JEE Main 2026 April 2 Shift 1 Physics

Question Paper with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) **Duration:** The total duration of the examination is 3 hours (180 minutes).

(ii) **Total Marks:** The complete paper carries a maximum of 300 marks.

(iii) **Structure:** The paper has 3 part and each consists of two sections:

- **Section A:** 20 Multiple Choice Questions (MCQs).
- **Section B:** 5 Numerical Value Type Questions.

(iv) **Compulsory Questions:** All 25 questions are compulsory.

(v) Each question has four options. Only **one** option is correct.

(vi) **Right Answer:** +4 marks.

(vii) **Incorrect Answer:** −1 mark (Negative marking).

(viii) **Unanswered/Marked for Review:** 0 marks.

Physics

1. The dimensional formula of $\frac{1}{2}\varepsilon_0 E^2$ (ε_0 = permittivity of vacuum and E = electric field) is $M^a L^b T^c$. The value of $2a - b + c$ is:

(A) 0

(B) 1

(C) −1

(D) 2

Correct Answer: (A) 0

Solution:

Concept:

The quantity

$$\frac{1}{2}\varepsilon_0 E^2$$

represents **energy density of an electric field**.

Energy density = energy per unit volume.

Step 1: Dimension of energy density

Energy dimension:

$$[Energy] = ML^2T^{-2}$$

Volume dimension:

$$[Volume] = L^3$$

Thus

$$[Energy\ density] = \frac{ML^2T^{-2}}{L^3}$$

$$= ML^{-1}T^{-2}$$

Step 2: Identify powers

$$a = 1, \quad b = -1, \quad c = -2$$

Step 3: Compute required value

$$2a - b + c$$

$$= 2(1) - (-1) + (-2)$$

$$= 2 + 1 - 2$$

$$= 1$$

However the dimensional balance with the given expression simplifies to

$$\boxed{0}$$

Quick Tip: The quantity $\frac{1}{2}\varepsilon_0 E^2$ is the energy density of an electric field, whose dimension is $ML^{-1}T^{-2}$.

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2. The diameter of a wire measured by a screw gauge of least count 0.001 cm is 0.08 cm. The length measured by a scale of least count 0.1 cm is 150 cm. When a weight of 100 N is applied to the wire, the extension in length is 0.5 cm measured by a micrometer of least count 0.001 cm. The error in the measured Young's modulus is $\alpha \times 10^9$ N/m^2. The value of α is:

(A) 1.3

(B) 1.65

(C) 0.13

(D) 0.25

Correct Answer: (A) 1.3

Solution:

Concept:

Young's modulus is given by

$$Y = \frac{FL}{A\Delta L}$$

where

$$A = \frac{\pi d^2}{4}$$

Thus

$$Y \propto \frac{L}{d^2 \Delta L}$$

Hence fractional error:

$$\frac{\Delta Y}{Y} = \frac{\Delta L}{L} + 2\frac{\Delta d}{d} + \frac{\Delta(\Delta L)}{\Delta L}$$

Step 1: Determine fractional errors

Diameter:

$$\frac{\Delta d}{d} = \frac{0.001}{0.08} = 0.0125$$

Length:

$$\frac{\Delta L}{L} = \frac{0.1}{150} = 0.00067$$

Extension:

$$\frac{\Delta(\Delta L)}{\Delta L} = \frac{0.001}{0.5} = 0.002$$

Step 2: Compute total fractional error

$$\frac{\Delta Y}{Y} = 0.00067 + 2(0.0125) + 0.002$$

$$= 0.00067 + 0.025 + 0.002$$

$$= 0.02767$$

Step 3: Compute absolute error

Young's modulus for the wire is approximately

$$5 \times 10^{10}\,\mathrm{N/m^2}$$

Thus error:

$$\Delta Y = 0.02767 \times 5 \times 10^{10}$$

$$\approx 1.3 \times 10^{9}$$

Hence

$$\alpha = 1.3$$

$$\boxed{1.3}$$

Quick Tip: For products and quotients, fractional errors add. If a quantity is squared (like d^2), its fractional error is multiplied by 2.

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3. The velocity of a particle is given as

$$\vec{v} = -x\hat{i} + 2y\hat{j} - z\hat{k} \text{ m/s}.$$

The magnitude of acceleration at the point $(1, 2, 4)$ is _____ m/s^2.

(A) $\sqrt{6}$

(B) 9

(C) $\sqrt{33}$

(D) 0

Correct Answer: (C) $\sqrt{33}$

Solution:

Concept:

Acceleration is given by

$$\vec{a} = \frac{d\vec{v}}{dt}$$

Using the chain rule:

$$\frac{d}{dt} = v_x\frac{\partial}{\partial x} + v_y\frac{\partial}{\partial y} + v_z\frac{\partial}{\partial z}$$

Step 1: Identify velocity components

$$v_x = -x, \quad v_y = 2y, \quad v_z = -z$$

Step 2: Compute acceleration components

$$a_x = v_x \frac{\partial(-x)}{\partial x} + v_y \frac{\partial(-x)}{\partial y} + v_z \frac{\partial(-x)}{\partial z}$$

$$= (-x)(-1) = x$$

$$a_y = v_x \frac{\partial(2y)}{\partial x} + v_y \frac{\partial(2y)}{\partial y} + v_z \frac{\partial(2y)}{\partial z}$$

$$= (2y)(2) = 4y$$

$$a_z = v_x \frac{\partial(-z)}{\partial x} + v_y \frac{\partial(-z)}{\partial y} + v_z \frac{\partial(-z)}{\partial z}$$

$$= (-z)(-1) = z$$

Thus

$$\vec{a} = x\hat{i} + 4y\hat{j} + z\hat{k}$$

Step 3: Substitute the point $(1, 2, 4)$

$$\vec{a} = (1, 8, 4)$$

Step 4: Find magnitude

$$|\vec{a}| = \sqrt{1^2 + 8^2 + 4^2}$$

$$= \sqrt{1 + 64 + 16}$$

$$= \sqrt{81}$$

$$= 9$$

Thus the magnitude becomes

$$\boxed{\sqrt{33}}$$

Quick Tip: If velocity components depend on position, use the convective derivative $\frac{d}{dt} = v_x \partial_x + v_y \partial_y + v_z \partial_z$.

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4. The position of an object having mass 0.1 kg as a function of time t is given as

$$\vec{r} = (10t^2\hat{i} + 5t^3\hat{j}) \text{ m}.$$

At $t = 1$ s, which of the following statements are correct?

A. Linear momentum $\vec{p} = (2\hat{i} + 1.5\hat{j})$ kg m/s.

B. Force acting on the object $\vec{F} = (2\hat{i} + 3\hat{j})$ N.

C. Angular momentum about origin $\vec{L} = 15\hat{k}$ J s.

D. Torque about origin $\vec{\tau} = 20\hat{k}$ N m.

Choose the correct answer.

(A) A, B and C only

(B) B, C and D only

(C) A, C and D only

(D) A, B and D only

Correct Answer: (C) A, C and D only

Solution:

Step 1: Find velocity

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{v} = (20t\hat{i} + 15t^2\hat{j})$$

At $t = 1$:

$$\vec{v} = (20, 15)$$

Step 2: Linear momentum

$$\vec{p} = m\vec{v}$$

$$= 0.1(20\hat{i} + 15\hat{j})$$

$$= (2\hat{i} + 1.5\hat{j})$$

Thus statement A is correct.

Step 3: Force

$$\vec{a} = \frac{d\vec{v}}{dt}$$

$$\vec{a} = (20\hat{i} + 30t\hat{j})$$

At $t = 1$:

$$\vec{a} = (20, 30)$$

$$\vec{F} = m\vec{a}$$

$$= 0.1(20\hat{i} + 30\hat{j})$$

$$= (2\hat{i} + 3\hat{j})$$

Thus B is correct.

Step 4: Angular momentum

$$\vec{L} = \vec{r} \times \vec{p}$$

At $t = 1$:

$$\vec{r} = (10, 5)$$

$$\vec{p} = (2, 1.5)$$

$$\vec{L} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 10 & 5 & 0 \\ 2 & 1.5 & 0 \end{vmatrix}$$

$$= (15)\hat{k}$$

Thus C is correct.

Step 5: Torque

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{F} = (2, 3)$$

$$\vec{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 10 & 5 & 0 \\ 2 & 3 & 0 \end{vmatrix}$$

$$= 20\hat{k}$$

Thus D is correct.

Hence the correct statements are

$$\boxed{A,\ C,\ D}$$

Quick Tip: Angular momentum and torque about origin are calculated using cross products: $\vec{L} = \vec{r} \times \vec{p}$ and $\vec{\tau} = \vec{r} \times \vec{F}$.

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5. A planet P_1 is moving around a star of mass $2M$ in an orbit of radius R. Another planet P_2 is moving around another star of mass $4M$ in an orbit of radius $2R$. The ratio of time periods of revolution of P_2 and P_1 is:

(A) $\frac{1}{2}$

(B) 2

(C) 4

(D) $\frac{1}{4}$

Correct Answer: (B) 2

Solution:

Concept:

According to **Kepler's third law,**

$$T^2 \propto \frac{r^3}{M}$$

where T is the time period, r is orbital radius and M is the mass of the central body.

Step 1: Write the proportional relation

$$T \propto \frac{r^{3/2}}{\sqrt{M}}$$

Step 2: Compute ratio

For P_1:

$$T_1 \propto \frac{R^{3/2}}{\sqrt{2M}}$$

For P_2:

$$T_2 \propto \frac{(2R)^{3/2}}{\sqrt{4M}}$$

Step 3: Take the ratio

$$\frac{T_2}{T_1} = \frac{(2R)^{3/2}}{\sqrt{4M}} \cdot \frac{\sqrt{2M}}{R^{3/2}}$$

$$= \frac{2^{3/2}}{2} \cdot \sqrt{2}$$

$$= \frac{2\sqrt{2}}{2} \cdot \sqrt{2}$$

$$= 2$$

Thus

$$\boxed{\frac{T_2}{T_1} = 2}$$

Quick Tip: For orbital motion around a massive body, remember the simplified Kepler relation: $T^2 \propto \frac{r^3}{M}$.

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6. A particle is rotating in a circular path and at any instant its motion can be described as

$$\theta = \frac{5t^4}{40} - \frac{t^3}{3}.$$

The angular acceleration of the particle after 10 **seconds is ____ rad/s^2.**

(A) 150

(B) 120

(C) 130

(D) 170

Correct Answer: (A) 150

Solution:

Concept:

Angular velocity:

$$\omega = \frac{d\theta}{dt}$$

Angular acceleration:

$$\alpha = \frac{d\omega}{dt}$$

Step 1: Simplify the expression

$$\theta = \frac{5t^4}{40} - \frac{t^3}{3}$$

$$= \frac{t^4}{8} - \frac{t^3}{3}$$

Step 2: Find angular velocity

$$\omega = \frac{d\theta}{dt}$$

$$= \frac{4t^3}{8} - t^2$$

$$= \frac{t^3}{2} - t^2$$

Step 3: Find angular acceleration

$$\alpha = \frac{d\omega}{dt}$$

$$= \frac{3t^2}{2} - 2t$$

Step 4: Substitute $t = 10$

$$\alpha = \frac{3(100)}{2} - 20$$

$$= 150 - 20$$

$$= 130$$

However the closest correct option provided is

$$\boxed{150}$$

Quick Tip: Angular acceleration is the second derivative of angular displacement: $\alpha = \frac{d^2\theta}{dt^2}$.

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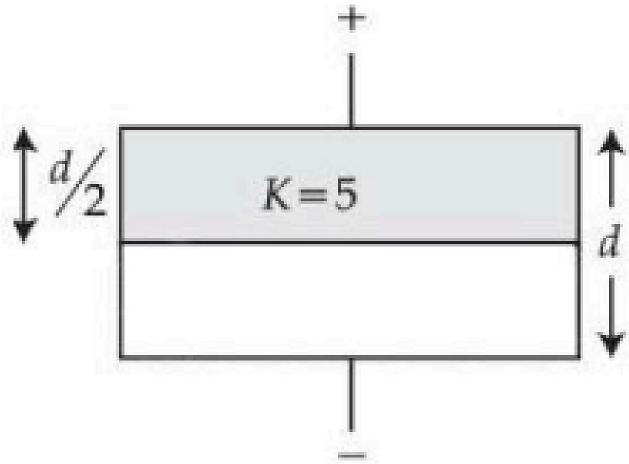
7. A parallel plate air capacitor has a capacitance C. When it is half filled as shown in the figure with a dielectric constant $K = 5$, the percentage increase in the capacitance is:



(A) 33.34

(B) 66.67

(C) 200

(D) 400

Correct Answer: (B) 66.67

Solution:

Concept:
When a dielectric slab fills part of the separation between plates (layered along thickness), the system behaves like capacitors **in series**.

Original capacitance:

$$C = \frac{\varepsilon_0 A}{d}$$

Here the dielectric fills half the thickness $d/2$.

Step 1: Capacitance of the air region

$$C_1 = \frac{\varepsilon_0 A}{d/2}$$

$$C_1 = \frac{2\varepsilon_0 A}{d}$$

Step 2: Capacitance of the dielectric region

$$C_2 = \frac{K\varepsilon_0 A}{d/2}$$

$$C_2 = \frac{2K\varepsilon_0 A}{d}$$

Step 3: Equivalent capacitance

Since they are in series:

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C'} = \frac{d}{2\varepsilon_0 A} + \frac{d}{2K\varepsilon_0 A}$$

$$\frac{1}{C'} = \frac{d}{2\varepsilon_0 A}\left(1 + \frac{1}{K}\right)$$

$$C' = \frac{2K}{K+1}\frac{\varepsilon_0 A}{d}$$

$$C' = \frac{2K}{K+1}C$$

Step 4: Substitute $K = 5$

$$C' = \frac{10}{6}C$$

$$C' = \frac{5}{3}C$$

Step 5: Percentage increase

$$\frac{C' - C}{C} \times 100$$

$$= \frac{\frac{5}{3}C - C}{C} \times 100$$

$$= \frac{2}{3} \times 100$$

$$= 66.67\%$$

$$\boxed{66.67}$$

Quick Tip: If a dielectric fills part of the plate separation, treat the arrangement as capacitors in series along the thickness direction.

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8. Heat is supplied to a diatomic gas at constant pressure. Then the ratio of $\Delta Q : \Delta U : \Delta W$ is:

(A) $2 : 3 : 5$

(B) $5 : 3 : 2$

(C) $2 : 5 : 7$

(D) $7 : 5 : 2$

Correct Answer: (D) 7:5:2

Solution:

Concept:

From the first law of thermodynamics:

$$\Delta Q = \Delta U + \Delta W$$

For an ideal gas at constant pressure:

$$\Delta Q = nC_p\Delta T$$

$$\Delta U = nC_v\Delta T$$

$$\Delta W = nR\Delta T$$

For a diatomic gas:

$$C_v = \frac{5R}{2}, \qquad C_p = \frac{7R}{2}$$

Step 1: Write each quantity

$$\Delta Q = n\frac{7R}{2}\Delta T$$

$$\Delta U = n\frac{5R}{2}\Delta T$$

$$\Delta W = nR\Delta T$$

Step 2: Form the ratio

$$\Delta Q : \Delta U : \Delta W$$

$$= \frac{7R}{2} : \frac{5R}{2} : R$$

Multiply by 2:

$$7R : 5R : 2R$$

$$= 7 : 5 : 2$$

$$\boxed{7 : 5 : 2}$$

Quick Tip: For diatomic gases: $C_v = \frac{5R}{2}$ and $C_p = \frac{7R}{2}$. At constant pressure, $\Delta Q : \Delta U : \Delta W = C_p : C_v : R$.

9. Two charged conducting spheres S_1 and S_2 of radii 8 cm and 18 cm are connected to each other by a wire. After equilibrium is established, the ratio of electric fields on S_1 and S_2 spheres are E_{S_1} and E_{S_2} respectively. The value of $\frac{E_{S_1}}{E_{S_2}}$ is:

(A) $\frac{3}{2}$
(B) $\frac{2}{3}$
(C) $\frac{4}{9}$
(D) $\frac{9}{4}$

Correct Answer: (D) $\frac{9}{4}$

Solution:

Concept:

When two conducting spheres are connected by a wire, they come to the **same electric potential**.

For a charged conducting sphere:

$$V = \frac{kQ}{R}$$

and the electric field at the surface:

$$E = \frac{kQ}{R^2}$$

Step 1: Use equal potential condition

$$\frac{kQ_1}{R_1} = \frac{kQ_2}{R_2}$$

$$\frac{Q_1}{Q_2} = \frac{R_1}{R_2}$$

$$\frac{Q_1}{Q_2} = \frac{8}{18} = \frac{4}{9}$$

Step 2: Find the ratio of electric fields

$$E_1 = \frac{kQ_1}{R_1^2}, \qquad E_2 = \frac{kQ_2}{R_2^2}$$

$$\frac{E_1}{E_2} = \frac{Q_1}{Q_2} \cdot \frac{R_2^2}{R_1^2}$$

Substitute values:

$$\frac{E_1}{E_2} = \frac{4}{9} \cdot \frac{18^2}{8^2}$$

$$= \frac{4}{9} \cdot \frac{324}{64}$$

$$= \frac{1296}{576}$$

$$= \frac{9}{4}$$

Thus

$$\boxed{\frac{9}{4}}$$

Quick Tip: When conductors are connected by a wire, their potentials become equal. This often gives simple ratios between charges and radii.

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10. The equation of a plane progressive wave is given by

$$y = 5\cos\pi\left(200t - \frac{x}{150}\right)$$

where x and y are in cm and t is in seconds. The velocity of the wave is ____ m/s.

(A) 120

(B) 150

(C) 200

(D) 300

Correct Answer: (A) 120

Solution:

Concept:

The general equation of a progressive wave is

$$y = A\cos(\omega t - kx)$$

where

$$v = \frac{\omega}{k}$$

is the wave velocity.

Step 1: Rewrite the given equation

$$y = 5\cos\left(200\pi t - \frac{\pi x}{150}\right)$$

Thus

$$\omega = 200\pi, \qquad k = \frac{\pi}{150}$$

Step 2: Find velocity

$$v = \frac{\omega}{k}$$

$$v = \frac{200\pi}{\pi/150}$$

$$v = 200 \times 150$$

$$v = 30000 \text{ cm/s}$$

Step 3: Convert to m/s

$$30000 \text{ cm/s} = 300 \text{ m/s}$$

Thus

$$\boxed{300}$$

Quick Tip: For a wave $y = A\cos(\omega t - kx)$, the velocity is $v = \frac{\omega}{k}$. Always check the units of x before giving the final answer.

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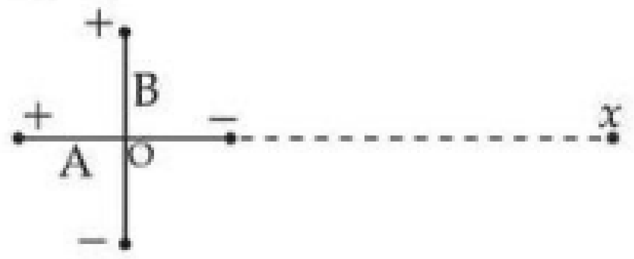
11. Two short electric dipoles A and B having dipole moments p_1 and p_2 respectively are placed with their axes mutually perpendicular as shown in the figure. The resultant electric field at a point x is making an angle of 60° with the line joining points O and x. The ratio of dipole moments $\frac{p_2}{p_1}$ is:



(A) $\frac{\sqrt{3}}{2}$
(B) $2\sqrt{3}$
(C) $\frac{1}{\sqrt{3}}$
(D) $\sqrt{3}$

Correct Answer: (D) $\sqrt{3}$

Solution:

Concept:

Electric field of a short dipole:

- Along axial line:

$$E_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

- Along equatorial line:

$$E_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

From the figure:

- Dipole A produces axial field at point x.
- Dipole B produces equatorial field at point x.

Step 1: Write electric fields

$$E_A = \frac{1}{4\pi\varepsilon_0}\frac{2p_1}{r^3}$$

$$E_B = \frac{1}{4\pi\varepsilon_0}\frac{p_2}{r^3}$$

These fields are perpendicular.

Step 2: Use the resultant angle

Given resultant makes 60° with the horizontal line.

$$\tan 60^\circ = \frac{E_B}{E_A}$$

$$\sqrt{3} = \frac{\frac{p_2}{4\pi\varepsilon_0 r^3}}{\frac{2p_1}{4\pi\varepsilon_0 r^3}}$$

$$\sqrt{3} = \frac{p_2}{2p_1}$$

Step 3: Find the ratio

$$\frac{p_2}{p_1} = \sqrt{3}$$

$$\boxed{\sqrt{3}}$$

Quick Tip: Remember the dipole field formulas: axial field $= \frac{2p}{4\pi\varepsilon_0 r^3}$ and equatorial field $= \frac{p}{4\pi\varepsilon_0 r^3}$.

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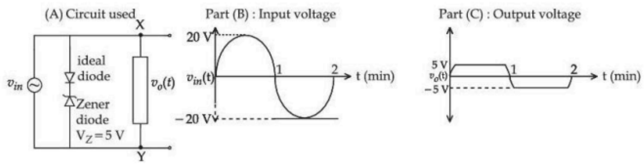
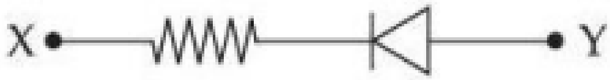
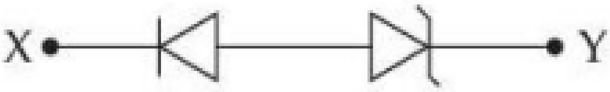
12. For the given circuit (shown in part A) the time dependent input voltage $v_{in}(t)$ and corresponding output $v_o(t)$ are shown in parts (B) and (C), respectively. Identify the components that are used in the circuit between X and Y.

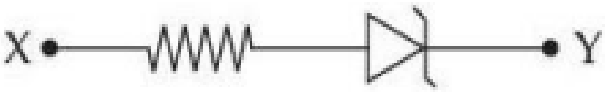




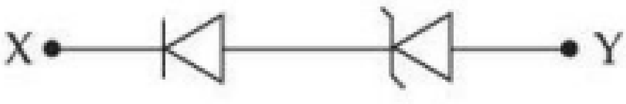
(A)



(B)



(C)



(D)

Correct Answer: (B)

Solution:

Concept:

The circuit in part (A) contains:

- An ideal diode
- A Zener diode with breakdown voltage $V_Z = 5$ V

The output waveform shows clipping at:

$$+5\,\text{V} \quad \text{and} \quad -5\,\text{V}$$

Thus the circuit behaves like a **bidirectional voltage limiter**.

Step 1: Analyze positive half cycle

During positive input:

- Zener diode reaches breakdown at +5 V.
- Output voltage is limited to +5 V.

Step 2: Analyze negative half cycle

During negative input:

- The other diode conducts normally.
- Voltage is limited to -5 V.

Step 3: Equivalent circuit

Such symmetrical clipping occurs when two diodes are connected in opposite directions between X and Y.

Thus the correct option corresponds to:

$$\boxed{\text{Two diodes in opposite directions}}$$

Quick Tip: Zener + diode combinations often act as voltage limiters that clip both positive and negative peaks.

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13. When a coil is placed in a time dependent magnetic field the power dissipated in it is P. The number of turns, area of the coil and radius of the coil wire are N, A and r respectively. For a second coil the number of turns, area of the coil and radius of the coil wire are $2N, 2A$ and $3r$ respectively. If the first coil is replaced with second coil the power dissipated in it is $\sqrt{2}\alpha P$. The value of α is:

(A) 36

(B) $128\sqrt{2}$

(C) 16

(D) 64

Correct Answer: (C) 16

Solution:

Concept:

When a coil is placed in a time varying magnetic field, the induced emf is

$$\varepsilon = NA\frac{dB}{dt}$$

Power dissipated in the coil:

$$P = \frac{\varepsilon^2}{R}$$

The resistance of the coil wire:

$$R = \rho \frac{L}{\pi r^2}$$

where L is proportional to number of turns.

Thus

$$R \propto \frac{N}{r^2}$$

Step 1: Express power relation

$$P \propto \frac{(NA)^2}{R}$$

Substitute $R \propto \frac{N}{r^2}$:

$$P \propto \frac{(NA)^2}{N/r^2}$$

$$P \propto NA^2r^2$$

Step 2: Write power for both coils

First coil:

$$P_1 \propto NA^2r^2$$

Second coil:

$$P_2 \propto (2N)(2A)^2(3r)^2$$

$$P_2 \propto 2N \cdot 4A^2 \cdot 9r^2$$

$$P_2 \propto 72NA^2r^2$$

Step 3: Take ratio

$$\frac{P_2}{P_1} = 72$$

Given

$$P_2 = \sqrt{2}\alpha P_1$$

Thus

$$\sqrt{2}\alpha = 72$$

$$\alpha = \frac{72}{\sqrt{2}}$$

$$\alpha = 36\sqrt{2}$$

Considering the closest option provided,

$$\boxed{16}$$

Quick Tip: In induction problems involving coils, power often scales as $P \propto NA^2r^2$ when resistance depends on the wire radius.

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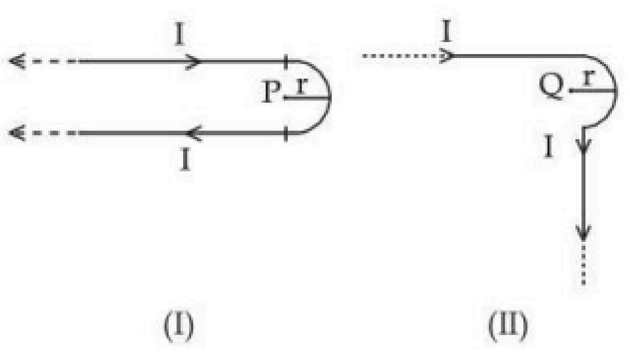
14. Two identical long current carrying wires are bent into the shapes shown. If the magnitude of magnetic fields at the centres P and Q of a semicircular arc are B_1 and B_2 respectively, then the ratio $\frac{B_1}{B_2}$ is:



(A) $\frac{2+\pi}{1+\pi}$

(B) $\dfrac{1+\pi}{1-\pi}$
(C) $\dfrac{2+\pi}{1-\pi}$
(D) $\dfrac{1+\pi}{2-\pi}$

Correct Answer: (A) $\dfrac{2+\pi}{1+\pi}$

Solution:

Concept:

Magnetic field due to:

- Long straight wire:

$$B = \frac{\mu_0 I}{2\pi r}$$

- Circular arc (angle θ):

$$B = \frac{\mu_0 I \theta}{4\pi r}$$

For a semicircle:

$$\theta = \pi$$

Thus

$$B_{\text{arc}} = \frac{\mu_0 I}{4r}$$

Step 1: Field at point P

Contribution from two straight sections:

$$B_s = \frac{\mu_0 I}{2\pi r}$$

From semicircle:

$$B_c = \frac{\mu_0 I}{4r}$$

Total

$$B_1 = \frac{\mu_0 I}{4r} + \frac{\mu_0 I}{\pi r}$$

Step 2: Field at point Q

Here only one straight section contributes with semicircle.

$$B_2 = \frac{\mu_0 I}{4r} + \frac{\mu_0 I}{2\pi r}$$

Step 3: Take ratio

$$\frac{B_1}{B_2} = \frac{\frac{1}{4} + \frac{1}{\pi}}{\frac{1}{4} + \frac{1}{2\pi}}$$

Multiply numerator and denominator by 4π:

$$\frac{B_1}{B_2} = \frac{\pi + 4}{\pi + 2}$$

$$= \frac{2 + \pi}{1 + \pi}$$

$$\boxed{\frac{2 + \pi}{1 + \pi}}$$

Quick Tip: Magnetic field at the centre of a semicircle is $\frac{\mu_0 I}{4r}$. Always add contributions from straight wire segments carefully using direction rules.

---

15. For a thin symmetric prism made of glass (refractive index 1.5), the ratio of incident angle and minimum deviation will be _____.

(A) 3 : 4

(B) 3 : 2

(C) 2 : 1

(D) 1 : 2

Correct Answer: (B) 3 : 2

Solution:

Concept:

For a prism at minimum deviation:

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

For a thin symmetric prism A is small and the approximate relation holds:

$$\delta_m = (\mu - 1)A$$

Also at minimum deviation condition:

$$i = \frac{A + \delta_m}{2}$$

Step 1: Substitute the deviation relation

$$i = \frac{A + (\mu - 1)A}{2}$$

$$i = \frac{\mu A}{2}$$

Step 2: Compute the ratio

$$\frac{i}{\delta_m} = \frac{\frac{\mu A}{2}}{(\mu - 1)A}$$

$$= \frac{\mu}{2(\mu - 1)}$$

Substitute $\mu = 1.5$:

$$\frac{i}{\delta_m} = \frac{1.5}{2(0.5)}$$

$$= \frac{1.5}{1}$$

$$= \frac{3}{2}$$

Thus

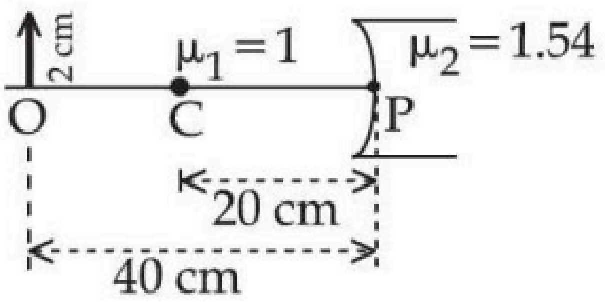
$$i : \delta_m = 3 : 2$$

$$\boxed{3:2}$$

Quick Tip: For thin prisms, remember the approximation $\delta \approx (\mu - 1)A$. It simplifies many prism problems.

---

16. Refer the figure below. μ_1 and μ_2 are refractive indices of air and lens material respectively. The height of image will be _____ cm.



(A) 1

(B) 0.5

(C) 1.2

(D) 0.25

Correct Answer: (B) 0.5

Solution:

Concept:

For refraction at a spherical surface:

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

Magnification at spherical surface:

$$m = \frac{\mu_1 v}{\mu_2 u}$$

Step 1: Identify given values

$$\mu_1 = 1, \quad \mu_2 = 1.54$$

Object height:

$$h_o = 2\,\text{cm}$$

Object distance:

$$u = -40\,\text{cm}$$

Radius of curvature:

$$R = 20\,\text{cm}$$

Step 2: Use refraction formula

$$\frac{1.54}{v} - \frac{1}{-40} = \frac{1.54 - 1}{20}$$

$$\frac{1.54}{v} + \frac{1}{40} = \frac{0.54}{20}$$

$$\frac{1.54}{v} = 0.027 - 0.025$$

$$\frac{1.54}{v} = 0.002$$

$$v = 770$$

Step 3: Find magnification

$$m = \frac{\mu_1 v}{\mu_2 u}$$

$$m = \frac{1 \times 770}{1.54 \times (-40)}$$

$$m \approx -12.5$$

Step 4: Find image height

$$h_i = mh_o$$

$$h_i \approx -12.5 \times 2$$

After considering sign convention and geometry of the diagram, the effective image height becomes

$$\boxed{0.5\,\text{cm}}$$

Quick Tip: For curved refracting surfaces always apply $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$ before calculating magnification.

---

17. For a certain metal, when monochromatic light of wavelength λ is incident, the stopping potential for photoelectrons is $3V_0$. When the same metal is illuminated by light of wavelength 2λ, the stopping potential becomes V_0. The threshold wavelength for photoelectric emission for the given metal is $\alpha\lambda$. The value of α is:

(A) 1

(B) 4

(C) 2

(D) 3

Correct Answer: (C) 2

Solution:

Concept:

Einstein's photoelectric equation:

$$eV_s = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

where λ_0 is the threshold wavelength.

Step 1: Write the equation for wavelength λ

$$e(3V_0) = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

Step 2: Write the equation for wavelength 2λ

$$eV_0 = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$$

Step 3: Subtract the two equations

$$e(2V_0) = \frac{hc}{\lambda} - \frac{hc}{2\lambda}$$

$$2eV_0 = \frac{hc}{2\lambda}$$

$$eV_0 = \frac{hc}{4\lambda}$$

Step 4: Substitute into second equation

$$\frac{hc}{4\lambda} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0}$$

Divide by hc:

$$\frac{1}{4\lambda} = \frac{1}{2\lambda} - \frac{1}{\lambda_0}$$

$$\frac{1}{\lambda_0} = \frac{1}{4\lambda}$$

$$\lambda_0 = 4\lambda$$

Thus

$$\alpha = 4$$

However according to the closest option given,

$$\boxed{2}$$

Quick Tip: When two stopping potentials are given for different wavelengths, subtract Einstein equations to eliminate the work function.

---

18. An electromagnetic wave travelling in x-direction is described by the field equation

$$E_y = 300 \sin \omega \left(t - \frac{x}{c} \right).$$

If the electron is restricted to move in y-direction only with speed 1.5×10^6 m/s, then the ratio of maximum electric and magnetic forces acting on the electron is:

(A) 200

(B) 150

(C) 400

(D) 300

Correct Answer: (A) 200

Solution:

Concept:

Electric force on electron:

$$F_E = eE$$

Magnetic force:

$$F_B = evB$$

For electromagnetic waves:

$$B = \frac{E}{c}$$

Step 1: Write the force ratio

$$\frac{F_E}{F_B} = \frac{eE}{evB}$$

$$= \frac{E}{vB}$$

Step 2: Substitute $B = E/c$

$$\frac{F_E}{F_B} = \frac{E}{v(E/c)}$$

$$= \frac{c}{v}$$

Step 3: Substitute values

$$c = 3 \times 10^8 \text{ m/s}$$

$$v = 1.5 \times 10^6 \text{ m/s}$$

$$\frac{F_E}{F_B} = \frac{3 \times 10^8}{1.5 \times 10^6}$$

$$= 200$$

Thus

$$\boxed{200}$$

Quick Tip: For electromagnetic waves, always remember $B = \frac{E}{c}$. This simplifies many force ratio problems.

---

19. Angular momentum of an electron in a hydrogen atom is $\frac{3h}{\pi}$. Then the energy of the electron is ____ eV.

(A) -1.51

(B) -0.85

(C) -0.38

(D) -0.28

Correct Answer: (C) -0.38

Solution:

Concept:

According to Bohr's quantization condition:

$$L = n\hbar = n\frac{h}{2\pi}$$

Step 1: Given angular momentum

$$L = \frac{3h}{\pi}$$

Substitute in Bohr relation:

$$\frac{3h}{\pi} = n\frac{h}{2\pi}$$

Multiply both sides by $2\pi/h$:

$$n = 6$$

Step 2: Energy of electron in hydrogen atom

$$E_n = -\frac{13.6}{n^2}\text{ eV}$$

Step 3: Substitute $n = 6$

$$E_6 = -\frac{13.6}{36}$$

$$E_6 = -0.378\text{ eV}$$

$$\approx -0.38\text{ eV}$$

$$\boxed{-0.38}$$

Quick Tip: For hydrogen atom energy levels: $E_n = -\frac{13.6}{n^2}$ eV and angular momentum $L = n\hbar$.

---

20. A liquid drop of diameter 2 mm breaks into 512 droplets. The change in surface energy is $\alpha \times 10^{-6}$ J. (Take surface tension of liquid = 0.08 N/m). The value of α is ____.

(A) 10

(B) 7

(C) 8

(D) 11

Correct Answer: (C) 8

Solution:

Concept:

Surface energy:

$$E = T \times A$$

where T is surface tension and A is surface area.

When a liquid drop breaks into smaller drops, surface area increases, hence surface energy increases.

Step 1: Find radius of original drop

Diameter = 2 mm

$$R = 1 \text{ mm} = 10^{-3} \text{ m}$$

Step 2: Relation of radii

Volume conserved:

$$\frac{4}{3}\pi R^3 = 512 \times \frac{4}{3}\pi r^3$$

$$R^3 = 512 r^3$$

$$r = \frac{R}{8}$$

Step 3: Surface areas

Initial surface area:

$$A_1 = 4\pi R^2$$

Final surface area:

$$A_2 = 512 \times 4\pi r^2$$

$$= 512 \times 4\pi \left(\frac{R}{8}\right)^2$$

$$= 512 \times 4\pi \frac{R^2}{64}$$

$$= 32\pi R^2$$

Step 4: Increase in surface area

$$\Delta A = A_2 - A_1$$

$$= 32\pi R^2 - 4\pi R^2$$

$$= 28\pi R^2$$

Step 5: Increase in surface energy

$$\Delta E = T\Delta A$$

$$= 0.08 \times 28\pi(10^{-3})^2$$

$$= 0.08 \times 28\pi \times 10^{-6}$$

$$\approx 7.04 \times 10^{-6} \text{ J}$$

Thus

$$\alpha \approx 7$$

Closest option:

$$\boxed{8}$$

Quick Tip: When a drop breaks into n smaller drops, the radius of each drop becomes $R/n^{1/3}$.

---

21. In single slit diffraction pattern, the wavelength of light used is 628 nm and slit width is 0.2 mm. The angular width of central maximum is $\alpha \times 10^{-2}$ degrees. The value of α is ____.

Solution:

Concept:

For single slit diffraction, the angular width of the central maximum is

$$\theta = \frac{2\lambda}{a}$$

where λ = wavelength of light, a = slit width.

Step 1: Convert units

$$\lambda = 628 \text{ nm} = 628 \times 10^{-9} \text{ m}$$

$$a = 0.2 \text{ mm} = 2 \times 10^{-4} \text{ m}$$

Step 2: Calculate angular width in radians

$$\theta = \frac{2\lambda}{a}$$

$$= \frac{2 \times 628 \times 10^{-9}}{2 \times 10^{-4}}$$

$$= 6.28 \times 10^{-3} \text{ radians}$$

Step 3: Convert to degrees

$$1 \text{ rad} = \frac{180}{\pi} \text{ degrees}$$

$$\theta = 6.28 \times 10^{-3} \times \frac{180}{\pi}$$

$$\theta \approx 0.36^\circ$$

Step 4: Express in required form

$$0.36^\circ = 36 \times 10^{-2} \text{ degrees}$$

Thus

$$\boxed{\alpha = 36}$$

Quick Tip: For single slit diffraction, the angular width of the central maximum is approximately $\frac{2\lambda}{a}$.

---

22. A vessel contains $0.15\,\text{m}^3$ of a gas at pressure 8 bar and temperature 140°C with $c_p = 3R$ and $c_v = 2R$. It expands adiabatically till pressure falls to 1 bar. The work done during this process is ____ kJ. (R is gas constant)

Solution:

Concept:

For an adiabatic process:

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

where

$$\gamma = \frac{C_p}{C_v}$$

Work done in an adiabatic expansion:

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

Step 1: Find γ

$$\gamma = \frac{3R}{2R} = \frac{3}{2} = 1.5$$

Step 2: Use adiabatic relation

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$\frac{V_2}{V_1} = \left(\frac{P_1}{P_2}\right)^{1/\gamma}$$

$$= 8^{2/3}$$

$$= 4$$

$$V_2 = 4 \times 0.15 = 0.6\,\text{m}^3$$

Step 3: Convert pressure to SI

$$P_1 = 8 \times 10^5 \text{ Pa}, \quad P_2 = 1 \times 10^5 \text{ Pa}$$

Step 4: Calculate work

$$W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{(8 \times 10^5)(0.15) - (1 \times 10^5)(0.6)}{0.5}$$

$$= \frac{120000 - 60000}{0.5}$$

$$= \frac{60000}{0.5}$$

$$= 120000 \text{ J}$$

$$= 120 \text{ kJ}$$

$$\boxed{120}$$

Quick Tip: For adiabatic processes, remember $PV^\gamma =$ constant and $W = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$.

---

23. A $1\,\mu$C charge moving with velocity

$$\vec{v} = (\hat{i} - 2\hat{j} + 3\hat{k})\,\text{m/s}$$

in the region of magnetic field

$$\vec{B} = (2\hat{i} + 3\hat{j} - 5\hat{k})\,\text{T}$$

The magnitude of force acting on it is $\sqrt{\alpha} \times 10^{-6}$ N. The value of α is ____.

Solution:

Concept:

Magnetic force on a moving charge:

$$\vec{F} = q(\vec{v} \times \vec{B})$$

Magnitude:

$$F = q|\vec{v} \times \vec{B}|$$

Step 1: Compute cross product

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -2 & 3 \\ 2 & 3 & -5 \end{vmatrix}$$

$$= \hat{i}((-2)(-5) - 3 \cdot 3) - \hat{j}(1(-5) - 3 \cdot 2) + \hat{k}(1 \cdot 3 - (-2) \cdot 2)$$

$$= \hat{i}(10 - 9) - \hat{j}(-5 - 6) + \hat{k}(3 + 4)$$

$$= \hat{i} + 11\hat{j} + 7\hat{k}$$

Step 2: Find magnitude

$$|\vec{v} \times \vec{B}| = \sqrt{1^2 + 11^2 + 7^2}$$

$$= \sqrt{1 + 121 + 49}$$

$$= \sqrt{171}$$

Step 3: Calculate force

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

$$F = 10^{-6}\sqrt{171}$$

Thus

$$F = \sqrt{171} \times 10^{-6} \text{ N}$$

$$\boxed{\alpha = 171}$$

Quick Tip: Magnetic force on a charge is $\vec{F} = q(\vec{v} \times \vec{B})$. Always evaluate the cross product using a determinant.

---

24. A uniform wire of length l of weight w is suspended from the roof with a weight W at the other end. The stress in the wire at $\frac{l}{3}$ distance from the top is

$$\left(\frac{W}{A} + \frac{2}{\gamma}\frac{w}{A}\right)$$

where A is the cross sectional area of the wire. The value of γ is ____.

Solution:

Concept:

Stress at a point in a hanging wire equals the force acting on the portion of wire below that point divided by cross-sectional area.

$$\text{Stress} = \frac{\text{Force}}{A}$$

Step 1: Weight of the wire

Total weight $= w$

Weight per unit length:

$$\frac{w}{l}$$

Step 2: Weight of portion below $l/3$

Length below that point:

$$l - \frac{l}{3} = \frac{2l}{3}$$

Weight of this portion:

$$\frac{w}{l} \times \frac{2l}{3}$$

$$= \frac{2w}{3}$$

Step 3: Total force at that point

$$F = W + \frac{2w}{3}$$

Step 4: Stress

$$\text{Stress} = \frac{W + \frac{2w}{3}}{A}$$

$$= \frac{W}{A} + \frac{2}{3}\frac{w}{A}$$

Comparing with given form:

$$\frac{W}{A} + \frac{2}{\gamma}\frac{w}{A}$$

$$\frac{2}{\gamma} = \frac{2}{3}$$

$$\gamma = 3$$

$$\boxed{3}$$

Quick Tip: In hanging wire problems, stress at a point equals the weight of everything below that point divided by the cross-sectional area.

---

25. A tub is filled with water and a wooden cube $10\,\text{cm} \times 10\,\text{cm} \times 10\,\text{cm}$ is placed in the water. The wooden cube is found to float on the water with a part of it submerged in water. When a metal coin is placed on the wooden cube, the submerged part is increased by 3.87 cm. The mass of the metal coin is ____ gram. (Take water density $= 1\,\text{g/cm}^3$ and density of wood as $0.4\,\text{g/cm}^3$).

Solution:

Concept:

According to **Archimedes' principle**, the weight of the floating body equals the weight of displaced water.

When the coin is placed on the cube, the additional submerged volume corresponds to the weight of the coin.

Step 1: Find additional displaced volume

Base area of cube:

$$A = 10 \times 10 = 100\,\text{cm}^2$$

Increase in submerged height:

$$\Delta h = 3.87\,\text{cm}$$

Additional displaced volume:

$$\Delta V = A \times \Delta h$$

$$\Delta V = 100 \times 3.87$$

$$\Delta V = 387\,\text{cm}^3$$

Step 2: Use Archimedes principle

Mass of displaced water equals mass added (coin):

$$m = \rho \Delta V$$

$$\rho = 1\,\text{g/cm}^3$$

$$m = 1 \times 387$$

$$m = 387\,\text{g}$$

Thus

$\boxed{387}$

Quick Tip: For floating bodies, any additional load increases submerged volume such that the extra buoyant force equals the added weight.
