JEE Main 2025 April 2 Shift 1 Question Paper with Solutions

Time Allowed :3 Hours	Maximum Marks :300	Total Questions :75

General Instructions

Read the following instructions very carefully and strictly follow them:

1. Multiple choice questions (MCQs)
2. Questions with numerical values as answers.
3. There are three sections: **Mathematics, Physics, Chemistry**.
4. **Mathematics:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory.
5. **Physics:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory..
6. **Chemistry:** 25 (20+5) 10 Questions with answers as a numerical value. Out of 10 questions, 5 questions are compulsory.
7. Total: 75 Questions (25 questions each).
8. 300 Marks (100 marks for each section).
9. **MCQs:** Four marks will be awarded for each correct answer and there will be a negative marking of one mark on each wrong answer.
10. **Questions with numerical value answers:** Candidates will be given four marks for each correct answer and there will be a negative marking of 1 mark for each wrong answer.

Physics

Section - A

26. A light wave is propagating with plane wave fronts of the type $x + y + z =$ constant. The angle made by the direction of wave propagation with the x-axis is:

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

Correct Answer: (1) $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$

Solution:

The direction of propagation of light is perpendicular to the wave front and is symmetric about the x, y, and z axes. The angle made by the direction of wave propagation with the x-axis is the same as that with the y-axis and the z-axis. Thus, the equation can be written as:

$\cos\theta = \cos\beta = \cos\gamma$ (where α, β, γ are the angles made by light with the x, y, z axes respectively)

Also, we know that $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$. Since the angles are equal, we have:

$$\cos^2\alpha + \cos^2\alpha + \cos^2\alpha = 1 \quad \Rightarrow \quad 3\cos^2\alpha = 1 \quad \Rightarrow \quad \cos\alpha = \frac{1}{\sqrt{3}}$$

Thus, the angle is $\cos^{-1}\left(\frac{1}{\sqrt{3}}\right)$.

Quick Tip

The symmetry of the wave propagation allows us to use the property that the angle made with the x, y, and z axes is the same.

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27. The equation for real gas is given by $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, where P, V, T, and R are the pressure, volume, temperature and gas constant, respectively. The dimension of ab is equivalent to that of:

(1) Planck's constant (2) Compressibility (3) Strain (4) Energy density

Correct Answer: (2) Compressibility

Solution:

From the given equation $\left(P + \frac{a}{V^2}\right)(V - b) = RT$, we have the following dimensions for each variable:

$$[a] = [P][V]^2 = ML^{-1}T^{-2}L^2 = MLT^{-2}$$

$$[b] = [V] = L^3$$

Now, $[ab] = (MLT^{-2})(L^3) = ML^4T^{-2}$.
Thus, the dimensions of ab correspond to the dimension of **compressibility**.

Quick Tip

To solve for dimensional analysis problems, break down each term into its basic dimensions and multiply accordingly.

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28. A cord of negligible mass is wound around the rim of a wheel supported by spokes with negligible mass. The mass of the wheel is 10 kg and radius is 10 cm and it can freely rotate without any friction. Initially the wheel is at rest. If a steady pull of 20 N is applied on the cord, the angular velocity of the wheel, after the cord is unwound by 1 m, will be:

(1) 20 rad/s (2) 30 rad/s (3) 10 rad/s (4) 0 rad/s

Correct Answer: (1) 20 rad/s

Solution:

The work done W_f by the force $F = 20\,N$ is given by:

$$W_f = F \cdot d = 20 \times 1 = 20\,J$$

This is the change in kinetic energy of the wheel:

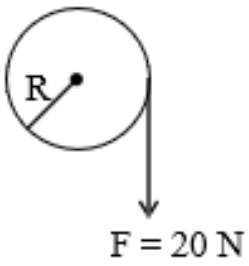
$$KE = \frac{1}{2} I\omega^2$$

Using $I = MR^2$ where $M = 10\,\text{kg}$ and $R = 0.1\,\text{m}$:

$$I = 10 \times (0.1)^2 = 0.1\,\text{kg m}^2$$

Now equating the work done to the change in kinetic energy:

$$20 = \frac{1}{2} \times 0.1 \times \omega^2 \quad \Rightarrow \quad \omega = 20\,\text{rad/s}$$



Quick Tip

When a steady force is applied and the object rotates, the work done on the object is equal to its kinetic energy.

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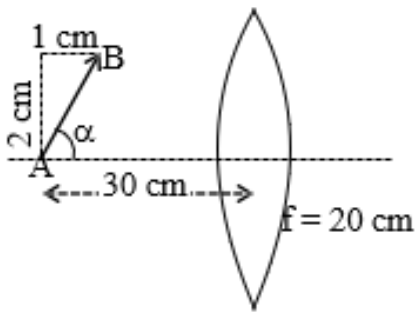
29. A slanted object AB is placed on one side of convex lens as shown in the diagram. The image is formed on the opposite side. Angle made by the image with principal axis is:



(1) $\frac{-\alpha}{2}$ (2) $-45°$ (3) $+45°$ (4) $-\alpha$

Correct Answer: (2) -45°

Solution:

The location of the image of A can be found using the lens formula:

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

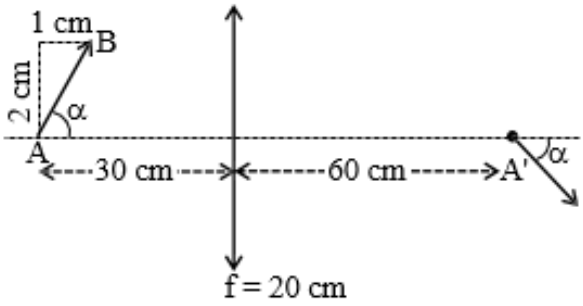
where $f = 20\,\text{cm}$, $u = -30\,\text{cm}$, and $v = 60\,\text{cm}$.
Using the magnification formula:

$$m = \frac{v}{u} = \frac{60}{-30} = -2$$

Since the object size is small with respect to the location, we can calculate the small change dv in the image:

$$dv = m^2 du = 4 \times 1 = 4\,\text{cm}$$

This gives us the size of the image at P as $h_i = mh_o = 2 \times 2 = 4\,\text{cm}$.
The angle made by the image with the principal axis is -45°, which corresponds to the correct answer.



Quick Tip

When the object is slanted and small compared to the location, use magnification and lens formulas to find the angle made by the image.

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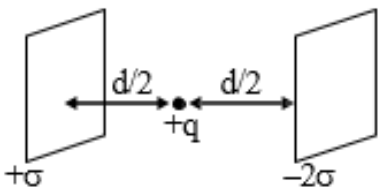
30. Consider two infinitely large plane parallel conducting plates as shown below. The plates are uniformly charged with a surface charge density $+\sigma$ and $-\sigma$. The force experienced by a point charge $+q$ placed at the mid point between the plates will be:

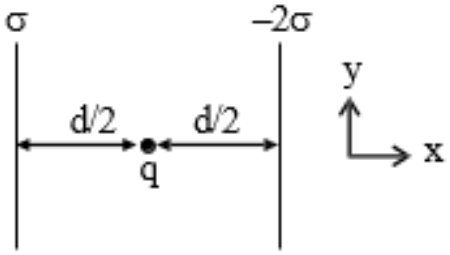


(1) $\frac{3q\sigma}{4\epsilon_0}$ (2) $\frac{3q\sigma}{2\epsilon_0}$ (3) $\frac{3q\sigma}{4\epsilon_0}$ (4) $\frac{q\sigma}{2\epsilon_0}$

Correct Answer: (2) $\frac{3q\sigma}{2\epsilon_0}$

Solution:

Let the charge distribution on the two plates be σ and $-\sigma$, with the point charge q placed at the midpoint between the plates.
The electric field due to each plate at the midpoint is as follows:

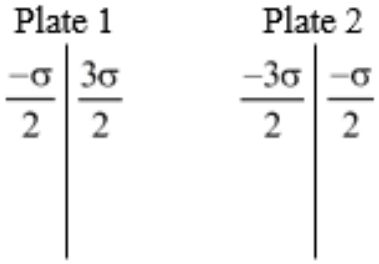


For Plate 1, the electric field is $\frac{\sigma}{2\epsilon_0}$ directed away from the plate, and for Plate 2, the electric field is $\frac{\sigma}{2\epsilon_0}$ directed towards the plate.
Thus, the net electric field experienced by the charge q is:

$$E_{\text{net}} = \frac{3\sigma}{2\epsilon_0}$$

Now, the force on the charge q is given by:

$$F = qE = q \times \frac{3\sigma}{2\epsilon_0} = \frac{3q\sigma}{2\epsilon_0}$$



Quick Tip

When calculating the electric field due to uniformly charged infinite plates, use the formula $E = \frac{\sigma}{2\epsilon_0}$ for each plate and then sum the fields considering the direction.

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31. A river is flowing from west to east direction with speed of 9 km/hr. If a boat capable of moving at a maximum speed of 27 km/hr in still water, crosses the river in half a minute, while moving with maximum speed at an angle of 150° to direction of river flow, then the width of the river is:

(1) 300 m (2) 112.5 m (3) 75 m (4) $112.5 \times \sqrt{3}$ m

Correct Answer: (2) 112.5 m

Solution:

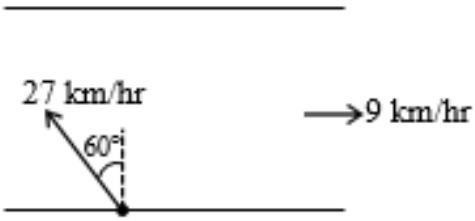
The speed of the boat relative to the river is 27 km/hr, and the boat crosses the river at an angle of 150° to the direction of the river flow.
Using the formula for the effective speed component of the boat in the direction perpendicular to the flow of the river:

$$V_L = 27\,\text{km/hr} \times \cos 60^\circ = \frac{27}{2} = 13.5\,\text{km/hr}$$

The time taken to cross the river is 30 seconds or $\frac{1}{2}$ minute. Using the formula for distance:

$$S = V_t \times t = 13.5\,\text{km/hr} \times \frac{30}{60}\,\text{hr} = 13.5 \times \frac{1}{2} = 112.5\,\text{m}$$

Thus, the width of the river is 112.5 m.



Quick Tip

When solving river crossing problems, decompose the boat's velocity into components: one parallel to the river flow and one perpendicular to it. The perpendicular component gives the speed for crossing the river.

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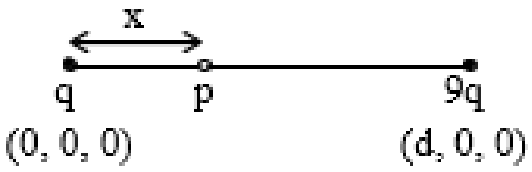
32. A point charge $+q$ is placed at the origin. A second point charge $+9q$ is placed at $(d, 0, 0)$ in Cartesian coordinate system. The point in between them where the electric field vanishes is:

(1) $\left(\frac{4d}{3}, 0, 0\right)$ (2) $\left(\frac{d}{4}, 0, 0\right)$ (3) $\left(\frac{3d}{4}, 0, 0\right)$ (4) $\left(\frac{d}{3}, 0, 0\right)$

Correct Answer: (2) $\left(\frac{d}{4}, 0, 0\right)$

Solution:

Let the electric field at point P in between the charges be zero. Let the position of P be at a distance x from the origin, where the electric field due to both charges cancels each other.



The electric field due to a point charge is given by:

$$E = \frac{kq}{r^2}$$

For the electric field to be zero at point P, the fields due to both charges must be equal and opposite. So:

$$\frac{kq}{x^2} = \frac{k(9q)}{(d-x)^2}$$

Simplifying:

$$\frac{1}{x^2} = \frac{9}{(d-x)^2}$$

Solving for x:

$$d - x = 3x \quad \Rightarrow \quad d = 4x \quad \Rightarrow \quad x = \frac{d}{4}$$

Thus, the coordinate of point P is $\left(\frac{d}{4}, 0, 0\right)$.

Quick Tip

In problems involving multiple charges, use the principle of superposition for electric fields and set the total field equal to zero to find the point of cancellation.

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33. The battery of a mobile phone is rated as 4.2 V, 5800 mAh. How much energy is stored in it when fully charged?

(1) 43.8 kJ (2) 48.7 kJ (3) 87.7 kJ (4) 24.4 kJ

Correct Answer: (3) 87.7 kJ

Solution:

Given the voltage $V = 4.2$ volts and the battery capacity 5800 mAh, we can calculate the energy stored in the battery using the formula:

$$\text{Energy supplied by battery} = Vq$$

where q is the charge in coulombs. Converting 5800 mAh to coulombs:

$$q = 5800 \times 3600 \times 10^{-3}\,\text{C} = 5800 \times 3.6\,\text{C} = 20880\,\text{C}$$

Thus, the energy supplied by the battery is:

$$\text{Energy} = 4.2 \times 5800 \times 3600 \times 10^{-3} = 87.696\,\text{kJ}$$

Therefore, the energy stored in the battery when fully charged is approximately 87.7 kJ.

Quick Tip

To calculate energy stored in a battery, use the formula $E = Vq$, where V is the voltage and q is the charge in coulombs.

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34. A particle is subjected to simple harmonic motions as:
$x_1 = \sqrt{7}\sin 5t$ cm $\qquad x_2 = 2\sqrt{7}\sin\left(5t + \frac{\pi}{3}\right)$ cm

where x is displacement and t is time in seconds.
The maximum acceleration of the particle is $x \times 10^{-2}$ m/s^2. The value of x is:

(1) 175 (2) 25 $\sqrt{7}$ (3) $5\sqrt{7}$ (4) 125

Correct Answer: (1) 175

Solution:

Given:
$x_1 = \sqrt{7}\sin 5t, \quad x_2 = 2\sqrt{7}\sin\left(5t + \frac{\pi}{3}\right)$

From phasor, the displacement is represented as:

$$\sqrt{7} \quad \text{and} \quad 2\sqrt{7} \quad \text{with angle } 60^\circ$$

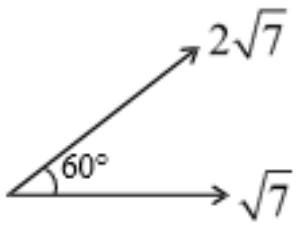
$$\text{Amplitude of resultant SHM} = 7$$

$$\phi = \tan^{-1}\left(\frac{2\sqrt{7} \times \frac{\sqrt{3}}{2}}{\sqrt{7} + 2\sqrt{7} \times \frac{1}{2}}\right) = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right) = \tan^{-1}\left(\sqrt{3}\right)$$

$$X_R = 7\sin(5t + \phi)$$

$$a_R = 7 \times 25\sin(5t + \phi)$$

$$a_{\max} = 175\,\text{cm/sec} = 175 \times 10^{-2}\,\text{m/sec}$$



Quick Tip

In problems involving the superposition of simple harmonic motions, phasor addition simplifies the calculation of resultant amplitude and phase.

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35. The relationship between the magnetic susceptibility χ and the magnetic permeability μ is given by:
μ_0 is the permeability of free space and μ_r is relative permeability.

(1) $\chi = \frac{\mu}{\mu_0} - 1$ (2) $\chi = \frac{\mu+1}{\mu_0}$ (3) $\chi = \mu_r + 1$ (4) $\chi = 1 - \frac{\mu}{\mu_0}$

Correct Answer: (1) $\chi = \frac{\mu}{\mu_0} - 1$

Solution:

We have:

$$\mu_r = (1 + \chi) \quad \text{so} \quad \chi = (\mu_r - 1)$$

Also,

$$\mu = \mu_0 \mu_r \quad \Rightarrow \quad \mu_r = \frac{\mu}{\mu_0}$$

Thus,

$$\chi = \frac{\mu}{\mu_0} - 1$$

Quick Tip

In problems involving magnetic susceptibility, remember that the relative permeability μ_r is directly related to χ, and permeability μ is proportional to $\mu_0 \times \mu_r$.

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36. A zener diode with 5V zener voltage is used to regulate an unregulated dc voltage input of 25V. For a 400 Ω resistor connected in series, the zener current is found to be 4 times load current. The load current I_L and load resistance R_L are:

(1) $I_L = 20\,\text{mA};\ R_L = 250\,\Omega$ (2) $I_L = 10\,\text{A};\ R_L = 0.5\,\Omega$ (3) $I_L = 0.02\,\text{mA};\ R_L = 250\,\Omega$ (4) $I_L = 10\,\text{mA};\ R_L = 500\,\Omega$

Correct Answer: (4) $I_L = 10\,\text{mA};\ R_L = 500\,\Omega$

Solution:

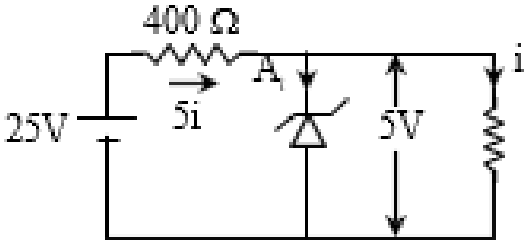
From the circuit diagram, we have the following:

$$i = \frac{20}{400}\,\text{A} = 10\,\text{mA} \quad \text{(Load current } I_L\text{)}$$

$$V_L = 5V \quad \text{(Zener voltage)}$$

Also,

$$R_L = \frac{V_L}{i} = \frac{5}{10 \times 10^{-3}} = 500\,\Omega$$



Quick Tip

In zener diode circuits, the load current and load resistance can be found by using Ohm's law and the given zener voltage.

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37. In an adiabatic process, which of the following statements is true?

(1) The molar heat capacity is infinite (2) Work done by the gas equals the increase in internal energy
(3) The molar heat capacity is zero (4) The internal energy of the gas decreases as the temperature increases

Correct Answer: (3) The molar heat capacity is zero

Solution:

For an adiabatic process, $dQ = 0$.

Thus, the molar heat capacity is zero:

$$dQ = 0 \Rightarrow dU = -dW$$

Also,

$$dU = \frac{f}{2} nRdT$$

Thus, the correct option is:

Only option (3) is correct.

Quick Tip

In an adiabatic process, the system is thermally isolated, so there is no heat transfer. This implies that the change in internal energy is equal to the work done by the system.

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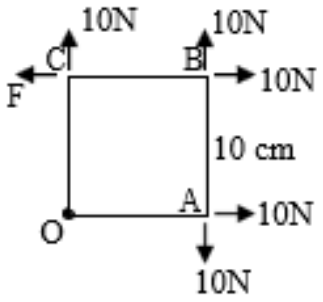
38. A square Lamina OABC of length 10 cm is pivoted at O. Forces act at Lamina as shown in figure. If Lamina remains stationary, then the magnitude of F is:



(1) 20 N (2) 0 (zero) (3) 10 N (4) $10\sqrt{2}$ N

Correct Answer: (3) 10 N

Solution:

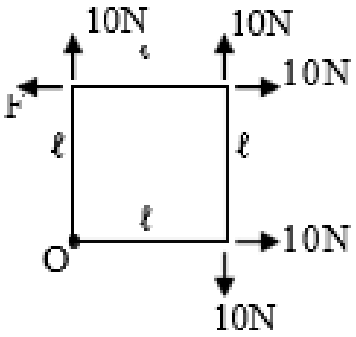
Since the lamina is in equilibrium, the net force and net torque must be zero. Thus:

$$F_{\text{net}} = 0 \quad \text{and} \quad T_{\text{net}} = 0$$

The torque due to force F at point O is given by the equation:

$$T = 10 \cdot 10 - F \cdot \ell = 0$$

Thus, $F = 10$ N.



Quick Tip

In problems involving torque, the point of rotation is essential. The sum of torques about any point in equilibrium is zero.

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39. Let B_1 be the magnitude of magnetic field at the center of a circular coil of radius R carrying current I. Let B_2 be the magnitude of magnetic field at an axial distance x from the center. For $x : R = 3 : 4$, $\frac{B_2}{B_1}$ is:

(1) 4 : 5 (2) 16 : 25 (3) 64 : 125 (4) 25 : 16

Correct Answer: (3) 64 : 125

Solution:

The magnetic field at the center of a circular coil is given by:

$$B_1 = \frac{\mu_0 I}{2R}$$

The magnetic field at an axial distance x from the center is given by:

$$B_2 = B_1 \sin\theta = \frac{B_1 \cdot \left(\frac{R}{x}\right)^2}{5}$$

Substituting $x : R = 3 : 4$, we get:

$$\frac{B_2}{B_1} = \frac{64}{125}$$

Quick Tip

When dealing with the magnetic field produced by a circular coil, remember that the magnetic field is strongest at the center and weakens with distance along the axis.

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40. Considering Bohr's atomic model for hydrogen atom :

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

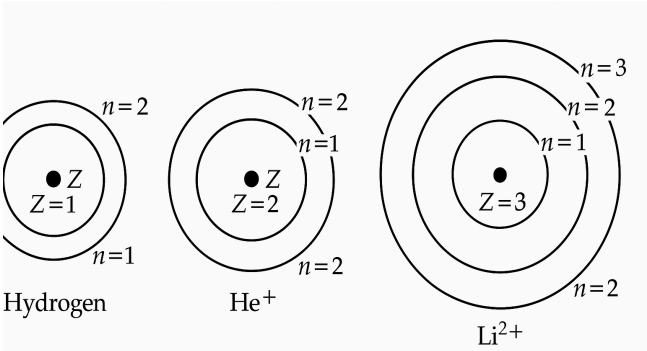
Correct Answer: (2) (A), (B) only

Solution:

The energy of an electron in a specific orbit is given by:

$$E \propto \frac{Z}{n^2}$$

For hydrogen atom, $Z_H = 1$, for He^+, $Z_{He^+} = 2$, and for Li^2+, $Z_{Li^{2+}} = 3$.
1st excited state $n = 2$ and 2nd excited state $n = 3$.
From the given statements, only (A) and (B) are correct.



Considering Bohr's atomic model for hydrogen

Quick Tip

In Bohr's atomic model, the energy levels depend on the atomic number Z and the principal quantum number n. For ions like He^+ and Li^2+, the energy will differ due to their increased nuclear charge.

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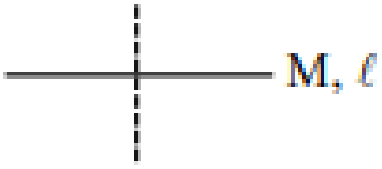
41. Moment of inertia of a rod of mass M and length L about an axis passing through its center and normal to its length is α. Now the rod is cut into two equal parts and these parts are joined symmetrically to form a cross shape. Moment of inertia of cross about an axis passing through its center and normal to the plane containing cross is:

(1) α (2) $\frac{\alpha}{4}$ (3) $\frac{\alpha}{8}$ (4) $\frac{\alpha}{2}$

Correct Answer: (2) $\frac{\alpha}{4}$

Solution:

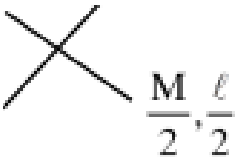
Let the moment of inertia of the rod about the axis passing through its center and normal to its length be $\alpha = \frac{ML^2}{12}$, where M is the mass and L is the length.



Now, the rod is cut into two equal parts, each having mass $\frac{M}{2}$ and length $\frac{L}{2}$. Each part has a moment of inertia α'.
For the cross shape, the total moment of inertia will be the sum of the moments of inertia of the two parts, considering the distance from the center of the rod. After using the parallel axis theorem, we get:

$$\alpha' = 2 \times \frac{ML^2}{48} = \frac{\alpha}{4}$$

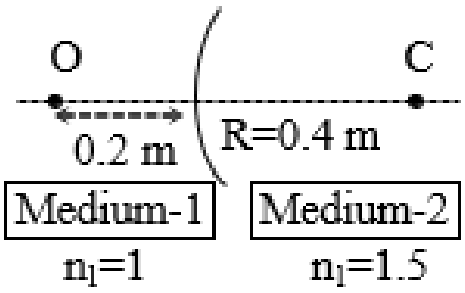
Thus, the correct option is $\frac{\alpha}{4}$.



Quick Tip

To calculate the moment of inertia of composite shapes, use the parallel axis theorem and add the individual moments of inertia.

42.



A spherical surface separates two media of refractive indices $n_1 = 1$ and $n_2 = 1.5$ as shown in the figure. Distance of the image of an object O, if C is the center of curvature of the spherical surface and R is the radius of curvature, is:

(1) 0.24 m right to the spherical surface (2) 0.24 m left to the spherical surface
(3) 0.24 m left to the spherical surface (4) 0.4 m right to the spherical surface

Correct Answer: (2) 0.24 m left to the spherical surface

Solution:

Using the lens formula:

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

Substitute the values:

$$\frac{1.5}{v} - \frac{1}{-0.2} = \frac{1.5 - 1}{0.4}$$

Simplifying:

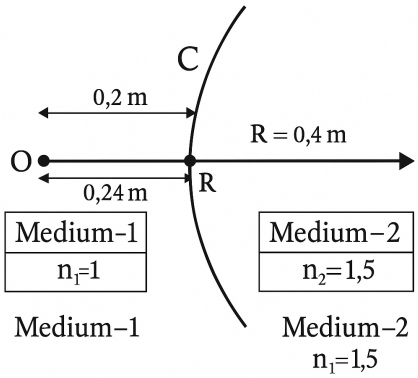
$$\frac{1.5}{v} + 5 = \frac{0.5}{0.4} = 1.25$$

Solving for v:

$$\frac{1.5}{v} = 1.25 - 5 = -3.75$$

$$v = -0.4\,\text{m}$$

Hence, the image is located 0.24 m left to the spherical surface.



Quick Tip

When solving for the position of an image in spherical surfaces, always use the appropriate sign convention for distances and refractive indices.

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43. Match List-I with List-II.

List-I

- (A) Coefficient of viscosity
- (B) Intensity of wave
- (C) Pressure gradient
- (D) Compressibility

List-II

- (I) $[ML^{-1}T^{-1}]$
- (II) $[ML^{-2}T^{-3}]$
- (III) $[ML^{-1}T^{-2}]$
- (IV) $[ML^{-1}T^{-2}]$

(1) (A)–(I), (B)–(IV), (C)–(III), (D)–(I)
(2) (A)–(I), (B)–(III), (C)–(II), (D)–(I)
(3) (A)–(IV), (B)–(II), (C)–(III), (D)–(I)
(4) (A)–(IV), (B)–(I), (C)–(II), (D)–(III)

Correct Answer: (2) (A)–(I), (B)–(III), (C)–(II), (D)–(I)

Solution:

(A) Coefficient of viscosity $[n] = [ML^{-1}T^{-1}]$
(B) Intensity $[I] = [ML^{1}T^{-3}]$
(C) Pressure gradient $[K] = [ML^{-1}T^{-2}]$
(D) Compressibility $[K] = [ML^{-1}T^{-2}]$

Quick Tip

In dimensional analysis, the dimensions of physical quantities are crucial for understanding their relationships. Pay attention to how exponents are used to represent various physical properties.

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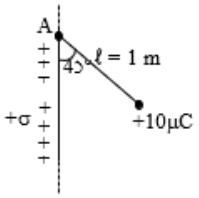
44. A small bob of mass 100 mg and charge +10 μC is connected to an insulating string of length 1 m. It is brought near to an infinitely long non-conducting sheet of charge density σ as shown in figure. If the string subtends an angle of 45° with the sheet at equilibrium, the charge density of sheet will be :

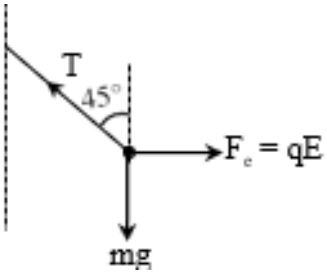


(1) 0.885 nC/cm^2 (2) 17.7 nC/cm^2 (3) 885 nC/cm^2 (4) 1.77 nC/cm^2

Correct Answer: (4) 1.77 nC/cm^2

Solution:

From the diagram in the solution, we have the force acting on the charge due to the electric field of the sheet:



The force is given by:

$$F_e = qE = mg$$

where q is the charge and E is the electric field due to the sheet. The electric field is related to the charge density σ as:

$$E = \frac{\sigma}{2\epsilon_0}$$

Thus, the equation becomes:

$$q\left(\frac{\sigma}{2\epsilon_0}\right) = mg$$

Rearranging to solve for σ:

$$\sigma = \frac{2gm}{q}$$

Substitute the known values:

$$\sigma = \frac{2 \times 8.85 \times 10^{-12} \times 100 \times 10^{-6} \times 10}{10 \times 10^{-6}}$$

$$\sigma = 17.7 \times 10^{-10} \text{ C/m}^2$$

$$\sigma = 1.77 \text{ nC/cm}^2$$

Thus, the charge density of the sheet is 1.77 nC/cm^2.

Quick Tip

When calculating the charge density from the angle, consider the forces acting on the object and how the electric field interacts with the charge. Use the equilibrium condition to set up the necessary equations.

---

45. A monochromatic light is incident on a metallic plate having work function ϕ. An electron, emitted normally to the plate from a point A with maximum kinetic energy, enters a constant magnetic field, perpendicular to the initial velocity of the electron. The electron passes through a curve and hits back the plate at a point B. The distance between A and B is:

(1) $\sqrt{\frac{2m\left(\frac{hc}{\lambda}-\phi\right)}{eB}}$ (2) $\frac{m\left(\frac{hc}{\lambda}-\phi\right)}{eB}$ (3) $\sqrt{8m\left(\frac{hc}{\lambda}-\phi\right)} \div eB$ (4) $2\frac{m\left(\frac{hc}{\lambda}-\phi\right)}{eB}$

Correct Answer: (3) $\sqrt{8m\left(\frac{hc}{\lambda}-\phi\right)} \div eB$

Solution:

The maximum kinetic energy K_E of the electron is given by:

$$K_E = \frac{hc}{\lambda} - \phi$$

where p is the momentum of the electron, and the relation for momentum is:

$$p = \sqrt{2mK_E} = \sqrt{2m\left(\frac{hc}{\lambda} - \phi\right)}$$

Since the motion is in a magnetic field, the radius of the circular path is:

$$d_{A-B} = 2R = \frac{p}{qB}$$

Thus, the distance between A and B becomes:

$$d_{A-B} = \frac{2}{eB}\sqrt{2m\left(\frac{hc}{\lambda} - \phi\right)} = \frac{\sqrt{8m\left(\frac{hc}{\lambda} - \phi\right)}}{eB}$$

Quick Tip

In problems involving magnetic fields, the radius of the electron's path is related to its momentum and the magnetic field. The formula for the distance is derived by equating the magnetic force to the centripetal force.

Physics

SECTION-B

46. A vessel with square cross-section and height of 6 m is vertically partitioned. A small window of 100 cm^2 with hinged door is fitted at a depth of 3 m in the partition wall. One part of the vessel is filled completely with water and the other side is filled with the liquid having density 1.5×10^3 kg/m^3. What force one needs to apply on the hinged door so that it does not open?

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

Correct Answer: (1) 150 N

Solution:

The force F_{ext} required to prevent the door from opening is given by:

$$F_{\text{ext}} + F_w = F_t$$

where F_w is the force due to water and F_t is the total force on the window.
In equilibrium:

$$F_{\text{ext}} = F_t - F_w$$

Now, F_t is the total force on the window, which is:

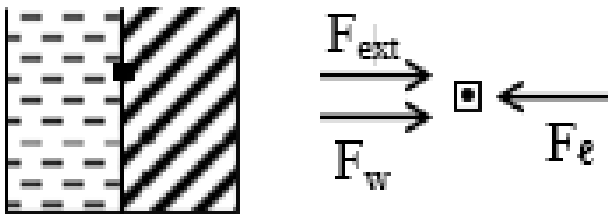
$$F_t = (\rho_1 + \rho_2)ghA$$

and

$$F_w = (\rho_1 + \rho_2)ghA$$

Thus, the force needed:

$$F_{\text{ext}} = (1500 - 1000) \times 10 \times 10^{-4} \times 150$$
$$= 150\,\text{N}$$



in equilibrium

Quick Tip

For problems involving fluid pressure and forces, the total force on an object can be computed by integrating the pressure over the area. Pay attention to the different fluid densities and heights.

---

47. A steel wire of length 2 m and Young's modulus $2.0 \times 10^{11}\,\mathrm{N/m^2}$ is stretched by a force. If Poisson's ratio and transverse strain for the wire are 0.2 and 10^{-3} respectively, then the elastic potential energy density of the wire is $\_\_\_ \times 10^6$ (in SI units).

(1) 15 (2) 25 (3) 35 (4) 45

Correct Answer: (2) 25

Solution:

Given:

$$\ell = 2\,\mathrm{m}, \quad Y = 2 \times 10^{11}\,\mathrm{N/m^2}$$

The elastic potential energy density μ is given by:

$$\mu = \frac{\Delta\varepsilon}{\ell} = \frac{Y\Delta r}{r}$$

where Δr is the elongation.
Now, for transverse strain u, we use the formula:

$$u = \frac{1}{2} \times \text{Poisson's ratio} \times \left(\frac{\Delta\varepsilon}{\ell}\right)$$

Substitute the values to get the energy density:

$$\mu = \frac{5 \times 10^{-3}}{2} \times 2 \times 10^{11} \times \left[5 \times 10^{-3}\right]^2 = 25$$

Thus, the elastic potential energy density is $25 \times 10^6\,\mathrm{N/m^2}$.

Quick Tip

In problems involving Young's modulus and strain, the potential energy density can be calculated using the relationship between the strain and the applied stress, considering Poisson's ratio and the transverse strain.

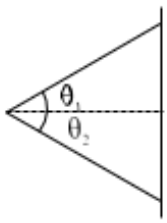
---

48. If the measured angular separation between the second minimum to the left of the central maximum and the third minimum to the right of the central maximum is 30° in a single slit diffraction pattern recorded using 628 nm light, then the width of the slit is μm.

(1) 2 μm (2) 8 μm (3) 6 μm (4) 4 μm

Correct Answer: (3) 6 μm

Solution:



The angular separation for the minima in a single-slit diffraction is given by:

$$\theta_1 = \sin^{-1}\left(\frac{2\lambda}{a}\right), \quad \theta_2 = \sin^{-1}\left(\frac{3\lambda}{a}\right)$$

where $\lambda = 628\,\text{nm}$ is the wavelength and a is the slit width. Also, we know:

$$\theta_1 + \theta_2 = 30^\circ$$

$$\Rightarrow \sin^{-1}\left(\frac{2\lambda}{a}\right) + \sin^{-1}\left(\frac{3\lambda}{a}\right) = \frac{\pi}{6}$$

Solving this, we find:

$$a = 6.07\,\mu m$$

Thus, the width of the slit is $a = 6\,\mu m$.

Quick Tip

In single-slit diffraction, the angular separation between adjacent minima is used to calculate the width of the slit. Ensure that you convert the wavelength to meters and carefully solve for the slit width.

---

49. γ_A is the specific heat ratio of monoatomic gas A having 3 translational degrees of freedom. γ_B is the specific heat ratio of polyatomic gas B having 3 translational, 3 rotational degrees of freedom and 1 vibrational mode. If

$$\frac{\gamma_A}{\gamma_B} = \left(1 + \frac{1}{n}\right)$$

then the value of n is _____.

(1) 1 (2) 2 (3) 3 (4) 4

Correct Answer: (3) 3

Solution:

$$\frac{\gamma_A}{\gamma_B} = \frac{f_A + 2}{f_A} : \text{for monoatomic gas A}$$
$$\frac{\gamma_B}{\gamma_B} = \frac{f_B + 2}{f_B} : \text{for polyatomic gas B}$$

For monoatomic gas A:

$$f_A = 3 \quad \text{(translational degrees of freedom)}$$

For polyatomic gas B:

$$f_B = 3 + 3 + 1 = 7 \quad \text{(translational, rotational, and vibrational modes)}$$

Substituting these values into the formula:

$$\frac{\gamma_A}{\gamma_B} = \frac{3+2}{3} : \frac{7+2}{7} = \frac{5}{3} : \frac{9}{7}$$
$$\frac{5}{3} : \frac{9}{7} = \left(1 + \frac{1}{n}\right)$$
$$\frac{5}{3} \cdot \frac{7}{9} = 1 + \frac{1}{n}$$
$$\frac{35}{27} = 1 + \frac{1}{n}$$
$$\frac{35}{27} - 1 = \frac{1}{n}$$
$$\frac{8}{27} = \frac{1}{n} \Rightarrow n = 3$$

Quick Tip

For problems involving specific heat ratios, break down the equation and substitute values for the translational, rotational, and vibrational degrees of freedom separately. This will help you arrive at the correct value of n.

---

50. A person travelling on a straight line moves with a uniform velocity v_1 for a distance x and with a uniform velocity v_2 for the next $\frac{3x}{2}$ distance. The average velocity in this motion is $\frac{50}{7}$ m/s. If v_1 is 5 m/s, then v_2 is _____ m/s.

(1) 10 m/s (2) 12 m/s (3) 15 m/s (4) 18 m/s

Correct Answer: (10) 10 m/s

Solution:

Given:

$$v_{\text{avg}} = \frac{x_1 + x_2}{t_1 + t_2}$$

Where $x_1 = x$, $x_2 = \frac{3x}{2}$, $v_1 = 5\,\text{m/s}$, and v_2 is the unknown velocity. Substituting the values:

$$v_{\text{avg}} = \frac{50}{7}\,\text{m/s}$$

$$\Rightarrow \frac{50}{7} = \frac{x + \frac{3x}{2}}{\frac{x}{v_1} + \frac{3x}{2v_2}}$$

$$\Rightarrow \frac{50}{7} = \frac{\frac{5x}{2}}{\frac{x}{5} + \frac{3x}{2v_2}}$$

Simplifying the equation:

$$\Rightarrow \frac{50}{7} = \frac{5x}{2} \times \frac{5}{x} \quad \text{(by cross-multiplying)}$$

$$\Rightarrow v_2 = 10\,\text{m/s}$$

Quick Tip

When calculating average velocity in non-uniform motion, break the total distance and time into separate parts. Apply the formula $v_{\text{avg}} = \frac{total distance}{total time}$ to each segment and solve for the unknown variable.
