 + \rho_2 g h_2\right)$$

As $v_2 << v_1, \therefore v_1 = \sqrt{2g\left[h_1 + h_2\left(\frac{\rho_2}{\rho_1}\right)\right]}$

37.Sol: Let h be the maximum height. At this point the quantity of water that flows in it is equal to the water that flows out.

$V_{in} = V$ (Given)

$$V_{out} = a\sqrt{2gh} \Rightarrow h = \frac{V^2}{2ga^2}$$

38.Sol: Atomiser is based on Bernoulli's principle.

39.Sol: From Bernoulli's equation,

$$P+\frac{1}{2}\rho v_1^2 = P'+\frac{1}{2}\rho v_2^2$$

Given, $v_2 = 2v, v_1 = v$

$$\therefore P+\frac{1}{2}\rho v^2 = p'+\frac{1}{2}\rho(2v)^2 \Rightarrow p' = p-\frac{3}{2}\rho v^2$$

40.Sol: Total pressure at the bottom $= 3atm$

$\therefore$ Pressure due to water height in the tank

$= 3atm - 1atm = 2atm$

$2\times 10^5 = 10^3 \times 10 \times h \Rightarrow h = 20cm$

So, velocity of efflux

$$= \sqrt{2gh} = \sqrt{2\times 10\times 20} = \sqrt{400}\, m/s$$

41.Sol: Working of blades of a kitchen mixer are not based upon Bernoulli's principle.

42.Sol: From the equation of continuity and Bernoulli's theorem Av = constant

$$\text{p} + \frac{1}{2}\rho v^2 + \rho\text{gh} = \text{constant}$$

When A increases velocity decreases and the pressure increases non linearly.

43.Sol: When we stir the tea the cup is at rest and the particles of the tea which are in contact with the walls of the cup also be at rest. When we move from center to circumference, the velocity of liquid goes on decreasing and finally becomes zero.

44.Sol: As the liquid is non-viscous the rotation of container will not have any effect on the liquid.

45.Sol: According to the equation of continuity, when cross-section of duct decreases, the velocity of flow of liquid increases Av = constant.

From Bernoulli's theorem,

$$\text{p} + \frac{1}{2}\rho v^2 + \rho\text{gh} = \text{constant}$$

Pressure decreases in the tube when the cross-section decreases. So the correct option is (3).

NTSE

MOTION

1. Velocity of vehicle increases from 5m/s to 15 m/s in 5 seconds. What is the magnitude of acceleration? ***(Gujarat)***

(a) 4 m/s (b) 4 m/s

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

2. The increase in velocity of a freely falling body in one second is ***(Gujarat)***

(a) 9.8 m/s ^{2} (b) 9.8 m/s

(c) -9.8 m/s ^{2} (d) -9.8 m/s

3. A cyclist travels 5 km in the east direction. Then he travels 12 km in the south direction. What is the magnitude of displacement of the cycle? ***(Gujarat)***

(a) 17 km (b) 13 km

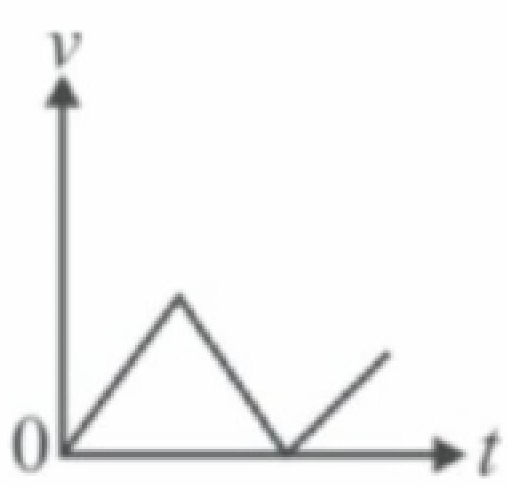
(c) 7 km (d) zero

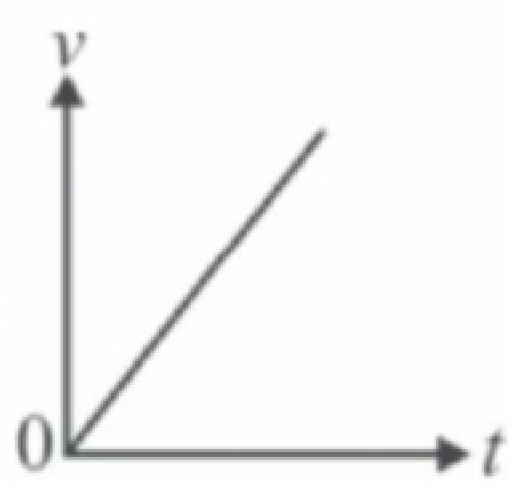
4. From an elevated point A, a stone is projected vertically upwards. When the stone reaches a distance h below A, its velocity is double of what it was at a height h above A. The greatest height attained by the stone is ***(Haryana)***

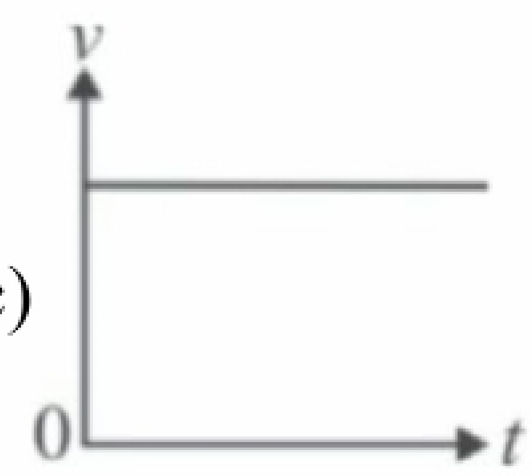
(a) $\frac{h}{3}$ (b) $\frac{2h}{3}$

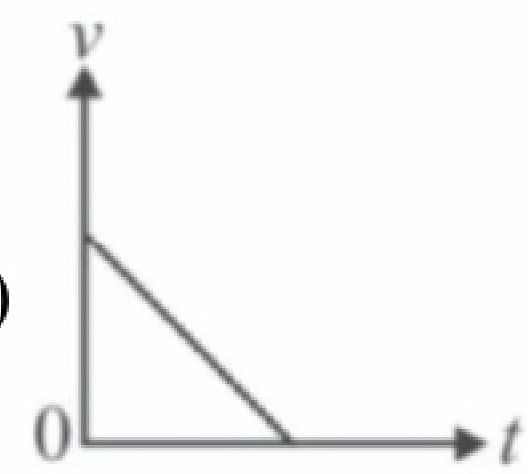
(c) $\frac{5h}{4}$ (d) $\frac{5h}{3}$

5. The velocity-time graph which represents a body moving with zero acceleration is ***(Karnataka)***

(a)


(b)


(c)


(d)


6. A 100 meters long train moving with constant speed of 90 Km/h cross the tunnel of 300 meter long. The time taken by the train crossing the tunnel completely is ***(Karnataka)***

(a) 16 seconds (b) 8 seconds

(c) 4 seconds (d) 2 seconds

7. If initial velocity of an object is u and acceleration is a, then find the distance travelled in nth second. ***(Madhya Pradesh)***

(a) $S_n = un + \frac{an^2}{2}$ (b) $S_n = un + an$

(c) $S_n = u + \frac{a}{2}(2n+1)$ (d) $S_n = \left(u + \frac{a}{2}\right)n^2$

8. If a person goes from town A to town B by a speed of 50 km/h and comes back with a speed of 150 km/h, then average speed of the person is ***(Madhya Pradesh)***

(a) 100 km/h (b) 75 km/h

(c) 0 km/h (d) 200 km/h

9. Distance covered by an object thrown upwards in the last second ***(Maharastra)***

(a) Depends on initial velocity

(b) Depends on mass

(c) Depends on air velocity

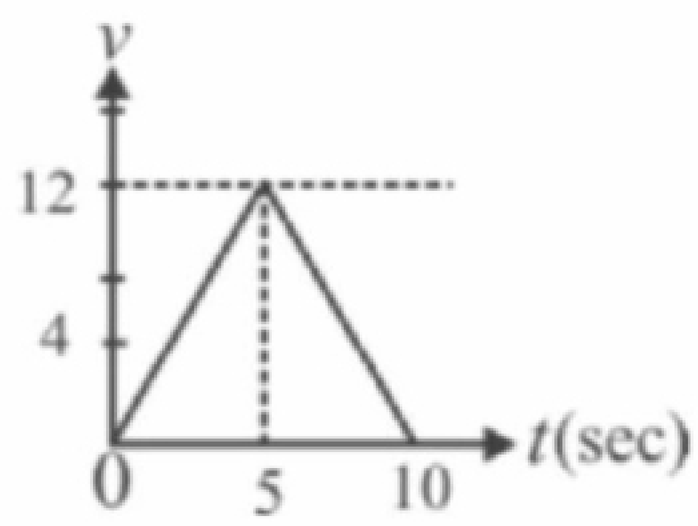
(d) Is always same

10. First half of the distance between two places is coverd by a car at speed of 40km/hr and the second half is coverd at a speed of 80 km/hr. Then what would be the average speed of the car? ***(Odisha)***

(a) 50 km/hr (b) 120 km/hr

(c) 53.3 km/hr (d) 40 km/hr

11. The speed (v) -time t) graph of a body moving along a fixed direction is as shown in the figure. Then how much distance the body must have travelled during time $t = 0$ and $t = 10$ sec? ***(Odisha)***



(a) 120 m (b) 60m

(c) 50 m (d) 10m

12. A ball is released from the top of tower of height h metre. It takes T seconds to reach the ground. What is the position of the ball at T/3 second? ***(Panjab)***

(a) h/9 m from the ground

(b) 7 h/9 m from the ground

(c) 8h/ 9 m from the ground

(d) 17 h/ 9 m from the ground

13. The brakes applied to a car produce an acceleration of 8 m/s^2 in the opposite direction to the motion. If the car takes 3 seconds to stop after the application of brakes, the distance it travels during the time will be ***(Rajasthan)***

(a) 30 m (b) 36 m (c) 25 m (d) 40 m

14. Two cars A and B accelerate in the ratio of $\frac{2}{3}$ their change in velocity is ***(Tamil Nadu)***

(a) 2 : 3 (b) 3 : 2

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

15. Two cars X and Y accelerate at the rate of 1 m/s^2 and 3 m/s^2 respectively from rest . The ratio of time taken by the cars X and Y is 4 : 5 . In that given ratio of time interval if the distance travelled by car X is 100 Km, then the distance travelled by car Y is ***(Tamil Nadu)***

(a) $\frac{187}{8}$ (b) $\frac{375}{2}$

(c) $\frac{1875}{4} km$ (d) $\frac{375}{4} km$

16. A car driver travelling with a uniform velocity of 2 m/s notices a railway level crossing at a distance of 435 m from him. And also he notices to cross the level crossing hence he accelerates his car at the rate of 2 m/s for five seconds. Then he decides to stop the car. So he applies brake and stop the car exactly before the level crossing (Without following the timer).Calculate the minimum rate at which he has to decelerate the car so that he stops the car exactly before the level crossing. ***(Tamil Nadu)***

(a) 1.8 m/s^2 (b) 18 m/s^2

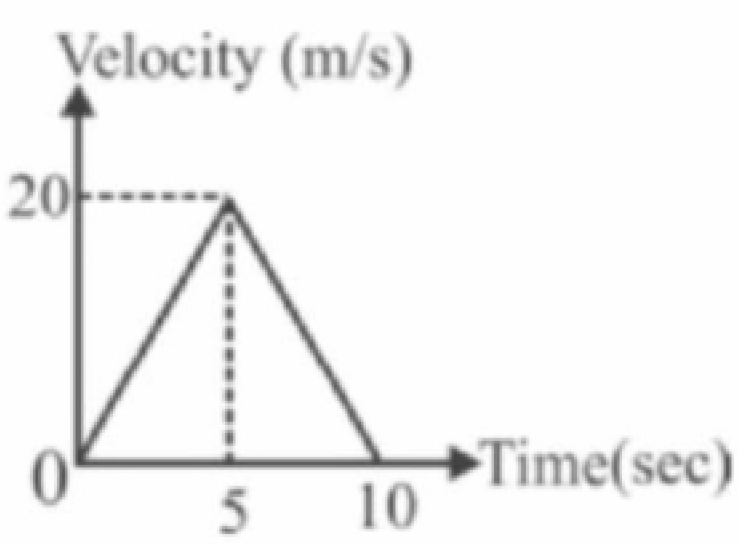
(c) 0.18 m/s^2 (d) 3.6 m/s^2

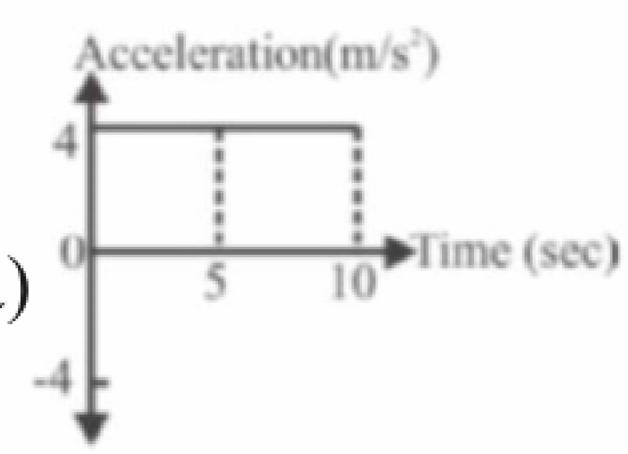
17. Two flies A and B revolve around concentric circular path s. The radius of cricular path of A is twice of B. A travels with a unifrom linear speed of 4 m/s while B travels with a uniform linear speed of 3 m/s. When A completes three full round s then B would have completed ***(Tamil Nadu)***

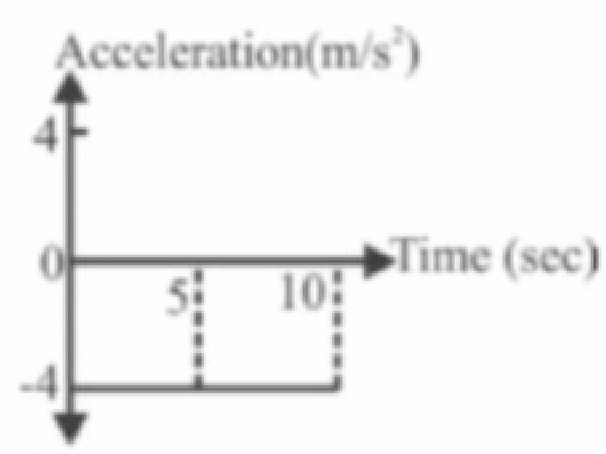
(a) 4 rounds (b) 3 rounds

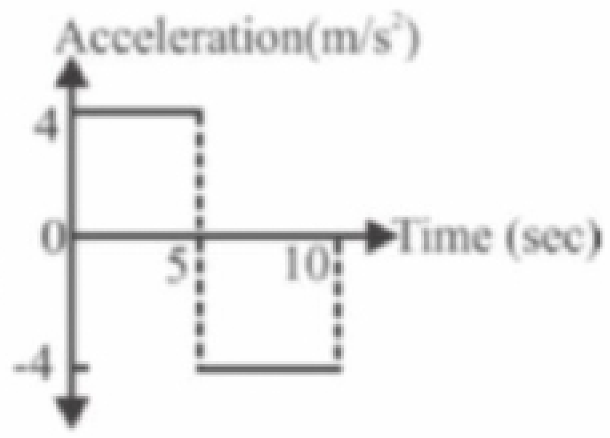
(c) 2 rounds (d) 1 round

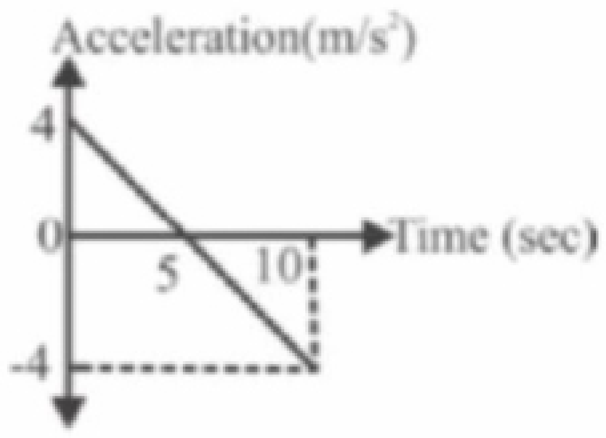
18. If the under ggiven velocity vs time graph can be changed into acceleration vs time graph, then which one of the given potions represents acceleration vs time graph? ***(Tamil Nadu)***



(a) 

(b) 

(c) 

(d) 

19. A boy travels along a circular path of radius rm. When his angular displacements is $\frac{\pi}{3}$ radians then his linear displacement is ***(Tamil Nadu)***

(a) $r\sqrt{2m}$ (b) $r\ m$

(c) $2\sqrt{r\ m}$ (d) $\frac{\pi r}{3} m$

20. From a tower of height 20 m a boy throws a stone in the vertically upward direction with a velocity of 40 m/s and at the same time a girl drops another identical stone from the same tower. When the momentum of the stone dropped by the gril is maximum what will be displacement of the stone projected the upward direction from the top of the tower? (Take acceleration due to gravity of earth as 10 m/s ^{2}) ***(Tamil Nadu)***

(a) 60 m (b) 40 m

(c) 20 m (d) 0 m

ANSWER KEY

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

HINTS & SOLUTIONS

1.Sol:

Here, Initial velocity, $u = 5\,m/s$ Final velocity is $v = 15\,m/s$; Time, $\Delta t = 5\,s$

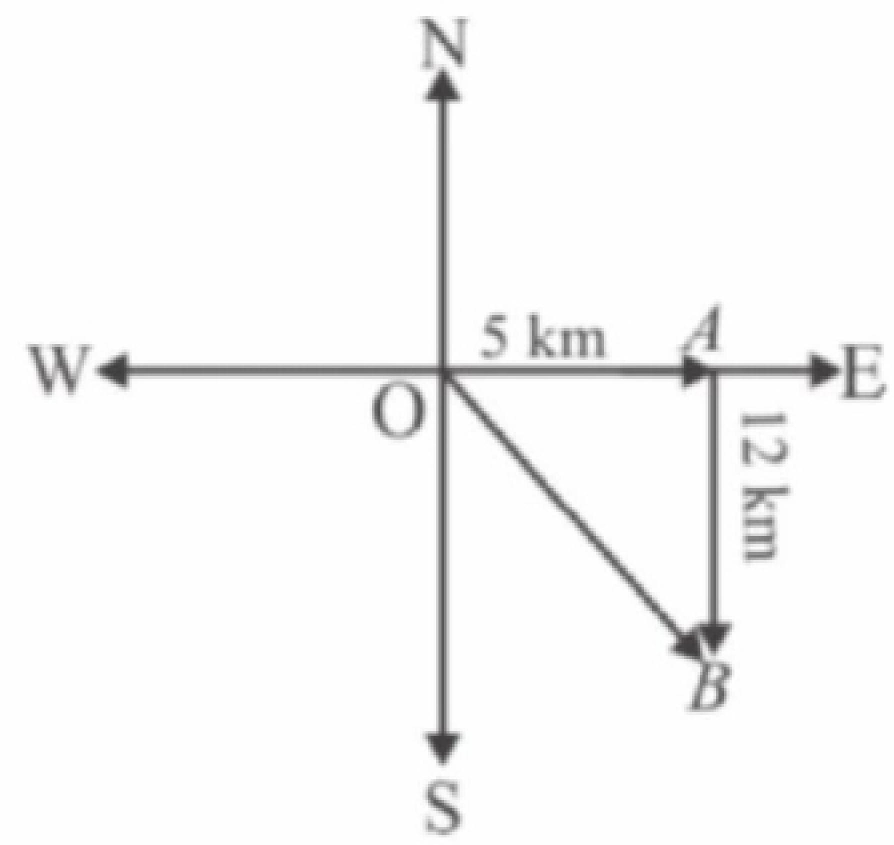
The acceleration is

$$a = \frac{v-u}{\Delta t} = \frac{15\,m/s - 5\,m/s}{5\,s} = 2\,m/s^2$$

Thus, the magnitude of acceleration is 2 m/s

2.Sol: When a body falls freely, it is moving under gravity. Because of gravitational acceleration velocity of falling body increases with a constant rate of $9.8\,m/s^2$ i.e., velocity of freely falling body increases by $9.8\,m/s$ in one second.

3.Sol: The situation is shown in the figure where O represent the starting point. As O is the initial position and B is the final position, so the magnitude of of the displacement of the cycle is

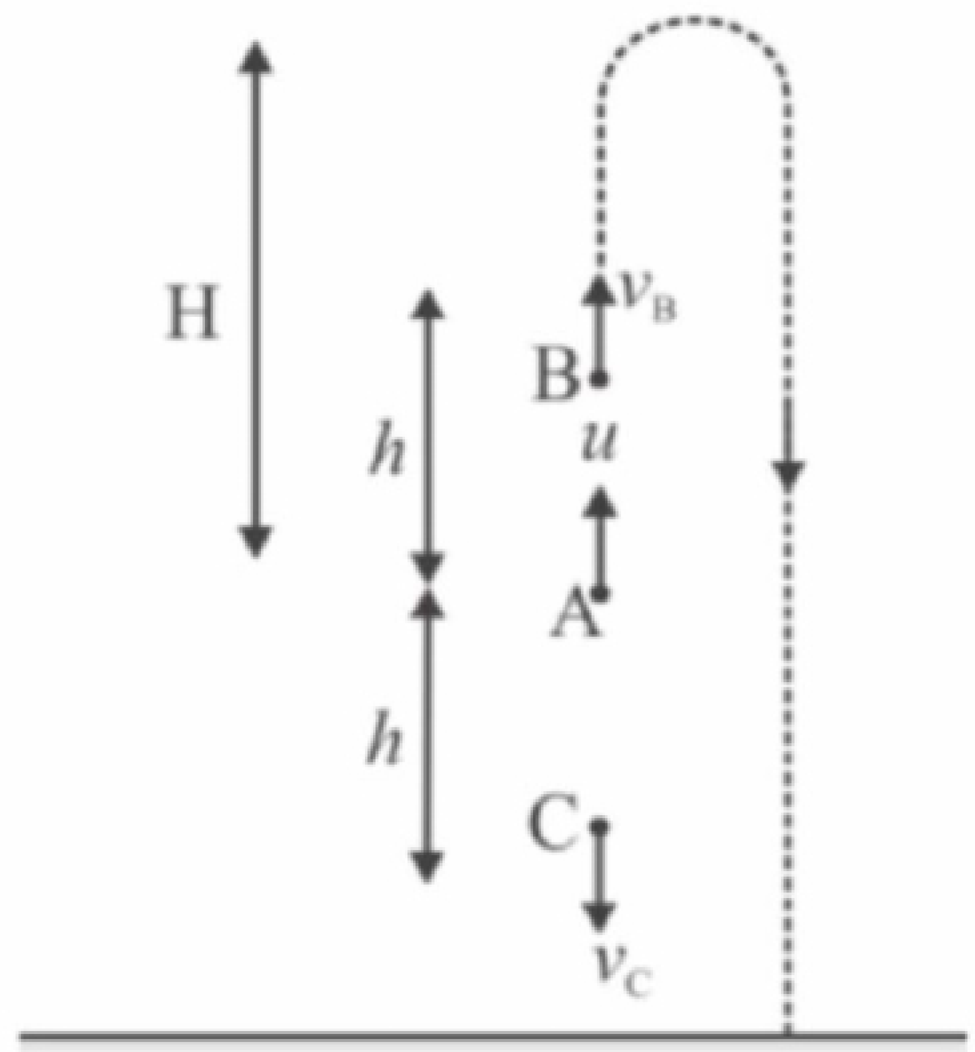


$$OB = \sqrt{OA^2 + AB^2} = \sqrt{(5\,km)^2 + (12\,km)^2}$$

$$= 13\,km$$

4.Sol: Let the stone be projected vertically upwards with velocity u from an elevated point A (i.e.,. above the level of the ground) as shown in the figure.

Let the velocities of the stone at the height h above A (i,e., at the point B) and at a distance h below A (i.e., at point C) be v_B and v_C respectively. Then



$$v_B^2 = u^2 + 2(-g)h = u^2 - 2gh$$

and $v_C^2 = u^2 + 2gh$

But according to the question $v_C = 2v_B$

$$\therefore \sqrt{u^2 + 2gh} = 2(\sqrt{u^2 - 2gh})$$

or $\quad u^2 + 2gh = 4(u^2 - 2gh)$

$$\Rightarrow \quad u^2 = \frac{10gh}{3}$$

The greatest height attained by the stone is

$$H = \frac{u^2}{2g} = \frac{10gh}{6g} = \frac{5h}{3}$$

5.Sol: Graph (c) represents a body moving with zero acceleration because velocity is constant for zero acceleration.

6.Sol: Total distance travelled by the train is

s = length of the train + length of the tunnel

= 100 m + 300 m = 400 m

Speed of the train is

$$v = 90km/h = \frac{90 \times 1000}{60 \times 60} m/s = 25m/s$$

$$t = \frac{s}{v} = \frac{400\,m}{25\,m/s} = 16s$$

7.Sol: Let s_n and s_{n-1} be the distance travelled in n seconds and (n-1) seconds respectively.

Distance travelled in n^{th} term second is

$$S_n = s_n - s_{n-1} \qquad \text{........(1)}$$

As distance travelled in t seconds is given by

$$s = ut + \frac{1}{2}at^2$$

$$\therefore \quad s_n = un + \frac{1}{2}an^2$$

and $\quad s_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$

Substituting these values in eqn.(1) ,We get

$$S_n = \left[un + \frac{1}{2}an^2\right] - \left[u(n-1) + \frac{1}{2}a(n-1)^2\right]$$

$$= \left[un + \frac{1}{2}an^2\right] - \left[un - u + \frac{1}{2}a(n^2 + 1 - 2n)\right]$$

$$= u - \frac{a}{2} + an = u + \frac{a}{2}(2n-1)$$

* None of the given options is correct

8.Sol: Let the distance between town A and town B be d km. Then time taken by the person to go from town A to B with a speed of 50 km/h is

$$t_1 = \frac{d\,km}{50\,km/h} = \frac{d}{50}h$$

and time taken to come back to town A from town B

$$t_2 = \frac{d\,km}{150\,km/h} = \frac{d}{150}h$$

$\therefore$ Total time taken is

$$t = t_1 + t_2 = \frac{d}{50}h + \frac{d}{150}h = \frac{4d}{150}h$$

Total distance travelled is

$$s = d\,km + d\,km = 2d\,km$$

The average speed of the person is

$$v_{av} = \frac{s}{t} = \frac{300}{4}km/h = 75km/h$$

Aliter: $v_{av} = \frac{2v_1v_2}{v_1 + v_2} = \frac{2(50km/h)(150km/h)}{50km/h + 150km/h}$

$$= \frac{2 \times 50 \times 150}{200}km/h = 75km/h$$

9.Sol: Let the object be thrown upwards with velocity u and let it take n seconds to reach the highest point. Then

$$v = u - gn$$

But at the highest point $v = 0$

$$\therefore \quad 0 = u - gn \Rightarrow u = gn$$

$\therefore$ Distance covered in the last second is

$$S = s_n - s_{n-1}$$

$$= \left[un - \frac{1}{2}gn^2\right] - \left[u(n-1) - \frac{1}{2}g(n-1)^2\right]$$

$$=\left[un-\frac{1}{2}gn^2\right]-\left[un-u-\frac{1}{2}g(n^2+1-2n)\right]$$

$$=u+\frac{g}{2}-gn$$

Substituting the value of u from eqn. (i) , we get

$$S=gn+\frac{g}{2}-gn=\frac{g}{2}$$

Thus, from the above expression it is clear that distance coverd by an object thrown upwards in the last second is always same.

10.Sol: Let the distance between two places be d km. Time taken by the car to cover first half at a speed at 40 km/ hr is

$$t_1=\frac{d/2\,km}{40\,km/hr}=\frac{d}{80}hr$$

and time taken to cover second half at a speed of 80 km/ hr is

$$t_2=\frac{s/2\,km\;80\,km/hr}{80km/hr}=\frac{s}{160}hr$$

$\therefore$ Total time taken

$$=t_1+t_2=\frac{s}{80}hr+\frac{s}{160}hr==\frac{3s}{160}hr$$

The average speed of the car is

$$v_{av}=\frac{\text{total distance travelled}}{\text{total time taken}}=\frac{s\,km}{\frac{3s}{160}hr}$$

$$=\frac{160}{3}km/hr=53.3km/hr$$

Aliter: $$v_{av}=\frac{2v_1v_2}{v_1+v_2}=\frac{2(40km/hr)(80km/hr)}{40km/hr+80km/hr}$$

$$=\frac{6400}{120}km/hr=53.3km/hr$$

11.Sol: Distance travelled by the body during $t=0$ to $t=10\,s$ is

$$S=\text{area under v-t graph }=\frac{1}{2}(10s)(12\,m/s)$$
$$=60m$$

12.Sol: As the ball takes T second to reach the ground, the height of the tower is

$$h=\frac{1}{2}gT^2 \qquad (as\ u=0)$$

Distance coverd by the bsll in T/3 Seconds is

$$h'=\frac{1}{2}g\left(\frac{T}{3}\right)^2=\frac{1}{2}\left(\frac{1}{9}gT^2\right)$$

$$\therefore \frac{h'}{h}=\frac{\frac{1}{2}\left(\frac{1}{9}gT^2\right)}{\frac{1}{2}gT^2}=\frac{1}{9} \quad \text{or} \quad h'=\frac{h}{9}$$

But this height h' is calculated from the top of the tower.

$\therefore$ Position of the ball at T/3 second from the ground

$$=h-h'=h-\frac{h}{9}=\frac{8h}{9}m$$

13.Sol: Acceleration, $a=-8\ m/s^2$ (a is taken to be negative as it is opposite to the direction of motion)

As $\quad v=u+at$

$\therefore \quad 0=u+(-8m/s^2)(3s)$ or

$\Rightarrow \quad u=24\,m/s$

Let the distance travelled by the car before it stops be d_s. Then using the relation

$s=ut+\frac{1}{2}at^2$, we get

$$d_s=(24m/s)(3s)+\frac{1}{2}(-8m/s^2)(3s)^2$$
$$=72\,m-36\,m=36\,m$$

14.Sol: As acceleration $=\dfrac{\text{change in velocity}}{\text{time taken}}$

$\Rightarrow \quad \Delta v=at$

For car A, $\Delta v_A=a_At_A$

For car B, $\Delta v_B=a_Bt_b$

Thus, $\quad \dfrac{\Delta v_A}{\Delta v_B}=\dfrac{a_At_A}{a_Bt_B}$

But according to the question $\frac{a_A}{a_B} = \frac{2}{3}$ and

$$t_A = t_B$$

$$\therefore \quad \frac{\Delta v_A}{\Delta v_B} = \frac{2}{3}$$

15.Sol: Since both cars X and Y accelerate rest, theri initial velocities must be zero.

$i.e., u = 0$

$$\text{As } s = ut + \frac{1}{2}at^2$$

$\therefore$ Distance travelled by car X is

$$s_X = u_X t_X + \frac{1}{2}a_X t_X^2 = \frac{1}{2}a_X t_X^2$$

and distance travelled by car Y is

$$s_Y = u_Y t_Y + \frac{1}{2}a_Y t_Y^2 = \frac{1}{2}a_Y t_Y^2$$

$$\text{Thus, } \frac{s_X}{s_Y} = \frac{\frac{1}{2}a_X t_X^2}{\frac{1}{2}a_Y t_Y^2} = \left(\frac{a_X}{a_Y}\right)\left(\frac{t_X}{t_Y}\right)^2$$

But according to the problem

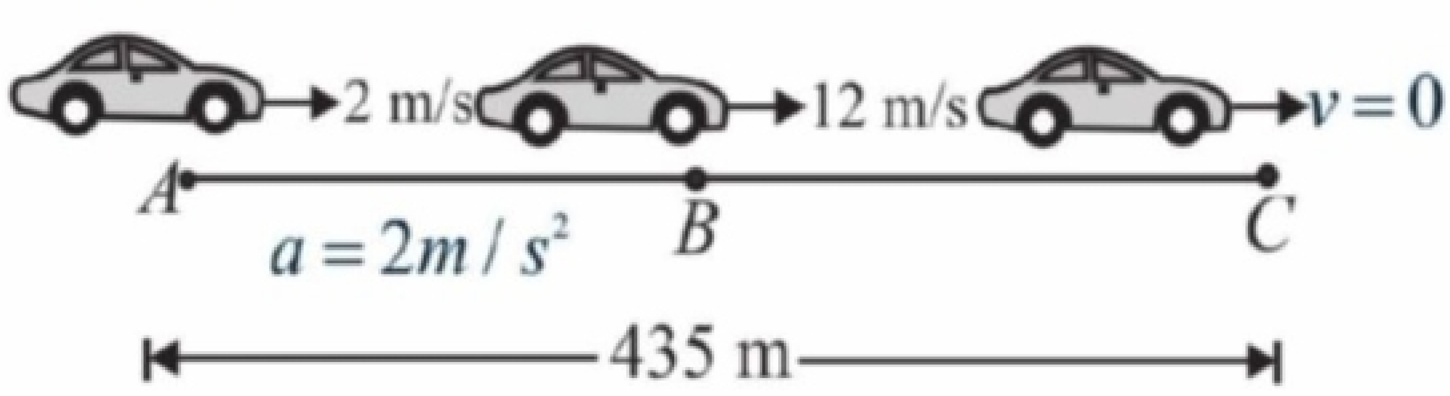
$$a_X = 2m/s^2, a_Y = 3m/s^2, \frac{t_X}{t_Y} = \frac{4}{5} \text{ and}$$

$$s_x = 100\,km$$

$$\therefore \quad \frac{100km}{s_Y} = \left(\frac{2}{3}\right)\left(\frac{4}{5}\right)^2$$

$$\Rightarrow \quad s_Y = \frac{7500}{32}km = \frac{1875}{8}km$$

16.Sol: The situation is shown in the figure.



Suppose at A the car driver travelling with 2 m/s notices the railway level crossing represented by C at m from, him and accelerates his at m/s² for 5 s and B he applies brake For the motion of the car from A to B, velocity of the car after 5 s (*i.e., AB*) is

$$s = ut + \frac{1}{2}at^2$$

$$= (2m/s)(5s) + \frac{1}{2}(2m/s^2)(5s)^2 = 35m$$

For the motion of the car from B to C,

$$u = 12m/s, v = 0, s = 400m$$

As

$$v^2 - u^2 = 2as \quad \therefore 0^2 - (12m/s)^2 = 2a(400m)$$

or

$$a = \frac{-(12m/s)^2}{800} = \frac{-144}{800}m/s^2 = -0.18m/s^2$$

Thus, the minimum rate at which he has to decelerate the car is $0.18m/s^2$.

17.Sol: Let B complete n rounds when A completes three full rounds. If r_A and r_B are the radius of circular paths of A and B respectively and v_A and v_B their respective uniform linear speeds, then time taken by A to complete three full rounds is $t_A = \frac{3(2\pi r_A)}{v_A}$ and time taken by B to complete n round is

$$t_A = \frac{n(2\pi r_B)}{v_B}$$

As $t_A = t_B$

$$\therefore \frac{3(2\pi r_A)}{v_A} = \frac{n(2\pi r_B)}{v_B} \Rightarrow n = 3\left(\frac{r_A}{r_B}\right)\left(\frac{v_B}{v_A}\right)$$

But according to the question

$r_A = 2r_B, v_A = 4m/s$ and $v_B = 3m/s$

$$\therefore n = 3\left(\frac{2r_B}{r_B}\right)\left(\frac{3m/s}{4m/s}\right) = 4\cdot 5$$

Thus, B would have completed 4 rounds.

18.Sol: As acceleration is slope of velocity vs time graph , So

From $t = 0$ to $t = 5s$

$$a = \frac{(20-0)m/s}{(5-0)s} = 4m/s^2$$

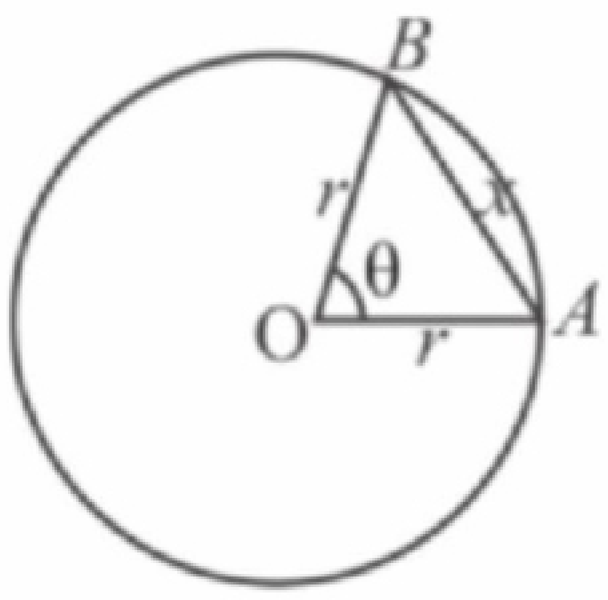
From $t = 10$ to $t = 5$

Thus, option (c) represents acceleration vs time graph.

19.Sol: Let O be the centre of circular path

$$OA = OB = r$$

AB will be his linear displacement.



By cosine formula,

$$x^2 = r^2 + r^2 - 2(r)(r)\cos\theta = 2r^2 - 2r^2\cos\theta$$

$$x^2 = 2r^2(1-\cos\theta) = 4r^2\sin^2\left(\frac{\theta}{2}\right)$$

$$\Rightarrow \quad x = 2r\sin\frac{\theta}{2}$$

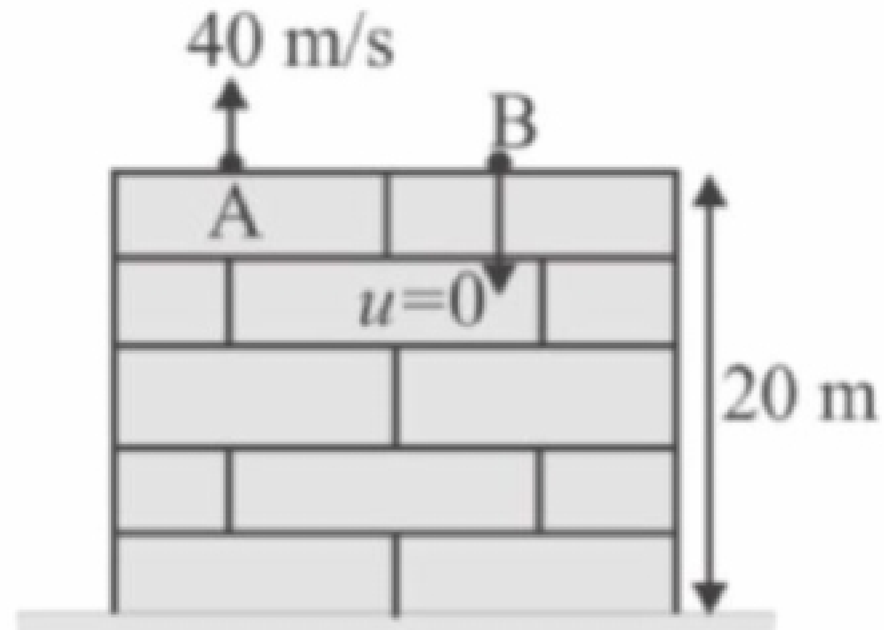
But according to the question

$$\theta = \frac{\pi}{3} \text{ radians } = \frac{180^\circ}{3} = 60^\circ$$

$$\therefore x = 2r\sin 30^\circ = 2r\left(\frac{1}{2}\right) = r\,m$$

Thus, his linear displacement is r m.

20.Sol: Let us denote the boy throwing the stone vertically upwards from the top of the tower as A and the girl dropping the stone from the same tower as B as shown in the figure.



For the stone dropped by B.

$$u = 0, a = g = 10m/s^2,$$

$$s = h = 20m$$

As $s = ut + \frac{1}{2}at^2 \quad \therefore h = 0\times t + \frac{1}{2}gt^2 = \frac{1}{2}gt^2$

or $t = \sqrt{\frac{2h}{g}}$

The momentum of the stone dropped by B to reach the ground is it reaches the ground.

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(20m)}{10m/s^2}} = 2s$$

For the stone thrown by $A, u = 40m/s,$

$$a - g = -10m/s^2$$

Distance covered by the stone thrown by A in 2 s is

$$s = ut + \frac{1}{2}at^2 = (40m/s)(2s) + \frac{1}{2}(-10m/s^2)(2s^2)$$

$$= 80m - 20m = 60m$$

Thus, the displacement of the stone thrown by A from the top of the tower is 60 m.

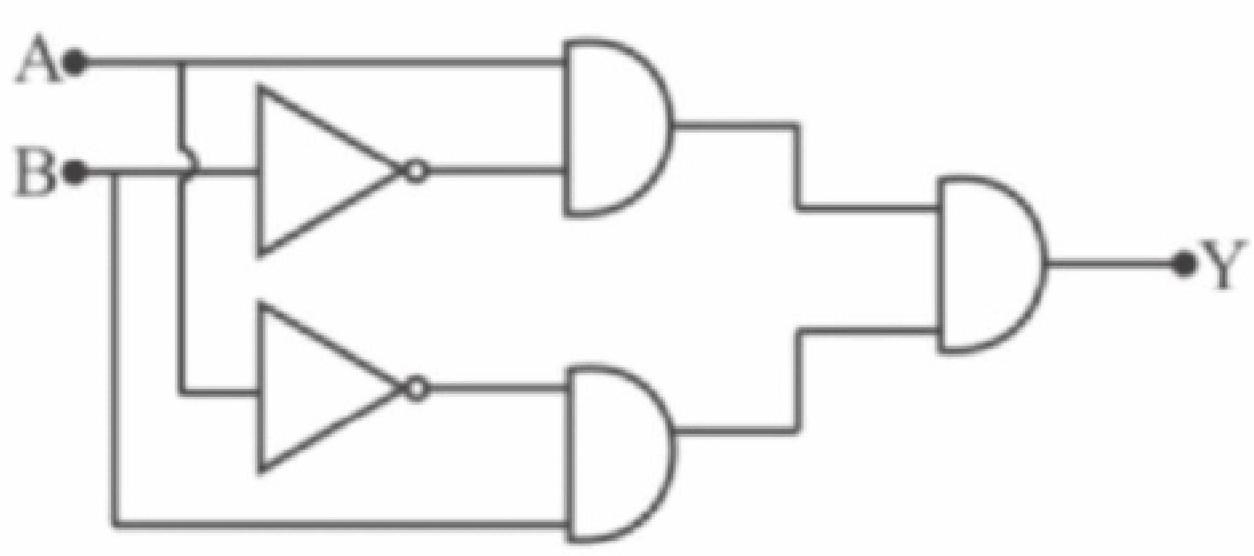
Previous years NEET/AIPMT Questions

SEMICONDUCTORS

1. In the circuit shown in the figure, the input voltage V_i is 20 V, $V_{BE} = 0$ and $V_{CE} = 0$. The values of I_B, I_C and β are given by **[2018]**
   (a) $I_B = 20\mu A, I_C = 5mA, \beta = 250$
   (b) $I_B = 40\mu A, I_C = 5mA, \beta = 125$
   (c) $I_B = 25\mu A, I_C = 5mA, \beta = 200$
   (d) $I_B = 40\mu A, I_C = 10mA, \beta = 250$

2. In a p-n junction diode, change in temperature due to heating **[2018]**
   (a) Does not affect resistance of p-n junction
   (b) Affects the overall V - I characteristics of p-n junction
   (c) Affects only forward resistance
   (d) Affects only reverse resistance

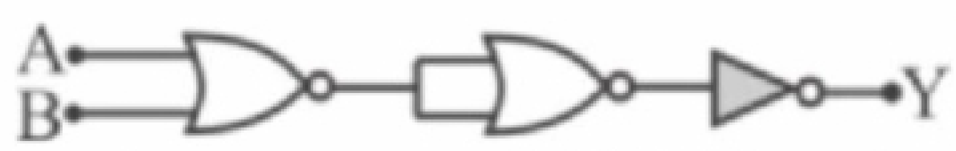
3. In the combination of the following gates the output Y can be written in terms of inputs A and B as **[2018]**



   (a) $\overline{A \cdot B} + A \cdot B$ (b) $\overline{A + B}$
   (c) $A \cdot \overline{B} + \overline{A} \cdot B$ (d) $\overline{A \cdot B}$

4. In a common emitter transistor amplifier the audio signal voltage across the collector is 3V. The resistance of collector is $3k\Omega$. If current gain is 100 and the base resistance of $2k\Omega$, voltage and power gain of the amplifier : **[2017]**
   (a) 15 and 200 (b) 150 and 15000
   (c) 20 and 2000 (d) 200 and 1000

5. The given electrical network is equivalent to: **[2017]**



   (a) OR gate (b) NOR gate
   (c) NOT gate (d) AND gate

6. Which one of the following represents forward bias diode? **[2017]**

   (a) 

   (b) 

   (c) 

   (d) 

7. Consider the junction diode as ideal. The value of current flowing through AB is: **[2016]**

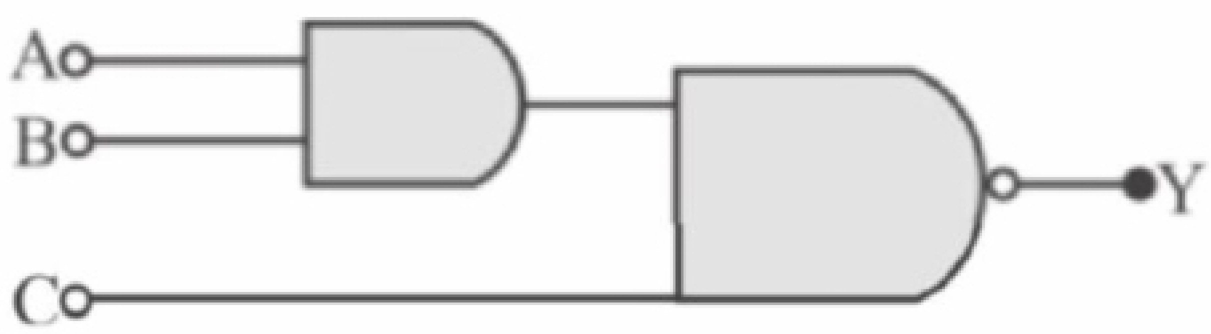
   (a) 0 A (b) $10^{-2} A$

(c) $10^{-1} A$ (d) $10^{-3} A$

8. A npn transistor is connected in common emitter configuration in a given amplifier. A load resistance of $800\,\Omega$ is connected in the collector circuit and the voltage drop across it is 0.8 V. If the current amplification factor is 0.96 and the input resistance of the circuit is $192\,\Omega$, the voltage gain and the power gain of the amplifier will respectively be **[2016]**

(a) 4, 3.84 (b) 3.69, 3.84
(b) 4, 4 (d) 4, 3.69

9. To get output 1 for the following circuit, the correct choice for the input is: **[2016]**

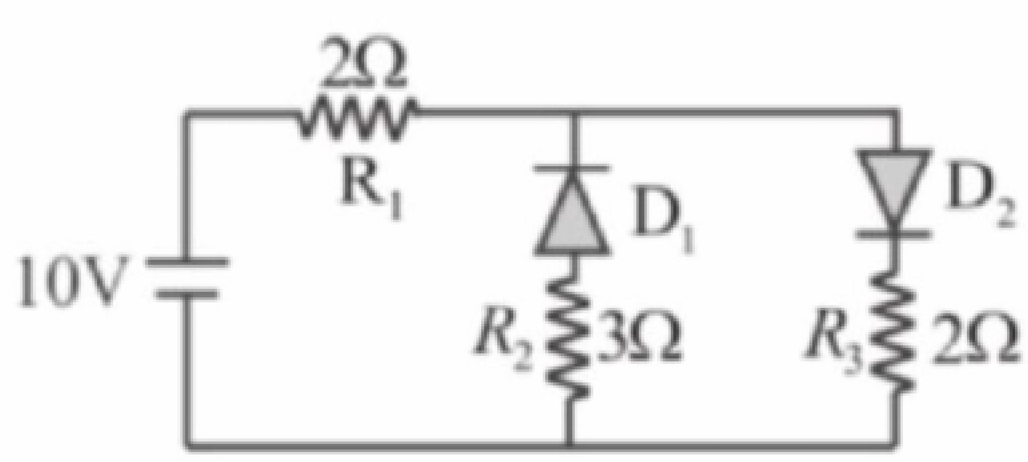


(a) A = 0, B = 1, C = 0
(b) A = 1, B = 0, C = 0
(c) A = 1, B = 1, C = 0
(d) A = 1, B = 0, C = 1

10. For CE transistor amplifier, the audio signal voltage across the collector resistance of $2k\Omega$ is 4 V. If the current amplification factor of the transistor is 100 and the base resistance is $1k\Omega$, then the input signal voltage is: **[2016]**

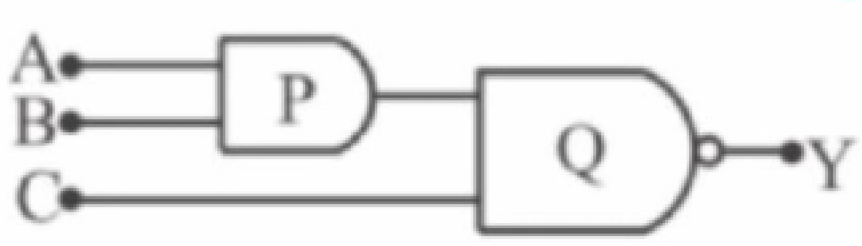
(a) 10 mV (b) 20 mV (c) 30 mV (d) 15 mV

11. The given circuit has two ideal diodes connected as shown in the figure below. The current flowing through the resistance R_1 will be: **[2016]**



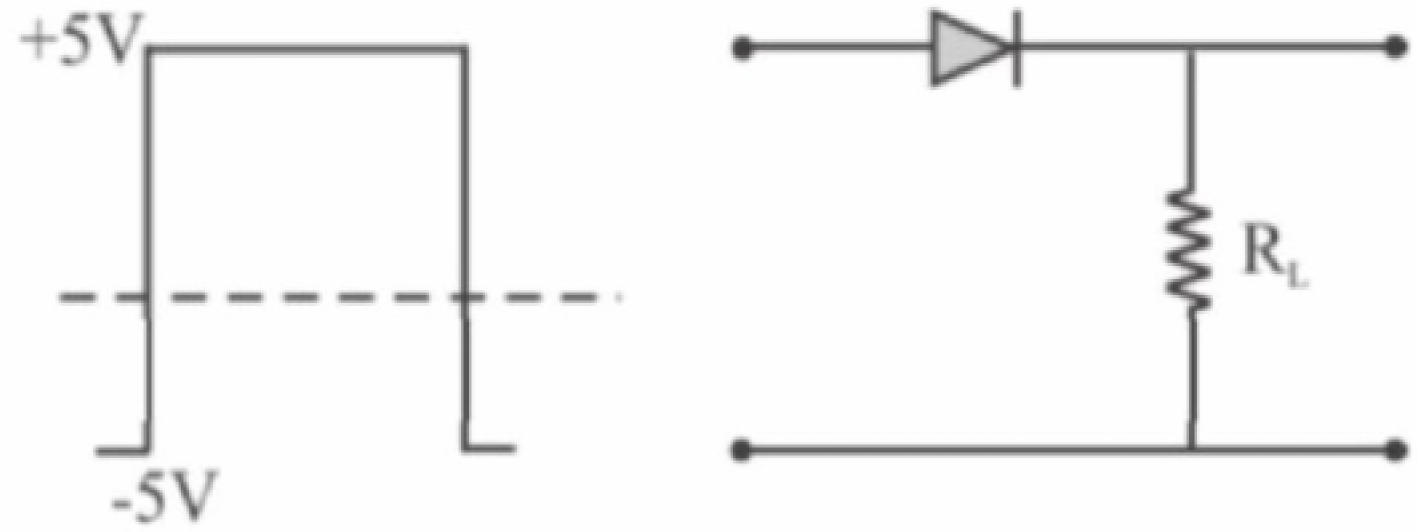
(a) 2.5 A (b) 10.0 A (c) 1.43 A (d) 3.13 A

12. What is the output Y in the following circuit, when all the three inputs A, B, C are first 0 and then 1 ? **[2016]**



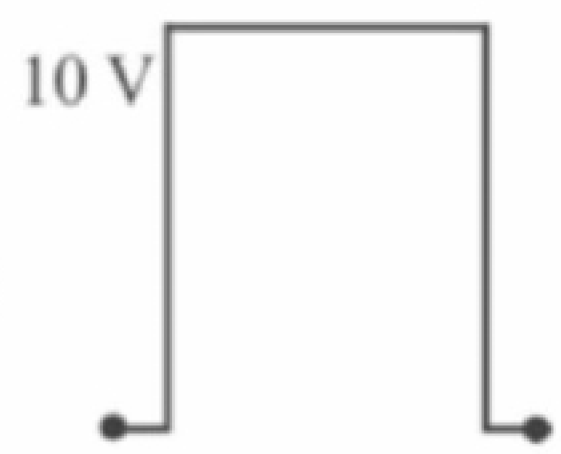
(a) 0, 1 (b) 0, 0
(c) 1, 0 (d) 1, 1

13. If in a p-n junction diode, a square input signal at 10 V is applied as shown **[2015]**



Then the output signal across R_L will be

(a)

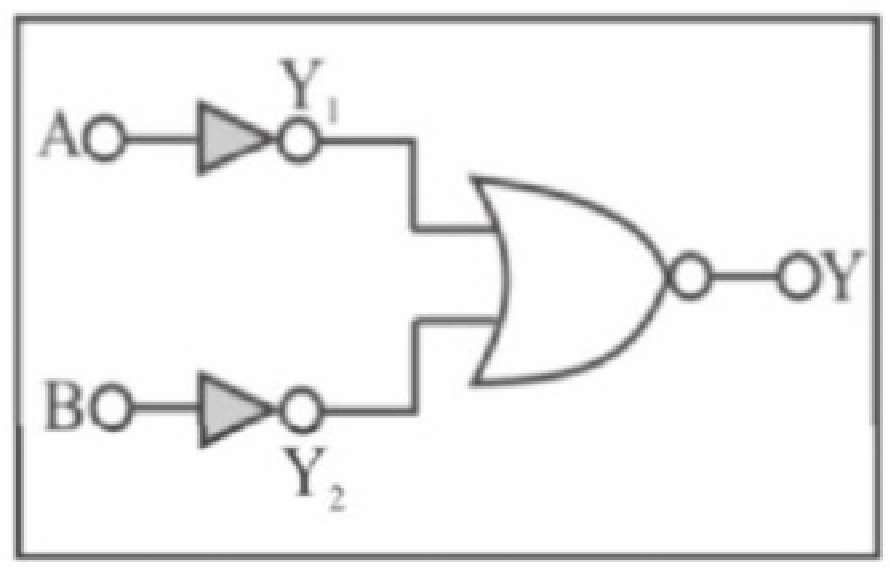


(b)

(c)

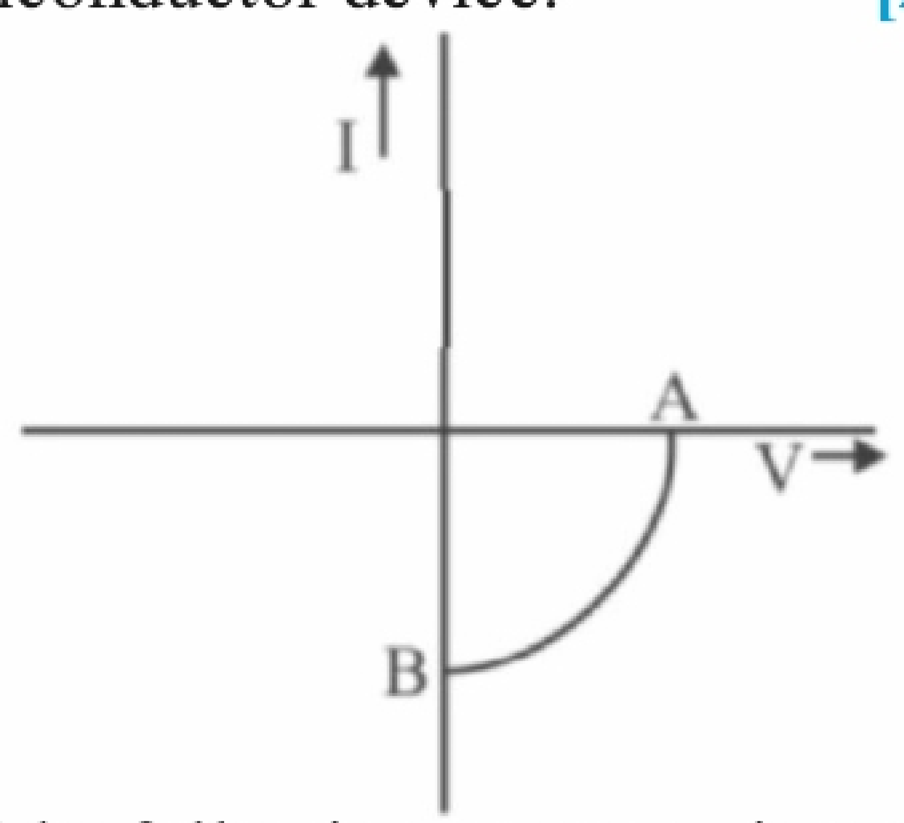
(d)

14. Which logic gate is represented by the following combination of logic gates?



(a) NOR (b) OR (c) NAND (d) AND

15. Thegiven graph represent V - Icharacteristics for a semiconductor device. **[2014]**



Which of the following statement is correct?

(a) It is V - I characteristics for solar cell where point A represents open circuit voltage and point B short circuit current.

(b) It is for a solar cell and points A and B represent open circuit voltage and current respectively.

(c) It is for a photodiode and points A and B represent open circuit voltage and current, respectively.

(d) It is for an LED and points A and B represent open circuit voltage and short circuit current,respectively.

16. The barrier potential of a $p-n$ junction depends on **[2014]**

(i) Type of semiconductor material

(ii) Amount of doping

(iii) Temperature

Which one of the following is correct?

(a) (i) and (ii) only (b) (ii) only

(c) (ii) and (iii) only (d) (i), (ii) and (iii)

17. In a $n-$type semiconductor, which of the following statement is true? **[2013]**

(a) Electrons are majority carriers and trivalent atoms are dopants.

(b) Electrons are minority carriers and petavalent atoms are dopants.

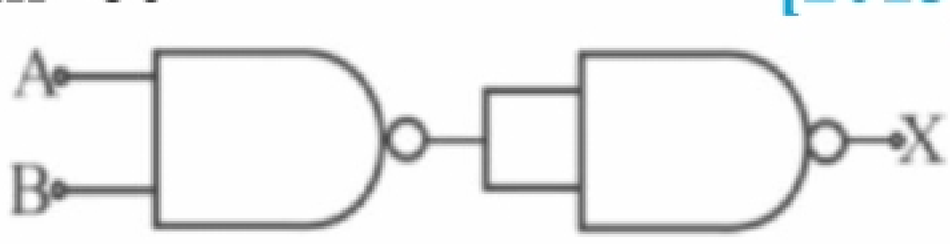
(c) Holes are minority carriers and pentavalent atoms are dopants.

(d) Holes are majority carriers and trivalent atoms are dopants.

18. In a common emitter (CE) amplifier having a voltage gain G, the transistor used has t ransconductance 0.03 mho and current gain 25. If the above transistor is replaced with another one with transconductance 0.02 mho and current gain 20, the voltage gain will **[2013]**

(a) $\frac{1}{3}G$ (b) $\frac{5}{4}G$ (c) $1.5G$ (d) $\frac{2}{3}G$

19. The output (X) of the logic circuit shown in figure will be **[2013]**



(a) $X = A \cdot B$ (b) $X = \overline{A.B}$

(c) $X = \overline{\overline{A}}.\overline{\overline{B}}$ (d) $X = \overline{A+B}$

20. In a CE transistor amplifier, the audio signal voltage across the collector resistance of $2k\Omega$ is 2V. If the base resistance is $1k\Omega$ and the current amplification of the transistor is 100, the input signal voltage is **[2012]**

(a) $1.0V$ (b) $0.1V$

(c) $10mV$ (d) $1mV$

21. C and Si both have same lattice structure, having 4 bonding electrons in each. However, C is insulator whereas Si is intrinsic semiconductor.This is because **[2012]**

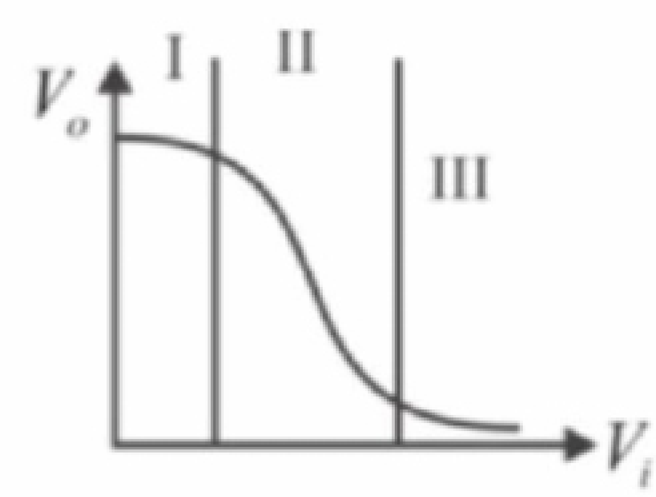
(a) The four bonding electrons in the case of C lie in the second orbit, whereas in the case of Si they lie in the third.

(b) In case of C, the valence bond is not completely filled at absolute zero temperature

(c) In case of C, the conduction band is partly filled even at absolute zero temperature

(d) The four bonding electrons in the case of C lie in the third orbit, whereas for Si they lie in the fourth orbit

22. Transistor characteristics [output voltage (V_0) vs input voltage (V_i)] for a base biased transistor in CE configuration is shown in the figure.For using transistor as a switch, it is used



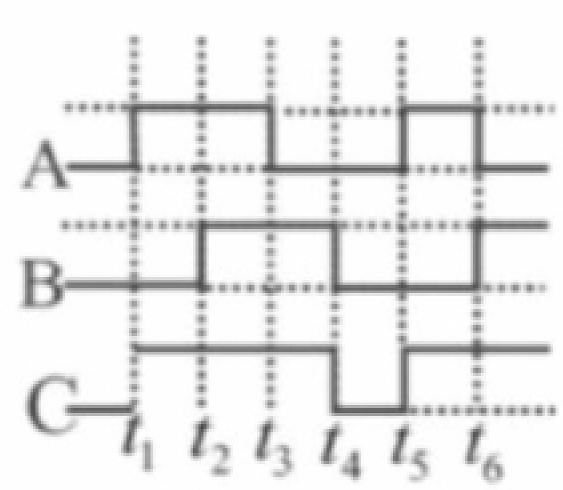
(a) In region II

(b) In region I

(c) In region III

(d) Both in region (I) and (III)

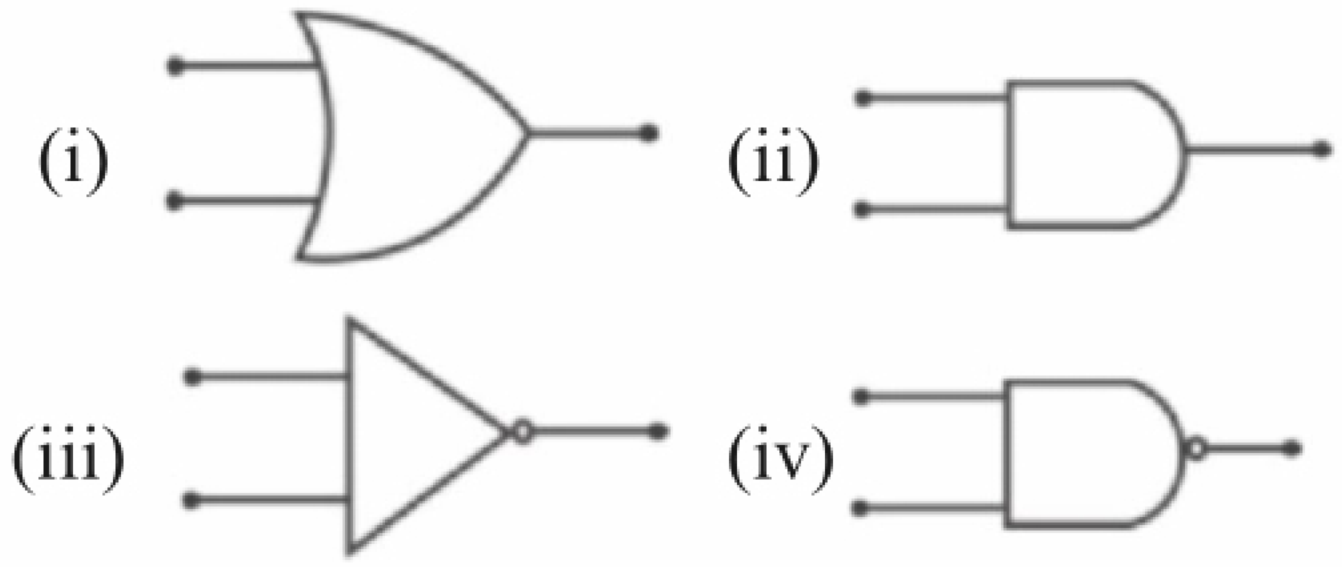
23. The figure shows a logic circuit with two inputs A and B and the output C. The voltage wave forms across A, B and C are as given. The logic circuit gate is **[2012]**



(a) NAND gate (b) OR gate

(c) AND gate (d) Nor gate

24. Symbolic representation of four logic gates are shown as [2011]



Pick out which ones are for AND, NAND and NOT gates, respectively.

(a) (iii), (ii) and (i) (b) (iii), (ii) and (iv)

(c) (ii), (iv) and (iii) (d) (ii), (iii) and (iv)

25. If a small amount of antimony is added to germanium crystal [2011]

(a) The positive terminal of the battery is connected to $p-$ side and the depletion region becomes thin

(b) The antimony becomes an acceptor atom

(c) There will be more free electrons than holes in the semiconductor

(d) The positive terminal of the battery is connected to $p-$ side and the depletion region becomes thick

26. In forward biassing of the $p-n$ junction [2011]

(a) The positive terminal of the battery is connected to $n-$ side and the depletion region becomes thin

(b) The positive terminal of the battery is connected to $n-$ side and the depletion region becomes thick

(c) The positive terminal of the battery is connected to $p-$ side and the depletion region becomes thick

(d) The positive terminal of the battery is connected to $p-$ side and the depletion region becomes thin

ANSWER KEY

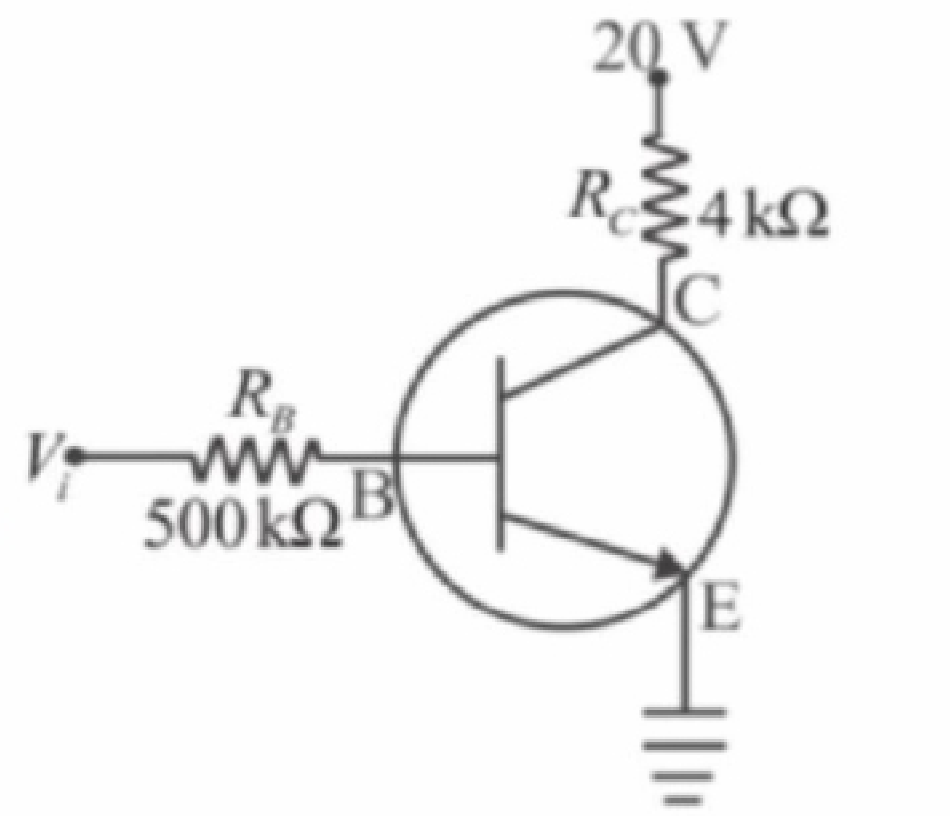
SEMICONDUCTORS

1. b	2. b	3. c	4. b	5. b
6. d	7. b	8. a	9. d	10. b
11. a	12. c	13. d	14. d	15. a
16. d	17. c	18. d	19. a	20. c
21. a	22. d	23. b	24. c	25. c
26. d				

HINTS & SOLUTIONS

SEMICONDUCTORS

1.Sol:



$$V_B = V_i = 500 i_b = 20 - 4 \times i_C = 0$$

$$i_b = \frac{20}{500} = 40\mu A, i_C = 5 mA$$

$$4 \times i_C = 500 \times i_b$$

$$i_C = 125 i_b$$

$$\beta = \frac{i_C}{i_b} = 125$$

2.Sol: Conceptual

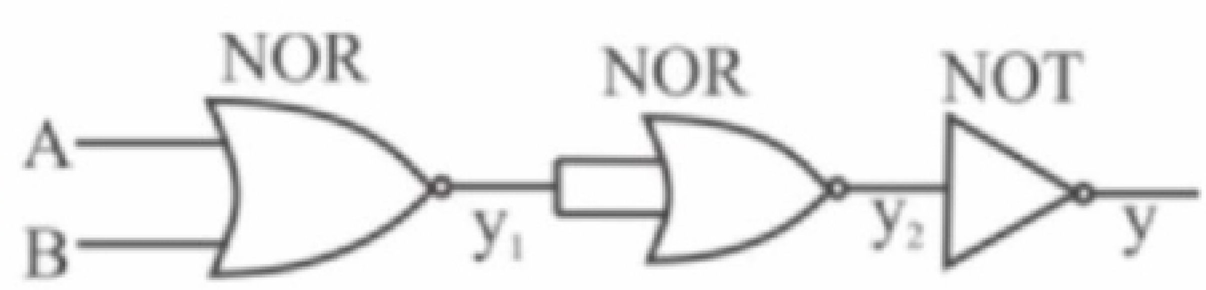
3.Sol: $A \cdot \overline{B} + \overline{A} \cdot B = Y$

4.Sol: Voltage gain is

$$A_V = \beta \frac{R_C}{R_B} = 100 \times \frac{3k\Omega}{2k\Omega} = 150$$

Power gain $= \beta A_V = 100 \times 150 = 15000$

5.Sol:



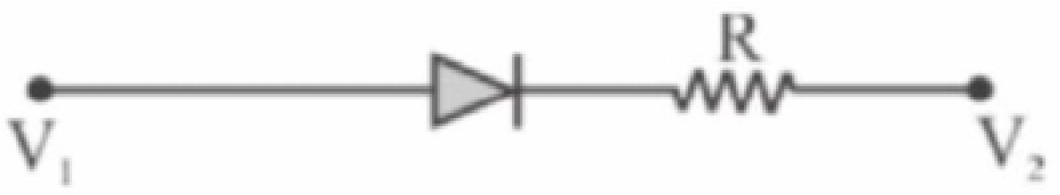
$$y_1 = \overline{A+B}$$

$$y_2 = \overline{y_1 + y_1} = \overline{y_1} = \overline{\overline{A+B}} = A+B$$

$$y = \overline{y_2} = \overline{A+B}$$

So it is a NOR gate

6. Sol:



In forward bias $V_1 > V_2$

$\Rightarrow$ only

is in forward bias, p-type semiconductor is at higher potential w.r.t n- type semiconductor is at lower potential

7.Sol: Since diode is in forward bias

$$i = \frac{\Delta V}{R} = \frac{4-(-6)}{1\times 10^3} = \frac{10}{10^3} = 10^{-2}A$$

8.Sol: Given $\alpha = 0.96, R_L = 800\Omega$

so, $\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{0.04} \Rightarrow \beta = 24$

Voltage gain for common emitter configuration

$$A_v = \beta.\frac{R_L}{R_1} = 24\times\frac{800}{192} = 100$$

Power gain for common emitter configuration

$$P_v = \beta A_v = 24\times 100 = 2400$$

Voltage gain for common base configuration

$$A_v = \alpha.\frac{R_L}{R_1} = 0.96\times\frac{800}{192} = 4$$

Power gain for common base configuration

$$P_v = A_v\alpha = \alpha^2\frac{R_L}{R_1} = 4\times 0.96 = 3.84$$

In the question it is asked about common emitter configuration but we got above answer for common base configuration.

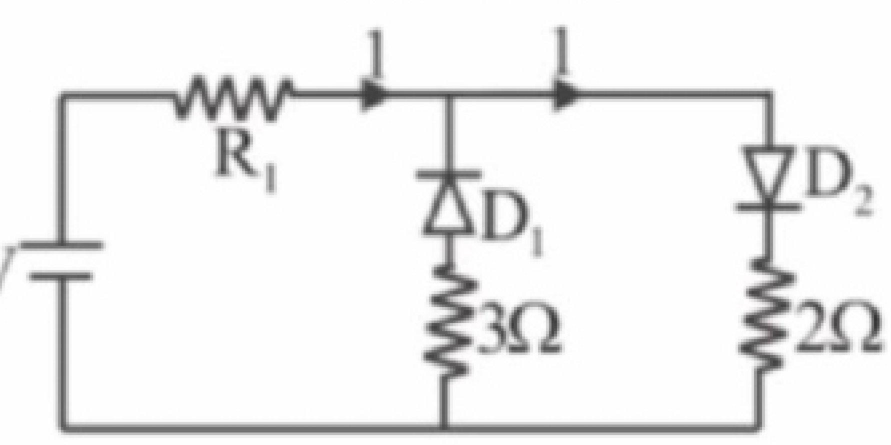
9.Sol: For the given inputs the output is 1

10.Sol: Given that $R_B = 1000\Omega$ & $R_L = 2000\Omega$

$$\beta = 100 = \frac{I_c}{I_B}, V_o = 4V$$

$$\frac{V_o}{V_i} = \beta\frac{R_L}{R_B} \Rightarrow V_i = \frac{4\times 1000}{100\times 2000} = 0.02 = 20mV$$

11. Sol:



Diode D_1 is reversed biased. Then no current will flow through D_1.

$$\therefore I = \frac{10}{4} = 2.5A$$

12.Sol: $Y = \overline{(A\cdot B)\cdot C}$

13.Sol: The given circuit is

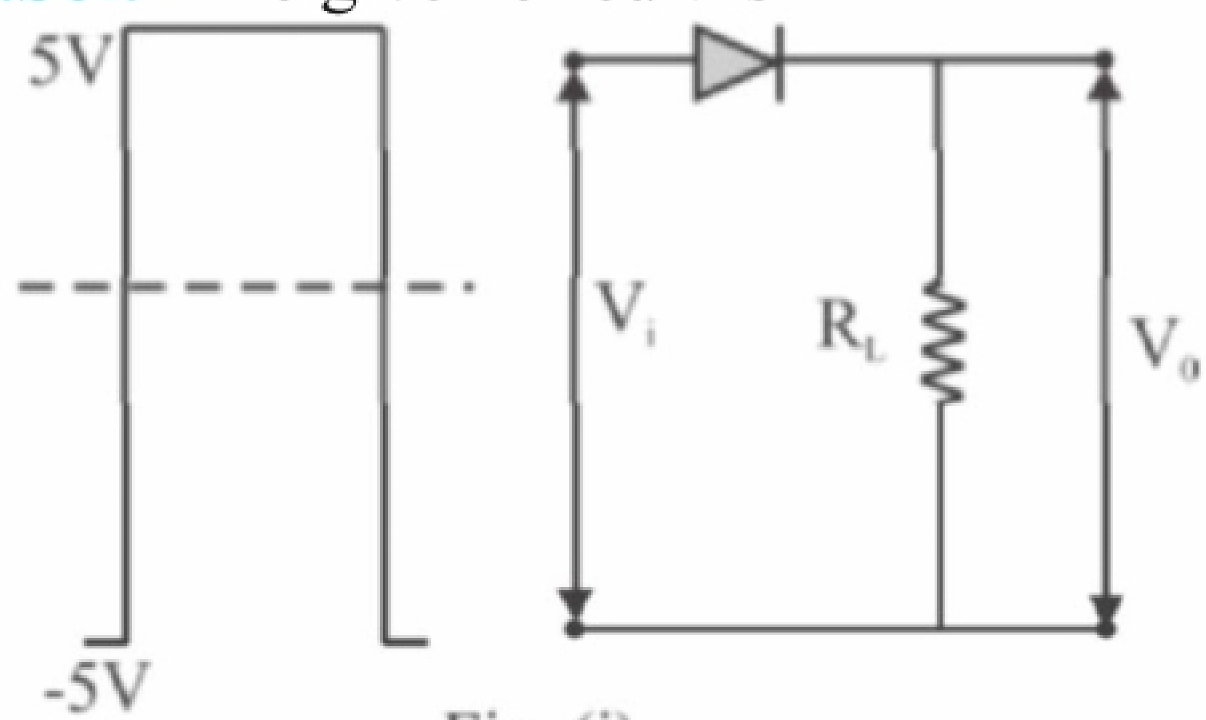


Fig. (i)

For, $V_i < 0$,

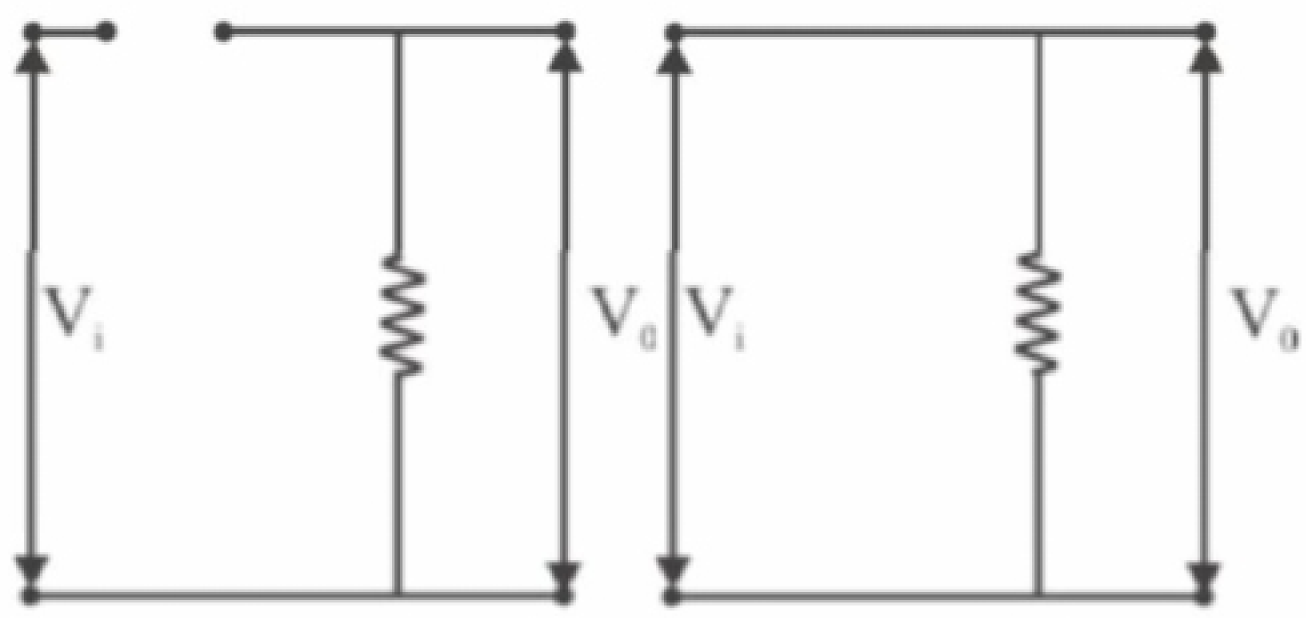
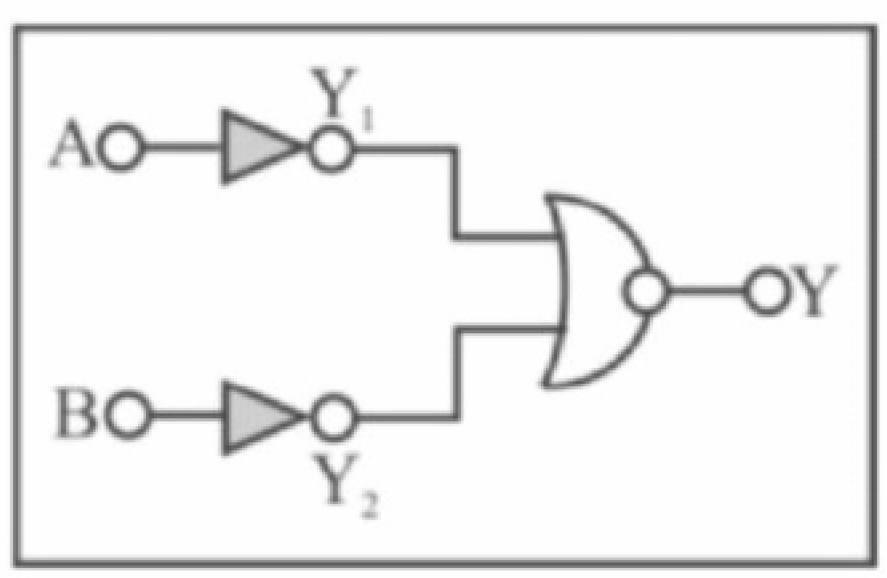


Fig. (ii) Fig. (iii)

the diode is reverse biased and hence offer infinite resistance, so, circuit would be like asshown in fig.(ii). The junction diode is forward biased, when $V_i = 5V$

So only (+)ve part of the signal will come as output

14.Sol: We have $\overline{(\overline{A}+\overline{B})}$



Truth table:

A	B	Y_1	Y_2	Y
0	0	1	1	0
1	0	0	1	0
0	1	1	0	0
1	1	0	0	1

When the i/p are high, we get high value of o/p. This corresponds to AND gate.

15.Sol: A solar cell does not draw current but supplies the current to the load resistor. The I - V characteristics are always drawn in fourth quadrant. When the cell is in open circuit then potential difference is developed because of radiation that strikes it and current is zero.

16.Sol: Barrier potential depends on the material used to make $p-n$ junction diode (whether it is Si or Ge). It also depends on amount of doping due to which the number of majority carriers will change. It also depends on temperature due to which the number of minority carriers will change.

17.Sol: The $n-$type semiconductor can be produced by doping an impurity atom of valence 5 i.e., petavalent atoms (phosphorous). Holes are minority carriers in them.

18.Sol: As $A_V = \beta \dfrac{R_L}{R_i}$

or $$G = \left(\frac{\beta}{R_i}\right) R_L$$

Transconductance

$$g_m = \frac{\beta}{R_i}$$

$$\Rightarrow G = g_m R_L \Rightarrow G \alpha g_m$$

$$\left[\because g_m = \frac{\Delta I_C}{\Delta V_B} = \frac{\Delta I_C}{\Delta I_B R_i}\right]$$

$$\therefore \frac{G_2}{G_1} = \frac{g_{m_2}}{g_{m_1}}$$

$$\Rightarrow G_2 = \frac{0.02}{0.03} \times G$$

So, voltage gain, $G_2 = \dfrac{2}{3} G$

19.Sol: $X = \overline{\overline{A.B}} = A \cdot B$ (i.e., AND gate)

20.Sol: Given that

$$R_L = 2000\Omega$$

$$R_B = 1000\Omega$$

$$\beta = 100 = \frac{I_C}{I_B}$$

$$V_o = 2V$$

$$\frac{V_o}{V_i} = \beta \frac{R_L}{R_B}$$

$$V_i = \frac{V_o R_B}{\beta R_L} = 10 mV$$

21.Sol: The four bonding electrons in the case of C lie in the second orbit. Whereas in case of Si they lie in the third orbit. So loosely bound valence electrons are present in Si as compared to C.

22.Sol: In region I the transistor is in saturated state.In region III the transistor is in cut off state so in both regions I & III the transistor can be used as a switch.

23.Sol: From the given waveforms, the following truth table can be made

Inputs		Output
A	B	C
0	0	0
1	0	1
1	1	1
0	1	1

This truth table obtained is of 'OR' gate. So, logic circuit gate is OR gate.

24.Sol: The symbols given in problems are (i) OR (ii) AND (iii) NOT (iv) NAND

25.Sol: When a small amount of antimony is added togermanium crystal, the crystal becomes $n-$type semiconductor, because antimony is a pentavalent substrate.

26.Sol: In forward biasing of $p-n$ junction, the positive terminal of the battery is connected to $p-$side and the depletion region becomes thin.

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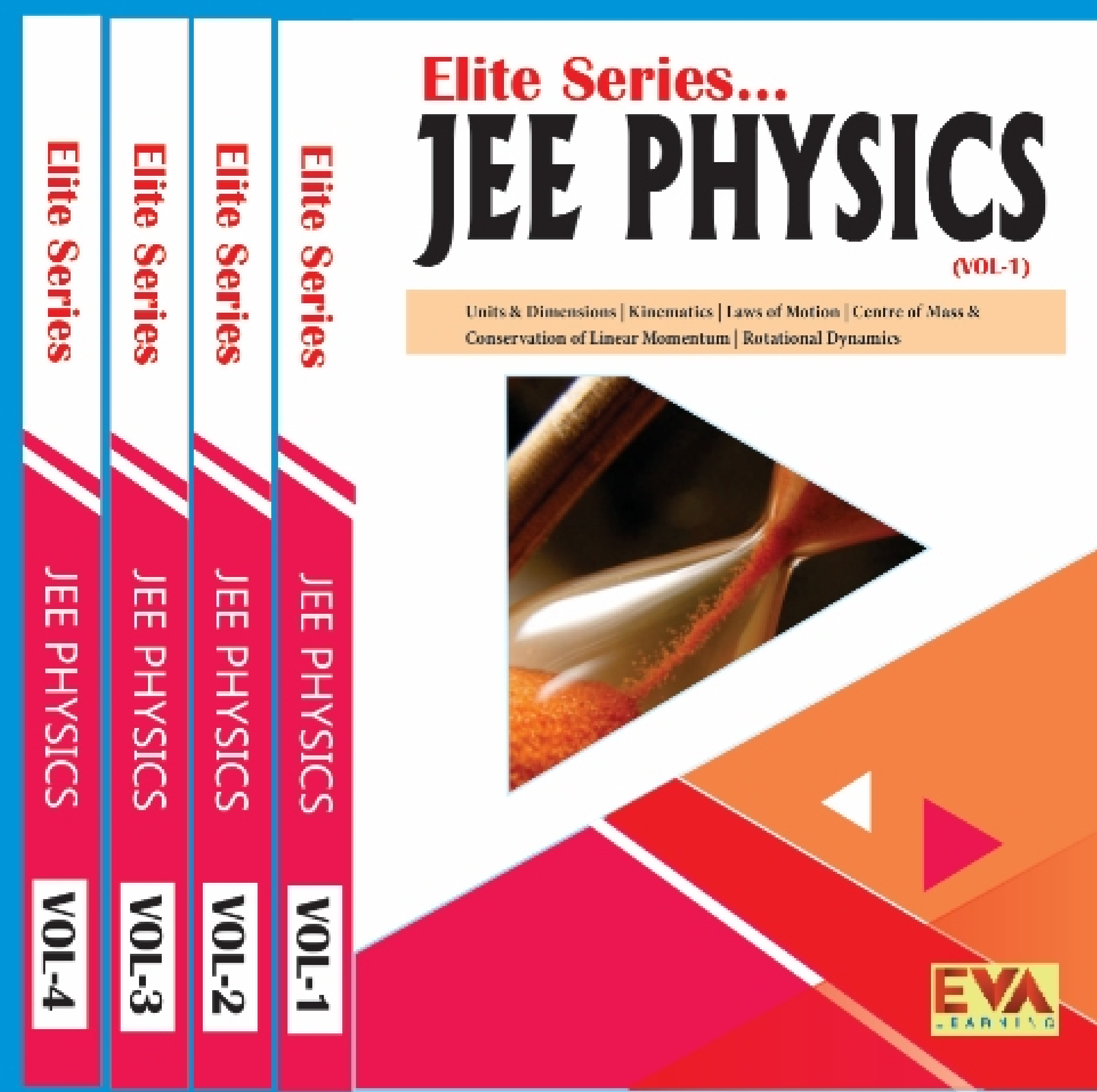

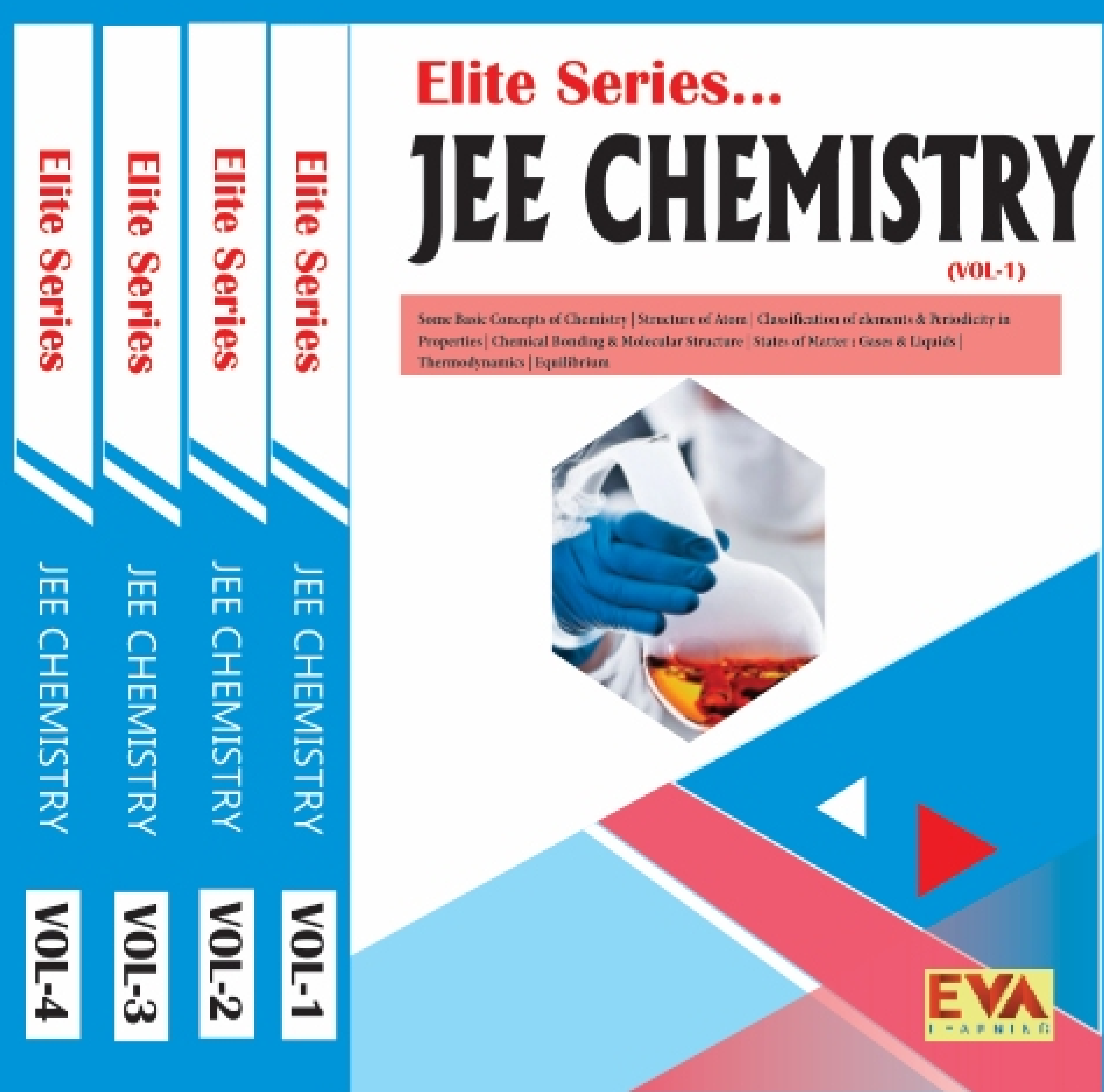

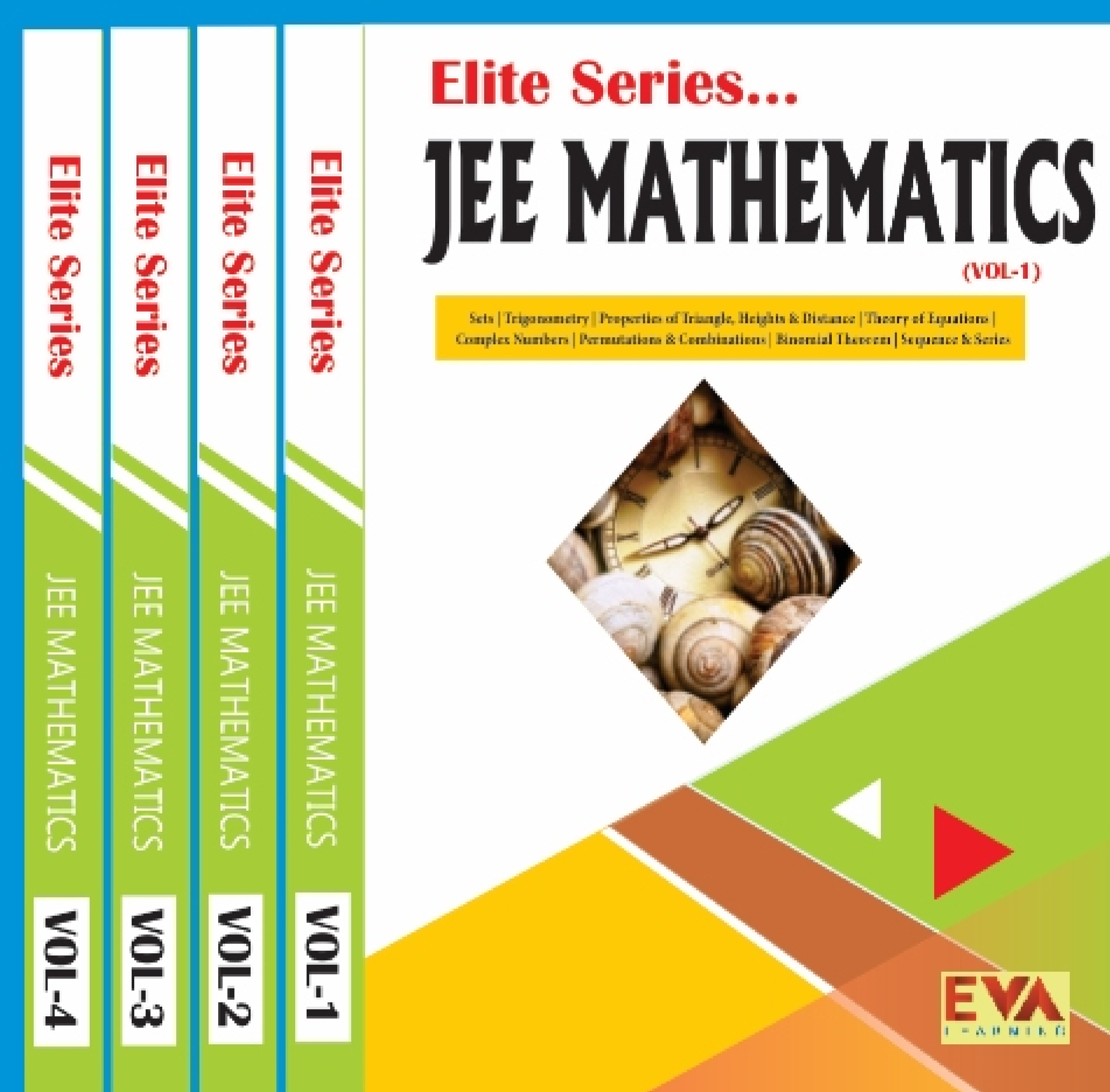

Highlights

- Chapter wise theory
- Chapter wise MCQ's with detailed solutions
- Hand picked treasures in MCQ's
- Graph based questions
- Matching type questions
- Assertion & Reason based questions
- Chapter wise JEE (online & offline) questions

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