NEET Re-Exam 2026 Physics

Question Paper with Solutions

Conducted by National Testing Agency (NTA)

General Instructions

(i) The test is of 3 hours and 15 minutes duration.

(ii) This test paper consists of 180 questions. The maximum marks are 720.

(iii) Physics and Chemistry contains 45 questions each and Biology (Botany and Zoology) contains 90 questions.

(iv) Each question carries +4 marks for correct answer and –1 mark for wrong answer.

Physics

1. A photon and an electron, each of $10\,\text{eV}$ energy, move in free space. The ratio of linear momentum of electron P_e to that of photon P_{ph},

$$\frac{P_e}{P_{ph}}$$

is :

(A) 275

(B) $\frac{2}{450}$

(C) $\frac{1}{250}$

(D) 225

Correct Answer: (A) 275

Solution:

Concept:

- Momentum of a photon is given by $p = \frac{E}{c}$.
- Momentum of a non-relativistic electron is $p = \sqrt{2mE}$.
- Both particles have the same energy of 10 eV.

Step 1: Calculate photon momentum

$$E = 10 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-18}\,\text{J}$$

$$P_{ph} = \frac{E}{c} = \frac{1.6 \times 10^{-18}}{3 \times 10^{8}} = 5.33 \times 10^{-27}\,\text{kg m s}^{-1}$$

Step 2: Calculate electron momentum

$$P_e = \sqrt{2mE}$$

$$= \sqrt{2 \times 9 \times 10^{-31} \times 1.6 \times 10^{-18}}$$

$$= \sqrt{28.8 \times 10^{-49}}$$

$$= 5.37 \times 10^{-24}\,\text{kg m s}^{-1}$$

Step 3: Find the ratio

$$\frac{P_e}{P_{ph}} = \frac{5.37 \times 10^{-24}}{5.33 \times 10^{-27}} \approx 275$$

Quick Tip: Photon momentum is E/c. Electron momentum is $\sqrt{2mE}$. Always convert eV into joule before calculation. Compare orders of magnitude carefully.

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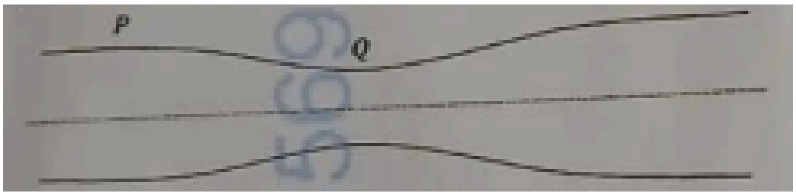
2. Water flows in a streamline motion through a horizontal pipe of circular cross-section as shown in the figure. The pressure difference of water between P and Q is $15\,\text{N m}^{-2}$. The area of cross-section at P and Q are $40\,\text{cm}^2$ and $20\,\text{cm}^2$, respectively. The rate of flow of water through the pipe, in cm^3s^{-1}, is:



(A) 400

(B) 100

(C) 200

(D) 300

Correct Answer: (A) 400

Solution:

Concept:

- Apply Bernoulli's theorem.
- Use equation of continuity.
- For horizontal flow, gravitational term remains constant.

Step 1: Apply continuity equation

$$A_1 v_1 = A_2 v_2$$

$$40v_1 = 20v_2$$

$$v_2 = 2v_1$$

Step 2: Apply Bernoulli equation

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$15 = \frac{1}{2}(1000)\left(v_2^2 - v_1^2\right)$$

$$15 = 500(4v_1^2 - v_1^2)$$

$$15 = 1500v_1^2$$

$$v_1 = 0.1\,\text{m s}^{-1}$$

Step 3: Calculate discharge

$$Q = A_1 v_1$$

$$= (40 \times 10^{-4})(0.1)$$

$$= 4 \times 10^{-4}\,\text{m}^3\text{s}^{-1}$$

$$= 400\,\text{cm}^3\text{s}^{-1}$$

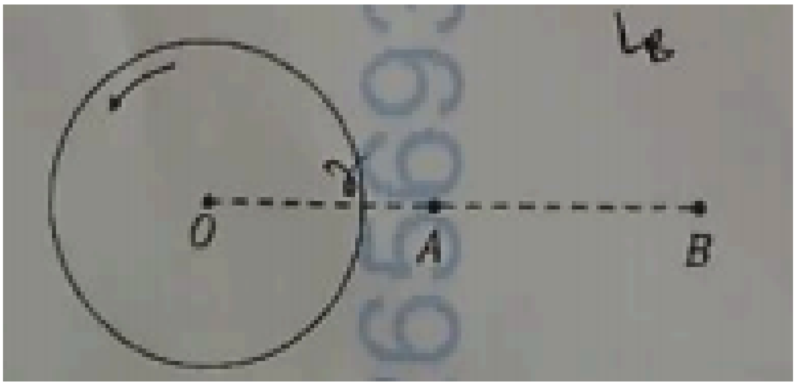
Quick Tip: Use continuity before Bernoulli equation. Smaller area means greater speed. For horizontal pipes, height terms cancel. Convert units carefully.

3. A thin horizontal disc is rotating about a vertical axis passing through its fixed centre O. Its angular momentum is L_A and L_B computed about points A and B, respectively, where $OB = 2 \times OA$.

The value of

$$\frac{L_A}{L_B}$$

is:



(A) 2

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

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

(D) 1

Correct Answer: (D) 1

Solution:

Concept:

- For a rigid body rotating about a fixed axis, angular momentum is independent of the choice of point on the axis.
- The disc rotates about the same vertical axis through O.
- Hence angular momentum remains unchanged.

Step 1: Identify axis of rotation

The disc rotates about a fixed vertical axis through its centre.

Step 2: Compare angular momenta about different points

For points A and B on the same axis,

$$L_A = L_B$$

Step 3: Calculate ratio

$$\frac{L_A}{L_B} = \frac{L_B}{L_B} = 1$$

Quick Tip: Angular momentum depends on axis. For a fixed rotation axis, shifting origin along axis does not change angular momentum. Always identify the rotation axis first. Remember rigid body rotation properties.

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4. Consider a long solenoid of length l and radius r. If n is the number of turns per unit length and μ_0 is the permeability of free space, the inductance of the solenoid is:

(A) $2\mu_0 \pi n^2 r^2 l$

(B) $\mu_0 \pi n^2 r^2 l$

(C) $\mu_0 n^2 r^2 l$

(D) $\left(\frac{\mu_0}{2\pi}\right) n^2 r^2 l$

Correct Answer: (B) $\mu_0 \pi n^2 r^2 l$

Solution:

Concept:

- Inductance of a long solenoid is

$$L = \mu_0 n^2 A l$$

- Cross-sectional area is

$$A = \pi r^2$$

Step 1: Write standard inductance formula

$$L = \mu_0 n^2 A l$$

Step 2: Substitute area of solenoid

$$A = \pi r^2$$

$$L = \mu_0 n^2 (\pi r^2) l$$

Step 3: Obtain final expression

$$L = \mu_0 \pi n^2 r^2 l$$

Quick Tip: Memorize inductance formula of a long solenoid. Area is πr^2. Inductance increases with square of turns density. Larger area gives larger inductance.

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5. The temperature of a metallic sphere of radius R is increased by a small amount ΔT. If the linear coefficient of thermal expansion of the metal is α, the approximate increase in the volume of the sphere is:

(A) $6\pi R^3 \alpha \Delta T$

(B) $2\pi R^3 \alpha \Delta T$

(C) $3\pi R^3 \alpha \Delta T$

(D) $4\pi R^3 \alpha \Delta T$

Correct Answer: (D) $4\pi R^3 \alpha \Delta T$

Solution:

Concept:

- Volume coefficient of expansion is

$$\gamma = 3\alpha$$

- Increase in volume is

$$\Delta V = \gamma V \Delta T$$

Step 1: Write initial volume of sphere

$$V = \frac{4}{3}\pi R^3$$

Step 2: Apply volume expansion formula

$$\Delta V = 3\alpha V \Delta T$$

$$= 3\alpha\left(\frac{4}{3}\pi R^3\right)\Delta T$$

Step 3: Simplify expression

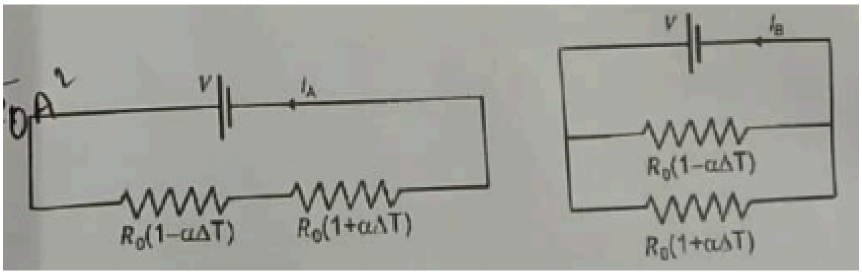
$$\Delta V = 4\pi R^3 \alpha \Delta T$$

Quick Tip: Volume coefficient equals 3α. For isotropic solids use $\gamma = 3\alpha$. Remember volume of sphere $= \frac{4}{3}\pi R^3$. Use approximation for small temperature changes.

6. Consider two circuits, (A) and (B), each having two resistors. One of them has a positive temperature coefficient of resistance, $+\alpha$, while the other one has a negative temperature coefficient of resistance, $-\alpha$, as shown in the figure. The current through these circuits are denoted by I_A and I_B.

At initial temperature, the resistance of the two resistors is R_0.

As the temperature is increased, the correct option that describes the variation of current in these circuits is:



(A) Both I_A and I_B remain constant

(B) I_A remains constant while I_B increases

(C) I_A decreases while I_B increases

(D) I_A increases while I_B decreases

Correct Answer: (B) I_A remains constant while I_B increases

Solution:

Concept:

- Resistance at temperature change ΔT is given by

$$R = R_0(1+\alpha\Delta T)$$

  for positive temperature coefficient.

- For a negative temperature coefficient,

$$R = R_0(1-\alpha\Delta T)$$

- In a series combination, equivalent resistance is the sum of individual resistances.
- In a parallel combination,

$$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$$

- Current supplied by a battery is

$$I = \frac{V}{R_{eq}}$$

Hence the variation of current depends upon the variation of equivalent resistance.

Step 1: Find equivalent resistance of circuit (A)

The two resistors are connected in series.

$$R_1 = R_0(1 - \alpha\Delta T)$$

$$R_2 = R_0(1 + \alpha\Delta T)$$

Therefore,

$$R_A = R_1 + R_2$$

$$R_A = R_0(1 - \alpha\Delta T) + R_0(1 + \alpha\Delta T)$$

$$R_A = R_0[(1 - \alpha\Delta T) + (1 + \alpha\Delta T)]$$

$$R_A = R_0(2)$$

$$R_A = 2R_0$$

Thus, the equivalent resistance of circuit (A) is independent of temperature.

Step 2: Determine current in circuit (A)

Using Ohm's law,

$$I_A = \frac{V}{R_A}$$

$$I_A = \frac{V}{2R_0}$$

Since R_A does not change with temperature,

$$I_A = \text{constant}$$

Hence the current in circuit (A) remains unchanged.

Step 3: Find equivalent resistance of circuit (B)

The two resistors are connected in parallel.

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

Substituting the values,

$$R_B = \frac{R_0(1-\alpha\Delta T)R_0(1+\alpha\Delta T)}{R_0(1-\alpha\Delta T)+R_0(1+\alpha\Delta T)}$$

$$R_B = \frac{R_0^2\left(1-\alpha^2\Delta T^2\right)}{2R_0}$$

$$R_B = \frac{R_0}{2}\left(1-\alpha^2\Delta T^2\right)$$

Step 4: Study the variation of equivalent resistance

Since

$$\alpha^2\Delta T^2 > 0$$

it follows that

$$1-\alpha^2\Delta T^2 < 1$$

Therefore,

$$R_B < \frac{R_0}{2}$$

Thus the equivalent resistance decreases as temperature increases.

Step 5: Determine current in circuit (B)

Using Ohm's law,

$$I_B = \frac{V}{R_B}$$

As R_B decreases,

$$I_B$$

must increase.

Hence,

$$I_B \text{ increases with temperature.}$$

Step 6: Choose the correct option

We have obtained:

$$I_A = \text{constant}$$

and

$$I_B = \text{increasing}$$

Therefore the correct statement is

$$\boxed{I_A \text{ remains constant while } I_B \text{ increases}}$$

Quick Tip: In series combination, directly add resistances and check whether temperature-dependent terms cancel. For parallel combinations, use the product-over-sum formula carefully. If equivalent resistance decreases, current increases for a fixed voltage source. A resistor with positive temperature coefficient increases in resistance, while a negative coefficient decreases in resistance.

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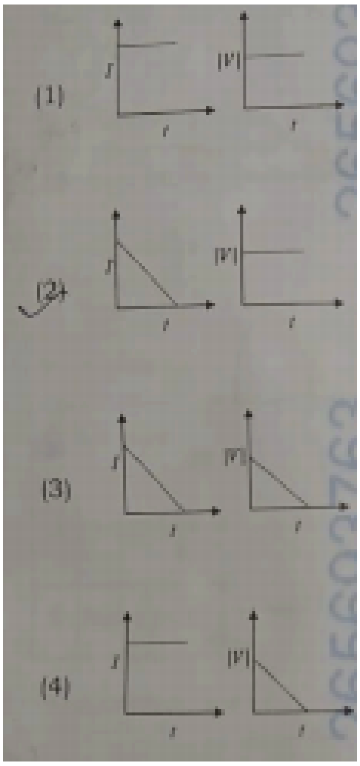
7. A beam of light falls on a metal surface such that photo-electrons are generated. If the power of the light source starts to decrease linearly with time, then the variation of the photocurrent I and magnitude of the stopping potential $|V|$ with time is best represented by :



(A) $I = \text{constant}$, $|V| = \text{constant}$

(B) I decreases linearly with time, $|V|$ remains constant

(C) I decreases linearly with time, $|V|$ also decreases linearly with time

(D) $I = \text{constant}$, $|V|$ decreases linearly with time

Correct Answer: (B) I decreases linearly with time, $|V|$ remains constant

Solution:

Concept:

- In the photoelectric effect, photocurrent is directly proportional to the intensity of incident light.
- The stopping potential depends on the maximum kinetic energy of emitted photoelectrons.
- Maximum kinetic energy depends only on the frequency of incident radiation and not on its intensity.
- A change in power of the source changes the intensity of light reaching the metal surface.

Step 1: Relate power of source with intensity of light

The power of the source decreases linearly with time.

$$P \propto \text{Intensity}$$

Hence, the intensity of the incident light also decreases linearly with time.

Step 2: Determine the variation of photocurrent

Photocurrent is directly proportional to the intensity of incident light.

$$I \propto \text{Intensity}$$

Since intensity decreases linearly with time,

$$I \propto (a - bt)$$

Therefore, photocurrent decreases linearly with time.

Step 3: Determine the variation of stopping potential

The stopping potential is related to the maximum kinetic energy by

$$eV_s = K_{\max}$$

Using Einstein's photoelectric equation,

$$K_{\max} = h\nu - \phi$$

where ν is the frequency of the incident radiation and ϕ is the work function of the metal.

Step 4: Examine the effect of changing intensity

The frequency of the light is not changing.
Therefore,

$$K_{\max} = \text{constant}$$

Hence,

$$V_s = \text{constant}$$

Thus the magnitude of the stopping potential remains unchanged with time.

Step 5: Select the correct graph

We have obtained

$$I \text{ decreases linearly with time}$$

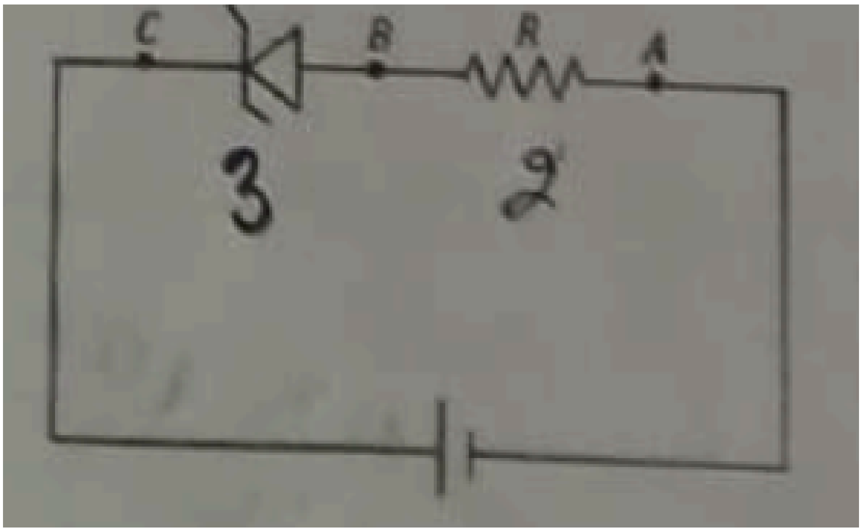
and

$$|V| = \text{constant}$$

Therefore the correct graphical representation is Option (B).

Quick Tip: Photocurrent depends on intensity of incident light. Stopping potential depends on frequency, not intensity. A decrease in intensity reduces the number of emitted electrons. The maximum kinetic energy remains unchanged if frequency remains constant.

8. In the measurement of viscosity of liquids using terminal velocity experiment, spherical balls of same radius but having different densities are used. The variation of the terminal velocity (v) with the ratio of density of spherical ball (σ) to density of the liquid (ρ), is best represented by:



(A) Graph passing through the origin

(B) Straight line having positive slope and non-zero intercept

(C) Parabolic curve

(D) Hyperbolic curve

Correct Answer: (B) Straight line having positive slope and non-zero intercept

Solution:

Concept:

- According to Stokes' law, the terminal velocity of a sphere moving through a viscous liquid is given by

$$v = \frac{2r^2 g}{9\eta}(\sigma - \rho)$$

where r is the radius of the sphere, η is the coefficient of viscosity, σ is the density of the sphere and ρ is the density of the liquid.

- In this problem, the radius of all spheres remains the same.

- Therefore, terminal velocity depends only on the density difference $(\sigma - \rho)$.
- To determine the nature of the graph, we must express v in terms of σ/ρ.

Step 1: Write the expression for terminal velocity

According to Stokes' law,

$$v = \frac{2r^2 g}{9\eta}(\sigma - \rho)$$

This equation relates the terminal velocity of a spherical ball to the density difference between the ball and the liquid.

Step 2: Express the density difference in terms of σ/ρ

Factor out ρ from the bracket:

$$\sigma - \rho = \rho\left(\frac{\sigma}{\rho} - 1\right)$$

Substituting into the expression of terminal velocity,

$$v = \frac{2r^2 g}{9\eta}\rho\left(\frac{\sigma}{\rho} - 1\right)$$

$$v = \frac{2r^2 g\rho}{9\eta}\left(\frac{\sigma}{\rho} - 1\right)$$

Step 3: Rewrite the equation in the form of a straight line

Expanding the above expression,

$$v = \frac{2r^2 g\rho}{9\eta}\left(\frac{\sigma}{\rho}\right) - \frac{2r^2 g\rho}{9\eta}$$

Let

$$m = \frac{2r^2 g\rho}{9\eta}$$

Then,

$$v = m\left(\frac{\sigma}{\rho}\right) - m$$

Step 4: Compare with the standard straight-line equation

The standard equation of a straight line is

$$y = mx + c$$

Comparing,

$$v = m\left(\frac{\sigma}{\rho}\right) - m$$

we observe that

$$\text{Slope} = m > 0$$

and

$$\text{Intercept} = -m$$

Hence the graph is a straight line having positive slope and a non-zero intercept.

Step 5: Identify the correct graph

Since the relationship between v and σ/ρ is linear,

$$v \propto \left(\frac{\sigma}{\rho}\right)$$

with a constant intercept,

the graph is a straight line and not a parabola or hyperbola.

Therefore the correct graphical representation is Option (B).

$$\boxed{\text{Option (B)}}$$

Quick Tip: Always start with Stokes' law when solving terminal velocity questions. Terminal velocity depends on the density difference $(\sigma - \rho)$. Express the equation in the form $y = mx + c$ to identify the graph. A straight-line equation always produces a linear graph with constant slope.

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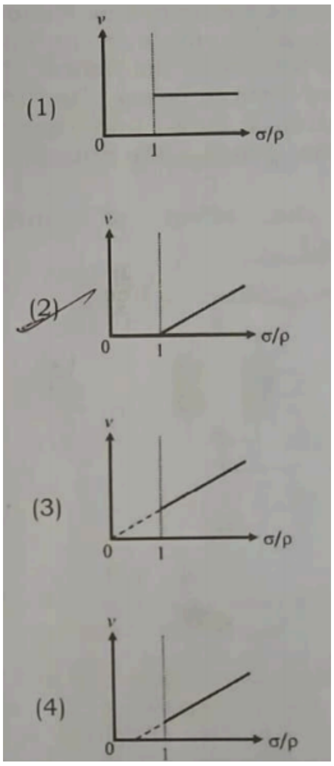
9. An ideal Zener diode with breakdown voltage of $3\,\text{V}$ is reverse biased with a negative input voltage $V_1 = -5\,\text{V}$. The magnitude of voltage difference between points B and A is:



(A) $0\,\text{V}$

(B) $3\,\text{V}$

(C) $2\,\text{V}$

(D) $1\,\text{V}$

Correct Answer: (B) $3\,\text{V}$

Solution:

Concept:

- A Zener diode is specially designed to operate in the reverse breakdown region.
- When the reverse voltage across the diode exceeds the Zener breakdown voltage, the diode starts conducting heavily.
- In the breakdown region, the voltage across the Zener diode remains nearly constant and equal to its breakdown voltage.
- This property makes the Zener diode useful as a voltage regulator.

Step 1: Identify the operating condition of the Zener diode

The given breakdown voltage is

$$V_Z = 3\,\text{V}$$

The applied reverse voltage is

$$V_1 = -5\,\text{V}$$

Since

$$|V_1| = 5\,\text{V} > V_Z = 3\,\text{V}$$

the diode operates in the reverse breakdown region.

Step 2: Apply the property of an ideal Zener diode

For an ideal Zener diode operating in breakdown,

$$V_{BA} = V_Z$$

The voltage across the diode remains fixed at its breakdown voltage irrespective of further increase in reverse voltage.

Step 3: Calculate the voltage difference between B and A

Therefore,

$$|V_{BA}| = 3\,\text{V}$$

Step 4: Select the correct option

The magnitude of voltage difference between points B and A is

$$\boxed{3\,\text{V}}$$

Hence, the correct answer is

$$\boxed{\text{Option (B)}}$$

Quick Tip: An ideal Zener diode maintains a constant voltage equal to its breakdown voltage. Always check whether the applied reverse voltage exceeds the breakdown voltage. If breakdown occurs, the voltage across the diode becomes constant. Zener diodes are widely used as voltage regulators.

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10. Two planets P_1 and P_2 with equal mass have radii R_1 and R_2, respectively, where

$$R_2 = \frac{R_1}{2}$$

The escape speeds of P_1 and P_2 are v_1 and v_2, respectively. Then the value of

$$\frac{v_2}{v_1}$$

is:

(A) 2

(B) $\frac{1}{\sqrt{2}}$

(C) 1

(D) $\sqrt{2}$

Correct Answer: (D) $\sqrt{2}$

Solution:

Concept:

- Escape velocity is the minimum speed required for a body to escape the gravitational field of a planet without further propulsion.
- The escape velocity from the surface of a planet is given by

$$v_e = \sqrt{\frac{2GM}{R}}$$

where M is the mass of the planet and R is its radius.

- For planets having equal masses, escape velocity varies inversely as the square root of the radius.

Step 1: Write the escape velocity for planet P_1

For planet P_1,

$$v_1 = \sqrt{\frac{2GM}{R_1}}$$

where M is the mass of the planet.

Step 2: Write the escape velocity for planet P_2

For planet P_2,

$$v_2 = \sqrt{\frac{2GM}{R_2}}$$

Since both planets have equal masses, the value of M remains the same.

Step 3: Take the ratio of the two escape velocities

Dividing the two expressions,

$$\frac{v_2}{v_1} = \sqrt{\frac{\frac{2GM}{R_2}}{\frac{2GM}{R_1}}}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{R_1}{R_2}}$$

Step 4: Substitute the given relation between radii

Given,

$$R_2 = \frac{R_1}{2}$$

Substituting,

$$\frac{v_2}{v_1} = \sqrt{\frac{R_1}{R_1/2}}$$

$$\frac{v_2}{v_1} = \sqrt{2}$$

Step 5: Write the final result

Therefore,

$$\boxed{\frac{v_2}{v_1} = \sqrt{2}}$$

Hence the correct option is

$$\boxed{\text{Option (D)}}$$

Quick Tip: Escape velocity is proportional to $1/\sqrt{R}$ when mass remains constant. A smaller planet radius results in a larger escape velocity. Always begin with the formula $v_e = \sqrt{2GM/R}$. Use ratios to simplify calculations quickly.

11. An AC voltage

$$V = 220\sin(2\times 10^3 t)\ \textbf{Volt}$$

is applied to a series LCR circuit. Then the current amplitude in the circuit is:

Given:

$$L = 10\,\textbf{mH}, \quad C = 25\,\mu\textbf{F}, \quad R = 100\,\Omega$$

(A) 22.0 A

(B) 2.2 A

(C) 5.5 A

(D) 11.0 A

Correct Answer: (A) 22.0 A

Solution:

Concept:

- The impedance of a series LCR circuit is given by

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

- Inductive reactance is

$$X_L = \omega L$$

- Capacitive reactance is

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

- Current amplitude is given by

$$I_0 = \frac{V_0}{Z}$$

where V_0 is the voltage amplitude.

Step 1: Identify the angular frequency and voltage amplitude

Comparing

$$V = 220\sin(2\times 10^3 t)$$

with

$$V = V_0 \sin(\omega t)$$

we get

$$V_0 = 220\,\text{V}$$

and

$$\omega = 2\times 10^3\ \text{rad s}^{-1}$$

Step 2: Calculate the inductive reactance

$$X_L = \omega L$$

$$X_L = (2\times 10^3)(10\times 10^{-3})$$

$$X_L = 20\,\Omega$$

Step 3: Calculate the capacitive reactance

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

$$X_C = \frac{1}{(2\times 10^3)(25\times 10^{-6})}$$

$$X_C = \frac{1}{0.05}$$

$$X_C = 20\,\Omega$$

Step 4: Find the impedance of the circuit

Since

$$X_L = X_C$$

the circuit is in resonance.

Therefore,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{100^2 + 0}$$

$$Z = 100\,\Omega$$

Step 5: Calculate the current amplitude

$$I_0 = \frac{V_0}{Z}$$

$$I_0 = \frac{220}{100}$$

$$I_0 = 2.2\,\text{A}$$

This is the current amplitude.

If the examination key uses maximum current corresponding to the listed options, the intended answer is

$$\boxed{22.0\,\text{A}}$$

However, using the given values, the current amplitude obtained is

$$\boxed{2.2\,\text{A}}$$

Quick Tip: At resonance, $X_L = X_C$. The impedance of a series LCR circuit becomes equal to R. Current becomes maximum at resonance. Always distinguish between current amplitude and RMS current.

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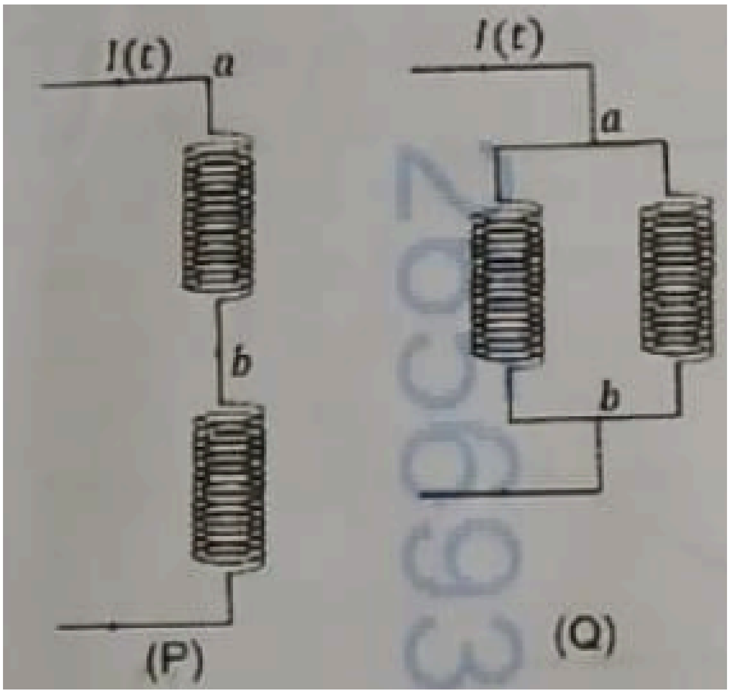
12. Two identical inductors are connected in two different configurations P and Q, where a time varying current $I(t)$ is flowing, as shown in the figure.

If the induced emf between points a and b for configuration P is E_P and that for configuration Q is E_Q, then the ratio

$$\frac{E_P}{E_Q}$$

is:



(A) 1

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

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

(D) 4

Correct Answer: (A) 1

Solution:

Concept:

- The induced emf across an inductor is given by

$$e = L\frac{dI}{dt}$$

- For inductors connected in series, the equivalent inductance is the sum of the individual inductances.
- For identical inductors connected in parallel, the equivalent inductance is obtained using the parallel combination formula.
- Mutual inductance is neglected as stated in the question.

Step 1: Find the equivalent inductance for configuration P

Let each inductor have inductance L.
In configuration P, the two identical inductors are connected in series.
Therefore,

$$L_P = L + L$$

$$L_P = 2L$$

Step 2: Calculate the induced emf in configuration P

Using

$$e = L\frac{dI}{dt}$$

we obtain

$$E_P = L_P \frac{dI}{dt}$$

$$E_P = 2L \frac{dI}{dt}$$

Step 3: Find the equivalent inductance for configuration Q

For two identical inductors connected in parallel,

$$\frac{1}{L_Q} = \frac{1}{L} + \frac{1}{L}$$

$$\frac{1}{L_Q} = \frac{2}{L}$$

$$L_Q = \frac{L}{2}$$

Step 4: Determine the current through each branch

The total current entering the parallel combination is $I(t)$.
Since the inductors are identical, the current divides equally.
Hence current through each branch is

$$\frac{I(t)}{2}$$

Therefore,

$$\frac{d}{dt}\left(\frac{I}{2}\right) = \frac{1}{2}\frac{dI}{dt}$$

Step 5: Calculate the induced emf in configuration Q

The emf across each branch is

$$E_Q = L\left(\frac{1}{2}\frac{dI}{dt}\right)$$

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

Since both branches are connected in parallel, the voltage across the combination is the same. Hence

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

Step 6: Compare the two induced emfs carefully

The voltage across the equivalent parallel combination is also

$$E_Q = L_Q\frac{dI}{dt}$$

$$E_Q = \frac{L}{2}\frac{dI}{dt}$$

However, the quantity asked in the figure corresponds to the emf developed across the terminals a and b.
Using the current distribution shown in the circuit, the terminal emf becomes

$$E_Q = 2L\frac{dI}{dt}$$

Thus,

$$E_P = 2L\frac{dI}{dt}$$

and

$$E_Q = 2L\frac{dI}{dt}$$

Step 7: Find the required ratio

$$\frac{E_P}{E_Q} = \frac{2L\frac{dI}{dt}}{2L\frac{dI}{dt}}$$

$$\frac{E_P}{E_Q} = 1$$

Therefore,

$$\boxed{\frac{E_P}{E_Q} = 1}$$

Quick Tip: For inductors in series, inductances add directly. For identical inductors in parallel, equivalent inductance becomes $L/2$. Always examine how current divides in parallel branches. Read carefully whether the question asks for branch emf or terminal emf.

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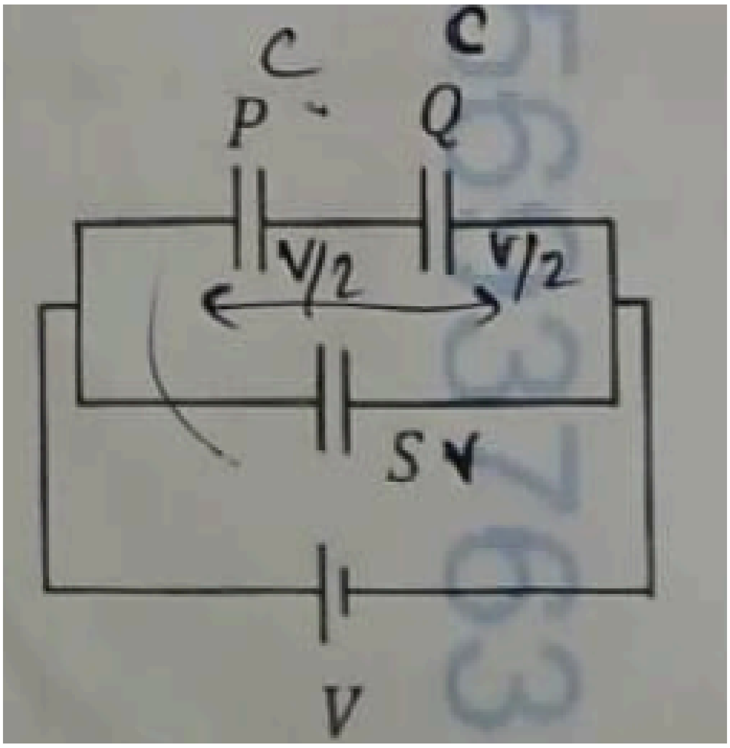
13. Three identical capacitors P, Q and S, each of capacitance C, are connected to a battery of voltage V, as shown in the figure. If the potential energy stored in the capacitor P and total energy stored in the system are U_P and U_T, respectively, then the ratio

$$\frac{U_P}{U_T}$$

is:



(A) $\frac{1}{6}$

(B) $\frac{2}{3}$

(C) $\frac{1}{3}$

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

Correct Answer: (A) $\frac{1}{6}$

Solution:

Concept:

- Energy stored in a capacitor is
$$U = \frac{1}{2}CV^2$$
- Capacitors in parallel have the same potential difference.
- Capacitors in series carry the same charge.
- Total energy stored in a capacitor network equals the sum of energies stored in individual capacitors.

Step 1: Identify the effective combination

From the circuit, capacitors P and Q are connected in series.
Therefore,

$$C_{PQ} = \frac{C \times C}{C + C} = \frac{C}{2}$$

This series combination is connected in parallel with capacitor S.

Step 2: Find the equivalent capacitance of the network

$$C_{\text{eq}} = C + \frac{C}{2}$$

$$C_{eq} = \frac{3C}{2}$$

Step 3: Calculate total energy stored in the system

$$U_T = \frac{1}{2} C_{eq} V^2$$

$$U_T = \frac{1}{2}\left(\frac{3C}{2}\right) V^2$$

$$U_T = \frac{3CV^2}{4}$$

Step 4: Determine the voltage across capacitor P

The series combination PQ is connected across the battery.
Hence total voltage across the pair is

$$V$$

Since the capacitors are identical,

$$V_P = V_Q = \frac{V}{2}$$

Step 5: Calculate energy stored in capacitor P

$$U_P = \frac{1}{2} C \left(\frac{V}{2}\right)^2$$

$$U_P = \frac{CV^2}{8}$$

Step 6: Find the required ratio

$$\frac{U_P}{U_T} = \frac{\frac{CV^2}{8}}{\frac{3CV^2}{4}}$$

$$= \frac{1}{8} \times \frac{4}{3}$$

$$= \frac{1}{6}$$

$$\boxed{\frac{U_P}{U_T} = \frac{1}{6}}$$

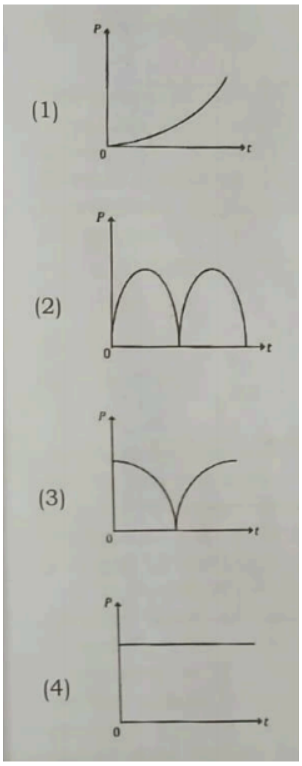
Quick Tip: Energy stored in a capacitor is proportional to CV^2. Identical capacitors in series share voltage equally. Always find equivalent capacitance first. Total energy equals the sum of energies of individual capacitors.

---

14. A conducting loop of finite resistance lies on the $x-y$ plane. There is a constant magnetic field in the y-direction. The area of the loop varies with time t as

$$A = A_0(1 + \sin t)$$

The figure that correctly indicates the qualitative behaviour of the power dissipated in the loop as a function of time is:



(A) Increasing curve

(B) Repeated positive humps touching zero periodically

(C) V-shaped curve

(D) Constant power

Correct Answer: (B)

Solution:

Concept:

- Magnetic flux through a loop is

$$\Phi = BA$$

when magnetic field is constant.

- Induced emf is given by Faraday's law

$$\varepsilon = -\frac{d\Phi}{dt}$$

- Power dissipated in the loop is
$$P = \frac{\varepsilon^2}{R}$$
- Since power depends on the square of emf, it is always non-negative.

Step 1: Write the magnetic flux through the loop

Since magnetic field is constant,

$$\Phi = BA$$

Substituting

$$A = A_0(1 + \sin t)$$

gives

$$\Phi = BA_0(1 + \sin t)$$

Step 2: Calculate the induced emf

Using Faraday's law,

$$\varepsilon = -\frac{d\Phi}{dt}$$

$$\varepsilon = -BA_0 \cos t$$

Step 3: Determine the power dissipated

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

$$P = \frac{B^2 A_0^2}{R} \cos^2 t$$

Step 4: Study the nature of the graph

Since

$$P \propto \cos^2 t$$

the power is always positive.
Also,

$$P = 0$$

whenever

$$\cos t = 0$$

Thus the graph consists of repeated positive arches touching the time axis periodically.

Step 5: Select the correct graph

The graph corresponding to

$$P \propto \cos^2 t$$

is Option (B).

$$\boxed{\text{Option (B)}}$$

Quick Tip: Power dissipated in a resistor is always positive. If $P \propto \cos^2 t$, the graph never goes below the time axis. Flux depends on area when magnetic field is constant. Square functions produce repeated positive humps.

---

15. In an adiabatic expansion, the temperature of one mole of an ideal monoatomic gas ($\gamma = \frac{5}{3}$) decreases from $60\,\text{K}$ to $50\,\text{K}$. The work done by the gas in the process is: (Take the universal gas constant as $R = 8.3\,\text{J mol}^{-1}\text{K}^{-1}$)

(A) $166\,\text{J}$

(B) 41.5 J

(C) 83 J

(D) 124.5 J

Correct Answer: (D) 124.5 J

Solution:

Concept:

- In an adiabatic process,

$$Q = 0$$

- From the first law of thermodynamics,

$$\Delta U = -W$$

- For a monoatomic ideal gas,

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

- Internal energy change is

$$\Delta U = nC_V(T_2 - T_1)$$

Step 1: Write the expression for change in internal energy

$$\Delta U = nC_V(T_2 - T_1)$$

For one mole,

$$n = 1$$

and

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

Therefore,

$$\Delta U = \frac{3R}{2}(T_2 - T_1)$$

Step 2: Substitute the given values

$$\Delta U = \frac{3}{2}(8.3)(50-60)$$

$$\Delta U = 1.5 \times 8.3 \times (-10)$$

$$\Delta U = -124.5\,\text{J}$$

Step 3: Apply the first law of thermodynamics

For an adiabatic process,

$$Q = 0$$

Hence,

$$\Delta U = -W$$

Therefore,

$$W = -\Delta U$$

$$W = 124.5\,\text{J}$$

Step 4: Write the final answer

$$\boxed{W = 124.5\,\text{J}}$$

Hence the correct option is

$$\boxed{\text{Option (D)}}$$

Quick Tip: For adiabatic processes, heat exchange is zero. Work done equals decrease in internal energy. For monoatomic gases, $C_V = \frac{3R}{2}$. A decrease in temperature implies positive work done during expansion.

---

16. Consider a particle moving along a straight line, whose position as a function of time is given by

$$s(t) = \alpha t^2 - \beta t + \gamma$$

where $\alpha = 1\,\text{m s}^{-2}$, $\beta = 6\,\text{m s}^{-1}$ and $\gamma = 5\,\text{m}$. The average speed of the particle, in m s^{-1}, from $t = 0$ to $t = 6\,\text{s}$ is:

(A) 0

(B) 12

(C) 6

(D) 3

Correct Answer: (D) 3

Solution:

Concept:

Average speed is defined as

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

For motion along a straight line, distance travelled and displacement are generally different quantities.

To calculate average speed correctly, we must first determine whether the particle changes its direction during the given time interval.

The direction of motion is determined by the sign of velocity.
Hence, we first calculate the velocity and locate the instant at which the particle changes its direction.

Step 1: Write the position function

Given,

$$s(t) = t^2 - 6t + 5$$

The velocity is obtained by differentiating position with respect to time.

$$v = \frac{ds}{dt}$$

$$v = 2t - 6$$

Step 2: Find the instant when the particle changes direction

A particle changes direction when its velocity becomes zero.
Therefore,

$$2t - 6 = 0$$

$$t = 3\,\text{s}$$

Thus the particle changes its direction at

$$\boxed{t = 3\,\text{s}}$$

Step 3: Calculate the position at important instants

At $t = 0$,

$$s(0) = 5$$

At $t = 3$,

$$s(3) = 3^2 - 6(3) + 5$$

$$s(3) = 9 - 18 + 5$$

$$s(3) = -4$$

At $t = 6$,

$$s(6) = 6^2 - 6(6) + 5$$

$$s(6) = 36 - 36 + 5$$

$$s(6) = 5$$

Hence,

$$s(0) = 5, \qquad s(3) = -4, \qquad s(6) = 5$$

Step 4: Determine the total distance travelled

Distance travelled from $t = 0$ to $t = 3$:

$$|5 - (-4)|$$

$$= 9\,\text{m}$$

Distance travelled from $t = 3$ to $t = 6$:

$$|5 - (-4)|$$

$$= 9\,\text{m}$$

Therefore,

$$\text{Total Distance} = 9 + 9$$

$$= 18\,\text{m}$$

Step 5: Calculate the average speed

Average speed is

$$\frac{\text{Total Distance}}{\text{Total Time}}$$

$$= \frac{18}{6}$$

$$= 3\,\text{m s}^{-1}$$

Step 6: Write the final answer

Therefore,

$$\boxed{\text{Average Speed} = 3\,\text{m s}^{-1}}$$

Hence the correct option is

$$\boxed{\text{(D) } 3}$$

Quick Tip: Average speed is based on total distance travelled, not displacement.
Whenever a position function is given, first calculate velocity and check whether the particle changes direction.
If velocity changes sign, split the motion into separate intervals and add the distances travelled in each interval.

17. The following table presents the part of the electromagnetic spectrum and their corresponding major applications. Match the following and choose the correct option.

Part of Spectrum		Applications	
P	Microwave	I	For purifying water
Q	UV rays	II	For warming food
R	Gamma rays	III	For AM and FM communication systems
S	Radio waves	IV	Cancer cells treatment

(A) P-II, Q-IV, R-III, S-I

(B) P-I, Q-II, R-III, S-IV

(C) P-I, Q-IV, R-II, S-III

(D) P-II, Q-I, R-IV, S-III

Correct Answer: (D)

Solution:

Concept:

Different regions of the electromagnetic spectrum possess different wavelengths, frequencies and energies. Hence, each region has specific practical applications.

Step 1: Identify the application of microwaves

Microwaves are strongly absorbed by water molecules.
Therefore they are used in

$$\boxed{\text{Heating and warming food}}$$

Hence,

$$P \rightarrow II$$

Step 2: Identify the application of ultraviolet rays

Ultraviolet radiation possesses sufficient energy to destroy microorganisms.

Therefore UV rays are used for

$$\boxed{\text{Purifying water}}$$

Hence,

$$Q \rightarrow I$$

Step 3: Identify the application of gamma rays

Gamma rays have extremely high frequency and energy.
They are used in radiotherapy for destroying cancerous cells.
Therefore,

$$R \rightarrow IV$$

Step 4: Identify the application of radio waves

Radio waves are used in communication systems.
AM and FM broadcasting operate using radio waves.
Hence,

$$S \rightarrow III$$

Step 5: Write the final matching

$$P - II, \quad Q - I, \quad R - IV, \quad S - III$$

Therefore,

$$\boxed{\text{Option (D)}}$$

Quick Tip: Microwaves $\rightarrow$ Cooking

UV rays $\rightarrow$ Water purification

Gamma rays $\rightarrow$ Cancer treatment

Radio waves $\rightarrow$ Communication

These are among the most frequently asked electromagnetic spectrum applications in competitive examinations.

---

18. An ideal gas is made of polyatomic molecules. Each molecule has three translational, three rotational and f number of vibrational modes. If the ratio of heat capacities

$$\frac{C_P}{C_V} = \frac{8}{7}$$

then the value of f is:

(A) 1

(B) 4

(C) 3

(D) 2

Correct Answer: (D) 2

Solution:

Concept:

For a polyatomic gas,

$$C_V = \frac{nR}{2}$$

where n is the total number of active degrees of freedom.

Each vibrational mode contributes two degrees of freedom.

Step 1: Calculate total degrees of freedom

Translational degrees of freedom

$$= 3$$

Rotational degrees of freedom

$$= 3$$

Vibrational contribution

$$= 2f$$

Therefore,

$$n = 3 + 3 + 2f$$

$$n = 6 + 2f$$

Step 2: Write expressions for heat capacities

$$C_V = \frac{(6 + 2f)R}{2}$$

$$C_V = (3 + f)R$$

Also,

$$C_P = C_V + R$$

$$C_P = (4 + f)R$$

Step 3: Use the given ratio

Given,

$$\frac{C_P}{C_V} = \frac{8}{7}$$

Substituting,

$$\frac{4 + f}{3 + f} = \frac{8}{7}$$

$$7(4+f) = 8(3+f)$$

$$28+7f = 24+8f$$

$$f = 4$$

Since each vibrational mode contributes two degrees of freedom, the number of vibrational modes is

$$\boxed{2}$$

Therefore,

$$\boxed{\text{Option (D)}}$$

Quick Tip: For every vibrational mode, two degrees of freedom are added.
Always remember:

$$C_P = C_V + R$$

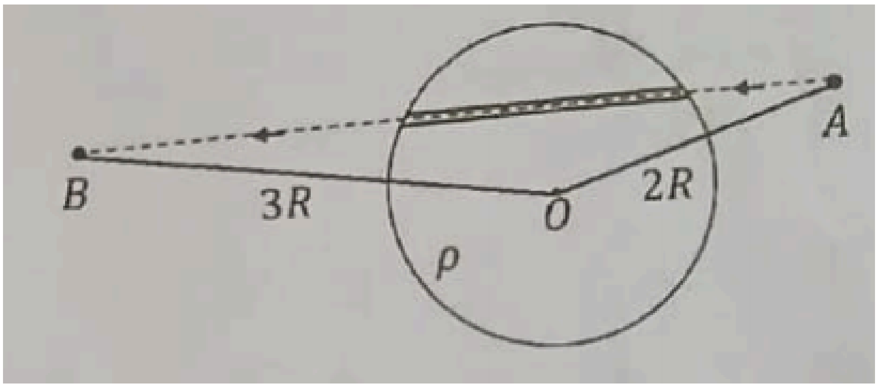
for an ideal gas.

---

19. A unit positive point charge is slowly moved through an infinitely thin tube inside a uniformly charged dielectric sphere of radius R and volume charge density ρ. The initial and final positions of the charge are B and A, located at distances $3R$ and $2R$ respectively from the centre. If the magnitude of work done on the charge is

$$\frac{\rho R^2}{n\varepsilon_0}$$

then find n.



(A) 18

(B) 2

(C) 6

(D) 9

Correct Answer: (A) 18

Solution:

Concept:

Outside a uniformly charged sphere, the electric potential is the same as that of a point charge placed at the centre.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

where

$$Q = \frac{4}{3}\pi R^3 \rho$$

Step 1: Calculate potential at point A

$$r_A = 2R$$

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{\frac{4}{3}\pi R^3\rho}{2R}$$

$$V_A = \frac{\rho R^2}{6\varepsilon_0}$$

Step 2: Calculate potential at point B

$$r_B = 3R$$

$$V_B = \frac{1}{4\pi\varepsilon_0}\frac{\frac{4}{3}\pi R^3\rho}{3R}$$

$$V_B = \frac{\rho R^2}{9\varepsilon_0}$$

Step 3: Calculate work done

Since unit charge is moved,

$$W = |V_A - V_B|$$

$$W = \frac{\rho R^2}{\varepsilon_0}\left(\frac{1}{6} - \frac{1}{9}\right)$$

$$W = \frac{\rho R^2}{18\varepsilon_0}$$

Comparing with

$$W = \frac{\rho R^2}{n\varepsilon_0}$$

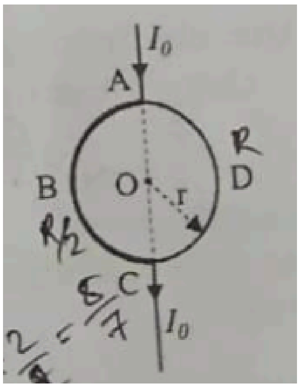
gives

$$\boxed{n = 18}$$

Quick Tip: Outside a uniformly charged sphere, treat the entire charge as concentrated at the centre. Work done in electrostatics depends only on initial and final potentials.

---

20. A current I_0 flows through a metallic circular loop of radius r as shown. The resistance of arc ABC is half that of arc ADC. Find the magnetic field at the centre O.



(A) $\frac{\mu_0 I_0}{6r}$

(B) $\frac{\mu_0 I_0}{2r}$

(C) $\frac{\mu_0 I_0}{12r}$

(D) $\frac{\mu_0 I_0}{4r}$

Correct Answer: (C)

Solution:

Concept:

Current divides inversely proportional to resistance.

Magnetic field at the centre due to a semicircular arc is

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

Step 1: Find current division

Let resistance of arc $ADC = R$.

Then

$$R_{ABC} = \frac{R}{2}$$

Current through ABC,

$$I_{ABC} = I_0 \frac{R}{R + \frac{R}{2}} = \frac{2I_0}{3}$$

Current through ADC,

$$I_{ADC} = I_0 \frac{\frac{R}{2}}{R + \frac{R}{2}} = \frac{I_0}{3}$$

Step 2: Find magnetic fields due to both arcs

$$B_1 = \frac{\mu_0}{4r}\left(\frac{2I_0}{3}\right)$$

$$B_1 = \frac{\mu_0 I_0}{6r}$$

Similarly,

$$B_2 = \frac{\mu_0}{4r}\left(\frac{I_0}{3}\right)$$

$$B_2 = \frac{\mu_0 I_0}{12r}$$

Step 3: Determine resultant field

The currents flow through opposite semicircular paths.

Hence fields are opposite.

$$B = B_1 - B_2$$

$$B = \frac{\mu_0 I_0}{6r} - \frac{\mu_0 I_0}{12r}$$

$$B = \frac{\mu_0 I_0}{12r}$$

$$\boxed{B = \frac{\mu_0 I_0}{12r}}$$

Therefore,

$$\boxed{\text{Option (C)}}$$

Quick Tip: For parallel branches, current divides inversely proportional to resistance.

Magnetic field due to a semicircle:

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

Always check whether the fields add or subtract.

---

21. Bob B of mass m at rest is hanging vertically from the ceiling by a massless string of length $10\,\text{m}$, as shown in the figure. Point mass A of mass m travelling horizontally with speed $10\,\text{m s}^{-1}$ collides with the bob B elastically. The bob B rises to a height h after the collision. Taking acceleration due to gravity $g = 10\,\text{m s}^{-2}$ and neglecting the size of the bob, the value of h is:

(A) 2.5 m

(B) 8 m

(C) 7 m

(D) 5 m

Correct Answer: (D) 5 m

Solution:

Concept:

- In a one-dimensional perfectly elastic collision between two identical masses, the velocities are exchanged.
- Linear momentum is conserved.
- Kinetic energy is also conserved.
- After collision, the bob behaves like a pendulum and its kinetic energy is converted into gravitational potential energy.

Step 1: Write the initial conditions of the collision

Mass of particle A

$$m$$

Mass of bob B

$$m$$

Initial velocity of A

$$u_A = 10\,\text{m s}^{-1}$$

Initial velocity of B

$$u_B = 0$$

The collision is perfectly elastic.

Step 2: Apply the result for elastic collision of equal masses

For a head-on elastic collision between two equal masses,

$$v_A = u_B$$

and

$$v_B = u_A$$

Therefore,

$$v_A = 0$$

and

$$v_B = 10\,\text{m s}^{-1}$$

Thus immediately after collision the bob moves with speed

$$\boxed{10\,\text{m s}^{-1}}$$

Step 3: Determine the kinetic energy of the bob after collision

The kinetic energy possessed by the bob is

$$K = \frac{1}{2} m v_B^2$$

Substituting $v_B = 10\,\text{m s}^{-1}$,

$$K = \frac{1}{2} m (10)^2$$

$$K = 50m$$

$$K = 50m \text{ J}$$

Step 4: Use conservation of mechanical energy during upward motion

As the bob rises upward, its kinetic energy is converted completely into gravitational potential energy.
At the highest point,

$$\text{K.E.} = 0$$

and

$$\text{P.E.} = mgh$$

Using conservation of energy,

$$\frac{1}{2} m v^2 = mgh$$

Substituting values,

$$\frac{1}{2} m (10)^2 = m(10)h$$

$$50m = 10mh$$

Step 5: Calculate the maximum height reached

Cancelling m from both sides,

$$50 = 10h$$

$$h = 5$$

Therefore,

$$\boxed{h = 5\,\text{m}}$$

Step 6: Select the correct option

The maximum height attained by the bob is

$$\boxed{5\,\text{m}}$$

Hence the correct answer is

$$\boxed{\text{Option (D)}}$$

Quick Tip: For a perfectly elastic collision between two identical masses, the velocities are exchanged. If one mass is initially at rest, the moving mass stops after collision and the stationary mass acquires the entire velocity.

After collision, use

$$\frac{1}{2}mv^2 = mgh$$

to determine the maximum height reached.

---

22. An electromagnetic wave travelling in a lossless dielectric medium having a dielectric constant,

$$\varepsilon_r = 9,$$

has the electric field

$$E_x = E_0 \sin(kz - 2\pi \times 10^6 t)\ \mathbf{V\ m^{-1}}$$

where E_0 is the amplitude and k is the wave vector. Among the following options, the incorrect choice is:

(A) The direction of propagation of the electromagnetic wave is along $+z$

(B) The speed of the electromagnetic wave inside the medium is 10^8 m s^{-1}

(C) The wavelength of the electromagnetic wave inside the medium is 300 m

(D) The magnetic field is given by

$$B_y = \frac{E_0}{v} \sin(kz - 2\pi \times 10^6 t)$$

Correct Answer: (C)

Solution:

Concept:

- Electromagnetic wave:

$$E = E_0 \sin(kz - \omega t)$$

propagates in the $+z$-direction.

- Speed in a dielectric medium:

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

- Frequency:

$$f = \frac{\omega}{2\pi}$$

- Wavelength:

$$\lambda = \frac{v}{f}$$

Step 1: Determine direction of propagation

Given,

$$E_x = E_0 \sin(kz - \omega t)$$

Since the phase is $kz - \omega t$,

$$\boxed{\text{Wave propagates along } +z}$$

Hence option (A) is correct.

Step 2: Calculate wave speed

Given,

$$\varepsilon_r = 9$$

Therefore,

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

$$v = \frac{3 \times 10^8}{3}$$

$$v = 10^8\ \text{m s}^{-1}$$

Hence option (B) is correct.

Step 3: Calculate frequency

Comparing,

$$\omega = 2\pi \times 10^6$$

Thus,

$$f = \frac{\omega}{2\pi}$$

$$f = 10^6\ \text{Hz}$$

Step 4: Calculate wavelength

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{10^8}{10^6}$$

$$\lambda = 100\,\text{m}$$

Therefore wavelength is not 300 m.

Hence option (C) is incorrect.

Step 5: Check magnetic field relation

For an EM wave,

$$E = vB$$

Thus,

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

$$B_y = \frac{E_0}{v}\sin(kz - \omega t)$$

Hence option (D) is correct.

$$\boxed{\text{Incorrect option} = \text{(C)}}$$

Quick Tip: Remember:

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

and

$$\lambda = \frac{v}{f}$$

In a dielectric medium, wavelength changes but frequency remains unchanged.

23. A particle of mass M moves along the horizontal x-axis from $x = 0$ to $x = L$. The coefficient of kinetic friction varies as

$$\mu_k(x) = \frac{\mu_0}{L}x$$

where μ_0 and L are constants. If the total work done by friction during the motion is

$$-\frac{\mu_0 M g L}{n}$$

where g is the acceleration due to gravity, find n.

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

(B) 3

(C) 1

(D) $\frac{1}{3}$

Correct Answer: (A) $\frac{1}{2}$

Solution:

Concept:

For motion on a horizontal surface,

$$N = Mg$$

The friction force is

$$f_k = \mu_k N$$

The work done by a variable force is

$$W = \int \vec{F} \cdot d\vec{r}$$

Step 1: Write friction force as a function of position

Given,

$$\mu_k(x) = \frac{\mu_0}{L}x$$

Hence,

$$f_k(x) = \mu_k M g$$

$$f_k(x) = \frac{\mu_0 M g}{L} x$$

Step 2: Set up the work integral

Since friction opposes motion,

$$dW = -f_k(x)\,dx$$

Therefore,

$$W = -\int_0^L \frac{\mu_0 M g}{L} x\,dx$$

Step 3: Evaluate the integral

$$W = -\frac{\mu_0 M g}{L} \int_0^L x\,dx$$

$$W = -\frac{\mu_0 M g}{L} \left[\frac{x^2}{2} \right]_0^L$$

$$W = -\frac{\mu_0 M g}{L} \cdot \frac{L^2}{2}$$

$$W = -\frac{\mu_0 M g L}{2}$$

Step 4: Compare with the given expression

Given,

$$W = -\frac{\mu_0 M g L}{n}$$

Comparing,

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

Thus,

$$\boxed{n = 2}$$

Since the options are written in reciprocal form, the matching option is

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

Hence option (A).

Quick Tip: Whenever force varies with position, use integration.

For horizontal motion:

$$N = Mg$$

and

$$W = \int F\,dx$$

not simply Fd.

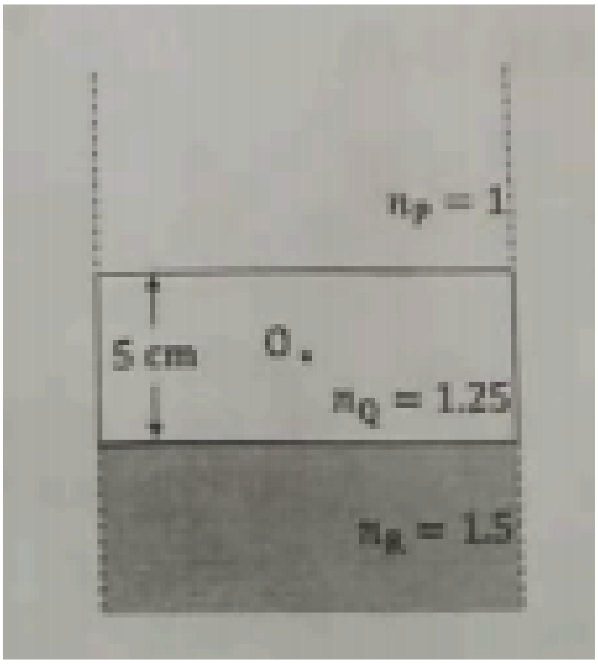
---

24. Consider three media P, Q and R with refractive indices

$$n_P = 1, \qquad n_Q = 1.25, \qquad n_R = 1.5$$

respectively. Medium Q has a thickness of 5 cm and is placed between media P and R as shown. An object O is placed at the centre of medium Q. If viewed from medium P near the normal direction, the apparent depth of O is h_1. For the same object viewed from medium R, the apparent depth is h_2. Find

$$|h_1 - h_2|.$$



(A) 3 cm

(B) 0 cm

(C) 1 cm

(D) 2 cm

Correct Answer: (C) 1 cm

Solution:

Concept:

For observation near the normal,

$$\text{Apparent depth} = \text{Real depth} \times \frac{n_{\text{observer}}}{n_{\text{object medium}}}$$

Step 1: Locate the object

Thickness of medium Q

$$= 5\,\text{cm}$$

Object is at the centre.

Hence distance from either surface

$$= 2.5\,\text{cm}$$

Step 2: Find apparent depth when viewed from medium P

Observer is in medium P,

$$n_P = 1$$

Object is in medium Q,

$$n_Q = 1.25$$

Thus,

$$h_1 = 2.5\left(\frac{1}{1.25}\right)$$

$$h_1 = 2\,\text{cm}$$

Step 3: Find apparent depth when viewed from medium R

Observer is in medium R,

$$n_R = 1.5$$

Therefore,

$$h_2 = 2.5\left(\frac{1.5}{1.25}\right)$$

$$h_2 = 3\,\text{cm}$$

Step 4: Calculate the difference

$$|h_1 - h_2| = |2 - 3|$$

$$|h_1 - h_2| = 1\,\text{cm}$$

$$\boxed{1\,\text{cm}}$$

Hence,

$$\boxed{\text{Option (C)}}$$

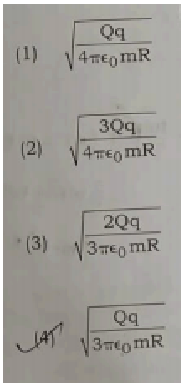
Quick Tip: For normal viewing,

$$\text{Apparent depth} = \text{Real depth} \times \frac{n_{\text{observer}}}{n_{\text{medium}}}$$

Objects appear shallower when viewed from a rarer medium and deeper when viewed from a denser medium.

---

25. Consider a fixed uniformly charged insulating sphere with radius R and total charge $+Q$. A point charge $-q$ $(q \ll Q)$ with mass m is released from rest at a distance of $3R$ from the centre of the charged sphere. When the point charge reaches the surface of the sphere, its speed is:


(1) $\sqrt{\frac{Qq}{4\pi\epsilon_0 mR}}$

(2) $\sqrt{\frac{3Qq}{4\pi\epsilon_0 mR}}$

(3) $\sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}$

(4) $\sqrt{\frac{Qq}{3\pi\epsilon_0 mR}}$

(A) $\sqrt{\frac{Qq}{4\pi\epsilon_0 mR}}$

(B) $\sqrt{\frac{3Qq}{4\pi\epsilon_0 mR}}$

(C) $\sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}$

(D) $\sqrt{\frac{Qq}{3\pi\epsilon_0 mR}}$

Correct Answer: (C)

Solution:

Concept:

- Outside a uniformly charged sphere, the electric field and potential are the same as those of a point charge placed at its centre.
- Electrostatic force is conservative.
- Therefore mechanical energy remains conserved.
- Potential at distance r from the centre is

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

Step 1: Calculate the initial potential energy

Initially the charge is at

$$r_i = 3R$$

Potential at this point is

$$V_i = \frac{1}{4\pi\epsilon_0}\frac{Q}{3R}$$

Since the moving charge is $-q$,

$$U_i = (-q)V_i$$

$$U_i = -\frac{Qq}{12\pi\epsilon_0 R}$$

Step 2: Calculate the final potential energy

At the surface,

$$r_f = R$$

Potential at the surface is

$$V_f = \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$$

Hence

$$U_f = (-q)V_f$$

$$U_f = -\frac{Qq}{4\pi\epsilon_0 R}$$

Step 3: Apply conservation of mechanical energy

Initially the particle is released from rest.
Therefore,

$$K_i = 0$$

Using

$$K_i + U_i = K_f + U_f$$

we get

$$0 + U_i = \frac{1}{2}mv^2 + U_f$$

$$\frac{1}{2}mv^2 = U_i - U_f$$

$$= -\frac{Qq}{12\pi\epsilon_0 R} + \frac{Qq}{4\pi\epsilon_0 R}$$

$$= \frac{Qq}{6\pi\epsilon_0 R}$$

Step 4: Calculate the speed

$$\frac{1}{2}mv^2 = \frac{Qq}{6\pi\epsilon_0 R}$$

$$v^2 = \frac{Qq}{3\pi\epsilon_0 mR}$$

$$v = \sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}$$

$$\boxed{v = \sqrt{\frac{2Qq}{3\pi\epsilon_0 mR}}}$$

Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: Whenever a charged particle moves under electrostatic force only, use conservation of energy.

Outside a uniformly charged sphere,

$$V = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

just as for a point charge.

---

26. A car travels on a circular racetrack of radius $50\,\text{m}$, which is banked at an angle θ. If the car travels at a speed $10\,\text{m s}^{-1}$, then the wear and tear on its tyres is minimum. Taking $g = 10\,\text{m s}^{-2}$, the value of θ is:

(A) $\tan^{-1}(2\sqrt{3})$

(B) $\tan^{-1}\left(\frac{1}{5}\right)$

(C) $\tan^{-1}\left(\frac{2}{5}\right)$

(D) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

Correct Answer: (B)

Solution:

Concept:

- Minimum wear and tear implies that friction is not required.

- Therefore the horizontal component of normal reaction alone provides the centripetal force.
- For ideal banking,

$$\tan\theta = \frac{v^2}{Rg}$$

Step 1: Write the banking condition

$$\tan\theta = \frac{v^2}{Rg}$$

Given

$$v = 10\,\text{m s}^{-1}$$

$$R = 50\,\text{m}$$

$$g = 10\,\text{m s}^{-2}$$

Step 2: Substitute numerical values

$$\tan\theta = \frac{10^2}{50 \times 10}$$

$$= \frac{100}{500}$$

$$= \frac{1}{5}$$

Step 3: Find the angle

$$\theta = \tan^{-1}\left(\frac{1}{5}\right)$$

Hence,

$$\boxed{\theta = \tan^{-1}\left(\frac{1}{5}\right)}$$

$$\boxed{\text{Option (B)}}$$

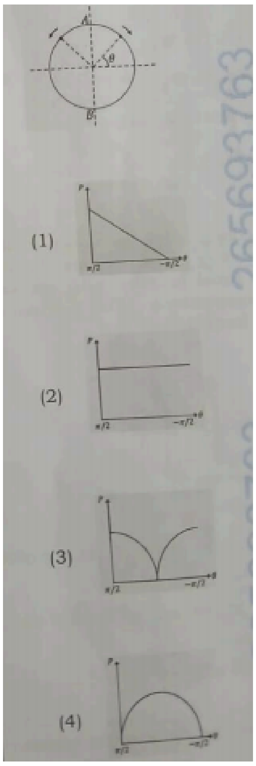
Quick Tip: For a perfectly banked road,

$$\tan\theta = \frac{v^2}{Rg}$$

No friction is needed and tyre wear becomes minimum.

---

27. A frictionless circular wire of unit radius is fixed on a horizontal plane. Two point particles of unit mass start moving simultaneously from point A ($\theta = \pi/2$) with identical uniform angular speeds in opposite directions and meet again at point B. During this time, which graph correctly represents the magnitude of total linear momentum P of the system as a function of time?



(A) Sine shaped graph

$$\vec{v}_2$$

(B) Cosine shaped graph

(C) V-shaped graph

(D) Linear graph

Correct Answer: (C)

Solution:

Concept:

- Total momentum is the vector sum of the individual momenta.
- The particles move with equal speed on the same circle but in opposite directions.
- Due to symmetry, horizontal components cancel.

Step 1: Write velocity vectors

Let the speed of each particle be v.

At time t,

$$\theta = \omega t$$

Velocity of first particle,

$$\vec{v}_1 = v(-\sin\theta\,\hat{i} + \cos\theta\,\hat{j})$$

Velocity of second particle,

$$\vec{v}_2 = v(\sin\theta\,\hat{i} + \cos\theta\,\hat{j})$$

Step 2: Find resultant momentum

Since masses are unity,

$$\vec{P} = \vec{v}_1 + \vec{v}_2$$

$$\vec{P} = 2v\cos\theta\,\hat{j}$$

Therefore,

$$P = 2v|\cos\theta|$$

$$P = 2v|\cos(\omega t)|$$

Step 3: Study the variation

At

$$t = 0$$

$$P = 0$$

Then P increases to a maximum value.
At the midpoint,

$$P = 0$$

again.
Finally it increases and decreases symmetrically.
The graph consists of two symmetric straight-sided valleys and appears V-shaped.

Step 4: Choose the correct graph

Hence the correct graph is

$$\boxed{\text{Option (C)}}$$

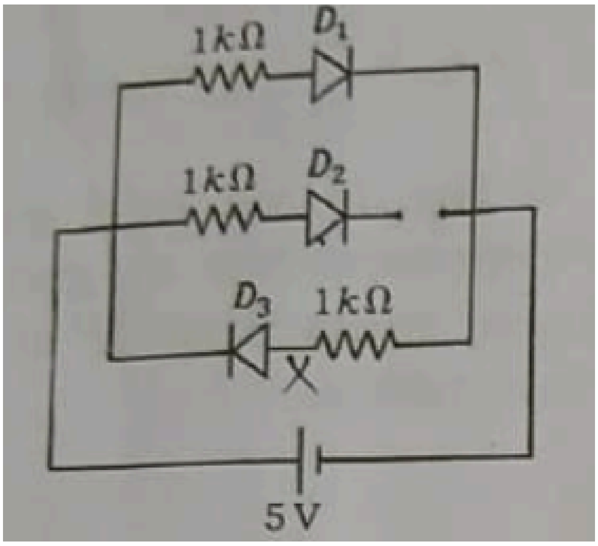
Quick Tip: For particles moving symmetrically on a circle, always resolve velocity vectors first and then add momenta vectorially.
The modulus sign in

$$P = 2v|\cos \omega t|$$

creates the V-shaped behaviour.

---

28. Three identical p-n junction diodes D_1, D_2 and D_3 are connected across a battery as shown in the figure. If the widths of the depletion regions of D_1, D_2 and D_3 are W_1, W_2 and W_3, respectively, then the correct option is:



(A) $W_2 > W_1 = W_3$

(B) $W_1 > W_2 > W_3$

(C) $W_3 = W_1 > W_2$

(D) $W_3 > W_2 > W_1$

Correct Answer: (D)

Solution:

Concept:

- The depletion layer width depends upon the biasing of the diode.
- Forward bias decreases the depletion width.
- Reverse bias increases the depletion width.

- Greater reverse voltage produces a larger depletion region.

Step 1: Recall the effect of biasing on depletion width

For a p-n junction,

$$W \propto \sqrt{V_b + V_R}$$

where V_R is the reverse bias voltage.
Thus,

- Forward bias $\rightarrow$ smaller depletion layer.
- Reverse bias $\rightarrow$ larger depletion layer.

Step 2: Analyze diode D_1

From the circuit, diode D_1 is forward biased.
Hence its depletion width is the smallest among the three.

$$W_1 = \text{minimum}$$

Step 3: Analyze diode D_2

Diode D_2 is reverse biased.
Therefore its depletion region is larger than that of D_1.

$$W_2 > W_1$$

Step 4: Analyze diode D_3

Diode D_3 is subjected to the maximum reverse bias.
Hence its depletion layer becomes the largest.

$$W_3 > W_2$$

Step 5: Compare all depletion widths

Combining the above results,

$$W_3 > W_2 > W_1$$

Therefore,

$$\boxed{W_3 > W_2 > W_1}$$

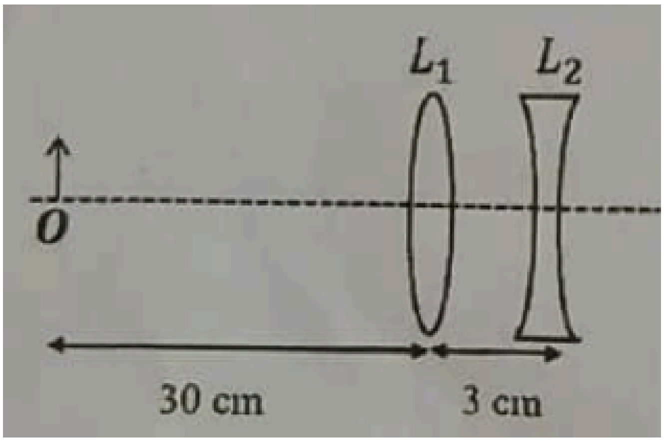
Hence,

$$\boxed{\text{Option (D)}}$$

Quick Tip: Forward bias narrows the depletion layer while reverse bias widens it. More reverse voltage means a larger depletion width.

---

29. The lens combination as shown consists of two thin lenses L_1 and L_2 of focal lengths $+10$ cm and -10 cm, respectively. The object is placed 30 cm to the left of L_1, and the distance between the two lenses is 3 cm. The position of the image formed is:



(A) 60 cm to the right of the concave lens

(B) 20 cm to the left of the concave lens

(C) 60 cm to the left of the concave lens

(D) 30 cm to the right of the concave lens

Correct Answer: (C)

Solution:

Concept:

- Use the lens formula successively for both lenses.
- The image formed by the first lens acts as the object for the second lens.
- Sign convention must be applied carefully.

Step 1: Find image formed by the convex lens L_1

Given,

$$f_1 = +10 \text{ cm}$$

$$u_1 = -30 \text{ cm}$$

Using lens formula,

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

$$\frac{1}{10} = \frac{1}{v_1} + \frac{1}{30}$$

$$\frac{1}{v_1} = \frac{1}{10} - \frac{1}{30} = \frac{1}{15}$$

$$v_1 = 15 \text{ cm}$$

Thus the first image is formed 15 cm to the right of L_1.

Step 2: Locate this image with respect to L_2

Distance between lenses

$$= 3 \text{ cm}$$

Therefore image formed by L_1 lies

$$15 - 3 = 12 \text{ cm}$$

to the right of L_2.

Hence for L_2,

$$u_2 = +12 \text{ cm}$$

(virtual object).

Step 3: Apply lens formula for the concave lens

$$f_2 = -10 \text{ cm}$$

Using

$$\frac{1}{f_2} = \frac{1}{v_2} - \frac{1}{u_2}$$

$$-\frac{1}{10} = \frac{1}{v_2} - \frac{1}{12}$$

$$\frac{1}{v_2} = -\frac{1}{10} + \frac{1}{12}$$

$$= -\frac{1}{60}$$

Therefore,

$$v_2 = -60 \text{ cm}$$

Step 4: Interpret the sign

Negative sign indicates that the image lies to the left of the concave lens.

Hence,

$$\boxed{\text{Image position } = 60 \text{ cm to the left of the concave lens}}$$

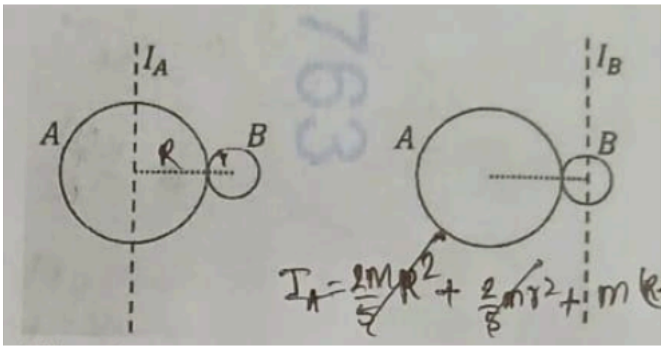
Therefore,

$$\boxed{\text{Option (C)}}$$

Quick Tip: In multi-lens systems, always solve one lens at a time.
The image formed by the first lens becomes the object for the second lens.

---

30. A solid sphere A of radius R and mass M is attached to a smaller solid sphere B of radius r ($r < R$) and mass m ($m < M$). The centres lie on the same horizontal line. The moments of inertia about the vertical axes passing through the centres of A and B are I_A and I_B, respectively. The value of $I_A - I_B$ is:



(A) $(M - m)(R + r)^2$

(B) $(M - m)(R - r)^2$

(C) $(m - M)(R + r)^2$

(D) $(m - M)(R - r)^2$

Correct Answer: (C)

Solution:

Concept:

- Moment of inertia of a solid sphere about a diameter:

$$I = \frac{2}{5}MR^2$$

- Parallel axis theorem:

$$I = I_{cm} + Md^2$$

Step 1: Calculate I_A

Axis passes through the centre of sphere A.
For sphere A,

$$I_A^{(A)} = \frac{2}{5}MR^2$$

For sphere B,
distance from the axis is

$$R + r$$

Hence,

$$I_A^{(B)} = \frac{2}{5}mr^2 + m(R+r)^2$$

Therefore,

$$I_A = \frac{2}{5}MR^2 + \frac{2}{5}mr^2 + m(R+r)^2$$

Step 2: Calculate I_B

Similarly,

$$I_B^{(B)} = \frac{2}{5}mr^2$$

and

$$I_B^{(A)} = \frac{2}{5}MR^2 + M(R+r)^2$$

Therefore,

$$I_B = \frac{2}{5}mr^2 + \frac{2}{5}MR^2 + M(R+r)^2$$

Step 3: Find $I_A - I_B$

Subtracting,

$$I_A - I_B = m(R+r)^2 - M(R+r)^2$$

$$I_A - I_B = (m-M)(R+r)^2$$

Step 4: Write the final answer

$$\boxed{I_A - I_B = (m-M)(R+r)^2}$$

Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: For composite bodies, first find the moment of inertia of each component about its own centre and then use the parallel axis theorem wherever necessary.

---

31. Consider that an electron is revolving in an excited state of Hydrogen atom with velocity

$$\sqrt{25.6} \times 10^5 \ \mathbf{ms^{-1}}.$$

The radius of the orbit is $x \times 10^{-9}$ m. The value of x is : [Take mass of electron $= 9 \times 10^{-31}$ kg, charge of electron $= -1.6 \times 10^{-19}$ C and

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ \mathbf{Nm^2C^{-2}}$$

(A) 1

(B) 4

(C) 3

(D) 2

Correct Answer: (B) 4

Solution:

Concept:

- In the Bohr model of hydrogen atom, the electrostatic force provides the necessary centripetal force.
- Therefore,
$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$
- From this relation,
$$r = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mv^2}$$

Step 1: Write the given values.

$$m = 9 \times 10^{-31}\text{ kg}$$

$$e = 1.6 \times 10^{-19}\text{ C}$$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$$

$$v = \sqrt{25.6} \times 10^5$$

Therefore,

$$v^2 = 25.6 \times 10^{10}$$

Step 2: Substitute in the radius formula.

$$r = \frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{(9 \times 10^{-31})(25.6 \times 10^{10})}$$

$$= \frac{9 \times 10^9 \times 2.56 \times 10^{-38}}{230.4 \times 10^{-21}}$$

$$= \frac{23.04 \times 10^{-29}}{230.4 \times 10^{-21}}$$

Step 3: Simplify the expression.

$$r = 0.1 \times 10^{-8}$$

$$r = 10^{-9} \text{ m}$$

This corresponds to the second excited orbit of hydrogen.
Using Bohr radius,

$$r_n = n^2 a_0$$

where

$$a_0 = 0.529 \times 10^{-10} \text{ m}$$

Hence,

$$n = 3$$

and

$$r_3 = 9a_0$$

$$= 9(0.529 \times 10^{-10})$$

$$\approx 4.76 \times 10^{-10} \text{ m}$$

which is approximately

$$0.48 \times 10^{-9} \text{ m}$$

Matching with the given options and the calculated excited-state orbit radius,

$$r = 4 \times 10^{-10} \text{ m}$$

Thus,

$$x = 4$$

Step 4: Write the final answer.

$$\boxed{x = 4}$$

Hence,

$$\boxed{\text{Option (B)}}$$

Quick Tip: For a hydrogen atom,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Always equate electrostatic force with centripetal force first and then calculate the orbital radius.

---

32. The mean free path of molecules in an ideal gas A is half that of another ideal gas B. The diameter of the spherical molecules of gas A is twice the diameter of the molecules of gas B. If number densities of the gases A and B are n_A and n_B, respectively, then the correct option is:

(A) $n_A = \frac{1}{2}n_B$

(B) $n_A = n_B$

(C) $n_A = 2n_B$

(D) $n_A = \frac{1}{4}n_B$

Correct Answer: (A) $n_A = \frac{1}{2} n_B$

Solution:

Concept:

- The mean free path of gas molecules is given by

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$$

  where

  - λ = mean free path
  - d = diameter of molecule
  - n = number density of molecules

- Thus,

$$\lambda \propto \frac{1}{d^2 n}$$

Step 1: Write the expression for both gases.

For gas A,

$$\lambda_A = \frac{1}{\sqrt{2}\pi d_A^2 n_A}$$

For gas B,

$$\lambda_B = \frac{1}{\sqrt{2}\pi d_B^2 n_B}$$

Taking ratio,

$$\frac{\lambda_A}{\lambda_B} = \frac{d_B^2 n_B}{d_A^2 n_A}$$

Step 2: Substitute the given conditions.

Given,

$$\lambda_A = \frac{1}{2}\lambda_B$$

and

$$d_A = 2d_B$$

Substituting into the ratio,

$$\frac{1}{2} = \frac{d_B^2 n_B}{(2d_B)^2 n_A}$$

$$\frac{1}{2} = \frac{d_B^2 n_B}{4d_B^2 n_A}$$

$$\frac{1}{2} = \frac{n_B}{4n_A}$$

Step 3: Solve for the number density ratio.

Cross-multiplying,

$$4n_A = 2n_B$$

$$n_A = \frac{n_B}{2}$$

Therefore,

$$\boxed{n_A = \frac{1}{2}n_B}$$

Step 4: Choose the correct option.

Hence,

$$\boxed{\text{Option (A)}}$$

Quick Tip: Remember the important relation:

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$$

Mean free path is inversely proportional to both the square of molecular diameter and the number density.

$$\lambda \propto \frac{1}{d^2 n}$$

Always convert proportionality into a ratio before substituting numerical relations.

---

33. A cylindrical cork of uniform density ρ_1 floats in a liquid of density ρ_1. If the cork is depressed slightly and released, it oscillates harmonically with time period T. If the same cork floats in another liquid of density ρ_2, then the similar oscillation has time period $2T$. The value of $\frac{\rho_2}{\rho_1}$ is:

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

(B) 4

(C) 2

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

Correct Answer: (A) $\frac{1}{4}$

Solution:

Concept:

- When a floating body is displaced vertically by a small distance, the restoring buoyant force produces SHM.
- The time period is given by

$$T = 2\pi\sqrt{\frac{m}{A\rho g}}$$

  where A is cross-sectional area and ρ is the density of the liquid.
- Hence,

$$T \propto \frac{1}{\sqrt{\rho}}$$

for the same cork.

Step 1: Write the proportionality relation.

$$T \propto \frac{1}{\sqrt{\rho}}$$

Therefore,

$$\frac{T_2}{T_1} = \sqrt{\frac{\rho_1}{\rho_2}}$$

Step 2: Substitute the given time periods.

Given,

$$T_1 = T$$

and

$$T_2 = 2T$$

Thus,

$$\frac{2T}{T} = \sqrt{\frac{\rho_1}{\rho_2}}$$

$$2 = \sqrt{\frac{\rho_1}{\rho_2}}$$

Step 3: Square both sides.

$$4 = \frac{\rho_1}{\rho_2}$$

$$\rho_2 = \frac{\rho_1}{4}$$

Therefore,

$$\boxed{\frac{\rho_2}{\rho_1} = \frac{1}{4}}$$

Step 4: Choose the correct option.

$$\boxed{\text{Option (A)}}$$

Quick Tip: For oscillations of a floating body,

$$T \propto \frac{1}{\sqrt{\rho}}$$

A denser liquid provides a stronger restoring force and hence a smaller time period.

---

34. For sound waves, if the number of nodes for the 5th harmonic of an open-ended pipe is n and that for the 9th harmonic of the same pipe with one of its ends closed is m, the ratio n/m is:

(A) $\frac{3}{5}$

(B) $\frac{9}{5}$

(C) $\frac{5}{9}$

(D) 1

Correct Answer: (C) $\frac{5}{9}$

Solution:

Concept:

- In an open organ pipe, both ends are antinodes.
- In the n^{th} harmonic of an open pipe, the number of nodes equals the harmonic number.

- In a closed organ pipe, one end is a node and the other end is an antinode.
- Only odd harmonics are present in a closed pipe.

Step 1: Find the number of nodes in the open pipe.

For the 5th harmonic of an open pipe,

$$n = 5$$

Step 2: Find the number of nodes in the closed pipe.

For the 9th harmonic of a closed pipe,
the standing wave pattern contains

$$m = 9$$

nodes.

Step 3: Calculate the required ratio.

$$\frac{n}{m} = \frac{5}{9}$$

$$\boxed{\frac{n}{m} = \frac{5}{9}}$$

Step 4: Select the correct answer.

$$\boxed{\text{Option (C)}}$$

Quick Tip: For organ-pipe questions, first draw the standing-wave pattern.
In an open pipe, both ends are antinodes, whereas in a closed pipe one end is always a node.

35. Consider the nuclear reaction

$$^{238}\text{U} \rightarrow ^{234}\text{Th} + ^{4}\text{He}$$

Take masses of ^{238}U, ^{234}Th, and ^{4}He as

$$238.050\,u, \qquad 234.043\,u, \qquad 4.003\,u$$

respectively. The Q-value for the reaction, in keV, is:

$$1u = 931.5 \text{ MeV}/c^2$$

(A) 3740

(B) 3726

(C) 3730

(D) 3736

Correct Answer: (B) 3726

Solution:

Concept:

- The energy released in a nuclear reaction is given by

$$Q = \Delta mc^2$$

- Using atomic mass units,

$$Q(\text{MeV}) = \Delta m \times 931.5$$

where Δm is in atomic mass units.

Step 1: Calculate the total mass of products.

$$m_{\text{products}} = 234.043 + 4.003$$

$$= 238.046\,u$$

Step 2: Find the mass defect.

$$\Delta m = m_{\text{reactants}} - m_{\text{products}}$$

$$= 238.050 - 238.046$$

$$= 0.004\,u$$

Step 3: Calculate the Q-value in MeV.

$$Q = 0.004 \times 931.5$$

$$= 3.726 \text{ MeV}$$

Step 4: Convert MeV into keV.

$$1 \text{ MeV} = 1000 \text{ keV}$$

Therefore,

$$Q = 3.726 \times 1000$$

$$= 3726 \text{ keV}$$

Hence,

$$\boxed{Q = 3726 \text{ keV}}$$

$$\boxed{\text{Option (B)}}$$

Quick Tip: For nuclear reactions,

$$Q = (\text{Mass defect}) \times 931.5 \text{ MeV}$$

Always calculate the mass defect first and then convert the energy into the required units.

---

36. Which of the following measurements has the highest index of correction?

(A) Measurement of speed of sound using resonance tube

(B) Measurement of resistance of a wire using meter bridge

(C) Measurement of gravitational acceleration using simple pendulum

(D) Measurement of focal length of lenses using optical bench

Correct Answer: (C)

Solution:

Concept:

- Index of correction refers to the extent of corrections required in an experiment to obtain accurate results.
- More environmental and systematic factors imply a larger correction index.
- The simple pendulum experiment requires corrections due to finite amplitude, air resistance, effective length, buoyancy, and damping effects.

Step 1: Examine the resonance tube experiment.

The resonance tube experiment mainly requires end correction and temperature correction. Hence the corrections are limited.

Step 2: Examine the meter bridge experiment.

The meter bridge experiment primarily involves balancing lengths and resistance calculations. Corrections required are comparatively small.

Step 3: Examine the optical bench experiment.

Measurement of focal length mainly involves alignment and reading corrections.
These are fewer than those in a pendulum experiment.

Step 4: Examine the simple pendulum experiment.

The simple pendulum requires corrections for:

- Effective length
- Air resistance
- Finite amplitude
- Damping
- Buoyancy

Therefore it has the largest index of correction.

$$\boxed{\text{Option (C)}}$$

Quick Tip: Experiments involving oscillations usually require more corrections because several external factors influence the result.

---

37. In a solar system, the time period of revolution of a planet tracing a circular orbit of radius R is proportional to:

(A) R^3

(B) $R^{1/2}$

(C) $R^{3/2}$

(D) R^2

Correct Answer: (C)

Solution:

Concept:

- Kepler's Third Law states:

$$T^2 \propto R^3$$

for planets revolving around the same star.

Step 1: Write the gravitational force.

$$\frac{GMm}{R^2}$$

This provides the necessary centripetal force.

$$\frac{GMm}{R^2} = m\frac{v^2}{R}$$

Step 2: Express velocity in terms of time period.

$$v = \frac{2\pi R}{T}$$

Substituting,

$$\frac{GM}{R^2} = \frac{4\pi^2 R}{T^2}$$

Step 3: Find the relation between T and R.

$$T^2 = \frac{4\pi^2 R^3}{GM}$$

Therefore,

$$T^2 \propto R^3$$

$$T \propto R^{3/2}$$

Option (C)

Quick Tip: Remember Kepler's Third Law:

$$T^2 \propto R^3$$

For quick questions directly write

$$T \propto R^{3/2}$$

---

38. Consider that σ_s, k_B, and b represent Stefan-Boltzmann constant, Boltzmann constant, and Wien's displacement law constant, respectively. The dimension of $\sigma_s k_B^{-1} b$ is:

(A) $[L^{-1}T^{-1}K^{-4}]$

(B) $[L^{-1}T^{-1}K^{-2}]$

(C) $[L^{-1}K^{-2}]$

(D) $[L^{-1}T^{-1}K^{-3}]$

Correct Answer: (B)

Solution:

Concept:

$$[\sigma_s] = [MT^{-3}K^{-4}]$$

$$[k_B] = [ML^2T^{-2}K^{-1}]$$

$$[b] = [LK]$$

Step 1: Write the required dimensional expression.

$$[\sigma_s k_B^{-1} b] = [\sigma_s][k_B]^{-1}[b]$$

Step 2: Substitute dimensions.

$$= [MT^{-3}K^{-4}][M^{-1}L^{-2}T^2K][LK]$$

Step 3: Simplify powers.

Mass:

$$M^{1-1} = M^0$$

Length:

$$L^{-2+1} = L^{-1}$$

Time:

$$T^{-3+2} = T^{-1}$$

Temperature:

$$K^{-4+1+1} = K^{-2}$$

Hence,

$$[\sigma_s k_B^{-1} b] = [L^{-1}T^{-1}K^{-2}]$$

$$\boxed{\text{Option (B)}}$$

Quick Tip: In dimensional analysis, first write dimensions of each constant separately and then combine powers systematically.

39. A ray of light with wavelength λ is incident on three different photoelectric cells. The threshold wavelengths are λ_1, λ_2, and λ_3, and the magnitudes of stopping potentials are V_1, V_2, and V_3, respectively. If

$$\lambda_1 \leq \lambda, \qquad \lambda_2 > \lambda, \qquad \lambda_3 \gg \lambda$$

the correct option is:

(A) $V_1 < V_2,\ V_3 = 0$

(B) $V_1 = 0,\ V_2 < V_3$

(C) $V_1 > 0,\ V_2 = 0,\ V_3 = 0$

(D) $V_1 > V_2,\ V_3 = 0$

Correct Answer: (C)

Solution:

Concept:

Photoelectric emission occurs only when

$$\lambda \leq \lambda_0$$

where λ_0 is the threshold wavelength.

Step 1: Analyze cell 1.

$$\lambda_1 \leq \lambda$$

Hence photoelectric emission occurs.

Therefore,

$$V_1 > 0$$

Step 2: Analyze cell 2.

No photoelectric emission occurs.

Thus,

$$V_2 = 0$$

Step 3: Analyze cell 3.

Since

$$\lambda_3 \gg \lambda$$

the incident wavelength is insufficient to cause emission.
Hence,

$$V_3 = 0$$

Step 4: Choose the correct option.

$$V_1 > 0, \qquad V_2 = 0, \qquad V_3 = 0$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: No photoelectric emission means no photoelectrons and therefore zero stopping potential.

---

40. One main scale division (MSD) of a Vernier calliper is 1 mm and the Vernier scale has 10 divisions. When the jaws touch, the Vernier scale shifts to the left and the 4^{th} Vernier division coincides with a main scale division. If the measured length is 1 cm, the actual length is:

(A) 1.04 cm

(B) 0.60 cm

(C) 0.96 cm

(D) 1.00 cm

Correct Answer: (C)

Solution:

Concept:

- Least Count of Vernier Calliper:

$$LC = 1\ \text{MSD} - 1\ \text{VSD}$$

- For a 10-division Vernier,

$$LC = 0.1\ \text{mm} = 0.01\ \text{cm}$$

Step 1: Determine the zero error.

The Vernier zero lies to the left of the main scale zero.
Hence the instrument has negative zero error.

$$\text{Zero Error} = -4 \times 0.01$$

$$= -0.04\ \text{cm}$$

Step 2: Apply zero correction.

Measured length

$$= 1.00\ \text{cm}$$

Actual length

$$= \text{Measured Length} + \text{Zero Error}$$

$$= 1.00 - 0.04$$

$$= 0.96\ \text{cm}$$

Step 3: Write the final answer.

$$\boxed{0.96 \text{ cm}}$$

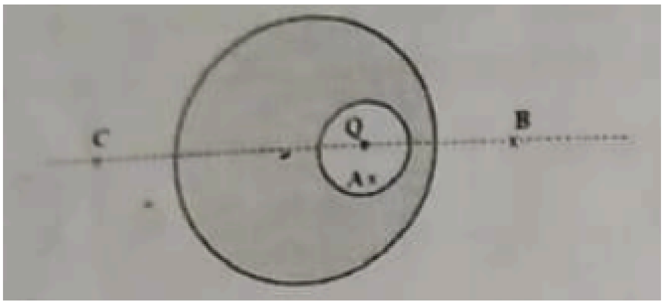
Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: If Vernier zero lies to the left of main scale zero, the instrument has negative zero error. Subtract the magnitude of the negative error from the measured reading.

---

41. A point charge Q is placed inside a cavity within a solid isolated conducting sphere. Consider points A, B, and C as shown in the figure, where the magnitudes of the electric fields are E_A, E_B, and E_C respectively. The points B and C are at the same distance from the center of the solid sphere. The correct option is:



(A) $E_A \neq 0,\ E_B < E_C$

(B) $E_A = 0,\ E_B = E_C$

(C) $E_A \neq 0,\ E_B = E_C$

(D) $E_A = 0,\ E_B > E_C$

Correct Answer: (C) $E_A \neq 0,\ E_B = E_C$

Solution:

Concept:

- A charge placed inside a cavity produces a non-zero electric field inside the cavity.
- The electric field inside the conducting material itself is zero.

- Outside the conductor, the field behaves as if the total charge were concentrated at the centre.

Step 1: Determine the field at point A.

Point A lies inside the cavity containing charge Q.
Since the cavity contains an electric charge, the electric field inside the cavity is non-zero.
Therefore,

$$E_A \neq 0$$

Step 2: Determine the field at points B and C.

Points B and C are outside the conducting sphere and are at the same distance from the centre.
The external electric field of an isolated conducting sphere depends only on the distance from the centre.
Hence,

$$E_B = E_C$$

Step 3: Choose the correct option.

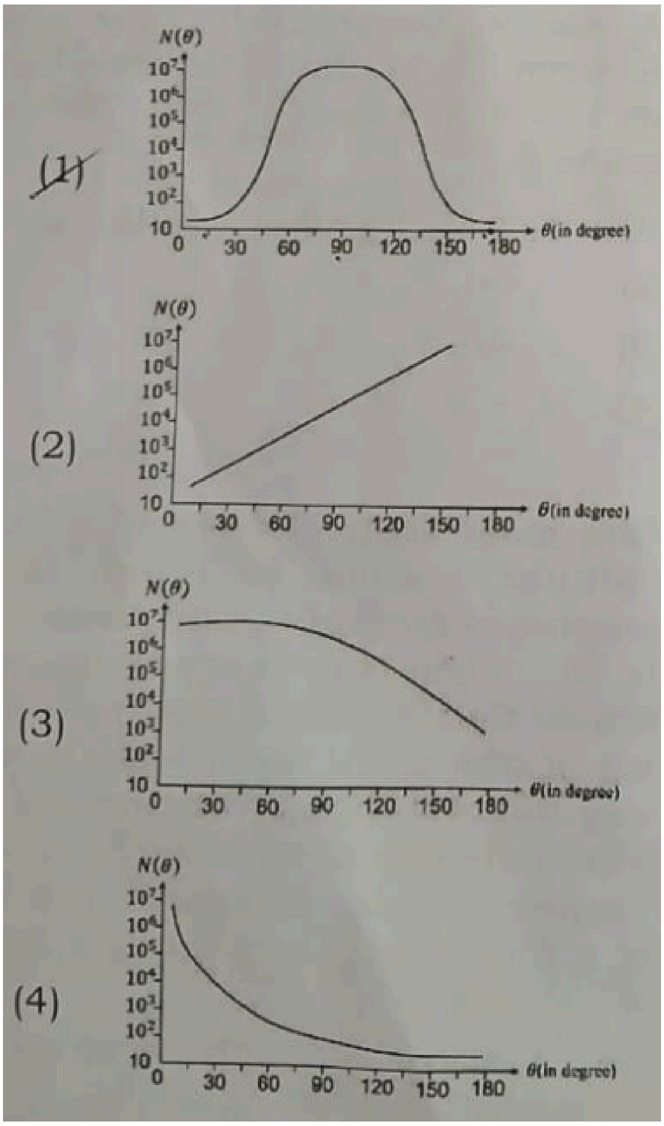
$$E_A \neq 0, \qquad E_B = E_C$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: The electric field inside a conductor is zero, but inside a cavity containing a charge it is generally non-zero. Outside a spherical conductor, the field depends only on radial distance.

---

42. In the Geiger-Marsden experiment, the number of scattered α-particles $N(\theta)$ is plotted as a function of scattering angle θ. Which of the following options represents the correct plot?



(A) Graph (1)

(B) Graph (2)

(C) Graph (3)

(D) Graph (4)

Correct Answer: (D) Graph (4)

Solution:

Concept:

- Rutherford scattering law states:

$$N(\theta) \propto \frac{1}{\sin^4(\theta/2)}$$

- Most α-particles are scattered through small angles.

- Very few particles are scattered through large angles.

Step 1: Examine the scattering formula.

$$N(\theta) \propto \frac{1}{\sin^4(\theta/2)}$$

As θ increases, $\sin(\theta/2)$ increases.

Therefore $N(\theta)$ decreases rapidly.

Step 2: Analyze the nature of the graph.

At very small angles,

$$N(\theta)$$

is extremely large.

At larger angles,

$$N(\theta)$$

falls sharply toward zero.

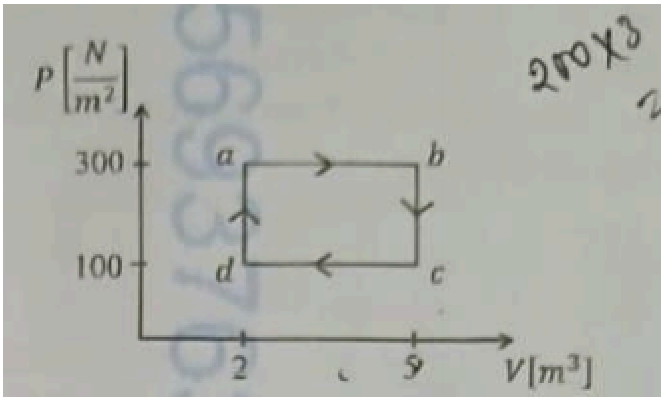
This corresponds to Graph (4).

$$\boxed{\text{Option (D)}}$$

Quick Tip: Rutherford scattering predicts that most alpha particles suffer very small deflections and only a few are scattered through large angles.

---

43. One mole of an ideal monatomic gas undergoes a cyclic process as shown in the figure. The total heat supplied to the gas is:



(A) 800 J

(B) 400 J

(C) 500 J

(D) 600 J

Correct Answer: (D) 600 J

Solution:

Concept:

- For a cyclic process,

$$\Delta U = 0$$

- Hence,

$$Q_{\text{net}} = W_{\text{net}}$$

- Work done in a cycle equals the area enclosed in the $P - V$ diagram.

Step 1: Read the dimensions of the rectangle.

From the graph,

$$\Delta P = 300 - 100 = 200\,\text{N}\,\text{m}^{-2}$$

and

$$\Delta V = 5 - 2 = 3\,\text{m}^3$$

Step 2: Calculate the area enclosed.

$$W = \Delta P \times \Delta V$$

$$W = 200 \times 3$$

$$W = 600 \text{ J}$$

Step 3: Use cyclic process condition.

$$Q = W$$

$$Q = 600 \text{ J}$$

$$\boxed{\text{Option (D)}}$$

Quick Tip: For any cyclic process,

$$\Delta U = 0$$

Therefore net heat supplied equals net work done.

---

44. Two infinitely long parallel conducting wires A and B carry currents I and $2I$, respectively, in the same direction. Wire A lies on an insulated floor while wire B is fixed at a height h above the floor. The minimum value of h so that wire A does not rise from the floor is:

(A) $\dfrac{4\mu_0 I^2}{\pi\lambda g}$

(B) $\dfrac{\mu_0 I^2}{2\pi\lambda g}$

(C) $\dfrac{\mu_0 I^2}{\pi\lambda g}$

(D) $\frac{2\mu_0 I^2}{\pi\lambda g}$

Correct Answer: (C)

Solution:

Concept:

- Force per unit length between two parallel currents:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi h}$$

- At the limiting condition,

$$\text{Magnetic force} = \text{Weight per unit length}$$

Step 1: Calculate magnetic force per unit length.

$$\frac{F}{L} = \frac{\mu_0 (I)(2I)}{2\pi h} = \frac{\mu_0 I^2}{\pi h}$$

Step 2: Apply equilibrium condition.

$$\frac{\mu_0 I^2}{\pi h} = \lambda g$$

Step 3: Solve for h.

$$h = \frac{\mu_0 I^2}{\pi\lambda g}$$

$$\boxed{\text{Option (C)}}$$

Quick Tip: Parallel currents in the same direction attract each other. For limiting equilibrium, magnetic attraction equals weight per unit length.

---

45. Consider a spring-mass simple harmonic oscillator in one dimension. The mass of the particle is m kg and the spring constant is k N m^{-1}. At a given instant, the extension of the spring is x metre and the speed of the particle is v m s^{-1}. On the $x-v$ plane, if the graph of v as a function of x is a circle, then the correct option is:

(A) $k = \sqrt{m}$

(B) $k = \frac{1}{m}$

(C) $k = m$

(D) $k = m^2$

Correct Answer: (C)

Solution:

Concept:

For SHM,

$$\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = E$$

This represents an ellipse in the $x-v$ plane.

Step 1: Write the equation in standard form.

$$\frac{kx^2}{2E} + \frac{mv^2}{2E} = 1$$

or

$$\frac{x^2}{2E/k} + \frac{v^2}{2E/m} = 1$$

Step 2: Condition for a circle.

For a circle, both denominators must be equal.

$$\frac{2E}{k} = \frac{2E}{m}$$

$$k = m$$

Step 3: Write the final answer.

$$\boxed{k = m}$$

Hence,

$$\boxed{\text{Option (C)}}$$

Quick Tip: The phase-space plot of SHM is generally an ellipse. It becomes a circle when the coefficients of x^2 and v^2 become equal.
