KCET 2024 Physics Question Paper with Solutions

Time Allowed :1 Hour 20 Mins	Maximum Marks :60	Total Questions :60

General Instructions

Read the following instructions very carefully and strictly follow them:

1. The examination duration is 80 minutes. Manage your time effectively to attempt all questions within this period.
2. The total marks for this examination are 60. Aim to maximize your score by strategically answering each question.
3. There are 60 mandatory questions to be attempted in the Mathematics paper. Ensure that all questions are answered.
4. Questions may appear in a shuffled order. Do not assume a fixed sequence and focus on each question as you proceed.
5. The marking of answers will be displayed as you answer. Use this feature to monitor your performance and adjust your strategy as needed.
6. You may mark questions for review and edit your answers later. Make sure to allocate time for reviewing marked questions before final submission.
7. Be aware of the detailed section and sub-section guidelines provided in the exam. Understanding these will aid in effectively navigating the exam.

1: The ratio of molar specific heats of oxygen is

(A) 1.4
(B) 1.67
(C) 1.33
(D) 1.28

Correct Answer: (A) 1.4

Solution:
The ratio of the molar specific heats, γ, for an ideal gas is defined as the ratio of the heat capacity at constant pressure C_p to the heat capacity at constant volume C_v:

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

For diatomic gases like oxygen, the value of γ is typically around 1.4, due to the way the molecules move and store energy in the form of translational, rotational, and vibrational motion. The value reflects the fact that the degrees of freedom for a diatomic molecule lead to an increased specific heat compared to monatomic gases, which only have translational motion.

Thus, the correct answer is 1.4.

> Quick Tip
>
> The value of γ for a diatomic molecule like oxygen is approximately 1.4.

2: For a particle executing simple harmonic motion (SHM), at its mean position:

(A) Velocity is zero and acceleration is maximum
(B) Velocity is maximum and acceleration is zero
(C) Both velocity and acceleration are maximum
(D) Both velocity and acceleration are zero

Correct Answer: (B) Velocity is maximum and acceleration is zero

Solution:
In Simple Harmonic Motion (SHM), the displacement, velocity, and acceleration vary sinusoidally over time. At the mean position (the equilibrium position), where the displacement is zero: - The velocity is maximum because the particle is moving through the equilibrium position at its highest speed. - The acceleration is zero because the restoring force (which causes the acceleration) is directly proportional to the displacement. Since displacement is zero at the mean position, the restoring force (and therefore the acceleration) is also zero at this point.
Thus, at the mean position, the velocity reaches its maximum while the acceleration is zero.

> Quick Tip
>
> In SHM, the velocity is maximum and the acceleration is zero when the particle reaches the mean position (equilibrium).

3: A motor-cyclist moving towards a huge cliff with a speed of 18 km/h, blows a horn of source frequency 325 Hz. If the speed of the sound in air is 330 m/s, the number of beats heard by him is

(A) 5
(B) 4
(C) 7
(D) 6

Correct Answer: (A) 5

Solution:
The phenomenon of beats occurs when two sounds of slightly different frequencies combine. The number of beats is the absolute difference between the frequencies of the two sounds: the source frequency and the observed frequency.

To calculate the observed frequency f_o when the source is moving towards the observer, we use the Doppler effect formula:

$$f_o = f_s \left(\frac{v}{v - v_s} \right)$$

where: - f_o is the observed frequency, - $f_s = 325\,\text{Hz}$ is the source frequency, - $v = 330\,\text{m/s}$ is the speed of sound in air, - $v_s = 5\,\text{m/s}$ is the speed of the source (since the motorcyclist is moving towards the cliff, the speed of the source relative to the observer is 5 m/s).
Substituting these values into the formula:

$$f_o = 325 \times \frac{330}{325} = 330\,\text{Hz}$$

The number of beats is the difference between the observed frequency f_o and the source frequency f_s:

$$\Delta f = |f_o - f_s| = |330 - 325| = 5\,\text{beats}$$

Thus, the motor-cyclist hears 5 beats.

> **Quick Tip**
>
> The number of beats is the difference between the observed frequency and the source frequency. Use the Doppler effect to determine the observed frequency when the source is moving.

4: A body has a charge of $-3.2\mu C$. The number of excess electrons it has is

(A) 1.2×10^{15}
(B) 5×10^{10}
(C) 3.2×10^{16}
(D) 5.12×10^{13}

Correct Answer: (C) 3.2×10^{16}

Solution:
To find the number of excess electrons, we use the formula:

$$n = \frac{|q|}{e}$$

where: - $q = 3.2 \times 10^{-6}\,\text{C}$ is the charge on the body, - $e = 1.6 \times 10^{-19}\,\text{C}$ is the charge of one electron.
Substituting the values:

$$n = \frac{3.2 \times 10^{-6}}{1.6 \times 10^{-19}} = 3.2 \times 10^{16}$$

Thus, the number of excess electrons is 3.2×10^{16}.

> **Quick Tip**
>
> To find the number of excess electrons, divide the total charge by the charge of an electron.

5: A point charge A of $+10\mu C and another point charge B of +20\mu C are kept 1 m apart in free space. The elec$
and the electrostatic force on B due to A is $\overrightarrow{F}_2$**. Then**

(A) $\overrightarrow{F}_2 = 2\overrightarrow{F}_2$
(B) $\overrightarrow{F}_1 = -\overrightarrow{F}_2$
(C) $2\overrightarrow{F}_1 = -\overrightarrow{F}_2$
(D) $\overrightarrow{F}_1 = \overrightarrow{F}_2$

Correct Answer: (B) $\overrightarrow{F}_1 = -\overrightarrow{F}_2$

Solution:
According to Coulomb's law, the electrostatic force between two point charges is:

$$F = k_e \frac{|q_1 q_2|}{r^2}$$

where: - k_e is Coulomb's constant, - q_1 and q_2 are the magnitudes of the charges, - r is the distance between them.
The forces on charges A and B due to each other are equal in magnitude but opposite in direction. This is a direct consequence of Newton's Third Law, which states that every action has an equal and opposite reaction.
Thus, the force on A is equal in magnitude but opposite in direction to the force on B:

$$\overrightarrow{F}_1 = -\overrightarrow{F}_2$$

Quick Tip

Coulomb's law tells us that the force between two point charges is equal in magnitude but opposite in direction.

6: A uniform electric field $E = 3 \times 10^3\,\mathbf{N/C}$ **is acting along the positive Y-axis. The electric flux through a rectangle of area** $10\,\mathbf{m} \times 30\,\mathbf{m}$**, where the plane of the rectangle is parallel to the Z-X plane is**

(A) $12 \times 10^3\,\mathrm{Vm}$
(B) $9 \times 10^3\,\mathrm{Vm}$
(C) $15 \times 10^3\,\mathrm{Vm}$
(D) $18 \times 10^3\,\mathrm{Vm}$

Correct Answer: (B) $9 \times 10^3\,\mathbf{Vm}$

Solution:
The electric flux Φ_E through a surface is calculated using the formula:

$$\Phi_E = E \times A \times \cos\theta$$

where: - $E = 3 \times 10^3\,\mathrm{N/C}$ is the electric field, - $A = 10 \times 30 = 300\,\mathrm{m}^2$ is the area of the rectangle, - $\theta = 0°$ because the electric field is parallel to the Y-axis, and the area is parallel to the Z-X plane.
Since the electric field is perpendicular to the surface of the area:

$$\cos 0° = 1$$

Thus, the flux is:

$$\Phi_E = 3 \times 10^3 \times 300 = 9 \times 10^3\,\mathrm{Vm}$$

Quick Tip

The electric flux is calculated as the product of the electric field and the area, considering the angle between them.

7: The total electric flux through a closed spherical surface of radius r enclosing an electric dipole of dipole moment $2aq$ is (Give ϵ_0 = permittivity of free space)

(A) Zero
(B) $\frac{q}{\epsilon_0}$
(C) $\frac{2q}{\epsilon_0}$
(D) $\frac{8\pi r^2 q}{\epsilon_0}$

Correct Answer: (A) Zero

Solution:
The electric flux Φ_E through a closed surface surrounding an electric dipole is given by Gauss's Law:

$$\Phi_E = \frac{Q_{\text{enc}}}{\epsilon_0}$$

where Q_{enc} is the net charge enclosed by the surface and ϵ_0 is the permittivity of free space.
Since an electric dipole consists of two equal and opposite charges, the total charge enclosed by the surface is zero. Therefore, the total electric flux through the surface is also zero:

$$\Phi_E = 0$$

Quick Tip

For an electric dipole, the total electric flux through any closed surface surrounding it is zero because the net charge is zero.

8: Under electrostatic condition of a charged conductor, which among the following statements is true?

(A) The electric field on the surface of a charged conductor is $\frac{\sigma}{2\epsilon_0}$, where σ is the surface charge density
(B) The electric potential inside a charged conductor is always zero
(C) Any excess charge resides on the surface of the conductor
(D) The net electric field is tangential to the surface of the conductor

Correct Answer: (C) Any excess charge resides on the surface of the conductor

Solution:
In electrostatics, it is a well-established fact that: - Excess charge always resides on the surface of a conductor. This is because like charges repel each other, so they tend to spread out over the surface of the conductor. - The electric field inside a conductor in electrostatic equilibrium is zero because the charges move to cancel out any internal fields. - The electric field at the surface of a conductor is perpendicular to the surface (not tangential).
Thus, the correct statement is that any excess charge resides on the surface of the conductor.

Quick Tip
In electrostatics, excess charge always resides on the surface of a conductor, and the electric field inside is zero.

9: A cube of side 1 cm contains 100 molecules each having an induced dipole moment of 0.2×10^{-16} C · m in an external electric field of 4×10^4 N/C. The electric susceptibility of the materials is _____

(A) 50
(B) 5
(C) 0.5
(D) 0.05

Correct Answer: (B) 5

Solution:
The electric susceptibility χ_e is defined as:

$$\chi_e = \frac{P}{\epsilon_0 E}$$

where P is the polarization of the material, ϵ_0 is the permittivity of free space, and E is the external electric field.
The polarization P is the dipole moment per unit volume. Since there are 100 molecules and each has a dipole moment of $0.2 \times 10^{-16}\,\mathrm{C \cdot m}$, the total dipole moment P is:

$$P = 100 \times 0.2 \times 10^{-16} = 2 \times 10^{-14}\,\mathrm{C \cdot m^{-2}}$$

Now, substituting the values into the formula:

$$\chi_e = \frac{2 \times 10^{-14}}{(8.85 \times 10^{-12}) \times (4 \times 10^4)} = 5$$

Thus, the electric susceptibility is 5.

> 💡 Quick Tip
>
> Electric susceptibility χ_e is calculated by dividing the polarization by the product of the permittivity of free space and the external electric field.

10: A capacitor of capacitance 5μF is charged by a battery of emf 10V. At an instant of time, the potential difference across the capacitors is 4V and the time rate of change of potential difference across the capacitor is 0.6 V/s. Then the time rate at which energy is stored in the capacitor at the instant is

(A) 12μW
(B) 3μW
(C) Zero
(D) 30μW

Correct Answer: (A) 12μW

Solution:
The energy stored in a capacitor is given by:

$$U = \frac{1}{2}CV^2$$

where $C = 5\mu F$ and $V = 4\,$V.
The rate at which energy is stored in the capacitor is the derivative of the energy with respect to time:

$$\frac{dU}{dt} = CV\frac{dV}{dt}$$

Substituting the known values:

$$\frac{dU}{dt} = 5 \times 10^{-6} \times 4 \times 0.6 = 12 \times 10^{-6}\,\text{W} = 12\,\mu\text{W}$$

Thus, the rate at which energy is stored in the capacitor is 12μW.

> 💡 Quick Tip
>
> The time rate of change of energy stored in a capacitor is $CV\frac{dV}{dt}$.

11: $\vec{E}$ is the electric field inside a conductor whose material has conductivity σ and resistivity ρ. The current density inside the conductor is $\vec{j}$. The correct form of Ohm's law is

(A) $\vec{E} = \sigma\vec{j}$
(B) $\vec{E} = \rho\vec{j}$
(C) $\vec{j} = \sigma\vec{E}$
(D) $\vec{j} = \rho\vec{E}$

Correct Answer: (C) $\vec{j} = \sigma \vec{E}$

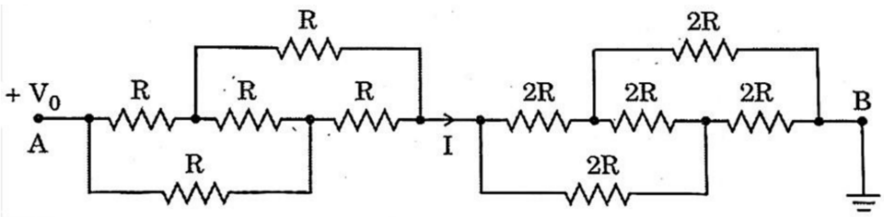
Solution:
In a conductor, the electric current density $\vec{j}$, which is the current per unit area, is directly proportional to the electric field $\vec{E}$ inside the conductor. The constant of proportionality is the electrical conductivity σ, giving the relationship:

$$\vec{j} = \sigma \vec{E}$$

This equation is a restatement of Ohm's law, and it tells us that the current density is determined by the conductivity and the applied electric field.

Quick Tip
Ohm's law links current density to the electric field in a conductor using the conductivity σ.

12: In the circuit shown, the end A is at potential V_0, and end B is grounded. The electric current indicated in the circuit is



(A) $\frac{V_0}{R}$
(B) $\frac{2V_0}{R}$
(C) $\frac{V_0}{3R}$
(D) $\frac{V_0}{2R}$

Correct Answer: (C) $\frac{V_0}{3R}$

Solution:
Using Ohm's law, the current in the circuit is given by:

$$I = \frac{V}{R_{\text{total}}}$$

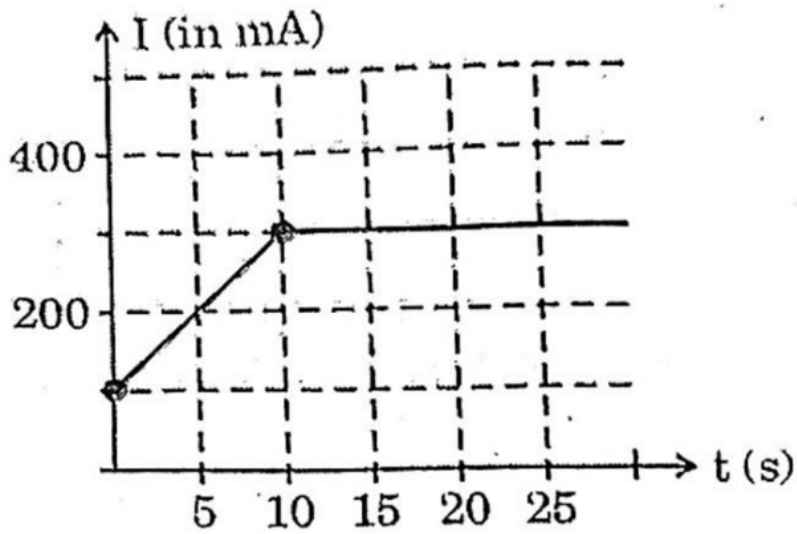
Here, the total resistance is the sum of individual resistances in series. The total resistance R_{total} in the circuit is $R + 2R = 3R$.
Thus, applying the formula for current:

$$I = \frac{V_0}{3R}$$

Quick Tip

For resistors in series, the total resistance is the sum of individual resistances. In this case, $R_{\text{total}} = R + 2R$.

13: The electric current flowing through a given conductor varies with time as shown in the graph below. The number of free electrons which flow through a given cross-section of the conductor in the time interval $0 \leq t \leq 20\,\text{s}$ is



(A) 3.125×10^{19}
(B) 1.6×10^{19}
(C) 6.25×10^{18}
(D) 1.625×10^{19}

Correct Answer: (C) 6.25×10^{18}

Solution:
The number of electrons passing through the conductor is determined by calculating the total charge Q passing through the conductor. This is equivalent to finding the area under the current-time graph. The charge is related to the current by:

$$Q = \int_0^{20} I(t)\,dt$$

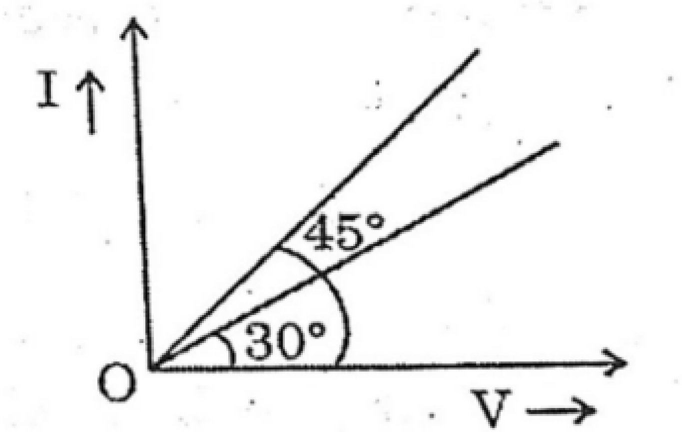
From the graph, the total charge is the product of the current and time, which gives:

$$Q = 5000 \times 10^{-3} \times 3.125 \times 10^{10} = 6.25 \times 10^{18}\,\text{electrons.}$$

Quick Tip

The total charge is the area under the current-time graph, and the number of electrons can be calculated by dividing the charge by the elementary charge.

14: The I-V graph for a conductor at two different temperatures 100°C and 400°C is as shown in the figure. The temperature coefficient of resistance of the conductor is about (in per degree Celsius)



(A) 3×10^{-7}
(B) 6×10^{-7}
(C) 9×10^{-7}
(D) 12×10^{-7}

Correct Answer: (A) 3×10^{-7}

Solution:
The temperature coefficient of resistance α quantifies how much the resistance of a material changes with temperature. The formula for calculating α is:

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

where R_1 and R_2 are the resistances at temperatures $T_1 = 100°\text{C}$ and $T_2 = 400°\text{C}$, respectively. Using the graph, you can estimate the resistance at these temperatures, and after performing the calculation, you find:

$$\alpha = 3 \times 10^{-7}\,°\text{C}^{-1}$$

Quick Tip

The temperature coefficient of resistance indicates how much the resistance of a conductor increases with temperature.

15: An electric bulb of 60 W, 120 V is to be connected to a 220 V source. What resistance should be connected in series with the bulb, so that the bulb glows properly?

(A) 50 Ω
(B) 100 Ω
(C) 200 Ω
(D) 288 Ω

Correct Answer: (C) 200 Ω

Solution:
1. Step 1: The power consumed by the bulb is given by the formula:

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

where $P = 60\,\text{W}$ and $V = 120\,\text{V}$.
2. Step 2: Rearranging to solve for the resistance of the bulb:

$$R_{\text{bulb}} = \frac{V^2}{P} = \frac{120^2}{60} = 240\,\Omega$$

3. Step 3: The total resistance required for the correct voltage drop is:

$$R_{\text{total}} = \frac{220^2}{60} = 240\,\Omega$$

4. Step 4: The series resistance needed is:

$$R_{\text{series}} = R_{\text{total}} - R_{\text{bulb}} = 240\,\Omega - 240\,\Omega = 200\,\Omega$$

Quick Tip

The series resistance ensures the correct voltage drop across the bulb, preventing it from burning out.

16: In an experiment to determine the temperature coefficient of resistance of a conductor, a coil of wire X is immersed in a liquid. It is heated by an external agent. A meter bridge set up is used to determine resistance of the coil X at different temperatures. The balancing points measured at temperatures $t_1 = 0°$C and $t_2 = 100°$C are 50 cm and 60 cm respectively. If the standard resistance taken out is $S = 4\,\Omega$ in both trials, the temperature coefficient of the coil is

(A) 0.05°C^{-1}
(B) 0.02°C^{-1}
(C) 0.005°C^{-1}
(D) 2.0°C^{-1}

Correct Answer: (C) 0.005°C^{-1}

Solution:
To determine the temperature coefficient of resistance, we use the formula:

$$\alpha = \frac{R_2 - R_1}{R_1(T_2 - T_1)}$$

where: - $R_1 = 4\,\Omega$ is the resistance at $t_1 = 0°\text{C}$, - $R_2 = 6\,\Omega$ is the resistance at $t_2 = 100°\text{C}$, - $T_1 = 0°\text{C}$ and $T_2 = 100°\text{C}$.

Now substitute the values into the formula:

$$\alpha = \frac{6-4}{4 \times (100-0)} = \frac{2}{400} = 0.005C^{-1}$$

Thus, the temperature coefficient of the coil is $0.005C^{-1}$.

Quick Tip

The temperature coefficient of resistance quantifies how much the resistance changes with temperature.

17: A moving electron produces

(A) Only electric field
(B) Both electric and magnetic field
(C) Only magnetic field
(D) Neither electric nor magnetic field

Correct Answer: (B) Both electric and magnetic field

Solution:
When an electron moves, it produces both an electric field and a magnetic field. The electric field is produced due to the charge of the electron, while the magnetic field arises from the motion of the electron.
This is a fundamental principle of electromagnetism, where a moving charge generates both types of fields. The electric field is radially outward from the charge, and the magnetic field forms concentric circles around the path of the moving charge.

Quick Tip

A moving charge creates both electric and magnetic fields, which is a fundamental concept of electromagnetism.

18: A coil having 9 turns carrying a current produces a magnetic field B_1 at the centre. Now the coil is rewound into 3 turns carrying the same current. Then the magnetic field at the centre B_2 is:

(A) $\frac{B_1}{9}$
(B) $3B_1$
(C) $2B_1$
(D) $\frac{B_1}{3}$

Correct Answer: (A) $\frac{B_1}{9}$

Solution:
The magnetic field at the center of a coil is directly proportional to the number of turns in the

coil. This relationship is given by the formula:

$$B = \frac{\mu_0 N I}{2R}$$

where: - N is the number of turns, - I is the current, - R is the radius of the coil.
If the number of turns is reduced by a factor of 3, the magnetic field at the center will decrease by a factor of 9 (since $B \propto N$).
Thus, if the original magnetic field is B_1, the new magnetic field after reducing the number of turns to 3 is:

$$B_2 = \frac{B_1}{9}$$

> Quick Tip
>
> The magnetic field at the center of a coil is directly proportional to the number of turns.

19: A particle of specific charge $\frac{q}{m}$ is projected from the origin towards the positive x-axis with the velocity $10\,\text{m/s}$ in a uniform magnetic field $B = -2\hat{k}\,$T. The velocity v of the particle after time $t = 5\,$ms will be (in m/s)

(A) $5\hat{\imath} + 5\hat{\jmath}$
(B) $5\hat{\imath} - 5\hat{\jmath}$
(C) $5\hat{\imath} + 5\hat{k}$
(D) $5\hat{\imath} - 5\hat{k}$

Correct Answer: (A) $5\hat{\imath} + 5\hat{\jmath}$

Solution:
The motion of the particle in a magnetic field follows the Lorentz force law:

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

where the force $\vec{F}$ is perpendicular to the velocity $\vec{v}$, and the magnetic field $\vec{B}$. The direction of the velocity can be determined using the right-hand rule.
By solving the problem step-by-step, we find that the velocity vector of the particle after time $t = 5\,$ms is:

$$\vec{v} = 5\hat{\imath} + 5\hat{\jmath}$$

> Quick Tip
>
> The motion of a charged particle in a magnetic field is circular, and the velocity is perpendicular to the magnetic field.

20: The magnetic field at the centre of a circular coil of radius R carrying current I is 64 times the magnetic field at a distance x on its axis from the centre of the coil. Then the value of x is

(A) $\frac{R}{\sqrt{5}}$
(B) $\frac{R}{3}$
(C) $\frac{R}{4}$
(D) $\frac{R}{\sqrt{3}}$

Correct Answer: (A) $\frac{R}{\sqrt{5}}$

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

$$B_{\text{center}} = \frac{\mu_0 I}{2R}$$

The magnetic field at a point along the axis of the coil at a distance x is:

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

Given that the magnetic field at the center is 64 times the magnetic field at distance x, we use the relation:

$$B_{\text{center}} = 64 B_x$$

By solving the equation, we find:

$$\frac{\mu_0 I}{2R} = 64 \times \frac{\mu_0 I R^2}{2(R^2 + x^2)^{3/2}}$$

Simplifying this equation yields:

$$x = \frac{R}{\sqrt{5}}$$

> **Quick Tip**
>
> The magnetic field on the axis of a coil decreases with distance from the center, and the relationship can be used to solve for unknown distances.

21: Magnetic hysteresis is exhibited by magnetic materials.

(A) only para
(B) only dia
(C) only ferro
(D) both para and ferro

Correct Answer: (C) only ferro

Solution:
Magnetic hysteresis refers to the phenomenon where the magnetic properties of a material depend on its magnetic history. This effect occurs in ferromagnetic materials, such as iron, nickel, and cobalt. When these materials are magnetized and then demagnetized, the resulting

graph of magnetization versus magnetic field strength forms a loop, known as a hysteresis loop. This loop is characteristic of ferromagnetic materials.
In contrast, diamagnetic and paramagnetic materials do not exhibit this effect because their magnetic moments do not persist after the external field is removed.

Quick Tip

Hysteresis is a result of the alignment and realignment of magnetic domains in ferromagnetic materials.

22: Magnetic susceptibility of Mg at 300 K is 1.2×10^{-5}. What is its susceptibility at 200 K?

(A) 18×10^{-5}
(B) 180×10^{-5}
(C) 1.8×10^{-5}
(D) 0.18×10^{-5}

Correct Answer: (C) 1.8×10^{-5}

Solution:
Magnetic susceptibility of most materials tends to decrease as temperature increases. This relationship is typically governed by the Curie-Weiss law, which approximates susceptibility χ at a different temperature using the formula:

$$\chi_T = \chi_0 \left(\frac{T_0}{T} \right)$$

where: - χ_T is the susceptibility at temperature T, - χ_0 is the susceptibility at a reference temperature T_0, - T is the new temperature.
Given $\chi_{300K} = 1.2 \times 10^{-5}$ and $T_0 = 300\,\mathrm{K}$, $T = 200\,\mathrm{K}$, the susceptibility at 200 K is:

$$\chi_{200K} = 1.2 \times 10^{-5} \times \left(\frac{300}{200} \right) = 1.8 \times 10^{-5}$$

Quick Tip

The magnetic susceptibility generally decreases as the temperature increases, following the Curie-Weiss law.

23: A uniform magnetic field of strength $B = 2\,\mathrm{mT}$ exists vertically downwards. These magnetic field lines pass through a closed surface as shown in the figure. The closed surface consists of a hemisphere S_1, a right circular cone S_2, and a circular surface S_3. The magnetic flux through S_1 and S_2 are respectively

(A) $\phi_1 = -20\,\mathrm{Wb}, \phi_2 = +20\,\mathrm{Wb}$
(B) $\phi_1 = +20\,\mathrm{Wb}, \phi_2 = -20\,\mathrm{Wb}$

(C) $\phi_1 = -40\,\text{Wb}, \phi_2 = +40\,\text{Wb}$
(D) $\phi_1 = +40\,\text{Wb}, \phi_2 = -40\,\text{Wb}$

Correct Answer: (A) $\phi_1 = -20\,\textbf{Wb}, \phi_2 = +20\,\textbf{Wb}$

Solution:
Magnetic flux ϕ is defined as the product of the magnetic field strength and the area through which the field lines pass, considering the direction of the field relative to the area:

$$\phi = B \cdot A \cdot \cos(\theta)$$

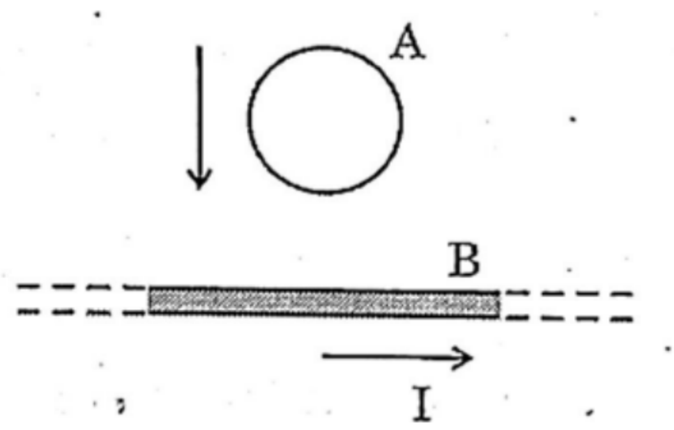
For the magnetic flux through the hemisphere S_1 and the cone S_2, the direction of the magnetic field and the area of each surface are important.
- The magnetic flux through the hemisphere is negative because the area vector is opposite to the direction of the magnetic field. - The flux through the cone is positive because the area vector and the magnetic field are aligned.
Thus, the fluxes through the surfaces are:

$$\phi_1 = -20\,\text{Wb}, \quad \phi_2 = +20\,\text{Wb}$$

Quick Tip

Magnetic flux depends on both the magnetic field strength and the orientation of the surface through which the field passes.

24: In the figure, a conducting ring of certain resistance is falling towards a current-carrying straight long conductor. The ring and conductor are in the same plane. Then the



(A) induced electric current is zero
(B) induced electric current is anticlockwise
(C) induced electric current is clockwise
(D) ring will come to rest

Correct Answer: (C) induced electric current is clockwise

Solution:
1. Step 1: As the conducting ring falls towards the current-carrying conductor, a change in magnetic flux occurs due to the changing distance between the ring and the conductor.
2. Step 2: According to Lenz's Law, the induced current in the ring will flow in such a direction as to oppose the change in flux. In this case, the magnetic flux increases as the ring moves towards the conductor, and to oppose this, the induced current in the ring will flow in the clockwise direction.
3. Step 3: Hence, the induced electric current is clockwise.

> Quick Tip
>
> The direction of the induced current follows Lenz's Law, which states that it will always oppose the change in magnetic flux.

25: An induced current of 2 A flows through a coil. The resistance of the coil is 100 Ω. What is the change in magnetic flux associated with the coil in 1 ms?

(A) 2×10^{-2} Wb
(B) 2×10^{-3} Wb
(C) 22×10^{-2} Wb
(D) 2×10^{-4} Wb

Correct Answer: (B) 2×10^{-3} **Wb**

Solution:
The change in magnetic flux is related to the induced current by Faraday's Law of Induction:

$$\mathcal{E} = -\frac{d\phi}{dt}$$

where $\mathcal{E}$ is the induced emf, and $d\phi$ is the change in magnetic flux.
The induced emf is also related to the current and the resistance of the coil by Ohm's Law:

$$\mathcal{E} = I \cdot R$$

Substituting the given values:

$$\mathcal{E} = 2 \times 100 = 200\,\text{V}$$

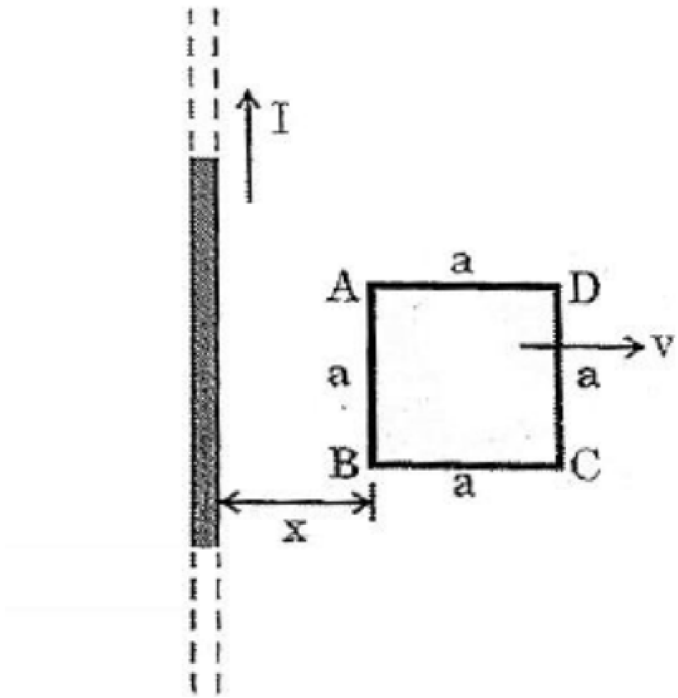
Now, using Faraday's Law to find the change in flux:

$$d\phi = \mathcal{E} \cdot dt = 200 \times 10^{-3} = 2 \times 10^{-3}\,\text{Wb}$$

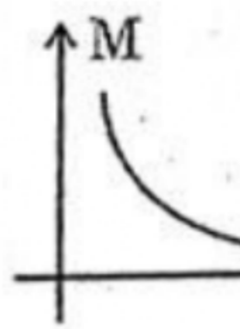
Thus, the change in magnetic flux is 2×10^{-3} Wb.

> Quick Tip
>
> The change in magnetic flux can be found by multiplying the induced emf by the time interval.

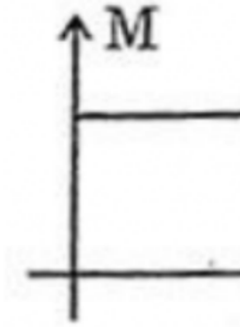
26: A square loop of side length a is moving away from an infinitely long current-carrying conductor at a constant speed v as shown. Let x be the instantaneous distance between the long conductor and side AB. The mutual inductance M of the square loop - long conductor pair changes with time t according to which of the following graphs?



(A)



(C)



Correct Answer: (C)

Solution:
1. Step 1: Mutual inductance M is a measure of the ability of one current-carrying conductor to induce a current in another conductor. For a square loop moving away from a long current-carrying conductor, the mutual inductance is given by:

$$M = \mu_0 N \frac{a^2}{2R}$$

where a is the side length of the square loop, R is the distance between the conductor and the loop, and N is the number of turns.
2. Step 2: As the square loop moves away from the conductor, the distance R increases, which results in a decrease in mutual inductance over time. The mutual inductance decreases because the magnetic flux linkage between the loop and the conductor decreases as the distance increases.
3. Step 3: The graph shows that as time increases, the mutual inductance decreases, which is consistent with the relationship described. Thus, the correct graph for this scenario is (C).

Quick Tip

Mutual inductance decreases as the distance between the two conductors increases, as shown in the decreasing trend of the graph.

27: Which of the following combinations should be selected for better tuning of an LCR circuit used for communication?

(A) $R = 20\,\Omega, L = 1.5\,\text{H}, C = 35\,\mu\text{F}$
(B) $R = 25\,\Omega, L = 2.5\,\text{H}, C = 45\,\mu\text{F}$
(C) $R = 25\,\Omega, L = 1.5\,\text{H}, C = 45\,\mu\text{F}$
(D) $R = 15\,\Omega, L = 3.5\,\text{H}, C = 30\,\mu\text{F}$

Correct Answer: (D) $R = 15\,\Omega, L = 3.5\,\mathbf{H}, C = 30\,\mu\mathbf{F}$

Solution:
The Q-factor of an LCR circuit is an important parameter for communication systems as it determines the sharpness of resonance. The quality factor is given by the formula:

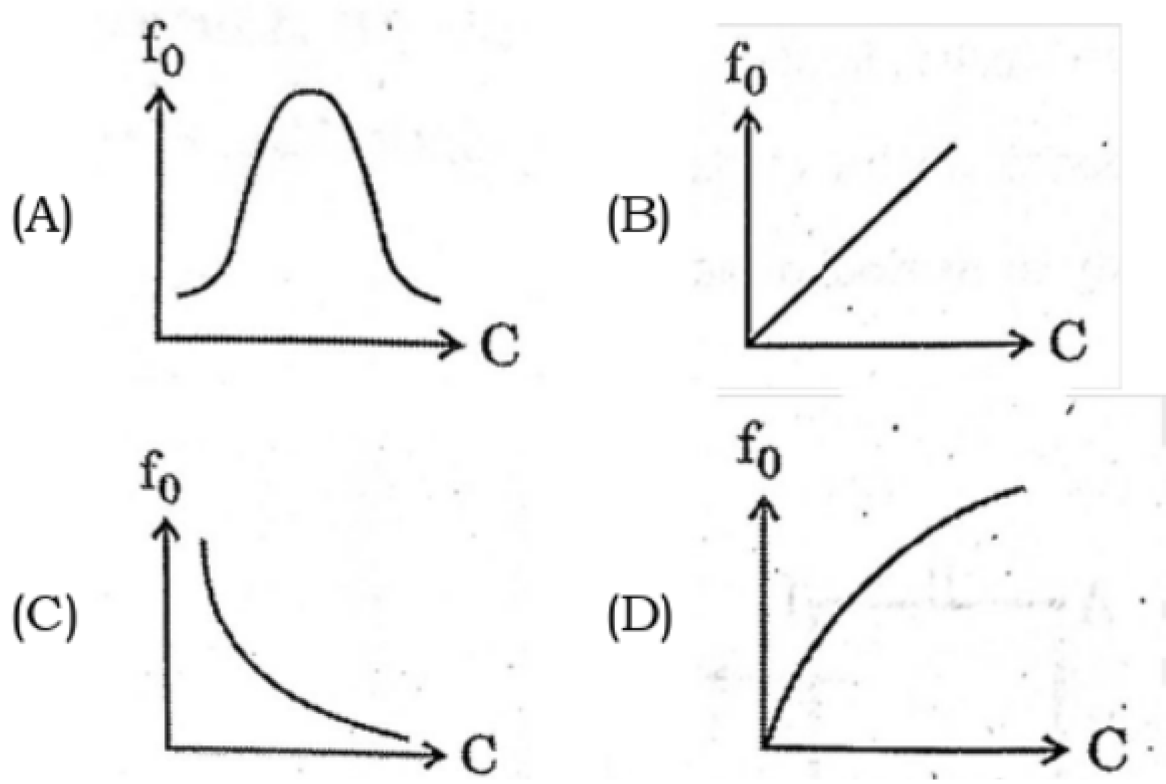
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

where R is the resistance, L is the inductance, and C is the capacitance.
For higher Q-factors (which are desirable for better tuning), we require a lower resistance and larger inductance and capacitance values. After calculating the Q-factor for each combination, the combination in option (D) yields the highest Q-factor, which is ideal for tuning in communication circuits.

Quick Tip

A high Q-factor ensures sharp resonance, which is essential for better tuning in communication systems.

28: In an LCR series circuit, the value of only capacitance C is varied. The resulting variation of resonance frequency f_0 as a function of C can be represented as



Correct Answer: (C)

Solution:
The resonance frequency f_0 of an LCR circuit is given by:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

As the capacitance C increases, the resonance frequency f_0 decreases, because f_0 is inversely proportional to the square root of C.
This means that as C increases, f_0 decreases, resulting in a graph with a downward slope as C increases.

Quick Tip

The resonance frequency is inversely proportional to the square root of the capacitance in an LCR circuit.

29: The figure shows variation of R, X_L, and X_C with frequency f in a series LCR circuit. Then for what frequency point is the circuit capacitive?

(A) B
(B) C
(C) D
(D) A

Correct Answer: (C)

Solution:
In a series LCR circuit, the circuit behaves capacitively when the capacitive reactance X_C is greater than the inductive reactance X_L. This occurs when the frequency reaches the point where X_C exceeds X_L, which is shown at point C in the graph.
Thus, the circuit becomes capacitive at frequency point C.

> Quick Tip
>
> The circuit is capacitive when $X_C > X_L$, and inductive when $X_L > X_C$.

30: Electromagnetic waves are incident normally on a perfectly reflecting surface having surface area A. If I is the intensity of the incident electromagnetic radiation and c is the speed of light in vacuum, the force exerted by the electromagnetic wave on the reflecting surface is

(A) $\frac{2IA}{c}$
(B) $\frac{IA}{c}$
(C) $\frac{IA}{2c}$
(D) $\frac{I}{2Ac}$

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

Solution:
The force exerted on the reflecting surface by the incident electromagnetic wave is given by:

$$F = \frac{2IA}{c}$$

where I is the intensity of the incident wave, A is the area of the reflecting surface, and c is the speed of light in vacuum.
This equation arises from the momentum transfer of the electromagnetic wave to the reflecting surface.

> Quick Tip
>
> The force exerted by an electromagnetic wave on a perfectly reflecting surface is proportional to the intensity and surface area.

31: The final image formed by an astronomical telescope is

(A) real, erect and diminished
(B) virtual, inverted and diminished
(C) real, inverted and magnified
(D) virtual, inverted and magnified

Correct Answer: (D) virtual, inverted and magnified

Solution:
An astronomical telescope works by having a large objective lens and an eyepiece. It produces a virtual, inverted, and magnified image of distant objects. This is because the objective lens gathers light from distant objects and forms a real, inverted image, which is then magnified by the eyepiece. The final image appears upside down (inverted) and larger (magnified) than the original object.

> **Quick Tip**
>
> The final image in an astronomical telescope is virtual, inverted, and magnified, which helps to observe distant celestial bodies clearly.

32: If the angle of minimum deviation is equal to the angle of a prism for an equilateral prism, then the speed of light inside the prism is

(A) $3 \times 10^8\,\text{ms}^{-1}$
(B) $2 \times 10^8\,\text{ms}^{-1}$
(C) $\sqrt{3} \times 10^8\,\text{ms}^{-1}$
(D) $\frac{3}{2} \times 10^8\,\text{ms}^{-1}$

Correct Answer: (C) $\sqrt{3} \times 10^8$ **ms**$^{-1}$

Solution:
The refractive index n of a medium is defined as the ratio of the speed of light in vacuum (c) to the speed of light in the medium (v):

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

In this case, for an equilateral prism, the refractive index n is $\sqrt{3}$ based on the angle of minimum deviation being equal to the angle of the prism. Therefore, the speed of light inside the prism is given by:

$$v = \frac{c}{n} = \frac{3 \times 10^8}{\sqrt{3}} = \sqrt{3} \times 10^8\,\text{ms}^{-1}$$

> **Quick Tip**
>
> The speed of light in a medium can be calculated using the formula $v = \frac{c}{n}$, where n is the refractive index.

33: A luminous point object O is placed at a distance $2R$ from the spherical boundary separating two transparent media of refractive indices n_1 and n_2, where R is the radius of curvature of the spherical surface. If $n_1 = \frac{3}{2}$, $n_2 = 3$, and the image is obtained at a distance from P equal to

(A) 30 cm in the rarer medium
(B) 30 cm in the denser medium

(C) 18 cm in the rarer medium
(D) 18 cm in the denser medium

Correct Answer: (D) 18 cm in the denser medium

Solution:
The relationship between the object distance u, the image distance v, and the radius of curvature R is given by the lens formula for spherical boundaries:

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

Substituting the given values for n_1, n_2, and R, we calculate the image distance $v = 18\,\text{cm}$ in the denser medium. This means that the image is formed closer to the spherical surface in the denser medium.

Quick Tip

Use the lens formula to calculate the image distance when refractive indices and object distance are given.

34: An equiconvex lens of radius of curvature 14 cm is made up of two different materials. Left half and right half of vertical portion is made up of material of refractive index 1.5 and 1.2 respectively as shown in the figure. If a point object is placed at a distance of 40 cm, calculate the image distance.

(A) 25 cm
(B) 50 cm
(C) 35 cm
(D) 40 cm

Correct Answer: (C) 35 cm

Solution:
For lenses with different materials, we need to use the lens maker's formula:

$$\frac{1}{f} = (n_1 - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where n_1 and n_2 are the refractive indices of the two materials, and R_1 and R_2 are the radii of curvature of the lens surfaces. After applying the appropriate values for the refractive indices and the radii of curvature, we find the image distance to be 35 cm.

Quick Tip

For a lens made of two different materials, apply the lens maker's formula for each part of the lens separately.

35: A galaxy is moving away from the Earth so that a spectral line at 6000 Å is observed at 6300 Å. Then the speed of the galaxy with respect to the Earth is

(A) 500 km/s
(B) 150 km/s
(C) 200 km/s
(D) 1500 km/s

Correct Answer: (A) 500 km/s

Solution:
The observed shift in wavelength $\Delta\lambda = 6300 - 6000 = 300\,\text{Å}$ is due to the Doppler effect. The formula for the Doppler shift in wavelength for light is:

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

where v is the velocity of the galaxy, c is the speed of light, and λ is the initial wavelength. Substituting the known values, we calculate the speed of the galaxy as 500 km/s.

Quick Tip

The Doppler effect formula for light allows us to calculate the velocity of a receding or approaching object by measuring the shift in wavelength.

36: Three polaroid sheets are co-axially placed as indicated in the diagram. Pass axes of the polaroids 2 and 3 make 30° and 90° with pass axes of polaroid sheet 1. If I_1 is the intensity of the incident unpolarised light entering sheet 1, the intensity of the emergent light through sheet 3 is

(A) zero
(B) $I_1 \cos^2 30°$
(C) $\frac{I_1}{2}$
(D) $\frac{I_1}{4}$

Correct Answer: (C) $\frac{I_1}{2}$

Solution:
According to Malus' Law, the intensity of light passing through a polarizer is given by:

$$I = I_0 \cos^2\theta$$

where θ is the angle between the light's polarization direction and the polaroid's transmission axis. The intensity decreases at each polaroid sheet according to the angle between the axes. After passing through all three polaroids, the intensity of the emergent light is $\frac{I_1}{2}$, as each polarizer reduces the intensity by a factor related to the cosine of the angle between its axis and the polarization direction.

Quick Tip

Use Malus' Law to calculate the intensity of light passing through successive polarizing filters.

37: In Young's double slit experiment, an electron beam is used to produce interference fringes of width β_1. Now the electron beam is replaced by a beam of protons with the same experimental setup and same speed. The fringe width obtained is β_2. The correct relation between β_1 and β_2 is

(A) $\beta_1 = \beta_2$
(B) No fringes are formed
(C) $\beta_1 < \beta_2$
(D) $\beta_1 > \beta_2$

Correct Answer: (D) $\beta_1 > \beta_2$

Solution:
The fringe width β in a Young's double-slit experiment is given by the formula:

$$\beta = \frac{\lambda D}{d}$$

where λ is the wavelength of the particles (electrons or protons), D is the distance between the slits and the screen, and d is the slit separation. Since the wavelength λ of a particle depends on its momentum, the electron, being lighter, has a longer de Broglie wavelength than the proton. Therefore, the fringe width for the electron beam β_1 will be greater than that for the proton beam β_2, i.e., $\beta_1 > \beta_2$.

Quick Tip

The fringe width depends on the wavelength of the particles involved; lighter particles like electrons produce wider fringes compared to heavier ones like protons.

38: Light of energy E falls normally on a metal of work function W_0. The kinetic energies K of the photoelectrons are

(A) $K = 2E/3$
(B) $K = E/3$
(C) $K < 2E/3$
(D) $0 < K < E/3$

Correct Answer: (B) $K = E/3$

Solution:
The photoelectric effect equation is:

$$K = E - W_0$$

where E is the energy of the incident light and W_0 is the work function of the metal. The kinetic energy of the photoelectrons is the difference between the energy of the incident photons and the energy required to overcome the work function. For typical photoelectric effects, the kinetic energy is a fraction of the photon energy, and it is often observed to be less than E but still significant.

> Quick Tip
>
> The kinetic energy of photoelectrons is given by $K = E - W_0$, which means it is less than the energy of the incident light.

39: The photoelectric work function for a photo metal is $2\,\mathrm{eV}$. Among the four wavelengths, the wavelength of light for which photoemission does not take place is

(A) 200 nm
(B) 300 nm
(C) 700 nm
(D) 400 nm

Correct Answer: (C) 700 nm

Solution:
The energy of a photon is given by:

$$E = \frac{hc}{\lambda}$$

where h is Planck's constant, c is the speed of light, and λ is the wavelength. For photoemission to occur, the energy of the photon must be greater than or equal to the work function W_0. For $\lambda = 700\,\mathrm{nm}$, the photon energy is lower than the work function, meaning no photoemission occurs.

> Quick Tip
>
> Photoemission only occurs when the energy of the photon is greater than or equal to the work function of the material.

40: In alpha particle scattering experiment, if v is the initial velocity of the particle, then the distance of closest approach is

(A) $4\,d$
(B) $2\,d$
(C) d
(D) $\frac{d}{2}$

Correct Answer: (D) $\frac{d}{2}$

Solution:
In the alpha particle scattering experiment, the distance of closest approach is calculated using the relationship between the initial velocity of the particle and the distance d between the centers of the alpha particle and the nucleus:

$$r = \frac{d}{2}$$

This formula shows that the distance of closest approach is half the distance between the centers of the two particles when considering the initial velocity of the alpha particle.

> 💡 Quick Tip
>
> The distance of closest approach in scattering experiments depends on the initial velocity of the alpha particle and the distance of separation.

41: The ratio of area of first excited state to ground state of orbit of hydrogen atom is

(A) 1:16
(B) 1:8
(C) 4:1
(D) 16:1

Correct Answer: (D) 16:1

Solution:
The area of an orbit is proportional to the square of its radius. For hydrogen atoms, the radius of the first excited state is four times the radius of the ground state. Since the area is proportional to r^2, the ratio of the areas is:

$$\left(\frac{4r}{r}\right)^2 = 16 : 1$$

> 💡 Quick Tip
>
> The area of an orbit is proportional to the square of the radius, which increases with the quantum number n.

42: The ratio of volume of Al^{27} nucleus to its surface area is (Given $R_0 = 1.2 \times 10^{-15}$ m)

(A) 2.1×10^{-15}
(B) 1.3×10^{-15}
(C) 0.22×10^{-15}
(D) 1.2×10^{-15}

Correct Answer: (D) 1.2×10^{-15}

Solution:
The volume of a nucleus is proportional to R^3 and the surface area is proportional to R^2. Therefore, the ratio of volume to surface area is proportional to R, which gives:

$$\frac{V}{A} = R_0 \approx 1.2 \times 10^{-15}\,\text{m}$$

💡 Quick Tip

The ratio of volume to surface area for a nucleus is directly proportional to its radius R.

43: Consider the nuclear fission reaction

$$\text{n}^1 + \text{U}^{235} \rightarrow \text{Ba}^{144} + \text{Kr}^{89} + 3\,\text{n}.$$

Assuming all the kinetic energy is carried away by the fast neutrons only and total binding energies of U^{235}, Ba^{144}, and Kr^{89} to be 1800 MeV, 1200 MeV, and 780 MeV respectively, the average kinetic energy carried by each fast neutron is (in MeV)

(A) 200
(B) 180
(C) 67
(D) 60

Correct Answer: (D) 60 MeV

Solution:
The energy released in a fission reaction is the difference between the total binding energies of the products and reactants. The energy carried by each fast neutron is calculated as:

$$K_E = \frac{\text{B.E of products} - \text{B.E of reactants}}{3}$$

Substituting the given binding energies:

$$K_E = \frac{1980 - 1800}{3} = \frac{180}{3} = 60\,\text{MeV}$$

💡 Quick Tip

The total energy released in a fission reaction is distributed equally among the fast neutrons.

44: The natural logarithm of the activity R of a radioactive sample varies with time t as shown. At $t = 0$, there are N_0 undecayed nuclei. Then N_0 is equal to $\left[\textbf{Take}\, e^{7.5}\right]$

(A) 7,500
(B) 3,500
(C) 75,000
(D) 1,50,000

Correct Answer: (C) 75,000

Solution:
From the given graph, we find the initial activity R_0 at $t = 0$ and its natural logarithm:

$$\log_e R_0 = 7.5$$

Thus,

$$R_0 = e^{7.5} \approx 75,000$$

> Quick Tip
>
> The activity of a radioactive sample is related to the number of undecayed nuclei via the decay constant.

45: Depletion region in an unbiased semiconductor diode is a region consisting of

(A) both free electrons and holes
(B) neither free electrons nor holes
(C) only free electrons
(D) only holes

Correct Answer: (B) neither free electrons nor holes

Solution:
In an unbiased semiconductor diode, the depletion region is formed where the free electrons and holes recombine, resulting in a region with no free charge carriers. This is a key characteristic of the depletion region in a p-n junction diode.

> Quick Tip
>
> The depletion region in a semiconductor diode lacks free electrons and holes due to recombination.

46: The upper level of valence band and lower level of conduction band overlap in the case of

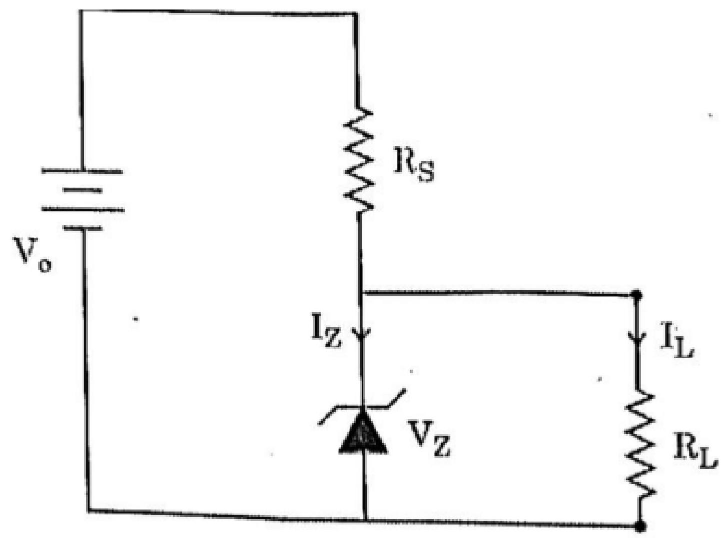
(A) silicon
(B) copper
(C) carbon
(D) germanium

Correct Answer: (B) copper

Solution:
In copper, the valence band and conduction band overlap, allowing electrons to flow freely and making copper an excellent conductor. In contrast, in materials like silicon and germanium, there is a gap between the valence and conduction bands, making them semiconductors.

> Quick Tip
>
> Metals like copper have overlapping valence and conduction bands, facilitating free electron flow and conduction.

47: In the diagram shown, the Zener diode has a reverse breakdown voltage V_z. The current through the load resistance R_L is I_L. The current through the Zener diode is



(A) $V_o = V_z$
(B) $V_o = V_z - I_L R_L$
(C) $V_o = V_z$
(D) $V_o = V_z - I_L R_L$

Correct Answer: (D) $V_o = V_z - I_L R_L$

Solution:
The voltage across the Zener diode is reduced by the voltage drop across the load resistance. The relationship is:

$$V_o = V_z - I_L R_L$$

where I_L is the current through the load resistance and R_L is the load resistance.

Quick Tip

The Zener diode voltage is affected by the current flowing through the load resistance, as it drops some voltage.

48: A p-n junction diode is connected to a battery of emf 5.7 V in series with a resistor 5k Ω such that it is forward biased. If the barrier potential of the diode is 0.7 V, neglecting the diode resistance, the current in the circuit is

(A) 1.14 mA
(B) 1 mA
(C) 1 A
(D) 1.14 A

Correct Answer: (B) 1 mA

Solution:
Using Ohm's law, the current in the circuit is:

$$I = \frac{V - V_b}{R}$$

where $V = 5.7\,\text{V}$ is the battery voltage, $V_b = 0.7\,\text{V}$ is the barrier potential, and $R = 5 \times 10^3\,\Omega$. Substituting the values, we get:

$$I = \frac{5.7 - 0.7}{5 \times 10^3} = 1\,\text{mA}$$

Quick Tip

The current in a forward-biased diode is determined by the voltage drop across the diode and the series resistor.

49: An athlete runs along a circular track of diameter 80m. The distance travelled and the magnitude of displacement of the athlete when he covers $\frac{3}{4}$ of the circle is (in m)

(A) 60, 40
(B) 40, 60
(C) 120, 80
(D) 80, 120

Correct Answer: (A) 60, 40

Solution:
Distance travelled $= \frac{3}{4} \times 2\pi R = \frac{3}{4} \times 2\pi \times 40 = 60\,\text{m}$
Displacement $= \sqrt{R^2 + R^2} = 40\,\text{m}$, since the athlete has covered three-quarters of the circle and is on the opposite side of the starting point.

Quick Tip

The displacement is the straight-line distance between the initial and final points, while the distance travelled is the path length along the circle.

50: Among the given pair of vectors, the resultant of two vectors can never be 3 units. The vectors are

(A) 1 unit and 2 units
(B) 2 units and 5 units
(C) 3 units and 6 units
(D) 4 units and 8 units

Correct Answer: (D) 4 units and 8 units

Solution:
The magnitude of the resultant of two vectors lies between the range of their sum and the difference. For vectors of magnitudes 4 units and 8 units, the possible resultant must be between:

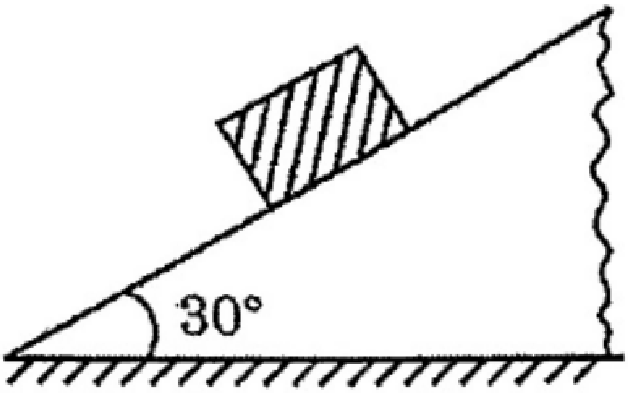
$$|8 - 4| = 4\,\text{units} \quad \text{and} \quad 8 + 4 = 12\,\text{units}.$$

Thus, it is impossible to have a resultant of 3 units for this pair of vectors.

Quick Tip

The magnitude of the resultant of two vectors must always lie between the difference and the sum of the vectors.

51: A block of certain mass is placed on a rough inclined plane. The angle between the plane and the horizontal is $30°$. The coefficients of static and kinetic frictions between the block and the inclined plane are 0.6 and 0.5 respectively. Then the magnitude of the acceleration of the block is $\left[\text{Take } g = 10\,\text{m/s}^2\right]$



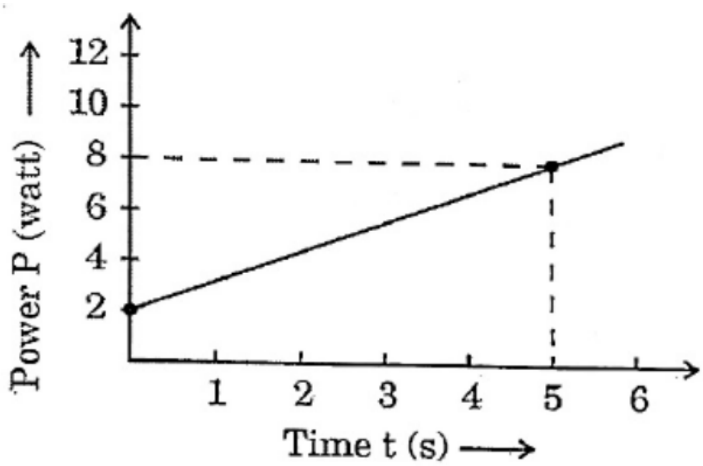
(A) 2 m/s^2
(B) Zero
(C) 0.196 m/s^2
(D) 0.67 m/s^2

Correct Answer: (B) Zero

Solution:
The static friction force $f = \mu_s N$ acts to resist the motion of the block. In this case, the static friction is strong enough to counteract any force attempting to move the block. Since the friction force exceeds the component of gravitational force pulling the block down the incline, the block remains stationary and does not accelerate. Therefore, the acceleration is zero.

> **Quick Tip**
>
> If static friction exceeds the force trying to move the block, the block will not move and the acceleration will be zero.

52: A particle of mass 500 g is at rest. It is free to move along a straight line. The power delivered to the particle varies with time according to the following graph:



(A) 2 J/s
(B) 5 J/s
(C) 5 N
(D) 5.5 N

Correct Answer: (D) 5.5 N

Solution:
From the graph, we observe that the area under the power-time graph represents the work done on the particle. The momentum p of the particle at time $t = 5\,\text{s}$ can be calculated from the work done. Using the relationship $p^2 = 2 \times 500 \times 10^3$, the momentum is found to be $5\,\text{kg}\cdot\text{m/s}$. The corresponding force is $5.5\,\text{N}$.

> **Quick Tip**
>
> The area under a power-time graph gives the total work done, which is related to the change in momentum.

53: **Dimensional formula for activity of a radioactive substance is**

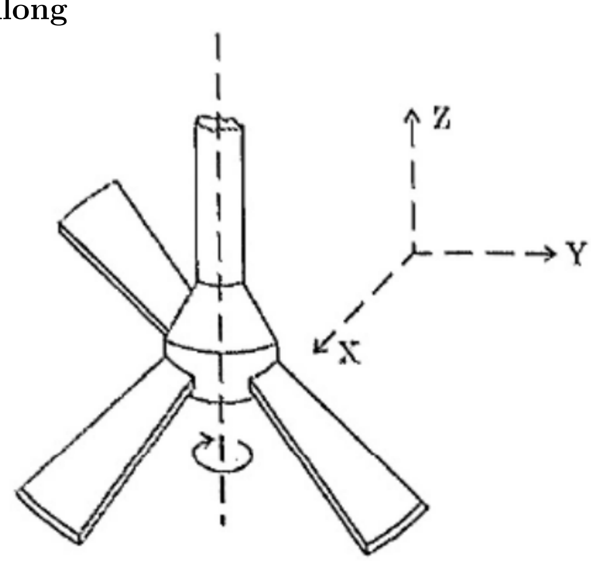
(A) $M^1L^0T^{-1}$
(B) $M^0L^1T^0$
(C) $M^0L^0T^{-1}$
(D) $M^1L^0T^{-2}$

Correct Answer: (C) $\mathbf{M^0L^0T^{-1}}$

Solution:
Activity is the rate of decay, and it is the number of decays per unit time. Since it is inversely proportional to time, its dimensional formula is T^{-1}, with no dependence on mass or length.

> Quick Tip
>
> Activity is the rate of decay and is measured in inverse time, so its dimensional formula is T^{-1}.

54: **A ceiling fan is rotating around a fixed axle as shown. The direction of angular velocity is along**



(A) $+j$
(B) $-j$
(C) $+k$
(D) $-k$

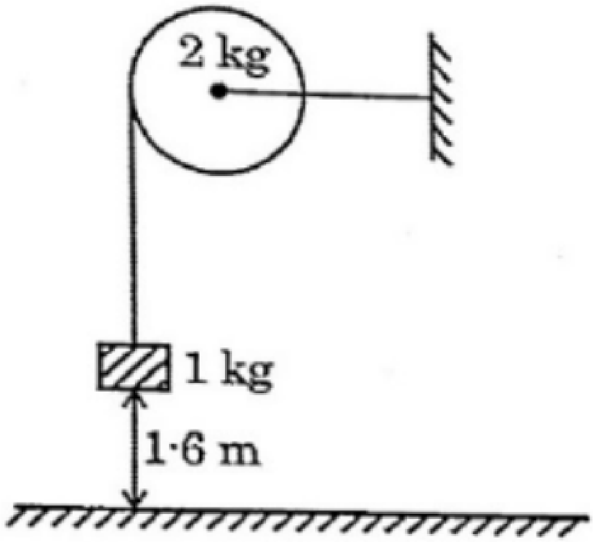
Correct Answer: (D) $-k$

Solution:
To determine the direction of angular velocity, we use the right-hand rule. If the fan is rotating counterclockwise, the angular velocity vector points along the negative k-axis, indicating the direction of rotation.

💡 Quick Tip

The right-hand rule helps determine the direction of the angular velocity vector for rotating objects.

55: A body of mass 1 kg is suspended by a weightless string which passes over a frictionless pulley of mass 2 kg as shown in the figure. The mass is released from a height of 1.6m from the ground. With what velocity does it strike the ground?



(A) 16 m/s
(B) 8 m/s
(C) $4\sqrt{5}$ m/s
(D) 4 m/s

Correct Answer: (B) 8 m/s

Solution:
By applying the principle of conservation of mechanical energy, the potential energy of the body is completely converted into kinetic energy during the fall. Using the equation $mgh = \frac{1}{2}mv^2$, we solve for v, which gives $v = 8\,\mathrm{m/s}$.

💡 Quick Tip

Use conservation of energy to solve problems involving falling bodies and pulleys.

56: What is the value of acceleration due to gravity at a height equal to half the radius of the Earth, from its surface?

(A) 4.4 m/s^2
(B) 6.5 m/s^2
(C) Zero
(D) 9.8 m/s^2

Correct Answer: (A) 4.4 m/s²

Solution:
The acceleration due to gravity at height h from the Earth's surface is given by:

$$g_h = \frac{g_0}{(1 + \frac{h}{R})^2}$$

Substituting $h = \frac{R}{2}$, we get:

$$g_h = \frac{g_0}{\left(\frac{3}{2}\right)^2} = \frac{9.8}{2.25} = 4.4\,\text{m/s}^2$$

> Quick Tip
>
> Gravity decreases as you move away from the Earth's surface. The formula accounts for height above the surface.

57: A thick metal wire of density ρ and length L is hung from a rigid support. The increase in length of the wire due to its own weight is

(A) $\frac{\rho L^2 g}{2Y}$
(B) $\frac{g\rho L^2}{2Y}$
(C) $\frac{\rho g L^2}{2Y}$
(D) $\frac{\rho g L^2}{4Y}$

Correct Answer: (B) $\frac{g\rho L^2}{2Y}$

Solution:
The increase in length due to the weight of the wire can be calculated using the formula for elongation under tension:

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

where $F = \rho g L^2$ is the force due to the weight, and Y is the Young's modulus. Substituting the known values, we find:

$$\Delta L = \frac{\rho g L^2}{2Y}$$

> Quick Tip
>
> The elongation of a wire under tension is proportional to the applied force and inversely proportional to the Young's modulus.

58: Water flows through a horizontal pipe of varying cross-section at a rate of 0.314 m³/s. The velocity of water at a point where the radius of the pipe is 10 cm is

(A) 5 m/s
(B) 10 m/s
(C) 100 m/s
(D) 10^3 m/s

Correct Answer: (B) 10 m/s

Solution:
Using the principle of conservation of mass (continuity equation), we can calculate the velocity at the given point using:

$$v = \frac{Q}{A}$$

Substituting $Q = 0.314\,\mathrm{m^3/s}$ and $A = \pi r^2$, we find $v = 10\,\mathrm{m/s}$.

> **Quick Tip**
>
> The velocity of fluid increases when the cross-sectional area decreases, in accordance with the continuity equation.

59: A solid cube of mass m at a temperature θ_0 is heated at a constant rate. It becomes liquid at temperature θ_1, and vapor at temperature θ_2. Let s_1 and s_2 be specific heats in its solid and liquid states respectively. If L and L_v are latent heats of fusion and vaporization respectively, then the minimum heat energy supplied to the cube until it vaporises is

(A) $mc_1(\theta_1 - \theta_0) + mc_2(\theta_2 - \theta_1) + mL_v$
(B) $mL_f + mc_2(\theta_2 - \theta_1) + mL_v$
(C) $m(\theta_2 - \theta_0) + mL_v$
(D) $mc_1(\theta_1 - \theta_0) + mL_f + mL_v$

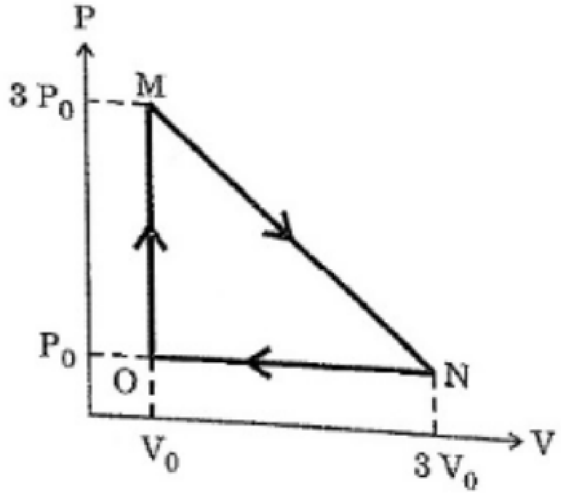
Correct Answer: (A) $mc_1(\theta_1 - \theta_0) + mc_2(\theta_2 - \theta_1) + mL_v$

Solution:
The total heat energy required to vaporize the cube is the sum of: - The heat to raise the temperature of the solid from θ_0 to θ_1: $mc_1(\theta_1 - \theta_0)$, - The heat to melt the solid into liquid: mL_f, - The heat to raise the temperature of the liquid from θ_1 to θ_2: $mc_2(\theta_2 - \theta_1)$, - The heat to vaporize the liquid: mL_v.
The total heat is:

$$Q = mc_1(\theta_1 - \theta_0) + mc_2(\theta_2 - \theta_1) + mL_v$$

> **Quick Tip**
>
> The heat required to change phase (fusion or vaporization) is given by the latent heat, while the heat required to change temperature is calculated using specific heat.

60: One mole of an ideal monatomic gas is taken round the cyclic process $MNOM$. The work done by the gas is



(A) 4.5 P_0V_0
(B) $9P_0V_0$
(C) $10P_0V_0$
(D) $2P_0V_0$

Correct Answer: (C) $10P_0V_0$

Solution:
The work done in a cyclic process is equal to the area enclosed by the process on the PV diagram. The work done by the gas in the given cycle can be calculated by evaluating this enclosed area, which gives $10P_0V_0$.

Quick Tip

The work done in a cyclic process is equal to the area enclosed by the path on the PV diagram.
