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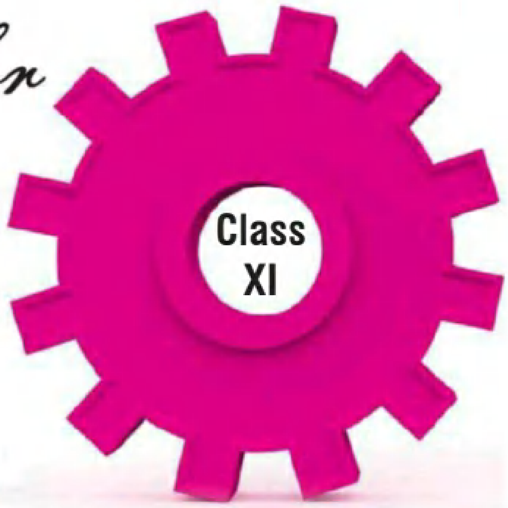
GET SET GO *for* JEE



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1. A neutron with velocity v strikes a stationary deuterium atom, its kinetic energy changes by a factor of

(a) $\frac{15}{16}$ (b) $\frac{1}{2}$ (c) $\frac{2}{1}$ (d) $\frac{8}{9}$

2. A statelllite of mass m revolves around the earth of radius R at a height x from its surface. If g is acceleration due to gravity on the surface of the earth, the orbital speed of the satellite is

(a) $\frac{gR^2}{R+x}$ (b) $\frac{gR}{R-x}$

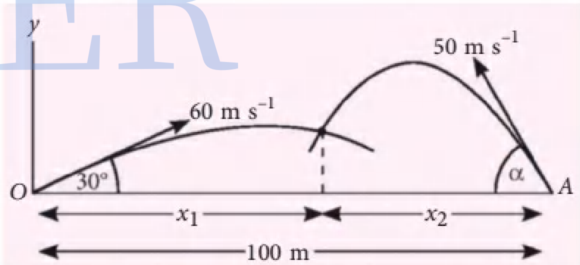
(c) gx (d) $\left(\frac{gR^2}{R+x}\right)^{1/2}$

3. A rubber cord catapult has cross-sectional area 25 mm^2 and initial length of rubber cord is 10 cm. It is stretched to 5 cm and then released to project a missile of mass 5 g. Taking $Y_{\text{rubber}} = 5 \times 10^8$ N m^{-2}. Velocity of projected missile is

(a) 20 m s^{-1} (b) 100 m s^{-1}

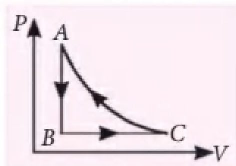
(c) 250 m s^{-1} (d) 200 m s^{-1}

4. A particle P is projected from a point O with an initial velocity of 60 m s^{-1} at an angle 30° to the horizontal. At the same instant a second particle Q is projected in the opposite direction with initial speed 50 m s^{-1} from a point level with O and 100 m from O. If the particle collide find the time when the collision occurs.



(a) 2.11s (b) 0.51s (c) 1.52s (d) 1.09s

5. In figure, a cyclic process $ABCA$ of 3 moles of an ideal gas is given. The temperature of the gas at B and C are 500 K and 1000 K respectively.



If the work done on the gas in process CA is 2500 J then find the net heat absorbed or released by an ideal gas. Take $R = 25/3$ J mol^{-1}K^{-1}.

(a) 10 kJ (b) 25 kJ (c) 2.5 kJ (d) 1.0 kJ

6. Two parallel glass plates are held vertically at a small separation d and dipped in a liquid of surface tension T, angle of contact $\theta = 0$ and density ρ. The height of water that climbs up in the gap between the plates is given by

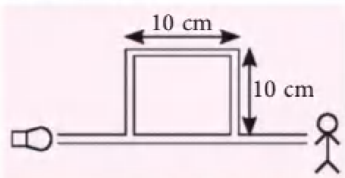
(a) $2T/d\rho g$ (b) $T/2\ d\rho g$
(c) $T/d\rho g$ (d) None of these

7. A weightless ladder 20 ft long rests against a frictionless wall at an angle of 60° from the horizontal. A 150 pound man is 4 ft from the top of the the ladder. A horizontal force is needed to kept it from slipping. Choose the correct magnitude from the following.
(a) 175 lb (b) 100 lb
(c) 120 lb (d) 17.3 lb

8. The molecules of a given mass of a gas have root mean square speeds of 100 m s^{-1} at 27°C and 1 atmospheric pressure. The root mean square speeds (in m s^{-1}) of the molecules of the gas at 127°C and 2 atmospheric pressure is
(a) $\frac{200}{\sqrt{3}}$ (b) $\frac{100}{\sqrt{3}}$
(c) $\frac{400}{3}$ (d) $\frac{200}{3}$

9. A spherical body of mass m and radius r is allowed to fall in a medium of viscosity η. The time in which the velocity of the body increases from zero to 0.63 time the terminal velocity (v) is called time constant τ. Dimensionally τ can be represented by
(a) $\frac{mr^2}{6\pi\eta}$ (b) $\sqrt{\left(\frac{6\pi m r\eta}{g^2}\right)}$
(c) $\frac{m}{6\pi\eta r v}$ (d) None of these

10. Figure shows a tube having sound source at one end and observer at the other end. Source produces frequencies upto 10000 Hz. Find the frequencies at which person hears maximum intensity. Speed of sound is 400 m s^{-1}.

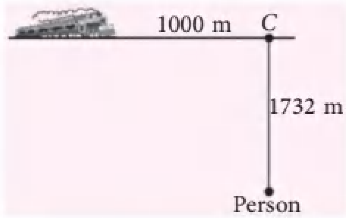


(a) 3000 Hz (b) 2500 Hz
(c) 4000 Hz (d) 4500 Hz

11. The collision frequency of nitrogen molecule in a cylinder containing nitrogen molecule at 2.0 atm pressure and temperature 17°C. (Take radius of a nitrogen molecule is 1.0 Å)
(a) $3.2 \times 10^5\ s^{-1}$ (b) $4.6 \times 10^9\ s^{-1}$
(c) $4.6 \times 10^{-9}\ s^{-1}$ (d) $3.2 \times 10^{-5}\ s^{-1}$

12. A chain of length l is placed on a smooth spherical surface of radius R with one of its ends fixed at the top of the sphere. What will be acceleration a of each element of the chain when its upper end is released? It is assumed that the length of chain $l < \left(p\frac{R}{2}\right)$.
(a) $\frac{g}{l}\left(1-\cos\frac{l}{R}\right)$ (b) $\frac{gR}{l}\left(1+\cos\frac{l}{R}\right)$
(c) $\frac{g}{l}\left(1+\cos\frac{l}{R}\right)$ (d) $\frac{gR}{l}\left(1-\cos\frac{l}{R}\right)$

13. A train producing frequency of 640 Hz is moving towards point C with speed 72 km h^{-1}. A person is sitting 1732 m from point C as shown in figure. Find the frequency heard by person if speed of sound is 330 m s^{-1}.



(a) 540 Hz (b) 660 Hz
(c) 740 Hz (d) 590 Hz

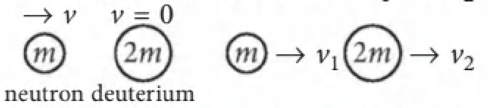
14. Two Aluminium rods and a steel rod of equal cross-section area and equal length l_0 are joined rigidly side by side as shown in figure. Initially the rods are at 0°C. Find the length of the rod at the temperature θ if Young's modulus of elasticity of the aluminium and steel are Y_a and Y_s respectively and coefficient of linear expansion of aluminium and steel are α_a and α_s respectively.

(a) $l_0\left[1+\frac{2Y_a\alpha_a+Y_s\alpha_s}{2Y_a+Y_s}\theta\right]$
(d) $l_0\left[1+\frac{Y_a\alpha_a+Y_s\alpha_s}{Y_a+Y_s}\theta\right]$
(c) $l_0\left[1-\frac{2Y_a\alpha_a-Y_s\alpha_s}{2Y_a-Y_s}\theta\right]$
(d) $l_0\left[1-\frac{Y_a\alpha_a-Y_s\alpha_s}{Y_a-Y_s}\theta\right]$

15. Two bodies begin a free fall from the same height at a time interval of N s. If vertical separation between the two bodies is 1 m after n second from the start of the first body, then n is equal to
(a) $\sqrt{nN}$ (b) $\frac{1}{gN}$
(c) $\frac{1}{gN}+\frac{N}{2}$ (d) $\frac{1}{gN}-\frac{N}{4}$

SOLUTIONS

1. (d): Let mass of neutron = m
then mass of deuterium = $2m$
[$\because$ it has double nuclides thus has neutron].
Let initial velocity of neutron = v and final velocities of neutron and deuterium are v_1 and v_2 respectively.



Applying conservation of momentum
$mv + 2m(0) = mv_1 + 2mv_2$
$\Rightarrow \quad v = v_1 + 2v_2$ ...(i)
applying conservation of energy
$\frac{1}{2}mv^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}(2m)v_2^2$
$\Rightarrow \quad v^2 = v_1^2 + 2v_2^2$ ...(ii)
from (i) and (ii), $v^2 = (v - 2v_2)^2 + 2v_2^2$
$\Rightarrow \quad v^2 = v^2 + 4v_2^2 - 4v_2v + 2v_2^2$
$6v_2^2 - 4v_2v = 0$
$\Rightarrow \quad v_2 = \frac{2v}{3}$ and $v_1 = -\frac{v}{3}$
Now fractional change in kinetic energy

$$= \frac{K_i - K_f}{K_i} = \frac{\frac{1}{2}mv^2 - \frac{1}{2}mv_1^2}{\frac{1}{2}mv^2} = \frac{v^2 - \frac{v^2}{9}}{v^2} = \frac{8}{9}$$

2. (d): $\frac{mv^2}{(R+x)} = \frac{GmM}{(R+x)^2}$ also $g = \frac{GM}{R^2}$

$\therefore \quad \frac{mv^2}{(R+x)} = m\left(\frac{GM}{R^2}\right)\frac{R^2}{(R+x)^2}$

or $\frac{mv^2}{(R+x)} = mg\frac{R^2}{(R+x)^2}$

or $v^2 = \frac{gR^2}{R+x} \Rightarrow v = \left(\frac{gR^2}{R+x}\right)^{1/2}$

3. (c): Young's modulus of rubber,
$Y_{\text{rubber}} = \frac{F}{A} \times \frac{l}{\Delta l} \Rightarrow F = YA.\frac{\Delta l}{l}$
On putting the values from question,

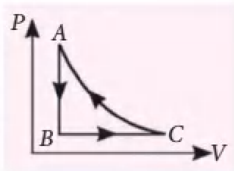
$$F = \frac{5\times10^8 \times 25\times10^{-6} \times 5\times10^{-2}}{10\times10^{-2}}$$

$= 25 \times 25 \times 10 = 6250$ N
Kinetic energy = Potential energy of rubber
$\frac{1}{2}mv^2 = \frac{1}{2}F\Delta l$

$v = \sqrt{\frac{F\Delta l}{m}} = \sqrt{\frac{6250\times5\times10^{-2}}{5\times10^{-3}}} = \sqrt{62500}$
$= 25 \times 10 = 250$ m s^{-1}

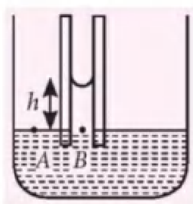
4. (d): If the particles collide they must be at the same point at the same time so as time is an important consideration we do not use the equation of the path.
Let t be the time between projection and collision.
For P we use O as origin and the x-axis along OA given
$x_P = (60\cos 30°)\,t$; $y_P = (60\sin 30°)\,t - \frac{1}{2}gt^2$
For Q we use A as origin and the x-axis along AO given
$x_Q = (50\cos\alpha)\,t$, $y_Q = (50\sin\alpha)\,t - \frac{1}{2}gt^2$
During collision
$x_P + x_Q = 100 \Rightarrow t(30\sqrt{3} + 50\cos\alpha) = 100$ ...(i)
Also, $y_P = y_Q \Rightarrow 30 = 50\sin\alpha \Rightarrow \sin\alpha = \frac{3}{5}$ ...(ii)
Hence, from equation (ii), $\cos\alpha = \frac{4}{5} \Rightarrow \alpha = 36.9°$
Therefore Q is projected at 36.9° to the horizontal.
Then equation (i) gives,
$t(30\sqrt{3} + 40) = 100 \Rightarrow t = 1.09$ s
Therefore the particle collide 1.09 seconds after projection.

5. (a): The change in internal energy during the cyclic process is zero. Hence, the heat supplied to the gas is equal to the work done by it. Hence,



$\Delta Q = W_{AB} + W_{BC} + W_{CA}$ ...(i)
The work done during the process AB is zero
$W_{BC} = P_B(V_C - V_B) = nR(T_C - T_B)$
$= (3\text{ mol})(25/3\text{ J mol}^{-1}\text{ K}^{-1})(500\text{ K}) = 12500$ J
As $W_{CA} = -2500$ J (given)
$\therefore \quad \Delta Q = 0 + 12500 - 2500$ (from (i))
$\Delta Q = 10$ kJ

6. (a): The meniscus between the plates has cylindrical shape with radius $r = \frac{d}{2}$. The pressure just inside the meniscus is



$P_0 - T\left(\frac{1}{r} + \frac{1}{\infty}\right) = P_0 - \frac{2T}{d}$
Now, $P_A = P_B$
or, $P_0 = \left(P_0 - \frac{2T}{d}\right) + h\rho g \Rightarrow h = \frac{2T}{d\rho g}$

7. **(d)**: AB is the ladder, let F be the horizontal force and W is the weight of man. Let N_1 and N_2 be normal reactions of ground and wall, respectively. Then for vertical equilibrium

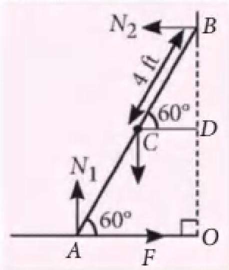
$W = N_1$ ...(i)

For horizontal equilibrium $N_2 = F$ ...(ii)

Taking moments about A

$N_2(AB \sin 60°) - W(BC \cos 60°) = 0$ ...(iii)

Using (ii) and $AB = 20$ ft, $BC = 4$ ft, we get



$$F\left(20\times\frac{\sqrt{3}}{2}\right)-W\left(4\times\frac{1}{2}\right)=0$$

$$\therefore\ F=\frac{2W\times 2}{20\sqrt{3}}=\frac{W}{5\sqrt{3}}$$

$$=\frac{150}{5\sqrt{3}}=10\sqrt{3}=17.3\text{ lb}$$

8. **(a)**: Here, let $v_{rms_1} = 100$ m s^{-1} at temperature $T_1 = 27$ °C $= (27 + 273)$ K $= 300$ K and Pressure $P_1 = 1$ atm,

Now for the same gas at temperature $T_2 = 127$°C $= (127 + 273)$ K $= 400$ K, $P_2 = 1$ atm, $v_{rms_2} = ?$,

$$\text{Using } \frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2};\ \frac{V_1}{V_2}=\frac{P_2}{P_1}\cdot\frac{T_1}{T_2}=2\times\frac{300}{400}=\frac{3}{2}$$

$$\text{Again } P_1=\frac{1}{3}\frac{M}{V_1}v_{rms_1}^2 \text{ and } P_2=\frac{1}{3}\frac{M}{V_2}v_{rms_2}^2$$

$$\therefore\ \frac{v_{rms_2}^2}{v_{rms_1}^2}\times\frac{V_1}{V_2}=\frac{P_2}{P_1}$$

$$v_{rms_2}^2=v_{rms_1}^2\times\frac{P_2}{P_1}\times\frac{V_2}{V_1}=(100)^2\times 2\times\frac{2}{3}$$

$$v_{rms_2}=\frac{200}{\sqrt{3}}\text{ m s}^{-1}$$

9. **(d)**: None of the expressions has the dimension of time.

10. **(c)**: The sound wave bifurcates at the junction of the straight and the rectangular parts. The wave through the straight part travels a distance $d_1 = 10$ cm and the wave through the rectangular part travels a distance $d_2 = 3 \times 10$ cm $= 30$ cm before they meet again and travel to the receiver. The path difference between the two waves received is, therefore

$\Delta d = d_2 - d_1 = 30$ cm $- 10$ cm $= 20$ cm

The wavelength of either wave is $\lambda=\dfrac{v}{\upsilon}=\dfrac{400\text{ m s}^{-1}}{\upsilon}$.

For constructive interference, $\Delta d = n\lambda$, where n is an integer.

$$\text{or, } \Delta d=n.\frac{v}{\upsilon}\Rightarrow \upsilon=\frac{n.v}{\Delta d}=\frac{400}{0.2}n=2000\,n$$

Thus, the frequencies within the specified range which cause maximum of intensity are 2000×1 Hz, 2000×2 Hz

11. **(b)**: Mean free path $\lambda=\dfrac{1}{\sqrt{2}\pi d^2\lambda}$

$$\lambda=\frac{K_BT}{\sqrt{2}\pi d^2 p}(p=nK_BT)$$

$$\lambda=\frac{(1.38\times10^{-23})(290)}{(1.414)(3.14)(2\times10^{-10})^2(2.026\times10^5)}=1.1\times10^{-7}$$

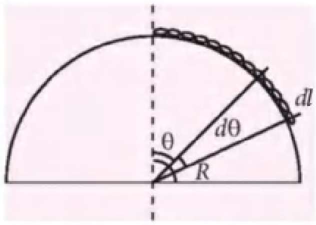
$$v_{rms}=\sqrt{\frac{3K_BT}{m}}=\sqrt{\frac{3\times1.38\times10^{-23}\times290}{28\times1.66\times10^{-27}}}$$

$= 5.1 \times 10^2$ m s^{-1}

$\therefore$ collision frequency

$$\upsilon=\frac{v_{rms}}{\lambda}=\frac{5.1\times10^2}{1.1\times10^{-7}}=4.6\times10^9\text{ s}^{-1}$$

12. **(d)**: Let m be the mass of the chain of length l. Consider an element of length dl of the chain at an angle θ with vertical, From figure, $dl = Rd\theta$;



Force responsible for acceleration, $dF = (dm)g \sin\theta$;

Mass of the element,

$$dm=\frac{m}{l}dl;\text{ or } dm=\frac{m}{l}.R\,d\,\theta$$

$$dF=\left(\frac{m}{l}R\,d\theta\right)(g\sin\theta)=\frac{mgR}{l}\sin\theta\,d\theta$$

Net force on the chain can be obtained by integrating the above relation between 0 to α, we have

$$F=\int_0^\alpha\frac{mg\,R}{l}\sin\theta\,d\theta=\frac{mg\,R}{l}[-\cos\theta]_0^\alpha=\frac{mg\,R}{l}[1-\cos\alpha]$$

$$=\frac{mg\,R}{l}\left[1-\cos\frac{l}{R}\right]$$

$$\therefore\ \text{Accelaration, } a=\frac{F}{m}=\frac{gR}{l}\left(1-\cos\frac{l}{R}\right).$$

13. **(b)**

14. **(a)**

15. **(c)**: $y_1=\dfrac{1}{2}gn^2,\ y_2=\dfrac{1}{2}g(n-N)^2$

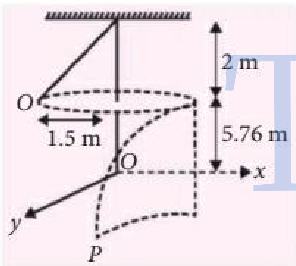
$$\therefore\ y_1-y_2=\frac{1}{2}g[n^2-(n-N)^2]$$

$$\Rightarrow\ 1=\frac{g}{2}(2n-N)N \qquad [\because y_1-y_2=1\text{m}]$$

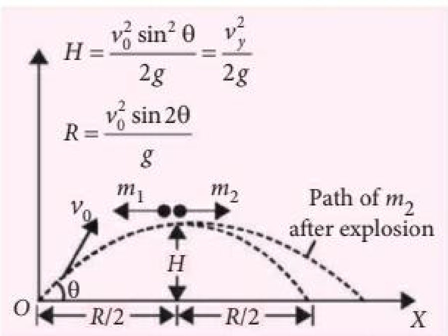
$$\Rightarrow\ n=\frac{1}{gN}+\frac{N}{2}$$

JEE WORK CUTS

1. A particle suspended from the ceiling by inextensible light string is moving along a horizontal circle of radius 1.5 m as shown in figure. The string traces a cone of height 2 m. The string breaks and the particle finally hits the floor (which is *xy* plane 5.76 m below the circle) at point *P*. Find the distance *OP*.



2. An explosive of mass 6 kg is projected at 35 m s^{-1} at an angle of 60° with the horizontal. At the top of its flight it explodes, breaking into two parts, one of which has twice the mass of the other. The two fragments land simultaneously. The lighter fragment lands back at the launch point. (i) Where does the other fragment land? (ii) What is the energy of the explosion?

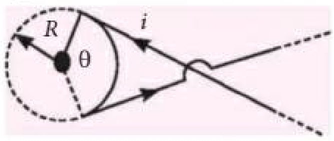


3. A cylindrical pipe of diameter 1 m is kept on a truck as shown in figure. If the truck now starts moving with a constant acceleration of 1 m s^{-2}, the pipe rolls backward without slipping on the floor of the truck and finally falls on the road. If the pipe moves a total length of 4 m on the floor of the truck, what is the velocity of the pipe in (m s^{-1}) relative to the truck and relative to ground at the instant it leaves contact with the truck? (g = 10 m s^{-2}).

4. A glass plate of area *A* and mass *m* is hinged along one of its sides. The speed with which the air should be blown parallel to its upper surface to hold the plate horizontal is $x\sqrt{\frac{mg}{18\rho A}}$? Find the value of *x*.

[The density of air is ρ]

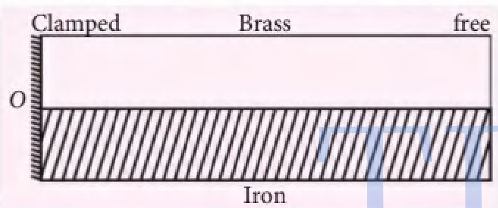
5. A wire carrying current *i* has the configuration shown in figure.



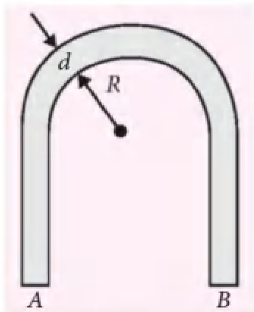
Two semi-infinite straight sections, each tangent to the same circle, are connected by a circular arc, of angle θ, along the circumference of the circle, with all sections lying in the same plane. What must θ (in rad) be in order for B to be zero at the center of circle?

6. An ac ammeter is used to measure current in a circuit. When a given direct current passes through the circuit, the ac ammeter reads 3 A. When another alternating current passes through the circuit, the ac ammeter reads 4 A. Then find the reading of this ammeter (in A), if dc and ac flow through the circuit simultaneously.

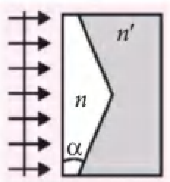
7. A bimetallic strip consisting of a brass strip and a steel strip, each of length 1 m and each of thickness 0.5 cm is clamped at one end as shown in figure. Calculate the depression to the nearest integer (in cm) of the free end when it is heated by 100°C.
[Take : $\alpha_{Iron} = 11 \times 10^{-6}\ K^{-1}$; $\alpha_{Brass} = 19 \times 10^{-6}\ K^{-1}$]



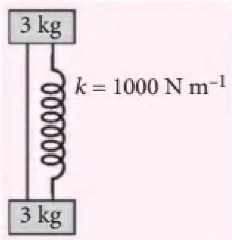
8. A rod made of glass, refractive index 1.5 and of square cross-section, is bent into the shape shown in figure. A parallel beam of light falls normally on the plane flat surface A. Referring to the diagram d is the width of a side and R is the radius of inner semicircle. Find the maximum value of ratio d/R so that all light entering the glass through surface A emerges from the glass through surface B.



9. A plane light wave of wavelength λ = 6000 Å falls normally on the base of a biprism made of glass (n = 1.52) and refracting angle α = 30°. Behind the biprism (see figure) there is a plane-parallel plate with the space filled up with benzene (n' = 1.50). Find the width of a fringe on a screen placed behind this system.



10. A system consists of two identical cubes, each of mass 3 kg, linked together by a compressed weightless spring of force constant 1000 N m^{-1}. The cubes are also connected by a thread which is burnt at a certain moment. At what minimum value of initial compression x_0 (in cm) of the spring will the lower cube bounce up after the thread is burnt through?



SOLUTIONS

1. Let the string breaks when the particle is 1.5 m right of point O and direction of its velocity v is along y-axis.

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

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

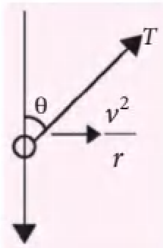
Now time to reach the floor,

$$t = \sqrt{\frac{2h_2}{g}}$$

∴ Before it hits the floor,

$$\Delta y = vt = \sqrt{2h_2 r\tan\theta}$$

where $\tan\theta = \frac{r}{h_1}$



$$\Delta y = \sqrt{2h_2\frac{r^2}{h_1}} = \sqrt{2\times\frac{144}{25}\times\frac{(1.5)^2}{2}} = \frac{18}{5}\text{m} = 3.6\text{ m}$$

Its position from O, when it hits the floor $= 1.5\hat{i} + 3.6\hat{j}$

$$OP = \sqrt{(1.5)^2 + (3.6)^2} = 3.9\text{ m}$$

2. (i) Just before the explosion the projectile has velocity components $v_x = v\cos\theta$, $v_y = 0$ and is at the topmost point of its trajectory.
From conservation of momentum along x-axis, we have $Mv_x = m_1 v'_{1x} + m_2 v'_{2x}$ (as $v'_{1y} = v'_{2y} = 0$)
Fragment m_1 will land back at the initial launch point if $v'_{1x} = -v_x$. Therefore,

$$v'_{2x} = \frac{Mv_x - m_1 v'_{1x}}{m_2} = \frac{M+m_1}{m_2} v_x = \frac{M+m_1}{m_2} v_{0x}$$

Time taken by m_2 to reach the ground

$$t = \sqrt{\frac{2H}{g}} = \frac{v_{0y}}{g}$$

Distance covered during this time

$$d = v'_{2x} t = \left(\frac{M+m_1}{m_2}\right) v_{0x} \cdot \frac{v_{0y}}{g} = \frac{M+m_1}{m_2} \frac{R}{2}$$

Coordinate of second fragment,

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

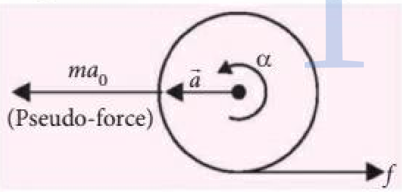
$$= \frac{6}{4} \times \frac{(35)^2}{9.81} \sin 60° \simeq 162 \text{ m}$$

(ii) The energy of the explosion is

$$\Delta E = \frac{1}{2} m_1 v'^2_x + \frac{1}{2} m_2 v'^2_{2x} - \frac{1}{2} M v_x^2 = \frac{2m_1 M}{m_2} v_{0x}^2$$

$$= \frac{2 \times 2 \times 6}{4} (35 \cos 30°)^2 \simeq 5512 \text{ J}$$

3. Let $\vec{a}$ be the acceleration of CM in reference frame of truck and α be its angular acceleration about an axis through its CM as shown in figure.



Equations of motion in reference frame of truck are

$ma_0 - f = ma$

$$a = a_0 - \frac{f}{m} \quad \text{...(i)}$$

$$\alpha = \frac{\tau}{I} = \frac{fR}{\frac{1}{2} mR^2} = \frac{2f}{mR} \quad \text{...(ii)}$$

Rolling constraint $a = R\alpha$ ...(iii)

Solving equations (i), (ii) and (iii), we get

$$a = \frac{2}{3} a_0 = \frac{2}{3}(1) = \frac{2}{3} \text{ m s}^{-2}$$

Displacement of CM of cylinder in reference frame of truck is $s = 4$m in time t given by

$$s = \frac{1}{2} a t^2 = \frac{1}{2}\left(\frac{2}{3}\right) t^2 \quad \text{or} \quad t = \sqrt{12} = 2\sqrt{3} \text{ s}$$

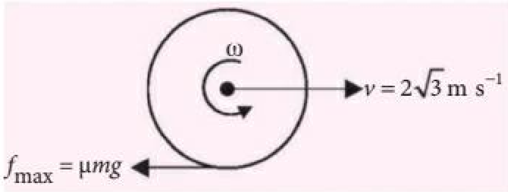
The linear velocity of the cylinder in reference frame of truck is

$$v_r = \vec{a}\, t = \left(\frac{2}{3}\right) 2\sqrt{3} = \frac{4}{\sqrt{3}} \text{m s}^{-1} \quad \text{(towards left)}$$

Velocity of truck after time t,

$$v_T = a_0 t = (1) 2\sqrt{3} = 2\sqrt{3} \text{m s}^{-1} \quad \text{(rightwards)}$$

Hence at the moment the cylinder leaves the truck, its absolute linear velocity [ground reference frame],



$$\vec{v} = v_r - v_T \frac{4}{\sqrt{3}} - 2\sqrt{3} = -\frac{2}{\sqrt{3}} \text{m s}^{-1}$$

or $\vec{v} = \dfrac{2}{\sqrt{3}}$ m s^{-1} (rightwards)

4. Applying Bernoulli's equation up and down the plate $\frac{1}{2}\rho v^2 = \frac{mg}{A}$

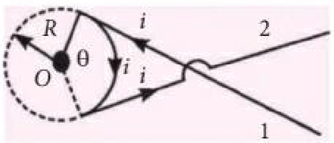
$$v = \sqrt{\frac{2mg}{\rho A}} = \sqrt{\frac{2mg \times 18}{\rho A \times 18}}$$

$$6\left(\sqrt{\frac{mg}{18\rho A}}\right) = x\sqrt{\frac{mg}{18\rho A}} \Rightarrow x = 6$$

5. Magnetic field at O due to wire 1 is, $\vec{B}_1 = \frac{\mu_0 i}{4\pi R} \odot$

and that due to wire 2 is

$$\vec{B}_2 = \frac{\mu_0 i}{4\pi R} \odot \Rightarrow \vec{B} = \vec{B}_1 + \vec{B}_2 = \frac{\mu_0 i}{2\pi R} \odot$$



Magnetic field at the centre due to circular arc subtending angle θ at the centre is given by

$$\vec{B}_{arc} = \frac{\mu_0 i}{2R}\left(\frac{\theta}{2\pi}\right) \otimes$$

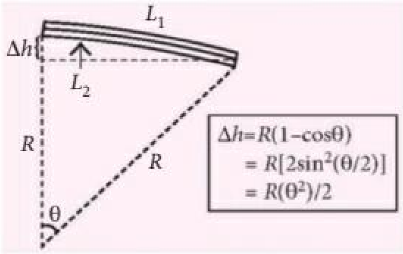
If $\vec{B}_{net} = 0 \Rightarrow \vec{B} + \vec{B}_{arc} = 0 \Rightarrow \vec{B} = -\vec{B}_{arc}$

$$\Rightarrow \frac{\mu_0 i}{2\pi R} \odot = -\frac{\mu_0 i}{2R}\left(\frac{\theta}{2\pi}\right) \otimes$$

$$\Rightarrow \frac{\mu_0 i}{2\pi R} = \frac{\mu_0 i}{2R}\left(\frac{\theta}{2\pi}\right) \Rightarrow \frac{1}{\pi} = \frac{\theta}{2\pi} \Rightarrow \theta = 2 \text{ rad}$$

6. Net current $I = 3 + 4\sqrt{2} \sin \omega t$

$$\text{Now } I_v = \sqrt{\frac{\int_0^T (3 + 4\sqrt{2} \sin \omega t)^2 dt}{T}} = 5\text{A}$$

7. 

$$L_1 = \left(R+\frac{1}{4}\right)\theta = 100(1+19\times10^{-6}\times100) \quad ...(i)$$

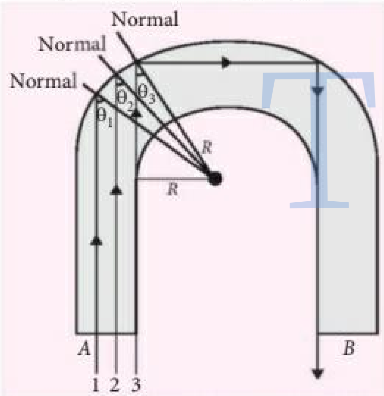
$$L_2 = \left(R-\frac{1}{4}\right)\theta = 100(1+11\times10^{-6}\times100) \quad ...(ii)$$

Subtracting equation (ii) from (i),

$\theta/2 = 100(8\times10^{-4}) \Rightarrow \theta = 16\times10^{-2} = 0.16$ rad

By geometry of figure, $\Delta h = \frac{(R\theta)\theta}{2} = 8\,\text{cm}$

8. Figure shows three rays 1, 2, 3 incident on plane face *A*. We can see that angle of incidence at curved surface is least for ray 3. If ray 3 reflects at the curved surface, then all the rays will reflect as their angle of incidence is greater than angle θ_3.



Hence the required condition is $\theta_3 \geq \theta_{critical}$

As $\sin\theta_{critical} = \frac{1}{\mu} = \frac{2}{3}$

from geometry of figure, we have, $\sin\theta_3 = \frac{R}{d+R}$

So $\sin n\,\theta_3 \geq \sin\theta_{critical}$

$\frac{R}{d+R} \geq \frac{2}{3}$ or $\frac{d}{R} \leq \frac{1}{2}$ Therefore $\left(\frac{d}{R}\right)_{maximum} = \frac{1}{2}$

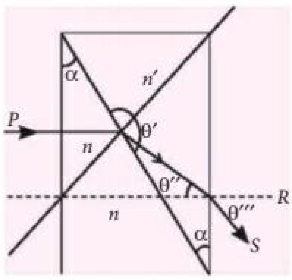
9. We will first determine the deviation produced by the system. From the figure, we see that

$n\sin\alpha = n'\sin\theta'$,

$n'\sin\theta'' = 1\cdot\sin\theta'''$.

Now, deviation of ray δ

$= (\theta' - \alpha) + (\theta''' - \theta'')$



In the given figure.

$\alpha + 90° + \theta'' + 90° - \theta' = 180° \Rightarrow \theta'' = \theta - \alpha$.

Since angle α is smal, $\theta', \theta'', \theta'''$ are also small.

$\therefore\ n\alpha = n'\theta'$ and $n'\theta'' = \theta'''$.

Solving θ', θ'' and θ''' in terms of α, $\theta' = \frac{n}{n'}\alpha$,

$\theta'' = \frac{n}{n'}\alpha - \alpha = \frac{n-n'}{n'}\alpha$ and

$\theta''' = n'\frac{n-n'}{n'}\alpha = (n-n')\alpha$.

$\therefore\ \delta = \frac{n}{n'}\alpha - \alpha + (n-n')\alpha - \left(\frac{n}{n'}\alpha - \alpha\right) = (n-n')\alpha$

If the source is at a distance *a*, then

d (distance between virtual sources)

$= 2a\delta = 2a(n-n')\alpha$.

$D = a + b$, where b = distance of screen from the system.

$\therefore\ \beta = \frac{\lambda(a+b)}{2a(n-n')\alpha} = \frac{\lambda(1+b/2)}{2(n-n')\alpha}$

For plane wave $\alpha \to \infty$.

$$\beta = \frac{\lambda}{2(n-n')\alpha} = \frac{6000\times10^{-10}}{2(1.52-1.50)\times30\times\pi/180}$$

$= 0.2864$ mm.

10. Let *x* be the elongation in the spring when it returns back.

$\frac{1}{2}kx_0^2 = \frac{1}{2}kx^2 + mg(x+x_0)$

On solving, we get

$kx = -mg \pm (mg - kx_0) = -2mg + kx_0$

(Ignoring negative sign)

And also lower block will bounce up if

$kx \geq mg \Rightarrow -2mg + kx_0 \geq mg$

So, $x_0 = \frac{3mg}{k} \Rightarrow x_0 = 9$ cm

◈◈

Monthly Test Drive CLASS XI ANSWER KEY

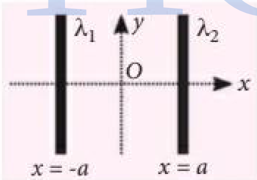
1.	(c)	**2.**	(a)	**3.**	(c)	**4.**	(d)	**5.**	(a)
6.	(a)	**7.**	(d)	**8.**	(a)	**9.**	(a)	**10.**	(d)
11.	(b)	**12.**	(b)	**13.**	(c)	**14.**	(c)	**15.**	(c)
16.	(d)	**17.**	(b)	**18.**	(c)	**19.**	(c)	**20.**	(a,c)
21.	(c,d)	**22.**	(a,d)	**23.**	(b,c,d)	**24.**	(3)	**25.**	(8)
26.	(4)	**27.**	(a)	**28.**	(b)	**29.**	(d)	**30.**	(b)

GET SET GO *for* NEET

with exclusive and brain storming MCQs

Practicing these MCQs help to strengthen your concepts and give you extra edge in your NEET preparation

1. Two positively charged infinitely long wires ($\lambda_1 > \lambda_2$) are placed parallel to each other at $x = -a$ and $x = +a$ as shown in figure. Find the x – coordinate of a point at which electric field is zero.



(a) $\frac{(\lambda_1+\lambda_2)a}{(\lambda_1-\lambda_2)}$ (b) $\frac{(\lambda_1-\lambda_2)a}{(\lambda_1+\lambda_2)}$

(c) $\frac{2(\lambda_1-\lambda_2)}{(\lambda_1+\lambda_2)}a$ (d) $\frac{(\lambda_1+\lambda_2)}{(\lambda_1-\lambda_2)a}$

2. A parallel plate capacitor is filled by a dielectric whose relative permittivity varies with the applied voltage according to the law $\mu_r = \alpha V$, where $\alpha = 1$ per volt. The same (but containing no dielectric) capacitor charged to a voltage 156 V is connected in parallel to the first non-linear uncharged capacitor. Determine the final voltage across the capacitors.

(a) 12 V (b) – 10 V

(c) – 15 V (d) – 20 V

3. A copper wire of length l and radius r is nickel plated till its final radius is $2r$. If the resistivity of the copper and nickle are ρ_c and ρ_n, then find the equivalent resistance of wire.

(a) $\left(\frac{3\rho_c+\rho_n}{\rho_c\rho_n}\right)\frac{l}{\pi r^2}$ (b) $\left(\frac{\rho_c+\rho_n}{\rho_c\rho_n}\right)\frac{l}{\pi r^2}$

(c) $\left(\frac{\rho_c\rho_n}{3\rho_c+\rho_n}\right)\frac{l}{\pi r^2}$ (d) $\left(\frac{\rho_c+\rho_n}{3\rho_c\rho_n}\right)\frac{1}{\pi r^2}$

4. The maximum intensity in Young's double slit experient is I_0. Distance between the slits is $d = 5\lambda$, where λ is the wavelength of monochromatic light used in the experiment. What will be the intensity of light in front of one of the slits on a screen at a distance $D = 10d$?

(a) I_0 (b) $2I_0$

(c) $I_0/4$ (d) $I_0/2$

5. A hydrogen like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. The value of n will be

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

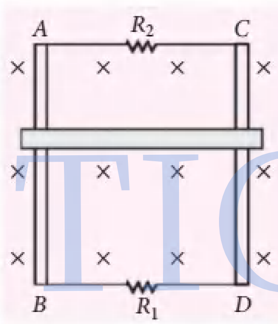
6. The displacement current flows in the dielectric of a capacitor when the potential difference across its plate

(a) is increasing with time
(b) is decreasing with time
(c) has assumed a constant value
(d) both (a) and (b).

7. The half life of a particle of mass 1.6×10^{-26} kg is 6.9 s and a stream of such particles is travelling with the kinetic energy of a particle being 0.05 eV. The fraction of particles which will decay when they travel a distance of 1 m is

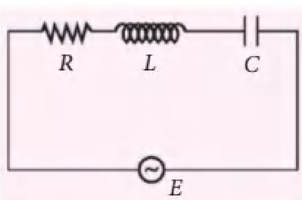
(a) 0.1 (b) 0.01
(c) 0.001 (d) 0.0001

8. Two parallel vertical metallic rails AB and CD are separated by 1 m. They are connected at the two ends by resistances R_1 and R_2 as shown in figure. A horizontal metallic bar of mass 0.2 kg slides without friction vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0.6 T perpendicular to the plane of the rails. It is observed that when the terminal velocity is attained, the power dissipated in R_1 and R_2 are 0.76 W and 1.2 W respectively. Find the terminal velocity of the bar.



(a) 1 m s^{-1} (b) 2 m s^{-1}
(c) 0.5 m s^{-1} (d) 5 m s^{-1}

9. If $E_0 = 200$ V, $R = 25\ \Omega$, $L = 0.1$ H and $C = 10^{-5}$ F and the frequency (υ) is variable, then the current at $\upsilon = 0$ and $\upsilon = \infty$ will be respectively

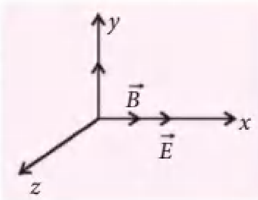


(a) 0 A, 8 A (b) 8 A, 0 A
(c) 8 A, 8 A (d) 0 A, 0 A

10. A thin prism P_1 with angle 4° and made from glass of refractive index 1.54 is combined with another prism P_2 made from glass of refractive index 1.72 to produce dispersion without deviation. What is the angle of the prism P_2?

(a) 6° (b) 3° (c) 4° (d) 9°

11. A particle of charge 1 μC and mass m = 1 g starts moving from origin at t = 0 under an electric field of 10^3 N C^{-1} along x-axis and magnetic field of 10 T along the same axis with the velocity of $\vec{v} = 20\hat{j}$ m s^{-1} as shown, the speed of the particle at the time of $20\sqrt{3}$ s will be



(a) 20 m s^{-1} (b) 40 m s^{-1}
(c) 10 m s^{-1} (d) None

12. A common emitter amplifier has a voltage gain of 50 and current gain is 25. The power gain of the amplifier is

(a) 500 (b) 1000 (c) 1250 (d) 100

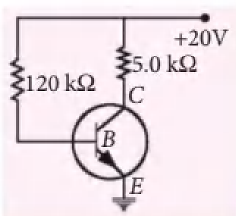
13. The combination of two bar magnets makes 10 oscillations per second in an oscillation magnetometer when like poles are tied together and 2 oscillations per second when unlike poles are tied together. Find the ratio of the magnetic moments of the magnets.

(a) $\frac{11}{10}$ (b) $\frac{13}{12}$
(c) $\frac{19}{11}$ (d) $\frac{13}{10}$

14. In a black body radiation at certain temperature T_1, the wavelength having maximum intensity of radiation equals 9000 Å. When the temperature is increased form T_1 to T_2 the total radiation increases 16 times. The peak radiation at T_2 is found to be capable of ejecting photoelectrons. The maximum kinetic energy of the photoelectrons is the same as the energy of photon that one gets when one of electrons in the M-shell of hydrogen atom jumps to L-shell. What is the work function of the metal ?

(a) 1.32 eV (b) 0.32 eV
(c) 0.88 eV (d) 6.63 eV

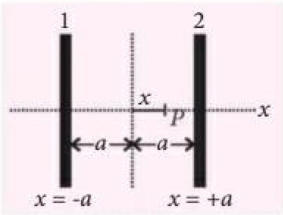
15. In the following circuit, the value of β is 200. Find the value of V_{BC}, when $I_C = 2.5$ mA. The transistor is in active cut off or saturation state.



(a) 12 V (b) 15 V (c) 17 V (d) 11 V

SOLUTIONS

1. **(b):** Let coordinates of P are $(x, 0)$.
The distance of point P from wire 1 = $(a + x)$ and from wire 2 = $(a - x)$



$\because E_1 = E_2$

$\therefore \frac{2k\lambda_1}{(a+x)} = \frac{2k\lambda_2}{(a-x)}$

$\lambda_1(a - x) = \lambda_2(a + x)$

$\lambda_1 a - \lambda_1 x = \lambda_2 a + \lambda_2 x$

$(\lambda_1 - \lambda_2)a = (\lambda_1 + \lambda_2)x$

$\therefore x = \frac{(\lambda_1 - \lambda_2)a}{(\lambda_1 + \lambda_2)}$

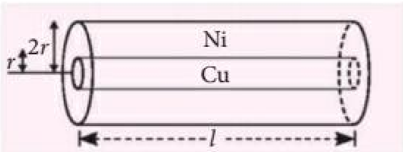
2. **(a):** From conservation of charge

$CV = (C + C')V_f \quad \Rightarrow CV = (C + \alpha V_f C)V_f$

$V_f^2 + V_f - V = 0 \quad \Rightarrow V_f^2 + V_f - 156 = 0$

$V_f = 12$ volt

3. **(c):** $R = \rho\frac{l}{A}$



Resistance of copper wire

$R_{Cu} = \rho_c \frac{l}{\pi r^2} \qquad (\because A = \pi r^2)$

Resistance of nickle wire

$\because A_{Ni} = \pi(2r)^2 - \pi r^2 = 3\pi r^2$

$R_{Ni} = \rho_n \frac{l}{3\pi r^2}$

Both wires are connected in parallel. So equivalent resistance $R = \frac{R_{Cu}R_{Ni}}{R_{Cu} + R_{Ni}} = \left(\frac{\rho_c\rho_n}{3\rho_c + \rho_n}\right)\frac{l}{\pi r^2}$

4. **(d):** Path difference $\Delta x = \frac{yd}{D}$

Here, $y = \frac{d}{2} = \frac{5\lambda}{2}$ and $D = 10d = 50\lambda$

$\therefore \Delta x = \left(\frac{5\lambda}{2}\right)\left(\frac{5\lambda}{50\lambda}\right) = \frac{\lambda}{4}$

Corresponding phase difference $\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$

$I = I_0 \cos^2\frac{\phi}{2} = I_0 \cos^2\left(\frac{\pi}{4}\right) = \frac{I_0}{2}$

5. **(b):** Let ground state energy (in eV) be E_1

Then from the given condition

$E_{2n} - E_1 = 204$ eV or $\frac{E_1}{4n^2} - E_1 = 204$ eV

$\Rightarrow \quad E_1\left(\frac{1}{4n^2} - 1\right) = 204 \text{ eV} \qquad ....(i)$

and $E_{2n} - E_n = 40.8$ eV

$\Rightarrow \quad \frac{E_1}{4n^2} - \frac{E_1}{n^2} = E_1\left(-\frac{3}{4n^2}\right) = 40.8 \text{ eV} \qquad ....(ii)$

From equation (i) and (ii),

$\frac{1 - \frac{1}{4n^2}}{\frac{3}{4n^2}} = 5 \Rightarrow n = 2$

6. **(d):** $I_D = \varepsilon_0\frac{d\phi}{dt} = \varepsilon_0\frac{AdE}{dt}$; $i_D \neq 0$ whenever $\frac{dE}{dt} \neq 0$

This will possible when potential difference across a capacitor varies.

7. **(d):** Speed of charge particle, $v = \sqrt{\frac{2K}{m}} = 10^3 \text{ m s}^{-1}$

$\frac{dN}{dt} = N\lambda \Rightarrow \frac{dN}{dt} = \lambda dt = \lambda \times \frac{1}{v}$

$= \frac{6.93}{6.9} \times 10^{-4} = 10^{-4}$

8. **(a):** The rod will acquire terminal velocity only when magnetic force $F_M = BIl$ due to electromagnetic induction balances its weight, i.e., $BIl = mg$, i.e.,

$I = \frac{0.2 \times 9.8}{0.6 \times 1} = \frac{9.8}{3}$ A

Now if ε is the *emf* induced in the rod,

$\varepsilon \times I = P = P_1 + P_2$ so, $\varepsilon = \frac{(0.76 + 1.20)}{(9.8/3)} = 0.6$ V

Now as this ε is generated due to motion of rod with terminal velocity in the magnetic field, i.e.,

$\varepsilon = Bv_T l$ so $v_T = \frac{\varepsilon}{Bl} = \frac{0.6}{0.6 \times 1} = 1 \text{ m s}^{-1}$

9. **(d)**

10. **(b):** In case of thin prism $\delta = (\mu - 1)A$, when two prisms are combined together,

$\delta = \delta_1 + \delta_2 = (\mu - 1)A + (\mu' - 1)A'$

For producing dispersion without deviation

$\delta = 0$, i.e., $(\mu' - 1)A' = -(\mu - 1)A$ or

$A' = -\frac{(1.54 - 1)}{(1.72 - 1)} \times 4° = -3°$

So the angle of the other prism is 3° and opposite to the first.

11. **(b):** As $v^2 = v_x^2 + v_y^2 = \left(\frac{qE}{m}t\right)^2 + (20)^2$

$= \left(\frac{10^{-6} \times 10^3}{10^{-3}} 20\sqrt{3}\right)^2 + (20)^2 = 1600$

$v = 40 \text{ m s}^{-1}$

12. (c) : AC power gain is ratio of change in output power to the change in input power.

AC power gain

$$= \frac{\text{Change in output power}}{\text{Change in input power}} = \frac{\Delta V_c \times \Delta i_c}{\Delta V_i \times \Delta i_b}$$

$$= \left(\frac{\Delta V_c}{\Delta V_i}\right) \times \left(\frac{\Delta i_c}{\Delta i_b}\right) = A_v \times \beta_{ac}$$

$\therefore \quad \beta_{ac} = 25 \quad A_V = 50$

Now, AC power gain $= A_v \times \beta_{ac} = 50 \times 25 = 1250$

13. (b) : $\upsilon = \frac{1}{2\pi}\sqrt{\frac{MB_H}{I}} \Rightarrow \upsilon_1 = \frac{1}{2\pi}\sqrt{\frac{(M_1 + M_2)B_H}{I_1 + I_2}}$

and $\upsilon_2 = \frac{1}{2\pi}\sqrt{\frac{(M_1 - M_2)B_H}{I_1 + I_2}}$, where $M_1 > M_2$

or, $\quad \frac{\upsilon_1^2}{\upsilon_2^2} = \frac{M_1 + M_2}{M_1 - M_2}$

or, $\quad \frac{\upsilon_1^2 + \upsilon_2^2}{\upsilon_1^2 - \upsilon_2^2} = \frac{(M_1 + M_2) + (M_1 - M_2)}{(M_1 + M_2) - (M_1 - M_2)} = \frac{M_1}{M_2}$

or, $\quad \frac{M_1}{M_2} = \frac{100 + 4}{100 - 4} = \frac{13}{12}$

14. (c) : $\frac{T_2^4}{T_1^4} = 16 \Rightarrow T_2 = 2T_1$

$\lambda_2 T_2 = \lambda_1 T_1 \quad \Rightarrow \lambda_2 = \frac{\lambda_1 T_1}{T_2} = 4500 \text{ Å}$

$\frac{hc}{\lambda_2} = \frac{12400}{4500} = \frac{124}{45} \text{ eV}$

Now according to question maximum kinetic energy of electron,

$K_{max} = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.9 \text{ eV}$

$\phi = \frac{hc}{\lambda_2} - K_{max} = \frac{124}{45} - 1.9 = 0.88 \text{ eV}$

15. (d) : $\beta = \frac{I_C}{I_B}$

$I_B = \frac{I_C}{\beta} = \frac{2.5}{200} = 0.0125 \text{ mA}$

Applying Kirchhoff's law to base emitter loop,

$V_{CE} = V_C - I_C R_C$

$= 20 - (2.5 \times 10^{-3}) \times (5 \times 10^3) = 7.5 \text{ V}$

$V_{BE} = V_B - I_B R_B$

$= 20 - (0.0125 \times 10^{-3}) \times (120 \times 10^3) = 18.5 \text{ V}$

$\therefore \quad V_{BC} = (V_{BE} - V_{CE}) = (18.5 - 7.5) = 11 \text{ V}$

◇◇

BOOST your NEET score

Practice Paper 2020

1. Turpentine oil is flowing through a tube of length L and radius r. The pressure difference between the two ends of the tube is p; the viscosity of the oil is given by $\eta = \frac{p(r^2 - x^2)}{4vL}$, where v is the velocity of oil at a distance x from the axis of the tube. From this relation, the dimensions of viscosity η are
(a) $[M^0L^0T^0]$ (b) $[MLT^{-1}]$
(c) $[ML^2T^{-2}]$ (d) $[ML^{-1}T^{-1}]$

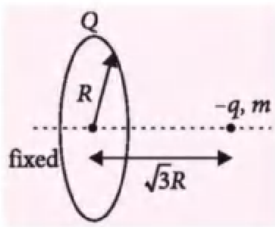
2. A body of mass 5 kg, initially at rest, explodes and breaks into three fragments of masses in the ratio 1 : 1 : 3. The two fragments of equal masses fly off perpendicular to each other, each with a velocity of 21 m s^{-1}. The velocity of heavier fragment is
(a) 6.5 m s^{-1} (b) 7 m s^{-1}
(c) 9.87 m s^{-1} (d) 11.5 m s^{-1}

3. A weightless spring of length 60 cm and force constant 100 N m^{-1} is kept straight and unstretched on a smooth horizontal table and its ends are rigidly fixed. A mass of 0.25 kg is attached at the middle of the spring and is slightly displaced along the length. The time period of the oscillation of the mass is
(a) $\frac{\pi}{20}$ (b) $\frac{\pi}{10}$ s (c) $\frac{\pi}{5}$ s (d) $\frac{\pi}{\sqrt{200}}$ s

4. A ball is bouncing down a flight of stairs. The coefficient of restitution is e. The height of each step is d and the ball descends one step for each bounce. After each bounce it rebounds to a height h above the next lower step. The height is large enough compared with the width of step so that the impacts are effectively head-on. The relationship between h and d is
(a) $h = \frac{d}{1-e^2}$ (b) $h = \frac{d}{1+e^2}$
(c) $h = \frac{d}{1+e}$ (d) $h = \sqrt{\frac{d}{1-e^2}}$

5. The binding energy per nucleon of ${}_5B^{10}$ is 8 MeV and that of ${}_5B^{11}$ is 7.5 MeV. The energy required to remove a neutron from ${}_5B^{11}$ is
(Mass of electron and proton are 9.11×10^{-31} kg and 1.67×10^{-27} kg respectively.)
(a) 2.5 MeV (b) 8.0 MeV
(c) 0.5 MeV (d) 7.5 MeV

6. A point charge $-q$ of mass m is released with negligible speed from a distance $\sqrt{3}R$ on the axis of a fixed uniformly charged ring of charge Q and radius R. Find out its velocity when it reaches the centre of the ring. $\left(\text{Here } k = \frac{1}{4\pi\varepsilon_0}\right)$



(a) $\sqrt{\frac{kQq}{mR}}$ (b) $\sqrt{\frac{kq}{mR}}$ (c) $\sqrt{\frac{kq}{mQR}}$ (d) $\sqrt{\frac{kR}{mq}}$

7. A parallel plate capacitor is made by stacking n equally spaced plates, connected alternatively. If the capacitance between any two plates is x, then the total capacitance is
(a) $n\,x$ (b) n/x (c) n^2x (d) $(n - 1)\,x$

8. Two unlike charges of the same magnitude Q are placed at a distance d. The intensity of the electric field at the middle point of the line joining the two charges is
(a) zero (b) $\frac{8Q}{4\pi\varepsilon_0 d^2}$
(c) $\frac{6Q}{4\pi\varepsilon_0 d^2}$ (d) $\frac{4Q}{4\pi\varepsilon_0 d^2}$

9. A rod of length L and mass M is bent to form a semicircular ring as shown in figure. The moment of inertia about XY is

(a) $\frac{ML^2}{2\pi^2}$ (b) $\frac{ML^2}{\pi^2}$

(c) $\frac{ML^2}{4\pi^2}$ (d) $\frac{2ML^2}{\pi^2}$

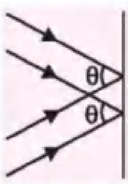
10. The transverse displacement equation of a string clamped at its both ends is given by

$$y(x, t) = 0.06 \sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$$

where x and y are in m and t in s. The length of the string is 1.5 m and its mass is 3×10^{-2} kg. The tension in the string is

(a) 324 N (b) 648 N (c) 832 N (d) 972 N

11. Two parallel beams of light of wavelength λ, inclined to each other at angle θ (<<1), are incident on a plane at nearly normal incidence. The fringe width will be



(a) $\frac{\lambda}{2\theta}$ (b) $\frac{2\lambda}{\theta}$ (c) $\frac{\lambda}{\theta}$ (d) $2\lambda \sin\theta$

12. An object of height 1 cm is kept perpendicular to the principal axis of a convex mirror of radius of curvature 20 cm. If the distance of the object from the mirror is 20 cm then the distance (in cm) between heads of the image and the object will be

(a) $\sqrt{\frac{6404}{9}}$ (b) $\sqrt{\frac{6414}{9}}$

(c) $\frac{40}{3}$ (d) None of these

13. The wavelength of the first Balmer line caused by a transition of electron from the $n = 3$ level to $n = 2$ level in hydrogen is λ_1. The wavelength of the line caused by an electronic transition from $n = 5$ to $n = 3$ is

(a) $\frac{375}{128}\lambda_1$ (b) $\frac{125}{64}\lambda_1$ (c) $\frac{64}{125}\lambda_1$ (d) $\frac{128}{375}\lambda_1$

14. Two cars are moving in the same direction with a speed of 30 km h^{-1}. They are separated from each other by 5 km. Third car moving in the opposite direction meets the two cars after an interval of 4 minutes. What is the speed of the third car?

(a) 35 km h^{-1} (b) 40 km h^{-1}

(c) 45 km h^{-1} (d) 75 km h^{-1}

15. Starting from rest, a body slides down a rough inclined plane of inclination 45° in twice the time it takes to slide down the same plane in the absence of friction. The coefficient of friction between the body and the inclined plane is

(a) 0.75 (b) 0.33 (c) 0.25 (d) 0.80

16. The relation $3t = \sqrt{3x} + 6$; describes the displacement of a particle in one direction where x is in metre and t in second. The displacement, when velocity is zero, is

(a) 24 m (b) 12 m (c) 5 m (d) zero

17. Three particles, each having a mass of 100 gram, are placed on the vertices of an equilateral triangle of side 20 cm. The work done in increasing the side of this triangle to 30 cm is ($G = 6{\cdot}6 \times 10^{-11}$ N m^2 kg^{-2})

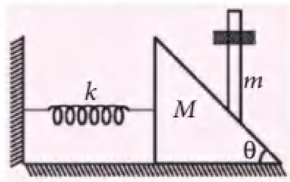
(a) $3{\cdot}3 \times 10^{-11}$ J (b) $3{\cdot}3 \times 10^{-12}$ J

(c) $9{\cdot}9 \times 10^{-12}$ J (d) $6{\cdot}6 \times 10^{-13}$ J

18. The temperature of a radiating body increases by 30%. Then, the increase in the amount of radiation emitted will be approximately

(a) 185% (b) 285% (c) 325% (d) 245%

19. A wedge of mass M fitted with a spring of stiffness constant k, is kept on a smooth horizontal surface. A rod of mass m is kept on the wedge as shown in the figure. System is in equilibrium and at rest. Assuming that all surfaces are smooth, the potential energy stored in the spring is



(a) $\frac{mg^2 \tan^2\theta}{2k}$ (b) $\frac{m^2 g \tan^2\theta}{2k}$

(c) $\frac{m^2g^2 \tan^2\theta}{2k}$ (d) $\frac{m^2g^2 \tan^2\theta}{k}$

20. Two symmetrical double convex lenses A and B have same focal length, but the radii of curvature differ so that $R_A = 0.9\, R_B$. If $\mu_A = 1.63$, find μ_B.

(a) 1.7 (b) 1.6 (c) 1.5 (d) 4/3

21. The length of a potentiometer wire is l. A cell of emf E is balanced at a length $l/5$ from the positive end of the wire. If length of the wire is increased by $l/2$, at what distance will the same cell give a balance point?

(a) $\frac{2}{15}l$ (b) $\frac{3}{15}l$ (c) $\frac{3}{10}l$ (d) $\frac{4}{10}l$

22. A wire of length 50 cm moves with a velocity of 300 m min^{-1}, perpendicular to a magnetic field. If the emf induced in the wire is 2 V, the magnitude of the magnetic field in tesla is

(a) 0.8 (b) 5 (c) 0.4 (d) 2.5

23. A particle of mass m is kept at rest, at a height $3R$ from the surface of earth of radius R and mass M. The minimum speed with which it should be projected, so that it does not return back, is (g is acceleration due to gravity on the surface of the earth)

(a) $\left(\frac{GM}{2R}\right)^{1/2}$ (b) $\left(\frac{gR}{4}\right)^{1/2}$

(c) $\left(\frac{2g}{R}\right)^{1/2}$ (d) $\left(\frac{GM}{R}\right)^{1/2}$

24. When 1 kg of ice at 0°C melts to water at 0°C, the resulting change in its entropy, taking latent heat of ice to be 80 cal g^{-1} is

(a) 273 cal K^{-1} (b) 8×10^4 cal K^{-1}

(c) 80 cal K^{-1} (d) 293 cal K^{-1}

25. The Young's double slit experiment is performed with blue and green light of wavelengths 4360 Å and 5460 Å, respectively. If X is the distance of 4^{th} maximum from the central one, then

(a) $X(\text{blue}) = X(\text{green})$ (b) $X(\text{blue}) > X(\text{green})$

(c) $X(\text{blue}) < X(\text{green})$ (d) $\frac{X(\text{blue})}{X(\text{green})} = \frac{5460}{4360}$

26. A body, projected horizontally with a speed u from the top of a tower of height h, reaches the ground at a horizontal distance R from the tower. Another body, projected horizontally from the top of a tower of height $4h$, reaches the ground at horizontal distance $2R$ from the tower. The initial speed of the second body is

(a) u (b) $2u$

(c) $3u$ (d) $4u$

27. Two bulbs of power 40 watt and 60 watt, and rated voltage 240 V, are connected in series across a potential difference of 420 V. Which bulb will work above its rated voltage?

(a) 40 W (b) 60 W

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

28. From a certain apparatus, the diffusion rate of hydrogen has an average value of 28.7 $cm^3\ s^{-1}$. The diffusion of another unknown gas, under the same conditions, is measured to have an average diffusion rate of 7.2 $cm^3\ s^{-1}$. The unknown gas is

(a) H_2 (b) F_2

(c) O_2 (d) Cl_2

29. A charged particle moving in a uniform magnetic field penetrates a layer of lead and thereby loses one half of its kinetic energy. How does the radius (r) of curvature of its path change?

(a) The radius increases to $r\sqrt{2}$.

(b) The radius reduces to $\frac{r}{\sqrt{2}}$.

(c) The radius remains the same.

(d) The radius become $r/2$.

30. A uniformly wound coil of self inductance 1.2×10^{-4} H and resistance 3 Ω is broken up into two identical coils. These coils are then connected in parallel across a 6 V battery of negligible resistance. The time constant for the current in the circuit is (neglect mutual inductance)

(a) 0.4×10^{-4} s (b) 0.2×10^{-4} s

(c) 0.5×10^{-4} s (d) 0.1×10^{-4} s

31. The angle of a prism is 60°. When light is incident at an angle of 60° on the prism, the angle of emergence is 40°. The angle of incidence i for which the light ray will deviate the least is such that

(a) $i < 40°$ (b) $40° < i < 50°$

(c) $50° < i < 60°$ (d) $i > 60°$

32. A particle of mass m is fixed to one end of a massless spring of spring constant k and natural length l_0. The system is rotated about the other end of the spring with an angular velocity ω, in gravity free space. The final length of spring is

(a) $\frac{m\omega^2 l_0}{k}$ (b) $\frac{m\omega^2 l_0}{k - m\omega^2}$

(c) $\frac{kl_0}{k - m\omega^2}$ (d) $\frac{m\omega^2 l_0}{k + m\omega^2}$

33. Angular width (θ) of central maximum of a diffraction pattern for a single slit does not depend upon

(a) distance between slit and source

(b) wavelength of light used

(c) width of the slit (d) frequency of light used

34. A radioactive nucleus is being produced at a constant rate of α per second. Its decay constant is λ. If N_0 are the number of nuclei at time t = 0, then maximum number of nuclei possible are

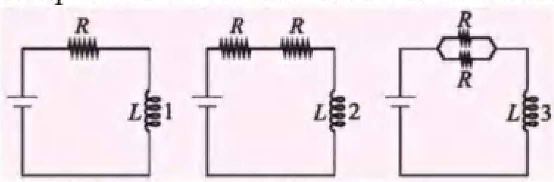
(a) $\frac{\alpha}{\lambda}$ (b) $N_0 + \frac{\alpha}{\lambda}$ (c) N_0 (d) $\frac{\lambda}{\alpha} + N_0$

35. An α particle is moving along a circle of radius R with a constant angular velocity ω. Point A lies in the same plane at a distance $2R$ from the centre. Point A records magnetic field produced by α particle. If the minimum time interval between two successive times at which A records zero magnetic field is t, the angular speed ω, in terms of t is

(a) $\frac{2\pi}{t}$ (b) $\frac{2\pi}{3t}$ (c) $\frac{3\pi}{2t}$ (d) $\frac{\pi}{t}$

36. A horizontal rod of length 1 m is rotated about a vertical axis, passing through one of its ends. The number of revolutions per second at which the rod breaks is (Breaking stress of material of rod = 3×10^9 N m^{-2} and density of material of rod = 6000 kg m^{-3})
(a) 1000 rps (b) 318.2 rps
(c) 159 rps (d) 259 rps

37. The figure shows three circuits with identical batteries, inductors and resistors. Rank the circuits according to the time for the current to rise to 30% of its equilibrium value after the switch is closed.



(a) $1 > 3 > 2$ (b) $3 > 1 > 2$
(c) $3 > 2 > 1$ (d) $1 > 2 > 3$

38. Consider atoms H, He^+, Li^{++} in their ground states. If L_1, L_2 and L_3 are magnitudes of angular momentum of their electrons about the nucleus respectively, then
(a) $L_1 = L_2 = L_3$ (b) $L_1 > L_2 > L_3$
(c) $L_1 < L_2 < L_3$ (b) $L_1 > L_2 > L_3$

39. There exists a uniform magnetic and electric field of magnitude 1 T and 1 V m^{-1}, respectively, along positive y-axis. A charged particle of mass 1 kg and charge 1 C is having velocity of 1 m s^{-1} along x-axis and is at origin at $t = 0$. Then the coordinates of particle at time π seconds will be
(a) $(0, 1, 2)$ (b) $(0, -\pi^2/2, -2)$
(c) $(2, \pi^2/2, 2)$ (d) $(0, \pi^2/2, 2)$

40. Electrons in an oscilloscope are deflected by two mutually perpendicular oscillating electric fields such that at any time, the displacements due to them are given by $x = A\cos\omega t$, $y = A\sin\left(\omega t + \frac{\pi}{6}\right)$.
Then the path of the electrons is
(a) a straight line having the equation $x = y$
(b) a circle having the equation $x^2 + y^2 = A^2$
(c) an ellipse having the equation
$$x^2 - \sqrt{3}xy + y^2 = \frac{A^2}{4}$$
(d) an ellipse having the equation
$$x^2 - xy + y^2 = \frac{3A^2}{4}$$

41. A vessel of height $2d$ is half-filled with a liquid of refractive index $\sqrt{2}$ and the other half with a liquid of refractive index n. (The given liquids are immiscible). Then, the apparent depth of the inner surface of the bottom of the vessel (neglecting the thickness of the bottom of the vessel) will be
(a) $\frac{n}{d(n+\sqrt{2})}$ (b) $\frac{d(n+\sqrt{2})}{n\sqrt{2}}$
(c) $\frac{\sqrt{2}n}{d(n+\sqrt{2})}$ (d) $\frac{nd}{d+\sqrt{2}n}$

42. A wire of length l is moving with a constant velocity $\vec{v}$ in a magnetic field. A potential difference appears across the two ends if
(a) $\vec{v} \parallel \vec{l}$ (b) $\vec{v} \parallel \vec{B}$
(c) $\vec{l} \parallel \vec{B}$ (d) none of these

43. A 5 W source emits monochromatic light of wavelength 5000 Å. When placed 0.5 m away, it liberates photoelectrons from a photosensitive metallic surface. When the source is moved to a distance of 1.0 m, the number of photoelectrons liberated will be reduced by a factor of
(a) 8 (b) 16 (c) 2 (d) 4

44. The pressure of water in a pipe when the tap is closed and open are 4.5×10^5 N m^{-2} and 4.0×10^5 N m^{-2} respectively. With the open tap, the velocity of water flowing out is
(Take density of water = 10^3 kg m^{-3})
(a) 5 m s^{-1} (b) 10 m s^{-1}
(c) 15 m s^{-1} (d) 20 m s^{-1}

45. The electric field of an electromagnetic wave is given by $E = (50 \text{ N C}^{-1}) \sin\omega(t - x/c)$.
The energy contained in a cyclinder of cross-section 10 cm^2 and length 50 cm along the x-axis is
(a) 5.5×10^{-10} J (b) 5.5×10^{-11} J
(c) 5.5×10^{-12} J (d) 5.5×10^{-13} J

SOLUTIONS

1. (d) : $[\eta] = \frac{[ML^{-1}T^{-2}][L^2]}{[LT^{-1}][L]} = [ML^{-1}T^{-1}]$

2. (c) : Since 5 kg body explodes into three fragments of masses in the ratio 1 : 1 : 3, hence masses of the three fragments will be 1 kg, 1 kg and 3 kg, respectively. The magnitude of resultant momentum of two fragments each of mass 1 kg, moving with velocity 21 m s^{-1} in perpendicular direction is $21\sqrt{2}$ kg m s^{-1}.
According to law of conservation of linear momentum,
$3 \times v = 21\sqrt{2}$ or $v = 21\sqrt{2}/3 = 7\sqrt{2} = 9.87$ m s^{-1}

3. (a) : Given $K = 100\ \text{N m}^{-1}$; When a mass (m) of 0.25 kg is attached at the middle of spring, it will work as the combination of two equal springs in parallel, each of force constant $k = 2K = 2 \times 100 = 200\ \text{N m}^{-1}$

Total force constant of system,

$k' = k + k = 200 + 200 = 400\ \text{N m}^{-1}$

$\therefore$ Time period, $T = 2\pi\sqrt{\frac{m}{k'}} = 2\pi\sqrt{\frac{0.25}{400}} = \frac{\pi}{20}$ s

4. (a) : The ball falls a distance h from its highest (rest) position and rebounds to a distance $(h - d)$.

$V_{\text{initial}} = (2gh)^{\frac{1}{2}}$, $V_{\text{final}} = [2g(h-d)]^{1/2}$

$\therefore\ e = \frac{V_{\text{final}} - 0}{V_{\text{initial}} - 0}$ (Velocity of stairs is zero)

Thus, the coefficient of restitution, $e = \sqrt{\frac{h-d}{h}}$

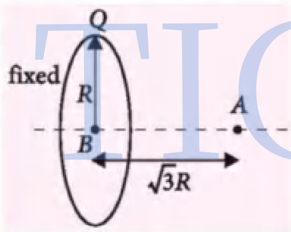
or $e^2 = \frac{h-d}{h}$ or $e^2 = 1 - \frac{d}{h}$ or $\frac{d}{h} = 1 - e^2$ or $h = \frac{d}{1-e^2}$

5. (a) : Total binding energy of $_5B^{10}$ nucleus, $= 10 \times 8 = 80$ MeV

Total binding energy of $_5B^{11}$ nucleus, $= 11 \times 7.5 = 82.5$ MeV

Energy required to remove newtron from $_5B^{11}$ nucleus $= 82.5 - 80 = 2.5$ MeV

6. (a) : As potential due to uniformly charged ring at its axis (at distance x) is



$V = \frac{kQ}{\sqrt{R^2 + x^2}}$;

So, potential at point A due to ring

$V_1 = \frac{kQ}{\sqrt{R^2 + 3R^2}} = \frac{kQ}{2R}$

So, potential energy of charge $-q$ at point A

$\text{P.E.}_1 = \frac{-kQq}{2R}$ Potential at centre B, $V_2 = \frac{kQ}{R}$

So, potential energy of charge $-q$ at point B $\text{P.E.}_2 = \frac{-kQq}{R}$

Now by law of conservation of energy

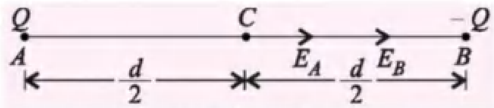
$\text{P.E.}_1 + \text{K.E.}_1 = \text{P.E.}_2 + \text{K.E.}_2$

$\frac{-kQq}{2R} + 0 = \frac{-kQq}{R} + \frac{1}{2}mv^2 \Rightarrow v^2 = \frac{kQq}{mR}$

So, velocity of charge $-q$ at point B, $v = \sqrt{\frac{kQq}{mR}}$

7. (d) : As the plates are connect alternately, positive plate of all $(n-1)$ capacitors are connected to one point and negative plate of all $(n-1)$ capacitors are connected to the other point, *i.e.*, all the $(n-1)$ capacitors are joined in parallel. Therefore, total capacitance $C_p = (n-1)x$.

8. (b) :



The magnitude of electric field due to charge at the point A is $E_A = |\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\left(\frac{d}{2}\right)^2} = \frac{1}{4\pi\varepsilon_0}\frac{4Q}{d^2}$

The magnitude of electric field due to charge at the point B is $E_B = |\vec{E}| = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\left(\frac{d}{2}\right)^2}$

The resultant electric field at point C due to two charges is $E_{\text{resultant}} = \sqrt{E^2 + E^2 + 2EE\cos 0°}$

$= \sqrt{(E^2 + E^2 + 2E^2)} = \sqrt{4E^2} = 2E = \frac{1}{4\pi\varepsilon_0}\frac{8Q}{d^2}$

9. (a) : A rod of length L is bent to form a semicircular ring of radius R,

$\therefore\ \pi R = L$ or $R = \frac{L}{\pi}$

Mass of semicircular ring = Mass of rod = M

Moment of inertia about $XY = \frac{1}{2}(MR^2)$

$= \frac{1}{2}M\left(\frac{L}{\pi}\right)^2 = \frac{ML^2}{2\pi^2}$

10. (b) : The given equation is

$y(x,t) = 0.06\sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t)$

Comparing it with $y(x, t) = 2a\sin kx\cos\omega t$

we get, $k = \frac{2\pi}{3}$ or $\frac{2\pi}{\lambda} = \frac{2\pi}{3}$ or $\lambda = 3$ m

and $\omega = 120\pi$ or $2\pi\upsilon = 120\pi$ or $\upsilon = 60\ \text{Hz} = 60\ \text{s}^{-1}$

Velocity of wave, $v = \upsilon\lambda = (60\ \text{s}^{-1})(3\ \text{m}) = 180\ \text{m s}^{-1}$

Mass per unit length of the string,

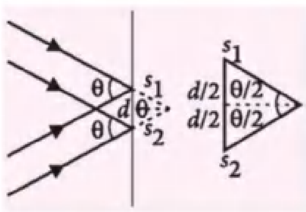
$\mu = \frac{3 \times 10^{-2}\ \text{kg}}{1.5\ \text{m}} = 2 \times 10^{-2}\ \text{kg m}^{-1}$

Velocity of transverse wave in the string,

$v = \sqrt{\frac{T}{\mu}}$ or $v^2 = \frac{T}{\mu}$ or $T = v^2\mu$

$T = (180\ \text{m s}^{-1})^2(2 \times 10^{-2}\ \text{kg m}^{-1}) = 648$ N

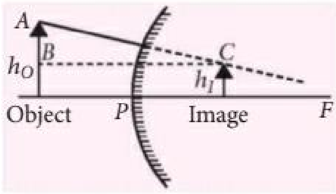
11. (c) : $\tan\frac{\theta}{2} = \frac{d/2}{D}$



$\therefore\ \theta = \frac{d}{D}$ ($\because \tan\frac{\theta}{2} \sim \frac{\theta}{2}$)

$\beta = \frac{\lambda D}{d}$; $\beta = \frac{\lambda}{\theta}$

12. (a) : $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$



$=\frac{1}{10}-\frac{1}{(-20)}=+\frac{3}{20};$

$v=+\frac{20}{3}$ cm

$h_I=-\frac{v}{u}\times h_O=-\frac{\frac{20}{3}}{(-20)}\times 1=\frac{1}{3}$

$\therefore$ The distance between heads of the object and image is

$$AC=\sqrt{(BC)^2+(AB)^2}$$

$$S=\sqrt{\left(20+\frac{20}{3}\right)^2+\left(1-\frac{1}{3}\right)^2}=\sqrt{\frac{6404}{9}}\text{ cm}$$

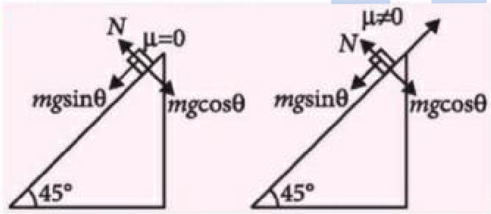
13. (b) : $\frac{\lambda_2}{\lambda_1}=\frac{\frac{1}{2^2}-\frac{1}{3^2}}{\frac{1}{3^2}-\frac{1}{5^2}}=\frac{\frac{1}{4}-\frac{1}{9}}{\frac{1}{9}-\frac{1}{25}}=\frac{125}{64}\Rightarrow \lambda_2=\frac{125}{64}\lambda_1$

14. (c) : Relative velocity between either car (1^{st} or 2^{nd}) and 3^{rd} car = u + 30 where u = velocity of 3^{rd} car
Relative displacement = 5 km
Time interval = 4 min

$\therefore\ u+30=\frac{5}{4}\text{km min}^{-1}=\frac{5\times 60}{4}\text{km h}^{-1}=75$

$\Rightarrow\ u=45\text{ km h}^{-1}$

15. (a) :



Let acceleration in 1^{st} case is a_1 and that in second case is a_2.

Now, $\frac{1}{2}a_2t^2=\frac{1}{2}a_1(2t)^2\ \Rightarrow\ a_2=\frac{a_1}{4}$ ...(i)

Clearly, $a_1=\frac{mg\sin\theta}{m}=g\sin\theta$ ...(ii)

$a_2=\frac{mg\sin\theta-\mu mg\cos\theta}{m}=g\sin\theta-\mu g\cos\theta$ ...(iii)

From (i), (ii) and (iii), we get μ = 0.75.

16. (d) : $3t=\sqrt{3x}+6;\ x=3(t-2)^2$

$v=\frac{dx}{dt}=6(t-2)$

When $v=0\Rightarrow t=2$ s
At t = 2 s, x = 0

17. (b) **18. (a)**

19. (c) : For m, $N\cos\theta=mg$
For M, $N\sin\theta=kx$

So, $\tan\theta=\frac{kx}{mg}\Rightarrow x=\frac{mg\tan\theta}{k}$

So, potential energy stored in the spring is

$$\frac{1}{2}kx^2=\frac{(mg\tan\theta)^2}{2k}$$

20. (a) : $\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

$\frac{1}{f}=(1.63-1)\left(\frac{2}{R_A}\right)=(\mu_B-1)\left(\frac{2}{R_B}\right)$

$\mu_B-1=0.63\times\frac{R_B}{R_A}=\frac{0.63}{0.9}=0.7$ or $\mu_B=1.7$

21. (c) : In first case, potential gradient, $k=E/l$, where E is the emf of the battery in potentiometer circuit. As per question

$E_1=\frac{kl}{5}=\frac{E}{l}\times\frac{l}{5}=\frac{E}{5}$

In second case, length of potentiometer wire $=l+\frac{l}{2}=\frac{3l}{2}$

Potential gradient, $k'=\frac{E}{3l/2}=\frac{2E}{3l}\quad\therefore\quad E_2=\frac{2E}{3l}\times l'$

Where l' is the new balancing length

$\frac{E}{5}=\frac{2E}{3l}\times l',\ \Rightarrow\ l'=\frac{3l}{10}$ $(\because E_1=E_2)$

22. (a) : When a wire of length l moves with velocity v, perpendicular to a magnetic field B, the induced emf is produced. The magnitude of induced emf is given by $|\varepsilon|=Blv$

Given : l = 50 cm = 0.5 m, v = 300 m min^{-1} = 5 m s^{-1}

$|\varepsilon|$ = 2 V.

$\therefore\quad B=\frac{|\varepsilon|}{lv}=\frac{2}{0.5\times 5}=0.8$ tesla

23. (a) : Escape speed is given by $v_e=\sqrt{\frac{2GM}{(R+h)}}$

($\because$ h = height of the object from earth's surface)

Here, h = 3R

$\therefore\quad v_e=\sqrt{\frac{2GM}{(R+3R)}}=\sqrt{\frac{GM}{2R}}=\sqrt{\frac{gR}{2}}$

24. (d) : Heat required to melt 1 kg ice at 0°C to water at 0°C is

$Q=m_{ice}L_{ice}$ = (1 kg) (80 cal g^{-1})
= (1000 g) (80 cal g^{-1}) = 8 × 10^4 cal

Change in entropy, $\Delta S=\frac{Q}{T}=\frac{8\times 10^4\text{ cal}}{(273\text{ K})}=293\text{ cal K}^{-1}$

25. (c) : Fourth maxima will be at $X = 4\beta$.

$$\Rightarrow \quad X = \frac{4\lambda D}{d}$$

as $\lambda_{green} > \lambda_{blue}$.

$\Rightarrow \beta_{green} > \beta_{blue} \Rightarrow X(\text{Green}) > X(\text{Blue})$

Also, $\frac{X(\text{blue})}{X(\text{green})} = \frac{4360}{5460}$

26. (a) : $y = \frac{gx^2}{2u^2}$, $h = \frac{gR^2}{2u^2}$, $4h = \frac{g(2R)^2}{2u_1^2}$ or $u_1 = u$

27. (a) : $R_{(40)} = \frac{(240)^2}{40}$, $R_{(60)} = \frac{(240)^2}{60}$

Since they are in series

$$R_{eq} = (240)^2\left[\frac{1}{40} + \frac{1}{60}\right] = \frac{(240)^2}{24}$$

$$\text{Current} = \frac{420 \times 24}{240 \times 240} = \frac{42}{240} = \frac{21}{120}$$

Potential difference across 40 watt bulb

$$= \frac{21}{120} \times \frac{240 \times 240}{40} = 252 \text{ V}$$

Potential difference across 60 watt bulb = 420 – 252 = 168 V.

Since potential difference across 40 watt bulb is greater than 240 V, so it will work above its rated voltage.

28. (c) : According to Graham's law of diffusion,

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} \quad \text{or} \quad M_2 = M_1\frac{r_1^2}{r_2^2}$$

where r_1 and r_2 are the diffusion rates of gases.

$$\therefore \quad M_2 = 2 \times \frac{(28.7)^2}{(7.2)^2} = 31.78 \approx 32 \text{ u}$$

This is the molecular mass of oxygen gas (O_2).

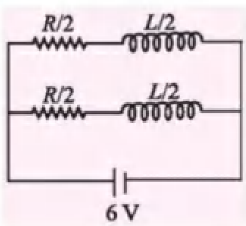
29. (b) : Radius of given charged particle, $r = \sqrt{2mE}/Bq$ ...(i)

Radius of given charged particle after losing half of its kinetic energy is $r_1 = \sqrt{2m(E/2)}/Bq$ ...(ii)

From eqn. (i) and (ii), $r_1 = r/\sqrt{2}$

30. (a) : Here $R = 3\ \Omega$, $L = 1.2 \times 10^{-4}$ H

When the coil is broken up into two identical coils, each coil will have resistance ($R/2$) and inductance ($L/2$). These coils are connected in parallel across 6 V as shown in figure. As the resistances are in parallel, their equivalent resistance is

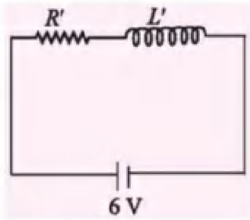


$$\frac{1}{R'} = \frac{1}{(R/2)} + \frac{1}{(R/2)} \quad \text{or} \quad R' = \frac{R}{4}$$

As the inductances are in parallel, its equivalent inductance is

$$\frac{1}{L'} = \frac{1}{(L/2)} + \frac{1}{(L/2)} \quad \text{or} \quad L' = \frac{L}{4}$$

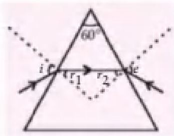
The equivalent circuit is shown in the figure.



$$\text{Time constant, } \tau = \frac{L'}{R'} = \frac{(L/4)}{(R/4)} = \frac{L}{R} = \frac{1.2 \times 10^{-4}}{3}$$

$$= 0.4 \times 10^{-4} \text{ s}$$

31. (b) : For minimum deviation, $i = e$



$$r_1 = r_2 = \frac{A}{2}$$

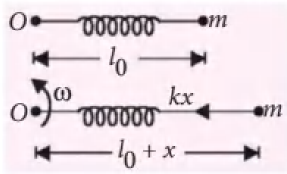
$\therefore \quad r_1 = r_2 = 30°$

For minimum deviation, i should lie between 40° to 50°

32. (c) : $kx = m\omega^2(l_0 + x)$

or $\quad kx = m\omega^2 l_0 + m\omega^2 x$

or $\quad (k - m\omega^2)x = m\omega^2 l_0$



$$x = \frac{m\omega^2 l_0}{k - m\omega^2}$$

$$\text{Final length} = l_0 + x = l_0 + \frac{m\omega^2 l_0}{k - m\omega^2} = \frac{kl_0}{k - m\omega^2}$$

33. (a) : Angular width of central maximum

$$\theta = \frac{\beta}{D} = \frac{2\lambda D}{aD} = \frac{2\lambda}{a}$$

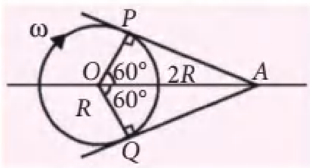
Hence, θ does not depend upon D, *i.e.*, distance between slit and source.

34. (a) : Maximum number of nuclei will be present when rate of decay = rate of formation

$$\lambda N = \alpha \quad \Rightarrow \quad N = \frac{\alpha}{\lambda}$$

35. (b) : Point A shall record zero magnetic field (due to α-particle) when the α-particle is at position P and Q as shown in figure.

The time taken by α particle to go from P to Q is



$$t = \frac{1}{3}\frac{2\pi}{\omega} \quad \text{or} \quad \omega = \frac{2\pi}{3t}$$

36. (c) : The centrifugal force due to rotation of rod will act at the centre of gravity of rod, *i.e.*, at length $l/2$ from the fixed end of rod.

Maximum centrifugal force, $F_{max} = m\omega^2\ (l/2)$

$= A\, l\, \rho \times 4\pi^2 \upsilon^2 \times l/2 = 2\, A\, l^2 \pi^2 \rho\, \upsilon^2$ ...(i)

F_{max} = breaking stress × area of cross-section = $3 \times 10^9 \times A$ ...(ii)

From eqn. (i) and (ii)

$2\,A\,l^2\,\pi^2\,\rho\,\upsilon^2 = 3\times10^9\times A$

$$\upsilon=\sqrt{\frac{3\times10^9}{2l^2\pi^2\rho}}=\sqrt{\frac{3\times10^9}{2\times1^2\times(3\cdot142)^2\times6000}}=159\,\text{rps}$$

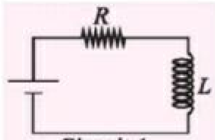
37. (b) : The growth of current in LR circuit is given by

$I=I_0\,(1-e^{-t/\tau})$

where τ is the time constant, I_0 is the maximum value of a current

Also, $\tau = L/R$

For circuit 1



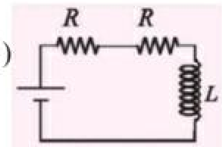
Circuit 1

$\tau_1 = L/R;\ I=I_0[1-e^{-t_1/\tau_1}]$

$\therefore\ \frac{30}{100}I_0 = I_0\left(1-e^{-\frac{Rt}{L}}\right)$

or $e^{-\frac{Rt_1}{L}} = 0.7$ or $\left(\frac{-Rt_1}{L}\right)=\ln(0.7)$ or $t_1=0.36\frac{L}{R}$

In circuit 2, resistances are connected in series



Circuit 2

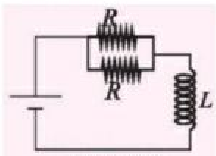
$\therefore\ R_S = 2R$

$t_2=\frac{L}{R_S}=\frac{L}{2R}\ \ \therefore\ I = I_0\,(1-e^{-t_2/\tau_2})$

$\Rightarrow\ \frac{30}{100}I_0=I_0\,(1-e^{-\frac{t_2\,2R}{L}})$

$e^{-\frac{2Rt_2}{L}}=0.7$ or $\frac{-2Rt_2}{L}=\ln(0.7);\ \therefore\ t_2=0.36\left(\frac{L}{2R}\right)$

In circuit 3, resistances are connected in parallel



Circuit 3

$\therefore\ R_P=\frac{R}{2};\ \ \tau_2=\frac{L}{R_P}=\frac{2L}{R}$

$\therefore\ I=I_0\left(1-e^{t_3/\tau_3}\right);\ \frac{30}{100}I_0$

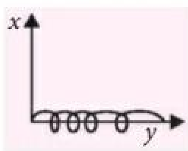
$=I_0\,(1-e^{-\frac{Rt_3}{2L}})$

$e^{-\frac{Rt_3}{2L}}=0.7$ or $\left(\frac{-Rt_3}{2L}\right)=\ln(0.7)$ or $t_3=0.36\left(\frac{2L}{R}\right)$

$\therefore\ t_3 = 2t_1,\ t_2=\frac{1}{2}t_1\ \ \therefore\ t_3>t_1>t_2$

38. (a) : Angular momentum, $L=\frac{nh}{2\pi}$ *i.e.* same for all.

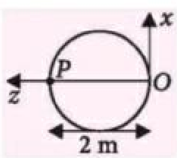
39. (d) : The particle will move in a non-uniform helical path with increasing pitch as shown in figure.



Its time period will be

$T=\frac{2\pi m}{qB}=2\pi$ s

Changing the view, the particle seems to move in a circular path in (x–z) plane as shown.



After π seconds, the particle will be at point P. Hence x coordinate will be 0.

For linear motion along y-direction.

$y(\pi)=0(\pi)+\frac{1}{2}\frac{Eq}{m}(\pi)^2\ \Rightarrow\ y(\pi)=\frac{\pi^2}{2}$ and $OP = 2$ m

Hence, the coordinates are $\left(0,\frac{\pi^2}{2},2\right)$

40. (d) : $x = A\cos\omega t,\ y = A\sin(\omega t+\pi/6)$

$y=A\sin\left(\omega t+\frac{\pi}{6}\right)=A\left[\sin\omega t\cos\frac{\pi}{6}+\cos\omega t\sin\frac{\pi}{6}\right]$

$=A\left[\frac{\sqrt{3}}{2}\sin\omega t+\frac{1}{2}\cos\omega t\right]$

$=\frac{A}{2}[\sqrt{3}(1-\cos^2\omega t)^{1/2}+\cos\omega t]=\frac{A}{2}\left[\sqrt{3}\left(1-\frac{x^2}{A^2}\right)^{\frac{1}{2}}+\frac{x}{A}\right]$

$\frac{2y}{A}-\frac{x}{A}=\sqrt{3}\left(1-\frac{x^2}{A^2}\right)^{\frac{1}{2}}$

Squaring both sides, $\frac{4y^2}{A^2}+\frac{x^2}{A^2}-\frac{4xy}{A^2}=3\left(1-\frac{x^2}{A^2}\right)$

$x^2+y^2-xy=\frac{3A^2}{4}$, which is equation of an ellipse.

41. (b) : $\mu=\frac{\text{Real depth}}{\text{Apparent depth}}=\frac{d}{x}$

$\therefore$ Due to first liquid, $\sqrt{2}=\frac{d}{x_1}$ or $x_1=\frac{d}{\sqrt{2}}$

And due to the second liquid, $n=\frac{d}{x_2}$ or $x_2=\frac{d}{n}$

$\therefore$ Total apparent depth $= x_1+x_2=\frac{d}{\sqrt{2}}+\frac{d}{n}$

Total apparent depth $=\frac{d(n+\sqrt{2})}{n\sqrt{2}}$

42. (d) : If $\vec{v}\parallel\vec{l}$ or if $\vec{v}\parallel\vec{B}$ or if $\vec{l}\parallel\vec{B}$ then $\frac{d\phi}{dt}$ is zero. Hence, potential difference is zero.

43. (d)

44. (b) : $P_{\text{closed}}=P_{\text{open}}+\frac{1}{2}\rho v^2;\ v=\sqrt{\frac{2(P_{\text{closed}}-P_{\text{open}})}{\rho}}$

$$=\sqrt{\frac{2(4\cdot5\times10^5-4\cdot0\times10^5)}{10^3}}=10\text{ m s}^{-1}$$

45. (c) : Total energy contained in cylinder

$=u_{\text{av}}\times\text{volume}=\left(\frac{1}{2}\varepsilon_0E_0^2\right)\times(Al)$

$=\frac{1}{2}\times(8.85\times10^{-12})\times(50)^2\times(10\times10^{-4})\times(0.50)$

$= 5.5\times10^{-12}$ J

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PRACTICE PAPER 2020

PAPER - I

Section 1 (Maximum Marks : 28)

- This section contains SEVEN questions.
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four options is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
- For each question, marks will be awarded in one of the following categories :

  Full Marks : +4 If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.

  Partial Marks : +1 For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened.

  Zero Marks : 0 If none of the bubbles is darkened.

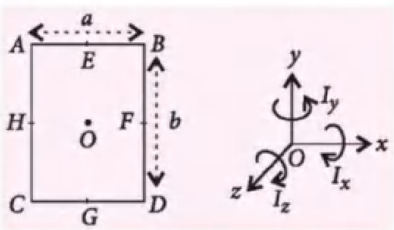
  Negative Marks : –2 In all other cases.
- For example, if (a), (c) and (d) are all the correct options for a question, darkening all these three will get +4 marks; darkening only (a) and (d) will get +2 marks; and darkening (a) and (b) will get –2 marks, as a wrong option is also darkened.

1. If the gravitational force between A and B (masses $2m$ and $3m$ respectively and separated by a distance $2d$) is 1 unit, the force between C and D (of masses $3m$ and $4m$ respectively with separation $3d$) will be between

(a) 0 and 0.5 (b) 0.5 and 1.0

(c) 1.0 and 1.5 (d) 1.5 and 2.0

2. The moment of inertia of a rectangular lamina $ABCD$ about O, along an axis perpendicular to the lamina, passing through the centre of mass O is $= \frac{a^2+b^2}{12}$. The moment of inertia



(a) about an axis perpendicular to the plane, passing through B is greater than that through O but smaller than that through H

(b) about an axis perpendicular to the plane, passing through B > through F > through O

(c) will be same if this had been a thick block

(d) I_z is always greater than I_x and I_y because $I_z = I_x + I_y$.

3. A boy of 40 kg is standing on a boat of mass 120 kg at a distance of 20 m from shore. He slowly moves in the direction of the shore on the boat by 8 m. Then

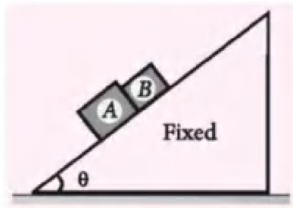
(a) the distance of the boy from the shore is now 14 m

(b) the boat moves back, thus disturbing the position of the centre of mass

(c) the centre of mass of the boat remains at same position but the boy has moved forward

(d) the centre of mass of the boat and the boy remains at the same place.

4. In the arrangement shown in figure all surfaces are smooth. Select the correct alternative(s).



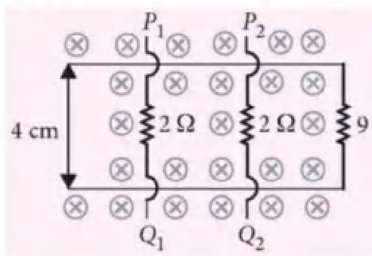
(a) For any value of θ acceleration of A and B are equal.

(b) Contact force between the two blocks is zero if $m_A/m_B = \tan\theta$.

(c) Contact force between the two is zero for any value of m_A or m_B.

(d) Normal reactions exerted by the wedge on the blocks are equal.

5. In figure shown, the wires P_1Q_1 are made to slide on the rails with same speed of 5 cm s^{-1}. In this region, a magnetic field of 1 T exists. The electric current in the 9 Ω resistance is



(a) zero if both wires slide toward left
(b) zero if both wires slide in opposite directions
(c) 0.2 mA if both wires move toward left
(d) 0.2 mA if both wires move in opposite directions

6. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring, such that it is half-submerged in a liquid of density ρ at equilibrium position. When the cylinder is given a small downward push and released, it starts oscillating vertically with small amplitude. If the force constant of the spring is k, the frequency of oscillation of the cylinder is

(a) $\frac{1}{2\pi}\left(\frac{k-A\rho g}{M}\right)^{1/2}$ (b) $\frac{1}{2\pi}\left(\frac{k+A\rho g}{M}\right)^{1/2}$

(c) $\frac{1}{2\pi}\left(\frac{k+\rho-gL}{M}\right)^{1/2}$ (d) $\frac{1}{2\pi}\left(\frac{k+A-gL}{A\rho g}\right)^{1/2}$

7. Oxygen gas is made to undergo a process in which its molar heat capacity C depends on its absolute temperature T as $C = \alpha T$. Work done by it when heated from an initial temperature T_0 to a final temperature $2T_0$, will be

(a) $4\alpha T_0^2$ (b) $(\alpha T_0 - R)\frac{3T_0}{2}$

(c) $(3\alpha T_0 - 5R)\frac{T_0}{2}$ (d) none of these

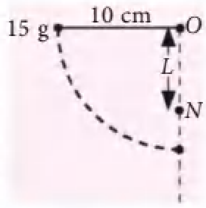
Section 2 (Maximum Marks : 15)

- This section contains FIVE questions.
- The answer to each question is a SINGLE DIGIT INTEGER ranging from 0 to 9, both inclusive.
- For each question, darken the bubble corresponding to the correct integer in the ORS.
- For each question, marks will be awarded in one of the following categories :
  Full Marks : +3 If only the bubble corresponding to the correct answer is darkened.
  Zero Marks : 0 In all other cases.

8. A steel tape is placed around the earth at the equator when the temperature is 0 °C. What will be the distance (in km) between the tape and the ground (assumed to be uniform) if the temperature of the tape rises to 30°C? (Neglect the expansion of the earth. Take $\alpha_{steel} = 11 \times 10^{-6}$ °C^{-1})

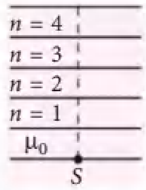
9. The electric potential between a proton and an electron is given by $V = V_0 \ln\left(\frac{r}{r_0}\right)$, where r_0 is a constant. Assuming Bohr's model to be applicable, the variation of r_n with n is given by $r_n \propto n^k$, n being the principal quantum number. Find the value of k.

10. A ball weighing 15 g is tied to a string 10 cm long. Initially the ball is held in position such that the string is horizontal. The ball is now released. A nail N is situated vertically below the support at a distance L. The minimum value of L (in cm) such that the string will be wound round the nail is



11. A point source S is placed at the bottom of different layers as shown in figure. The refractive index of bottom most layer is μ_0. The refractive index of any other upper layer is $\mu(n) = \mu_0 - \frac{\mu_0}{4n-18}$

where $n = 1, 2, \ldots$.
A ray of light starts from the source S as shown. Total internal reflection takes place at the upper surface of a layer having n (minimal value) equal to



12. A proton has kinetic energy E = 100 keV which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ratio λ_2/λ_1 is given by $c\sqrt{2m_p}\, E^{-1/n}$. Find the value of n.

Section 3 (Maximum Marks : 18)

- This section contains SIX questions of matching type.
- This section contains TWO tables (each having 3 columns and 4 rows).
- Based on each table, there are THREE questions.
- Each question has FOUR options (a), (b), (c), and (d). ONLY ONE of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :
  Full Marks : +3 If only the bubble corresponding to the correct option is darkened.
  Zero Marks : 0 If none of the bubbles is darkened
  Negative Marks : –1 In all other cases

Answer Q.13, Q.14 and Q.15 by appropriately matching the information given in the three columns of the following table.

A mercury lamp is a convenient source for studying frequency dependence of photoelectric emission, since it gives a number of spectral lines ranging from the UV to the red end of the visible spectrum. The energy level diagram of mercury is shown in the figure. Assume ground state energy is 0 eV.

	$n = 8$	10.44 eV
	$n = 7$	8.85 eV
	$n = 6$	7.70 eV
	$n = 5$	6.68 eV
	$n = 4$	5.43 eV
	$n = 3$	4.87 eV
	$n = 2$	4.66 eV
(ground state)	$n = 1$	0

In our experiment with rubidium photocell, some lines from mercury source were used. The rubidium has work function of 2.01 eV. The given matrix has three columns in which column 1 contains wavelengths of line used, column 2 contains the transition states from which the spectral lines contained in column 1 had been obtained and column 3 lists the stopping voltages measured in our experiment.

Column 1	Column 2	Column 3
(I) 3626 Å	(i) $n = 5$ to $n = 3$	(P) 0.82 V
(II) 5714 Å	(ii) $n = 7$ to $n = 5$	(Q) 1.41 V
(III) 6850 Å	(iii) $n = 6$ to $n = 3$	(R) 0 V
(IV) 4381 Å	(iv) $n = 7$ to $n = 4$	(S) 0.16 V

13. For which of the following combinations, the photoelectron has maximum velocity equals to 5.37×10^5 m s^{-1}?

(a) (I) (iv) (S) (b) (II) (i) (P)
(c) (IV) (ii) (S) (d) (IV) (iii) (P)

14. For which of the following combinations, photon emitted by mercury lamp will be fully absorbed by rubidium photocell?

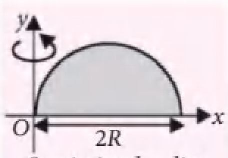
(a) (III) (i) (R) (b) (II) (ii) (Q)
(c) (II) (i) (R) (d) (III) (iv) (S)

15. For which of the following combinations, photon striking the photocell has energy 5.472×10^{-19} J?

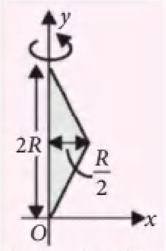
(a) (I) (iii) (P) (b) (IV) (iii) (P)
(c) (I) (iv) (Q) (d) (IV) (iv) (Q)

Answer Q. 16, Q.17 and Q. 18 by appropriately matching the information given in the three columns of the following table.

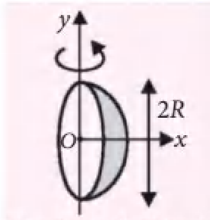
A student takes four different rigid objects having continuous mass distribution. He rotates the objects about y-axis as shown in the figure.



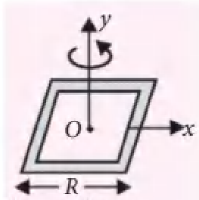
Semi-circular disc



Triangular plate



Hemispherical bowl



Square frame

The figure shows the position of bodies at $t = 0$.
All the four objects has mass m and dimensions of the objects are described in the figure.
The table shown below contains three columns in which column 1 describes the rigid body, column 2 gives the coordinates of centre of mass of the bodies at the given instant and column 3 contains the value of moment of inertia of bodies about y-axis. All the data in table is kept in random order

Column 1	Column 2	Column 3
(I) Semicircular disc of diameter $2R$	(i) $\left(\frac{R}{6}, R\right)$	(P) $\frac{2}{3}mR^2$
(II) Triangular plate of height $\frac{R}{2}$ and base $2R$	(ii) (0, 0)	(Q) $\frac{5}{4}mR^2$
(III) Hemispherical bowl of radius R	(iii) $\left(R, \frac{4R}{3\pi}\right)$	(R) $\frac{mR^2}{3}$
(IV) Square frame made of four identical rods of length R	(iv) $\left(\frac{R}{2}, 0\right)$	(S) $\frac{mR^2}{24}$

16. Which of the following combinations is correct, for the object whose axis of rotation passes through its centre of mass?

(a) (IV) (ii) (R) (b) (IV) (ii) (P)
(c) (II) (iv) (S) (d) (II) (i) (S)

17. If all the object have same rotational kinetic energy, then which of the following combinations will have maximum angular velocity?

(a) (I) (iii) (Q) (b) (III) (iv) (S)
(c) (II) (i) (S) (d) (IV) (ii) (R)

18. If a point of mass m is added to the origin (O) of each rigid point, then in which of following combination the centre of mass of new system will not lie on x-axis?

(a) (III) (iv) (P)
(b) (I) (iii) (Q)
(c) (IV) (iv) (R)
(d) (III) (i) (S)

PAPER - II

Section 1 (Maximum Marks : 21)

- This section contains SEVEN questions.
- Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :

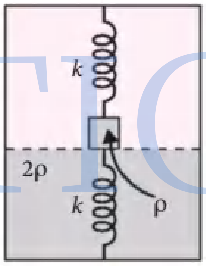
Full Marks : +3 If only the bubble corresponding to the correct option is darkened.
Zero Marks : 0 If none of the bubbles is darkened.
Negative Marks : –1 In all other cases.

1. A uniform ball of radius r rolls without slipping down from the top of a sphere of radius R. The angular velocity of the ball when it breaks from the sphere is

(a) $\sqrt{\dfrac{5g(R+r)}{17r^2}}$ (b) $\sqrt{\dfrac{10g(R+r)}{17r^2}}$

(c) $\sqrt{\dfrac{5g(R-r)}{10r^2}}$ (d) $\sqrt{\dfrac{10g(R+r)}{7r^2}}$

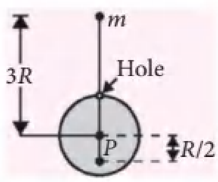
2. A cubic block of side a is connected with two similar vertical springs as shown. Initially, bottom surface of the block of density ρ touches the surface of the fluid of density 2ρ while floating. A weight is placed on the block so that it is immersed half in the fluid, find the weight.



(a) $a\left(\dfrac{k}{2}+a^2\rho g\right)$ (b) $a(k + a^2\rho g)$

(c) $a\left(k+\dfrac{a^2}{2}\rho g\right)$ (d) $\dfrac{a}{2}(k+a^2\rho g)$

3. A point mass m is released from rest at a distance of $3R$ from the centre of a thin-walled hollow sphere of radius R and mass M as shown in figure. The hollow sphere is fixed in position and the only force on the point mass is the gravitational attraction of the hollow sphere. There is a very small hole in the hollow sphere through which the point mass falls as shown. The velocity of a point mass when it passes through P at a distance $R/2$ from the centre of the sphere is



(a) $\sqrt{\dfrac{2GM}{3R}}$ (b) $\sqrt{\dfrac{5GM}{3R}}$

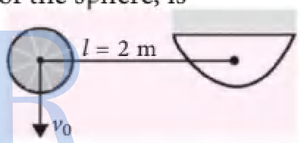
(c) $\sqrt{\dfrac{25GM}{24R}}$ (d) $\sqrt{\dfrac{4GM}{3R}}$

4. The deceleration experienced by a moving motor boat, after its engine is switched off is given by $dv/dt = -kv^3$, where k is constant. If v_0 is the magnitude of the velocity of the boat when engine is switched off, the magnitude of the velocity at a time t after the engine is switched off is

(a) $v_0/2$ (b) v

(c) v_0e^{-kt} (d) $\dfrac{v_0}{\sqrt{2v_0^2kt+1}}$

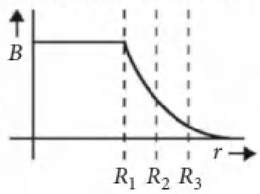
5. A small sphere is given vertical velocity of magnitude $v_0 = 5\text{ m s}^{-1}$ and it swings in a vertical plane about the end of a massless string. The angle θ with the vertical at which string will break, knowing that it can withstand a maximum tension equal to twice the weight of the sphere, is

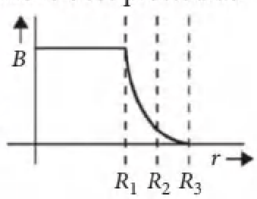


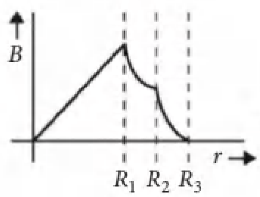
(a) $\cos^{-1}\left(\dfrac{2}{3}\right)$ (b) $\cos^{-1}\left(\dfrac{1}{4}\right)$

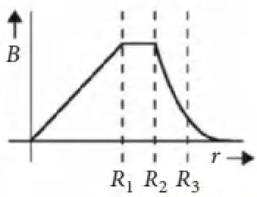
(c) 60° (d) 30°

6. A coaxial cable is made up of two conductors. The inner conductor is solid and is of radius R_1 and the outer conductor is hollow of inner radius R_2 and outer radius R_3. The space between the conductors is filled with air. The inner and outer conductors are carrying currents of equal magnitudes and in opposite directions. Then the variation of magnetic field with distance from the axis is best plotted as

(a)


(b)


(c)


(d)


7. When 100 V dc is applied across a solenoid, a current of 1.0 A flows in it. When 100 V ac is applied across the same coil, the current drops to 0.5 A. If the frequency of the ac source is 50 Hz, the impedance and inductance of the solenoid are
(a) 200 Ω and 0.55 H (b) 100 Ω and 0.86 H
(c) 200 Ω and 1.0 H (d) 100 Ω and 0.93 H

Section 2 (Maximum Marks : 28)

- This section contains SEVEN questions.
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four options is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
- For each question, marks will be awarded in one of the following categories :

Full Marks : +4 If only the bubble(s) corresponding to all the correct option(s) is(are) darkened.

Partial Marks: +1 For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened.

Zero Marks : 0 If none of the bubbles is darkened.

Negative Marks : –2 In all other cases.

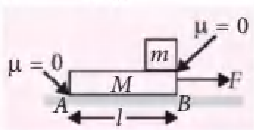
- For example, if (a), (c) and (d) are all the correct options for a question, darkening all these three will result in +4 marks; darkening only (a) and (d) will result in +2 marks; and darkening (a) and (b) will result in –2 marks, as a wrong option is also darkened.

8. Two balls A and B thrown with speeds u and $u/2$, respectively. Both the balls cover the same horizontal distance before returning to the plane of projection. If the angle of projection of ball B is 15° with the horizontal, then the angle of projection of A is

(a) $\sin^{-1}\left(\frac{1}{8}\right)$ (b) $\frac{1}{2}\sin^{-1}\left(\frac{1}{8}\right)$

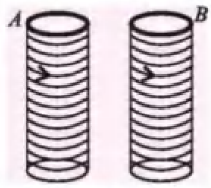
(c) $\frac{1}{3}\sin^{-1}\left(\frac{1}{8}\right)$ (d) $\frac{1}{4}\sin^{-1}\left(\frac{1}{8}\right)$

9. In shown figure, a small block is kept on slab of mass M. Then



(a) the acceleration of m with respect to ground is F/m.
(b) the acceleration of m with respect to ground is zero.
(c) the time taken by m to separate from M is $\sqrt{\frac{2lm}{F}}$.
(d) the time taken by m to separate from M is $\sqrt{\frac{2lM}{F}}$.

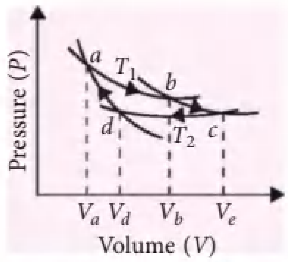
10. Two metallic rings A and B, identical in shape and size but having different resistivities ρ_A and ρ_B, are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights h_A and h_B, respectively, with $h_A > h_B$. The possible relation(s) between their resistivities and their masses m_A and m_B is(are)



(a) $\rho_A > \rho_B$ and $m_A = m_B$
(b) $\rho_A < \rho_B$ and $m_A = m_B$
(c) $\rho_A > \rho_B$ and $m_A > m_B$
(d) $\rho_A < \rho_B$ and $m_A < m_B$

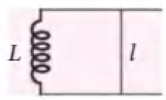
11. A choke coil of resistance 5 Ω and inductance 0.6 H is in series with a capacitor of capacitance of 10 μF. If a voltage of 200 V is applied and the frequency is adjusted to resonance, the current and voltage across the inductor are I_0 and V_0, and across the capacitor are I_1 and V_1.
(a) $I_0 = 40$ A (b) $V_0 = 9.8$ kV
(c) $V_1 = 9.8$ kV (d) $V_1 = 19.6$ kV

12. An ideal gas undergoes the cyclic process shown in a graph below.



(a) $T_1 = T_2$
(b) $T_1 > T_2$
(c) $V_aV_c = V_bV_d$
(d) $V_aV_b = V_cV_d$

13. Two parallel resistance rails are connected by an inductor of inductance L at one end as shown in figure. A magnetic field B exists in the space which is perpendicular to the plane of the rails. Now a conductor of length l and mass m is placed transverse on the rail and given an impulse J toward the rightward direction. Then choose the correct option(s).

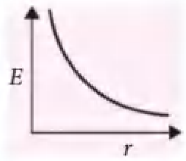


(a) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d = \sqrt{\frac{3J^2L}{4B^2l^2m}}$
(b) Current flowing through the inductor at the instant when velocity of the conductor is half of the initial velocity is $i = \sqrt{\frac{3J^2}{4Lm}}$

(c) Velocity of the conductor is half of the initial velocity after a displacement of the conductor $d = \sqrt{\dfrac{3J^2L}{B^2l^2m}}$

(d) Current flowing through the inductor at the instant when velocity of the conductor is half of the initial velocity is $i = \sqrt{\dfrac{3J^2}{mL}}$

14. Energy density E (energy per unit volume) of the medium at a distance r from a sound source varies according to the curve shown in figure. Which of the following are possible?



(a) The source may be a point isotropic source.
(b) If the source is a plane source then the medium particles have damped oscillations.
(c) If the source is a plane source then power of the source is decreasing with time.
(d) All of these

Section 3 (Maximum Marks : 12)

- This section contains TWO paragraphs.
- Based on each paragraph, there are TWO questions.
- Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is correct.For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :

Full Marks : +3 If only the bubble corresponding to the correct option is darkened.

Zero Marks : 0 In all other cases.

PARAGRAPH 1

A 500 g teapot and an insulated thermos are in a 20 °C room. The teapot is filled with 1000 g of the boiling water. 12 tea bags are then placed into the teapot. The brewed tea is allowed to cool to 80 °C, then 250 g of the tea is poured from the teapot into the thermos. The teapot is then kept on an insulated warmer that transfers 500 cal min^{-1} to the tea. Assume that the specific heat of brewed tea is the same as that of pure water, and that the tea bags have a very small mass compared to that of the water, and a negligible effect on the temperature. The specific heat of teapot is 0.17 J g^{-1}K^{-1} and that of water is 4.18 J g^{-1}K^{-1}. The entire procedure is done under atmospheric pressure. There are 4.18 J in one calorie.

15. After the tea is added to the thermos, the temperature of the liquid quickly falls from 80 °C to 75 °C as it reaches thermal equilibrium with the thermos flask. What is the heat capacity of the thermos?

(a) 9.5 J K^{-1} (b) 14 J K^{-1}
(c) 95 J K^{-1} (d) 878 J K^{-1}

16. If, after some of the tea has been transferred to the thermos (as described in the passage), the teapot with its contents (at a temperature of 80°C) was placed on the insulated warmer for 5 minutes, what would be the temperature at the end of this 5 minutes period (Assume that no significant heat transfer occurs with the surroundings)?

(a) 80.7 °C (b) 82.5 °C
(c) 83.2 °C (d) 95.2 °C

PARAGRAPH 2

It is assumed that an electron is revolving round the proton in a circular path. However, both are revolving round their centre of mass. This is a two body problem. The energy of the hydrogen atom or any one electron system is normally given as

$$E_n = -\frac{1}{2}m_ec^2\alpha^2 \cdot \frac{Z^2}{n^2}.$$

where m_e is the rest mass of the electron, α is a Sommerfield fine structure constant.

$$\alpha = \frac{e^2}{4\pi\varepsilon_0} \cdot \frac{1}{hc} = \frac{1}{137}.$$

If both the particles are revolving about their centre of mass, m_e is replaced by the reduced mass μ where

$$\frac{1}{\mu} = \frac{1}{m_e} + \frac{1}{m_p} \quad \text{or,} \quad \frac{1}{\mu} = \frac{1}{m_1} + \frac{1}{m_2}.$$

17. As the mass of the hydrogen nucleus is different from that of deuterium (D) and tritium (T) but having the same Z,

(a) the energy levels for H and D are not the same
(b) the energy levels are different and therefore different isotopes can be distinguished
(c) the energy levels are different but the difference is very small to be observed
(d) none of these.

18. If an electron is caught in the orbit of a positron (having a charge e^+, mass = m_e)

(a) the energy of the ground state is $E_1 = -13.6$ eV
(b) observed frequencies will be higher than that for H
(c) the energy of the ground state is $E_1 = -\dfrac{13.6 \text{ eV}}{2}$
(d) the frequencies of lines observed will only be thrice of that for H.

SOLUTIONS

PAPER - 1

1. (b): The gravitational force between A and B is

$$F=\frac{G(2m)(3m)}{(2d)^2}=\frac{6Gm^2}{4d^2}=\frac{3}{2}\frac{Gm^2}{d^2} \quad \text{... (i)}$$

The gravitational force between C and D is

$$F'=\frac{G(3m)(4m)}{(3d)^2}=\frac{12Gm^2}{9d^2}=\frac{4}{3}\frac{Gm^2}{d^2} \quad \text{... (ii)}$$

Divide (ii) by (i), we get

$$\frac{F'}{F}=\frac{8}{9} \quad \text{or} \quad F'=\frac{8}{9}F$$

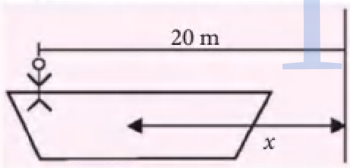
But $F = 1$ unit (given) $\therefore \quad F'=\frac{8}{9}\times 1 \text{ unit} = 0.9 \text{ unit}$

2. (b, c, d) : (b) The parallel axes theorem gives that $I_B = I_0 + M(OB)^2$ is having the greatest value compared to O, F, G, H, E.

(c) For block also it is valid.

(d) For this rectangular lamina it is valid but not valid for a sphere, thin cylindrical rod etc. The perpendicular axes theorem is not always valid. It depends on the shape.

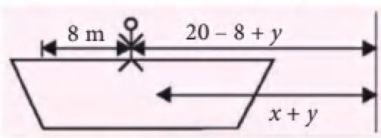
3. (a,d) : Let the centre of mass of boat is at x m from the shore. The given situation is shown in figure



Centre of mass of the system is at

$$r_{CM}=\frac{40\times 20+120\times x}{40+120}=\frac{800+120x}{160}$$

Now, boy starts moving towards the shore, so the boat will move backward, say, a distance y.



$$\text{Now, } r'_{CM}=\frac{(12+y)40+120(x+y)}{160}$$

Since there is no external force acting on the system,

$\therefore \quad r_{CM} = r'_{CM}$

$$\frac{800+120x}{160}=\frac{(12+y)40+12(x+y)}{160}$$

$\therefore \quad y = 2$ m

So, boy is now 14 m from the shore and centre of mass of system will remain at same place.

4. (a,c) : $a_A = a_B = g\sin\theta$

If the surface is smooth, contact force between the two is zero.

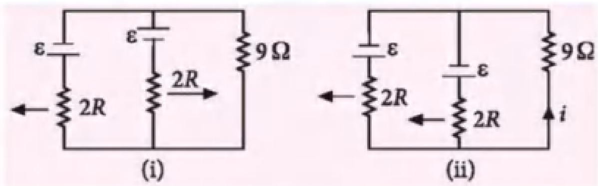
5. (b,c) : Each wire can be replaced by a battery whose emf is equal to $Blv = 1 \times 4 \times 10^{-2} \times 5 \times 10^{-2}$
$= 20 \times 10^{-4}$ V

The polarity of the battery can be given by Fleming's right hand rule. When both wire move in opposite direction, the circuit diagram looks like as shown in figure (i).

The effective emf of the two batteries shown in the diagram is zero.

So, choice (b) is correct and choice (d) is wrong.

When both wires move towards left, the circuit diagram looks like as shown in figure (ii) shown.



Effective emf of two batteries shown is E ($= 20 \times 10^{-4}$ V) and internal resistance is 1 Ω.

Hence, current in the circuit is

$$i=\frac{20\times 10^{-4}}{10}=0.2 \text{ mA}$$

Hence, choice (c) is correct and choice (a) is wrong.

6. (b) : When the cylinder is given a small push downwards, say x, then two forces start acting on the cylinder trying to bring it to its mean position.

Restoring force = – (upthrust + spring force

$$F = -(\rho Axg + kx)$$

$\Rightarrow \; Ma = -(\rho Ag + k)x$, where a is the acceleration of cylinder

$$\text{or} \quad a=\frac{(\rho Ag+k)}{M}x$$

on comparing with standard equation for SHM *i.e.* $a = -\omega^2 x$, where ω is the angular frequency we have

$$\omega=\left[\frac{\rho Ag+k}{M}\right]^{1/2} \Rightarrow \upsilon=\frac{1}{2\pi}\left[\frac{\rho Ag+k}{M}\right]^{1/2}$$

7. (c) : $C = C_V + W'$

where W' is the work done by the gas per mole per unit rise in temperature. So $W' = \alpha T - C_V = \alpha T - (5R/2)$

$$\Delta W=\int W' dT=\int_{T_0}^{2T_0}\left(\alpha T-\frac{5R}{2}\right)dT=(3\alpha T_0-5R)\frac{T_0}{2}$$

8. (2)

9. (1) : Given : $V = V_0 \ln\left(\frac{r}{r_0}\right)$

$\therefore$ Potential energy $U = eV$

or $U = eV_0 \ln\frac{r}{r_0}$ $\therefore$ $\frac{dU}{dr} = eV_0\left(\frac{r_0}{r}\right)\frac{1}{r_0}$

or $|\text{force}| = \frac{eV_0}{r}$

This force provides the necessary centripetal force.

$\therefore$ $\frac{mv^2}{r} = \frac{eV_0}{r}$ or $v = \sqrt{\frac{eV_0}{m}}$ ...(i)

By Bohr's postulate, $mvr = \frac{nh}{2\pi}$

or $v = \frac{nh}{2\pi mr}$ ...(ii)

From (i) and (ii),

$\frac{nh}{2\pi mr} = \sqrt{\frac{eV_0}{m}}$ or $r = \frac{nh}{2\pi m} \times \sqrt{\frac{m}{eV_0}}$

or $r = \left[\frac{h}{2\pi}\sqrt{\frac{1}{meV_0}}\right] \times n$ $\therefore$ $r_n \propto n$. $\therefore$ $k = 1$.

10. (6) : For string to be wound around the nail,

$v \geq \sqrt{5gr}$ $\Rightarrow$ $v \geq \sqrt{5g(10-L)}$

Now $\frac{1}{2}mv^2 = mg(10)$ $\Rightarrow v^2 = 2g(10)$

$\sqrt{2g.10} \geq \sqrt{5g(10-L)}$

$\Rightarrow$ $20g \geq 5g(10 - L)$ $\Rightarrow$ $20 \geq 50 - 5L$

$\Rightarrow$ $5L \geq 30$ $\Rightarrow$ $L \geq 6$

$L_{min} = 6$ cm.

11. (4) : Total internal reflection can happen only when $\mu\ (n) < \mu_0$

$\Rightarrow \mu_0 - \frac{\mu_0}{4n-18} < \mu_0 \Rightarrow \frac{-\mu_0}{4n-18} < 0$ or $\frac{\mu_0}{4n-18} > 0$

$\Rightarrow$ $4n - 18 > 0$ $\Rightarrow$ $n > \frac{18}{4} = 4.5$

The minimum integral value of n satisfying the inequality is $n = 5$.

Total internal reflection can happen when light is going from 4^{th} to the 5^{th} layer or on the upper layer of 4^{th} layer, since $\mu_5 < \mu_4$.

$\Rightarrow$ Required answer is $n = 4$.

12. (2) : For photon, $E = \frac{hc}{\lambda_2}$ or $\lambda_2 = \frac{hc}{E}$ ....(i)

For proton kinetic energy $K = \frac{1}{2}m_p v_p^2$

or $2m_pK = m_p^2v_p^2$ or $2m_pK = p^2$

or $2m_pK = \left(\frac{h}{\lambda_1}\right)^2$, by de Broglie equation

K = K.E. = energy E.

or $\lambda_1 = \frac{h}{\sqrt{2m_pK}} = \frac{h}{\sqrt{2m_pE}}$ ....(ii)

From (i) and (ii),

$\frac{\lambda_2}{\lambda_1} = \frac{hc}{E} \times \frac{\sqrt{2m_pE}}{h}$ or $\frac{\lambda_2}{\lambda_1} = \frac{c \times \sqrt{2\,m_p}}{\sqrt{E}} = c\sqrt{2m_p} \times E^{-1/2}$

$\therefore$ $n = 2$

13. (d) **14. (a)** **15. (c)**

Let us start calculating from the given transitions (column 2)

(i) $n = 5$ to $n = 3$

Energy of photon emitted

$h\upsilon_1 = E_5 - E_3 = 6.68 - 4.87 = 1.81$ eV

Wavelength of emitted photon

$\lambda_1 = \left(\frac{12400}{1.81}\right)$ Å = 6850 Å

Since $h\upsilon_1 < \phi$ ($\phi = 2.01$ eV)

Hence no electron will be emitted, all the energy of the photon is absorbed by the photocell. So stopping potential, $V_1 = 0$

$\therefore$ (III) (i) (R) is correct combination for Q. 14.

(ii) $n = 7$ to $n = 5$

Energy of emitted photon,

$h\upsilon_2 = E_7 - E_5 = 8.85 - 6.68 = 2.17$ eV

Wavelength of emitted photon,

$\lambda_2 = \frac{12400}{2.17}$ Å = 5714 Å

Maximum kinetic energy of emitted photoelectron

$= h\upsilon_2 - \phi = 2.17 - 2.01 = 0.16$ eV

So, stopping potential photon, $V_2 = 0.16$ V

(iii) $n = 6$ to $n = 3$

Energy of emitted

$h\upsilon_3 = E_6 - E_3 = 7.70 - 4.87 = 2.83$ eV

$\lambda_3 = \frac{12400}{2.83}$ Å = 4381 Å

$V_3 = \frac{(h\upsilon_3 - \phi)}{e} = (2.83 - 2.01)\text{V} = 0.82\text{ V}$

(iv) $n = 7$ to $n = 4$

$h\upsilon_4 = E_7 - E_4 = 8.85 - 5.43 = 3.42$ eV

$$\lambda_4 = \frac{12400}{3.42}\ \text{Å} = 3626\ \text{Å}$$

$V_4 = 1.41$ V

Now, for maximum velocity of emitted photoelectron, $v_{max} = 5.37 \times 10^5$ m s^{-1}.

$$eV = \text{K.E}_{max} = \frac{1}{2} m v_{max}^2 = 1.31 \times 10^{-19}\ \text{J} = 0.82\ \text{eV}$$

So, correct combination for Q.13 is (IV) (iii) (P)

If energy of photon striking electron is 5.472×10^{-19} J, then

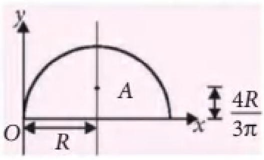
$h\upsilon = 3.42$ eV which is same as case (iv)

So, correct combination for Q.15 is (I) (iv) (Q).

16. (a) **17. (c)** **18. (b)**

(I) For semicircular disc, centre of mass lies at point A.

Coordinates of centre of mass $\left(R, \frac{4R}{3\pi}\right)$.



Moment of inertia about axis passing through A, parallel to y-axis $= \frac{mR^2}{4}$

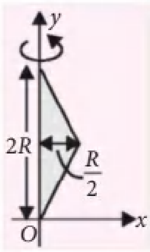
$\therefore$ Moment of inertia about y-axis

$$= \frac{mR^2}{4} + mR^2 = \frac{5}{4} mR^2$$

If a point mass m is placed at O then centre of mass will shift toward origin but will not lie on any of axis.

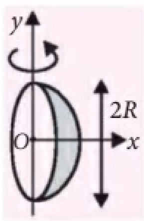
(I) (iii) (Q)

(II) Triangular plate has centre of mass at $B\left(\frac{R}{6}, R\right)$, *i.e.*, centroid.



Moment of inertia about $O = \frac{mh^2}{6} = \frac{m(R/2)^2}{6} = \frac{mR^2}{24}$

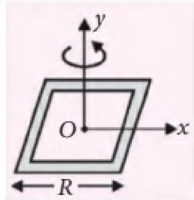
(III) Hemispherical bowl has centre of mass lie at C on x-axis, $C\left(\frac{R}{2}, 0\right)$



Moment of inertia of bowl is $\frac{2}{3} mR^2$ about y-axis.

(IV) Square frame has centre of mass at origin *i.e.*, (0, 0).

Moment of inertia of one rod about y-axis



$$= \frac{m}{4}\left(\frac{R^2}{12}\right) + \frac{m}{4}\left(\frac{R}{2}\right)^2$$

$$= \frac{mR^2}{4}\left(\frac{1}{12} + \frac{1}{4}\right) = \frac{mR^2}{12}$$

Moment of inertia of frame about y-axis

$$= \frac{4 \times mR^2}{12} = \frac{mR^2}{3}$$

For square frame axis of rotation passes through centre of mass.

$\therefore$ (IV) (ii) (R) is the correct combination for Q. 16.

If the bodies has same rotational kinetic energy

$$K = \frac{1}{2} I\omega^2 \Rightarrow \omega \propto \frac{1}{\sqrt{I}}$$

then angular velocity will be maximum if moment of inertia is least:

For triangular plate the angular velocity is maximum.

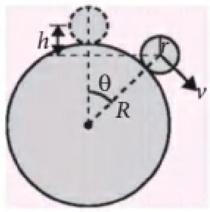
$\therefore$ (II) (i) (S) is the correct combination for Q. 17.

If a mass m is added to origin then the centre of mass will shift towards origin. In the case of semicircular disc and triangular plate the centre of mass will not lie on x-axis.

So, (I)(iii)(Q) is the correct combination for Q. 18.

PAPER - II

1. (b): $\frac{mv^2}{(R+r)} = mg\cos\theta$, ...(i)



$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$mg(R+r)(1-\cos\theta) = \frac{1}{2}mv^2 + \frac{1}{5}mv^2$$

$$= \frac{7}{10}mv^2 \qquad \{\because\ h = (R+r)(1-\cos\theta)\} \quad \text{...(ii)}$$

From eqn. (i) and (ii)

$$\frac{10}{7} mg \frac{(R+r)(1-\cos\theta)}{(R+r)} = mg\cos\theta$$

$$\frac{10}{7}(1-\cos\theta) = \cos\theta$$

Substituting in eqn. (i)

$$v = \sqrt{g(R+r)\cos\theta} = \sqrt{\frac{10}{17} g(R+r)}$$

$$\text{and } \omega = \frac{v}{r} = \sqrt{\frac{10g(R+r)}{17r^2}}$$

2. (b): Let W_0 be the weight placed on block

Initially, $W - 2kx = 0$ ...(i)

Finally $W' - 2k\left(x + \frac{a}{2}\right) - a \cdot a \cdot \frac{a}{2}(2\rho) \cdot g = 0$ ...(ii)

Here, $W' = W + W_0$

$\therefore \quad W + W_0 - 2Kx - Ka - a^3 \rho g = 0$ [From eqn. (ii)]

From eqn. (i),

$W_0 = ka + a^3 \rho g = a(k + a^2 \rho g).$

3. (d): Inside the spherical shell, V is constant, so speed of point mass is also constant.

From energy conservation,

$$\frac{-GMm}{3R} = \frac{mv^2}{2} - \frac{GMm}{R}$$

$$\frac{v^2}{2} = \frac{GM}{R}\left[1 - \frac{1}{3}\right] = \frac{GM}{R} \times \frac{2}{3} \quad \text{or} \quad v = \sqrt{\frac{4GM}{3R}}$$

4. (d): Here $\frac{dv}{dt} = -kv^3$ or $\frac{dv}{v^3} = -kdt$ ...(i)

At $t = 0$, the velocity of the boat is V_0.

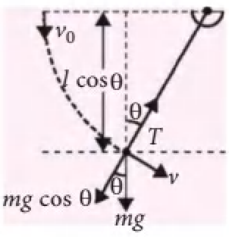
By integrating both side of eqn. (i).

$$\int_{v_0}^{v} \frac{dv}{v^3} = \int_0^t -k\,dt$$

$$\text{or} \quad \left[-\frac{1}{2v^2}\right]_{v_0}^{v} = -kt \quad \text{or} \quad -\frac{1}{2v^2} + \frac{1}{2v_0^2} = -kt$$

$$\text{or} \quad v^2 = \frac{v_0^2}{1 + 2v_0^2 kt} \quad \text{or} \quad v = \frac{v_0}{\sqrt{2v_0^2 kt + 1}}$$

5. (b): $v^2 = v_0^2 + 2gl\cos\theta$ ...(i)



$$T = mg\cos\theta + \frac{mv^2}{l}$$

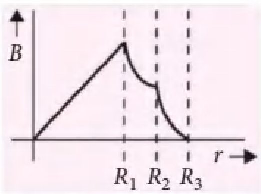
$\because \quad T = 2mg$ (Given)

$$2mg = mg\cos\theta + \frac{m}{l}\,(v_0^2 + 2gl\cos\theta)$$

{using (i)}

$$\therefore \quad \cos\theta = \frac{1}{4} \quad \Rightarrow \quad \theta = \cos^{-1}\left(\frac{1}{4}\right)$$

6. (c): From Ampere's circuital law, the field at the axis is zero. From $x = 0$ to R_1, the field increases linearly as the current enclosed increases.



From $x = R_1$ to R_2 and from $x = R_2$ to R_3, the field decreases hyperbolically but with different slopes as the media are different. Hence, the required graph is (c).

7. (a): For dc : $R = \frac{\varepsilon}{I_{dc}} = \frac{100}{1} = 100\,\Omega$

For ac : $Z = [R^2 + (2\pi\upsilon L)^2]^{1/2}$

$$= \frac{\varepsilon_{ac}}{I_{ac}} = \frac{100}{0.5} = 200\,\Omega$$

or $\quad 200 = [(100)^2 + (100\pi L)^2]^{1/2}$

On solving, we get $L = 0.55$ H

8. (b): Since horizontal range for both balls are same

$$\frac{u^2 \sin 2\theta}{g} = \frac{(u/2)^2 \sin 30^\circ}{g} = \frac{u^2}{8g}$$

$$\therefore \quad \sin 2\theta = \frac{1}{8} \quad \text{or} \quad \theta = \frac{1}{2}\sin^{-1}\left(\frac{1}{8}\right)$$

9. (b,d) : Acceleration of slab of mass M, $a = \left(\frac{F}{M}\right)$

Using Newton's equation of motion,

$$l = \frac{1}{2}\frac{F}{M}t^2 \Rightarrow t = \sqrt{\frac{2Ml}{F}}$$

10. (b, d) : The magnetic flux is changing at the same rate for both the solenoids.

The induced emf, $\varepsilon = -\frac{d\phi}{dt}$ is the same for both the rings. However, the resistance of A has to be lower, if the masses of the rings A and B are the same, because the repulsion is more for ring A *i.e.*, $\mu_0 iA$ is more. The resistance is less, the current is more (b).

It is also possible that ρ_A is less than ρ_B and the mass of the ring m_A is also smaller.

$\therefore$ (d) is also correct.

11. (a,b,c) : The frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} = \frac{1}{2\pi}\sqrt{\frac{1}{0.6 \times 10 \times 10^{-6}}} = 65 \text{ Hz}$$

The current at resonance is $I_0 = \frac{200\,\text{V}}{5\,\Omega} = 40$ A

Since coil and capacitor are connected in series, to current across them will be same, *i.e.*, 40 A.

The voltage across inductor, $V_0 = I_0\sqrt{R^2 + (\omega L)^2}$

$$= 40\sqrt{25^2 + (0.6 \times 2\pi \times 65)^2} = 9.8\,\text{kV}$$

Voltage across capacitor, $V_1 = \frac{I_0}{\omega C} = \frac{40 \times 10^5}{2\pi \times 65} = 9.8\,\text{kV}$

12. (b,c) : For adiabatic process 'bc'.

$T_1 V_b^{\gamma-1} = T_2 V_c^{\gamma-1}$

For adiabatic process 'da', $T_2 V_d^{\gamma-1} = T_1 V_a^{\gamma-1}$

Multiplying eqns. (i) and (ii), we get

$T_1 T_2 (V_b V_d)^{\gamma-1} = T_1 T_2 (V_a V_c)^{\gamma-1}$

❖❖

$V_b V_d = V_a V_c$

Since adiabatic expansion leads to cooling,

So, $T_1 > T_2$

13. (a,b) : $L\frac{di}{dt} = Bvl$

$$\therefore \int di = \frac{Bl}{L}\int v dt \Rightarrow i = \frac{Bl}{L}x \quad ...(i)$$

$$F = ma \text{ or, } -iBl = mv\frac{dv}{dx}$$

$$\text{or, } -\frac{B^2l^2x}{L} = mv\frac{dv}{dx} \text{ or, } -\frac{B^2l^2}{mL}\int_0^d x dx = \int_{v_0}^{v_0/2} v dv$$

$$\text{or } -\frac{B^2l^2d^2}{2mL} = \frac{-3v_0^2}{8},$$

$$\text{Since, } v_0 = \frac{J}{m} \Rightarrow d = \sqrt{\frac{3J^2L}{4B^2l^2m}}$$

$$\text{Put } x = d \text{ in eqn. (i), } i = \frac{Bl}{L}\sqrt{\frac{3J^2L}{4B^2l^2m}} = \sqrt{\frac{3J^2}{4Lm}}$$

14. (a,b) : Due to propagation of a wave the energy density at point is given by $E = I/v$

where I is intensity at that point and v is wave propagation velocity.

It means energy density E is directly proportional to intensity I.

If power emitted by a point source is P then intensity at a distance r from it is equal to

$$I = \frac{P}{4\pi r^2} \text{ or } I \propto \frac{1}{r^2}$$

Hence, the shape of the curve between I and r will also be same as that given in figure of the question.

Hence, option (a) is correct.

If the source is a plane sound source then intensity at every point in front of the source will be same if damping does not take place. But if damping takes place then the amplitude of oscillation of medium particles decreases with distance. Hence, the intensity decreases with the distance from the source. In that case, the curve between I and r may have the same shape as shown in the figure given in the question. Hence, option (b) is also correct.

If the source is a plane source, intensity at every point of the source will be the same. But if power of the source is decreasing with time, intensity will also decrease with time. But at any in instant, intensity at every point in front of source will be same. Therefore, the energy density at every point in front of source will also be same, though it will decrease with time. Hence, option (c) is wrong.

15. (c) : 250 g × 4.18 × (80 – 75) = (ms)(75 – 20)

$\therefore$ $(ms) = 95$ J K^{-1}

16. (c) : As rate of heat transfer from warmer = 500 cal min^{-1}

$\therefore$ In 5 min heat transferred = 2500 cal

$2500 \times 4.18 = (750 \times 4.18 + 500 \times 0.17)\Delta\theta$

$\Rightarrow \Delta\theta = 3.24$

Therefore, final temperature = 83.24 °C.

17. (c) : The correction for reduced mass is very small for hydrogen and its isotopes because even in hydrogen, the mass of the proton is about 1857 times the mass of the electron.

$$\therefore \mu = \frac{m_e \cdot m_p}{m_e + m_p} = \frac{m_e \cdot 1857 m_e}{1858 m_e} \simeq m_e.$$

It is only slightly less. $\mu = 0.999 m_e \simeq m_e$.

Unless very high resolving power instruments are used, one cannot distinguish between the spectra of H and D or H and T.

18. (c) : In the case of positronium, $\mu = \frac{m_e \cdot m_e}{m_e + m_e} = \frac{m_e}{2}$

as the positron has the same mass as the electron.

Therefore, $E_n = -\frac{1}{2}m_e c^2 \cdot \alpha^2 \frac{Z^2}{n^2}$. for normal H-atom.

For positronium,

$$E_n = -\frac{1}{2}\left(\frac{m_e}{2}c^2\right)\alpha^2 \cdot \frac{Z^2}{n^2} = -\frac{13.6}{2}\frac{1}{n^2}$$

$$\therefore E_1 = -\frac{13.6 \text{ eV}}{2}.$$

BRAIN MAP

SYSTEM OF PARTICLES AND ROTATIONAL MOTION

- Velocity, $\vec{v}_{CM} = \dfrac{m_1\vec{v}_1 + m_2\vec{v}_2 + ...}{m_1 + m_2 + ...}$
- Acceleration, $\vec{a}_{CM} = \dfrac{m_1\vec{a}_1 + m_2\vec{a}_2 + ...}{m_1 + m_2 + ...}$
- If $\vec{F}_{ext.} = 0$, then $\vec{v}_{CM} = \text{constant}$.

- The position of centre of mass is independent of the choice of co-ordinate system.
- Centre of mass of an isolated system moves with uniform velocity along a straight-line.
- The sum of the moments of masses of the system about the centre of mass is zero.
- When body rolls without slipping no work is done against friction.
- The axis of rotation of the rolling body is parallel to the plane on which it rolls.

Some Important Points to Remember

- For a system of particles
  - Position, $\vec{r}_{CM} = \dfrac{m_1\vec{r}_1 + m_2\vec{r}_2 + ...}{m_1 + m_2 + ...}$

Pure Translation Motion

In this motion, all the particles have same displacement (s), velocity (v) and acceleration (a) during any interval and at any instant.

SYSTEM OF PARTICLES AND THEIR MOTION

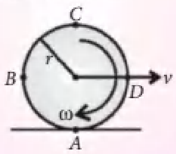
ROTATIONAL MOTION OF RIGID BODIES

COMBINED TRANSLATIONAL AND ROTATIONAL MOTION

Centre of Mass and Centre of Gravity

- The centre of mass of a system of particles is the point at which the entire system's mass is supposed to be concentrated.
- The centre of gravity of a body is a point where the weight of the body acts.
- The centre of gravity of a body coincides with its centre of mass only if the gravitational field does not vary from one point of the body to other.

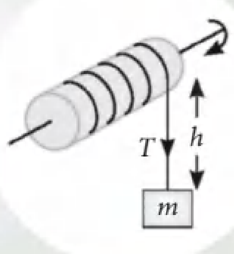
- Velocity of any point of the rigid body in combined motion is the vector sum of $\vec{v}$ and $\vec{r} \times \vec{\omega}$.



- The speed of a point on the circumference at any instant t is $2r\omega \sin(\omega t/2)$
- x and y coordinates of the bottommost point at any time t,
  $(x, y) \equiv (vt - r\sin\omega t,\ r - r\cos\omega t)$

Motion of Connected Mass

- Downward acceleration of point mass
  $a = \dfrac{g}{1 + \dfrac{I}{mR^2}}$



- Tension in string
  $T = mg\left[\dfrac{I}{I + mR^2}\right]$
- Velocity of point mass $v = \sqrt{\dfrac{2gh}{1 + \dfrac{I}{mR^2}}}$
- Angular velocity of rigid body $\omega = \sqrt{\dfrac{2mgh}{I + mR^2}}$

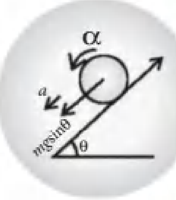
Pure Rolling Motion

If all points in the body rotates about an axis of rotation and the axis of rotation moves with respect to the surface.

Rolling on Inclined Plane

- A rigid body of radius R, mass M and moment of inertia, $I = CMR^2$ is released at rest.

$a = \dfrac{g\sin\theta}{1 + C}$ $\left\{ C(= k^2/R^2) \text{ is a constant varies for different bodies} \right.$



- Velocity at the lowest point : $v = \sqrt{\dfrac{2gh}{1 + C}}$
- Time of descent : $t = \dfrac{1}{\sin\theta}\sqrt{\dfrac{2h}{g}(1 + C)}$

Snapshot of Rolling Motion

For rigid bodies : solid cylinder, hollow cylinder, solid sphere and hollow sphere

- Order of acceleration

  $a_{\text{solid sphere}} > a_{\text{solid cylinder}} > a_{\text{hollow sphere}} > a_{\text{hollow cylinder}}$

- Order of required friction force for pure rolling

  $f_{\text{hollow cylinder}} > f_{\text{hollow sphere}} > f_{\text{solid cylinder}} > f_{\text{solid sphere}}$

- Order of co-efficient of friction for pure rolling

  $\mu_{\text{hollow cylinder}} > \mu_{\text{hollow sphere}} > \mu_{\text{solid cylinder}} > \mu_{\text{solid sphere}}$

Kinematics of Rotational Motion

- Angular displacement, $\theta = \frac{s}{r}$
- Angular velocity, $\omega = \frac{d\theta}{dt}$
- Angular acceleration, $\alpha = \frac{d\omega}{dt}$
- Equations of rotational motion
  - $\omega = \omega_0 + \alpha t$
  - $\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
  - $\omega^2 = \omega_0^2 + 2\alpha\theta$

Conservation of Angular Momentum

- If $\vec{\tau}_{net} = 0$, then $\frac{d\vec{L}_{net}}{dt} = 0$, so that $\vec{L} = I\omega$ = constant

Angular Momentum

- Of a particle about a point

  $\vec{L} = \vec{r} \times \vec{p}; L = r\ p \sin\theta$

- Of a rigid body rotating about a fixed axis

  $\vec{L} = \sum_{i=1}^{i=n} m_i(\vec{r}_i \times \vec{v}_i)\ ; L = I\omega$

Pure Rotational Motion

Every particle of the body moves in a circle whose centre lies on the axis of rotation and moves through the same angle.

Dynamics of Rotational Motion

- From Newton's 2nd law $\vec{\tau}_{net} = \frac{d\vec{L}}{dt}$
- Torque about the axis of rotation

  $\vec{\tau} = \vec{r} \times \vec{F}\ ;\ \tau = rF\sin\theta = I\alpha$

- Work done by torque, $W = \tau d\theta$
- Power, $P = \tau\omega$

Moment of Inertia

- For a rigid body, $I = \sum_{i=1}^{i=n} m_i r_i^2$
- In general $I = Mk^2$

  Here, k = Radius of gyration

- Perpendicular axes theorem :

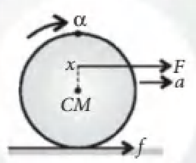
  $I_z = I_x + I_y$

  (Object is in x-y plane)

- Parallel axes theorem :

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

- A force F is applied at a distance x above the centre of a rigid body of radius R, mass M and moment of inertia CMR^2 about an axis passing through the centre of mass



$a = \frac{F(R+x)}{MR(C+1)}$,

$f = \frac{F(x-RC)}{R(C+1)}$ $\left\{ \begin{array}{l} f \text{ must be} \\ \le \mu_s mg \end{array} \right.$

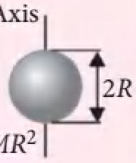
- For a body rolling without slipping, velocity of centre of mass, $\vec{v}_{CM} = r\boldsymbol{\omega}$

  Kinetic energy,

  $K_{\text{roll.}} = K_{\text{trans.}} + K_{\text{rot.}}$

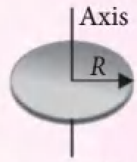
  $= \frac{1}{2}mv_{CM}^2(1+C)$

Spherical Shell



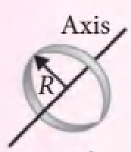
$I = \frac{2}{3}MR^2$

Uniform Disc



$I = M\ R^2/2$

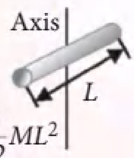
Circular Ring



$I = MR^2$

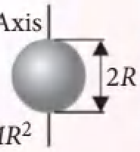
$I = \frac{1}{2}MR^2$

Uniform Rod



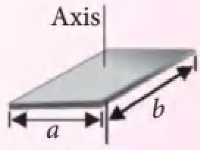
$I = \frac{1}{12}ML^2$

Solid Sphere



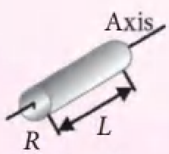
$I = \frac{2}{5}MR^2$

Plane Lamina

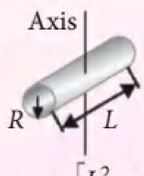


$I = \frac{1}{12}M(a^2 + b^2)$

Solid Cylinder

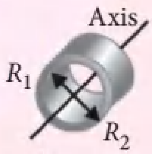


$I = \frac{1}{2}MR^2$



$I = M\left[\frac{L^2}{12} + \frac{R^2}{4}\right]$

Hollow Cylinder



$I = \frac{1}{2}M(R_1^2 + R_2^2)$

PRACTICE PAPER

BITSAT

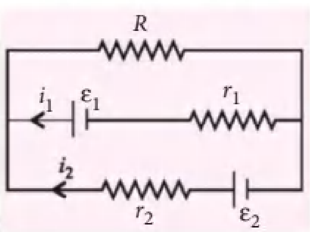
1. In Young's double slit experiment, the intensity at a point is $(1/4)^{th}$ of the maximum intensity. Angular position of this point is
   (a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$
   (c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

2. Two radioactive materials X_1 and X_2 have decay constants 5λ and λ respectively. If initially they have the same number of nuclei, then after what time the ratio of the number of nuclei of X_1 to that X_2 will be $1/e$?
   (a) $\frac{1}{4\lambda}$ (b) e/λ (c) λ (d) $\frac{1}{2\lambda}$

3. A train approaching a railway platform with a speed of 20 m s^{-1} starts blowing the whistle. Speed of sound in air is 340 m s^{-1}. If the frequency of the emitted sound from the whistle is 640 Hz, the frequency of sound as heard by person standing on the platform is
   (a) 600 Hz (b) 640 Hz
   (c) 680 Hz (d) 720 Hz

4. A block of mass M is held against a rough vertical wall by pressing it with a finger. If the coefficient of friction between the block and the wall is μ and the acceleration due to gravity is g, calculate the minimum force required to be applied by the finger to hold the block against the wall ?
   (a) μMg (b) Mg/μ (c) $\mu g/M$ (d) Mg

5. See the electrical circuit shown in this figure. Which of the following equations is a correct equation for it?



   (a) $\varepsilon_2 - i_2r_2 - \varepsilon_1 - i_1r_1 = 0$
   (b) $-\varepsilon_2 - (i_1 + i_2)R + i_2r_2 = 0$
   (c) $\varepsilon_1 - (i_1 + i_2)R + i_1r_1 = 0$
   (d) $\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$

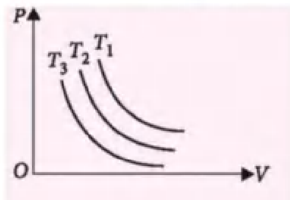
6. A solid cylinder of mass 20 kg and radius 20 cm rotates about its axis with an angular speed 100 rad s^{-1}. The angular momentum of the cylinder about its axis is
   (a) 40 J s (b) 400 J s
   (c) 20 J s (d) 200 J s

7. Two long and parallel straight wires A and B are carrying currents of 4 A and 7 A in the same direction are separated by a distance of 5 cm. The force acting on a 8 cm section of wire A is
   (a) 3×10^{-6} N (b) 6×10^{-6} N
   (c) 9×10^{-6} N (d) 12×10^{-6} N

8. A particle is projected at 60° to the horizontal with a kinetic energy K. The kinetic energy at the highest point is
   (a) $K/2$ (b) K (c) zero (d) $K/4$

9. For a given lens, the magnification was found to be twice as larger as when the object was 0.15 m distant from it as when the distance was 0.2 m. The focal length of the lens is
   (a) 1.5 m (b) 0.20 m
   (c) 0.10 m (d) 0.05 m

10. The isothermal diagram of a gas at three different temperatures T_1, T_2 and T_3, is shown in the given figure. Then



   (a) $T_1 < T_2 < T_3$
   (b) $T_1 < T_2 > T_3$
   (c) $T_1 > T_2 > T_3$
   (d) $T_1 > T_2 < T_3$

11. An electric charge of 8.85×10^{-13} C is placed at the centre of a sphere of radius 1 m. The electric flux through the sphere is
   (a) 0.2 N C^{-1} m^2 (b) 0.1 N C^{-1} m^2
   (c) 0.3 N C^{-1} m^2 (d) 0.01 N C^{-1} m^2

12. Speeds of two identical cars are u and $4u$ at a specific instant. The ratio of the respective distances at which the two cars are stopped from that instant is

(a) 1 : 1 (b) 1 : 4
(c) 1 : 8 (d) 1 : 16

13. The primary and secondary coils of a transformer have 50 and 1500 turns respectively. If the magnetic flux ϕ linked with the primary coil is given by $\phi = \phi_0 + 4t$, where ϕ is in weber, t is time in second and ϕ_0 is a constant, the output voltage across the secondary coil is

(a) 90 V (b) 120 V
(c) 220 V (d) 30 V

14. Two pendulums differ in lengths by 22 cm. They oscillate at the same place so that one of them makes 30 oscillations and the other makes 36 oscillations during the same time. The lengths (in cm) of the pendulums are

(a) 72 and 50 (b) 60 and 38
(c) 50 and 28 (d) 80 and 58

15. A body moving with some initial velocity and having uniform acceleration attains a final velocity v m s^{-1} after travelling x m. If its final velocity is $v = \sqrt{180 - 7x}$, find the acceleration of the body.

(a) – 3.5 m s^{-2} (b) – 7 m s^{-2}
(c) – 15 m s^{-2} (d) – 30 m s^{-2}

16. A proton and an α-particle are accelerated through a potential difference of 100 V. The ratio of the wavelength associated with the proton to that associated with an α-particle is

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

17. The figure shows the energy levels of certain atom. When the electron de-excites from $3E$ to E, an electromagnetic wave of wavelength λ is emitted. What is the wavelength of the electromagnetic wave emitted, when the electron de-excites from $\frac{5E}{3}$ to E?

(a) 3λ (b) 2λ (c) 5λ (d) $\frac{3\lambda}{5}$

18. If P, Q, R are physical quantities, having different dimensions, which of the following combinations can never be a meaningful quantity?

(a) $\frac{(P-Q)}{R}$ (b) $PQ - R$
(c) $\frac{PQ}{R}$ (d) $\frac{(PR-Q^2)}{R}$

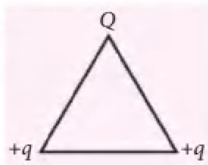
19. The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between

(a) $n = 3$ to $n = 1$ states (b) $n = 2$ to $n = 1$ states
(c) $n = 4$ to $n = 3$ states (d) $n = 3$ to $n = 2$ states

20. The following logic circuit represents

(a) NAND gate with output $O = \overline{X} + \overline{Y}$
(b) NOR gate with output $O = \overline{X + Y}$
(c) NAND gate with output $O = \overline{X.Y}$
(d) AND gate with output $O = X . Y$

21. Three charges are placed at the vertex of an equilateral triangle as shown in figure. For what value of Q, the electrostatic potential energy of the system is zero?



(a) $-q$ (b) $q/2$
(c) $-2q$ (d) $-q/2$

22. If three molecules have velocities 0.5 km s^{-1}, 1 km s^{-1} and 2 km s^{-1}, the ratio of the rms speed and average speed is

(a) 2.15 (b) 1.13
(c) 0.53 (d) 3.96

23. A hollow pipe of length 0.8 m is closed at one end. At its open end a 0.5 m long uniform string is vibrating in its second harmonic and it resonates with the fundamental frequency of the pipe. If the tension in the wire is 50 N and the speed of sound is 320 m s^{-1}, the mass of the string is

(a) 5 g (b) 10 g
(c) 20 g (d) 40 g

24. A convex lens of refractive index 3/2 has a power of 2.5 D in air. If it is placed in a liquid of refractive index 2, then the new power of the lens is

(a) –1.25 D (b) –1.5 D
(c) 1.25 D (d) 1.5 D

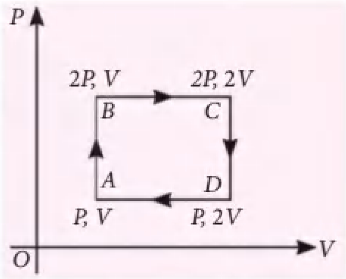
25. Consider two rods of same length and different specific heats (c_1,c_2), thermal conductivities (K_1,K_2) and area of cross-sections (A_1,A_2) and both having temperatures (T_1, T_2) at their ends. If their rate of loss of heat due to conduction is equal, then

(a) $K_1A_1 = K_2A_2$ (b) $K_1A_1/c_1 = K_2A_2/c_2$
(c) $K_2A_1 = K_1A_2$ (d) $K_2A_1/c_2 = K_1A_2/c_1$

26. A circuit area 0.01 m^2 is kept inside a magnetic field which is normal to its plane. The magnetic field changes from 2 T to 1 T in 1 ms. If the resistance of the circuit is 2 Ω. The rate of heat evolved is

(a) 5 J s^{-1} (b) 50 J s^{-1}
(c) 0.05 J s^{-1} (d) 0.5 J s^{-1}

27. An ideal monatomic gas is taken around the cycle *ABCDA* as shown in the *P-V* diagram. The work done during the cycle is given by

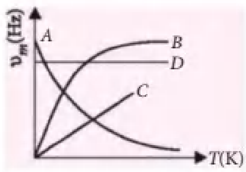


(a) 1/2 *PV*
(b) *PV*
(c) 2*PV* (d) 4 *PV*

28. The imaginary angular velocity of the earth for which the effective acceleration due to gravity at the equator shall be zero is equal to
(Take $g = 10$ m s^{-2} for the acceleration due to gravity if the earth were at rest and radius of earth equal to 6400 km.)

(a) 1.25×10^{-3} rad s^{-1} (b) 2.50×10^{-3} rad s^{-1}
(c) 3.75×10^{-3} rad s^{-1} (d) 5.0×10^{-3} rad s^{-1}

29. Which one of the following is υ_m-T graph for perfectly black body? υ_m is the frequency of radiation with maximum intensity. *T* is the absolute temperature.

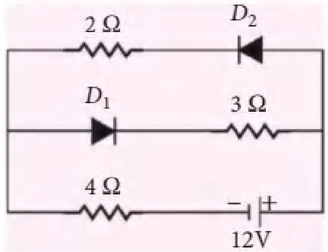


(a) *A*
(b) *B*
(c) *C*
(d) *D*

30. Two particles *X* and *Y* having equal charges, after being accelerated through the same potential difference enter a region of uniform magnetic field and describe circular paths of radii r_1 and r_2 respectively. The ratio of the mass of *X* to that of *Y* is

(a) $\left(\frac{r_1}{r_2}\right)^{1/2}$ (b) $\left(\frac{r_2}{r_1}\right)$
(c) $\left(\frac{r_1}{r_2}\right)^2$ (d) $\left(\frac{r_1}{r_2}\right)$

31. The circuit has two oppositely connected ideal diodes in parallel. What is the current flowing in the circuit?



(a) 1.71 A
(b) 2.0 A
(c) 2.31 A
(d) 1.33 A

32. An electrical device draws 2 kW power from ac mains voltage 223 V(rms). The current differs lags in phase by $\phi = \tan^{-1}\left(-\frac{3}{4}\right)$ as compared to voltage. The resistance *R* in the circuit is

(a) 15 Ω (b) 20 Ω
(c) 25 Ω (d) 30 Ω

33. An explosion blows a rock into three parts. Two parts go off at right angles to each other, first part of 1 kg moves with a velocity of 12 m s^{-1} and second part of 2 kg moves with a velocity of 8 m s^{-1}. If the third part flies off with a velocity of 4 m s^{-1}, its mass would be

(a) 3 kg (b) 5 kg (c) 7 kg (d) 17 kg

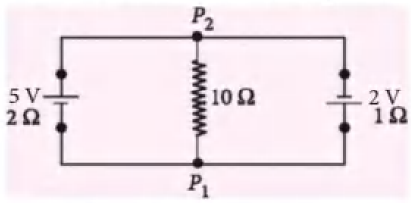
34. A beam of light of wavelength 600 nm from a distant source falls on a single slit 1.00 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between the first dark fringes on either side of the central bright fringe is

(a) 1.2 cm (b) 1.2 mm
(c) 2.4 cm (d) 2.4 mm

35. The frequency of electromagnetic wave which is best suitable to observe a particle of radius 3×10^{-4} cm is of the order of

(a) 10^{15} Hz (b) 10^{10} Hz
(c) 10^{13} Hz (d) 10^{12} Hz

36. A 5 V battery with internal resistance 2 Ω and 2 V battery with internal resistance 1 Ω are connected to a 10 Ω resistor as shown in the figure.



The current in the 10 Ω resistor is

(a) 0.27 A P_1 to P_2 (b) 0.27 A P_2 to P_1
(c) 0.03 A P_1 to P_2 (d) 0.03 A P_2 to P_1

37. A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Then the elastic energy stored in the wire is

(a) 0.2 J (b) 10 J (c) 20 J (d) 0.1 J

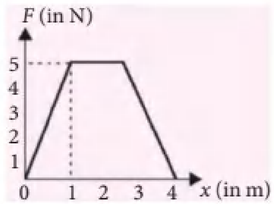
38. The rise in the water level in a capillary tube of radius 0.07 cm when dipped vertically in a beaker containing water of surface tension 0.07 N m^{-1} is (Take $g = 10$ m s^{-2} and angle of contact of water with beaker = 0°)

(a) 2 cm (b) 4 cm (c) 1.5 cm (d) 3 cm

39. In the magnetic meridian of a certain place the horizontal component of earth's magnetic field is 0.25 G and dip angle is 60°. The magnetic field of the earth at this location is

(a) 0.50 G (b) 0.52 G (c) 0.54 G (d) 0.56 G

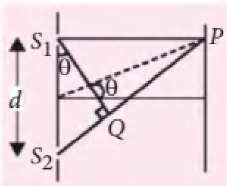
40. The force F acting on a particle moving in a straight line is shown in figure. What is the work done by the force on the particle in the 1st meter of the trajectory?



(a) 5 J (b) 10 J (c) 15 J (d) 2.5 J

SOLUTIONS

1. (c) : Intensity at any point in Young's double slit experiment,



$$I = I_{max}\cos^2\left(\frac{\phi}{2}\right)$$

$$\therefore \quad \frac{I_{max}}{4} = I_{max}\cos^2\frac{\phi}{2}$$

or $\cos\frac{\phi}{2} = \frac{1}{2}$ or $\frac{\phi}{2} = \frac{\pi}{3}$

$\therefore \quad \phi = \frac{2\pi}{3} = \frac{2\pi\Delta x}{\lambda}$, where Δx is the path difference

or $\Delta x = \frac{\lambda}{3}$

Path difference, $\Delta x = S_2Q = d\sin\theta$

$\therefore \quad d\sin\theta = \frac{\lambda}{3}$ or $\sin\theta = \frac{\lambda}{3d}$ or $\theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

2. (a) : $X_1 = N_0e^{-\lambda_1 t}$; $X_2 = N_0e^{-\lambda_2 t}$

$$\frac{X_1}{X_2} = e^{-1} = e^{(-\lambda_1+\lambda_2)t}\ ;\ e^{-1} = e^{-(\lambda_1-\lambda_2)t}$$

$$\therefore \quad t = \frac{1}{(\lambda_1-\lambda_2)} = \frac{1}{(5\lambda-\lambda)} = \frac{1}{4\lambda}$$

3. (c) : Here, speed of source (*i.e.* train), $v_s = 20$ m s^{-1}

Speed of sound in air, $v = 340$ m s^{-1}

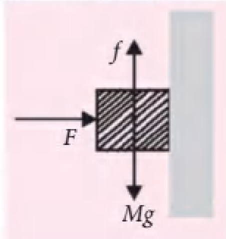
Frequency of the source, $\upsilon_0 = 640$ Hz

The frequency heard by the person standing on the platform is

$$\upsilon' = \upsilon_0\left[\frac{v}{v-v_s}\right]$$

$$= 640\left[\frac{340}{340-20}\right] = \frac{640\times340}{320} = 680 \text{ Hz}$$

4. (b) : Let F = Minimum force applied by finger to hold the block



Mg = weight of block.

f = friction force on the block

Normal reaction, $N = F$

$\therefore \quad f = \mu N = \mu F$ ...(i)

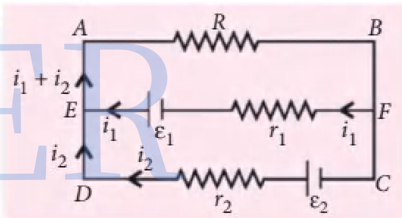
Also, $f = Mg$ ...(ii)

(As block does not move)

From equation (i) and (ii), $Mg = \mu F$

$$\Rightarrow \quad F = \frac{Mg}{\mu}$$

5. (d) :



Applying Kirchhoff's rule to the loop *ABFE*,

$$\varepsilon_1 - (i_1 + i_2)R - i_1r_1 = 0$$

For loop *EFCD*, $\varepsilon_2 - i_2r_2 - \varepsilon_1 + i_1r_1 = 0$

For loop *ABCD*, $(i_1 + i_2)R - \varepsilon_2 - i_2r_2 = 0$

$\therefore$ Only option (d) is correct.

6. (a) : Here, $M = 20$ kg

$R = 20$ cm $= 20 \times 10^{-2}$ m, $\omega = 100$ rad s^{-1}

Moment of inertia of the solid cylinder about its axis is

$$I = \frac{MR^2}{2} = \frac{(20\text{ kg})(20\times10^{-2}\text{ m})^2}{2} = 0.4 \text{ kg m}^2$$

Angular momentum of the cylinder about its axis is

$L = I\omega = (0.4$ kg $m^2)$ $(100$ rad $s^{-1}) = 40$ J s

7. (c) : Here, $I_1 = 4$ A, $I_2 = 7$ A

$d = 5$ cm $= 5 \times 10^{-2}$ m, $l = 8$ cm $= 8 \times 10^{-2}$ m

$$\therefore \quad F = \frac{\mu_0}{4\pi}\frac{2I_1I_2l}{d} = \frac{10^{-7}\times2\times4\times7}{5\times10^{-2}}\times8\times10^{-2}$$

$$= 89.6 \times 10^{-7} \text{ N} = 9 \times 10^{-6} \text{ N}$$

8. **(d)**: Initial K.E., $K = \frac{1}{2}mv^2$

Velocity at the highest point = Horizontal component of $v = v\cos 60° = \frac{v}{2}$

$\therefore$ K.E. at the highest point $= \frac{1}{2}m\left(\frac{v}{2}\right)^2 = \frac{K}{4}$

9. **(c)**: Here $m_1 = 2m_2$

$$\frac{f}{f-0.15} = 2\frac{f}{f-0.20} \qquad \left(\because m = \frac{f}{f+u}\right)$$

or $2f - 0.30 = f - 0.20$ or $f = 0.10$ m.

10. **(c)**: The given diagram shows that the curves move away from the origin as temperature increases.

11. **(b)**: According to Gauss's law, the electric flux through the sphere is

$$\phi = \frac{q_{in}}{\varepsilon_0} = \frac{8.85\times10^{-13}\,\text{C}}{8.85\times10^{-12}\,\text{C}^2\,\text{N}^{-1}\,\text{m}^{-2}} = 0.1\,\text{N C}^{-1}\,\text{m}^2$$

12. **(d)**: For first car : $u = u$, $a = -a$, $v = 0$

As $v^2 - u^2 = 2as$

$\therefore$ $v^2 - u^2 = 2(-a)s_1$ or $s_1 = u^2/2a$

For second car : $u = 4u$, $a = -a$, $v = 0$

$\therefore$ $s_2 = \frac{(4u)^2}{2a} = \frac{8u^2}{a}$

Hence, $\frac{s_1}{s_2} = \frac{u^2}{2a}\cdot\frac{a}{8u^2} = \frac{1}{16} = 1:16$

13. **(b)**: Flux linked with the primary coil,

$\phi = \phi_0 + 4t$

Voltage across primary, $V_p = \frac{d\phi}{dt} = 0 + 4\times1 = 4\,\text{V}$

Voltage across secondary,

$V_s = \frac{N_s}{N_p}.V_p = \frac{1500}{50}\times4 = 120$ V

14. **(a)**

15. **(a)**: $v = \sqrt{180 - 7x}$, where x is the distance.

$\therefore$ $v^2 = 180 - 7x$

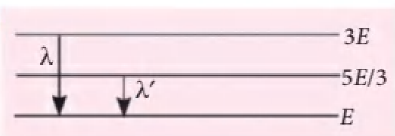
For a body travelling with uniform acceleration, $v^2 - u^2 = 2ax$ is valid. By inspection one can say $u^2 = 180$, $2ax = -7x$. $\therefore$ $a = -3.5$ m s^{-2}

16. **(c)**: For a particle accelerated through potential difference V, $\lambda = \frac{h}{\sqrt{2mqV}}$

$\lambda_p = \frac{h}{\sqrt{2meV}}$; $\lambda_\alpha = \frac{h}{\sqrt{2\times4m\times2e\times V}} = \frac{1}{2\sqrt{2}}\lambda_p$

$\frac{\lambda_p}{\lambda_\alpha} = 2\sqrt{2}:1$

17. **(a)**:



From figure,

$\frac{hc}{\lambda} = 3E - E = 2E$ ...(i) $\quad \frac{hc}{\lambda'} = \frac{5E}{3} - E = \frac{2}{3}E$ ...(ii)

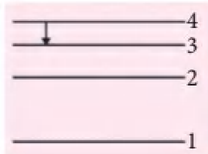
Divide (i) by (ii), we get

$\frac{\lambda'}{\lambda} = 3$ or $\lambda' = 3\lambda$

18. **(a)**: Physical quantities having different dimensions cannot be added or subtracted.

As P, Q and R are physical quantities having different dimensions, therefore they can neither be added nor be subtracted. Thus, (a) can never be a meaningful quantity.

19. **(c)**: $\frac{n(n-1)}{2} = 6$



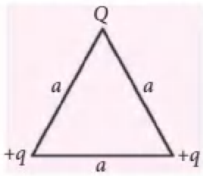
$n^2 - n - 12 = 0$

$(n - 4)(n + 3) = 0$ or $n = 4$

Maximum wavelength corresponds to lowest energy ($E_4 \to E_3$).

20. **(b)**: The given logic circuit represents a NOR gate with output $O = \overline{X + Y}$.

21. **(d)**: Electrostatic potential energy of the system of charges is



$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qq}{a} + \frac{Qq}{a} + \frac{q^2}{a}\right]$$

$$U = \frac{1}{4\pi\varepsilon_0 a}[2Qq + q^2]$$

Given, $U = 0 \Rightarrow 2Qq + q^2 = 0 \Rightarrow Q = -q/2$

22. **(b)**

23. **(b)**: For hollow pipe, fundamental frequency is

$f = \frac{v}{4l} = \frac{320}{4\times0.8}$

For string in 2nd harmonic,

$f = \frac{1}{l}\sqrt{\frac{T}{\mu}} = \frac{1}{l}\sqrt{\frac{Tl}{m}} = \frac{1}{0.5}\sqrt{\frac{50\times0.5}{m}}$

Equating and solving, we get $m = 0.01$ kg = 10 g

24. **(a)**: $P \propto (\mu - 1)$

$$\therefore \frac{P_l}{P_a} = \frac{({}^l\mu_g - 1)}{({}^a\mu_g - 1)} = \frac{\left(\frac{3/2}{2} - 1\right)}{\left(\frac{3}{2} - 1\right)} = -\frac{1}{4}\times\frac{2}{1} = -0.5$$

$P_l = -0.5\,P_a = -0.5\times2.5 = -1.25$ D

25. **(a)**: Given : $\frac{Q_1}{t} = \frac{Q_2}{t}$

or $\frac{K_1A_1(T_1 - T_2)}{l} = \frac{K_2A_2(T_1 - T_2)}{l}$ or $K_1A_1 = K_2A_2$

26. (b): Induced emf, $\varepsilon = \frac{-d\phi}{dt} = \frac{-d}{dt}(BA)$

$$\Rightarrow \quad \varepsilon = \frac{-A(B_2 - B_1)}{t} = \frac{-0.01(1-2)}{1\times10^{-3}}$$

$\varepsilon = 0.01 \times 10^3 = 10$ V

$V = IR$ or $I = \frac{10}{2}$ $\therefore$ $I = 5$ A.

Rate of heat evolved $= I^2R = (5)^2 \times 2 = 50$ J s^{-1}.

27. (b): Work done = Area of the loop $ABCDA$
$= (2P - P)(2V - V) = PV$

28. (a): The effective acceleration due to gravity at the equator is $g' = g - R\omega^2$

As per question, $g' = 0$

$$\therefore \quad \omega = \sqrt{\frac{g}{R}}$$

Substituting the given values, we get

$$\omega = \sqrt{\frac{10 \text{ m s}^{-2}}{6400\times10^3 \text{m}}} = \frac{1}{8}\times10^{-2} \text{rad s}^{-1} = 1.25\times10^{-3} \text{rad s}^{-1}$$

29. (c): According to Wien's displacement law

$\lambda_m T = b$, where b is the Wien's constant.

In terms of frequency, $\frac{c}{\upsilon_m}T = b$ or $\upsilon_m = \frac{c}{b}T$

Hence, the (υ_m-T) graph is a straight line.

30. (c)

31. (b): No current flows through diode D_1 because it is reverse biased. Only diode D_2 conducts because it is forward biased.

$$I = \frac{V}{R} = \frac{12}{2+4} = 2.0 \text{ A}$$

32. (b): As, $P = \frac{V_{rms}^2}{Z}$; $Z = \frac{V_{rms}^2}{P} = \frac{(223)^2}{2000} \approx 25\ \Omega$

$\tan\phi = \frac{X_C - X_L}{R} = -\frac{3}{4}$ $\therefore$ $X_C - X_L = -\frac{3}{4}R$.

As, $Z^2 = R^2 + (X_C - X_L)^2$

$$\therefore \quad (25)^2 = R^2 + \left(-\frac{3}{4}R\right)^2$$

$$625 = R^2 + \frac{9}{16}R^2 = \frac{25R^2}{16}$$

$$R^2 = \frac{625\times16}{25} = 400 \quad \Rightarrow \quad R = 20\ \Omega$$

33. (b): $\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = \vec{0}$ or $\vec{p}_3 = -(\vec{p}_1 + \vec{p}_2)$

$\therefore$ $m_3 v_3 = \sqrt{p_1^2 + p_2^2}$ $[\because \vec{p}_1 \perp \vec{p}_2]$

or $m_3 = \frac{\sqrt{(1\times12)^2 + (2\times8)^2}}{4} = 5$ kg

34. (d): Distance between the first dark fringes on either side of central maxima = Width of central maximum

$$= \frac{2D\lambda}{d} = \frac{2\times2\times600\times10^{-9}}{1.00\times10^{-3}} \text{ m}$$

$= 2.4 \times 10^{-3}$ m $= 2.4$ mm

35. (a): Let λ be the radius of the particle then

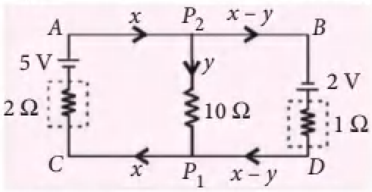
$\lambda = 3\times10^{-4}\times10^{-2}$ m $= 3\times10^{-6}$ m

Frequency of electromagnetic wave,

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^8}{3\times10^{-6}} = 10^{14} \text{ Hz}$$

Thus to observe the particle, the frequency of wave should be more than 10^{14} Hz *i.e* 10^{15} Hz or smaller value of wavelength.

36. (d): Applying Kirchhoff's law for the loops



AP_2P_1CA and $P_2BDP_1P_2$, one gets

$-10y - 2x + 5 = 0 \Rightarrow 2x + 10y = 5$ ...(i)

$+2 - 1(x - y) + 10y = 0$

$\Rightarrow 2x - 22y = 4$ ...(ii)

From eqns. (i) and (ii),

$\Rightarrow y = \frac{1}{32}$ A $= 0.03$ A from P_2 to P_1.

37. (d): Elastic potential energy $= \frac{1}{2}\times F\times\Delta L$

$= \frac{1}{2}\times200\times(1\times10^{-3}) = 0.1$ J

38. (a): Rise of a liquid in a capillary tube,

$$\therefore \quad h = \frac{2\times(0.07 \text{ N m}^{-1})\times1}{(0.07\times10^{-2}\text{ m})(10^3 \text{ kg m}^{-3})(10 \text{ m s}^{-2})}$$

$= 2\times10^{-2}$ m $= 2$ cm

39. (a): Here, $H_E = 0.25$ G and $\cos\delta = \frac{H_E}{B_E}$

$\therefore$ the magnetic field of earth at the given location is

$$B_E = \frac{H_E}{\cos 60°} = \frac{0.25}{1/2} = 0.50 \text{ G}$$

40. (d)

◈◈

Monthly Test Drive CLASS XII ANSWER KEY

1.	(b)	**2.**	(b)	**3.**	(a)	**4.**	(b)	**5.**	(b)
6.	(a)	**7.**	(b)	**8.**	(c)	**9.**	(c)	**10.**	(c)
11.	(b)	**12.**	(b)	**13.**	(d)	**14.**	(d)	**15.**	(b)
16.	(b)	**17.**	(b)	**18.**	(b)	**19.**	(c)	**20.**	(a,b,c)
21.	(b,d)	**22.**	(b, d)	**23.**	(a,c,d)	**24.**	(9)	**25.**	(2)
26.	(3)	**27.**	(c)	**28.**	(c)	**29.**	(d)	**30.**	(a)

MONTHLY TEST DRIVE

XI

This specially designed column enables students to self analyse their extent of understanding of all chapters (Class XI). Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Total Marks : 120 **Time Taken : 60 min**

NEET

Only One Option Correct Type

1. Two identical containers A and B have frictionless pistons. They contain the same volume of an ideal gas at the same temperature. The mass of the gas in A is m_A and that in B is m_B. The gas in each cylinder is now allowed to expand isothermally to double the initial volume. The change in the pressure in A and B, respectively, is ΔP and $1.5\ \Delta P$. Then

(a) $4m_A = 9m_B$ (b) $2m_A = 3m_B$
(c) $3m_A = 2m_B$ (d) $9m_A = 4m_B$

2. The maximum height reached by projectile is 4 m. The horizontal range is 12 m. The velocity of projection in m s^{-1} is (g is acceleration due to gravity)

(a) $5\sqrt{g/2}$ (b) $3\sqrt{g/2}$
(c) $\frac{1}{3}\sqrt{g/2}$ (d) $\frac{1}{5}\sqrt{g/2}$

3. A bucket full of hot water cools from 75 °C to 70 °C in time T_1, from 70 °C to 65 °C in time T_2 and from 65 °C to 60 °C in time T_3, then

(a) $T_1 = T_2 = T_3$ (b) $T_1 > T_2 > T_3$
(c) $T_1 < T_2 < T_3$ (d) $T_1 > T_2 < T_3$

4. An observer standing on a railway crossing receives frequencies 2.2 kHz and 1.8 kHz when the train approaches and recedes from the observer. Find the velocity of the train (speed of sound in air is 300 m s^{-1}).

(a) 10 m s^{-1} (b) 20 m s^{-1}
(c) 25 m s^{-1} (d) 30 m s^{-1}

5. The velocity of a body falling freely under gravity varies as $g^a h^b$, where g is the acceleration due to gravity and h is the height. The value of a and b respectively are

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

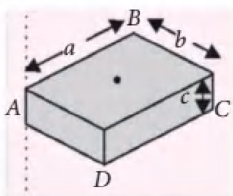
6. A cubical block of wood 10 cm along each side floats at the interface between an oil and water with its lowest surface 2 cm below the interface. If the heights of oil and water columns are 10 cm each and $\rho_{oil} = 0.8$ g cm^{-3}, find the mass of the block.

(a) 840 g (b) 940 g (c) 1040 g (d) 1500 g

7. A block is lying on the horizontal frictionless surface. One end of a uniform rope is fixed to the block which is pulled in the horizontal direction by applying a force F at the other end. If the mass of the rope is half the mass of the block, the tension in the middle of the rope will be

(a) F (b) $2F/3$ (c) $3F/5$ (d) $5F/6$

8. Figure shows a uniform solid block of mass M and edge lengths a, b and c. Its moment of inertia about an axis through one edge and perpendicular (as shown) to the large face of the block is



(a) $\frac{M}{3}(a^2+b^2)$ (b) $\frac{M}{4}(a^2+b^2)$
(c) $\frac{7M}{12}(a^2+b^2)$ (d) $\frac{M}{12}(a^2+b^2)$

9. What should be the lengths of steel and copper rods respectively so that the length of steel rod is 5 cm longer than copper rod at all temperatures? [α for copper = 1.7×10^{-5} °C^{-1} and α for steel = 1.1×10^{-5} °C^{-1}].
(a) 14.17 cm, 9.17 cm (b) 19 cm, 14 cm
(c) 17 cm, 12 cm (d) 9.17 cm, 4.17 cm

10. Four moles of hydrogen, 2 moles of helium and 1 mole of water vapour form an ideal gas mixture. What is the molar specific heat at constant pressure of mixture?
(a) $\frac{16}{7}R$ (b) $\frac{7R}{16}$ (c) R (d) $\frac{23}{7}R$

11. A stone is dropped into a well and its splash is heard after an interval of 1.45 s. Find the depth of top surface of water in the well. Given that the velocity of sound in air at room temperature is 332 m s^{-1}.
(a) 5 m (b) 11 m (c) 20 m (d) 30 m

12. A mass M is lowered with the help of a string by a distance h at a constant acceleration $g/2$. The work done by the string will be
(a) $\frac{Mgh}{2}$ (b) $-\frac{Mgh}{2}$
(c) $\frac{3Mgh}{2}$ (d) $-\frac{3Mgh}{2}$

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

13. **Assertion :** If the earth suddenly stops rotating about its axis, then the acceleration due to gravity will become the same at all the places.
Reason : The value of acceleration due to gravity is independent of rotation of the earth.

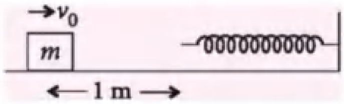
14. **Assertion :** The force of friction is dependent on normal reaction and the ratio of force of friction and normal reaction cannot exceed unity.
Reason : The coefficient of friction can be greater than unity.

15. **Assertion :** The time of flight of a body becomes n time the original value if its speed is made n time.
Reason : The range of the projectile becomes n times when speed becomes n times.

JEE MAIN / JEE ADVANCED

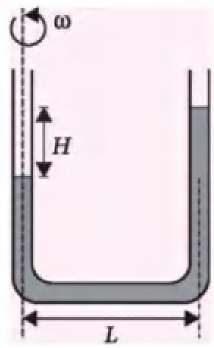
Only One Option Correct Type

16. A block of mass m = 2 kg is moving with velocity v_0 towards a massless unstretched spring of force constant k = 10 N m^{-1}. Coefficient of friction between the block and the ground is $\mu = \frac{1}{5}$.



Find maximum value of v_0, so that after pressing the spring, the block does not return back but stops there permanently.
(a) $\sqrt{12}$ m s^{-1} (b) $\sqrt{4.2}$ m s^{-1}
(c) $\sqrt{10}$ m s^{-1} (d) $\sqrt{6.4}$ m s^{-1}

17. A U-shaped tube contains a liquid of density ρ and it is rotated about the left dotted line as shown in the figure. Find the difference in the levels of the liquid column.



(a) $\frac{\omega^2 L^2}{2\sqrt{2}g}$
(b) $\frac{\omega^2 L^2}{2g}$
(c) $\frac{2\omega^2 L^2}{g}$
(d) $\frac{2\sqrt{2}\,\omega^2 L^2}{g}$

18. The molar heat capacity C for an ideal gas going through a process is given by $C = \frac{a}{T}$, where a is a constant. If $\gamma = \frac{C_P}{C_V}$, the work done by one mole of gas during heating from T_0 to $\eta\, T_0$ will be
(a) $a \ln(\eta)$
(b) $\frac{1}{a \ln(\eta)}$
(c) $a \ln(\eta) - \left(\frac{\eta - 1}{\gamma - 1}\right) RT_0$
(d) $a \ln(\eta) - (\gamma - 1) RT_0$

19. A particle performs SHM in a straight line. In the first second, starting from rest, it travels a distance a and in the next second it travels a distance b in the same direction. The amplitude of the SHM is

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

(c) $\frac{2a^2}{3a-b}$ (d) None of these

More than One Options Correct Type

20. A driver in a stationary car blows a horn which produces sound waves of frequency 1000 Hz normally towards a reflecting wall. The sound reflected from the wall approaches the car with a speed of 3.3 m s^{-1}.

(a) The frequency of sound reflected from wall and heard by the driver is 1020 Hz.

(b) The frequency of sound reflected from wall and heard by the driver is 980 Hz.

(c) The percentage increase in frequency of sound after reflection from wall is 2%.

(d) The percentage decrease in frequency of sound after reflection from wall is 2%.

21. Two cities A and B are connected by a regular bus service with buses plying in either direction every T seconds. The speed of each bus is uniform and equal to v_b. A cyclist cycles from A to B with a uniform speed of v_c. A bus goes past the cyclist in T_1 second in the direction A to B and every T_2 second in the direction B to A. Then

(a) $T_1 = \frac{v_b T}{v_b + v_c}$ (b) $T_2 = \frac{v_b T}{v_b - v_c}$

(c) $T_1 = \frac{v_b T}{v_b - v_c}$ (d) $T_2 = \frac{v_b T}{v_b + v_c}$

22. A double star is a system of two stars of masses m and $2m$, rotating about their centre of mass only under their mutual gravitational attraction. If r is the separation between these two stars then their time period of rotation about their centre of mass will be proportional to

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

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

23. 5 kg of steam at 100 °C is mixed with 10 kg of ice at 0 °C. Then (Given s_{water} = 1 cal g^{-1} °C, L_F = 80 cal g^{-1}, L_V = 540 cal g^{-1})

(a) equilibrium temperature of mixture is 160 °C

(b) equilibrium temperature of mixture is 100 °C

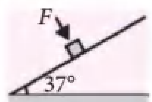
(c) at equilibrium, mixture contains $13\frac{1}{3}$ kg of water

(d) at equilibrium, mixture contains $1\frac{2}{3}$ kg of steam

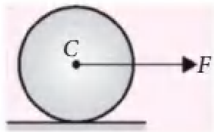
Integer Answer Type

24. The value of $\gamma = C_P/C_V$ is 4/3 for an adiabatic process of an ideal gas for which internal energy $U = K + nPV$. Find the value of n (K is a constant).

25. A block of mass m = 2 kg is resting on a rough inclined plane of inclination 37° as shown in figure. The coefficient of friction between the block and the plane is μ = 0.5. What minimum force F (in N) should be applied perpendicular to the plane on the block so, that the block does not slip on the plane? $\left[\sin 37° = \frac{3}{5}\right]$

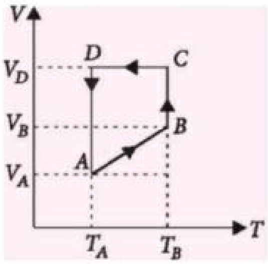


26. A horizontal force F = 14 N acts at the centre of mass of a sphere of mass m = 1 kg. If the sphere rolls without sliding, find the frictional force (in N).



Comprehension Type

A monatomic ideal gas of two moles is taken through a cyclic process starting from A as shown in figure with $V_B/V_A = 2$. Temperature T_A at A is 27 °C



27. The temperature at B, T_B is

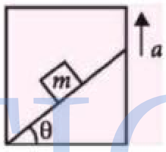
(a) 600 K (b) 450 K
(c) 400 K (d) 900 K

28. The work done during the process $A \to B$ is

(a) 1200 R (b) 1500 R
(c) 1600 R (d) 1000 R

Matrix Match Type

29. A block of mass m is stationary with respect to a rough wedge as shown in figure. Starting from rest in time t, work done by various force is given in the columns. Match the column I with column II. (g = 10 m s^{-2}, m = 1 kg, a = 2 m s^{-2}, t = 4 s).



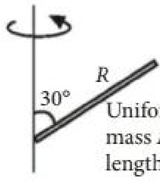
	Column I		Column II
(A)	By gravity	(P)	144 J
(B)	By normal reaction	(Q)	32 J
(C)	By friction	(R)	160 J
(D)	By all the forces	(S)	48 J

	A	B	C	D
(a)	P	Q	S	R
(b)	S	Q	P	R
(c)	P	Q	R	S
(d)	R	P	S	Q

30. Column I gives some systems whose moment of inertia are listed in column II about the shown axis. Match column I with column II.

Column I **Column II**

(A)



Uniform rod of mass M and length R

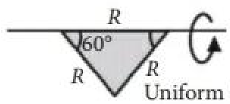
(P) $\frac{8MR^2}{11}$

(B)

Uniform semicircular ring of mass M. Axis is perpendicular to its plane.

(Q) $\frac{MR^2}{12}$

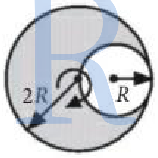
(C)



Uniform triangular plate of mass M

(R) $\frac{13MR^2}{8}$

(D)



Uniform disk of initial mass M from which a circular portion of radius R is then removed. Axis is perpendicular to its plane.

(S) $\frac{MR^2}{8}$

	A	B	C	D
(a)	Q	R	P	S
(b)	Q	P	S	R
(c)	S	P	R	Q
(d)	R	S	Q	P

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Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted ……
No. of questions correct ……
Marks scored in percentage ……

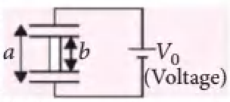
Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.

10 MIND BLOWING OLYMPIAD PROBLEMS

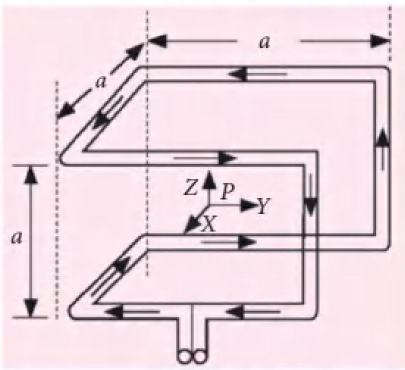
1. A long glass tube of length L, sealed at both ends, contains a small column of mercury (density = ρ) of length 'a' ($a << L$) at its middle and air at pressure P on both sides. The tube is fixed horizontally. If the mercury column gets a small displacement, the time period of its oscillations would be (assuming that the air on the sides undergoes isothermal expansion or compression):
(a) $\pi[\rho La/P]^{1/2}$ (b) $2\pi[\rho La/P]^{1/2}$
(c) $\pi[2\rho La/P]^{1/2}$ (d) $\pi[\rho La/2P]^{1/2}$

2. Figure shows two capacitors in series. The rigid center section of length 'b' is movable. The area of each plate is S. If the voltage difference between the plates is maintained constant at V_0. The change in stored energy if the center section is removed is



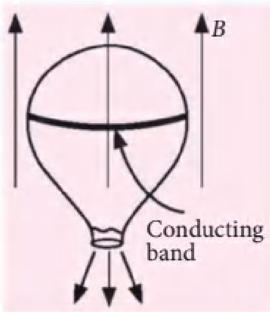
(a) $\dfrac{S\varepsilon_0 V_0^2 a}{2b(a-b)}$ (b) $\dfrac{S\varepsilon_0 V_0^2 b}{2a(a-b)}$
(c) $\dfrac{S\varepsilon_0 V_0^2 b}{a(a-b)}$ (d) $\dfrac{S\varepsilon_0 V_0^2 a}{b(a-b)}$

3. Current I flows around the wire frame along the edges of a cube as shown in figure. Point P is the center of the cube. The incoming and outgoing wires have orientation toward P. Then,



(a) the magnetic field at P is toward $+y$ direction
(b) the magnetic field at P is toward $-y$ direction
(c) the unit vector of magnetic field at P is $-\dfrac{1}{\sqrt{2}}(\hat{i}-\hat{j})$
(d) the magnitude of magnetic field P is $\dfrac{4\sqrt{2}\mu_0 I}{3\pi a}$.

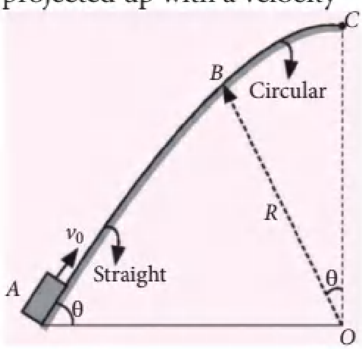
4. An elasticized conducting band is around a spherical balloon (Figure). Its plane passes through the center of the balloon. A uniform magnetic field of magnitude 0.04 T is directed perpendicular to the plane of the band. Air is let out of the balloon at 100 cm^3 s^{-1} at an instant when the radius of the balloon is 10 cm. The induced emf in the band is



(a) 15 μV (b) 25 μV (c) 10 μV (d) 20 μV

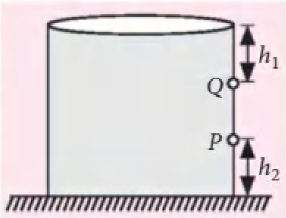
5. The speed of a projectile at its highest point is v_1 and at the point half the maximum height is v_2. If $\dfrac{v_1}{v_2}=\sqrt{\dfrac{2}{5}}$, then find the angle of projection.
(a) 45° (b) 30° (c) 37° (d) 60°

6. A block of mass m is projected up with a velocity v_0 along an inclined plane of angle of inclination $\theta = 37°$. The coefficient of friction between the inclined plane AB and block is $\mu(=\tan\theta)$. For what value of v_0 the block moves in a circular path form B to C?



(a) $\sqrt{\dfrac{18gR}{5}} \le v_0 \le \sqrt{3gR}$ (b) $\sqrt{\dfrac{18gR}{5}} \le v_0 \le \sqrt{4gR}$
(c) $\sqrt{4gR} \le v_0 \le \sqrt{\dfrac{18gR}{5}}$ (d) $\sqrt{2gR} \ge v_0 \ge \sqrt{\dfrac{1}{5}gR}$

7. In a cylindrical water tank there are two small holes Q and P on the wall at a depth of h_1 from the upper level of water and at a height of h_2 from the lower end of the tank, respectively, as shown in the figure. Water coming out from both the holes strike the ground at the same point. The ratio of h_1 and h_2 is



(a) 1 (b) 2 (c) >1 (d) <1

8. A planet is in a circular orbit about a massive star. The star undergoes a spherically symmetric explosion in which one percent of its mass is suddenly ejected to a distance well beyond that of the planet's orbit. Find the eccentricity of the new orbit of the planet assuming that the planet is unaffected by the explosion.
(a) 0.001 (b) 1.01 (c) 0.01 (d) 0.05

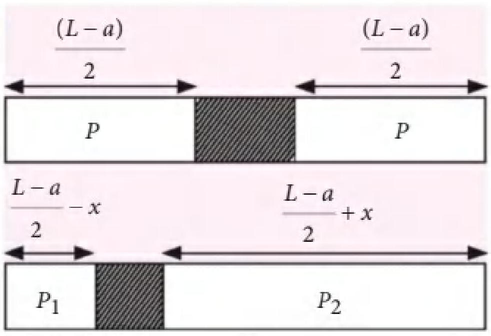
9. Due to a vertical temperature gradient in the atmosphere the index of refraction varies. Suppose index of refraction varies as $n = n_0\sqrt{1+ay}$ where n_0 is the index of refraction at the surface and $a = 2.0 \times 10^{-6}\ \text{m}^{-1}$. A person of height $h = 2.0$ m stands on a level surface. Beyond what distance he cannot see the runway?
(a) 2100 m (b) 2500 m (c) 2000 m (d) 1500 m

10. A small ball attached with one end of an inextensible thread is moving in a vertical circle. Ratio of its maximum to minimum velocity is 2 : 1.
Calculate acceleration of the ball at the moment when velocity of the ball is directed vertically downward. ($g = 10\ \text{ms}^{-2}$).

(a) $g\sqrt{109}$ (b) $\frac{g}{3}\sqrt{109}$ (c) $\frac{1}{3}\sqrt{109}$ (d) $2g\sqrt{109}$

SOLUTIONS

1. **(a):**



$P_1V_1 = P_2V_2$

$$P\left(\frac{L-a}{2}\right)A = P_2\left(\frac{L-a}{2}-x\right)A$$

$$P_2 = \frac{P(L-a)}{(L-a-2x)}$$

Again applying $P_1V_1 = P_2'V_2$

$$P\left(\frac{L-a}{2}\right)A = \left(\frac{L-a}{2}+x\right)AP_2'$$

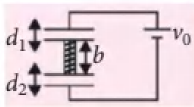
$$P_2' = \frac{P(L-a)}{(L-a+2x)}$$

$$P_2 - P_2' = \frac{P(L-a)}{[(L-a)-(2x)]} - \frac{P(L-a)}{[(L-a)+2x]}$$

$$\Delta P = \frac{4P(L-a)x}{[(L-a)^2-4x^2]}; \quad F = \Delta PA = \frac{4PA(L-a)x}{[(L-a)^2-4x^2]}$$

$$\omega = \sqrt{\frac{4P}{L\rho a}} = 2\sqrt{\frac{P}{L\rho a}}; \quad T = \frac{2\pi}{\omega} = \pi\left(\frac{L\rho a}{P}\right)^{1/2}$$

2. **(b):** Let 'd_1' be the distance between the two upper plates and 'd_2' be the distance between the two lower plates



$\therefore \quad d_1 + d_2 = a - b$

$$\therefore \quad C_1 = \frac{\varepsilon_0 S}{d_1}, C_2 = \frac{\varepsilon_0 S}{d_2}$$

$$\Rightarrow \quad C_{net} = \frac{C_1C_2}{C_1+C_2} = \frac{S\varepsilon_0}{d_1+d_2} = \frac{S\varepsilon_0}{a-b}$$

As C_{net} is independent of d_1 and d_2

$\Rightarrow$ energy stored is independent of position of centre section

$$u = \frac{1}{2}CV_0^2 = \frac{1}{2}\frac{S\varepsilon_0V_0^2}{a-b}$$

If centre section is removed, energy stored

$$\Rightarrow \quad u' = \frac{1}{2}\frac{S\varepsilon_0V_0^2}{a}; \quad \Delta u = u - u' = \frac{S\varepsilon_0V_0^2 b}{2(a-b)a}$$

3. **(a)**

4. **(d):** Volume of the balloon at any instant, when radius is r, $V = \frac{4}{3}\pi r^3$

Time rate of change of volume,

$$\frac{dV}{dt} = 4\pi r^2\frac{dr}{dt}$$

Time rate of change of radius of balloon,

$$\frac{dr}{dt} = \frac{1}{4\pi r^2}\frac{dV}{dt}$$

Flux through rubber band at the given instant,

$\phi = B(\pi r^2)$

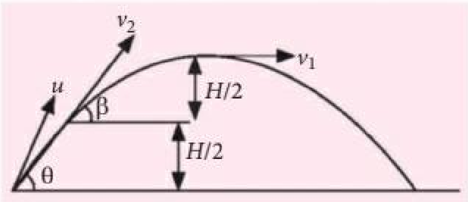
$$\text{Induced emf} = -\frac{d\phi}{dt} = -\frac{d}{dt}(B\pi r^2) = -2\pi rB\frac{dr}{dt}$$

$$= -2\pi rB\left(\frac{1}{4\pi r^2}\frac{dV}{dt}\right) = -\frac{B}{2r}\frac{dV}{dt}$$

As volume of the balloon is decreasing, $\frac{dV}{dt}$ is negative.

$$E_{\text{induced}} = -\frac{(0.04)}{2\times10\times10^{-2}} \times (-100\times10^{-6}) = 20\ \mu V$$

5. (d): $v_1 = v_2 \cos\beta = u\cos\theta$



$0 = (v_2 \sin\beta)^2 - 2g(H/2) \Rightarrow\ v_1^2 = v_2^2 - gH$

Also $\frac{v_1}{v_2} = \sqrt{\frac{2}{5}}$

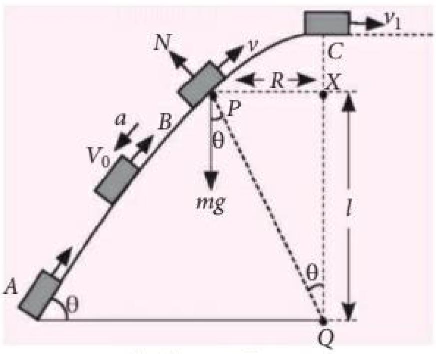
From above $v_1 = \sqrt{\frac{2gH}{3}}, v_2 = \sqrt{\frac{5gH}{3}}$

$$H = \frac{u^2\sin^2\theta}{2g}\ \Rightarrow\ \sin^2\theta = \frac{2gH\cos^2\theta}{v_1^2}$$

or $\tan^2\theta = \frac{2gH}{v_1^2}$ or $\tan^2\theta = \frac{2gH\times3}{2gH}$

or $\tan\theta = \sqrt{3}$ or $\theta = 60°$

6. (b): In triangle PQX, $\frac{R}{l} = \tan\theta = \frac{3}{4}\ \Rightarrow l = \frac{4R}{3}$



For contact not to be lost at B

$$mg\cos\theta - N = \frac{mv^2}{R}$$

$\Rightarrow\ N = mg\cos\theta - \frac{mv^2}{R} \ge 0$

$\Rightarrow\ v \le \sqrt{gR\cos\theta}$ ...(i)

From B to C, $\Delta K + \Delta U = 0$

$$\left(\frac{1}{2}mv_1^2 - \frac{1}{2}mv^2\right) + mg(R - R\cos\theta) = 0$$

$\Rightarrow\ v_2 = v_1^2 + 2gR(1-\cos\theta)$ ...(ii)

From A to B, $a = g\sin\theta + \mu g\cos\theta$

$= g\sin\theta + (\tan\theta)g\cos\theta$

$\Rightarrow\ a = 2g\sin\theta$

$\Rightarrow\ v^2 = v_0^2 - \frac{4g\sin\theta R}{\tan\theta}$

$\Rightarrow\ v^2 = v_0^2 - 4gR\cos\theta$ ...(iii)

From Eqs (i) and (iii),

$v_0^2 - 4gR\cos\theta \le gR\cos\theta$ or $v_0^2 \le 5gR\cos\theta$

$\Rightarrow\ v_0^2 \le 5gR\left(\frac{4}{5}\right) = 4gR \Rightarrow v_0 \le \sqrt{4gR}$ ...(iv)

From Eqs (ii) and (iii),

$v_1^2 + 2gR[1-\cos\theta] = v_0^2 - 4gR\cos\theta$

$\Rightarrow\ v_1^2 = v_0^2 - 2gR - 2gR\cos\theta$

Now to reach at C, $v_1 \ge 0$

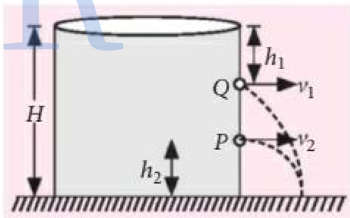
or $v_0^2 - 2gR - 2gR\cos\theta \ge 0$

$\Rightarrow\ v_0 \ge \sqrt{2gR(1+\cos\theta)}$

$\Rightarrow\ v_0 \ge \sqrt{2gR(1+4/5)}\ \Rightarrow v_0 \ge \sqrt{\frac{18gR}{5}}$ ...(v)

From (iv) and (v) $\sqrt{\frac{18gR}{5}} \le v_0 \le \sqrt{4gR}$

7. (a) : The two streams strike at the same point on the ground.



$R_1 = R_2 = R$

$v_1t_1 = v_2t_2$ ...(i)

Where v_1 = velocity of efflux at $Q = \sqrt{(2gh_1)}$

and v_2 = velocity of efflux at $P = \sqrt{[2g(H-h_2)]}$

t_1 = time of fall of water stream through Q is

$$= \sqrt{\frac{2(H-h_1)}{g}}$$

t_2 = time of fall of the water stream through

$P = \sqrt{\frac{2h_2}{g}}$

Putting these value in Eq. (i), we get

$(H-h_1)h_1 = (H-h_2)h_2$ or $[H-(h_1+h_2)][h_1-h_2] = 0$

$H = h_1 + h_2$ is irrelevant because the holes are at two different heights. Therefore, $h_1 = h_2$ or $h_1/h_2 = 1$

8. **(c) :** Before explosion orbital velocity of the planet is $v_0 = \left(\frac{GM}{r_0}\right)^{1/2}$. The planet's position and velocity immediately after explosion are not affected. The process is sudden, infinitesimal in time, therefore it would require infinite velocity and acceleration to change position and velocity of planet. At the instant of explosion planet is moving tangentially, it is nearest point of the new orbit. In order to find farthest distance we have to apply conservation of angular momentum and energy.

$mv_0r_0 = mv_1r_1$

$$v_1 = \frac{v_0r_0}{r_1} \quad \ldots(1)$$

$$\frac{1}{2}mv_0^2 - \frac{GMm}{r_0} = \frac{1}{2}mv_1^2 - \frac{GM'm}{r_1}$$

$$\frac{GMm}{2r_0} - \frac{GMm}{r_0} = \frac{1}{2}m\left(\frac{v_0r_0}{r_1}\right)^2 - \frac{GM'm}{r_1}$$

$$\frac{GMm}{2r_0} - \frac{GM'm}{r_0} = \frac{GMmr_0}{2r_1^2} - \frac{GM'm}{r_1} \quad \ldots(2)$$

Now we have to solve the above expression. Consider

$\frac{M'}{M} = a$ and $\frac{r_1}{r_0} = b.$

Equation (2) reduces to $1 - 2a = \frac{1}{b^2} - \frac{2a}{b}$

or $b^2(1 - 2a) + 2ab - 1 = 0$

or $(b - 1)[b(1 - 2a) + 1] = 0$

Since $b \neq 1$, we must have $b = \frac{1}{2a-1}$

Now $r_0 = a(1 - e)$; $r_1 = a(1 + e)$

where a is semi-major axis and e is the eccentricity.

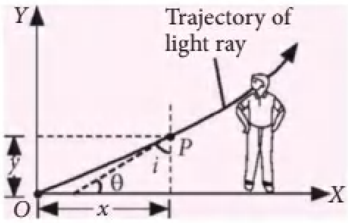
$$\frac{r_1}{r_0} = b = \left(\frac{1+e}{1-e}\right)$$

$$\therefore \quad e = \left(\frac{b-1}{b+1}\right)$$

On substituting expression for b, we get $e = \frac{1-a}{a}$

$e = 0.01$

9. **(c) :** As refractive index is changing along Y-direction, we can assume a number of thin layers of air placed parallel to X-axis. Let O be the distant object just visible to the man. Consider a layer of air at a distance 'y' from the ground. Let P be a point on the trajectory of the ray. From figure, $\theta = 90 - i$.



The slope of tangent at point P is

$\tan\theta = dy/dx = \cot i$.

From Snell's law,

$n \sin i$ = constant

At the surface $n = n_0$ and $i = 90°$

$n_0 \sin 90° = n \sin i$

$= (n_0\sqrt{1+ay}) \sin i$

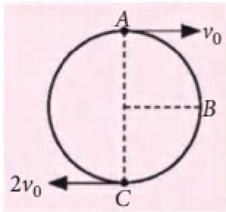
$$\sin i = \frac{1}{\sqrt{1+ay}} \Rightarrow \cot i = \frac{dy}{dx} = \sqrt{ay}$$

$$\int_0^y \frac{dy}{\sqrt{ay}} = \int_0^x dx \Rightarrow x = 2\sqrt{\frac{y}{a}}$$

On substituting $y = 2.0$ m and $a = 2 \times 10^{-6}$ m^{-1}, we have

$$x_{man} = 2\sqrt{\frac{2}{2\times10^{-6}}} = 2000 \text{ m.}$$

10. **(b):** Let a ball of mass m be moving in a vertical circle of radius r, as shown in figure. Velocity of the ball is minimum when ball passes through highest point A and maximum when it passes through the lowest point C.



Let velocity of ball at A be v_0 then that at C will be equal to $2v_0$.

According to law of conservation of energy.

K.E at C = K.E at A + Loss of energy from A to C

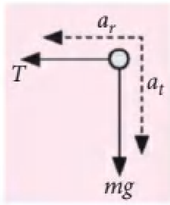
$$\frac{1}{2}m(2v_0)^2 = \frac{1}{2}mv_0^2 + mg(2r)$$

$$v_0^2 = \frac{4}{3}gr;\ v^2 = \frac{4}{3}gr + 2gr = \frac{10}{3}gr$$

Velocity of the ball is directed vertically downward when the ball passes through B. Let velocity at this point be v. Then according to law of conservation of energy.

K.E at B = K.E at A + loss of energy from A to B

$$\frac{1}{2}mv^2 = \frac{1}{2}mv_0^2 + mg(r)$$



$mg = ma_t$ or tangential acceleration, $a_t = g$ normal or centripetal acceleration.

$$a_n = \frac{v^2}{r} = \frac{10}{3}g$$

Net acceleration at ball of B will be equal to the vector sum of these two.

$$a = \sqrt{a_t^2 + a_n^2} = \frac{g}{3}\sqrt{109}.$$

◈◈

8. Four charges each with charge $+q$ are placed at the four corners of a square of side l, a charge $\frac{-q}{4}$ is at centre of the square. Force on the charge at the centre due to other charges is (where $K = 1/4\pi\varepsilon_0$)

(a) $\frac{Kq^2}{l^2}$ (b) $K\frac{\sqrt{2}q^2}{l^2}$

(c) zero (d) $K\frac{2\sqrt{2}q^2}{l^2}$

9. A charged particle moves in a magnetic field $\vec{B} = 10\hat{i}$ with initial velocity $\vec{u} = 5\hat{i} + 4\hat{j}$. The path of the particle will be

(a) straight line (b) circle

(c) helical path (d) None of these

10. A light beam, $E = 100\,[\sin(\omega_1 t) + \sin(\omega_2 t)]$ V m^{-1} with $\omega_1 = 5 \times 10^{15}$ rad s^{-1} and $\omega_2 = 8 \times 10^{15}$ rad s^{-1}, falls on a metal surface of work function 2.0 eV. Maximum kinetic energy of emitted photoelectrons is

(a) 3.20 eV (b) 1.5 eV (c) 3.27 eV (d) 2.1 eV

11. The electric field part of an electromagnetic wave in a medium is represented by $E_x = 0$;

$$E_y = 2\cdot 5\text{N C}^{-1}\cos\left[\left(2\pi\times 10^6\text{rad s}^{-1}\right)t - \left(\pi\times 10^{-2}\text{rad m}^{-1}\right)x\right]$$

$E_z = 0$. The wave is

(a) moving along the x-direction with frequency 10^6 Hz and wavelength 100 m

(b) moving along x-direction with frequency 10^6 Hz and wavelength 200 m

(c) moving along $-x$ direction with frequency 10^6 Hz and wavelength 200 m

(d) moving along y-direction with frequency $2\pi \times 10^6$ Hz and wavelength 200 m

12. 90% of the active nuclei present in a radioactive sample are found to remain undecayed after 1 day. The percentage of undecayed nuclei left after two days will be

(a) 85% (b) 81%

(c) 80% (d) 79%

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

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

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

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

(d) If both assertion and reason are false.

13. **Assertion :** If a rod has a resistance 4 Ω is turned into semicircle, then its resistance along its diameter is 1.0 Ω.

Reason : On bending a rod, its length decreases and hence resistance decreases.

14. **Assertion :** Charge never flows from a condenser of higher capacity to the condenser of lower capacity.

Reason : Direction of flow of charge is determined by the difference in charge in the two condenser.

15. **Assertion :** When radius of a circular wire carrying current is doubled, its magnetic moment becomes four times.

Reason : Magnetic moment depends on area of the loop.

JEE MAIN / JEE ADVANCED

Only One Option Correct Type

16. There is a stream of neutrons with a kinetic energy of 0.0327 eV. If the half-life of neutrons is 700 s, what fraction of neutrons will decay before they travel a distance of 10 m?

Given, mass of neutron = 1.676×10^{-27} kg.

(a) 4.8×10^{-5} (b) 3.9×10^{-6}

(c) 8.4×10^{-5} (d) 2.3×10^{-6}

17. A thin circular ring of area A is held perpendicular to a uniform field of induction B. A small cut is made in the ring and a galvanometer is connected across the ends such that the total resistance of the circuit is R. When the ring is suddenly squeezed to zero area, the charge flowing through the galvanometer is

(a) $\frac{BR}{A}$ (b) $\frac{AB}{R}$ (c) ABR (d) $\frac{B^2A}{R^2}$

18. A ray of light enters a rectangular glass slab of refractive index $\sqrt{3}$ at an angle of incidence 60°. It travels a distance of 5 cm inside the slab and emerges out of the slab. The perpendicular distance between the incident and the emergent rays is

(a) $5\sqrt{3}$ cm (b) $\frac{5}{2}$ cm

(c) $5\sqrt{\frac{3}{2}}$ cm (d) 5 cm

19. An electromagnetic wave of frequency $\upsilon = 3.0$ MHz passes from vacuum into a dielectric medium with permittivity $\varepsilon = 4.0$. Then

(a) wavelength is doubled and the frequency remains unchanged

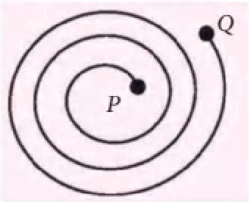
(b) wavelength is doubled and frequency becomes half

(c) wavelength is halved and frequency remains unchanged

(d) wavelength and frequency both remain unchanged.

More than One Options Correct Type

20. A charged particle enters into a region which offers a resistance against its motion and a uniform magnetic field exists in the region. The particle traces a spiral path as shown in figure. Which of the following statements are correct?



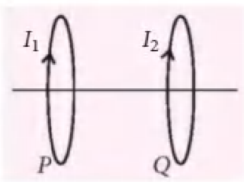
(a) Component of magnetic field in the plane of spiral is zero.

(b) The particle enters the region at Q.

(c) If magnetic field is outward, then the particle is positively charged.

(d) If magnetic field is outward, then the particle is negatively charged.

21. Two circular coils P and Q are fixed coaxially and carry currents I_1 and I_2 respectively as shown in figure. Mark the correct options.



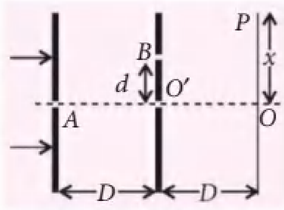
(a) If $I_2 = 0$ and P moves towards Q, a current in the same direction as I_1 is induced in Q

(b) If $I_1 = 0$ and Q moves towards P, a current in the opposite direction to that of I_2 is induced in P.

(c) When $I_1 \neq 0$ and $I_2 \neq 0$ are in the same direction then the two coils tend to move apart.

(d) When $I_1 \neq 0$ and $I_2 \neq 0$ are in opposite directions then the coils tends to move apart.

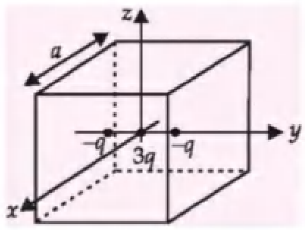
22. The minimum value of d so that there is a dark fringe at O is d_{min}. For the value of d_{min}, the distance at which the next bright fringe is formed is x. Then



(a) $d_{\text{min}} = \sqrt{\lambda D}$ (b) $d_{\text{min}} = \sqrt{\dfrac{\lambda D}{2}}$

(c) $x = \dfrac{d_{\text{min}}}{2}$ (d) $x = d_{\text{min}}$

23. A cubical region of side a has its centre at the origin. It encloses three fixed point charges, $-q$ at $\left(0, \dfrac{-a}{4}, 0\right)$, $+3q$ at (0, 0, 0) and $-q$ at $\left(0, +\dfrac{a}{4}, 0\right)$. Choose the correct option(s).



(a) The net electric flux crossing the plane $x = +\dfrac{a}{2}$ is equal to the net electric flux crossing the plane $x = -\dfrac{a}{2}$.

(b) The net electric flux crossing the plane $y = +\dfrac{a}{2}$ is more than the net electric flux crossing the plane $y = -\dfrac{a}{2}$

(c) The net electric flux crossing the entire region is $\dfrac{q}{\varepsilon_0}$

(d) The net electric flux crossing the plane $z = +\dfrac{a}{2}$ is equal to the net electric flux crossing the plane $x = +\dfrac{a}{2}$

Integer Answer Type

24. A square loop of side $a = 6$ cm carries a current $I = 1$ A. Calculate magnetic induction B (in μT) at point P, lying on the axis of loop and at a distance $x = \sqrt{7}$ cm from the center of loop.

25. A solid sphere of radius R has a charge Q distributed in its volume with a charge density $\rho = \kappa r^a$, where κ and a are constants and r is the distance from its centre. If the electric field at $r = R/2$ is 1/8 times that at $r = R$, find the value of a.

26. A silver ball of radius 4.8 cm is suspended by a thread in a vacuum chamber. Ultraviolet light of wavelength 200 nm is incident on the ball for some time during which a total light energy of 1.0×10^{-7} J falls on the surface. Assuming that on the average, one photon out of ten thousand photons is able to eject a photoelectron, find the electric potential (in $\times 10^{-1}$ V) at the surface of the ball assuming zero potential at infinity.

Comprehension Type

In a mixture of H – He^+ gas (He^+ is singly ionized He atom), H atoms and He^+ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He^+ ions (by collisions). Assume that the Bohr model of atom is exactly valid.

27. The quantum number n of the state finally populated in He^+ ions is

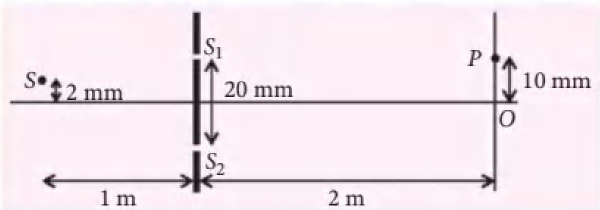
(a) 2 (b) 3 (c) 4 (d) 5

28. The wavelength of light emitted in the visible region by He^+ ions after collisions with H atoms is

(a) 6.5×10^{-7} m (b) 5.6×10^{-7} m
(c) 4.6×10^{-7} m (d) 4.0×10^{-7} m

Matrix Match Type

29. In Young's double-slit experiment, the point source S is placed above the central axis as shown in figure and the interference pattern was obtained. Now he pasted a transparent paper of thickness 0.02 mm and refractive index 1.45 in front of slit S_1 and again obtained the pattern. Column II contains the nature and order of fringe and Column I contains positions on the screen. If $\lambda = 500$ nm, then match column I with column II.



	Column I		Column II
(A)	At P, before pasting transparent paper	(P)	Bright fringe of order 80
(B)	At O, before pasting transparent paper	(Q)	Bright fringe of order 262
(C)	At P, after pasting the transparent paper	(R)	Bright fringe of order 62
(D)	At O, after pasting the transparent paper	(S)	Bright fringe of order 280

	A	B	C	D
(a)	P	R	S	Q
(b)	Q	R	S	P
(c)	P	Q	S	R
(d)	S	P	Q	R

30. Column I shows the state of motion of a charged particle. Column II shows the possible combination of electric field and magnetic field under which the path in column I is possible. Match column I with column II.

	Column I		Column II
(A)	Charge at rest experience a force.	(P)	$E = 0, B = 0$
(B)	A charge in motion goes undeviated with same velocity.	(Q)	$E \neq 0, B \neq 0$
(C)	A charge in motion goes undeviated with varying speed.	(R)	$E = 0, B \neq 0$
(D)	A charged particle undergoes helical motion.	(S)	$E \neq 0, B = 0$

	A	B	C	D
(a)	Q,S	P,Q,R	Q,S	Q,R
(b)	P,R	R,S	Q,R	R,S
(c)	P,R	Q,S	Q,R	Q,S
(d)	Q	P,S	R,Q	Q,S

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