

JEE – Advanced 17th May 2026

Paper 02

Question paper and Solution

PHYSICS

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- 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 equated **according to the following marking scheme:**
 Full Marks : +3 If **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.

SECTION 2 (Maximum Marks: 20)

- This section contains **FIVE (05)** questions.
- 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 equated **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 a correct option;
 Zero Marks : 0 if none of the options is chosen (i.e. the question is 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 +2 marks;
 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 (i.e. the question is unanswered) will get 0 marks; and
 choosing any other combination of options will get -1 marks.

SECTION 3 (Maximum Marks: 20)

- This section contains **FIVE (05)** questions.
- 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 equated **according to the following marking scheme:**
 Full Marks : +4 If **ONLY** the correct numerical value is entered in the designated place;
 Zero Marks : 0 In all other cases.

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 equated **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.

Section 1**Multiple choice questions with one correct alternative**

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 $6.35 \times 10^3 \text{ kg m}^{-3}$, 63.5 gm/mole and $2 \times 10^8 \text{ mho m}^{-1}$, 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 $1.6 \times 10^{-19} \text{ C}$.]

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

Ans (C)

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A} = \frac{100}{2 \times 10^8 \times 0.5 \times 10^{-6}}$$

$$R = 1 \Omega, r = 1 \Omega$$

$$I = \frac{\varepsilon}{R + r} = \frac{2V}{1 + 1} = 1A = neAV_d$$

$$V_d = \frac{I}{neA}$$

For number of free electrons.

$$1 \text{ mole} = 6 \times 10^{23} \text{ atom} = 6 \times 10^{23} e^-$$

$$63.5 \text{ g} = 6 \times 10^{23} e^- \Rightarrow 1 \text{ kg} = \frac{6 \times 10^{23}}{63.5} \times 10^3 e^-$$

$$\rho = 6.35 \times 10^3 \frac{\text{kg}}{\text{m}^3} = \frac{M}{V} = \frac{6.35 \times 10^3 \times 6 \times 10^{26}}{63.5}$$

$$n = 6 \times 10^{28}$$

$$V_d = \frac{1}{6 \times 10^{28} \times 1.6 \times 10^{-19} \times 0.5 \times 10^{-6}} = 0.208 \times 10^{-3} \text{ m s}^{-1} = 0.208 \text{ mm s}^{-1}$$

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

Ans (A)

Rate of change of number of nuclei is equator rate of production

Rate of decay.

$$\frac{dN}{dt} = \alpha - \lambda N$$

$$\int_0^N \frac{dN}{\alpha - \lambda N} = \int_0^t dt$$

$$\frac{\ln(\alpha - \lambda N)}{-\lambda} = T \Rightarrow \ln(\alpha - \lambda N)_0^N = -\lambda t \Rightarrow \ln\left(\frac{\alpha - \lambda N}{\alpha}\right) = -\lambda t$$

$$1 - \frac{\lambda}{\alpha} N = e^{-\lambda t} \Rightarrow \frac{\lambda}{\alpha} N = 1 - e^{-\lambda t}$$

$$N = \frac{\alpha}{\lambda} [1 - e^{-\lambda t}]$$

$$\text{Power} = \frac{dQ}{dt} \Rightarrow \frac{d}{dt}(msT) = \lambda N E_0$$

$$ms \frac{dT}{dt} = \frac{\lambda \alpha}{\lambda} [1 - e^{-\lambda t}] E_0$$

$$\frac{dT}{dt} = \frac{\alpha}{ms} [1 - e^{-\lambda t}] E_0$$

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 $\alpha = 3\mu\text{m}^{-1}$ and $\beta = 0.096 \mu\text{m}^2$. 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)

$$A = 6^\circ$$

$$n(\lambda) = \alpha\lambda + \frac{\beta}{\lambda^2} \quad \alpha = 3\mu\text{m}^{-1}, \beta = 0.096$$

$$\lambda_m \rightarrow D_m = A(\mu - 1)$$

$$D_m = 6^\circ \left(\alpha\lambda + \frac{\beta}{\lambda^2} \right)$$

Differentiating

$$\frac{dD_m}{d\lambda} = 6^\circ \left[\alpha(1) - \frac{2\beta}{\lambda^3} \right] = 0$$

$$\alpha = \frac{2\beta}{\lambda^3}$$

$$\lambda^3 = \frac{2\beta (\mu\text{m})^2}{\alpha (\mu\text{m})^{-1}} = \frac{2 \times 0.096 \times 10^{-6}}{3 \times 10^{-6}} \Rightarrow \lambda^3 = 0.064 \Rightarrow \lambda_{\min} = 0.4 \mu\text{m}$$

$$= A^\circ(n-1)$$

$$D_m = 6^\circ(n-1) = 6^\circ \left(\alpha\lambda + \frac{\beta}{\lambda^2} - 1 \right) = 6^\circ \left[3(\mu\text{m})^{-1} 0.4 \mu\text{m} + \frac{0.096(\mu\text{m})^2}{(0.4\mu\text{m})^2} - 1 \right]$$

$$= 6^\circ[1.2 + 0.6 - 1] = 6^\circ \times 0.8 \Rightarrow D_{\min} = 4.8^\circ$$

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 $\delta r \ll r_0$, due to which its radial distance varies periodically. The corresponding time period is:

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

Ans (A)

$$\vec{F} = -\frac{k}{r^2} \hat{r}$$

For circular motion

$$\frac{k}{r_0^2} = m\omega^2 r_0 \quad l = mvr \quad l = m\omega r^2$$

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

$$k = \frac{l^2}{mr_0}$$

$$F_{\text{net}} = F' - F_e^0 = \frac{k}{(r_0 + dr)^2} - m(\omega_1)^2 (r + dr)$$

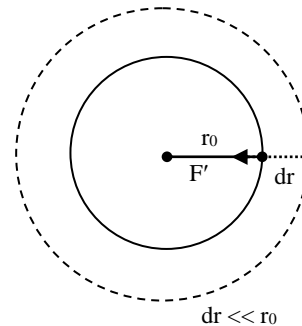
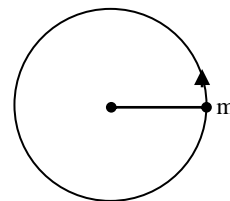
$$ma = \frac{k}{r_0^2} \left(1 + \frac{dr}{r_0} \right)^2 - m(\omega + d\omega)^2 (r + dr)$$

$$dl = 0 = [\omega 2r dr + r^2 d\omega]$$

$$ma = \frac{k}{r_0^2} \left[1 + \frac{2dr}{r_0} \right] - m \left[\omega - \frac{2\omega dr}{r} \right]^2 (r + dr) \quad d\omega = -\frac{2\omega}{r} dr$$

$$ma = \frac{k}{r_0^2} \left[1 + \frac{2dr}{r_0} \right] - m\omega^2 \left[1 - \frac{dr}{r} \right] (r + dr)$$

$$-ma = \frac{k}{r_0^2} + \frac{2k}{r_0^3} dr - m\omega^2 r_0 - m\omega^2 dr$$



$$-ma = \left(\frac{2k}{r_0^3} - m\omega^2 \right) dr \quad \because \omega = \frac{l}{mr_0^2}$$

$$k = \frac{l^2}{mr_0}$$

$$-a = \left(\frac{l^2}{m^2 r_0^4} \right) dr$$

$$\text{SHM frequency} = \sqrt{\frac{l^2}{m^2 r_0^4}} = \frac{l}{mr_0^2}$$

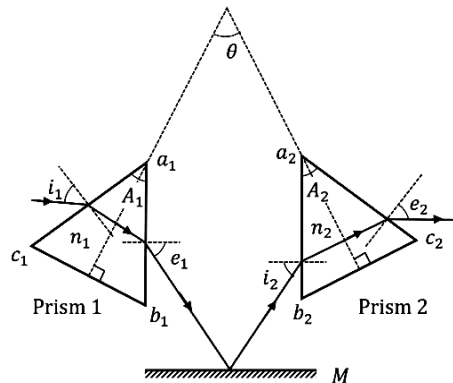
$$T = \frac{2\pi mr_0^2}{l} \quad k = \frac{l^2}{mr_0}$$

$$T = \frac{2\pi m}{l} \left(\frac{l^2}{mk} \right)^2 \Rightarrow T = \frac{2\pi ml^4}{lm^2 k^2} \Rightarrow T = \frac{2\pi l^3}{mk^2}$$

Section 2

Multiple choice questions with one or more than one correct alternative/s

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 $a_1 b_1$ and $a_2 b_2$ are parallel to each other and perpendicular to the mirror M . If a ray of light is incident on the face $a_1 c_1$ and emerges from the face $a_2 c_2$, then the correct statement(s) is/are:



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

(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 (A), (C) and (D)

$$(A) n_1 \times \sin \frac{A_1}{2} = 1 \times \sin e_1$$

$$n_2 \times \sin \frac{A_2}{2} = 1 \times \sin i_2$$

$$e_1 = i_2$$

$$n_1 \sin \frac{A_1}{2} = n_2 \sin \frac{A_2}{2}$$

$$\boxed{\frac{n_2}{n_1} = \frac{\sin\left(\frac{A_1}{2}\right)}{\sin\left(\frac{A_2}{2}\right)}}$$

$$(B) 1 \times \sin i_2 = n_2 \times \sin \frac{A_2}{2}$$

$$1 \times \sin e_1 = n_2 \sin\left(\frac{A_2}{2}\right)$$

$$e_1 \neq i_1$$

$$\sin i_1 \neq n_2 \sin \frac{A_2}{2}$$

$$\sin i = n_2 \sin\left(\frac{A_2}{2}\right) \times \frac{\sin r_1}{\sin(A_1 - r_1)}$$

$$(C) \delta_{m1} = (n_1 - 1) A_1$$

$$\delta_{m2} = (n_2 - 1) A_2$$

$$\frac{A_1}{2} + \frac{A_2}{2} = \theta$$

$$\frac{\delta_{m1}}{2(n_1 - 1)} + \frac{\delta_{m2}}{2(n_2 - 1)} = \frac{A_1 + A_2}{2} = \theta$$

$$(D) \sin i_2 = n_1 \sin\left(\frac{A_1}{2}\right)$$

E

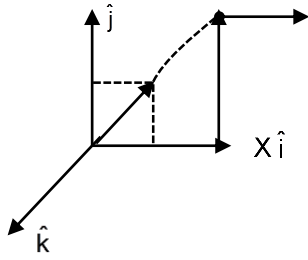
$$e_1 = i_2 \Rightarrow 1 \times \sin i_2 = n_1 \sin\left(\frac{A_1}{2}\right)$$

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

- (A) The vertical distance of the particle from the XZ plane at $t = 0.3 \text{ s}$ is 15 cm .
 (B) The vertical distance of the particle from the XZ plane at $t = 0.4 \text{ s}$ is 10 cm .
 (C) The radius of the trajectory of the particle for $t > 0.2 \text{ s}$ is 20 cm .
 (D) The particle will be in the XZ plane at $t = 0.35 \text{ s}$.

Ans (A) and (C)

$$q = 1 \mu\text{C} = 10^{-6} \text{ C}$$



$$m = 1 \text{ mg} = 10^{-6} \text{ kg} \text{ initial } \vec{u} = (\hat{i} + 2\hat{j})$$

$$\vec{E} = \hat{i} \text{ Vm}^{-1}$$

$$\vec{g} = -10\hat{j} \text{ ms}^{-2}$$

$$t = 0 \rightarrow t = 0.2 \text{ sec}$$

$$\vec{F} = q\vec{E} = 10^{-6} \times 1 \hat{i} \text{ N} = 10^{-6} \text{ N} = m\vec{a}$$

$$\vec{a}_e = 1 \text{ ms}^{-2} \hat{i}$$

$$\vec{a}_{\text{net}} = \hat{i} - 10\hat{j}$$

$$\vec{u} = \hat{i} + 2\hat{j}$$

$$\vec{v} = \vec{u} + \vec{a}t$$

$$v_x = u_x + a_x t = \hat{i} + \hat{i} \times 0.2 = 1.2\hat{i} \quad \text{and} \quad v_y = 2\hat{j} - 10 \times 0.2 \hat{j} = 0$$

$$\vec{v} = 1.2\hat{i} \text{ ms}^{-1}$$

$$y = u_y t + \frac{1}{2} a_y t^2 = 2(0.2) + -10 \times (0.2)^2 = 0.2 \text{ m} = 20 \text{ cm (above x-z plane)}$$

Now, magnetic field on electric field off

No force along y-direction

So only gravity will act in y-direction

y velocity at 0.2 sec

$$v_y = 0 \text{ and } y \text{ position } 20 \text{ cm}$$

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

At $t = 0.3 \text{ sec}$ means further 0.1 sec

$$y = -\frac{1}{2} \times 5s = -5 \times 0.1^2 = -0.05 \text{ m} = -5 \text{ cm}$$

At $t = 0.4 \text{ sec}$

Means further 0.2 sec

$$y = -5 \times (0.2)^2 = 20 \text{ cm}$$

Velocity \perp to magnetic field, $V_{\perp} = 1.2$

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

(D) $t = 0.35 \text{ sec}$

Further, $t = 0.15$

$$y = -5 \times (0.15)^2 \Rightarrow 5 \times 0.0225 = 0.1125 \text{ m} \Rightarrow 11.25 \text{ cm} = 8.75$$

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 (A), (B) and (C)

$$V_1 = V_2 \Rightarrow \frac{KQ_1}{\sqrt{(x-a)^2 + (y-b)^2}} = \frac{KQ_2}{\sqrt{(ma-x)^2 + (mb-y)^2}} = \frac{KmQ_1}{\sqrt{(ma-x)^2 + (mb-y)^2}}$$

$$\Rightarrow m^2a^2 + x^2 - 2max + m^2b^2 + y^2 - 2mby = m^2(x-a)^2 + m^2(y-b)^2$$

For option (A), $m = -1$

$$\Rightarrow 2ax + 2by = 0 \Rightarrow ax + by = 0$$

For option (B), $m = 2 \Rightarrow x^2 + y^2 - \frac{4ax}{3} - \frac{4by}{3} = 0$

$$x^2 + y^2 - 2hx - 2ky = r^2 - h^2 = k^2$$

$$r = \sqrt{h^2 + k^2}$$

$$h = \frac{2a}{3}, k = \frac{2b}{3}$$

$$\text{Centre } \left(\frac{2a}{3}, \frac{2b}{3}\right), r = \frac{2}{3}\sqrt{a^2 + b^2}$$

For option (C), $m = -2$

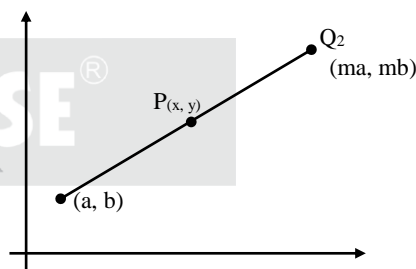
$$\Rightarrow x^2 + y^2 - 4ax - 4by = 0$$

$$2h = 4a, \Rightarrow h = 2a$$

$$2k = 4b \Rightarrow k = 2b$$

$$r = \sqrt{h^2 + k^2} = 2\sqrt{a^2 + b^2}$$

Centre $(h, k) = (2a, 2b)$



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

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

Ans (B) and (D)

(A) $\vec{E} = E\hat{j}$

Uniform field, $\vec{F} = 0$

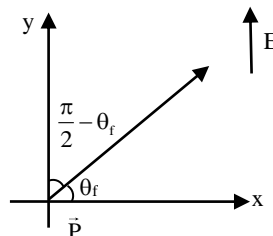
$$\Delta K = \frac{1}{2} I \omega^2 = -\Delta U$$

$$= \frac{1}{2} \times 2 \times m \times \frac{d^2}{4} \omega^2 = - \left(-q\alpha E \cos \left(\frac{\pi}{2} - \theta_f \right) - 0 \right) = q\alpha E \sin \theta_f$$

$$\omega^2 = \frac{4qE}{md} \sin \theta_f$$

(B) $\theta_f = \frac{\pi}{6}$

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



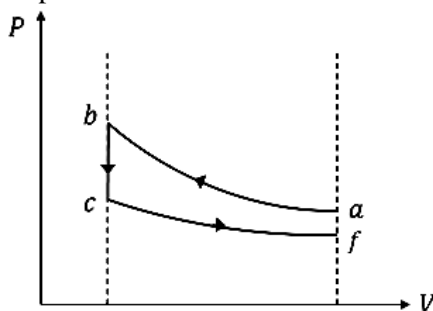
(C) $\Delta K = qE \sin \frac{\pi}{3} = \frac{\sqrt{3}}{2} qEd$

(D) $\alpha = 0$ after field is turned off

Dipole rotates with constant angular velocity

9. Ten moles of an ideal monoatomic gas, initially in state **a** at atmospheric pressure and temperature $T_a = 27^\circ\text{C}$, 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 $\frac{V_0}{3}$. Now, keeping the piston stationary, the cylinder is submerged in a water bath of temperature 11°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 $4860R$.
 (C) The net change in the internal energy in the whole process is $-240R$.
 (D) The pressure and temperature of the state **b** are 2.08 times the atmospheric pressure and 624 K, respectively.

Ans (A), (B) and (C)

(A) Process a – b is adiabatic

$$TV^{\gamma-1} = \text{constant}$$

$$T_b = T_a \left(\frac{V_a}{V_b} \right)^{\gamma-1} = 300 \left(3^{\frac{2}{3}} \right) = 624 \text{ K}$$

$$PV^\gamma = \text{constant}$$

$$P_b = P_a \left(\frac{V_a}{V_b} \right)^\gamma = P_0 (3)^{\frac{5}{3}} = 6.24P_0$$

(B) Change in internal energy

$$\Delta U_{ab} = nC_v \Delta T = 10 \times \frac{3}{2} R (624 - 300) = 4860R$$

(C) B to C \rightarrow isochoric process

$$T_C = 11^\circ\text{C} = 284\text{ K}$$

(D) Net change in internal energy

$$\Delta U_{\text{tot}} = U_f - U_a = nC_v (T_f - T_a) = 10 \times \frac{3}{2} R (284 - 300) = -240R$$

Section 3

Numerical problems (truncate/round-off the value to TWO decimal places)

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

For wire-1: $LC = \frac{0.5\text{mm}}{100} = \frac{1}{200}\text{mm}$

$$0.650\text{ mm} = 0.5\text{ mm} + \left(42 \times \frac{1}{200} \right) \text{mm} = 0.71\text{ mm}$$

i.e. LHS \neq RHS

$$\Rightarrow \text{Z.E.} = 0.71\text{ mm} - 0.65$$

$$= 0.06\text{ mm (more than actual reading)}$$

\Rightarrow ZE is positive

For wire-2

$$d = 1.5\text{ mm} + \left(95 \times \frac{1}{200} \right) = 1.975\text{ mm}$$

$$\text{Actual reading} = 1.975\text{ mm} - \text{ZE} = 1.975\text{ mm} - 0.06 = 1.915\text{ mm}$$

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 $(2^\circ \pm 4')$. The value of the fractional error in the measurement of wavelength is: [Given: $\sin(2^\circ) = 0.035$]

Ans 0.45 or 0.46

$$\lambda = a \sin \theta$$

$$\frac{d\lambda}{d\theta} = a \cos \theta + \sin \theta \frac{da}{d\theta} \quad \therefore d\lambda = a \cos \theta \cdot d\theta + \sin \theta \cdot da$$

$$\text{Fractional error} = \frac{d\lambda}{\lambda} = \frac{a \cos \theta d\theta + \sin \theta da}{a \sin \theta} = (\cot \theta) d\theta + \frac{da}{a}$$

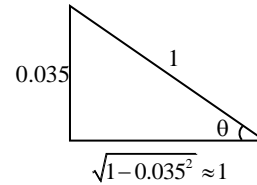
Here, $a = 0.016$, $da = 0.002$

$$\frac{da}{a} = \frac{0.002}{0.016} = \frac{1}{8} = 0.125$$

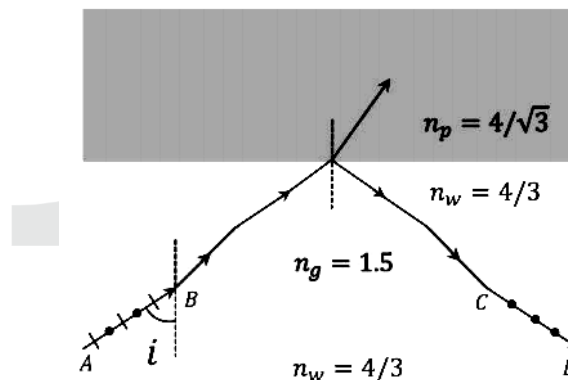
Also, $\sin \theta = \sin 2^\circ = 0.035$

$$\therefore \cot \theta = \frac{1}{0.035} \Rightarrow d\theta = 40' = \frac{2}{3} = \frac{2}{3} \times \frac{\pi}{180} \text{ rad} = \frac{2}{3} \times \frac{22}{7 \times 180}$$

$$f = \left(\frac{1}{0.035} \times \frac{2}{3} \times \frac{22}{7 \times 180} \right) + \frac{1}{8} = 0.457$$



12. As shown in the figure, a ray AB of unpolarized light enters from water of refractive index $n_w = \frac{4}{3}$ into a medium of refractive index $n_p = \frac{4}{\sqrt{3}}$ 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 t (in degrees) is

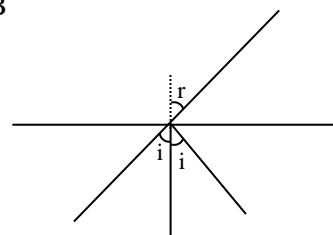


Ans 60

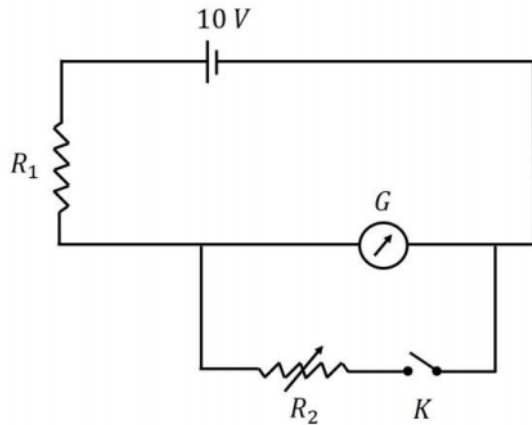
When light goes from glass to water, it is again parallel to AB

According to Brewster's law, reflected light is polarized

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



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

Correct through galvanometer when key is open = I_g

Correct through galvanometer when key is closed = $I_{g1} = I_g = \frac{I_g}{2}$

$$I_g = \frac{V}{R_1 + G} \Rightarrow I_g = \frac{10}{R_1 + 6}$$

Combined Resistance of Galvanometer & R_2

$$R_p = \frac{R_g \times R_2}{R_g + R_p} = \frac{6 \times 4}{6 + 4} = 2.4 \Omega$$

Total Resistance $R = R_1 + 2.4$

$$\text{Current through Resistance } R_1 \Rightarrow I_{R1} = \frac{10}{R_1 + 2.4}$$

$$I_{R2} + I_{g1} = I_{R1}$$

$$I_{g1} \left(\frac{R_g + R_2}{R_2} \right) = I_{R1}$$

$$\frac{I_g}{2} = \frac{10}{R_1 + 2.4} \times \frac{4}{10}$$

$$\frac{5}{(R_1 + 6)} = \frac{4}{(R_1 + 2.4)}$$

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

$$R_1 = 12$$

$$I_{R1} = \frac{10}{14.9} = 0.694A$$

$$I_{R1} = 694 \text{ mA.}$$

14. In a new system of units, the units of mass, length, time and current are 5 kg, 5 m, 5 s 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 $\sqrt{\frac{\mu_0}{\epsilon_0}}$ is

Ans 25

$$\sqrt{\frac{\mu_0}{\epsilon_0}}$$

$$\Rightarrow C = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$C^2 = \frac{1}{\epsilon_0 \mu_0}$$

$$\mu_0 = \frac{1}{C^2 \epsilon_0}$$

$$\sqrt{\frac{\mu_0}{\epsilon_0}} = \frac{1}{C \epsilon_0}$$

$$|\epsilon_0| \Rightarrow I^2 T^4 M^{-1} L^{-3}$$

$$|C| = L T^{-1}$$

$$\left| \frac{1}{C \epsilon_0} \right| = M L^2 I^{-2} T^{-3}$$

$$n = \left(\frac{M_1}{M_2} \right) \left(\frac{L_1}{L_2} \right)^2 \left[\frac{I_1}{I_2} \right]^{-2} \left[\frac{T_1}{T_2} \right]^{-3}$$

$$= \left[\frac{M}{5M} \right] \times \left[\frac{L}{5L} \right]^2 \left[\frac{5I}{I} \right]^2 \times \left[\frac{5T}{T} \right]^{-3}$$

$$= \frac{1}{5} \times \frac{1}{25} \times \frac{25}{1} \times \frac{125}{1}$$

$$n = 25$$

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Section 4

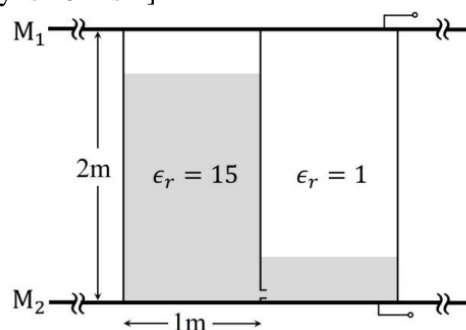
Numerical problems (truncated/round-off the value to two decimal places)

Stem - 1

Question Stem for Question number 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 $\epsilon_r = 15$ and the right chamber is empty ($\epsilon_r = 1$). 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 $\epsilon_r = 1$ 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 $t = 500$ s is

Ans 1.25

Velocity of efflux $V = \sqrt{2g(y - (2 - y))}$

$$V = \sqrt{2g(2y - 2)}$$

$$V = 2\sqrt{g}\sqrt{y - 1}$$

$$\frac{dy}{dt} = V_1 = \text{speed of liquid level moving down from first chamber}$$

Even $-A \frac{dy}{dt} = ay$

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

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

$$\int_2^y \frac{dy}{\sqrt{y - 1}} = \int_0^{500} -2 \times 10^{-3} dt$$

$$2\sqrt{y - 1} \Big|_2^y = -1$$

$$\sqrt{y - 1} \Big|_2^y = -\frac{1}{2}$$

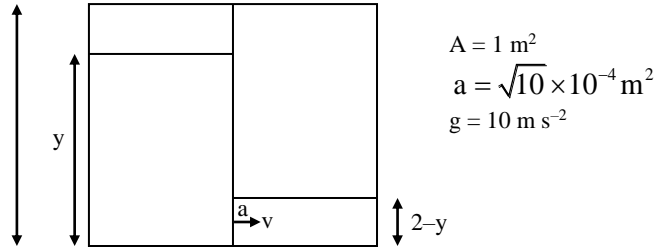
$$\sqrt{y - 1} - 1 = -\frac{1}{2}$$

$$\sqrt{y - 1} = \frac{1}{2}$$

$$y - 1 = \frac{1}{4}$$

$$y = \frac{5}{4}$$

$$y = 1.25 \text{ m}$$



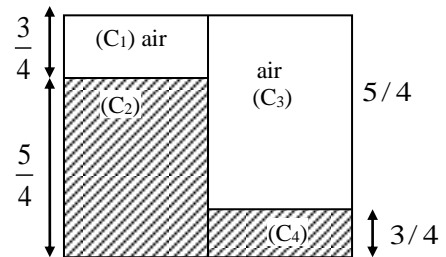
16. The difference in the capacitance (in F) between the metal plates at $t = 0$ and that at $t = 500$ s is $(8 - n)\epsilon_0$, where ϵ_0 is the permittivity of free space. The value of n is

Ans 1.97

$$C_1 = \frac{14\epsilon_0 \times 1 \times 1}{3}, C_2 = \frac{15\epsilon_0 \times 1 \times 1}{\frac{5}{4}} = 12\epsilon_0$$

$$C_1, C_2 \text{ are in series} \Rightarrow C' = \frac{C_1 C_2}{C_1 + C_2} = \frac{\frac{4}{3}\epsilon_0 \times 12\epsilon_0}{\frac{4}{3}\epsilon_0 + 12\epsilon_0}$$

$$C' = \frac{48\epsilon_0}{3} \times \frac{3}{40} = \frac{6\epsilon_0}{5}$$



$$C_3 = \frac{\epsilon_0 \times 1 \times 1}{\frac{5}{4}} = \frac{4\epsilon_0}{5}, \quad C_4 = \frac{15\epsilon_0 \times 1 \times 1}{\frac{3}{4}} = 20\epsilon_0$$

$$C_3, C_4 \text{ are in series} \Rightarrow C'' = \frac{C_3 C_4}{C_3 + C_4} = \frac{\frac{4\epsilon_0}{5} \times 20\epsilon_0}{\frac{4\epsilon_0}{5} + 20\epsilon_0}$$

$$= \frac{80\epsilon_0}{5} \times \frac{5}{104} = \frac{10\epsilon_0}{13}$$

$$C', C'' \text{ are parallel} \Rightarrow C_{\text{Final}} = \frac{6\epsilon_0}{5} + \frac{10\epsilon_0}{13} = 1.969\epsilon_0$$

At $t = 0$ s

$$C_{01} = \frac{15\epsilon_0 \times 1 \times 1}{2}, \quad C_{02} = \frac{\epsilon_0 \times 1 \times 1}{2}$$

$$C_{\text{initial}} = 8\epsilon_0$$

$$C_{\text{initial}} - C_{\text{final}} = 8 - n$$

$$8\epsilon_0 - 1.969\epsilon_0 = (8 - n)\epsilon_0$$

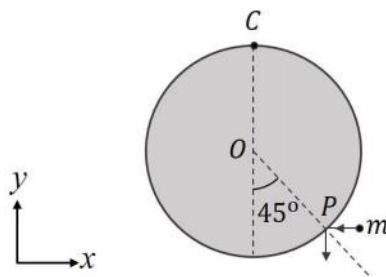
$$n = 1.969 \approx 1.97$$

Stem - 2

Question Stem for Question number 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) = $-10\hat{j} \text{ ms}^{-2}$]



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:

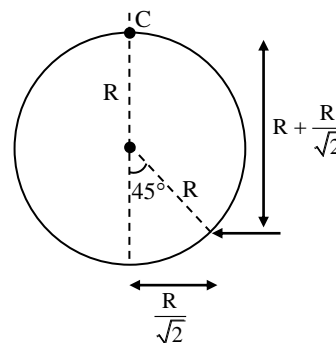
Ans 0.15

$$I_C = \frac{MR^2}{2} + MR^2 = \frac{3}{2}MR^2 = \frac{3}{2} \times 1 \times (0.2)^2 = 0.06 \text{ kg m}^2$$

By conservation of angular momentum

$$\frac{20}{1000} \times 100 \times 0.2 \left(1 + \frac{1}{\sqrt{2}}\right) = \frac{20}{1000} \times 90 \times \frac{0.2}{\sqrt{2}} + \frac{3}{2} \times 1 \times (0.2)^2 \omega^2$$

$$\omega = 7.138 \text{ rad s}^{-1}$$



By energy conservation : $\frac{1}{2}I\omega^2 = Mg\Delta h$

$$\frac{1}{2} \times 0.06 \times (7.138)^2 = 1 \times 10 \times \Delta h$$

$$1.53 = 10\Delta h$$

$$\Delta h = 0.15 \text{ m}$$

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

Ans 17.47

$$(KE)_i = \frac{1}{2} \times \frac{20}{1000} \times 100 \times 100 = 100 \text{ J}$$

$$(KE)_f = \left(\frac{1}{2} \times \frac{20}{1000} \times 90 \times 90 \right) + \left(\frac{1}{2} \times \frac{3}{2} \times 1 \times (0.2)^2 \right) (7.138)^2 = 81 \text{ J} + 1.53 \text{ J}$$

$$\text{Loss of energy} = 100 - (81 + 1.53) = 17.47 \text{ J}$$

* * *

