# JEE Main 2023 1 Feb Shift 1 Physics Question Paper with Solutions

| **Time Allowed :**3 Hours | **Maximum Marks :**300 | **Total Questions :**90 |
|---|---|---|

## General Instructions

**Read the following instructions very carefully and strictly follow them:**

1. The test is of 3 hours duration.
2. The question paper consists of 90 questions, out of which 75 are to attempted. The maximum marks are 300.
3. There are three parts in the question paper consisting of Physics, Chemistry and Mathematics having 30 questions in each part of equal weightage.
4. Each part (subject) has two sections.
   (i) Section-A: This section contains 20 multiple choice questions which have only one correct answer. Each question carries 4 marks for correct answer and –1 mark for wrong answer.
   (ii) Section-B: This section contains 10 questions. In Section-B, attempt any five questions out of 10. The answer to each of the questions is a numerical value. Each question carries 4 marks for correct answer and –1 mark for wrong answer. For Section-B, the answer should be rounded off to the nearest integer

## PHYSICS

### Section-A

**1. Match the List I with List II:**

| List I | List II |
|---|---|
| A. Intrinsic Semiconductor | I. Fermi-level near conduction band |
| B. n-type Semiconductor | II. Fermi-level at middle |
| C. p-type Semiconductor | III. Fermi-level near valence band |
| D. Metals | IV. Fermi-level inside conduction band |

**Choose the correct answer from the options given below:**

(1) (A) $\rightarrow$ I, (B) $\rightarrow$ II, (C) $\rightarrow$ III, (D) $\rightarrow$ IV

(2) (A) $\rightarrow$ II, (B) $\rightarrow$ I, (C) $\rightarrow$ III, (D) $\rightarrow$ IV

(3) (A) $\rightarrow$ II, (B) $\rightarrow$ III, (C) $\rightarrow$ I, (D) $\rightarrow$ IV

(4) (A) $\rightarrow$ III, (B) $\rightarrow$ I, (C) $\rightarrow$ II, (D) $\rightarrow$ IV

**Correct Answer:** (3)

**Solution:**

Based on semiconductor theory, the correct matching is determined by analyzing the Fermi level positions in different types of materials.

**Quick Tip**

Understanding the position of the Fermi level is key to distinguishing different types of semiconductors and metals.

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**2. An object moves with speed $v_1, v_2, v_3$ along a line segment AB, BC, and CD respectively as shown in the figure. Where AB = BC and AD = 3AB, then the average speed of the object will be:**

(1) $\frac{(v_1+v_2+v_3)}{3}$

(2) $\frac{v_1v_2v_3}{3(v_1v_2+v_2v_3+v_3v_1)}$

(3) $\frac{3v_1v_2v_3}{v_1v_2+v_2v_3+v_3v_1}$

(4) $\frac{(v_1+v_2+v_3)}{3v_1v_2v_3}$

**Correct Answer:** (3)

**Solution:**

Given: $AB = x$, $BC = x$, $AD = 3x$

$$\text{Total Distance} = 3x$$

$$\text{Total Time} = \frac{x}{v_1} + \frac{x}{v_2} + \frac{x}{v_3}$$

$$\text{Average Speed} = \frac{3x}{\frac{x}{v_1} + \frac{x}{v_2} + \frac{x}{v_3}} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

**Quick Tip**

For average speed, use the formula:

$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time}}$$

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**3. Given below are two statements:**

**Statement-I:** Acceleration due to gravity is different at different places on the surface of Earth.

**Statement-II:** Acceleration due to gravity increases as we go down below the Earth's surface.

**Choose the correct answer from the options given below:**

(1) Both Statement I and Statement II are true

(2) Both Statement I and Statement II are false

(3) Statement I is true but Statement II is false

(4) Statement I is false but Statement II is true

**Correct Answer:** (3)

**Solution:**

Acceleration due to gravity is given by:

$$g_{\text{eff}} = g - \omega^2 R \sin^2 \theta$$

which depends on latitude.

Inside the Earth, gravity decreases with depth as:

$$g_{\text{eff}} = g\left(1 - \frac{d}{R}\right), \quad d \text{ is depth.}$$

Thus, Statement I is true but Statement II is false.

**Quick Tip**

Gravity varies with altitude, latitude, and depth.

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**4. Match the List I with List II:**

| List I | List II |
|---|---|
| A. AC generator | I. Presence of both L and C |
| B. Transformer | II. Electromagnetic Induction |
| C. Resonance Phenomenon | III. Quality Factor |
| D. Sharpness of Resonance | IV. Mutual Inductance |

**Choose the correct answer from the options given below:**

(1) A-IV, B-II, C-I, D-III

(2) A-II, B-I, C-III, D-IV

(3) A-II, B-IV, C-I, D-III

(4) A-IV, B-III, C-I, D-II

**Correct Answer:** (3)

**Solution:**

Based on fundamental electrical engineering concepts:

- An AC generator operates on Electromagnetic Induction (II).

- A Transformer operates based on Mutual Inductance (IV).

- Resonance phenomenon occurs due to Presence of both L and C (I).

- Sharpness of Resonance is linked to Quality Factor(III).

Quick Tip

For matching questions, analyze core principles and working mechanisms.

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**5. Match the List-I with List-II:**

| List I | List II |
|---|---|
| A. Microwaves | I. Radioactive decay of the nucleus |
| B. Gamma rays | II. Rapid acceleration and deceleration of electrons in aerials |
| C. Radio waves | III. Inner shell electrons |
| D. X-rays | IV. Klystron valve |

**Choose the correct answer from the options given below:**

(1) A-I, B-II, C-III, D-IV

(2) A-IV, B-I, C-II, D-III

(3) A-I, B-III, C-IV, D-II

(4) A-IV, B-III, C-II, D-I

**Correct Answer:** (2)

**Solution:**

Based on electromagnetic wave theory, the correct mapping is determined by the characteristics of each wave type.

Quick Tip

Gamma rays are linked to radioactive decay, whereas microwaves are generated using a Klystron valve.

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**6. If Earth has a mass nine times and radius twice that of a planet P, then**

$$\frac{V_e}{3}\sqrt{x}\ \text{ms}^{-1}$$

**will be the minimum velocity required by a rocket to pull out of the gravitational force of P, where $V_e$ is escape velocity on Earth. The value of $x$ is:**

(1) 2

(2) 3

(3) 18

(4) 1

**Correct Answer:** (1)

**Solution:**

Escape velocity for a planet is given by:

$$V_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

For planet P,

$$V_{\text{escape, P}} = \sqrt{\frac{2G\left(\frac{M}{9}\right)}{\frac{R}{2}}}$$

$$= V_e \frac{\sqrt{2}}{3}, \quad x = 2$$

**Quick Tip**

Escape velocity is directly proportional to the square root of the planet's mass-to-radius ratio.

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**7. 'n' polarizing sheets are arranged such that each makes an angle $45^\circ$ with the preceding sheet. An unpolarized light of intensity $I$ is incident into this arrangement. The output intensity is found to be**

$$\frac{I}{64}.$$

**The value of $n$ will be:**

(1) 3

(2) 6

(3) 5

(4) 4

**Correct Answer:** (2)

**Solution:**

After passing through the first sheet:

$$I_1 = \frac{I}{2}$$

After passing through the second sheet:

$$I_2 = I_1 \cos^2(45^\circ) = \frac{I}{4}$$

After passing through the $n$th sheet:

$$I_n = \frac{I}{2^n} = \frac{I}{64}$$

Solving for $n$,

$$n = 6$$

**Quick Tip**

Malus' Law states that transmitted light intensity through a polarizer is given by $I = I_0 \cos^2\theta$.

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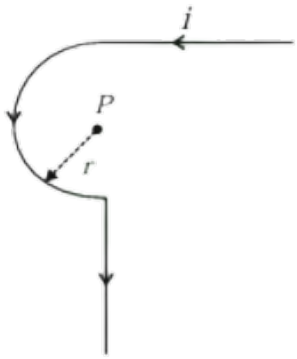
**8. Find the magnetic field at the point P in the figure. The curved portion is a semicircle connected to two long straight wires.**




(1) $\frac{\mu_0 I}{2r}\left(1+\frac{2}{\pi}\right)$
(2) $\frac{\mu_0 I}{2r}\left(1+\frac{1}{\pi}\right)$
(3) $\frac{\mu_0 I}{2r}\left(\frac{1}{2}+\frac{1}{2\pi}\right)$
(4) $\frac{\mu_0 I}{2r}\left(1+\frac{1}{\pi}\right)$

**Correct Answer:** (3)

**Solution:**

Applying Biot-Savart's Law:

$$B_p = \left(\frac{\mu_0 I}{4r} + \frac{\mu_0 I}{4\pi r}\right) = \frac{\mu_0 I}{2r}\left(\frac{1}{2} + \frac{1}{2\pi}\right)$$

**Quick Tip**

Use Biot-Savart's Law for calculating the field due to current-carrying loops.

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**9. Which of the following frequencies does not belong to FM broadcast?**

(1) 106 MHz

(2) 64 MHz

(3) 99 MHz

(4) 89 MHz

**Correct Answer:** (2)

**Solution:**

FM broadcast range is 88 MHz to 108 MHz. Since 64 MHz falls outside this range, it is the correct answer.

**Quick Tip**

FM radio frequencies lie between **88 MHz and 108 MHz**.

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**10. A steel wire with mass per unit length** $7.0 \times 10^{-3}\ kgm^{-1}$ **is under tension of 70 N. The speed of transverse waves in the wire will be:**

(1) $200\pi$ m/s

(2) $100$ m/s

(3) $10$ m/s

(4) $50$ m/s

**Correct Answer:** (2)

**Solution:**

The velocity of transverse waves in a stretched string is given by:

$$v = \sqrt{\frac{T}{\mu}}$$

Substituting the values:

$$v = \sqrt{\frac{70}{7.0 \times 10^{-3}}} = 100 \text{ m/s}$$

**Quick Tip**

The velocity of waves in a string depends on tension $T$ and linear mass density $\mu$.

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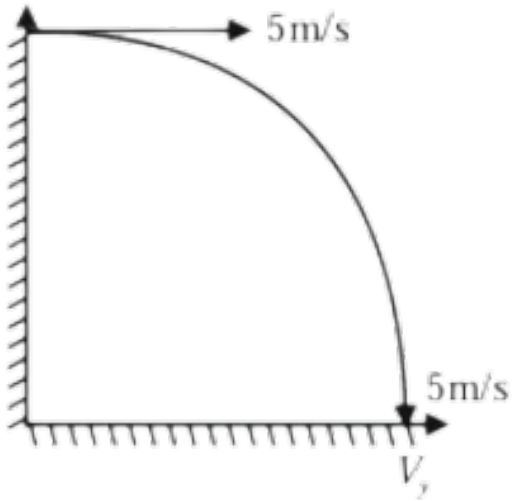
**11. A child stands on the edge of the cliff 10 m above the ground and throws a stone horizontally with an initial speed of 5 m/s. Neglecting air resistance, the speed with which the stone hits the ground will be ___ m/s (given, $g = 10$ m/s$^2$).**




(1) 20

(2) 15

(3) 30

(4) 25

**Correct Answer:** (2)

**Solution:**

Using kinematic equation for vertical motion:

$$v_y = \sqrt{2gh} = \sqrt{200}$$

Horizontal velocity remains unchanged:

$$v_x = 5 \text{ m/s}$$

Net velocity:

$$v_{\text{net}} = \sqrt{v_x^2 + v_y^2} = \sqrt{25 + 200} = 15 \text{ m/s}$$

**Quick Tip**

In projectile motion, horizontal velocity remains constant, and vertical velocity follows free fall equations.

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**12. A proton moving with one-tenth of velocity of light has a certain de-Broglie wavelength $\lambda$. An alpha particle having certain kinetic energy has the same de-Broglie wavelength $\lambda$. The ratio of kinetic energy of proton and that of alpha particle is:**

(1) 2 : 1

(2) 4 : 1

(3) 1 : 2

(4) 1 : 4

**Correct Answer:** (2)

**Solution:**

De-Broglie wavelength is given by:

$$\lambda = \frac{h}{p}$$

Equating for both particles:

$$\frac{KE_p}{KE_\alpha} = \frac{m_\alpha}{m_p} = 4 : 1$$

**Quick Tip**

De-Broglie wavelength is inversely proportional to momentum.

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**13. A sample of gas at temperature $T$ is adiabatically expanded to double its volume. The work done by the gas in the process is (given, $\gamma = \frac{3}{2}$):**

(1) $W = TR[\sqrt{2} - 2]$

(2) $W = \frac{T}{R}[\sqrt{2} - 2]$

(3) $W = RT[2 - \sqrt{2}]$

(4) $W = RT[2 - \sqrt{2}]$

**Correct Answer:** (4)

**Solution:**

Using the formula for adiabatic work:

$$W = \frac{R(T_1 - T_2)}{\gamma - 1}$$

Solving for given conditions:

$$W = RT[2 - \sqrt{2}]$$

**Quick Tip**

For adiabatic expansion, use the Poisson's relation: $PV^{\gamma} = \text{constant}$.

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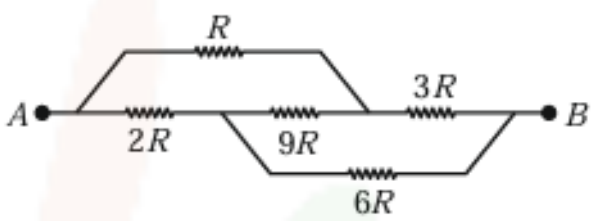
**14. The equivalent resistance between A and B of the network shown in figure:**




(1) $\frac{11R}{3}$

(2) $14R$

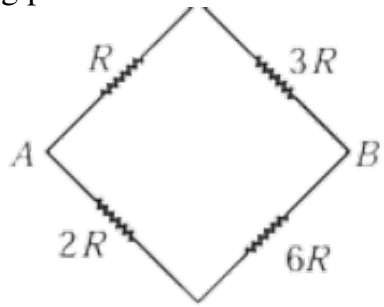
(3) $21R$

(4) $\frac{8R}{3}$

**Correct Answer:** (4)

**Solution:**

Using parallel and series resistance formulas:




$$\frac{1}{R_{\text{eq}}} = \frac{1}{4R} + \frac{1}{8R}$$

$$R_{\text{eq}} = \frac{8R}{3}$$

**Quick Tip**

For resistances in series, add directly. For resistances in parallel, use:

$$\frac{1}{R_{\text{eq}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

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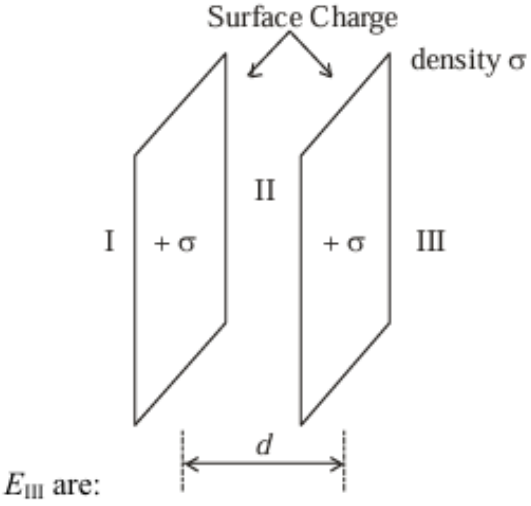
**15. Let $\sigma$ be the uniform surface charge density of two infinite thin plane sheets shown in the figure. Then the electric fields in three different regions $E_I$, $E_{II}$ and $E_{III}$ are:**




(1) $\vec{E}_I = \frac{2\sigma}{\varepsilon_0}\hat{n}, \quad \vec{E}_{II} = 0, \quad \vec{E}_{III} = \frac{2\sigma}{\varepsilon_0}\hat{n}$

(2) $\vec{E}_I = 0, \quad \vec{E}_{II} = \frac{\sigma}{\varepsilon_0}\hat{n}, \quad \vec{E}_{III} = 0$

(3) $\vec{E}_I = \frac{\sigma}{2\varepsilon_0}\hat{n}, \quad \vec{E}_{II} = 0, \quad \vec{E}_{III} = \frac{\sigma}{2\varepsilon_0}\hat{n}$

(4) $\vec{E}_I = -\frac{\sigma}{\varepsilon_0}\hat{n}, \quad \vec{E}_{II} = 0, \quad \vec{E}_{III} = \frac{\sigma}{\varepsilon_0}\hat{n}$

**Correct Answer:** (4)

**Solution:**

Assuming the right-hand side (RHS) to be along $\hat{n}$:

$$\vec{E}_I = \frac{\sigma}{2\varepsilon_0}(-\hat{n}) + \frac{\sigma}{2\varepsilon_0}(-\hat{n}) = -\frac{\sigma}{\varepsilon_0}\hat{n}$$

$$\vec{E}_{II} = 0$$

$$\vec{E}_{III} = \frac{\sigma}{2\varepsilon_0}(\hat{n}) + \frac{\sigma}{2\varepsilon_0}(\hat{n}) = \frac{\sigma}{\varepsilon_0}\hat{n}$$

**Quick Tip**

For an infinite sheet of charge, the electric field is given by $E = \frac{\sigma}{2\varepsilon_0}$. The net field in different regions depends on the superposition of fields from both sheets.

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**16. A mercury drop of radius $10^{-3}$ m is broken into 125 equal size droplets. Surface tension of mercury is $0.45$ Nm$^{-1}$. The gain in surface energy is:**

(1) $2.26 \times 10^{-5}$ J

(2) $28 \times 10^{-5}$ J

(3) $17.5 \times 10^{-5}$ J

(4) $5 \times 10^{-5}$ J

**Correct Answer:** (1)

**Solution:**

Initial surface energy:

$$0.45 \times 4\pi(10^{-3})^2$$

$$\frac{4}{3}\pi(10^{-3})^3 = 125 \times \frac{4\pi}{3}R_{\text{new}}^3$$

$$10^{-3} = 5R_{\text{new}}$$

$$R_{\text{new}} = \frac{10^{-3}}{5} \text{ m}$$

Final surface energy:

$$0.45 \times 125 \times 4\pi \left(\frac{10^{-3}}{5}\right)^2$$

Increase in energy:

$$0.45 \times 4\pi \times (10^{-3})^2 \left[\frac{125}{25} - 1\right]$$

$$= 4 \times 0.45 \times 4\pi \times 10^{-6}$$

$$= 2.26 \times 10^{-5} \text{ J}$$

**Quick Tip**

The total surface area increases when a drop breaks into multiple smaller droplets, leading to an increase in surface energy.

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**17. The mass of proton, neutron and helium nucleus are respectively** 1.0073 u, 1.0087 u **and** 4.0015 u. **The binding energy of helium nucleus is:**

(1) 14.2 MeV

(2) 28.4 MeV

(3) 56.8 MeV

(4) 7.1 MeV

**Correct Answer:** (2)

**Solution:**

Binding Energy of Helium:

$$B.E = (2m_p + 2m_n - m_{\text{He}})c^2$$

$$= 28.4 \text{ MeV}$$

**Quick Tip**

Binding energy is the energy required to separate a nucleus into its constituent protons and neutrons.

**18. The equation of state for some gases is given by:**

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

**The physical quantity, which has the same dimensional formula as $\frac{b^2}{a}$, will be:**

(1) Bulk modulus

(2) Modulus of rigidity

(3) Compressibility

(4) Energy density

**Correct Answer:** (3)

**Solution:**

$$[b] = [V]$$

$$\left[\frac{a}{b^2}\right] = [P] \quad \Rightarrow \quad \left[\frac{b^2}{a}\right] = \frac{1}{[P]} = \frac{1}{[B]} = [K]$$

**Quick Tip**

Compressibility is the reciprocal of bulk modulus, representing how much a material deforms under pressure.

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**19. The average kinetic energy of a molecule of the gas is:**

(1) Proportional to absolute temperature

(2) Proportional to volume

(3) Proportional to pressure

(4) Dependent on the nature of the gas

**Correct Answer:** (1)

**Solution:**

Translational kinetic energy per molecule:

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

It is independent of nature, pressure, and volume.

**Quick Tip**

The kinetic energy of gas molecules depends only on temperature, not on pressure or volume.

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**20. A block of mass 5 kg is placed at rest on a rough surface. If a force of 30N is applied parallel to the surface and the block slides through a distance of 50 m in 10s, then the coefficient of kinetic friction is** (given, $g = 10\ \text{ms}^{-2}$):

(1) 0.60

(2) 0.75

(3) 0.50

(4) 0.25

**Correct Answer:** (3)

**Solution:**

Using kinematic equation:

$$S = ut + \frac{1}{2}at^2$$

$$50 = 0 + \frac{1}{2}a \times 100$$

$$a = 1\ \text{m/s}^2$$

Force equation:

$$F - \mu mg = ma$$

$$30 - \mu \times 50 = 5 \times 1$$

$$50\mu = 25$$

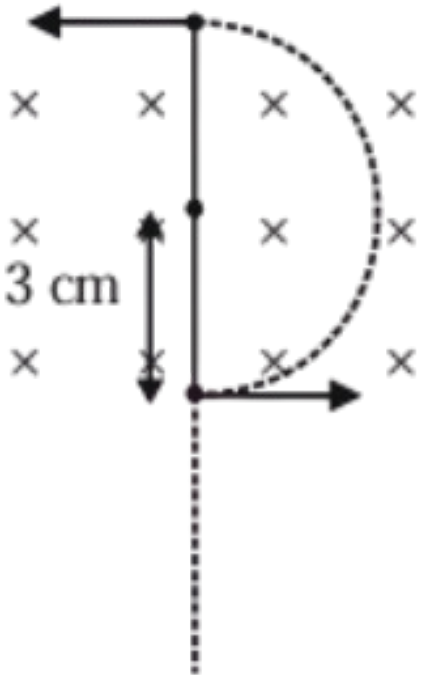
$$\mu = \frac{1}{2}$$

**Quick Tip**

Kinetic friction depends on the coefficient $\mu_k$ and normal force. It acts opposite to motion.

**21. A charge particle of 2 C accelerated by a potential difference of 100V enters a region of uniform magnetic field of magnitude 4 mT at right angle to the direction of field. The charge particle completes semicircle of radius 3 cm inside magnetic field. The mass of the charge particle is ___ × $10^{-18}$ kg.**

**Solution:**




$$r = \frac{mv}{qB} = \sqrt{\frac{2km}{qB}}, \quad m = \frac{r^2q^2B^2}{2k}$$

$$m = \frac{1}{100} \times \frac{3}{100} \times 2 \times 2 \times 4 \times 10^{-3} \times 4 \times 10^{-3} \times 10^{-12}$$

$$= 144 \times 10^{-18} \text{ kg}$$

**Quick Tip**

For a charged particle moving perpendicular to a uniform magnetic field, the motion follows a circular path, and the mass can be determined using the centripetal force relation.

**22. In an experiment to find emf of a cell using potentiometer, the length of null point for a cell of emf 1.5 V is found to be 60 cm. If this cell is replaced by another cell of emf E, the length-of null point increases by 40 cm. The value of E is $\frac{x}{10}$ V. The value of x is _____.**

**Solution:**

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

$$\frac{1.5}{E_2} = \frac{60}{60+40} = \frac{6}{10} = \frac{3}{5}$$

$$E_2 = \frac{5}{2} = \frac{x}{10}$$

$$x = 25$$

**Quick Tip**

In a potentiometer experiment, the emf of a cell is directly proportional to the length of the null point.

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**23. A small particle moves to position $5\hat{i} - 2\hat{j} + \hat{k}$ from its initial position $2\hat{i} + 3\hat{j} - 4\hat{k}$ under the action of force $5\hat{i} + 2\hat{j} + 7\hat{k}$ N. The value of work done will be ____ J.**

**Solution:**

$$W = \mathbf{F} \cdot (\mathbf{r_f} - \mathbf{r_i})$$

$$= (5\hat{i} + 2\hat{j} + 7\hat{k}) \cdot [(5\hat{i} - 2\hat{j} + \hat{k}) - (2\hat{i} + 3\hat{j} - 4\hat{k})]$$

$$W = 40 \text{ J}$$

**Quick Tip**

Work done by a force in moving an object is calculated as the dot product of force and displacement.

**24. A light of energy 12.75 eV is incident on a hydrogen atom in its ground state. The atom absorbs the radiation and reaches to one of its excited states. The angular momentum of the atom in the excited state is $\frac{x}{\pi} \times 10^{-17}$ eVs. The value of x is**

**Solution:**

$$\text{Energy in ground state} = -13.6 \text{ eV}$$

$$-\frac{13.6}{n^2} = -13.6 + 12.75$$

$$-\frac{13.6}{n^2} = -0.85$$

$$n = \sqrt{16}$$

$$n = 4$$

$$\text{Angular momentum} = \frac{nh}{2\pi} = \frac{4h}{2\pi} = \frac{2h}{\pi}$$

$$\text{Angular momentum} = \frac{2}{\pi} \times 4.14 \times 10^{-15}$$

$$= \frac{828 \times 10^{-17}}{\pi} \text{ eVs}$$

**Quick Tip**

For a hydrogen atom, angular momentum in the nth excited state is given by $\frac{nh}{2\pi}$.

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**25. A certain pressure $P$ is applied to 1 litre of water and 2 litre of a liquid separately. Water gets compressed to 0.01% whereas the liquid gets compressed to 0.03%. The ratio of Bulk modulus of water to that of the liquid is $\frac{3}{x}$. The value of $x$ is _____.**

(1) 1

(2) 2

(3) 3

(4) 4

**Correct Answer:** (1) 1

**Solution:**

$$B_{\text{water}} = \frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}$$

$$B_{\text{water}} = \frac{-\Delta P}{0.01} \times 100$$

$$B_{\text{liquid}} = \frac{-\Delta P}{0.03} \times 100$$

$$\frac{B_{\text{water}}}{B_{\text{liquid}}} = 3$$

$$x = 1$$

**Quick Tip**

Bulk modulus is a measure of a substance's resistance to uniform compression. Higher bulk modulus means less compressibility.

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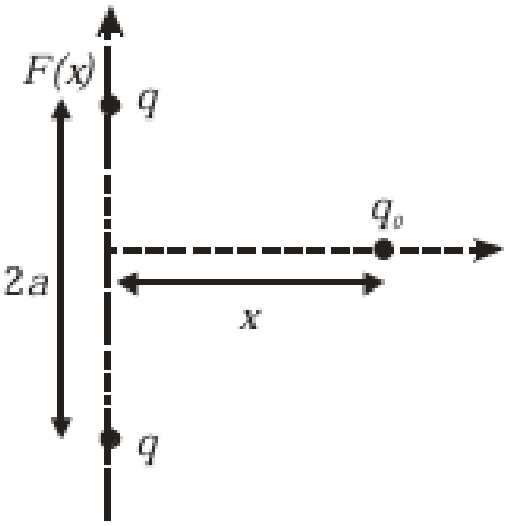
**26. Two equal positive point charges are separated by a distance $2a$. The distance of a point from the centre of the line joining two charges on the equatorial line (perpendicular bisector) at which force experienced by a test charge $q_0$ becomes maximum is $\frac{a}{\sqrt{x}}$. The value of $x$ is _____.**

(1) 1

(2) 2

(3) 3

(4) 4




**Correct Answer:** (2) 2

**Solution:**

$$F = \frac{2Kqq_0x}{(x^2 + a^2)^{3/2}}$$

For $F$ to be maximum,

$$\frac{dF}{dx} = 0$$

$$x = \frac{a}{\sqrt{2}}$$

**Quick Tip**

The force experienced by a test charge is maximum when the derivative of the force equation with respect to distance is zero.

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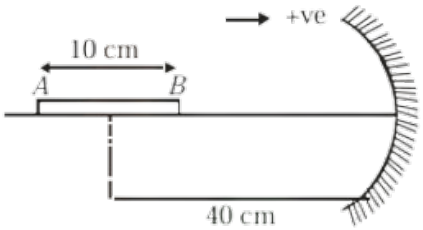
**27. A thin cylindrical rod of length 10 cm is placed horizontally on the principle axis of a concave mirror of focal length 20 cm. The rod is placed in a such a way that mid point of the rod is at 40 cm from the pole of mirror. The length of the image formed by the mirror will be $\frac{x}{3}$ cm. The value of $x$ is _____.**




(1) 30

(2) 32

(3) 34

(4) 36

**Correct Answer:** (2) 32

**Solution:**

$$U_A = -45 \text{ cm}, \quad f = -20 \text{ cm}$$

$$V_A = \frac{-45 \times (-20)}{-45 - (-20)} = \frac{900}{25} = -36 \text{ cm}$$

And

$$U_B = -35 \text{ cm}$$

$$V_B = \frac{-35 \times (-20)}{-35 - (-20)} = \frac{700}{-15}$$

$$V_A - V_B = \text{length of image}$$
$$= \left(-36 + \frac{140}{3}\right) \text{ cm}$$
$$= \frac{-108 + 140}{3} \text{ cm}$$
$$= \frac{32}{3} \text{ cm}$$
$$\therefore x = 32$$

**Quick Tip**

For image formation using concave mirrors, apply the mirror formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$.

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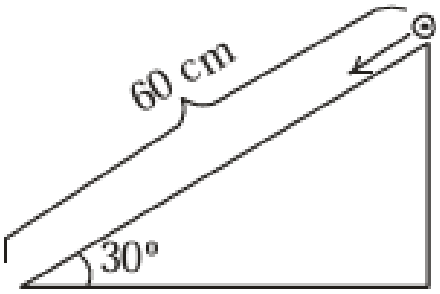
**28. A solid cylinder is released from rest from the top of an inclined plane of inclination $30^\circ$ and length 60 cm. If the cylinder rolls without slipping, its speed upon reaching the bottom of the inclined plane is _____ ms$^{-1}$. (Given $g = 10$ ms$^{-2}$)**




(1) 1

(2) 2

(3) 3

(4) 4

**Correct Answer:** (2) 2

**Solution:**

$$v = \sqrt{\frac{2gh}{1 + \frac{k^2}{R^2}}}$$

Where $h = 60 \sin 30^\circ = 30$ cm

$$k^2 = \frac{R^2}{2}$$
$$v = 2 \text{ ms}^{-1}$$

Quick Tip

For rolling motion, use the energy conservation principle: $PE = KE_{\text{linear}} + KE_{\text{rotational}}$.

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**29. The amplitude of a particle executing SHM is 3 cm. The displacement at which its kinetic energy will be 25% more than the potential energy is _____ cm.**

(1) 3 cm

(2) 2 cm

(3) 4 cm

(4) 5 cm

**Correct Answer:** (2) 2 cm

**Solution:**

$$KE = PE + \frac{PE}{4}$$

$$KE = \frac{5}{4}PE$$

$$\frac{1}{2}m\omega^2(A^2 - x^2) = \frac{5}{4} \times \frac{1}{2}m\omega^2x^2$$

$$[v = \omega\sqrt{A^2 - x^2}]$$

$$A^2 - x^2 = \frac{5}{4}x^2$$

$$\frac{9x^2}{4} = A^2$$

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

$$\therefore x = \frac{2}{3} \times 3cm$$

$$x = 2cm$$

**Quick Tip**

Kinetic energy in SHM is given by $KE = \frac{1}{2}m\omega^2(A^2 - x^2)$.

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**30. A series LCR circuit is connected to an ac source of 220V, 50Hz. The circuit contains a resistance $R = 100\Omega$ and an inductor of inductive reactance $X_L = 79.6\Omega$. The capacitance of the capacitor needed to maximize the average rate at which energy is supplied will be _____ μF.**

(1) 30 μF

(2) 40 μF

(3) 50 μF

(4) 60 μF

**Correct Answer:** (2) 40 μF

**Solution:**

To maximize the average rate at which energy is supplied i.e., power will be maximum. So in LCR circuit, power will be maximum at the condition of resonance and in resonance condition

$$X_L = X_C$$

$$79.6 = \frac{1}{\omega C}$$

$$C = \frac{1}{2\pi \times 50 \times 79.6}$$

$$C = 40\mu F$$

**Quick Tip**

At resonance in an LCR circuit, the inductive reactance and capacitive reactance cancel each other, leading to maximum power transfer.

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