KCET 2026 Physics Code C2

Question Paper with Solutions

Conducted by KEA

General Instructions

(i) **Duration:** The total duration of the examination is 80 minutes.

(ii) **Total Marks:** The complete paper carries a maximum of 60 marks.

(iii) **Compulsory Questions:** All 60 questions are compulsory.

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

(v) Correct Answer: +1 marks.

(vi) **Incorrect Answer:** There is no Negative marking for incorrect answers.

1. An electron falls through a distance 1.5 cm in a uniform electric field of magnitude 2.0×10^4 N/C from rest. The time taken to cover this distance in second is _____.
($e = 1.6 \times 10^{-19}$ C, $m_e = 9.11 \times 10^{-31}$ kg)

(1) 2.9×10^{-9}

(2) 2.9×10^{9}

(3) 4×10^{-6}

(4) 4×10^{6}

Correct Answer: (1) 2.9×10^{-9}

Solution:

Step 1: Understanding the Question:

The problem asks for the time an electron takes to fall from rest through a specific distance in a uniform electric field. This is a kinematics problem where the acceleration is provided by the electric force.

Step 2: Key Formula or Approach:

1. Electric force: $F = qE$
2. Newton's second law: $F = ma \Rightarrow a = \frac{qE}{m}$
3. Kinematics equation for constant acceleration (from rest): $s = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2s}{a}}$

Step 3: Detailed Explanation:

Given values:

$s = 1.5 \text{ cm} = 0.015 \text{ m}$

$E = 2.0 \times 10^4 \text{ N/C}$

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

$m_e = 9.11 \times 10^{-31} \text{ kg}$

First, calculate the acceleration (a):

$$a = \frac{eE}{m_e} = \frac{(1.6 \times 10^{-19}) \times (2.0 \times 10^4)}{9.11 \times 10^{-31}}$$

$$a = \frac{3.2 \times 10^{-15}}{9.11 \times 10^{-31}} \approx 3.51 \times 10^{15} \text{ m/s}^2$$

Now, find the time (t):

$$t = \sqrt{\frac{2 \times 0.015}{3.51 \times 10^{15}}}$$

$$t = \sqrt{\frac{0.03}{3.51 \times 10^{15}}} \approx \sqrt{0.00854 \times 10^{-15}}$$

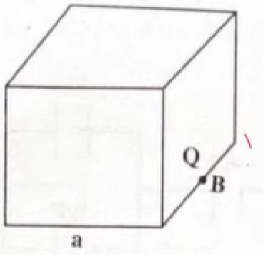
$$t = \sqrt{8.54 \times 10^{-18}} \approx 2.92 \times 10^{-9} \text{ s}$$

Step 4: Final Answer:

The time taken is approximately 2.9×10^{-9} seconds.

Quick Tip: In problems involving microscopic particles in electric fields, the effect of gravity is usually negligible compared to electric forces because the mass is extremely small. Focus only on the electric acceleration $a = \frac{qE}{m}$.

2. What will be the total electric flux through the faces of the cube as given in the figure with side of length 'a' if a charge Q is placed at B, midpoint of an edge of the cube (see figure)?



(1) $\frac{Q}{8\epsilon_0}$

(2) $\frac{Q}{3\epsilon_0}$

(3) $\frac{Q}{4\epsilon_0}$

(4) $\frac{Q}{2\epsilon_0}$

Correct Answer: (3) $\frac{Q}{4\epsilon_0}$

Solution:

Step 1: Understanding the Question:

The question asks for the net electric flux through a single cube when a point charge is placed exactly at the midpoint of one of its edges. We can use Gauss's Law and symmetry to solve this.

Step 2: Key Formula or Approach:

Gauss's Law states that the total flux through a closed surface is $\Phi = \frac{Q_{enclosed}}{\epsilon_0}$.
If a charge is on the boundary of a surface, we can construct a larger symmetrical surface consisting of identical units to enclose the charge completely.

Step 3: Detailed Explanation:

1. The charge Q is placed at the midpoint of an edge.
2. To enclose this point charge completely and symmetrically, we need 4 such identical cubes sharing that same edge.
3. According to Gauss's Law, the total flux through this large composite surface (consisting of 4 cubes) is $\Phi_{total} = \frac{Q}{\epsilon_0}$.
4. Since the charge is placed symmetrically with respect to all 4 cubes, the flux through each individual cube will be one-fourth of the total flux.

$$\Phi_{cube} = \frac{1}{4}\Phi_{total} = \frac{Q}{4\epsilon_0}$$

Step 4: Final Answer:

The total electric flux through the faces of the cube is $\frac{Q}{4\epsilon_0}$.

Quick Tip: Remember these symmetry rules for a charge Q and a cube:

- At the center: $\Phi = \frac{Q}{\epsilon_0}$
- On a face center: $\Phi = \frac{Q}{2\epsilon_0}$ per cube.
- On an edge midpoint: $\Phi = \frac{Q}{4\epsilon_0}$ per cube.
- On a vertex: $\Phi = \frac{Q}{8\epsilon_0}$ per cube.

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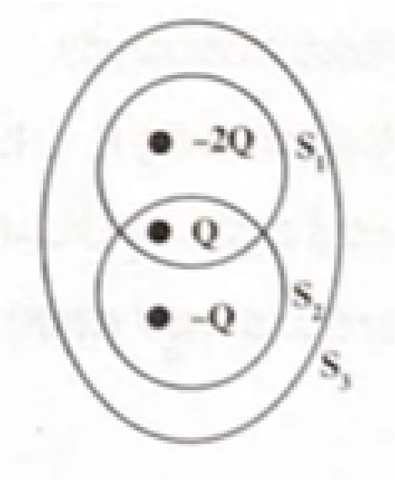
3. Consider three point charges $-2Q, Q$ and $-Q$ and three surfaces S_1, S_2 and S_3 as shown in the figure. Match the entries of List-I with that of List-II.



List-I

(a) Net flux through S_1

(b) Net flux through S_2

(c) Net flux through S_3

List-II

(i) $\frac{-2Q}{\epsilon_0}$

(ii) $\frac{-Q}{\epsilon_0}$

(iii) Zero

Codes:

(1) a - ii, b - i, c - iii

(2) a - iii, b - ii, c - i

(3) a - i, b - ii, c - iii

(4) a - ii, b - iii, c - i

Correct Answer: (4) a - ii, b - iii, c - i

Solution:

Step 1: Understanding the Question:

The problem requires calculating the net electric flux through different Gaussian surfaces by identifying which charges are enclosed within each surface.

Step 2: Key Formula or Approach:

By Gauss's Law, $\Phi = \frac{\sum q_{in}}{\epsilon_0}$, where $\sum q_{in}$ is the algebraic sum of charges inside the closed surface.

Step 3: Detailed Explanation:

From the figure:

1. **Surface S_1** encloses the charges $-2Q$ and Q.

Net flux through $S_1 = \frac{-2Q+Q}{\epsilon_0} = \frac{-Q}{\epsilon_0}$.

This matches with (ii).

2. **Surface S_2** encloses the charges Q and $-Q$.

Net flux through $S_2 = \frac{Q-Q}{\epsilon_0} = 0$.

This matches with (iii).

3. **Surface S_3** is the outermost surface and encloses all three charges: $-2Q, Q$, and $-Q$.

Net flux through $S_3 = \frac{-2Q+Q-Q}{\epsilon_0} = \frac{-2Q}{\epsilon_0}$.

This matches with (i).

Therefore, the correct matching is: a - ii, b - iii, c - i.

Step 4: Final Answer:

The correct code is (4).

Quick Tip: Charges located outside a Gaussian surface do not contribute to the net flux through that surface, regardless of their magnitude or proximity.

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4. A parallel plate capacitor has a uniform electric field 'E' in the space between the plates. If the distance between the plates is 'd' and area of each plate is 'A', the energy stored in the capacitor is

(1) $\frac{1}{2}\epsilon_0 E^2$

(2) $\epsilon_0 EAd$

(3) $\frac{1}{2}\epsilon_0 E^2 Ad$

(4) $\frac{E^2 Ad}{\epsilon_0}$

Correct Answer: (3) $\frac{1}{2}\epsilon_0 E^2 Ad$

Solution:

Step 1: Understanding the Question:

The question asks for the expression of the total electrostatic energy stored in a parallel plate capacitor in terms of the internal electric field and physical dimensions.

Step 2: Key Formula or Approach:

1. Energy stored in a capacitor: $U = \frac{1}{2}CV^2$

2. Capacitance of parallel plates: $C = \frac{\epsilon_0 A}{d}$

3. Potential difference: $V = E \times d$

Step 3: Detailed Explanation:

Substitute the expressions for C and V into the energy formula:

$$U = \frac{1}{2}\left(\frac{\epsilon_0 A}{d}\right)(Ed)^2$$

$$U = \frac{1}{2}\left(\frac{\epsilon_0 A}{d}\right)(E^2 d^2)$$

$$U = \frac{1}{2}\epsilon_0 E^2 Ad$$

Alternatively, using the concept of energy density (u):

Energy density $u = \frac{1}{2}\epsilon_0 E^2$

Total energy $U = u \times \text{Volume} = \left(\frac{1}{2}\epsilon_0 E^2\right) \times (Ad)$

$$U = \frac{1}{2}\epsilon_0 E^2 Ad$$

Step 4: Final Answer:

The energy stored in the capacitor is $\frac{1}{2}\epsilon_0 E^2 Ad$.

Quick Tip: Remember that Ad represents the volume of the space between the capacitor plates. Energy stored per unit volume (energy density) is a fundamental property of the electric field itself.

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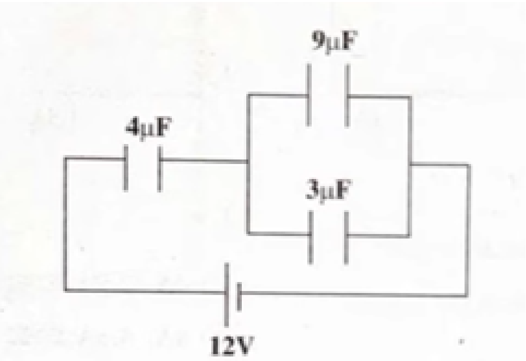
5. In the circuit shown in the figure, the potential difference across the 4μF capacitor is



(1) 3 V

(2) 4 V

(3) 9 V

(4) 12 V

Correct Answer: (3) 9 V

Solution:

Step 1: Understanding the Question:

We need to find the voltage across a specific capacitor in a series-parallel combination connected to a 12V DC source.

Step 2: Key Formula or Approach:

1. Capacitance in parallel: $C_p = C_1 + C_2$
2. Capacitance in series: $\frac{1}{C_s} = \frac{1}{C_a} + \frac{1}{C_b}$
3. Charge: $Q = CV$. In series, charge is the same for all components.
4. Potential difference: $V = \frac{Q}{C}$

Step 3: Detailed Explanation:

1. First, simplify the parallel part: The 9μF and 3μF capacitors are in parallel.
$C_{parallel} = 9 + 3 = 12\mu$F.
2. This 12μF combination is in series with the 4μF capacitor and the 12V battery.
3. Equivalent capacitance of the circuit (C_{eq}):

$$C_{eq} = \frac{4 \times 12}{4 + 12} = \frac{48}{16} = 3\mu\text{F}$$

4. Total charge supplied by the battery (Q):

$$Q = C_{eq} \times V = 3\mu\text{F} \times 12\text{V} = 36\mu\text{C}$$

5. Since the 4μF capacitor is in series with the main circuit, it carries the total charge $Q = 36\mu$C.
6. Potential difference across the 4μF capacitor ($V_{4\mu\text{F}}$):

$$V_{4\mu\text{F}} = \frac{Q}{C_1} = \frac{36\mu\text{C}}{4\mu\text{F}} = 9\text{V}$$

Step 4: Final Answer:

The potential difference across the 4μF capacitor is 9 V.

Quick Tip: Voltage divider rule for two capacitors in series: $V_1 = V_{total} \times \frac{C_2}{C_1+C_2}$.
Here, $V_{4\mu\text{F}} = 12 \times \frac{12}{4+12} = 12 \times \frac{12}{16} = 12 \times 0.75 = 9\text{V}$.

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6. An electric dipole of dipole moment $\vec{P}$ is placed in the uniform electric field $\vec{E}$. Then which of the following statements are correct?

Statement I: The torque on the dipole is $\vec{P} \times \vec{E}$

Statement II: The potential energy of the dipole is $-\vec{P} \cdot \vec{E}$

Statement III: The net force on the dipole is non zero

(1) I, II and III

(2) I and II only

(3) II and III only

(4) I and III only

Correct Answer: (2) I and II only

Solution:

Step 1: Understanding the Question:

The question asks to evaluate three fundamental properties of an electric dipole when it is situated within a uniform external electric field.

Step 3: Detailed Explanation:

Statement I: The torque ($\vec{\tau}$) on a dipole in an external field is given by the cross product of the dipole moment and the field.

$\vec{\tau} = \vec{P} \times \vec{E}$. Magnitude $\tau = PE \sin\theta$.

This statement is **correct**.

Statement II: The electrostatic potential energy (U) of a dipole is the work done in bringing it from infinity (or a reference orientation of 90°).

$U = -PE \cos\theta = -\vec{P} \cdot \vec{E}$.

This statement is **correct**.

Statement III: In a **uniform** electric field, the force on the positive charge ($+qE$) and the force on the negative charge ($-qE$) are equal in magnitude and opposite in direction.

Net force $\vec{F}_{net} = +q\vec{E} + (-q\vec{E}) = 0$.

Therefore, the net force is zero.

Statement III says the net force is "non zero", so it is **incorrect**.

Step 4: Final Answer:

Only Statements I and II are correct. Hence, option (2) is the right answer.

Quick Tip: If the electric field were non-uniform, then both a net torque and a net force would act on the dipole. Always check if the field is described as "uniform" or "non-uniform" in the problem statement.

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7. A 200 J of work is done in moving a charge 5C from a point A where the potential is - 20 V to another point B where potential is V volt. The value of V at B is

(1) 10 V

(2) 20 V

(3) 40 V

(4) 60 V

Correct Answer: (2) 20 V

Solution:

Step 1: Understanding the Question:

The problem involves calculating the electric potential at a point based on the work done to move a known charge between two points with a given potential difference.

Step 2: Key Formula or Approach:

The work done (W) in moving a charge (q) from point A to point B is given by:

$$W = q \cdot (V_B - V_A)$$

Where:

- W is the work done (in Joules).
- q is the magnitude of the charge (in Coulombs).
- V_B is the potential at final point B.
- V_A is the potential at initial point A.

Step 3: Detailed Explanation:

Given values:

- Work done, $W = 200$ J.

- Charge, $q = 5$ C.
- Potential at A, $V_A = -20$ V.
- Potential at B, $V_B = V$.

Substituting these into the formula:

$$200 = 5 \cdot (V - (-20))$$

Divide both sides by 5:

$$40 = V + 20$$

Solving for V:

$$V = 40 - 20 = 20 \text{ V}$$

Therefore, the value of potential at point B is 20 V.

Step 4: Final Answer:

The potential V at B is 20 V.

Quick Tip: Always be careful with signs when substituting potential values. Subtracting a negative potential $(-(-20))$ becomes addition. Also, ensure the work is done **on** the charge by an external force to use this specific formula form.

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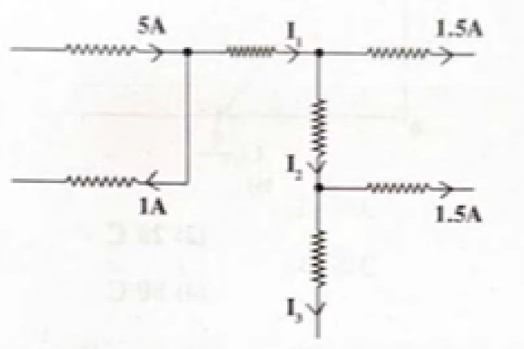
8. In the figure, the values of currents I_1, I_2 and I_3 respectively are



(1) 6A, 1.5A and 1A

(2) 4A, 2.5A and 2A

(3) 4A, 2.5A and 1A

(4) 6A, 4.5A and 1.5A

Correct Answer: (3) 4A, 2.5A and 1A

Solution:

Step 1: Understanding the Question:

This question requires applying Kirchhoff's Current Law (KCL) at multiple junctions in a circuit branch to find unknown currents. KCL states that the sum of currents entering a junction equals the sum of currents leaving it.

Step 2: Key Formula or Approach:

Kirchhoff's Current Law:

$$\sum I_{\text{in}} = \sum I_{\text{out}}$$

Step 3: Detailed Explanation:

Let's analyze the junctions from left to right as per the diagram:

At the first junction (left):

- Current entering from the top-left branch = 5A.

- Current leaving through the bottom-left branch = 1A (as indicated by the arrow pointing away from the junction).

- Current leaving towards the right $= I_1$.

Applying KCL: $5 = 1 + I_1 \Rightarrow I_1 = 4\text{A}$.

At the second junction (middle-top):

- Current entering from the left $= I_1 = 4\text{A}$.
- Current leaving towards the right $= 1.5\text{A}$.
- Current leaving downwards $= I_2$.

Applying KCL: $I_1 = 1.5 + I_2 \Rightarrow 4 = 1.5 + I_2 \Rightarrow I_2 = 2.5\text{A}$.

At the third junction (bottom-right):

- Current entering from the top $= I_2 = 2.5\text{A}$.
- Current leaving towards the right $= 1.5\text{A}$.
- Current leaving downwards $= I_3$.

Applying KCL: $I_2 = 1.5 + I_3 \Rightarrow 2.5 = 1.5 + I_3 \Rightarrow I_3 = 1\text{A}$.

Comparing these values $(I_1 = 4\text{A}, I_2 = 2.5\text{A}, I_3 = 1\text{A})$ with the options, it matches option (3).

Step 4: Final Answer:

The values of currents are $I_1 = 4\text{A}, I_2 = 2.5\text{A}$ and $I_3 = 1\text{A}$.

Quick Tip: To avoid errors in nodal analysis, strictly follow the direction of the arrows given in the diagram. A current entering a node is positive, and leaving is negative in the sum.

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9. The number of electrons moving per second through the filament of a lamp of 60W operating at 120V is nearly (e = 1.6 × 10^{-19} C) _______

(1) 6.2×10^{18}

(2) 6.2×10^{19}

(3) 3.1×10^{18}

(4) 3.1×10^{19}

Correct Answer: (3) 3.1×10^{18}

Solution:

Step 1: Understanding the Question:

The goal is to find the rate of electron flow (electrons per second) in a circuit given the power and voltage of an appliance.

Step 2: Key Formula or Approach:

1. Electric Power: $P = V \cdot I \Rightarrow I = \frac{P}{V}$.
2. Current and Charge: $I = \frac{Q}{t}$.
3. Quantization of Charge: $Q = n \cdot e$.

Combining these, the number of electrons per second (n for $t = 1$s) is:

$$n = \frac{I}{e} = \frac{P}{V \cdot e}$$

Step 3: Detailed Explanation:

Given:

- Power, $P = 60$ W.
- Voltage, $V = 120$ V.
- Electronic charge, $e = 1.6 \times 10^{-19}$ C.

First, calculate the current (I):

$$I = \frac{P}{V} = \frac{60}{120} = 0.5 \text{ A}$$

Now, calculate the number of electrons per second (n):

$$n = \frac{I}{e} = \frac{0.5}{1.6 \times 10^{-19}}$$

$$n = \frac{5}{16} \times 10^{19}$$

$$n \approx 0.3125 \times 10^{19} = 3.125 \times 10^{18}$$

Rounding to the nearest significant figures as per options: 3.1×10^{18}.

Step 4: Final Answer:

The number of electrons moving per second is nearly 3.1×10^{18}.

Quick Tip: Remember that 1 Ampere corresponds to approximately 6.25×10^{18} electrons passing per second. Since our current is 0.5 A, the answer must be half of that value, which is $\approx 3.12 \times 10^{18}$.

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10. Given below are two statements:

Statement I: The resistivity of a conductor is independent of its temperature

Statement II: The resistivity of a semiconductor decreases with increase in temperature

Select the correct option.

(1) Both Statement I and Statement II are false

(2) Both Statement I and Statement II are true

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

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

Correct Answer: (4) Statement I is false but Statement II is true

Solution:

Step 1: Understanding the Question:

The question evaluates theoretical knowledge regarding how temperature affects the electrical resistivity of different classes of materials (conductors and semiconductors).

Step 3: Detailed Explanation:

Analysis of Statement I:

Resistivity (ρ) of a conductor (metal) depends on temperature as:

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

where α is the temperature coefficient. For conductors, α is positive. As temperature increases, thermal vibrations of lattice ions increase, causing more frequent collisions with electrons. This increases resistance and resistivity. Therefore, Statement I is **false**.

Analysis of Statement II:
For semiconductors, the temperature coefficient of resistivity α is negative. As temperature increases, more valence electrons gain enough thermal energy to jump into the conduction band, significantly increasing the charge carrier density (n). This effect outweighs the increase in lattice scattering. Consequently, the resistivity decreases. Therefore, Statement II is **true**.

Step 4: Final Answer:
Statement I is false but Statement II is true, which corresponds to option (4).

Quick Tip: Recall the graph of resistivity (ρ) vs temperature (T):
- For conductors: Graph shows a positive slope (linear or nearly linear at high T).
- For semiconductors/insulators: Graph shows an exponential decay ($\rho = \rho_0 e^{E_g/k_B T}$).

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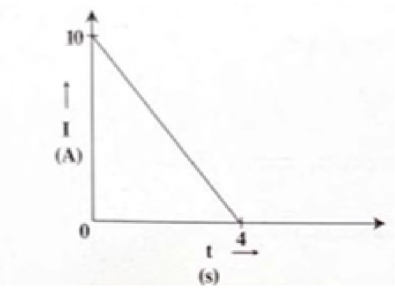
11. Current flowing through a wire decreases linearly from 10A to zero in 4s as shown in the graph. Find the total charge flowing through the wire in the given time interval.



(1) 40C

(2) 20C

(3) 10C

(4) 80C

Correct Answer: (2) 20C

Solution:

Step 1: Understanding the Question:

The total charge flowing through a circuit component is equal to the area under its current-time $(I - t)$ graph.

Step 2: Key Formula or Approach:

The charge Q is given by the definite integral of current over time:

$$Q = \int I(t)dt$$

Geometrically, this corresponds to the area of the region between the graph and the time axis.

Step 3: Detailed Explanation:

The provided graph forms a right-angled triangle with the following dimensions:

- Base $(\Delta t) = 4$ s
- Height (initial current I_0) $= 10$ A

The area of a triangle is calculated using the formula:

$$\text{Area} = \frac{1}{2} \times \text{base} \times \text{height}$$

Substituting the values:

$$Q = \frac{1}{2} \times 4 \text{ s} \times 10 \text{ A} = 20 \text{ C}$$

Step 4: Final Answer:

The total charge flowing through the wire is 20C.

Quick Tip: For any linear change in current from I_{initial} to I_{final}, the total charge can also be calculated using average current:

$Q = I_{avg} \times \Delta t = \frac{I_{\text{initial}} + I_{\text{final}}}{2} \times \Delta t$.

In this specific case, $Q = \frac{10+0}{2} \times 4 = 5 \times 4 = 20$ C.

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12. In a conducting region, 10ˆ19 electrons and 10ˆ19 protons move to the left, while 10ˆ19 α-particles move to the right per second. The resulting electric current is (e = 1.6 × 10ˆ-19 C)

(1) 3.2 A towards left

(2) 3.2 A towards right

(3) 1.6 A towards left

(4) 1.6 A towards right

Correct Answer: (2) 3.2 A towards right

Solution:

Step 1: Understanding the Question:

Conventional electric current is defined as the flow of positive charge per unit time. We must calculate the individual current contributions from each type of charge carrier and find their vector sum.

Step 3: Detailed Explanation:

The rate of flow for each particle type is given as $n = 10^{19}$ particles per second.

1. **Electrons:** These have a negative charge $(-e)$. Moving to the left, they contribute to a conventional current directed towards the **right**.

$I_e = n \times e = 10^{19} \times 1.6 \times 10^{-19} = 1.6$ A (Right)

2. **Protons:** These have a positive charge $(+e)$. Moving to the left, they contribute to a conventional current directed towards the **left**.

$I_p = n \times e = 10^{19} \times 1.6 \times 10^{-19} = 1.6$ A (Left)

3. **α-particles:** These have a positive charge $(+2e)$. Moving to the right, they contribute to a conventional current directed towards the **right**.

$I_\alpha = n \times 2e = 10^{19} \times 2 \times 1.6 \times 10^{-19} = 3.2$ A (Right)

Resultant Current Calculation:

Assigning "right" as the positive direction:

$I_{\text{net}} = I_e(\text{right}) + I_p(\text{left}) + I_\alpha(\text{right})$

$I_{\text{net}} = 1.6 + (-1.6) + 3.2 = 3.2 \text{ A (Right)}$

Step 4: Final Answer:

The resulting electric current is 3.2 A towards the right.

Quick Tip: Conventional current is always in the direction of positive charge flow and opposite to the direction of negative charge flow. Using a fixed sign convention (e.g., right = positive, left = negative) for all vector quantities prevents summation errors.

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13. A point charge is placed in a moving train. A passenger A sitting in the train and person B on the ground observe the fields due to this charge. Then

(1) A observes both electric and magnetic fields

(2) B observes both electric and magnetic fields

(3) A observes only magnetic field

(4) B observes only electric field

Correct Answer: (2) B observes both electric and magnetic fields

Solution:

Step 1: Understanding the Question:

The manifestation of electromagnetic fields is relative and depends on the state of motion of the observer with respect to the source charge.

Step 3: Detailed Explanation:

1. **Observer A (Passenger):** Since A is sitting in the same moving train as the point charge, the charge is at rest relative to A. According to electrostatics, a stationary charge produces only an electric field in its local rest frame.

2. **Observer B (Person on ground):** From the perspective of person B, the train and the charge within it are in motion. A moving point charge constitutes a convective current. According to Maxwell's equations, a moving charge generates a magnetic field in addition to its electric

field.

Therefore, observer B will detect both electric and magnetic field components.

Step 4: Final Answer:

The person B on the ground observes both electric and magnetic fields.

Quick Tip: Electric and magnetic fields are not absolute entities; they are frame-dependent components of the single electromagnetic field tensor. A field that appears purely electric in its source's rest frame will generally appear to have both electric and magnetic components in any frame moving relative to it.

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14. A proton, an electron and an α-particle enter at right angles to a uniform magnetic field with the same velocity. If R_p, R_e and R_α are the radii of circular paths of these particles, then

(1) $R_\alpha = R_p = R_e$

(2) $R_\alpha > R_p > R_e$

(3) $R_\alpha < R_p < R_e$

(4) $R_\alpha > R_p = R_e$

Correct Answer: (2) $R_\alpha > R_p > R_e$

Solution:

Step 1: Understanding the Question:

We must compare the radii of curvature for three distinct charged particles injected perpendicularly into a uniform magnetic field at equal speeds.

Step 2: Key Formula or Approach:

The radius R of a circular orbit for a particle with mass m and charge q moving with velocity v perpendicular to a uniform magnetic field B is given by the centripetal force condition:

$$R = \frac{mv}{qB}$$

Since velocity v and magnetic induction B are identical for all three particles, the radius is directly proportional to the mass-to-charge ratio:

$$R \propto \frac{m}{q}$$

Step 3: Detailed Explanation:

Let's analyze the m/q ratios for the given particles:

1. **Electron:** Mass m_e, Charge magnitude $q_e = e$.

$R_e \propto \frac{m_e}{e}$

2. **Proton:** Mass m_p, Charge $q_p = e$.

$R_p \propto \frac{m_p}{e}$

Since $m_p \approx 1836 \times m_e$, we conclude that $R_p > R_e$.

3. **α-particle (Helium nucleus):** Mass $m_\alpha \approx 4m_p$, Charge $q_\alpha = 2e$.

$R_\alpha \propto \frac{4m_p}{2e} = 2\left(\frac{m_p}{e}\right)$

This shows that $R_\alpha = 2R_p$, therefore $R_\alpha > R_p$.

Synthesizing the results, we get the following order: $R_\alpha > R_p > R_e$.

Step 4: Final Answer:

The correct order of radii is $\mathrm{R}_\alpha > \mathrm{R}_p > \mathrm{R}_e$.

Quick Tip: For particles moving with the same velocity in a magnetic field, the radius of the path depends solely on the specific mass (mass per unit charge). Particles with a higher "specific mass" have more inertia relative to the magnetic force and thus form larger circular paths.

---

15. Biot-Savart law indicates that an electron moving with a velocity $\vec{V}$ produces a magnetic field $\vec{B}$ around it such that

(1) $\vec{B}$ is parallel to $\vec{V}$

(2) $\vec{B}$ is perpendicular to $\vec{V}$

(3) $\vec{B}$ is anti-parallel to $\vec{V}$

(4) $\vec{B}$ is inclined to $\vec{V}$ by 45°

Correct Answer: (2) $\vec{B}$ is perpendicular to $\vec{V}$

Solution:

Step 1: Understanding the Question:

The question asks about the orientation of the magnetic field produced by a moving point charge (an electron) relative to its direction of motion.

Step 2: Key Formula or Approach:

The Biot-Savart law for a point charge q moving with velocity $\vec{V}$ is given by:

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q(\vec{V} \times \hat{r})}{r^2}$$

Where $\hat{r}$ is the unit vector from the charge to the point of observation.

Step 3: Detailed Explanation:

According to the cross-product property in the formula $\vec{B} \propto \vec{V} \times \hat{r}$, the resultant vector $\vec{B}$ is always perpendicular to the plane containing the velocity vector $\vec{V}$ and the position vector $\vec{r}$. This fundamental property implies that the magnetic field $\vec{B}$ at any point in space is always perpendicular to the velocity vector $\vec{V}$ of the moving charge.

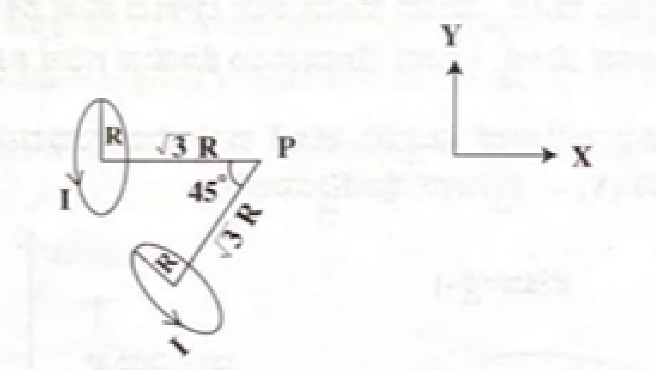
Step 4: Final Answer:

Therefore, $\vec{B}$ is always perpendicular to $\vec{V}$, which corresponds to option (2).

Quick Tip: Remember the "Right-Hand Rule": the magnetic field lines form circles around the path of the moving charge. In any instantaneous cross-section, the field vector at any point will always be in a direction perpendicular to the velocity vector.

---

16. Two identical circular current loops carrying equal currents are placed with their axes inclined at 45° to each other as shown in the figure. The resultant magnetic field at P is



(1) $\frac{\mu_0 I}{16\sqrt{2}R}[(\sqrt{2}+1)\hat{i}+\hat{j}]$
(2) $\frac{\mu_0 I}{16\sqrt{2}R}[\sqrt{2}\hat{i}+\hat{j}]$
(3) $\frac{\mu_0 I}{16R}[(\sqrt{2}+1)\hat{i}+\hat{j}]$
(4) $\frac{\mu_0 I}{16R}[\sqrt{2}\hat{i}+\hat{j}]$

Correct Answer: (1) $\frac{\mu_0 I}{16\sqrt{2}R}[(\sqrt{2}+1)\hat{i}+\hat{j}]$

Solution:

Step 1: Understanding the Question:

We need to find the vector sum of magnetic fields produced by two identical circular loops at a point P that lies on the axes of both loops at a distance of $\sqrt{3}R$ from their centers.

Step 2: Key Formula or Approach:

The magnetic field at a point on the axis of a circular current-carrying loop of radius R at a distance x from the center is:

$$B = \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$$

Step 3: Detailed Explanation:

Given:

Distance $x = \sqrt{3}R$.

Calculating the magnitude of the magnetic field from one loop:

$$B_0 = \frac{\mu_0 I R^2}{2(R^2 + (\sqrt{3}R)^2)^{3/2}} = \frac{\mu_0 I R^2}{2(R^2 + 3R^2)^{3/2}} = \frac{\mu_0 I R^2}{2(4R^2)^{3/2}}$$

$$B_0 = \frac{\mu_0 I R^2}{2(8R^3)} = \frac{\mu_0 I}{16R}$$

Now, let's represent these fields as vectors based on the coordinate system in the figure:

1. The field from the first loop (whose axis is along the X-axis) is:

$\vec{B}_1 = B_0\hat{i}$

2. The field from the second loop (whose axis is inclined at 45° to the X-axis) is:

$\vec{B}_2 = B_0(\cos 45°\hat{i} + \sin 45°\hat{j}) = B_0\left(\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right)$

The resultant magnetic field $\vec{B}$ is the vector sum:

$$\vec{B} = \vec{B}_1 + \vec{B}_2 = B_0\hat{i} + B_0\left(\frac{1}{\sqrt{2}}\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right)$$

$$\vec{B} = B_0\left[\left(1 + \frac{1}{\sqrt{2}}\right)\hat{i} + \frac{1}{\sqrt{2}}\hat{j}\right] = \frac{B_0}{\sqrt{2}}[(\sqrt{2}+1)\hat{i} + \hat{j}]$$

Substituting the value of B_0:

$$\vec{B} = \frac{\mu_0 I}{16\sqrt{2}R}[(\sqrt{2}+1)\hat{i} + \hat{j}]$$

Step 4: Final Answer:

The resultant magnetic field at P is $\frac{\mu_0 I}{16\sqrt{2}R}[(\sqrt{2}+1)\hat{i} + \hat{j}]$, which corresponds to option (1).

Quick Tip: When combining axial fields, always resolve them into components. If you find a common factor like $\frac{1}{\sqrt{2}}$, factor it out early to make the expression look like the options provided in the question.

---

17. If a paramagnetic bar is brought near a bar magnet, then it is

(1) Attracted by both the poles of the bar magnet

(2) Repelled by both the poles of the bar magnet

(3) Attracted by the South-pole and repelled by the North-pole of the bar magnet

(4) Attracted by the North-pole and repelled by the South-pole of the bar magnet

Correct Answer: (1) Attracted by both the poles of the bar magnet

Solution:

Step 1: Understanding the Question:

The question asks about the magnetic interaction between a paramagnetic material and the poles of a standard permanent bar magnet.

Step 3: Detailed Explanation:

Paramagnetic materials have atoms with permanent magnetic dipoles. When placed in an external magnetic field, these dipoles tend to align themselves in the direction of the external field.

A characteristic property of paramagnetic substances is that they are weakly attracted toward stronger parts of an external magnetic field.

A bar magnet has its strongest field intensity near its poles (both North and South).

Therefore, a paramagnetic bar will experience a weak attractive force when brought near either the North pole or the South pole of a bar magnet.

Step 4: Final Answer:

It is attracted by both the poles of the bar magnet, which is option (1).

Quick Tip: Remember:

- Ferromagnetic: Strongly attracted to both poles.
- Paramagnetic: Weakly attracted to both poles.
- Diamagnetic: Weakly repelled by both poles.

---

18. Pick out the WRONG statements about magnetic substances (χ = magnetic susceptibility) (μ_r = relative permeability).

I. Substances with $-1 \leq \chi < 0$ are diamagnetic

II. Substances with $\chi \gg 1$ are paramagnetic

III. Substances with $\chi \ll 1$ are ferromagnetic

IV. Substances with $\mu_r \gg 1$ are ferromagnetic

(1) I and II

(2) III and IV

(3) II and III

(4) II and IV

Correct Answer: (3) II and III

Solution:

Step 1: Understanding the Question:

The question asks to identify the incorrect statements among the four provided, which describe the magnetic properties of different classes of substances based on their susceptibility (χ) and relative permeability (μ_r).

Step 3: Detailed Explanation:

Let us examine each statement individually:

Statement I: Diamagnetic substances exhibit a small, negative magnetic susceptibility. For a perfect diamagnet (like a superconductor), $\chi = -1$. For typical diamagnetic materials, $-1 \le \chi < 0$. This statement is **correct**.

Statement II: Paramagnetic substances have a small, positive magnetic susceptibility (typically 10^{-3} to 10^{-5}). It is ferromagnetic substances that have $\chi \gg 1$. Therefore, this statement is **wrong**.

Statement III: Ferromagnetic substances are characterized by very high magnetic susceptibility, where $\chi \gg 1$. The condition $\chi \ll 1$ (small positive) describes paramagnetic materials. Therefore, this statement is **wrong**.

Statement IV: The relationship between relative permeability and susceptibility is given by $\mu_r = 1 + \chi$. Since ferromagnetic substances have very large values of χ, their relative permeability is also very large ($\mu_r \gg 1$). This statement is **correct**.

Step 4: Final Answer:

The wrong statements are II and III. This corresponds to option (3).

Quick Tip: Remember the broad trends for χ:

- Diamagnetic: Small and Negative.
- Paramagnetic: Small and Positive.
- Ferromagnetic: Large and Positive.

---

19. Work function of the metal is

(1) Maximum possible energy acquired by an electron

(2) Equal for all metals

(3) Minimum energy required by an electron to just eject from metal surface

(4) Maximum energy which is given to electron to move out of metal surface

Correct Answer: (3) Minimum energy required by an electron to just eject from metal surface

Solution:

Step 1: Understanding the Question:

This question asks for the fundamental definition of the "work function" in the context of the photoelectric effect and solid-state physics.

Step 3: Detailed Explanation:

Electrons within a metal are held by the attractive forces of the atomic nuclei. To escape the surface of the metal, an electron must overcome a potential energy barrier.

The **work function** (Φ_0 or W) is defined as the minimum amount of energy that must be supplied to an electron to just enable it to escape from the surface of the metal with zero kinetic energy.

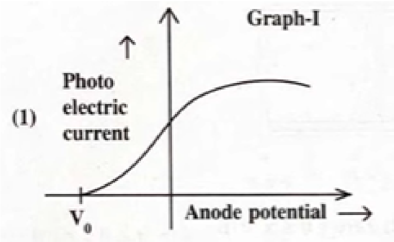
- It is a characteristic property of the metal; different metals have different work functions (e.g., Alkali metals have low work functions while transition metals like Platinum have high ones).
- If the incident photon energy is less than the work function, no photoemission occurs.
- Therefore, option (1) is wrong as it describes kinetic energy, option (2) is wrong because it's not universal, and option (4) is wrong because it's a minimum threshold, not a maximum limit.

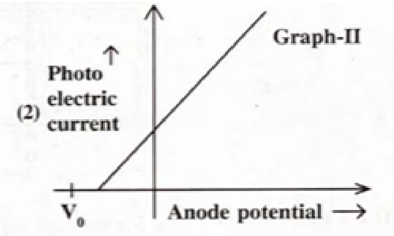
Step 4: Final Answer:

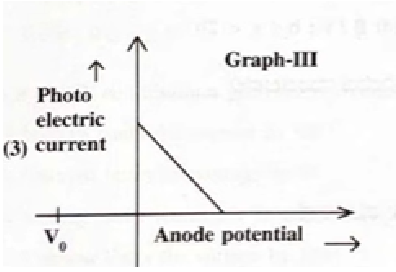
The work function is the minimum energy required for an electron to just eject from the metal surface, which is option (3).

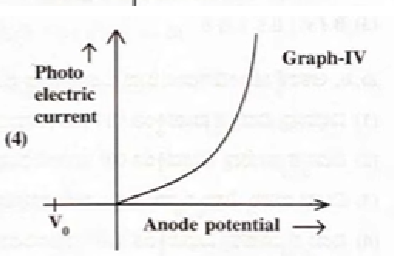
Quick Tip: Think of the work function as the "entry fee" or "toll" an electron must pay to leave the metal "territory." Any extra energy provided by a photon above this "toll" becomes the kinetic energy of the electron.

20. Variation of photoelectric current with anode potential is shown below. Choose the correct option (V_0 = stopping potential).









(1) Graph-I

(2) Graph-II

(3) Graph-III

(4) Graph-IV

Correct Answer: (1) Graph-I

Solution:

Step 1: Understanding the Question:

The goal is to identify the experimentally observed graph that correctly depicts the relationship between the photoelectric current and the potential applied to the collector (anode) plate.

Step 3: Detailed Explanation:

In the photoelectric effect experiment:

1. **Stopping Potential:** When the anode is given a negative potential relative to the cathode, it repels photoelectrons. At a specific negative potential called the stopping potential ($-V_0$), even the electrons with the highest kinetic energy cannot reach the anode, and the current becomes zero.

2. **Increasing Current:** As the anode potential is increased (made less negative and then positive), more photoelectrons are able to reach the collector, resulting in an increase in the measured photoelectric current.

3. **Saturation:** At sufficiently high positive potentials, all the photoelectrons emitted from the cathode are collected by the anode. Beyond this point, increasing the potential does not increase the current further. this constant value is called the **saturation current**.

4. **Graph Analysis:** Graph-I correctly shows the current starting at zero for $V = -V_0$, increasing as potential becomes positive, and eventually leveling off due to saturation. Graph-II is linear, Graph-III shows a decrease, and Graph-IV starts from the origin without showing a stopping potential; hence they are incorrect.

Step 4: Final Answer:

The correctly shown variation is in Graph-I, which corresponds to option (1).

Quick Tip: Saturation current depends on the **intensity** of incident light, while stopping potential depends on the **frequency** of incident light and the nature of the material. In the standard graph, always look for the intersection with the negative voltage axis at V_0.

---

21. In Faraday-Henry's experiment, a coil is connected to a galvanometer. For the deflection of pointer in the galvanometer, which of the following statement/s is/are WRONG?

The pointer in the galvanometer deflects -

(a) When the bar magnet is moved towards the stationary coil along its axis

(b) When the bar magnet is moved away from the stationary coil along its axis

(c) When the coil is moved towards the stationary bar magnet along its axis

(d) When the coil and the magnet are moved without relative motion between them

(1) a and b

(2) b and c

(3) a, b and c

(4) Only d

Correct Answer: (4) Only d

Solution:

Step 1: Understanding the Question:

The question asks to identify the incorrect statement regarding the conditions under which a galvanometer connected to a coil shows a deflection during electromagnetic induction experiments.

Step 3: Detailed Explanation:

According to Faraday's experiments, an electromotive force (emf) is induced in a coil only when there is a change in the magnetic flux linked with it. This change in flux is typically caused by the **relative motion** between the source of the magnetic field (the magnet) and the conductor (the coil).

- **Statements (a), (b), and (c):** All these cases involve relative motion between the magnet and the coil. This motion changes the magnetic flux passing through the coil, inducing a current and causing the galvanometer pointer to deflect. Thus, these statements describe correct observations.

- **Statement (d):** When both the coil and the magnet move with the same velocity in the same direction, there is no relative motion between them. Consequently, the magnetic flux through the coil remains constant, no emf is induced, and the galvanometer pointer does not deflect. Stating that the pointer deflects in this scenario is **WRONG**.

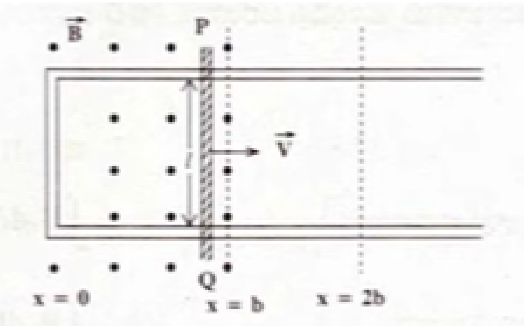
Step 4: Final Answer:

The only wrong statement is (d). Hence, the correct option is (4).

Quick Tip: Galvanometer deflection is a direct indicator of induced current. Induced current requires a **rate of change** of magnetic flux ($\frac{d\phi}{dt} \neq 0$). If there is no relative motion, the flux is constant and no induction occurs.

---

22. In the figure shown, the conductor PQ of length l is moved from $x = 0$ to $x = b$ and then up to $x = 2b$ with a constant velocity $\vec{v}$. A uniform magnetic field $\vec{B}$ is perpendicular to the plane of the paper and extends from $x = 0$ to $x = b$ and it is zero from $x > b$. The magnitude of emf induced in the conductor is



(1) $Blx; 0 \leq x < b$

(2) Zero ; $0 \leq x < b$

(3) $Blv; 0 \leq x \leq b$

(4) $Blv; b \leq x < 2b$

Correct Answer: (3) $Blv; 0 \leq x \leq b$

Solution:

Step 1: Understanding the Question:

The question asks for the magnitude of the induced emf in a rod moving with constant velocity through a region with a spatially limited magnetic field.

Step 2: Key Formula or Approach:

The magnitude of motional emf (ε) induced in a conductor of length l moving with velocity v perpendicular to a uniform magnetic field B is:

$$\varepsilon = Blv$$

Step 3: Detailed Explanation:

1. **Region** $0 \leq x \leq b$**:** In this region, the conductor is moving through a uniform magnetic field B. Since the velocity v, field B, and length l are mutually perpendicular, the induced motional emf is constant and is given by $\varepsilon = Blv$.

2. **Region** $b < x < 2b$**:** According to the problem, the magnetic field B is zero in this region. Since $B = 0$, there is no magnetic flux change linked with the moving rod, and thus the induced emf is zero.

Looking at the options, option (3) correctly identifies the magnitude and the correct spatial interval where the field is present.

Step 4: Final Answer:

The magnitude of emf is Blv for the interval $0 \leq x \leq b$.

Quick Tip: Motional emf only exists when a conductor "cuts" magnetic field lines. If the field is zero or if the conductor moves parallel to the field lines, the induced emf will be zero. Always check the boundaries of the magnetic field region.

---

23. In a circuit containing a pure resistor connected to an AC source,

(1) Voltage leads the current by 90°

(2) Current leads the voltage by 90°

(3) Voltage and current are in same phase with each other

(4) Current leads the voltage by 180°

Correct Answer: (3) Voltage and current are in same phase with each other

Solution:

Step 1: Understanding the Question:

The question asks about the phase relationship between the instantaneous voltage and the instantaneous current in a purely resistive AC circuit.

Step 3: Detailed Explanation:

Let the alternating voltage from the source be represented as:

$$v = V_m \sin(\omega t)$$

According to Ohm's Law, the instantaneous current i through a resistor with resistance R is:

$$i = \frac{v}{R} = \frac{V_m}{R} \sin(\omega t)$$

We can write this as $i = I_m \sin(\omega t)$, where $I_m = \frac{V_m}{R}$.

Comparing the expressions for v and i, we see that both have the same phase angle (ωt). This means that they reach their maximum, minimum, and zero values at the same time. Therefore, the voltage and current are in phase.

Step 4: Final Answer:

In a pure resistor, voltage and current are in the same phase with each other, which corresponds to option (3).

Quick Tip: Use the mnemonic **CIVIL**:

- In a **C**apacitor, **I** (current) leads **V** (voltage).
- In an **I**nductor (**L**), **V** (voltage) leads **I** (current).
- For a Resistor, they are "together" (in phase).

---

24. A light bulb rated 100 W is connected to an AC source of 220 V, 50 Hz. The rms current through the bulb is

(1) 0.454 A

(2) 0.545 A

(3) 2.20 A

(4) 0.22 A

Correct Answer: (1) 0.454 A

Solution:

Step 1: Understanding the Question:

The question asks for the root mean square (rms) current flowing through a light bulb, given its power rating and the rms voltage of the AC supply.

Step 2: Key Formula or Approach:

For a purely resistive load like an incandescent light bulb, the average power P in an AC circuit is given by the product of the rms voltage (V_{rms}) and the rms current (I_{rms}):

$$P = V_{rms} \times I_{rms}$$

Rearranging to find the rms current:

$$I_{rms} = \frac{P}{V_{rms}}$$

Step 3: Detailed Explanation:

Given parameters:

Power rating, $P = 100$ W

RMS Voltage, $V_{rms} = 220$ V

Frequency, $f = 50$ Hz (Note: frequency does not affect current in a pure resistor).

Calculating the current:

$$I_{rms} = \frac{100}{220} \text{ A}$$

$$I_{rms} = \frac{10}{22} \text{ A} = \frac{5}{11} \text{ A}$$

$$I_{rms} \approx 0.4545... \text{ A}$$

Rounding to three decimal places, we get approximately 0.454 A.

Step 4: Final Answer:

The rms current through the bulb is 0.454 A, which corresponds to option (1).

Quick Tip: For AC circuits containing only resistance, the RMS values of current and voltage behave exactly like DC values. You can use Ohm's law ($V_{rms} = I_{rms}R$) and standard power formulas ($P = V_{rms}I_{rms} = I_{rms}^2R$) directly.

---

25. A small town with a demand of 900 kW of electric power at 220 V is situated 20 km away from an electric power generating station. The two-wires line has resistance per unit length of 5×10^{-4} Ωm^{-1}. The town gets power from the line through 45000 V to 220 V stepdown transformer at a substation in the town. The line power loss in the form of heat is

(1) 4 kW

(2) 8 kW

(3) 40 kW

(4) 80 kW

Correct Answer: (2) 8 kW

Solution:

Step 1: Understanding the Question:

The goal is to calculate the power wasted as heat in the transmission lines (line loss) before the power reaches the town's step-down transformer.

Step 2: Key Formula or Approach:

1. Total line resistance $R =$ resistance per meter $\times$ total length of wire.

2. Transmission current $I = \frac{P_{demand}}{V_{transmission}}$.

3. Line power loss $P_{loss} = I^2R$.

Step 3: Detailed Explanation:

Part 1: Calculate the total line resistance.

The station is 20 km away. A "two-wires line" means current goes through 20 km and returns through another 20 km.

Total length $D = 2 \times 20$ km $= 40$ km $= 40,000$ m.

Resistance per meter $r = 5 \times 10^{-4}$ Ω/m.

Total resistance $R = r \times D = (5 \times 10^{-4}\ \Omega/\text{m}) \times (40,000\ \text{m}) = 20\ \Omega$.

Part 2: Calculate the transmission current.

The power demand is $P = 900$ kW $= 900,000$ W.

The voltage at which power is transmitted over the lines (entering the substation) is $V = 45,000$ V.

Current in the line $I = \frac{P}{V} = \frac{900{,}000}{45{,}000} = \frac{900}{45} = 20$ A.

Part 3: Calculate the line power loss.
$P_{\text{loss}} = I^2R = (20)^2 \times 20$

$P_{\text{loss}} = 400 \times 20 = 8,000$ W $= 8$ kW

Step 4: Final Answer:

The line power loss in the form of heat is 8 kW, which corresponds to option (2).

Quick Tip: To minimize power loss (I^2R), electricity is transmitted at very high voltages. High voltage means low current for the same power demand ($P = VI$), which significantly reduces the energy lost in the resistance of the long transmission cables.

---

26. Match the following Maxwell's equations: (The symbols used here have their usual meanings)

List-I	List-II
(a) Gauss' law for electrostatics	(i) $\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$
(b) Gauss' law for magnetism	(ii) $\oint \vec{B} \cdot d\vec{l} = \mu_0 \left[i_c + \epsilon_0 \frac{d\phi_E}{dt} \right]$
(c) Faraday's law	(iii) $\oint \vec{B} \cdot d\vec{A} = 0$
(d) Ampere-Maxwell's law	(iv) $\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$

(1) a - i, b - iii, c - iv, d - ii

(2) a - ii, b - iii, c - i, d - iv

(3) a - i, b - ii, c - iii, d - iv

(4) a - ii, b - iii, c - iv, d - i

Correct Answer: (1) a - i, b - iii, c - iv, d - ii

Solution:

Step 1: Understanding the Question:

The task is to match the names of the four fundamental equations of electromagnetism with their integral mathematical forms as formulated by Maxwell.

Step 3: Detailed Explanation:

- **(a) Gauss' law for electrostatics:** States that the net electric flux through any closed surface is proportional to the enclosed electric charge. The formula is $\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\epsilon_0}$. This matches with **(i)**.
- **(b) Gauss' law for magnetism:** States that the net magnetic flux through any closed surface is always zero, implying that magnetic monopoles do not exist. The formula is $\oint \vec{B} \cdot d\vec{A} = 0$. This matches with **(iii)**.
- **(c) Faraday's law:** States that a changing magnetic field induces an electromotive force (emf), where the line integral of the electric field around a closed loop is equal to the negative rate of change of magnetic flux. The formula is $\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$. This matches with **(iv)**.
- **(d) Ampere-Maxwell's law:** Generalizes Ampere's law by including displacement current. It states that magnetic fields are produced by both conduction currents (i_c) and time-varying electric fields (flux ϕ_E). The formula is $\oint \vec{B} \cdot d\vec{l} = \mu_0[i_c + \epsilon_0 \frac{d\phi_E}{dt}]$. This matches with **(ii)**.

Mapping: a → i, b → iii, c → iv, d → ii.

Step 4: Final Answer:

The correct matching sequence is given in code (1).

Quick Tip: To remember them:

1. Gauss Electro: $\Phi_E \propto Q$.

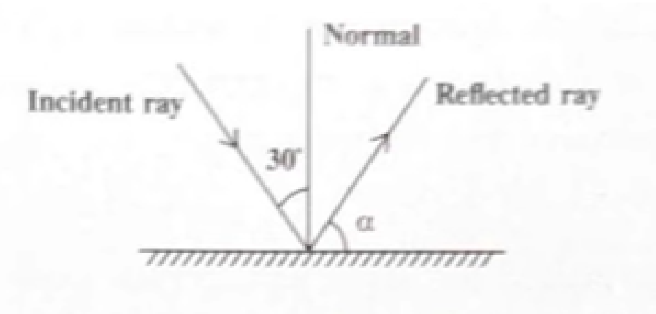
2. Gauss Magnet: $\Phi_B = 0$.

3. Faraday: emf $= -d\Phi_B/dt$.

4. Ampere-Maxwell: B loop relates to I and $d\Phi_E/dt$.

---

27. With reference to the figure shown below, match the following:



List-I	**List-II**
(a) Angle of reflection	(i) 60°
(b) Value of α	(ii) 120°
(c) Angle of deviation	(iii) 30°

(1) a - i, b - ii, c - iii

(2) a - ii, b - i, c - iii

(3) a - iii, b - i, c - ii

(4) a - iii, b - ii, c - i

Correct Answer: (3) a - iii, b - i, c - ii

Solution:

Step 1: Understanding the Question:

This question requires applying the basic laws of reflection at a plane mirror and understanding geometric optics terms like angle of reflection, glancing angle, and angle of deviation.

Step 2: Key Formula or Approach:

1. **Law of Reflection:** Angle of incidence (i) = Angle of reflection (r). 2. **Normal Geometry:** The normal is perpendicular to the mirror surface. Glancing angle $(\alpha) = 90^\circ - r$. 3. **Angle of Deviation (δ):** The angle through which the incident ray is turned after reflection. For a

single reflection, $\delta = 180^\circ - 2i$ or $180^\circ - (i + r)$.

Step 3: Detailed Explanation:

From the given figure: - The incident ray makes an angle of 30° with the normal. Thus, Angle of incidence $i = 30^\circ$. - **(a) Angle of reflection (r):** By the law of reflection, $r = i = 30^\circ$. This matches with **(iii)**.

- **(b) Value of α:** α is the angle between the reflected ray and the mirror surface. Since the angle between the normal and the mirror is 90°, $\alpha = 90^\circ - r = 90^\circ - 30^\circ = 60^\circ$. This matches with **(i)**.

- **(c) Angle of deviation (δ):** The deviation is $\delta = 180^\circ - 2i = 180^\circ - 2(30^\circ) = 180^\circ - 60^\circ = 120^\circ$. This matches with **(ii)**.

Combining these: a - iii, b - i, c - ii.

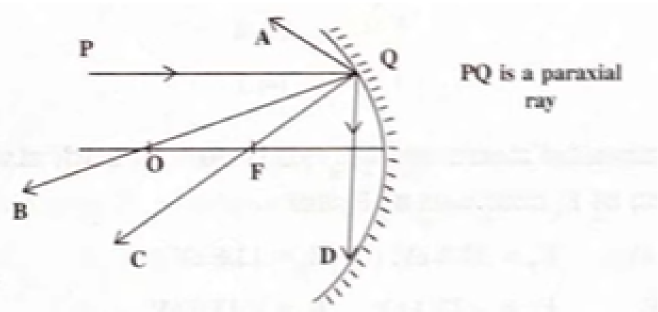
Step 4: Final Answer:

The correct matching corresponds to code (3).

Quick Tip: The angle of deviation δ is effectively the "turn" the light takes. If it strikes at 30° and reflects at 30°, it has changed direction by 180° minus the total angle between the rays (60°), resulting in 120°.

---

28. The direction of a ray of light incident on a concave mirror is shown by PQ, while direction in which the ray would travel after reflection is shown by four rays marked as A, B, C and D as shown in the figure. Which of the four rays correctly shows the direction of the reflected ray?



(1) D

(2) C

(3) B

(4) A

Correct Answer: (2) C

Solution:

Step 1: Understanding the Question:

The question asks to identify the correct reflected path for a specific incident ray on a concave mirror based on standard rules of ray diagrams.

Step 2: Detailed Explanation:

According to the properties of spherical mirrors:

1. A ray of light incident parallel to the principal axis of a concave mirror will, after reflection, pass through its principal focus (F).

2. In the provided diagram, the ray PQ is incident parallel to the principal axis (noted as a paraxial ray).

3. Analyzing the four proposed reflected paths:

- Ray A: Reflects upwards away from the axis (incorrect for concave reflection).
- Ray B: Passes through the center of curvature O (incorrect for a parallel incident ray).
- Ray C: Passes through the principal focus F. This follows the fundamental rule.
- Ray D: Reflects straight down (incorrect).

Therefore, ray C correctly represents the reflected ray.

Step 4: Final Answer:

The reflected ray is shown by ray C, which corresponds to option (2).

Quick Tip: Always remember the "parallel $\longleftrightarrow$ focus" rule for concave mirrors:

- Incident parallel $\rightarrow$ Reflected through F.
- Incident through F $\rightarrow$ Reflected parallel.
- Incident through C $\rightarrow$ Reflected back through C along the same path.

---

29. The incorrect statement about refractive index for a pair of media is

(1) It depends upon nature of the first medium

(2) It depends upon nature of the second medium

(3) It depends upon wavelength of light

(4) It depends upon angle of incidence

Correct Answer: (4) It depends upon angle of incidence

Solution:

Step 1: Understanding the Question:

The question asks to identify which factor does NOT determine the refractive index of a pair of media.

Step 3: Detailed Explanation:

The relative refractive index (n_{21}) for light traveling from medium 1 to medium 2 is a characteristic physical property of that pair of substances for a given wavelength. It is defined as the ratio of the speed of light in medium 1 to the speed of light in medium 2.

- **Nature of media:** Since speed of light varies in different substances (vacuum, water, glass, etc.), the refractive index inherently depends on the nature of both the first and second media.
- **Wavelength of light:** According to Cauchy's equation, refractive index decreases as wavelength increases ($n \approx A + \frac{B}{\lambda^2}$). Thus, it depends on the color/wavelength of light.
- **Angle of incidence:** While Snell's law states that $n = \frac{\sin i}{\sin r}$, this ratio is a **constant** for the given media and wavelength. Changing the angle of incidence (i) will change the angle of refraction (r) accordingly, but the value of the refractive index itself remains unchanged.

Therefore, statement (4) is incorrect.

Step 4: Final Answer:

The incorrect statement is (4).

Quick Tip: Refractive index is a material property. Just as the density of a substance doesn't change regardless of its mass, the refractive index doesn't change regardless of the angle at which light strikes it.

---

30. The critical angle for a monochromatic light going from medium A to medium B is θ. If the speed of light in medium A is V, then the speed of light in medium B is

(1) V (1 - cos θ)

(2) $\frac{V}{\cos\theta}$

(3) $\frac{V}{\sin\theta}$

(4) V (1 - $\sin\theta$)

Correct Answer: (3) $\frac{V}{\sin\theta}$

Solution:

Step 1: Understanding the Question:

The goal is to find the speed of light in the second medium (B) using the given critical angle and the speed of light in the first medium (A).

Step 2: Key Formula or Approach:

1. Relationship between critical angle (θ) and refractive indices: $\sin\theta = \frac{n_2}{n_1} = n_{21}$
2. Relationship between refractive index and speed: $n = \frac{c}{v} \Rightarrow \frac{n_2}{n_1} = \frac{v_1}{v_2}$

Step 3: Detailed Explanation:

For total internal reflection to occur, light must go from a denser medium (A) to a rarer medium (B). Thus $n_A > n_B$.

From the definition of critical angle:

$$\sin\theta = \frac{n_B}{n_A}$$

Since refractive index is inversely proportional to the speed of light in the medium ($n \propto 1/v$):

$$\frac{n_B}{n_A} = \frac{v_A}{v_B}$$

Substituting the given speed $v_A = V$:

$$\sin\theta = \frac{V}{v_B}$$

Solving for v_B:

$$v_B = \frac{V}{\sin\theta}$$

Step 4: Final Answer:

The speed of light in medium B is $\frac{V}{\sin\theta}$.

Quick Tip: Remember that light travels faster in a rarer medium. Since $\sin\theta$ is always ≤ 1, dividing by it will give a value larger than V, which makes physical sense as medium B is rarer.

---

31. What range of electromagnetic spectrum is considered as light?

(1) 1 mm to 700 nm

(2) 400 nm to 1 nm

(3) 400 nm to 700 nm

(4) 1 nm to 10^{-3} nm

Correct Answer: (3) 400 nm to 700 nm

Solution:

Step 1: Understanding the Question:

The question asks for the approximate wavelength range of the visible part of the electromagnetic spectrum, which is commonly referred to as "light".

Step 3: Detailed Explanation:

The electromagnetic spectrum consists of waves ranging from very long radio waves to very short gamma rays. The "visible light" portion is a tiny fraction that the human eye can perceive.
- Standard scientific texts define this range as approximately **400 nm (violet)** to **700 nm (red)**.
- In terms of frequency, this corresponds to roughly 430–750 THz.
- Option (1) includes infrared, option (2) includes ultraviolet/X-rays, and option (4) is the range for Gamma rays.

Step 4: Final Answer:

The considered range of light is 400 nm to 700 nm.

Quick Tip: A useful mnemonic is VIBGYOR. Violet starts at $\approx$ 400 nm and Red ends at $\approx$ 700 nm. In Ångströms, this is 4000 Å to 7000 Å.

---

32. In Young's double slit experiment, how many maxima can be seen on a screen (including central maxima) if d = $\frac{5\lambda}{2}$ (where λ is wavelength of light and d is distance between the two slits).

(1) 5

(2) 4

(3) 7

(4) 1

Correct Answer: (1) 5

Solution:

Step 1: Understanding the Question:

The question asks for the total number of interference maxima possible in a YDSE setup given the slit separation in terms of the wavelength.

Step 2: Key Formula or Approach:

The condition for a maximum in YDSE is:

$$d \sin\theta = n\lambda$$

where n is the order of the maximum and θ is the angular position.

Step 3: Detailed Explanation:

The maximum possible value for $\sin\theta$ is 1 (corresponding to $\theta = 90^\circ$ at infinity on the screen). So, the maximum order n is constrained by:

$$|n| \leq \frac{d}{\lambda}$$

Given $d = \frac{5\lambda}{2} = 2.5\lambda$:

$$|n| \leq \frac{2.5\lambda}{\lambda} \Rightarrow |n| \leq 2.5$$

Since n must be an integer, the possible values for n are:

$$n = 0, \pm 1, \pm 2$$

- $n = 0$ is the central maximum.
- $n = 1, 2$ are maxima on one side of the center.
- $n = -1, -2$ are maxima on the other side.

Total number of maxima $= 2 \times (\text{maximum integer value of } n) + 1 = (2 \times 2) + 1 = 5$.

Step 4: Final Answer:

A total of 5 maxima can be seen on the screen.

Quick Tip: To find the total number of maxima, use the formula $2 \times \lfloor d/\lambda \rfloor + 1$. If d/λ is exactly an integer, the maxima at $\pm 90°$ are usually not "seen" on a flat screen at a finite distance, but here the value is 2.5, so 5 is the clear result.

---

33. The radius of first orbit in hydrogen atom is 5.3×10^{-11} m. The kinetic energy E_K, potential energy E_P and total energy E_T of electron in first orbit are

(1) E_K = - 13.6 eV, E_P = 27.2 eV, E_T = 13.6 eV

(2) E_K = 13.6 eV, E_P = - 27.2 eV, E_T = - 13.6 eV

(3) E_K = - 27.2 eV, E_P = - 13.6 eV, E_T = 13.6 eV

(4) E_K = 13.6 eV, E_P = - 6.8 eV, E_T = - 13.6 eV

Correct Answer: (2) E_K = 13.6 eV, E_P = - 27.2 eV, E_T = - 13.6 eV

Solution:

Step 1: Understanding the Question:

The question asks for the different energy components of an electron in the ground state ($n = 1$) of a hydrogen atom.

Step 2: Key Formula or Approach:

For a Bohr atom, the relationship between energies is:

1. Total Energy $E_T = \frac{E_P}{2} = -E_K$
2. For Hydrogen ground state, $E_T = -13.6$ eV

Step 3: Detailed Explanation:

In the first orbit of Hydrogen ($n = 1$):

- **Total Energy (E_T):** By Bohr's formula, $E_n = -13.6\frac{Z^2}{n^2}$ eV. For $Z = 1, n = 1$, $E_T = -13.6$ eV.
- **Kinetic Energy (E_K):** Kinetic energy is always positive and $E_K = -E_T = -(-13.6) = 13.6$ eV.
- **Potential Energy (E_P):** Potential energy is negative for an attractive system and $E_P = 2E_T = 2 \times (-13.6) = -27.2$ eV.

Checking the options, (2) perfectly matches these calculations.

Step 4: Final Answer:

The correct set of energies is given in option (2).

Quick Tip: Always remember: Kinetic energy is positive, Total energy is negative (for bound states), and Potential energy is twice the total energy (also negative). This immediately eliminates options (1) and (3).

---

34. Bohr's second postulate implies quantisation of

(1) Charge of an electron

(2) Energy of an electron

(3) Angular momentum of electron

(4) Radiated energy by an electron

Correct Answer: (3) Angular momentum of electron

Solution:

Step 1: Understanding the Question:

The question refers to the specific physical quantity that is quantized according to Bohr's second postulate in his atomic model of hydrogen.

Step 3: Detailed Explanation:

Bohr's second postulate (also known as the quantum condition) states that an electron can revolve around the nucleus only in those fixed circular orbits for which its orbital angular momentum (L) is an integral multiple of $\frac{h}{2\pi}$, where h is Planck's constant.

Mathematically, this is expressed as:

$$L = mvr = \frac{nh}{2\pi}$$

where $n = 1, 2, 3, \dots$ is the principal quantum number. This implies that angular momentum is not continuous but exists in discrete "packets" or quanta.

Step 4: Final Answer:

Bohr's second postulate implies the quantisation of angular momentum of an electron, which corresponds to option (3).

Quick Tip: Remember the formula $L = n\hbar$, where $\hbar = \frac{h}{2\pi}$. This postulate was later explained by de-Broglie's hypothesis of matter waves, showing that only certain orbits can accommodate a standing wave of the electron.

---

35. An electron transition takes place from excited state to ground state in hydrogen atom, then

(1) Its kinetic energy increases but potential energy and total energy decrease

(2) Its kinetic energy, potential energy and total energy decrease

(3) Kinetic energy decreases, potential energy increases but total energy remains same

(4) Kinetic energy and total energy decrease but potential energy increases

Correct Answer: (1) Its kinetic energy increases but potential energy and total energy decrease

Solution:

Step 1: Understanding the Question:

The goal is to determine how the kinetic, potential, and total energy of an electron change when it moves from a higher energy level (excited state) to a lower energy level (ground state).

Step 2: Key Formula or Approach:

For an electron in the n-th orbit of a hydrogen atom:

- Total Energy: $E_n = -13.6\frac{1}{n^2}$ eV
- Kinetic Energy: $K_n = -E_n = 13.6\frac{1}{n^2}$ eV
- Potential Energy: $U_n = 2E_n = -27.2\frac{1}{n^2}$ eV

Step 3: Detailed Explanation:

Transition is from an excited state (higher n) to the ground state ($n = 1$).

1. **Total Energy (E):** As n decreases, $\frac{1}{n^2}$ increases. Since E is negative, a larger numerical value means a **decrease** (it becomes more negative).

2. **Kinetic Energy (K):** K is positive and proportional to $\frac{1}{n^2}$. As n decreases, K **increases**.

3. **Potential Energy (U):** Since U is negative and proportional to $\frac{1}{n^2}$, as n decreases, U **decreases** (it becomes more negative).

Comparing with options, statement (1) is correct.

Step 4: Final Answer:

Upon transition to a lower state, kinetic energy increases while potential and total energy decrease. This is option (1).

Quick Tip: The closer the electron is to the nucleus (lower n), the faster it must move to stay in orbit (higher kinetic energy), and the more tightly bound it is (lower/more negative potential and total energy).

---

36. An n-type and p-type semiconductor can be obtained by respectively doping pure silicon with

(1) Arsenic and Phosphorous respectively

(2) Indium and Aluminium respectively

(3) Phosphorous and Indium respectively

(4) Aluminium and Boron respectively

Correct Answer: (3) Phosphorous and Indium respectively

Solution:

Step 1: Understanding the Question:

The question asks to identify the correct pairs of dopant elements required to create n-type and p-type semiconductors from intrinsic silicon.

Step 3: Detailed Explanation:

Silicon is a Group 14 element with 4 valence electrons.

1. **n-type semiconductor:** Obtained by doping silicon with pentavalent impurities (Group 15 elements) which have 5 valence electrons. Common examples are Phosphorous (P), Arsenic (As), and Antimony (Sb). The fifth electron remains free as a majority charge carrier.

2. **p-type semiconductor:** Obtained by doping silicon with trivalent impurities (Group 13 elements) which have 3 valence electrons. Common examples are Boron (B), Aluminium (Al), Gallium (Ga), and Indium (In). The deficiency of one electron creates a "hole" as a majority charge carrier.

Evaluating option (3): Phosphorous (Group 15) for n-type and Indium (Group 13) for p-type is a correct match.

Step 4: Final Answer:

Phosphorous and Indium are the respective dopants for n and p-type semiconductors, matching option (3).

Quick Tip: Remember:

- **n** is for **n**egative (electron): needs Group **15** (4 + 1 extra).
- **p** is for **p**ositive (hole): needs Group 1**3** (4 - 1 missing).

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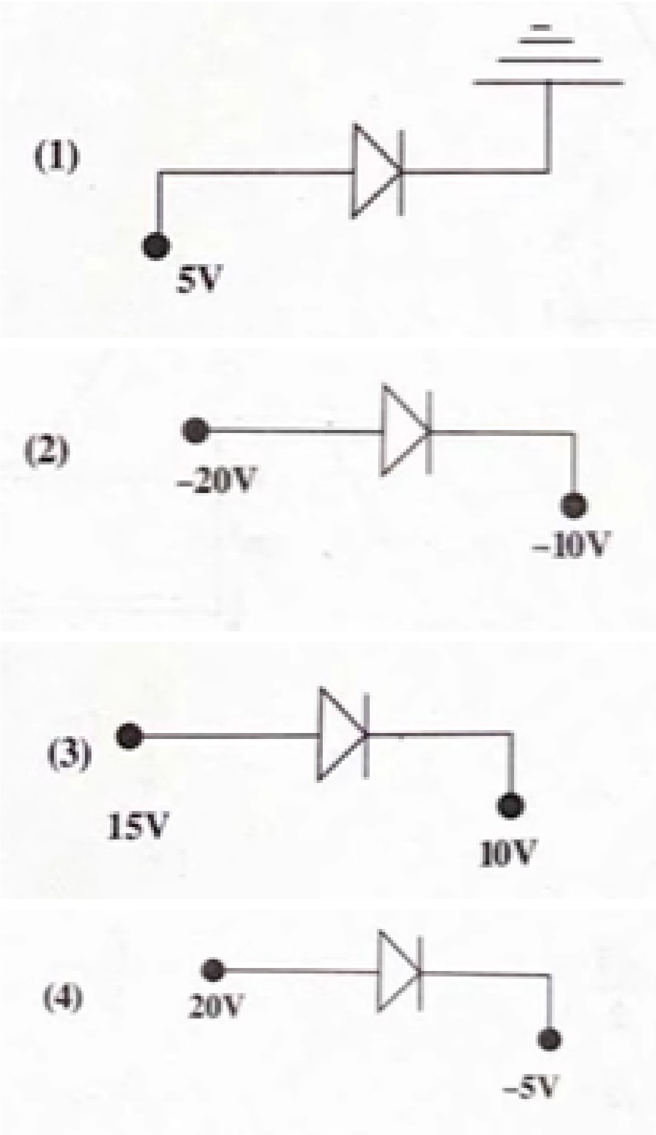
37. In which of the following figures, diode is reverse biased?



(1) Figure (1)

(2) Figure (2)

(3) Figure (3)

(4) Figure (4)

Correct Answer: (2) Figure (2)

Solution:

Step 1: Understanding the Question:

We need to determine which circuit configuration results in a reverse-biased diode by comparing the potentials of the p-side and n-side.

Step 3: Detailed Explanation:

A diode is:

- **Forward biased** if the potential of the p-side (V_P) is higher than the potential of the n-side (V_N), i.e., $V_P > V_N$.
- **Reverse biased** if the potential of the p-side (V_P) is lower than the potential of the n-side (V_N), i.e., $V_P < V_N$.

Let's analyze each case:

(1) $V_P = 5$ V, $V_N = 0$ V (grounded). $V_P > V_N \Rightarrow$ Forward biased.

(2) $V_P = -20$ V, $V_N = -10$ V. Since $-20 < -10$, $V_P < V_N \Rightarrow$ **Reverse biased**.

(3) $V_P = 15$ V, $V_N = 10$ V. $V_P > V_N \Rightarrow$ Forward biased.

(4) $V_P = 20$ V, $V_N = -5$ V. $V_P > V_N \Rightarrow$ Forward biased.

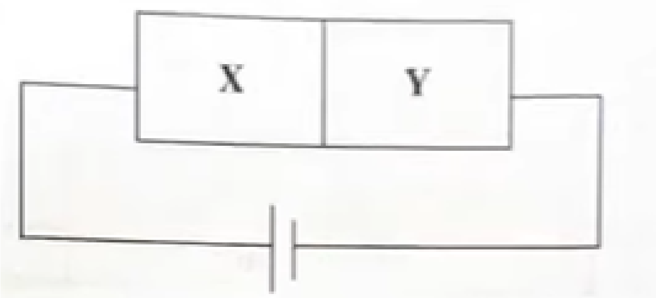
Step 4: Final Answer:

In figure (2), the diode is reverse biased. This corresponds to option (2).

Quick Tip: Always treat "less negative" as a higher potential. For example, -10 V is at a higher potential than -20 V. If the arrow of the diode (p-side) points towards a higher potential, it's reverse biased.

---

38. A wafer of pure germanium crystal has two parts X and Y. The end X is obtained by doping with arsenic and Y with indium. It is connected to a battery as shown in the figure. Which of the following statements is correct?



(A) X is p-type, Y is n-type and the junction is forward biased

(B) X is n-type, Y is p-type and the junction is forward biased

(C) X is p-type, Y is n-type and the junction is reverse biased

(D) X is n-type, Y is p-type and the junction is reverse biased

Correct Answer: (B) X is n-type, Y is p-type and the junction is forward biased

Solution:

Step 1: Understanding the Question:

The goal of this question is to identify the type of semiconductor formed in each region (X and Y) based on the dopants used and then determine the biasing condition of the resulting p-n junction from the provided circuit diagram.

Step 3: Detailed Explanation:

1. **Identification of Semiconductor Types:**

- Pure Germanium (Ge) belongs to Group 14 of the periodic table.
- **Part X:** This part is doped with Arsenic (As). Arsenic is a Group 15 element, which means it has 5 valence electrons (pentavalent impurity). When a pentavalent impurity is added to a tetravalent semiconductor like Ge, it provides an extra free electron, creating an **n-type** semiconductor.
- **Part Y:** This part is doped with Indium (In). Indium is a Group 13 element, which has 3 valence electrons (trivalent impurity). When a trivalent impurity is added to Ge, it creates a vacancy or "hole," resulting in a **p-type** semiconductor.

2. **Biasing Analysis:**

- In the provided diagram, a battery is connected to the X-Y block.
- The longer vertical line of the battery symbol represents the positive terminal, and the shorter,

thicker line represents the negative terminal.

- Region X (n-type) is connected to the **negative terminal**.
- Region Y (p-type) is connected to the **positive terminal**.
- When the p-type region is connected to the positive terminal and the n-type region is connected to the negative terminal of an external source, the junction is said to be **forward biased**.

Step 4: Final Answer:

Region X is n-type, region Y is p-type, and the configuration is forward biased. This matches statement (B).

Quick Tip: To remember doping types easily:

- Group 15 (**P**entavalent) $\rightarrow$ **N**-type (**P**lenty of electrons).
- Group 13 (**T**rivalent) $\rightarrow$ **P**-type (**P**ositive holes).

For biasing, remember **P**ositive to **P**-type is **F**orward bias.

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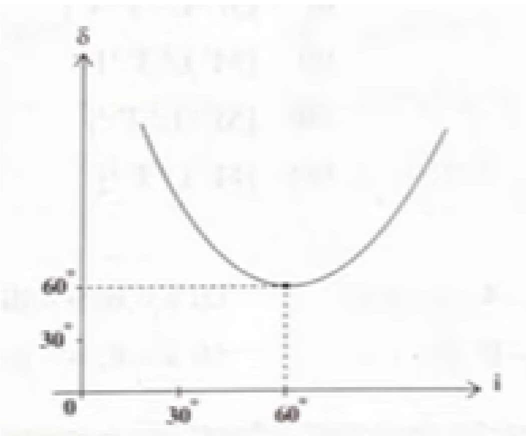
39. From the graph of angle of deviation versus angle of incidence for an equilateral prism, the refractive index of material of prism is



(A) $\frac{\sqrt{3}}{2}$

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

(C) $\sqrt{3}$

(D) $\sqrt{2}$

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

Solution:

Step 1: Understanding the Question:

The question asks us to calculate the refractive index of a prism's material based on a given graph of angle of deviation (δ) vs. angle of incidence (i) for an equilateral prism.

Step 2: Key Formula or Approach:

The refractive index (n) of a prism can be determined using the prism formula:

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

Where:

- A is the angle of the prism.
- δ_m is the angle of minimum deviation.

Step 3: Detailed Explanation:

1. **Determine the Prism Angle (A):**

An "equilateral prism" has all its internal angles equal to 60°. Therefore, the angle of the prism $A = 60^\circ$.

2. **Identify the Minimum Deviation (δ_m) from the graph:**

The graph shows how the deviation changes with the angle of incidence. The lowest point on the U-shaped curve represents the condition of minimum deviation.

Looking at the graph, the coordinates of the minimum point are $(i, \delta) = (60^\circ, 60^\circ)$.

Thus, the angle of minimum deviation $\delta_m = 60^\circ$.

3. **Calculation of Refractive Index (n):**

Substitute the values $A = 60^\circ$ and $\delta_m = 60^\circ$ into the formula:

$$n = \frac{\sin\left(\frac{60^\circ+60^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)}$$

$$n = \frac{\sin(60^\circ)}{\sin(30^\circ)}$$

Using known trigonometric values: $\sin(60^\circ) = \frac{\sqrt{3}}{2}$ and $\sin(30^\circ) = \frac{1}{2}$.

$$n = \frac{\sqrt{3}/2}{1/2} = \sqrt{3}$$

Step 4: Final Answer:

The refractive index of the prism material is $\sqrt{3}$, which corresponds to option (C).

Quick Tip: For an equilateral prism, if the minimum deviation is also equal to the prism angle ($\delta_m = A = 60^\circ$), the refractive index will always evaluate to $\sqrt{3}$. Note that in this state, the angle of incidence i also equals 60°.

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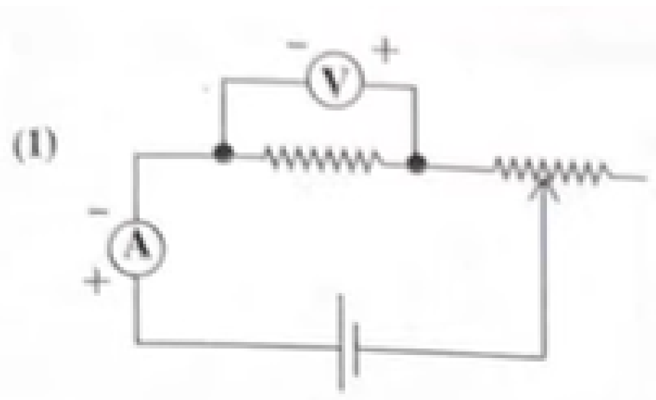
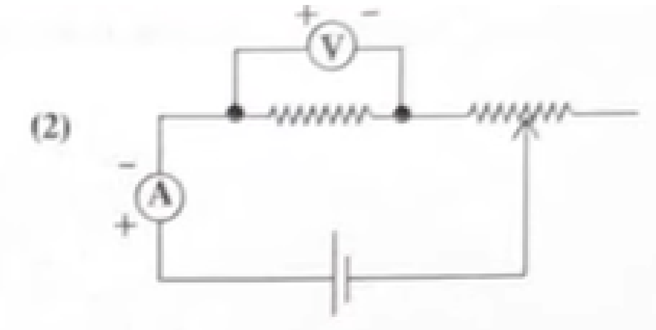
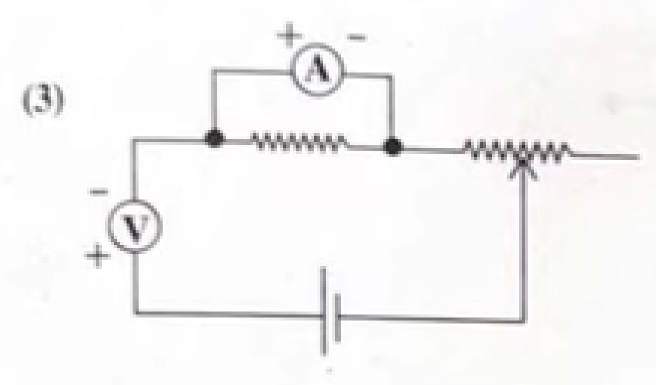
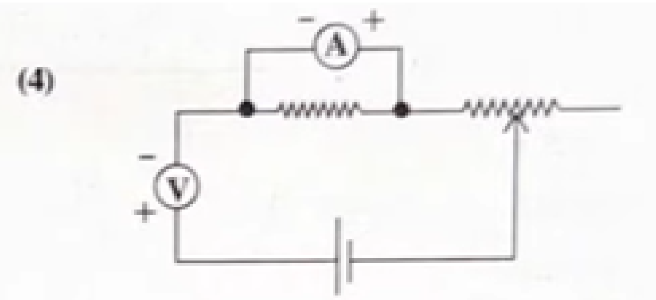
40. Which of the following circuits is correct for verification of Ohm's law?









(1) Figure (1)

(2) Figure (2)

(3) Figure (3)

(4) Figure (4)

Correct Answer: (1) Figure (1)

Solution:

Step 1: Understanding the Question:

Ohm's law states that the current passing through a conductor is directly proportional to the potential difference across it, provided physical conditions remain constant ($V = IR$). To verify this experimentally, we need to measure both current and voltage across a known resistor.

Step 3: Detailed Explanation:

To correctly measure electrical parameters in a circuit:

1. **Ammeter (A):** It measures the current (I) and must be connected in **series** with the circuit components to ensure the same current flows through it.

2. **Voltmeter (V):** It measures the potential difference (V) and must be connected in **parallel** across the resistor.

3. **Polarity:** The positive terminal (+) of both the ammeter and voltmeter must be connected towards the positive terminal of the power source (battery/cell).

Analyzing the provided circuit options:

- In **Figure (1)**, the ammeter is in series and the voltmeter is in parallel. Tracing from the battery's positive terminal (the long line on the right), the current flows through the rheostat and enters the right side of the resistor. The positive terminal of the voltmeter is correctly on the right. Current leaves the left side of the resistor and enters the ammeter's positive terminal at the bottom. This configuration is correct.
- In **Figure (2)**, the voltmeter's polarity is reversed (+ is incorrectly on the left).
- In **Figures (3)** and **(4)**, the ammeter is incorrectly placed in parallel across the resistor and the voltmeter is incorrectly placed in series.

Step 4: Final Answer:

The correct circuit for verification of Ohm's law is shown in Figure (1).

Quick Tip: Remember the mnemonic: **A**mmeter in **S**eries (A-S) and **V**oltmeter in **P**arallel (V-P). Always ensure that the '+' terminal of every meter is electrically closer to the '+' terminal of the battery.

---

41. Match the physical quantities given in List-I with dimensions expressed in terms of mass (M), length (L), time (T) and electric current (A) given in List-II.

List-I	List-II
(a) Torque	(i) $[M^{-1}L^{-2}T^{4}A^{2}]$
(b) Gravitational constant	(ii) $[M^{1}L^{2}T^{-1}]$
(c) Capacitance	(iii) $[M^{-1}L^{3}T^{-2}]$
(d) Planck's constant	(iv) $[M^{1}L^{2}T^{-2}]$

Codes:

(1) a - iv, b - ii, c - iii, d - i

(2) a - iv, b - iii, c - i, d - ii

(3) a - iv, b - i, c - iii, d - ii

(4) a - ii, b - i, c - iii, d - iv

Correct Answer: (2) a - iv, b - iii, c - i, d - ii

Solution:

Step 1: Understanding the Question:

The objective is to derive the dimensional formulas for each physical quantity and match them with the corresponding dimensions given in List-II.

Step 3: Detailed Explanation:

(a) Torque (τ):

Formula: τ = Force × perpendicular distance.

Dimensions: $[MLT^{-2}] \times [L] = [ML^2T^{-2}]$.

This matches with **(iv)**.

(b) Gravitational constant (G):

Formula: $F = G\frac{m_1m_2}{r^2} \Rightarrow G = \frac{Fr^2}{m_1m_2}$.

Dimensions: $\frac{[MLT^{-2}]\times[L^2]}{[M^2]} = [M^{-1}L^3T^{-2}]$.

This matches with **(iii)**.

(c) Capacitance (C):

Formula: $C = \frac{Q}{V} = \frac{Q^2}{W}$ (since Potential V = Work W/Charge Q).

Dimensions of Charge $Q = [AT]$.

Dimensions of Work $W = [ML^2T^{-2}]$.

Dimensions of $C = \frac{[AT]^2}{[ML^2T^{-2}]} = [M^{-1}L^{-2}T^4A^2]$.

This matches with **(i)**.

(d) Planck's constant (h):

Formula: $E = h\nu \Rightarrow h = \frac{E}{\nu}$ (where ν is frequency).

Dimensions: $\frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$.

This matches with **(ii)**.

Step 4: Final Answer:

The correct matching is a-iv, b-iii, c-i, d-ii. This corresponds to code (2).

Quick Tip: To quickly derive dimensions, relate quantities to Energy or Work. For instance, Torque and Energy have identical dimensions (ML^2T^{-2}). Similarly, Planck's constant has the same dimensions as Angular Momentum (ML^2T^{-1}).

---

42. A car covers the first half of the distance between two places at 40 km/h and another half at 50 km/h. The average speed of the car is

(1) 45.00 km/h

(2) 44.44 km/h

(3) 43.14 km/h

(4) 42.04 km/h

Correct Answer: (2) 44.44 km/h

Solution:

Step 1: Understanding the Question:

The problem asks for the average speed of a car that travels two equal distances at different constant speeds.

Step 2: Key Formula or Approach:

Average speed is total distance divided by total time.

When two equal distances (d) are covered at speeds v_1 and v_2, the average speed is the **harmonic mean** of the two speeds:

$$v_{avg} = \frac{2v_1v_2}{v_1 + v_2}$$

Step 3: Detailed Explanation:

Given:

Speed for first half, $v_1 = 40$ km/h

Speed for second half, $v_2 = 50$ km/h

Substituting these values into the harmonic mean formula:

$$v_{avg} = \frac{2 \times 40 \times 50}{40 + 50}$$

$$v_{avg} = \frac{4000}{90}$$

$$v_{avg} = \frac{400}{9} \approx 44.444\ldots \text{ km/h}$$

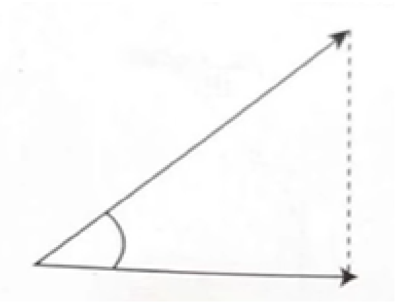
Step 4: Final Answer:

The average speed of the car is 44.44 km/h.

Quick Tip: Avoid the common error of using the arithmetic mean ($\frac{40+50}{2} = 45$). The arithmetic mean only represents average speed if the **times** spent at each speed are equal. For equal distances, the average speed is always closer to the lower speed.

---

43. Two bodies are projected with the same velocity. If one is projected at an angle of 30° and the other at 45° to the horizontal, then the ratio of maximum heights attained is



(1) 3:1

(2) 1:2

(3) 4:1

(4) 1:3

Correct Answer: (2) 1:2

Solution:

Step 1: Understanding the Question:

The problem asks for the ratio of maximum heights attained by two projectiles launched with the same initial velocity but at different angles of projection.

Step 2: Key Formula or Approach:

The maximum height (H) for a projectile launched with initial velocity u at an angle θ to the horizontal is given by:

$$H = \frac{u^2 \sin^2\theta}{2g}$$

Since u and g are constant for both projections, $H \propto \sin^2\theta$.

Step 3: Detailed Explanation:

Let H_1 be the maximum height for the first body projected at $\theta_1 = 30^\circ$, and H_2 for the second body projected at $\theta_2 = 45^\circ$.

The ratio of their maximum heights will be:

$$\frac{H_1}{H_2} = \frac{\frac{u^2\sin^2\theta_1}{2g}}{\frac{u^2\sin^2\theta_2}{2g}} = \frac{\sin^2\theta_1}{\sin^2\theta_2}$$

Substitute the given angles:

$$\frac{H_1}{H_2} = \frac{\sin^2(30^\circ)}{\sin^2(45^\circ)}$$

We know that $\sin(30^\circ) = \frac{1}{2}$ and $\sin(45^\circ) = \frac{1}{\sqrt{2}}$.

$$\frac{H_1}{H_2} = \frac{(1/2)^2}{(1/\sqrt{2})^2} = \frac{1/4}{1/2} = \frac{1}{4} \times 2 = \frac{1}{2}$$

So, the ratio of maximum heights attained is 1:2.

Step 4: Final Answer:

The ratio of maximum heights attained is 1:2.

Quick Tip: Remember that maximum height depends on the vertical component of the initial velocity squared. So, if angles are complementary, say θ and $90° - \theta$, $\sin^2\theta$ will be different from $\sin^2(90° - \theta) = \cos^2\theta$. This problem highlights the direct dependence on the square of the sine of the angle.

---

44. The velocity of a particle moving along x-axis is given as $V = x^2 - 5x + 4$ (in m/s) where x denotes the x-coordinate of the particle in metres. The magnitude of the acceleration of the particle when the velocity of the particle zero is

(1) 2 m/s^2

(2) 3 m/s^2

(3) Zero

(4) 1 m/s^2

Correct Answer: (2) 3 m/s^2

Solution:

Step 1: Understanding the Question:

The velocity of the particle is given as a function of position:

$$v = x^2 - 5x + 4$$

We are asked to find the magnitude of acceleration when the velocity becomes zero.

Step 2: Key Formula or Approach:

Acceleration can be written as:

$$a = \frac{dv}{dt} = \frac{dv}{dx} \cdot \frac{dx}{dt} = v\frac{dv}{dx}$$

Step 3: Detailed Explanation:

First, find when velocity is zero:

$$x^2 - 5x + 4 = 0$$

$$(x-1)(x-4) = 0 \Rightarrow x = 1 \text{ or } x = 4$$

Now, compute:

$$\frac{dv}{dx} = 2x - 5$$

Acceleration:

$$a = v \cdot (2x - 5)$$

At both $x = 1$ and $x = 4$, we already know:

$$v = 0$$

So,

$$a = 0 \cdot (2x - 5) = 0$$

Step 4: Final Answer:

The magnitude of acceleration is:

$$\boxed{0}$$

Quick Tip: When velocity is given as a function of position, use:

$$a = v\frac{dv}{dx}$$

If velocity becomes zero, acceleration also becomes zero (unless the expression is undefined).

---

45. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 6 m/s^2. What would be his weight in kg? (g = 10 m/s^2)

(1) Zero

(2) 48 kg

(3) 120 kg

(4) 128 kg

Correct Answer: (4) 128 kg

Solution:

Step 1: Understanding the Question:

The question asks for the apparent weight of a man (in kg, which implies a mass reading on a scale) in a lift accelerating upwards.

Step 2: Key Formula or Approach:

Apparent weight in a lift accelerating upwards: $N = m(g + a)$, where N is the normal force exerted by the scale.

If the scale reads "weight in kg", it is effectively measuring mass m' such that $m'g = N$.

So, apparent mass $m' = \frac{N}{g} = \frac{m(g+a)}{g} = m\left(1 + \frac{a}{g}\right)$.

Step 3: Detailed Explanation:

Given values:

Mass of man, $m = 80$ kg

Acceleration of lift, $a = 6\ \text{m/s}^2$ (upwards)

Acceleration due to gravity, $g = 10\ \text{m/s}^2$

Calculate the apparent mass (m'):

$$m' = 80\left(1 + \frac{6}{10}\right)$$

$$m' = 80(1 + 0.6)$$

$$m' = 80 \times 1.6$$

$$m' = 128 \text{ kg}$$

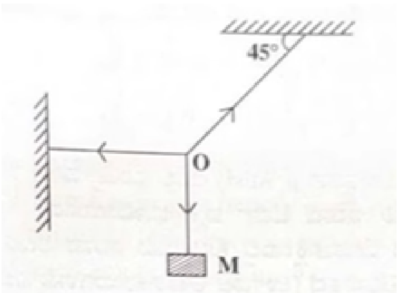
Step 4: Final Answer:

His weight (apparent mass) in kg would be 128 kg.

Quick Tip: Apparent weight is the normal force exerted by the scale. Always be clear if the question asks for apparent weight in Newtons or apparent mass in kg (which is the apparent weight divided by g).

---

46. A mass M is hung with a light inextensible string as shown in figure. Find the tension of the horizontal string.



(1) $\sqrt{2}$ Mg

(2) $\sqrt{3}$ Mg

(3) Mg

(4) 3 Mg

Correct Answer: (3) Mg

Solution:

Step 1: Understanding the Question:

The problem asks for the tension in the horizontal string that supports a mass M, given that another string is inclined at 45° and connected to the same junction. This is a static equilibrium problem.

Step 2: Key Formula or Approach:

For a system in equilibrium, the net force in both horizontal and vertical directions is zero. Let T_H be the tension in the horizontal string and T_I be the tension in the inclined string. The weight of the mass is $W = Mg$.

Step 3: Detailed Explanation:

Draw a Free Body Diagram (FBD) for the junction point O where the three strings meet.

- Downwards force: Mg (due to the hanging mass).
- Horizontal force (to the left): T_H (tension in the horizontal string).
- Inclined force: T_I (tension in the string making 45° with the horizontal).

Resolve the inclined tension T_I into its horizontal and vertical components:
- Horizontal component of T_I: $T_I \cos 45^\circ$ (to the right).
- Vertical component of T_I: $T_I \sin 45^\circ$ (upwards).

Apply equilibrium conditions:

1. **Vertical equilibrium ($\sum F_y = 0$):**

Forces acting upwards = Forces acting downwards

$$T_I \sin 45^\circ = Mg$$
$$T_I \left(\frac{1}{\sqrt{2}}\right) = Mg \Rightarrow T_I = Mg\sqrt{2}$$

2. **Horizontal equilibrium ($\sum F_x = 0$):**

Forces acting to the right = Forces acting to the left

$$T_I \cos 45^\circ = T_H$$

Substitute $T_I = Mg\sqrt{2}$ and $\cos 45^\circ = \frac{1}{\sqrt{2}}$:

$$T_H = (Mg\sqrt{2})\left(\frac{1}{\sqrt{2}}\right)$$
$$T_H = Mg$$

Step 4: Final Answer:

The tension in the horizontal string is Mg.

Quick Tip: Always start by drawing a clear Free Body Diagram (FBD) at the point where forces meet. Resolve forces into components along convenient axes (usually horizontal and vertical) and then apply equilibrium conditions.

---

47. Two bodies with kinetic energies in the ratio of 3:1 are moving with equal linear momentum. The ratio of their masses is

(1) 1:4

(2) 1:3

(3) 1:2

(4) 1:1

Correct Answer: (2) 1:3

Solution:

Step 1: Understanding the Question:

The problem asks for the ratio of the masses of two bodies, given the ratio of their kinetic energies and the fact that they have equal linear momentum.

Step 2: Key Formula or Approach:

1. Kinetic Energy (K): $K = \frac{1}{2}mv^2$

2. Linear Momentum (p): $p = mv$

These two are related by: $K = \frac{p^2}{2m}$. This form is convenient when momentum is constant.

Step 3: Detailed Explanation:

Let the two bodies be 1 and 2.

Given:

- Ratio of kinetic energies: $\frac{K_1}{K_2} = \frac{3}{1}$

- Equal linear momentum: $p_1 = p_2 = p$

Using the relation $K = \frac{p^2}{2m}$:

For body 1: $K_1 = \frac{p^2}{2m_1}$

For body 2: $K_2 = \frac{p^2}{2m_2}$

Now, take the ratio of their kinetic energies:

$$\frac{K_1}{K_2} = \frac{\frac{p^2}{2m_1}}{\frac{p^2}{2m_2}} = \frac{m_2}{m_1}$$

We are given $\frac{K_1}{K_2} = \frac{3}{1}$.

So, $\frac{m_2}{m_1} = \frac{3}{1}$.

The question asks for the ratio of their masses ($m_1 : m_2$):

$$\frac{m_1}{m_2} = \frac{1}{3}$$

Step 4: Final Answer:

The ratio of their masses is 1:3.

Quick Tip: Remember the inverse relationship between kinetic energy and mass when momentum is constant: $K \propto \frac{1}{m}$. So, if kinetic energy is in ratio $K_1 : K_2$, then mass ratio $m_1 : m_2$ will be $K_2 : K_1$.

---

48. A horizontal force of 5 N is applied on a stationary body of mass 5 kg, which is initially at rest on a frictionless table. The change in kinetic energy of the body in 10 s is

(1) 25 J

(2) Zero

(3) 125 J

(4) 250 J

Correct Answer: (3) 125 J

Solution:

Step 1: Understanding the Question:

The problem asks for the change in kinetic energy of a body after a constant force acts on it for a specific time, starting from rest on a frictionless surface.

Step 2: Key Formula or Approach:

1. Newton's second law: $F = ma \Rightarrow a = F/m$.

2. Kinematics (from rest): $v = u + at \Rightarrow v = at$.

3. Kinetic Energy: $K = \frac{1}{2}mv^2$.

4. Work-Energy Theorem: $\Delta K = W_{net} = F \cdot s$.

Alternatively, we can find the final velocity and then the final kinetic energy.

Step 3: Detailed Explanation:

Given values:

- Force, $F = 5$ N
- Mass, $m = 5$ kg
- Initial velocity, $u = 0$ m/s (at rest)
- Time, $t = 10$ s

First, calculate the acceleration (a):

$$a = \frac{F}{m} = \frac{5 \text{ N}}{5 \text{ kg}} = 1 \text{ m/s}^2$$

Next, calculate the final velocity (v) after 10 s:

$$v = u + at = 0 + (1 \text{ m/s}^2)(10 \text{ s}) = 10 \text{ m/s}$$

Now, calculate the change in kinetic energy (ΔK):

Since it starts from rest, initial kinetic energy $K_i = 0$.

Final kinetic energy $K_f = \frac{1}{2}mv^2 = \frac{1}{2}(5 \text{ kg})(10 \text{ m/s})^2$

$$K_f = \frac{1}{2} \times 5 \times 100 = 250 \text{ J}$$

$$\Delta K = K_f - K_i = 250 \text{ J} - 0 \text{ J} = 250 \text{ J}$$

Step 4: Final Answer:

The change in kinetic energy of the body is 250 J.

Quick Tip: In problems involving constant force and frictionless surfaces, you can either use kinematic equations to find velocity/displacement and then energy, or use the Work-Energy Theorem directly. Both methods should yield the same result.

---

49. The angular momentum of a moving body remains constant, if

(1) net external force is applied

(2) net pressure is applied

(3) net external torque is applied

(4) net external torque is not applied

Correct Answer: (4) net external torque is not applied

Solution:

Step 1: Understanding the Question:

The question asks for the condition under which the angular momentum of a system remains conserved.

Step 3: Detailed Explanation:

The principle of conservation of angular momentum states that the total angular momentum of a system remains constant if no external torque acts on it.

Mathematically, the relationship between torque ($\vec{\tau}$) and angular momentum ($\vec{L}$) is given by:

$$\vec{\tau} = \frac{d\vec{L}}{dt}$$

If the net external torque ($\vec{\tau}$) acting on the body is zero, then $\frac{d\vec{L}}{dt} = 0$, which implies that the angular momentum $\vec{L}$ is constant.

- Option (1) refers to force, which causes a change in linear momentum, not necessarily angular momentum (unless the force also produces a torque).

- Option (2) refers to pressure, which is force per unit area and not directly related to angular momentum conservation in this context.

- Option (3) suggests that if net external torque is applied, angular momentum is constant, which is the opposite of the principle.

Step 4: Final Answer:

The angular momentum of a moving body remains constant if no net external torque is applied.

Quick Tip: Compare with linear momentum: Linear momentum is conserved if no net external **force** acts. Angular momentum is conserved if no net external **torque** acts. Both are direct consequences of Newton's laws.

---

50. If the earth were to suddenly contract to half of its present radius, what would be the duration of the day?

(1) 6 h

(2) 18 h

(3) 24 h

(4) 30 h

Correct Answer: (1) 6 h

Solution:

Step 1: Understanding the Question:

The problem describes a scenario where the Earth's radius suddenly changes while its mass remains constant. We need to find the new duration of a day, which implies a change in its angular velocity. This is a classic problem involving conservation of angular momentum.

Step 2: Key Formula or Approach:

1. **Conservation of Angular Momentum:** If no external torque acts on a system, its angular momentum (L) remains constant.

$$L = I\omega = \text{constant}$$

2. **Moment of Inertia of a Sphere:** For a solid sphere, $I = \frac{2}{5}MR^2$.

3. **Angular Velocity:** Angular velocity $\omega = \frac{2\pi}{T}$, where T is the period of rotation (duration of a day).

Step 3: Detailed Explanation:

Let the initial radius be R_1 and the initial duration of the day be $T_1 = 24$ h.

Let the final radius be $R_2 = R_1/2$ and the final duration of the day be T_2.

By conservation of angular momentum:

$$I_1\omega_1 = I_2\omega_2$$

Substitute $I = \frac{2}{5}MR^2$ and $\omega = \frac{2\pi}{T}$:

$$\left(\frac{2}{5}MR_1^2\right)\left(\frac{2\pi}{T_1}\right) = \left(\frac{2}{5}MR_2^2\right)\left(\frac{2\pi}{T_2}\right)$$

Cancel common terms ($\frac{2}{5}M(2\pi)$):

$$\frac{R_1^2}{T_1} = \frac{R_2^2}{T_2}$$

Substitute $R_2 = R_1/2$:

$$\frac{R_1^2}{T_1} = \frac{(R_1/2)^2}{T_2} = \frac{R_1^2/4}{T_2}$$

$$\frac{1}{T_1} = \frac{1}{4T_2}$$

$$T_2 = \frac{T_1}{4}$$

Substitute $T_1 = 24$ h:

$$T_2 = \frac{24 \text{ h}}{4} = 6 \text{ h}$$

Step 4: Final Answer:

The duration of the day would be 6 h.

Quick Tip: This is a common conservation of angular momentum problem. The key is that $I \propto R^2$, so if R halves, I becomes 1/4 of its original value. To conserve $I\omega$, ω must become 4 times larger, meaning the period T becomes 1/4 of its original value.

---

51. Imagine a new planet having the same density as that of the earth, but it is two times bigger than the earth in size. If the acceleration due to gravity on the surface of the new planet is g' and that on the surface of the earth is g, then

(1) $g' = \frac{g}{4}$

(2) $g' = 8g$

(3) $g' = 2g$

(4) $g' = 4g$

Correct Answer: (3) $g' = 2g$

Solution:

Step 1: Understanding the Question:

The problem compares the acceleration due to gravity on the surface of Earth to that of a hypothetical new planet. We are given that the new planet has the same density as Earth but twice its size (radius).

Step 2: Key Formula or Approach:

The acceleration due to gravity on the surface of a planet is given by:

$$g = \frac{GM}{R^2}$$

Where G is the gravitational constant, M is the mass of the planet, and R is its radius.

We can express mass M in terms of density (ρ) and volume (V) for a sphere: $M = \rho \times V = \rho \times \frac{4}{3}\pi R^3$.

Substituting M into the formula for g:

$$g = \frac{G\left(\rho \frac{4}{3}\pi R^3\right)}{R^2} = G\rho\frac{4}{3}\pi R$$

So, $g \propto \rho R$.

Step 3: Detailed Explanation:

Let the properties of Earth be g, R, ρ.

For the new planet, let the properties be g', R', ρ'.

Given:

- Same density: $\rho' = \rho$
- Two times bigger in size (radius): $R' = 2R$

Now, form the ratio:

$$\frac{g'}{g} = \frac{G\rho'\frac{4}{3}\pi R'}{G\rho\frac{4}{3}\pi R} = \frac{\rho' R'}{\rho R}$$

Substitute the given relations:

$$\frac{g'}{g} = \frac{\rho(2R)}{\rho R} = 2$$

Therefore, $g' = 2g$.

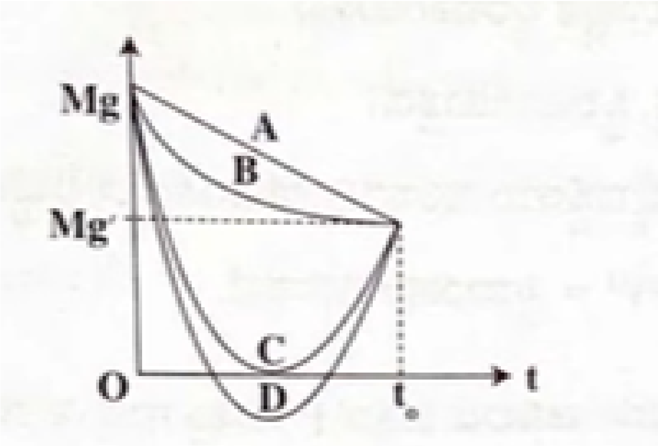
Step 4: Final Answer:

The acceleration due to gravity on the surface of the new planet is $2g$.

Quick Tip: When density is constant, $g \propto R$. This is a quick mental shortcut. If radius doubles, g doubles. If mass is constant, $g \propto \frac{1}{R^2}$. Always check what parameter is kept constant or related.

---

52. Suppose the acceleration due to gravity at the earth's surface is g m/s^2 and at the surface of moon it is g' m/s^2. An M kg passenger goes from the earth to the moon in a spaceship moving with a constant velocity (Neglect all other objects in the sky). Which curve best represents the weight (net gravitational force) as a function of time?



(1) A

(2) B

(3) C

(4) D

Correct Answer: (4) D

Solution:

Step 1: Understanding the Question:

The question asks to identify the graph that best represents the net gravitational force (weight) experienced by a passenger traveling from Earth to the Moon.

Step 3: Detailed Explanation:

1. **Starting point (Earth's surface):** The passenger's weight is Mg. This is the initial maximum value on the graph.

2. **Moving away from Earth:** As the spaceship moves away from Earth, the gravitational force due to Earth decreases with the inverse square of the distance ($F_{Earth} \propto 1/r^2$). Simultaneously, the gravitational force due to the Moon (initially very small) starts to increase as the spaceship gets closer to the Moon ($F_{Moon} \propto 1/(D-r)^2$).

3. **Neutral Point:** There will be a point somewhere between Earth and Moon where the gravitational forces exerted by Earth and Moon are equal and opposite, resulting in a net gravitational force of zero. This point is closer to the Moon because Earth is more massive.

4. **Approaching the Moon:** After passing the neutral point, the gravitational force due to the Moon becomes dominant and increases as the spaceship approaches the Moon's surface.

5. **Moon's surface:** The gravitational force on the Moon's surface is Mg', which is less than Mg (typically $g' \approx g/6$).
6. **Constant Velocity:** The mention of "constant velocity" for the spaceship implies that the journey takes a finite time, and the gravitational force profile will be a continuous curve.
Looking at the graphs:
- Curve A and B show a linear or decreasing curve that doesn't reach zero.
- Curve C starts from Mg and linearly decreases to Mg', which is incorrect as gravitational force follows an inverse square law.
- Curve D correctly shows:
- Starting at Mg.
- Decreasing non-linearly to zero at some point between Earth and Moon.
- Increasing again non-linearly as it approaches the Moon.
- Ending at a lower value Mg' on the Moon's surface.
This precisely matches the expected behavior of net gravitational force.

Step 4: Final Answer:
Curve D best represents the weight as a function of time.

Quick Tip: Remember the "neutral point" in gravitational fields between two massive bodies. The net gravitational force becomes zero there. This is a key feature to look for in such graphs. Also, gravitational force is always non-linear (inverse square law).

---

53. Instrument fitted in the carburetor of the automobile to provide the correct mixture of air and fuel necessary for combustion works on
(1) Pascal's Law
(2) Bernoulli's Principle
(3) Newton's Law of Cooling
(4) Archimedes' Principle

Correct Answer: (2) Bernoulli's Principle

Solution:

Step 1: Understanding the Question:

The question asks for the fundamental physics principle behind the operation of an automobile's carburetor.

Step 3: Detailed Explanation:

A carburetor's main function is to mix air and fuel in the correct ratio for efficient combustion in an internal combustion engine.

It achieves this by creating a low-pressure area (venturi) in the airflow path.

- As air flows through the narrow section of the venturi, its velocity increases.
- According to **Bernoulli's Principle**, an increase in fluid velocity corresponds to a decrease in its static pressure.
- This reduced pressure in the venturi draws fuel from a connected fuel jet into the airstream, where it atomizes and mixes with the air.
- Pascal's Law relates to pressure transmission in static fluids, Newton's Law of Cooling relates to heat transfer, and Archimedes' Principle relates to buoyancy. None of these describe the primary mechanism of a carburetor.

Step 4: Final Answer:

The carburetor works on Bernoulli's Principle.

Quick Tip: Many practical applications involving fluid flow, like carburetors, aircraft wings (lift), and atomizers/sprayers, rely on Bernoulli's principle. It's a key concept in fluid dynamics.

---

54. There are two wires of same material and same length while the diameter of second wire is two times the diameter of the first wire. Then the ratio of extensions produced in the wires by applying same load will be

(1) 1:1

(2) 1:2

(3) 2:1

(4) 4:1

Correct Answer: (4) 4:1

Solution:

Step 1: Understanding the Question:

We need to find the ratio of extensions (elongations) in two wires. The wires are made of the same material (same Young's modulus), have the same length, but one has twice the diameter of the other. They are subjected to the same load.

Step 2: Key Formula or Approach:

Young's modulus (Y) is defined as:

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

Rearranging for elongation (ΔL):

$$\Delta L = \frac{FL}{AY}$$

The cross-sectional area of a wire is $A = \pi r^2 = \pi\left(\frac{D}{2}\right)^2 = \frac{\pi D^2}{4}$, where D is the diameter.

So, $\Delta L = \frac{FL}{(\frac{\pi D^2}{4})Y} = \frac{4FL}{\pi D^2 Y}$.

Step 3: Detailed Explanation:

Given:

- Same material: $Y_1 = Y_2 = Y$
- Same length: $L_1 = L_2 = L$
- Same load: $F_1 = F_2 = F$
- Diameter of second wire is two times the first: $D_2 = 2D_1$

Let ΔL_1 and ΔL_2 be the extensions of the first and second wires, respectively.

$$\Delta L_1 = \frac{4FL}{\pi D_1^2 Y}$$

$$\Delta L_2 = \frac{4FL}{\pi D_2^2 Y}$$

Form the ratio $\frac{\Delta L_1}{\Delta L_2}$:

$$\frac{\Delta L_1}{\Delta L_2} = \frac{\frac{4FL}{\pi D_1^2 Y}}{\frac{4FL}{\pi D_2^2 Y}} = \frac{D_2^2}{D_1^2}$$

Substitute $D_2 = 2D_1$:

$$\frac{\Delta L_1}{\Delta L_2} = \frac{(2D_1)^2}{D_1^2} = \frac{4D_1^2}{D_1^2} = \frac{4}{1}$$

Step 4: Final Answer:

The ratio of extensions produced in the wires is 4:1.

Quick Tip: When force, length, and material are the same, elongation is inversely proportional to the square of the diameter ($\Delta L \propto \frac{1}{D^2}$). If diameter doubles, elongation becomes $1/4$. Thus, the ratio of elongations will be 4 : 1.

---

55. In a capillary tube experiment, a vertical 30 cm long capillary tube is dipped in water, water rises upto a height of 10 cm due to capillarity. If this experiment is conducted in a freely falling elevator, then the length of the water column becomes

(1) 10 cm

(2) 20 cm

(3) 30 cm

(4) Zero

Correct Answer: (3) 30 cm

Solution:

Step 1: Understanding the Question:

The problem describes a capillary rise experiment performed on Earth and then asks what happens to the height of the water column if the same experiment is conducted in a freely falling elevator.

Step 2: Key Formula or Approach:

The height of capillary rise (h) is given by the Jurin's Law:

$$h = \frac{2T\cos\theta}{\rho g r}$$

Where:
- T is the surface tension of the liquid.
- θ is the contact angle.
- ρ is the density of the liquid.
- g is the acceleration due to gravity.
- r is the radius of the capillary tube.

Step 3: Detailed Explanation:

In a freely falling elevator, the apparent weight of objects inside becomes zero. This means the effective acceleration due to gravity (g_{eff}) inside the elevator is zero ($g_{eff} = g - a = g - g = 0$, where $a = g$ for free fall).

From Jurin's Law, the height of capillary rise (h) is inversely proportional to g: $h \propto \frac{1}{g}$.

If $g_{eff} = 0$, then the height h would theoretically become infinite. However, the water cannot rise beyond the length of the capillary tube.

Given that the capillary tube is 30 cm long, the water will rise to fill the entire length of the tube.

Step 4: Final Answer:

The length of the water column becomes 30 cm.

Quick Tip: Remember that apparent weightlessness (free fall) implies $g_{eff} = 0$. In situations where a physical quantity is inversely proportional to g, a zero g means the effect would theoretically be infinite, limited only by physical boundaries.

---

56. In thermodynamic processes, which of the following statements is not true?

(1) In an isothermal process, the temperature remains constant

(2) In an isobaric process, the volume remains constant

(3) In an adiabatic process, the system is insulated from the surroundings

(4) In an adiabatic process, PV^{γ} = a constant

Correct Answer: (2) In an isobaric process, the volume remains constant

Solution:

Step 1: Understanding the Question:

The question asks to identify the incorrect statement among those describing different types of thermodynamic processes.

Step 3: Detailed Explanation:

Let's analyze each statement:

(1) **Isothermal process:** A process where the temperature of the system remains constant throughout. This statement is **true**.

(2) **Isobaric process:** A process where the pressure of the system remains constant. If the volume remains constant, it is an **isochoric** (or isovolumetric) process. Therefore, this statement is **not true**.

(3) **Adiabatic process:** A process where no heat is exchanged between the system and its surroundings. This implies the system is perfectly insulated. This statement is **true**.

(4) **Adiabatic process:** For an ideal gas undergoing an adiabatic process, the relationship between pressure and volume is $PV^\gamma =$ constant, where γ is the ratio of specific heats (C_p/C_v). This statement is **true**.

Step 4: Final Answer:

The statement that is not true is (2).

Quick Tip: Remember the prefixes:

- **Iso**thermal: Constant **T**emperature.
- **Iso**baric: Constant **P**ressure.
- **Iso**choric: Constant **V**olume.
- **Adia**batic: No heat **transfer**.

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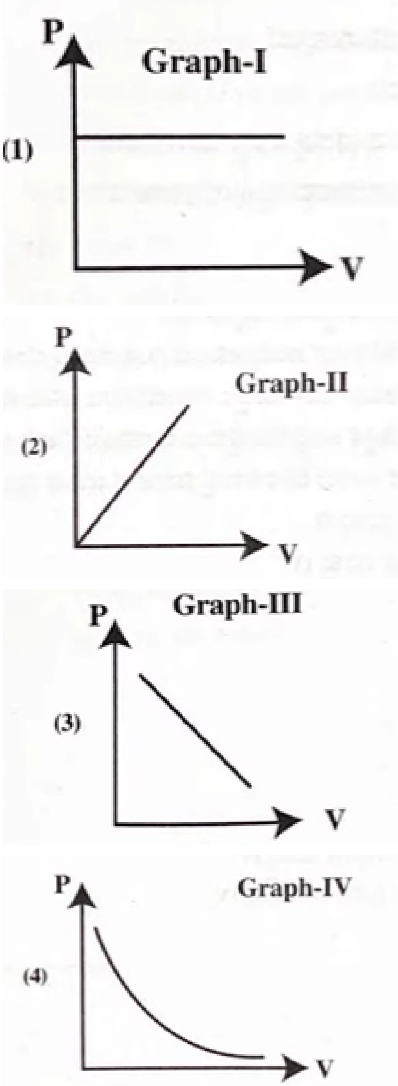
57. The graph of pressure P and volume V of 1 mole of an ideal gas at constant temperature is



(1) Graph-I

(2) Graph-II

(3) Graph-III

(4) Graph-IV

Correct Answer: (4) Graph-IV

Solution:

Step 1: Understanding the Question:

The question asks to identify the correct Pressure-Volume (P-V) graph for an ideal gas undergoing an isothermal process (constant temperature).

Step 2: Key Formula or Approach:

For an ideal gas, the ideal gas law is $PV = nRT$.

In an isothermal process, temperature (T) is constant, and for 1 mole, $n = 1$. So, $PV = RT =$ constant.

This implies $P \propto \frac{1}{V}$. This is the mathematical form of Boyle's Law.

Step 3: Detailed Explanation:

A graph of P versus V where their product is constant ($P = \frac{\text{constant}}{V}$) will be a rectangular hyperbola.

Let's examine each graph:

- **Graph-I:** Shows pressure (P) remaining constant as volume (V) changes. This represents an isobaric process.
- **Graph-II:** Shows a linear relationship where $P \propto V$. This is not isothermal.
- **Graph-III:** Shows a linear relationship where P decreases linearly with V. This is also not isothermal.
- **Graph-IV:** Shows a curve where P decreases as V increases, and the product PV remains constant. This is characteristic of a rectangular hyperbola, which correctly represents an isothermal process.

Step 4: Final Answer:

Graph-IV correctly depicts the relationship between pressure and volume for an ideal gas at constant temperature.

Quick Tip: Remember the shapes of P-V diagrams for common processes:

- Isothermal: Rectangular hyperbola ($PV =$ constant)
- Adiabatic: Steeper hyperbola ($PV^\gamma =$ constant)
- Isobaric: Horizontal line ($P =$ constant)
- Isochoric: Vertical line ($V =$ constant)

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58. A mass of 1 kg is executing SHM. Its displacement is given by $x = 6.0\cos(100t + \pi/4)$ cm. What is the maximum kinetic energy?

(1) 3 J

(2) 6 J

(3) 9 J

(4) 18 J

Correct Answer: (4) 18 J

Solution:

Step 1: Understanding the Question:

The question asks for the maximum kinetic energy of a mass undergoing Simple Harmonic Motion (SHM), given its mass and displacement equation.

Step 2: Key Formula or Approach:

The general equation for SHM is $x = A\cos(\omega t + \phi)$.

Comparing this with the given equation, we can identify the amplitude (A) and angular frequency (ω).

The maximum kinetic energy (K_{max}) in SHM is given by:

$$K_{max} = \frac{1}{2}mA^2\omega^2$$

Step 3: Detailed Explanation:

Given:

Mass, $m = 1$ kg

Displacement equation: $x = 6.0\cos(100t + \pi/4)$ cm

From the equation:

- Amplitude, $A = 6.0 \text{ cm} = 0.06 \text{ m}$
- Angular frequency, $\omega = 100 \text{ rad/s}$

Substitute these values into the maximum kinetic energy formula:

$$K_{max} = \frac{1}{2} \times (1 \text{ kg}) \times (0.06 \text{ m})^2 \times (100 \text{ rad/s})^2$$

$$K_{max} = \frac{1}{2} \times 1 \times (0.0036) \times (10000)$$

$$K_{max} = \frac{1}{2} \times 36 = 18 \text{ J}$$

Step 4: Final Answer:

The maximum kinetic energy is 18 J.

Quick Tip: Always ensure consistency in units. If mass is in kg and frequency in rad/s, amplitude must be in meters to obtain energy in Joules. Convert cm to m before calculation.

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59. A source of frequency ν gives 6 beats/second when sounded with a source of frequency 200 Hz. The second Harmonic of frequency 2ν of the source gives 8 beats/second when sounded with a source of frequency 420 Hz. The value of ν is

(1) 205 Hz

(2) 206 Hz

(3) 195 Hz

(4) 210 Hz

Correct Answer: (3) 195 Hz

Solution:

Step 1: Understanding the Question:

A source of frequency ν produces 6 beats per second with a 200 Hz source.

Its second harmonic 2ν produces 8 beats per second with a 420 Hz source.

Step 2: Key Formula or Approach:

Number of beats per second:

$$\text{Beats} = |f_1 - f_2|$$

Step 3: Detailed Explanation:

From the first condition:

$$|\nu - 200| = 6$$

$$\nu = 200 \pm 6 = 206 \text{ Hz or } 194 \text{ Hz}$$

From the second condition:

$$|2\nu - 420| = 8$$

$$2\nu = 420 \pm 8 = 428 \text{ or } 412$$

$$\nu = 214 \text{ Hz or } 206 \text{ Hz}$$

Now, the common value from both conditions is:

$$\nu = 206 \text{ Hz}$$

Step 4: Final Answer:

$$\boxed{206 \text{ Hz}}$$

Quick Tip: Always solve beat frequency equations carefully and check for common values when multiple conditions are given.

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60. Following are statements of a few processes taking place in nature.

I. Free expansion of a gas

II. The combustion of a mixture of petrol and air ignited by a spark

III. The leaking of gas from the kitchen cylinder

IV. The transfer of heat from one heated part of a liquid to the other colder part

Which amongst these processes are irreversible in nature?

(1) I and II

(2) III and IV

(3) II, III and IV

(4) I, II, III and IV

Correct Answer: (4) I, II, III and IV

Solution:

Step 1: Understanding the Question:

The question asks to identify which of the listed natural processes are irreversible. An irreversible process is one that cannot be undone without leaving some change in the surroundings. All spontaneous natural processes are irreversible.

Step 3: Detailed Explanation:

1. **Free expansion of a gas:** This is a spontaneous process where a gas expands into a vacuum. It cannot be reversed spontaneously without external work. Thus, it is **irreversible**.

2. **The combustion of a mixture of petrol and air ignited by a spark:** Combustion is a highly exothermic and spontaneous chemical reaction. It cannot be reversed spontaneously. Thus, it is **irreversible**.

3. **The leaking of gas from the kitchen cylinder:** Gas leaking from a high-pressure region to a low-pressure region (atmosphere) is a spontaneous and unrestrained expansion. It cannot be reversed to get the gas back into the cylinder without doing work. Thus, it is **irreversible**.

4. **The transfer of heat from one heated part of a liquid to the other colder part:** Heat always flows spontaneously from a hotter body to a colder body (second law of thermodynamics). It cannot spontaneously flow from cold to hot. Thus, it is **irreversible**.

All four processes are spontaneous natural phenomena and are therefore irreversible.

Step 4: Final Answer:

All processes (I, II, III, and IV) are irreversible in nature.

Quick Tip: A simple rule: If a process occurs spontaneously in nature, it is typically irreversible. Reversible processes are idealizations that involve infinitesimally slow changes and no dissipative forces (like friction or unrestrained expansion).