JEE Adv. May 2026

Question Paper With Text Solution

17 May | Paper-2

PHYSICS

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JEE ADV. MAY 2026 | 17 MAY PAPER-2

SECTION – 1 (MAXIMUM MARKS: 12)

- This section contains **FOUR (04)** question stems.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 **ONLY** the correct option is chosen;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

Negative Marks : –1 In all other cases.

1. A metal wire of cross-sectional area 0.5 mm^2 and length 100 m is connected across a battery of e.m.f. 2 V and internal resistance 1Ω. The density, atomic mass and electrical conductivity of the metal are $6.35\times10^3\ kg\,m^{-3}$, $63.5 gm / mole$ and $2\times10^8\,mho\,m^{-1}$, respectively. Assuming one conduction electron per atom of the metal, the drift velocity (in mm s^{-1}) of the electrons in the wire is :

[Take Avogadro's number as 6×10^{23} and charge of the electron as 1.6×10^{-19} C.]

(A) 0.052 (B) 0.104 (C) 0.208 (D) 0.156

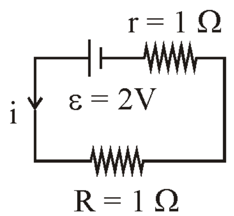
Ans. C

Sol. Area of cross-section A = 0.5 mm^2 = $0.5 \times 10^{-6} m^2$

length l = 100 m

conductivity $\sigma = 2 \times 10^8$ mho m^{-1}

$$\therefore \text{ Resistance of wire } R = \frac{\ell}{\sigma A} = \frac{100}{(2\times10^8)(0.5\times10^{-6})}\Omega = 1\Omega$$



$i = \frac{\varepsilon}{r+R} = \frac{2}{1+1} = 1A$

As we know that $i = neAV_d$

$\Rightarrow$ drift speed $V_d = \frac{i}{neA}$

($e = 1.6 \times 10^{-19}$C, $A = 0.5 \times 10^{-6}$ m^2, $i = 1$A)

Assuming that wire has mass 'm' then number of atoms in wire is $\frac{m}{(\text{molar mass})} \times N_A$. Given that each atom contributes one free electron so number of atoms is equal to number of free electron.

free electron density $n = \frac{\text{number of free electrons}}{\text{Volume}}$

$$\Rightarrow n = \frac{\text{mass}}{(\text{molar mass})} \times \frac{N_A}{\text{Volume}} = \left(\frac{\text{mass}}{\text{Volume}}\right) \times \left(\frac{N_A}{\text{molar mass}}\right)$$

$$\Rightarrow n = (\text{density}) \times \frac{N_A}{\text{Molar mass}} = \frac{(6.35 \times 10^3)(6 \times 10^{23})}{(63.5 \times 10^{-3})} = 6 \times 10^{28}/\text{m}^3$$

Hence drift speed $V_d = \frac{i}{neA} = \frac{1}{(6 \times 10^{28})(1.6 \times 10^{-19})(0.5 \times 10^{-6})}$

$$\Rightarrow V_d = \frac{1}{4.8} \times 10^{-3} \text{ m/s} = 0.208 \text{ mm/s}$$

2. A nuclear reactor starts producing a radioactive nuclide X from $t = 0$, at a constant rate of α per second. Each decay of X produces energy E_0, which is utilized to heat a liquid of mass m and specific heat s. Assuming no heat loss from the liquid and taking λ as the decay constant of X, the rate of increase in the temperature of the liquid is:

(A) $\frac{\alpha E_0}{ms}\left(1 - e^{-\lambda t}\right)$ (B) $\frac{\alpha E_0}{ms}\left(e^{\lambda t} - 1\right)$ (C) $\frac{\lambda E_0}{ms}\left(1 - e^{-\lambda t}\right)$ (D) $\frac{E_0}{ms}\left(\alpha - \lambda e^{-\lambda t}\right)$

Ans. A

Sol. $\text{Reactor} \xrightarrow{\alpha \text{ Per sec}} X \xrightarrow{\lambda(\text{Decay constant})} Y$

at t = 0 O O

at t = t N

Rate of formation of X = α.

Rate of decay X = λN

So, net rate of formation is $\frac{dN}{dt} = \alpha - \lambda N$

$$\int_O^N \frac{dN}{\alpha - \lambda N} = \int_O^t dt \Rightarrow \frac{\left[\ell n(\alpha - \lambda N)\right]_0^N}{-\lambda} = t$$

$$\Rightarrow \ell n\left(\frac{\alpha - \lambda N}{\alpha}\right) = -\lambda t$$

$$\Rightarrow \frac{\alpha - \lambda N}{\alpha} = e^{-\lambda t} \Rightarrow N = \frac{\alpha\left(1 - e^{-\lambda t}\right)}{\lambda}$$

each production of y (or decay of x) produces E_0 energy. Let dQ energy produced increases the temperature by dT then

$$dQ = ms\,dT \;\&\; \frac{dQ}{dt} = E_0\left(\frac{dN}{dt}\right)_{decay} = E_0(\lambda N)$$

$$\Rightarrow \frac{dQ}{dt} = ms\frac{dT}{dt} \Rightarrow \frac{dT}{dt} = \frac{1}{ms}\left(\frac{dQ}{dt}\right)$$

$$\Rightarrow \frac{dT}{dt} = \frac{1}{ms}E_0(\lambda N) = \frac{E_0\lambda}{ms}\left(\frac{\alpha\left(1 - e^{-\lambda t}\right)}{\lambda}\right)$$

$$\Rightarrow \frac{dT}{dt} = \frac{E_0\alpha}{ms}\left(1 - e^{-\lambda t}\right)$$

3. A beam of polychromatic light passes through a thin prism of prism angle 6°. The refractive index of the material of the prism varies with wavelength (λ) as $n(\lambda) = \alpha\lambda + \frac{\beta}{\lambda^2}$, where $\alpha = 3\mu m^{-1}$ and $\beta = 0.096\mu m^2$. If λ_{min} is the wavelength at which the angle of minimum deviation D_m is smallest, then the correct value of D_m at λ_{min} is

(A) 6.4° (B) 4.8° (C) 3.2° (D) 2.4°

Ans. B

Sol. Prism angle A = 6°, $n = \alpha\lambda + \frac{\beta}{\lambda_2}$

deviation through thin prism D = A(n – 1)

$$D = 6°\left(\alpha\lambda + \frac{\beta}{\lambda^2} - 1\right)$$

for minimum deviation,

$$\frac{dD}{d\lambda} = 0 \Rightarrow \alpha - \frac{2\beta}{\lambda^3} = 0 \Rightarrow \lambda = \left(\frac{2\beta}{\alpha}\right)^{\frac{1}{3}}$$

$$\Rightarrow \lambda = \left[\frac{2(0.096)}{3}\right]^{\frac{1}{3}} = 0.4\mu m$$

& $\frac{d^2D}{d\lambda^2}$ = +Ve so, at λ = 0.4 μm, deviation is minimum and that minimum deviation is

$$D_m = 6°\left((3)(0.4) + \frac{0.096}{(0.4)^2} - 1\right) = 4.8°$$

4. A particle of mass m, and angular momentum ℓ is moving in a circular orbit of radius r_0 under the influence of an attractive force $\vec{F}(r) = -\frac{k}{r^2}\hat{r}$. Keeping its angular momentum unchanged, the particle is displaced radially by a small distance $\delta r << r_0$, due to which its radial distance varies periodically. The corresponding time period is:

(A) $\frac{2\pi\ell^3}{mk^2}$ (B) $2\pi\sqrt{\frac{m}{k}}$ (C) $\frac{2\pi\ell^3}{3mk^2}$ (D) $\frac{2\pi\ell^3}{5mk^2}$

Ans. A

Sol. When the particle is moving in circular orbit of radius r_0.

$$\frac{k}{r_0} = \frac{mv_0^2}{r_0} \Rightarrow \frac{k}{r_0^2} = mv_0^2 \qquad .....(1)$$

& angular momentum $\ell = mv_0r_0 \Rightarrow v_0 = \frac{\ell}{mr_0}$

then $\frac{k}{r_0} = m\left(\frac{\ell^2}{m^2r_0^2}\right) \Rightarrow k = \frac{\ell^2}{mr_0} \Rightarrow r_0 = \frac{\ell^2}{km}$ .....(2)

if we increase the radius by dr($<<< r_0$) then $mvr = mv_0r_0$

$$\Rightarrow mv(r_0 + dr) = mv_0r_0$$

$$\Rightarrow v = \frac{v_0r_0}{r_0 + dr} = \frac{v_0r_0}{r_0\left(1+\frac{dr}{r_0}\right)} = v_0\left(1-\frac{dr}{r_0}\right)$$

Net force towards the centre now is

$$f = \frac{k}{r^2} - \frac{mv^2}{r}$$

$$\Rightarrow f = \frac{k}{(r_0+dr)^2} - \frac{mv_0^2}{(r_0+dr)}\left(1-\frac{dr}{r}\right)^2$$

$$\Rightarrow f=\frac{k}{r_0^2}\left(1-\frac{2dr}{r_0}\right)-\frac{mv_0^2}{r_0\left(1+\frac{dr}{r}\right)}\left(1-\frac{dr}{r}\right)^2$$

$$\Rightarrow f=\frac{k}{r_0^2}\left(1-\frac{2dr}{r_0}\right)-\frac{mv_0^2}{r_0}\left(1-\frac{dr}{r_0}\right)^3$$

$$\Rightarrow f=\frac{k}{r_0^2}\left(1-\frac{2dr}{r_0}\right)-\frac{mv_0^2}{r_0}\left(1-\frac{3dr}{r_0}\right)$$

$$\Rightarrow f=\frac{k}{r_0^2}-\frac{2k\,dr}{r_0^3}-\frac{mv_0^2}{r_0}+\frac{3mv_0^2dr}{r_0^2}$$

$$\left[\because \frac{k}{r_0^2}=\frac{mv_0^2}{r_0}\right]$$

$$\Rightarrow f=-\frac{2kdr}{r_0^3}+\frac{3mv_0^2dr}{r_0^2}$$

using the value from equation ....(1)

$$\Rightarrow f=-\frac{2kdr}{r_0^3}+\frac{3k}{r_0^3}dr=\frac{k}{r_0^3}dr$$

$$\Rightarrow ma=\frac{k}{r_0^3}dr$$

$$\Rightarrow \alpha=\left(\frac{k}{mr_0^3}\right)dr \qquad \left[\because a=\omega^2(dr)\right]$$

$$\Rightarrow \omega^2=\frac{k}{mr_0^3}=\frac{k}{m\left(\frac{\ell^2}{km}\right)^3}=\frac{kk^3m^3}{m\,\ell^6}=\frac{k^4m^2}{\ell^6}$$

$$\Rightarrow \omega=\frac{mk^2}{\ell^3}$$

Time period $T = \frac{2\pi}{\omega} = \frac{2\pi\,\ell^3}{mk^2}$

Method-2 :

This motion is similar to the motion of earth around sun in elliptical path as it goes around the sun passing throught perihelion (nearest point) & aphelion (farthest point).

As the earth completes one orbit around the Sun, it's motion along the radius also completes one oscillation. So the time period of a orbit is equal to time period of radial oscillation.

$$F = \frac{GMm}{r_0^2} \simeq \frac{k}{r_0^2} \qquad [\because\ k = GMm]$$

Also net torque on earth with respect to sum is always zero so angular momentum remain conserved.

$l = mv_0r_0$

$T_{orbit} = T_{radial}$ ......(1)

$\because\ (F_{net})_{centre} = ma_c$

$$\frac{k}{r_0^2} = \frac{mv_0^2}{r_0} \Rightarrow \frac{k}{r_0} = mv_0^2$$

$$\frac{k}{r_0} = m\left(\frac{\ell}{mr_0}\right)^2 \Rightarrow \frac{k}{r_0} = \frac{\ell^2}{mr_0^2} \Rightarrow r_0 = \frac{\ell^2}{mk}$$

$$\&\ \ v_0 = \frac{\ell}{mr_0} = \frac{\ell}{m\left(\frac{\ell^2}{mk}\right)} = \frac{k}{\ell}$$

$$T_{orbit} = \frac{2\pi r_0}{v_0} = 2\pi\left(\frac{\ell^2}{mk}\right)\left(\frac{1}{\frac{k}{\ell}}\right)$$

$$= \frac{2\pi\ell^3}{mk^2} = T_{oscillation}$$

SECTION – 2 (MAXIMUM MARKS: 20)

- This section contains **FIVE (05)** question stems.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;

Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;

Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is acorrect option;

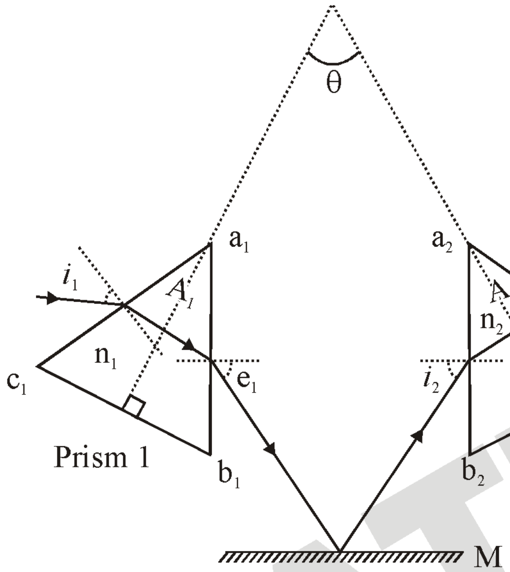
Zero Marks : 0 If unanswered;

Negative Marks : –1 In all other cases.

- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to correct answers, then

choosing ONLY (A), (B) and (D) will get +4 marks;
choosing ONLY (A) and (B) will get +2 marks;
choosing ONLY (A) and (D) will get +2marks;
choosing ONLY (B) and (D) will get +2 marks;
choosing ONLY (A) will get +1 mark;
choosing ONLY (B) will get +1 mark;
choosing ONLY (D) will get +1 mark;
choosing no option(s) (i.e. the question is unanswered) will get 0 marks and choosing any other option(s) will get -1 marks.

5. Consider two isosceles prisms 1 and 2 with prism angles A_1 and A_2 and refractive indices n_1 and n_2, respectively, as shown in the figure. The faces a_1b_1 and a_2b_2 are parallel to each other and perpendicular to the mirror M. If a ray of light is incident on the face a_1c_1 and emerges from the face a_2c_2, then the correct statement(s) is/are:



(A) If both the prisms are at minimum deviation condition, then $\frac{n_2}{n_1} = \sin\left(\frac{A_1}{2}\right) / \sin\left(\frac{A_2}{2}\right)$.

(B) If prism 2 is at minimum deviation condition, then $\sin i_1 = n_2 \sin\left(\frac{A_2}{2}\right)$ is always true.

(C) If both the prisms 1 and 2 are thin and are at minimum deviation condition with angles of deviation δ_{m1} and δ_{m2}, respectively, then $\theta = \frac{\delta_{m1}}{2(n_1-1)} + \frac{\delta_{m2}}{2(n_2-1)}$.

(D) If prism 1 is at minimum deviation condition, then $\sin i_2 = n_1 \sin\left(\frac{A_1}{2}\right)$ is always true.

Ans. ACD

Sol. As $a_1b_1 \parallel a_2b_2 \Rightarrow e_1 = i_2$ ---------(i)

(A) In case of minimum deviation $\Rightarrow i_1 = e_1$ and $i_2 = e_2$ ----------(2)

by (i) & (2), $i_1 = e_1 = i_2 = e_2$ -----------(3)

$\delta_{min} = 2i - A$

Prism-1, $\delta_{\min_1} = 2i_1 - A_1 \Rightarrow \frac{\delta_{\min_1} + A_1}{2} = i_1$ --------------(4)

Prism-2, $\delta_{\min_2} = 2i_2 - A_2 \Rightarrow \frac{\delta_{\min_2} + A_2}{2} = i_2$ -----------(5)

by (3), (4) & (5), $\frac{\delta_{\min 1} + A_1}{2} = \frac{\delta_{\min 2} + A_2}{2}$

$$\frac{n_2}{n_{air}} = \frac{\text{Sin}\left(\frac{\delta_{\min_2} + A_2}{2}\right)}{\text{Sin}\, A_2/2}$$

$$\frac{n_2}{n_{air}} = \frac{\text{Sin}\left(\frac{\delta_{\min_1} + A_1}{2}\right)}{\text{Sin}\frac{A_1}{2}}$$

$$\frac{n_2}{n_1} = \frac{\text{Sin}\frac{A_1}{2}}{\text{Sin}\frac{A_2}{2}}$$

(B) Prism-2 is at minimum deviation, $\sin i_2 = n_2 \sin\frac{A_2}{2}$

by (1), $\sin e_1 = n_2 \sin\frac{A_2}{2}$

as prism-1 is not at minimum deviation, $i_1 \neq e_1$ i.e. $\sin(i_1) \neq n_2 \sin\frac{A_2}{2}$

(C) $\theta = \frac{A_1}{2} + \frac{A_2}{2}$

$$\delta_{m_1} = A_1(n_1 - 1) \Rightarrow \frac{A_1}{2} = \frac{\delta_{m_1}}{2(n_1 - 1)}$$

$$\delta_{m_2} = A_2(n_2 - 1) \Rightarrow \frac{A_2}{2} = \frac{\delta_{m_2}}{2(n_2 - 1)}$$

$$\theta = \frac{\delta_{m_1}}{2(n_1 - 1)} + \frac{\delta_{m_2}}{2(n_2 - 1)}$$

(D) If prism-1 is at minimum deviation, $\sin e_i = n_1 \sin\frac{A_1}{2}$ as $e_1 = i_2 \Rightarrow \sin i_2 = n_1 \sin\frac{A_1}{2}$

6. In a vacuum chamber, a particle of charge $1\mu C$ and mass 1 mg is projected with a velocity $(\hat{i} + 2\hat{j})ms^{-1}$ from the XZ plane at time t = 0 in an electric field of $1\hat{i}\,Vm^{-1}$. At t = 0.2s, the electric field is switched off and a magnetic field of $6\hat{j}$ T is switched on. The acceleration due to gravity is $-10\hat{j}\,ms^{-2}$. Correct option(s) is/are:

(A) The vertical distance of the particle from the XZ plane at t = 0.3 s is 15 cm.

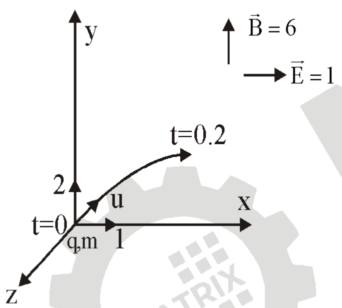
(B) The vertical distance of the particle from the XZ plane at t = 0.4 s is 10 cm.

(C) The radius of the trajectory of the particle for t > 0.2 s is 20 cm.

(D) The particle will be in the XZ plane at t = 0.35 s.

Ans. AC

Sol.



At $t = 0.2\text{sec}, \vec{V} = \left(1 + \frac{10^{-6} \times 1}{10^{-6}} \times 0.2\right)\hat{i} + (2 - 10 \times 0.2)\hat{j}$

$\vec{V} = 1.2\hat{i}\, m/s$

$\vec{F_B} = q(\vec{v} \times \vec{B}) \rightarrow$ it is alway perpendicular to $\vec{B} \Rightarrow \vec{F_B}$ is parallel to x–z plane and gravity is in $-\hat{j}$ dirn

(A,B) distance from xz plane, $S_y = u_y t + \frac{1}{2} a_y t^2$

at, t = 0.3 sec $\quad d = 2 \times 0.3 - \frac{1}{2}(10)(0.3)^2 = 0.15\,m$

at, t = 0.4sec, $d = 2\times 0.4 - \frac{1}{2}(10)(0.4)^2 = 0$

For t > 0.2 sec,

(C) $r = \frac{mv_\perp}{qB} = \frac{10^{-6}\times(1.2)}{10^{-6}\times 6} = 0.2\,m = 20\,cm$

(D) Particle will be in xz plane at $t = 0.4sec$ _____ (by option (B))

7. Two charges $Q_1 = q$ and $Q_2 = mq$ are placed at the points $P_1(a, b)$ and $P_2(ma, mb)$, respectively, in the XY plane, where $a, b \neq 0$ and $m \neq 0$, 1. If V_1 is the potential at a point in the XY plane due to charge Q_1 and V_2 is the potential at that point due to charge Q_2. Correct statement(s) for the points at which $|V_1| = |V_2|$ is/are:

(A) For m = – 1, locus of these points is ax + by = 0.

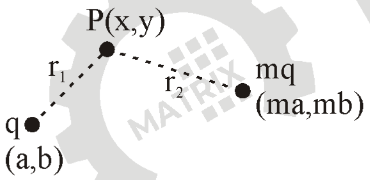
(B) For m = 2, the locus of these points is a circle of radius $\frac{2}{3}\sqrt{a^2+b^2}$ centered at $\left(\frac{2}{3}a, \frac{2}{3}b\right)$

(C) For m = –2, the locus of these points is a circle of radius $2\sqrt{a^2+b^2}$ centered at (2a, 2b)

(D) For m = –3, locus of these points is 3bx + 3ay = 0.

Ans. ABC

Sol.



$$|V_1| = \left|\frac{Kq}{\sqrt{(x-a)^2+(y-b)^2}}\right| = \left|\frac{Kmq}{\sqrt{(x-ma)^2+(y-mb)^2}}\right| = |V_2|$$

$$\frac{K^2q^2}{(x-a)^2+(y-b)^2} = \frac{K^2m^2q^2}{(x-ma)^2+(y-mb)^2}$$

$(x - ma)^2 + (y - mb)^2 = m^2((x - a)^2 + (y - b)^2)$

$x^2 - 2max + m^2a^2 + y^2 - 2mby + m^2b^2 = m^2x^2 - 2m^2ax + m^2a^2 + m^2y^2 - 2m^2by + m^2b^2$

$(m^2 - 1)x^2 + (m^2 - 1)y^2 - 2(m - 1)max - 2(m - 1)mby = 0$

for $m = -1 \Rightarrow -4ax - 4by = 0 \Rightarrow ax + by = 0$

for m = 2 $\Rightarrow 3x^2 + 3y^2 - 4ax - 4by = 0$

$$x^2 + y^2 - \frac{4a}{3}x - \frac{4b}{3}y = 0$$

$$\left(x - \frac{2a}{3}\right)^2 + \left(y - \frac{2b}{3}\right)^2 = \left(\frac{2}{3}\sqrt{a^2 + b^2}\right)^2$$

for m = –2 $\Rightarrow 3x^2 + 3y^2 - 12ax - 12by = 0$

$x^2 + y^2 - 4ax - 4by = 0$

$$(x - 2a)^2 + (y - 2b)^2 = \left(2\sqrt{a^2 + b^2}\right)^2$$

for m = –3 $\Rightarrow 8x^2 + 8y^2 - 24ax - 24by = 0$

$x^2 + y^2 - 3ax - 3by = 0$

8. Consider an electric dipole comprising two charges +q and –q each with mass m, separated by a fixed distance d and initially at rest with its dipole moment pointing along $\hat{i}$. A uniform electric field $E\hat{j}$ is turned on at time t = 0 and it is turned off at $t = t_f$, when the dipole moment makes an angle θ_f with $\hat{i}$. Neglecting any sources of energy loss, correct option(s) is/are:

(A) The center of mass of the dipole is deflected towards $\hat{j}$ in the presence of the field.

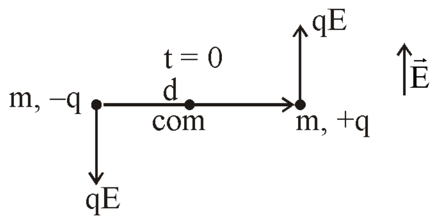
(B) If the magnitude of the final angular velocity $\omega_f = \sqrt{\frac{2qE}{md}}$, then $\theta_f = \frac{\pi}{6}$.

(C) If $\theta_f = \pi/3$, then the change in kinetic energy of the dipole is given by $2\sqrt{3}qEd$.

(D) For $\theta_f = \pi/4$, the dipole rotates around its center of mass with a constant angular velocity after $t > t_f$

Ans. BD

Sol. (A)



$F_{net} = 0 \Rightarrow$ com remains at rest and dipole rotates about it's centre (com).

(B) $\Delta U + \Delta KE = 0$

$$\left(-PE\cos\left(\frac{\pi}{2}-\frac{\pi}{6}\right)+PE\cos\left(\frac{\pi}{2}\right)\right)+\frac{1}{2}I\left(\omega^2-0\right)=0$$

$$\frac{1}{2}\left(2m\frac{d^2}{4}\right)\omega^2=\frac{qdE}{2}$$

$$\omega=\sqrt{\frac{2qE}{md}}$$

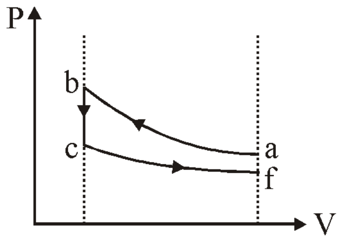
(C) $$-PE\cos\left(\frac{\pi}{2}-\frac{\pi}{3}\right)+PE\cos\left(\frac{\pi}{2}\right)+\Delta KE=0$$

$$\Delta KE=\frac{\sqrt{3}qdE}{2}$$

(D) For $t > t_f \Rightarrow E = 0 \Rightarrow \tau = 0 \Rightarrow \omega \rightarrow$ constant

9. Ten moles of an ideal monoatomic gas, initially in state a at atmospheric pressure and temperature $T_a = 27^\circ C$, is enclosed in a metal cylinder of volume V_0 fitted with a frictionless piston. The gas is suddenly compressed to state b with volume $V_0/3$. Now, keeping the piston stationary, the cylinder is submerged in a water bath of temperature $11^\circ C$ until the gas reaches the temperature of the water bath, which is denoted as state c. Finally, while still in the water bath, the piston is brought slowly to its initial position, which is denoted as state f. If R is universal gas constant, then the correct option(s) is/are: [Given: $9^{1/3} = 2.08$]

(A) The schematic P-V diagram of the processes described above is:



(B) The change in internal energy in going from state a to b is $4860\,R$.

(C) The net change in the internal energy in the whole process is $-240\,R$.

(D) The pressure and temperature of the state b are 2.08 times the atmospheric pressure and $624\,K$, respectively.

Ans. ABC

Sol. For $a \rightarrow b$: $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$$\Rightarrow 300 \times V_0^{\gamma-1} = T_2\left(\frac{V_0}{3}\right)^{\gamma-1} \quad \left(\gamma = \frac{5}{3}\right)$$

$\Rightarrow T_2 = 624$ K

$a \rightarrow b$ is adiabatic, $\therefore \Delta U = -\Delta W$

$$\Delta U = -\frac{P_1V_1 - P_2V_2}{\gamma - 1} = -\frac{nR(T_1 - T_2)}{\gamma - 1}$$

$$= -\frac{10R(300 - 624)}{\frac{5}{3} - 1} = 4860R \rightarrow B$$

(A) $a \rightarrow b$ is adiabatic, $b \rightarrow c$ is isochoric, $c \rightarrow f$ is isothermal. So the graph in option(A) is correct.

(C) $T_f = T_c = 11 + 273 = 284\,K$

For complete process: $\Delta U = nC_V(T_f - T_a)$

$$\Delta U = 10 \times \frac{3R}{2}(284 - 300) = -240R \rightarrow C$$

(D) For $a \rightarrow b$: $P_0V_0^{\gamma} = P_b \cdot (V_0/3)^{\gamma}$

$\Rightarrow P_b = 2.08 \times 3 \times P_0$; P_0 = atmospheric pressure. $\rightarrow$ D is wrong

So, answer is A, B, C

SECTION – 3 (MAXIMUM MARKS: 20)

- This section contains **FIVE (05)** question stems.
- The answer to each question is a **NUMERICAL VALUE.**
- For each question, enter the correct integer corresponding to the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If **ONLY** the correct integer is entered;

Zero Marks : 0 In all other cases.

10. Two thin wires, Wire-1 of diameter 0.650 mm and Wire-2 of unknown diameter d are given. To obtain the value of d, the diameters of the two wires are measured with a screw gauge. The screw gauge has a pitch of 0.5 mm and there are 100 divisions on the circular scale (CS). The smallest division on the linear scale (LS) is 0.5 mm . The table shows the readings of LS and CS for the measurements. The value of d (in μm) is:

	Readings	
	LS (mm)	CS
Wire- 1	0.5	42
Wire- 2	1.5	95

Ans. 1915

Sol. L.C. $= \dfrac{0.5\,\text{mm}}{100} = 0.5 \times 10^{-2}$ mm

for wire -1:

measured diameter $= 0.5\,\text{mm} + 42 \times 0.5 \times 10^{-2}$ mm

= 0.710 mm

actual diameter = 0.650 mm

+ve zero error = 0.710 – 0.650 = 0.060 mm

for wire - 2:

measured diameter $= 1.5 + 95 \times 0.5 \times 10^{-2}$

=1.975 mm

actual diameter = 1.975 – 0.060

= 1.915 mm

=1915 μm

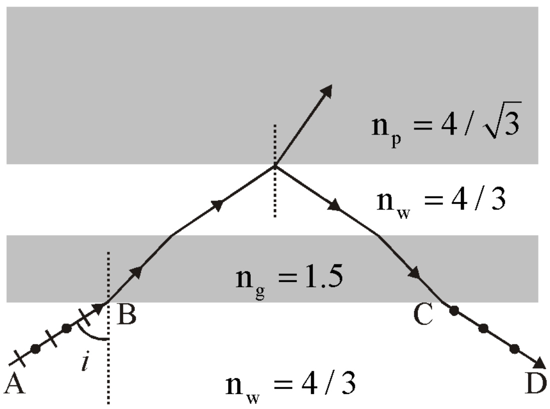
11. In a single slit diffraction experiment, a slit of width (0.016 ± 0.002)mm is used to measure the wavelength of a monochromatic light source. In the diffraction pattern, the angular distance between the central maximum and first minimum is measured to be $(2^\circ \pm 40')$. The value of the fractional error in the measurement of wavelength is: [Given: $\sin(2^\circ) = 0.035$]

Ans. 0.46

Sol. $d\sin\theta = \lambda \Rightarrow \frac{d\lambda}{\lambda} = \frac{dd}{d} + \frac{\cos\theta}{\sin\theta} \cdot d\theta$

$\frac{d\lambda}{\lambda} = 0.46$

12. As shown in the figure, a ray AB of unpolarized light enters from water of refractive index $n_w = 4/3$ into a medium of refractive index $n_p = 4/\sqrt{3}$ after passing through a glass plate of refractive index $n_g = 1.5$ and a layer of water. At a particular incident angle i the reflected ray CD is polarized in the direction as shown in the figure. The value of i (in degrees) is:



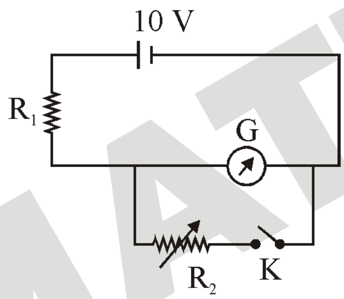
Ans. 60

Sol. Complete polarization can occur in reflected light ray only. So it will occur at boundary of water and the medium $(4/\sqrt{3})$, if

$$i = \theta_p = \tan^{-1}\mu = \tan^{-1}\left(\frac{4/\sqrt{3}}{4/3}\right) = 60^\circ$$

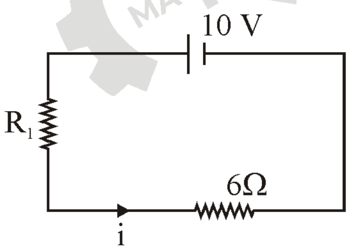
$\therefore$ Ans : 60

13. As shown in the figure, the resistance of a galvanometer G can be found by the half-deflection method. Here the resistance R_2 is adjusted such that when the key K is closed the deflection in the galvanometer becomes half of the value as compared to when K is open. Half-deflection is obtained at $R_2 = 4\Omega$ and thus the galvanometer resistance is found to be 6Ω. In this half-deflection condition the current (in mA) through the resistor R_1 is:



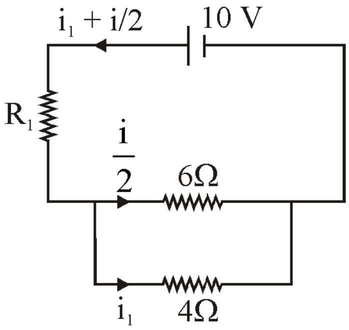
Ans. 694.44

Sol. When the key is open :



$$i = \frac{10}{R_1 + 6}$$

When the key is closed :



$$6\times\frac{i}{2}=4\times i_1$$

$$\Rightarrow i_1=\frac{3i}{4}$$

$$i_1+\frac{i}{2}=\frac{5i}{4}=\frac{10}{R_1+\left(\frac{6\times 4}{6+4}\right)}$$

$$\Rightarrow \frac{5}{4}\left(\frac{10}{R_1+6}\right)=\frac{10}{R_1+2.4}$$

$$\Rightarrow 5R_1+12=4R_1+24$$

$$\Rightarrow R_1=12\Omega$$

$$\Rightarrow i=\frac{10}{R_1+6}=\frac{10}{18}A=\frac{5}{9}A$$

$\Rightarrow$ Current through R_1 during half deflection

$$\Rightarrow i_1+\frac{i}{2}=\frac{5i}{4}=\frac{5}{4}\times\frac{5}{9}A=\frac{25}{36}A$$

$\Rightarrow 694.44\text{mA}$

14. In a new system of units, the units of mass, length, time and current are 5kg, 5m, 5s and 5 A, respectively. If μ_0 and ε_0 are the permeability and permittivity of free space, respectively, then in this new system of units, the magnitude of one SI unit of $\sqrt{\mu_0 / \varepsilon_0}$, is:

Ans. 25

Sol. Given physical quantity

$$\Rightarrow \sqrt{\frac{\mu_0}{\varepsilon_0}} \Rightarrow \sqrt{\frac{\mu_0^2}{\mu_0\varepsilon_0}} \Rightarrow \sqrt{\mu_0^2}.\frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow \mu_0.C$$

C = speed of light

We can calculate the dimension of μ_0 using $\frac{\text{Force}}{\text{Length}} = \frac{\mu_0 i_1 i_2}{2\pi d}$ for two parallel wires having current.

$$\Rightarrow [\mu_0] = [MLT^{-2}A^{-2}]$$

$$\Rightarrow [\mu_0 C] = [MLT^{-2}A^{-2}][LT^{-1}]$$

$$= [ML^2T^{-3}A^{-2}]$$

Using $n_1u_1 = n_2u_2$ for unit conversion $\Rightarrow$ we get $\Rightarrow$

$$\Rightarrow \frac{1\text{kg m}^2}{S^3A^2} = n_2 \frac{5\text{kg}(5\text{m})^2}{(5\text{s})^2(5\text{A})^2}$$

$$\Rightarrow n_2 = 25$$

SECTION – 4 (MAXIMUM MARKS: 8)

- This section contains **TWO (02)** question stems.
- This section contains **TWO (02)** questions corresponding to each question stem.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value corresponding to the answer in the designated place using the mouse and the on-screen virtual numeric keypad.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

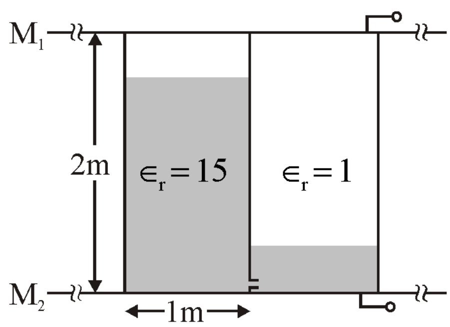
Full Marks : +2 If **ONLY** the correct numerical value is entered in the designated place;

Zero Marks : 0 In all other cases.

Question Stem for Question Nos. 15 and 16

A container of height 2 m, length 2 m and breadth 1 m is made of insulating vertical walls and two large area horizontal metal plates (M_1 and M_2) which extend far beyond the vertical walls in all directions. The container is partitioned into two equal chambers with a thin insulating vertical wall. The partition wall contains a small hole of cross-sectional area $\sqrt{10}\ \text{cm}^2$ near its bottom edge. Initially the hole is closed and the left chamber of the container is completely filled with a liquid of dielectric constant $\varepsilon_r = 15$ and the right chamber is empty $(\varepsilon_r = 1)$. At time t = 0, the hole is opened and the liquid flows from the left chamber to the right chamber. In both the chambers, the space above the liquid has $\varepsilon_r = 1$ and is maintained at atmospheric pressure. The schematic of the container at a time t > 0 is shown in the figure.

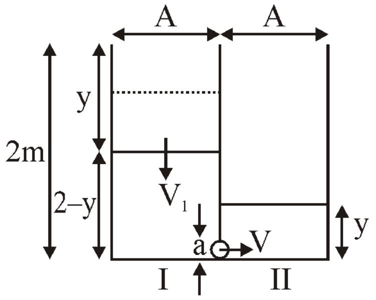
[Given: acceleration due to gravity is 10 ms^{-2}.]



15. The height (in m) of the liquid in left chamber at ..=500 s is :

Ans. 1.25

Sol.



Height difference between side I and II is

$$\Rightarrow h = (2-y) - y = 2 - 2y$$

Using Toricelli equation $\Rightarrow V = \sqrt{gh} \Rightarrow \frac{dy}{dt} = V_1$

Using continuity equation $AV_1 = av$

$$\Rightarrow V_1 = \frac{a}{A}V = \frac{\sqrt{10}\times 10^{-4}}{1} \times \sqrt{2g(2-2y)}$$

$$\Rightarrow \frac{dy}{dt} = 2\times 10^{-3} \times \sqrt{1-y}$$

$$\Rightarrow \int_0^4 \frac{dy}{\sqrt{1-y}} = 2\times 10^{-3} \int_0^{500} dt$$

$$\Rightarrow \text{take} 1 - y = p^2 \Rightarrow -dy = 2pdp$$

$$\Rightarrow \int \frac{-2pdp}{p} = 2\times 10^{-3} \times (500)$$

$$\Rightarrow 2.[-p] = 1$$

$$\Rightarrow 2.\left[-\sqrt{1-y}\right]_0^y = 1$$

$$\Rightarrow 2\left[1-\sqrt{1-y}\right]=1$$

$$\Rightarrow y=\frac{3}{4}m$$

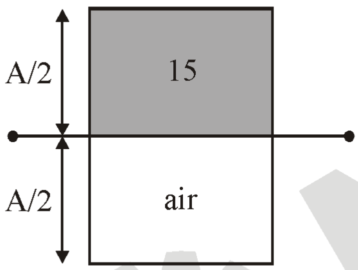
Height of liquid in the left chamber

$$\Rightarrow 2-y=2-\frac{3}{4}=\frac{5}{4}=1.25m$$

16. The difference in the capacitance (in F) between the metal plates at $t = 0$ and that at $t = 500$ s is $(8-n)\in_0$, where $\in_0$ is the permittivity of free space. The value of n is :

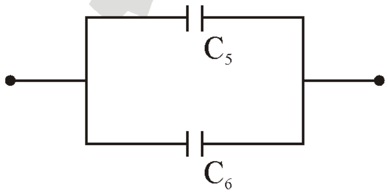
Ans. 1.97

Sol.



$A = 2m^2$

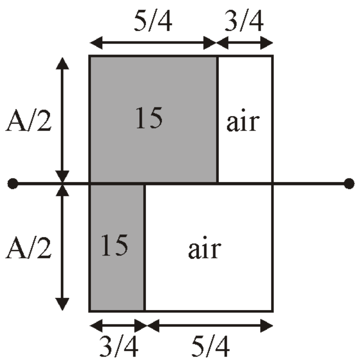
at $t = 0$



$$\Rightarrow C_5=15\left(\frac{\in_0 A/2}{2}\right)$$

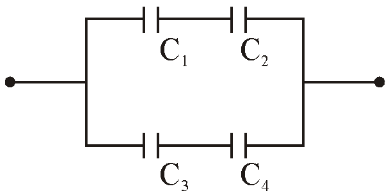
$$\Rightarrow C_6=\left(\frac{\in_0 A/2}{2}\right)$$

$$(eq)_{initial}=C_5+C_6=8\in_0$$



at t = 500

Equivalent diagram



$$\Rightarrow C_1 = 15\left(\frac{\epsilon_0 \frac{A}{2}}{\frac{5}{4}}\right), C_2 = \left(\frac{\epsilon_0 \frac{A}{2}}{\frac{3}{4}}\right)$$

$$\Rightarrow C_3 = 15\left(\frac{\epsilon_0 \frac{A}{2}}{\frac{3}{4}}\right), C_4 = \left(\frac{\epsilon_0 \frac{A}{2}}{\frac{5}{4}}\right)$$

$$\Rightarrow (eq)_{final} = \frac{C_1C_2}{C_1+C_2} + \frac{C_3C_4}{C_3+C_4} = \frac{128}{65}\epsilon_0$$

$$\text{Difference} = 8\epsilon_0 - \frac{128}{65}\epsilon_0$$

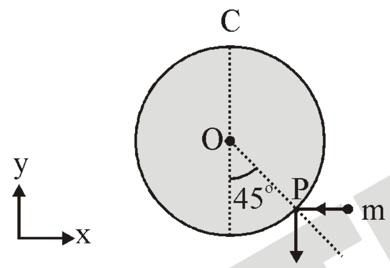
$$= (8 - 1.97)\epsilon_0$$

$$n = 1.97$$

Question Stem for Question Nos. 17 and 18

A uniform circular disk of radius 0.2 m and mass 1 kg is pivoted at its top point C such that it can rotate freely around C in the XY plane, as shown in the figure. Initially, when the disk is at rest, a particle of mass 20 g, travelling along negative x direction in the XY plane with speed 100 ms^{-1}, hits the circumference of the disk at a point P. After collision the particle moves along negative y direction at a speed of 90 ms^{-1}.

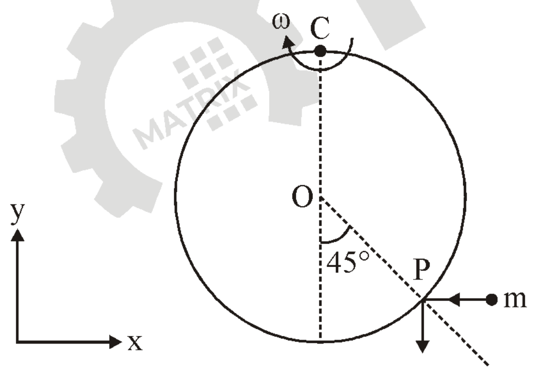
[Given: the acceleration due to gravity $(g) = -10\hat{j} ms^{-2}$]



17. After the collision the disk starts to rotate around point C in the XY plane. The maximum change in the height (in m) of its center O is:

Ans. 0.15

Sol.



Angular momentum conservation about C.

$$mu\,(R + R\cos 45°) = mv\,R\sin 45° + \left(\frac{MR^2}{2} + MR^2\right)\omega$$

$$\frac{20}{1000} \times 100 \times \frac{2}{10}\left(\frac{\sqrt{2}+1}{\sqrt{2}}\right) = \frac{20}{1000} \times 90 \times \frac{2}{10} \times \frac{1}{\sqrt{2}} + \frac{3}{2} \times 1 \times \frac{4}{100}\omega$$

$$\frac{40}{100}+\frac{40}{100\sqrt{2}}=\frac{36}{100\sqrt{2}}+\frac{6}{100}\omega$$

$$\frac{40}{100}+\frac{4}{100\sqrt{2}}=\frac{6}{100}\omega$$

$7.13 = \omega$

Mechanical energy conservation for disc after collision.

$$\frac{1}{2}I_C\omega^2 = Mg\Delta h$$

$$\Delta h=\frac{I_C\omega^2}{2Mg}=\frac{3MR^2}{2}\frac{\omega^2}{2Mg}$$

$$\Delta h=\frac{3}{4}\frac{R^2\omega^2}{g}$$

$$=\frac{3}{4}\times\frac{4}{100}\times\frac{1}{10}\times\frac{1600}{36}\left(1+\sqrt{2}\right)^2$$

$\Delta h = 0.1525$ m

$= 0.15$ m

18. Amount of energy loss (in J) in the collision is:

Ans. 17.47

Sol. Loss of energy $= E_{intial} - E_{final}$

$$=\frac{1}{2}mu^2-\frac{1}{2}mv^2-\frac{1}{2}I_C\omega^2$$

$$=\frac{1}{2}\times\frac{20}{1000}\left(100^2-90^2\right)-\frac{1}{2}\frac{3}{2}MR^2\omega^2$$

$= 19 - 1.53$

$= 17.47$

Note : You can also use $Mg\Delta h$ instead of $\frac{1}{2}I_C\omega^2$ for easier calculation.