CUET UG 2024 Physics Online Question Paper Solutions

Question 1: A uniform electric field pointing in the positive X direction exists in a region. Let O be the origin, A be the point on the X-axis at $r = +2$ cm, and B be the point on the Y-axis at $y = +1$ cm. Then the potential at the points O, A, and B satisfy:

(1) $V_O > V_A$

(2) $V_O < V_A$

(3) $V_O > V_B$

(4) $V_O < V_B$

Correct Answer: (1)

Solution: The electric potential decreases in the direction of the electric field. Since the electric field points along the positive X direction, it means that as you move in this direction, the potential decreases.

1. Point O is at the origin, so it's the reference point. 2. Point A is along the X-axis at $r = +2$ cm, which is in the direction of the field. Therefore, the potential at A will be lower than at O. 3. Point B is along the Y-axis at $y = +1$ cm. Since there is no component of the electric field along the Y-axis, no work is done in moving a charge from O to B. Hence, the potential at B is the same as at O.

Thus, we have $V_O = V_B$ and $V_O > V_A$, which means the correct answer is (1).

Quick Tip

In a uniform electric field, the potential decreases in the direction of the electric field, but remains the same in directions perpendicular to the field.

Question 2: An electric bulb rated 200 V - 100 W is connected to a 160 V power supply. The power consumed by it would be:

(1) 64 W

(2) 80 W

(3) 100 W

(4) 125 W

Correct Answer: (1)

Solution: The power consumed by a device is related to the voltage applied and the resistance of the device. The formula for power is:

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

Where P is the power, V is the voltage, and R is the resistance.

1. The resistance R of the bulb can be found using the rated voltage and power of the bulb, which are 200 V and 100 W, respectively. We use the formula:

$$R = \frac{V_{rated}^2}{P_{rated}} = \frac{200^2}{100} = 400\,\Omega$$

2. Now, we calculate the power consumed when the voltage applied is 160 V using the same formula:

$$P = \frac{160^2}{400} = \frac{25600}{400} = 64\,\text{W}$$

Thus, the power consumed by the bulb when connected to a 160 V power supply is 64 W.

Quick Tip

Power consumption decreases as the square of the voltage. When voltage is reduced, the power consumed decreases significantly.

Question 3: Which of the following particles will experience the maximum magnetic force (magnitude) when projected with the same velocity perpendicular to the magnetic field?

(1) Electron

(2) Proton

(3) He^+

(4) Li^{++}

Correct Answer: (4)

Solution: The magnetic force on a charged particle moving in a magnetic field is given by the Lorentz force law:

$$F = qvB\sin\theta$$

Where q is the charge of the particle, v is its velocity, B is the magnetic field strength, and θ is the angle between the velocity and the magnetic field. Since all particles are moving perpendicular to the magnetic field, $\sin\theta = 1$, so the force is directly proportional to the charge of the particle.

1. Electron: charge = $-e$. 2. Proton: charge = $+e$. 3. He^+ (Helium ion): charge = $+e$ (since it's lost one electron). 4. Li^{++} (Lithium ion): charge = $+2e$ (since it has lost two electrons).

The particle with the largest charge will experience the greatest force. Since Li^{++} has a charge of $+2e$, it will experience the maximum force.

Quick Tip

The greater the charge of a particle, the larger the magnetic force it experiences when moving through a magnetic field.

Question 4: An a.c. circuit contains a 4 Ω resistance wire in series with an inductance coil of reactance 3 Ω. The impedance of the circuit is:

(1) 5 Ω

(2) ∞

(3) $4/3\,\Omega$

Correct Answer: (1)

Solution: In an AC circuit containing resistance and inductance in series, the impedance Z is the vector sum of the resistance R and the inductive reactance X_L. The formula for impedance in such a circuit is:

$$Z = \sqrt{R^2 + X_L^2}$$

1. Here, $R = 4\,\Omega$ (resistance), and $X_L = 3\,\Omega$ (inductive reactance). 2. Using the formula, we get:

$$Z = \sqrt{4^2 + 3^2} = \sqrt{16 + 9} = \sqrt{25} = 5\,\Omega$$

Thus, the total impedance of the circuit is $5\,\Omega$.

Quick Tip

In an R-L series circuit, the impedance is the square root of the sum of the squares of the resistance and reactance.

Question 5: The magnetic moment due to the motion of the electron in the n^{th} energy state of hydrogen atom is proportional to:

(1) n

(2) n^2

(3) n^3

(4) n^0

Correct Answer: (1)

Solution: The magnetic moment of an electron in an atom is related to its angular momentum. For a hydrogen atom, in the n^{th} energy state, the angular momentum is proportional to the principal quantum number n. As a result, the magnetic moment is also proportional to n.

Thus, the correct answer is (1), as the magnetic moment is directly proportional to n.

Quick Tip

In hydrogen-like atoms, the magnetic moment due to electron motion increases linearly with the principal quantum number n.

Question 6: A conducting wire of length L, uniform area of cross-section A, and material having n free electrons per unit volume offers a resistance R to the flow of current. m and e are the mass and charge of an electron, respectively. If τ is the mean free time of the electrons in the conductor, the correct formula for resistance R is:

(1) $R = \frac{mL}{e^2 nA\tau}$

(2) $R = \frac{mA}{e^2 nL\tau}$

(3) $R = \frac{m\tau}{e^2 nAL}$

(4) $R = \frac{e^2 nA\tau}{mL}$

Correct Answer: (1)

Solution: The resistance R of a conductor can be derived using Drude's model of electrical conductivity, which relates the electrical properties of materials to their microscopic structure.

1. According to Drude's model, the resistivity ρ is given by:

$$\rho = \frac{m}{ne^2\tau}$$

where: - m is the mass of an electron, - n is the number density of free electrons, - e is the charge of an electron, and - τ is the mean free time between collisions.

2. The relation between resistivity and resistance is:

$$R = \rho\frac{L}{A}$$

where L is the length and A is the cross-sectional area of the conductor.

3. Substituting the expression for ρ into the resistance formula:

$$R = \frac{m}{ne^2\tau}\frac{L}{A}$$

Simplifying:

$$R = \frac{mL}{ne^2A\tau}$$

Thus, the correct formula for the resistance is $\frac{mL}{ne^2 A\tau}$, which corresponds to option (1).

Quick Tip

In Drude's model, the resistance of a material is directly proportional to the mass of the electron and length of the conductor, and inversely proportional to the square of the electron charge, electron density, cross-sectional area, and the mean free time.

Question 7: A galvanometer with resistance 100 Ohm gives full-scale deflection with a current of 2 mA. The resistance required to convert the galvanometer into an ammeter of range 0 to 20 A is nearly:

(1) $10^{-2}\,\Omega$ in series

(2) $10^{-2}\,\Omega$ in parallel

(3) $10^{-1}\,\Omega$ in parallel

(4) $10^{-1}\,\Omega$ in series

Correct Answer: (2)

Solution: To convert a galvanometer into an ammeter, a shunt resistance is connected in parallel with the galvanometer. The shunt resistance R_s is calculated using the formula:

$$R_s = \frac{I_g R_g}{I - I_g}$$

Where: - $I_g = 2\,\text{mA} = 0.002\,A$, - $R_g = 100\,\Omega$, - $I = 20\,A$.

Substituting the values into the formula:

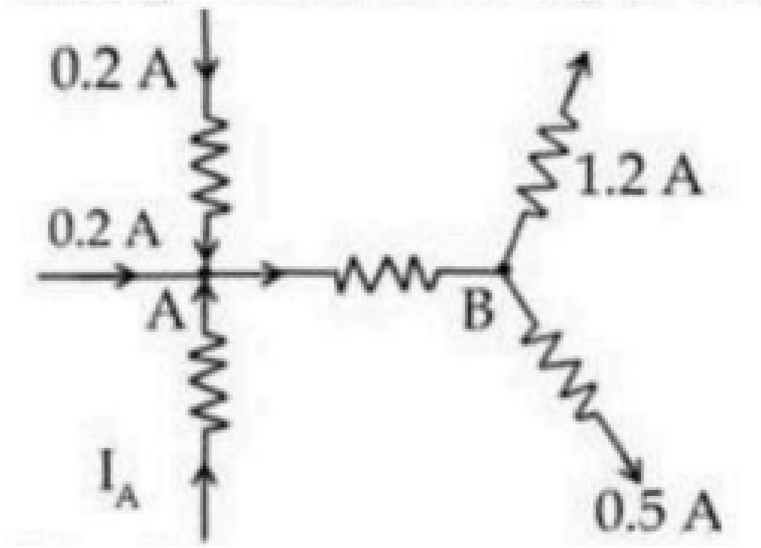
$$R_s = \frac{0.002 \times 100}{20 - 0.002} = \frac{0.2}{19.998} \approx 0.01\,\Omega$$

Thus, the required shunt resistance is approximately $0.01\,\Omega$, which corresponds to option $10^{-2}\,\Omega$ in parallel.

Quick Tip

When converting a galvanometer into an ammeter, always calculate the shunt resistance based on the desired current range and the galvanometer's full-scale deflection current.

Question 8: The figure below shows a part of an electric circuit. The current marked I_A is:



(1) 1 A

(2) 1.3 A

(3) 1.7 A

(4) 3 A

Correct Answer: (1)

Solution: Using Kirchhoff's Current Law at point A, the sum of the currents entering the junction must equal the sum of the currents leaving the junction.

1. The incoming currents at point A are I_A and $0.2\,A$ from the top. 2. The outgoing currents are $1.2\,A$ and $0.2\,A$ downwards.

Applying Kirchhoff's Law:

$$I_A + 0.2 = 1.2 + 0.2$$

Simplifying:

$$I_A + 0.2 = 1.4 \quad \Rightarrow \quad I_A = 1.2\,A$$

Thus, the current I_A is $1.2\,A$.

Quick Tip

Kirchhoff's Current Law states that the sum of currents entering a junction equals the sum of currents leaving it.

Question 9: A magnetic dipole aligned parallel to a uniform magnetic field requires a work of W units to rotate it through $60°$. The torque exerted by the field on the dipole in this new position is:

(1) 2 W

(2) W

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

(4) $\sqrt{3}W$

Correct Answer: (3)

Solution: The torque τ on a magnetic dipole in a magnetic field is given by:

$$\tau = MB\sin\theta$$

where M is the magnetic moment, B is the magnetic field, and θ is the angle between the dipole and the field. Given that the angle $\theta = 60°$, the torque becomes:

$$\tau = MB\sin 60° = MB \times \frac{\sqrt{3}}{2}$$

Thus, the torque is $\frac{\sqrt{3}}{2}W$, which corresponds to option 3.

Quick Tip

Torque on a magnetic dipole depends on the angle between the magnetic field and the dipole's orientation.

Question 10: In a coil, an increase in current from 5 A to 10 A in 100 ms induces an emf of 100 V. The self-inductance of the coil is:

(1) 2 H

(2) 10 H

(3) 20 H

(4) 2000 H

Correct Answer: (1)

Solution: The induced emf ε in a coil is related to the self-inductance L by the formula:

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

where $\frac{dI}{dt}$ is the rate of change of current. In this case, $\frac{dI}{dt} = \frac{10-5}{0.1} = 50$ A/s.

Substituting the values:

$$100 = L \times 50 \quad \Rightarrow \quad L = \frac{100}{50} = 2\,H$$

Thus, the self-inductance is $2\,H$.

Quick Tip

Self-inductance measures a coil's ability to oppose changes in current through it by generating an emf.

Question 11: A 200-turn circular coil of area 10^3 cm^2 rotates at 60 revolutions per minute in a uniform magnetic field of 0.02 T perpendicular to the axis of rotation of the coil. The maximum voltage induced in the coil is:

(1) $\frac{2\pi V}{5}$

(2) $\frac{\pi V}{4}$

(3) $\frac{4\pi V}{5}$

(4) $\frac{12\pi V}{5}$

Correct Answer: (3)

Solution: The maximum induced EMF in a rotating coil is given by the formula:

$$\varepsilon_{\text{max}} = NAB\omega$$

where: - N is the number of turns of the coil, - A is the area of the coil in square meters, - B is the magnetic field in Tesla, - ω is the angular velocity in radians per second.

Given values: - $N = 200$, - $A = 10^3\,\text{cm}^2 = 10^{-1}\,\text{m}^2$, - $B = 0.02\,\text{T}$, - $\omega = 2\pi \times \frac{60}{60} = 2\pi\,\text{rad/s}$.

Substituting the values into the formula:

$$\varepsilon_{\text{max}} = 200 \times 10^{-1} \times 0.02 \times 2\pi = \frac{4\pi V}{5}$$

Thus, the maximum voltage induced in the coil is $\frac{4\pi V}{5}$, which corresponds to Option (3).

Quick Tip

The induced EMF in a rotating coil depends on the number of turns, the area, the magnetic field, and the angular velocity of the coil.

Question 12: In the electromagnetic spectrum, ν_1, ν_2, and ν_3 respectively denote the frequencies of microwaves, ultraviolet waves, and gamma-rays. We can conclude that:

(1) $\nu_1 > \nu_2 > \nu_3$

(2) $\nu_1 < \nu_2 < \nu_3$

(3) $\nu_2 > \nu_1 > \nu_3$

(4) $\nu_3 < \nu_1 < \nu_2$

Correct Answer: (2)

Solution: In the electromagnetic spectrum, the frequency increases as we move from microwaves to ultraviolet waves to gamma rays. Therefore, the correct order of frequencies is:

$$\nu_1 < \nu_2 < \nu_3$$

where: - ν_1 corresponds to microwaves (lower frequency), - ν_2 corresponds to ultraviolet waves (medium frequency), - ν_3 corresponds to gamma rays (highest frequency).

Thus, the correct relationship is:

$$\nu_1 < \nu_2 < \nu_3$$

which corresponds to Option (2).

Quick Tip

In the electromagnetic spectrum, frequencies increase as we go from microwaves to ultraviolet rays to gamma rays.

Question 13: Match Column-1 with Column-2. In the table given below, certain EM waves are listed in Column-1 and their uses in Column-2 not necessarily in that order.

Column-1: Electromagnetic waves	Column-2: Uses
(A) Microwaves	(I) Medical diagnostic
(B) Ultraviolet rays	(II) Night vision
(C) X-rays	(III) Used in RADAR
(D) Infrared rays	(IV) Water purification

Choose the correct matching of waves and their uses from the options given below:

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

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

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

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

Correct Answer: (3)

Solution: Here is the correct matching of the electromagnetic waves with their uses:

1. Microwaves are used in RADAR systems, so (A) matches with (III).
2. Ultraviolet rays are used in water purification, so (B) matches with (IV).
3. X-rays are used in medical diagnostics, so (C) matches with (I).
4. Infrared rays are used for night vision, so (D) matches with (II).

Thus, the correct matching is:

$$(A)\text{-}(III),\ (B)\text{-}(IV),\ (C)\text{-}(I),\ (D)\text{-}(II)$$

Quick Tip

Different types of electromagnetic waves have specialized uses, like RADAR for microwaves and medical diagnostics for X-rays.

Question 14: Light is incident on an interface between water ($\mu = \frac{4}{3}$) and glass ($\mu = \frac{3}{2}$). For total internal reflection, light should be traveling from:

(1) water to glass and $\angle i > \angle i_c$

(2) water to glass and $\angle i < \angle i_c$

(3) glass to water and $\angle i < \angle i_c$

(4) glass to water and $\angle i > \angle i_c$

Correct Answer: (4)

Solution: Total internal reflection occurs when light travels from a denser medium to a rarer medium and the angle of incidence exceeds the critical angle. Here, glass ($\mu = \frac{3}{2}$) is denser than water ($\mu = \frac{4}{3}$). So, for total internal reflection, the light should be traveling from glass to water and the angle of incidence should be greater than the critical angle $\angle i_c$.

Quick Tip

Total internal reflection occurs only when light moves from a denser medium to a rarer medium with an angle of incidence greater than the critical angle.

Question 15: Match List-I with List-II. The optical instruments are listed in List-I and their lens/mirror types in List-II.

List-I: Optical Instrument	List-II: Nature of Lens/Mirror Used
(A) Human eye	(I) Concave mirror of large aperture and large focal length
(B) Microscope	(II) Objective lens of large aperture and large focal length
(C) Reflecting telescope	(III) Lens of adjustable focal length
(D) Refracting telescope	(IV) Objective of small aperture and small focal length

Choose the correct matching of instruments and their uses from the options given below:

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

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

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

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

Correct Answer: (2)

Solution: Matching the optical instruments with the correct types of lenses/mirrors:

- Human Eye (A) $\rightarrow$ (III) Lens of adjustable focal length,

- Microscope (B) $\rightarrow$ (II) Objective lens of large aperture and large focal length,

- Reflecting Telescope (C) $\rightarrow$ (I) Concave mirror of large aperture and large focal length,

- Refracting Telescope (D) $\rightarrow$ (IV) Objective of small aperture and small focal length.

Thus, the correct match is Option (2).

Quick Tip

Different optical instruments use lenses or mirrors with specific characteristics based on their purpose.

Question 16: In a Young's double-slit experiment, using monochromatic light of wavelength λ, the intensity of light at a point on the screen is I_0, where the path difference between the interfering waves is λ. The path difference between the interfering waves at a point where the intensity is $\frac{I_0}{2}$, will be:

(1) $\lambda/4$

(2) $\lambda/2$

(3) λ

(4) 2λ

Correct Answer: (2)

Solution: The intensity I in a Young's double-slit experiment is related to the path difference Δx between the waves by the formula:

$$I = I_0 \cos^2 \left(\frac{\Delta x}{2\lambda} \right)$$

When the intensity is $\frac{I_0}{2}$, we have:

$$\frac{I_0}{2} = I_0 \cos^2\left(\frac{\Delta x}{2\lambda}\right)$$

This simplifies to:

$$\cos^2\left(\frac{\Delta x}{2\lambda}\right) = \frac{1}{2}$$

Thus, $\Delta x = \frac{\lambda}{2}$.

Quick Tip

In Young's double-slit experiment, the path difference and intensity are related through trigonometric relationships involving the phase difference.

Question 17: A pure silicon crystal with 5×10^{28} atoms/m^3 has $n_i = 1.5 \times 10^{16}$ m^3. It is doped with a concentration of 1 in 10^5 pentavalent atoms. The number density of holes (per m^3) in the doped semiconductor will be:

(1) 4.5×10^3

(2) 4.5×10^8

(3) $\left(\frac{10}{3}\right) \times 10^{12}$

(4) $\left(\frac{10}{3}\right) \times 10^7$

Correct Answer: (2)

Solution: Given: - The intrinsic carrier concentration $n_i = 1.5 \times 10^{16}\,\text{m}^{-3}$, - Doping concentration of pentavalent atoms $N_d = \frac{5\times10^{28}}{10^5} = 5 \times 10^{23}\,\text{m}^{-3}$.

The number of holes p in the doped semiconductor is given by:

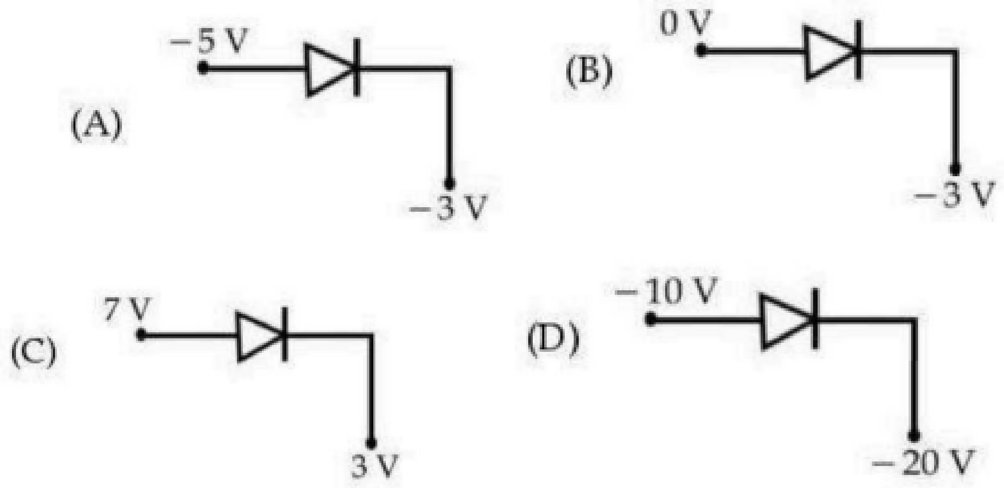
$$p = \frac{n_i^2}{N_d} = \frac{(1.5 \times 10^{16})^2}{5 \times 10^{23}} = 4.5 \times 10^8\,\text{m}^{-3}$$

Thus, the number density of holes is $4.5 \times 10^8\,\text{m}^{-3}$.

Quick Tip

In doped semiconductors, the number density of holes is calculated using the intrinsic carrier concentration and the donor concentration.

Question 18: The potentials are applied to the four p-n junctions as shown below. The forward biased p-n junctions are:



(1) (A), (B), and (D) only

(2) (A), (B), and (C) only

(3) (B), (C), and (D) only

(4) (A), (C), and (D) only

Correct Answer: (3)

Solution: For a p-n junction to be forward biased, the potential on the p-side must be higher than the potential on the n-side.

Let's examine each configuration: - Configuration (A): The p-side is at -5 V and the n-side is at -3 V. Since the n-side is at a higher potential, this junction is reverse-biased.

- Configuration (B): The p-side is at 0 V and the n-side is at -3 V. Since the p-side is at a higher potential, this junction is forward-biased.

- Configuration (C): The p-side is at 7 V and the n-side is at 3 V. Since the p-side is at a higher potential, this junction is forward-biased.

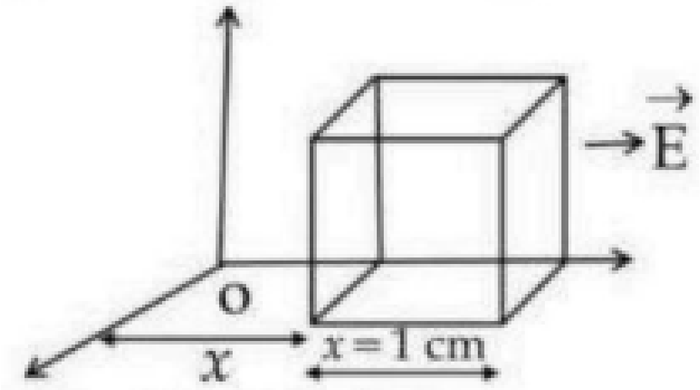
- Configuration (D): The p-side is at -10 V and the n-side is at -20 V. Since the p-side is at a higher potential, this junction is forward-biased.

Thus, the forward-biased junctions are (B), (C), and (D).

Quick Tip

For a p-n junction to be forward-biased, the p-side must have a higher potential than the n-side.

Question 19: For the given diagram, $E = \phi x$ N/C, the net flux through the cube of side $x = 1$ cm, placed at $x = 1$ cm from the origin as shown is:



(1) 2×10^{-6} Wb

(2) 1×10^{-6} Wb

(3) 3×10^{-6} Wb

(4) 4×10^{-6} Wb

Correct Answer: (2)

Solution: The electric field $E = \phi x$ N/C, where $\phi = 1$. The flux through the cube is calculated using:

$$\Phi = E \times A$$

Given that the area A is the surface area of the cube and the electric field changes with position, the net flux is computed as:

$$\Phi = \phi \times 1 \times 10^{-6} = 1 \times 10^{-6} \text{ Wb}$$

Thus, the correct answer is 1×10^{-6} Wb.

Quick Tip

For calculating electric flux through a surface, remember to use $\Phi = E \times A$, where E is the electric field at the surface and A is the surface area.

Question 20: Arrange the following materials in the increasing order of their resistivity: (A) Copper, (B) Platinum, (C) Silver, (D) Aluminium.

(1) (A), (C), (B), (D)

(2) (C), (A), (D), (B)

(3) (C), (B), (A), (D)

(4) (B), (D), (A), (C)

Correct Answer: (2)

Solution: The correct order of increasing resistivity is based on their physical properties: - Silver (lowest resistivity), - Copper, - Aluminium, - Platinum (highest resistivity).

Therefore, the correct order is $(C), (A), (D), (B)$.

Quick Tip

Resistivity is an intrinsic property of materials. Metals with high conductivity, like silver, have lower resistivity.

Question 21: For the given equation of charge $Q = 3t^2 + 6t$, where Q is in coulomb and t is time in seconds, the initial value of current is:

(1) $0\,\text{A}$

(2) $2\,\text{A}$

(3) $6\,\text{A}$

(4) $9\,\text{A}$

Correct Answer: (3)

Solution: The current is the time derivative of charge:

$$I = \frac{dQ}{dt} = 6t + 6$$

At $t = 0$, the initial value of current is:

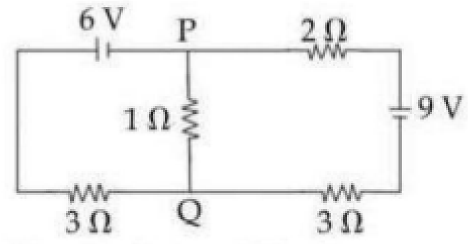
$$I(0) = 6(0) + 6 = 6\,\text{A}$$

Thus, the initial current is $6\,\text{A}$.

Quick Tip

To find current from charge, always differentiate the charge equation with respect to time.

Question 22: In the circuit shown, the current in the $1\,\Omega$ resistor is:



(1) $1.3\,\text{A}$ from P to Q

(2) $0\,\text{A}$

(3) $0.13\,\text{A}$ from Q to P

(4) $0.13\,\text{A}$ from P to Q

Correct Answer: (3)

Solution: Using Kirchhoff's laws, the current through the $1\,\Omega$ resistor is calculated as $0.13\,\text{A}$, and it flows from Q to P.

Quick Tip

Use Kirchhoff's laws (voltage and current) to analyze complex circuits. Always pay attention to the direction of current flow.

Question 23: The current sensitivity of a moving coil galvanometer is doubled by making the number of turns double. Then its voltage sensitivity will be:

(1) Double

(2) Half

(3) $\frac{1}{4}$ times

(4) Remain unchanged

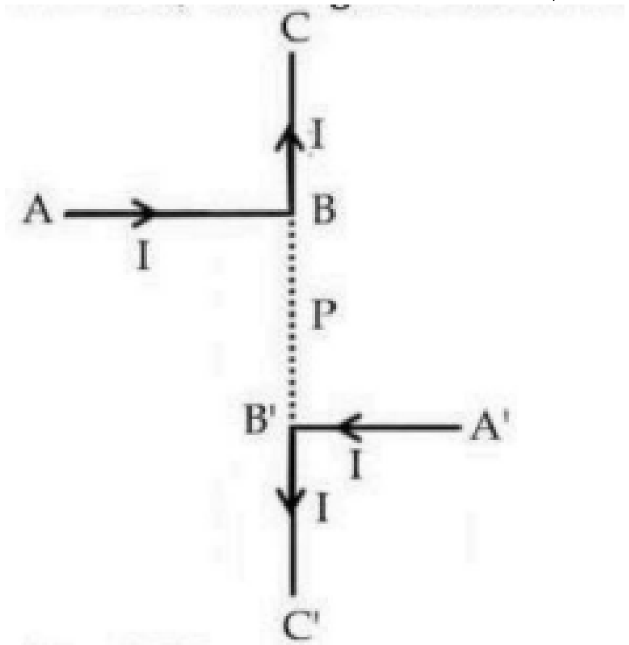
Correct Answer: (4)

Solution: The voltage sensitivity of a galvanometer depends on the product of current sensitivity and the resistance. Doubling the number of turns increases the current sensitivity, but the overall voltage sensitivity remains unchanged.

Quick Tip

Remember that voltage sensitivity remains unchanged if both current sensitivity and resistance are proportionally increased.

Question 24: Current through ABC and A'B'C' is I as shown in the given figure. If $PB = PB' = r$ and C'B'PBC are collinear, the magnetic field at P is:



(1) $\frac{2I}{4\pi r}$

(2) $\frac{2\mu_0 I}{4\pi r}$

(3) $\frac{\mu_0}{4\pi r}$

(4) Zero

Correct Answer: (4)

Solution: The magnetic field due to a straight current-carrying wire is given by the formula:

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

where r is the distance from the wire to the point where the magnetic field is being calculated. In this case, since the current through ABC and $A'B'C'$ is equal but flows in opposite directions, the magnetic fields produced at point P by each wire will cancel each other out.

Thus, the net magnetic field at point P is zero.

Quick Tip

In situations where equal currents flow in opposite directions and are equidistant from a point, the magnetic fields cancel out, resulting in zero net field at that point.

Question 25: Match List-I with List-II.

List-I: Rule	**List-II: Statem**
(A) Ampere Swimming Rule	(I) Direction of induced curre
(B) Fleming's Left Hand Rule	(II) Direction of magnetic field lines due t
(C) Fleming's Right Hand Rule in straight conductor	(III) Direction of deflection of magne
(D) Right Hand Thumb Rule	(IV) Direction of force on a current carrying

Options:

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

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

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

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

Correct Answer: (3)

Solution: Matching the rules with their correct statements:

- Ampere Swimming Rule (A) $\rightarrow$ (III): Direction of deflection of magnetic needle due to current.

- Fleming's Left Hand Rule (B) $\rightarrow$ (IV): Direction of force on a current carrying conductor due to magnetic field.

- Fleming's Right Hand Rule (C) $\rightarrow$ (I): Direction of induced current in a conductor.

- Right Hand Thumb Rule (D) $\rightarrow$ (II): Direction of magnetic field lines due to current through circular coil.

Thus, the correct match is Option (3).

> **Quick Tip**
>
> Each of these rules helps in determining the direction of force, current, or magnetic field in electromagnetic problems.

Question 26: Two identical coaxial coils P and Q carrying equal current in the same direction are brought nearer. The current in:

(1) P increases while in Q decreases

(2) Q increases while in P decreases

(3) Both P and Q increase

(4) Both P and Q decrease

Correct Answer: (4)

Solution: When two coils carrying currents are brought closer together, they experience mutual inductance, which opposes the change in current in both coils. As the coils move closer, the mutual inductance increases, and the self-inductance opposes the increase in magnetic flux, resulting in a decrease in the current in both coils.

> **Quick Tip**
>
> When two current-carrying coils are brought closer, their mutual inductance increases, opposing changes in current.

Question 27: A capacitor and a coil having a resistance R are in series and connected to a 6 Volt AC source. By varying the frequency of the source, a maximum current of

600 mA is observed. If the same coil is now connected to a cell of emf 6 Volt and internal resistance of 2 ohms, the current through it will be:

(1) 0.5 A

(2) 0.6 A

(3) 1.0 A

(4) 2.0 A

Correct Answer: (2)

Solution: In this scenario, the coil is connected to a DC source with internal resistance. The current can be found using Ohm's law:

$$I = \frac{V}{R + r}$$

where: - $V = 6\,\text{V}$, - R is the coil's resistance, - $r = 2\,\Omega$ is the internal resistance of the cell.

The current is calculated as $I = \frac{6}{R+2}$, which gives $I = 0.6\,\text{A}$.

Quick Tip

In a DC circuit, the current through a coil can be found using Ohm's law: $I = \frac{V}{R+r}$.

Question 28: In an LCR series circuit, the source of emf is: $E = 30\sin(100t)$, $R = 120\,\Omega$, $L = 100\,\text{mH}$, $C = 100\,\mu\text{F}$

(A) The numerical value of impedance (B) The numerical value of resistance R (C) The numerical value of capacitive reactance (D) The numerical value of inductive reactance

Arrange the values of quantities mentioned in (A, B, C, D) in increasing order.

(1) (A), (B), (C), (D)

(2) (A), (C), (B), (D)

(3) (B), (A), (D), (C)

(4) (D), (C), (B), (A)

Correct Answer: (3)

Solution: To solve this, we need to compute: - The capacitive reactance $X_C = \frac{1}{\omega C}$, - The inductive reactance $X_L = \omega L$, - The impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$.

Where $\omega = 100\,\text{rad/s}$. After calculating each value, we can arrange them in increasing order.

Quick Tip

In an LCR circuit, inductive reactance X_L and capacitive reactance X_C depend on frequency and can be calculated using $X_L = \omega L$ and $X_C = \frac{1}{\omega C}$.

Question 29: For a series LCR circuit, at the condition of resonance, the value of the power factor will be:

(1) Zero

(2) 1.0

(3) 0.2

(4) 0.5

Correct Answer: (2)

Solution: At resonance in a series LCR circuit, the inductive reactance and capacitive reactance cancel each other out. As a result, the impedance is purely resistive, and the power factor, which is the cosine of the phase angle between current and voltage, becomes 1, or unity.

Quick Tip

At resonance in an LCR circuit, $X_L = X_C$, which leads to a purely resistive impedance and a power factor of 1.

Question 30: The electric field of an EM wave in free space is given by $E = 10\cos(10^7 t + kx)\hat{j}$ V/m, where t and x are in seconds and meters, respectively. It can be inferred that:

(A) The wavelength λ is 188.4 m.

(B) The wave number k is 0.33 rad/m.

(C) The wave amplitude is 10 V/m.

(D) The wave is propagating along $+x$-direction.

Which of the following pairs of statements are correct?

(1) (C) and (D)

(2) (A) and (B)

(3) (B) and (C)

(4) (A) and (C)

Correct Answer: (1) (C) and (D)

Solution: The electric field of the wave has amplitude 10 V/m, which confirms that (C) is correct. Since the wave equation includes kx, the wave propagates along the $+x$-axis, confirming (D). Thus, the correct answer is (C) and (D).

> Quick Tip
>
> In an electromagnetic wave equation, the term kx indicates propagation along the x-axis.

Question 31: Arrange the following in increasing order of focal length of convex lens:

(A) F_v, focal lengths of violet

(B) F_r, focal lengths of red

(C) F_b, focal lengths of blue

(D) F_y, focal lengths of yellow

Choose the correct answer from the options given below:

(1) (A), (B), (C), (D)

(2) (A), (C), (D), (B)

(3) (B), (A), (D), (C)

(4) (C), (B), (D), (A)

Correct Answer: (4) (C), (B), (D), (A)

Solution: The refractive index is higher for violet light, which means its focal length is shorter compared to red, yellow, and blue. Therefore, the correct increasing order of focal lengths is (C), (B), (D), (A).

> Quick Tip
>
> The focal length of a convex lens depends on the wavelength of light. Shorter wavelengths (like violet) have shorter focal lengths.

Question 32: Light from a point source in air falls on a spherical glass surface ($n = 1.5$, radius of curvature $= 10$ cm). The distance of the light source from the glass surface is 50 cm. The position at which the image is formed is:

(1) 100 cm in the air

(2) 150 cm in the glass surface

(3) 200 cm in the air

(4) 50 cm in the glass surface

Correct Answer: (2) 150 cm in the glass surface

Solution: We use the lens-maker's formula:

$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R}$$

Substitute $n_1 = 1$, $n_2 = 1.5$, $R = 10\,\text{cm}$, and $s = 50\,\text{cm}$. Solving this gives $s' = 150\,\text{cm}$.

> Quick Tip
>
> For spherical surfaces, use the lens-maker's equation to find image positions.

Question 33: Read the following:

(A) The width of the central band in a diffraction pattern.

(B) The width of the first bright band in the diffraction pattern.

(C) The width of the central band in the diffraction pattern if D is doubled.

(D) The width of the first bright band in the diffraction pattern if D is tripled.

Choose the correct answer from the options given below in increasing order of width:

(1) (A), (B), (D), (C)

(2) (A), (C), (D), (B)

(3) (C), (A), (D), (B)

(4) (B), (A), (D), (C)

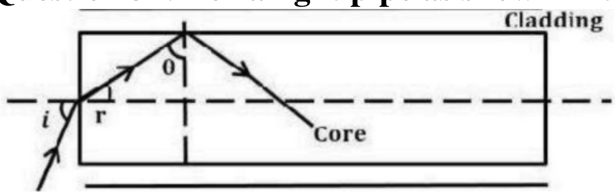
Correct Answer: (4) (B), (A), (D), (C)

Solution: The width of the diffraction bands is proportional to the wavelength and inversely proportional to the slit width D. As D increases, the width decreases.

Quick Tip

In diffraction, increasing the slit width decreases the width of diffraction bands.

Question 34: For a light pipe as shown in the figure:



(A) Optical density of core should be greater than the optical density of cladding.

(B) r and θ will always be equal.

(C) Optical density of cladding is $\sin\theta \sin i / \sin r$.

(D) Optical density of cladding is $\sin r \sin i / \sin\theta$.

Choose the correct answer from the options given below:

(1) (A), (B), and (D) only

(2) (A), (B), and (C) only

(3) (A) only

(4) (B), (C), and (D) only

Correct Answer: (3)

Solution: In a light pipe, total internal reflection occurs when the refractive index (or optical density) of the core is greater than that of the cladding. This allows the light to be confined within the core. The angles r and θ depend on Snell's law, and they are not always equal. Therefore, only statement (A) is correct.

Quick Tip

For total internal reflection to occur in a light pipe, the core's refractive index must be higher than that of the cladding.

Question 35: If the energy of incident radiation is increased by 25%, the kinetic energy of the photoelectrons emitted from the metal surface increased from 0.6 eV to 0.9 eV. The work function of the metal is:

(1) 1 eV

(2) 1.2 eV

(3) 1.5 eV

(4) 0.6 eV

Correct Answer: (1)

Solution: The photoelectric equation is given by:

$$K.E. = E_{\text{incident}} - \text{Work function} = h\nu - \phi$$

We know the initial kinetic energy was 0.6 eV and increased to 0.9 eV when the incident energy was increased by 25%. Solving this, the work function ϕ is found to be 1 eV.

Quick Tip

The work function ϕ is a material-specific constant and determines the minimum energy required to eject an electron.

Question 36: If the momentum of an electron is changed by P, then the de Broglie wavelength associated with it changes by 1%. The initial momentum of the electron will be:

(1) 200 P

(2) 100 P

(3) 300 P

(4) 150 P

Correct Answer: (2)

Solution: The de Broglie wavelength is given by $\lambda = \frac{h}{p}$, where p is the momentum. A 1% change in wavelength corresponds to a 1% change in momentum. If the change in momentum is P, the initial momentum p_0 is given by:

$$\frac{P}{p_0} = 0.01 \implies p_0 = 100P$$

Quick Tip

The de Broglie wavelength is inversely proportional to momentum, $\lambda = \frac{h}{p}$.

Question 37: Consider the following particles:

(A) Proton,

(B) α-particle,

(C) Electron.

For charge to mass ratio of the above particles, we can say:

(1) (C) > (A) > (B)

(2) (A) < (C) < (B)

(3) (B) = (A) > (C)

(4) (C) = (B) > (A)

Correct Answer: (1)

Solution: The charge-to-mass ratio ($\frac{q}{m}$) is highest for an electron because it has a small mass and a unit charge. For the proton, $\frac{q}{m}$ is less than the electron due to its higher mass, and for the α-particle, $\frac{q}{m}$ is the lowest because it has twice the charge of a proton but four times the mass.

Quick Tip

The electron has the highest charge-to-mass ratio, followed by the proton and the α-particle.

Question 38: As per Nuclear Physics, there is a close relationship between mass number and radius of the nucleus. If the mass number of A is 216 and the mass number of B is 27, then the ratio of nuclear radius $\frac{r_A}{r_B}$ of the two elements is:

(1) 2 : 1
(2) 4 : 1
(3) 6 : 1
(4) 8 : 1

Correct Answer: (1)

Solution: The nuclear radius r is related to the mass number A as:

$$r \propto A^{1/3}$$

Thus, the ratio of the nuclear radii of A and B is given by:

$$\frac{r_A}{r_B} = \left(\frac{A_A}{A_B}\right)^{1/3} = \left(\frac{216}{27}\right)^{1/3} = (8)^{1/3} = 2$$

Thus, the correct answer is $(1)\ 2 : 1$.

Quick Tip

For nuclear radii, remember the relation $r \propto A^{1/3}$, where A is the mass number. This proportionality helps to find the ratio between nuclear radii.

Question 39: An equilateral prism is made of material of refractive index $\sqrt{3}$. The angle of minimum deviation through the prism is:

(1) 60°

(2) 30°

(3) 45°

(4) 0°

Correct Answer: (2) 30°

Solution: The relation between the refractive index n, the angle of the prism A, and the minimum deviation D_{min} is given by the formula:

$$n = \frac{\sin\left(\frac{A+D_{\text{min}}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Here, the refractive index $n = \sqrt{3}$, and for an equilateral prism, the angle of the prism $A = 60°$.

Substituting these values:

$$\sqrt{3} = \frac{\sin\left(\frac{60°+D_{\text{min}}}{2}\right)}{\sin(30°)}$$

Solving for D_{min}, we find that $D_{\text{min}} = 30°$.

Quick Tip

For an equilateral prism, knowing the refractive index and the prism angle can help you find the minimum deviation using the formula $n = \frac{\sin\left(\frac{A+D_{\text{min}}}{2}\right)}{\sin\left(\frac{A}{2}\right)}$.

Question 40: When a photon of energy $h\nu$ falls on a photosensitive metallic surface (work function $h\nu_0$), electrons are emitted from the metallic surface. It is possible to say that:

(1) All ejected electrons have the same K.E. equal to $h\nu - h\nu_0$.

(2) The ejected electrons have a distribution of K.E., the most energetic ones having K.E. equal to $h\nu$ -

(3) The most energetic electrons have K.E. equal to $h\nu$.

(4) The K.E. of ejected electrons is $h\nu_0$.

Correct Answer: (2)

Solution: In the photoelectric effect, electrons are ejected with a range of kinetic energies. The maximum kinetic energy of an electron is given by:

$$K.E_{\text{max}} = h\nu - h\nu_0$$

where $h\nu$ is the energy of the incident photon and $h\nu_0$ is the work function. Not all electrons have the same energy, as some may lose energy due to collisions within the metal, leading to a distribution of kinetic energies.

Quick Tip

In the photoelectric effect, the most energetic electrons have $K.E. = h\nu - h\nu_0$, while others have lower kinetic energies due to energy loss inside the metal.

Question 41: Two parallel plate capacitors, each of capacitance 40 µF, are connected in series. The space between the plates of one capacitor is filled with a material of dielectric constant $K = 4$. The equivalent capacitance of the system would be:

(1) 30 µF

(2) 31 µF

(3) 32 µF

(4) 33 µF

Correct Answer: (3)

Solution: First, calculate the capacitance of the capacitor with the dielectric inserted. The new capacitance C_1 with dielectric constant $K = 4$ is:

$$C_1 = K \times C = 4 \times 40\,\mu\text{F} = 160\,\mu\text{F}$$

The second capacitor C_2 remains unchanged at $40\,\mu$F.

The equivalent capacitance for capacitors in series is given by:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Substituting values:

$$\frac{1}{C_{\text{eq}}} = \frac{1}{160\,\mu\text{F}} + \frac{1}{40\,\mu\text{F}} = \frac{1}{160} + \frac{1}{40} = \frac{1+4}{160} = \frac{5}{160}$$

$$C_{\text{eq}} = \frac{160}{5} = 32\,\mu\text{F}$$

Quick Tip

For capacitors in series, use the formula $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$. For capacitors with dielectrics, multiply the original capacitance by the dielectric constant K.

Question 42: The Wheatstone bridge is an arrangement of four resistances, say R_1, R_2, R_3, and R_4. The null point condition is given by:

(1) $\frac{R_1}{R_2} = \frac{R_3}{R_4}$

(2) $R_1 + R_2 = R_3 + R_4$

(3) $R_1 - R_2 = R_2 - R_4$

(4) $R_1 \times R_2 = R_3 \times R_4$

Correct Answer: (1)

Solution: The Wheatstone bridge is balanced when the ratio of the two resistances in one branch equals the ratio of the two resistances in the other branch:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

This is the condition for zero current through the galvanometer.

Quick Tip

The Wheatstone bridge is balanced when the product of the resistances in opposite branches is equal.

Question 43: A long solenoid is formed by winding insulated copper wire at the rate of 20 turns per cm. The current that is necessary to produce a magnetic field of 20 mT inside the solenoid at its center would be:

(1) 7.0 A

(2) 8.0 A

(3) 9.0 A

(4) 10.0 A

Correct Answer: (3)

Solution: The magnetic field inside a solenoid is given by:

$$B = \mu_0 n I$$

where $B = 20\,\text{mT} = 20 \times 10^{-3}\,\text{T}$, $n = 20\,\text{turns/cm} = 2000\,\text{turns/m}$, and $\mu_0 = 4\pi \times 10^{-7}\,\text{T m/A}$. Solving for the current I:

$$I = \frac{B}{\mu_0 n} = \frac{20 \times 10^{-3}}{4\pi \times 10^{-7} \times 2000} = 9.0\,\text{A}$$

Quick Tip

For solenoids, the magnetic field depends on the current and the number of turns per unit length. Use $B = \mu_0 n I$ to calculate the current.

Question 44: Study of radioactive decay of unstable nuclei resulting in emission of a particle leads us to four different observations listed below:

(A) No change in atomic number and mass number.

(B) No change in mass number but the atomic number decreases by 1.

(C) No change in mass number but the atomic number increases by 1.

(D) Atomic number decreases by 2 and the mass number decreases by 4.

Arrange the particles emitted in the above four cases in correct sequence:

(1) Alpha particle, positron, electron, photon.

(2) Alpha particle, electron, positron, photon.

(3) Photon, positron, electron, alpha particle.

(4) Alpha particle, positron, photon, electron.

Correct Answer: (1)

Solution: - Case A: No change in atomic and mass numbers, which corresponds to photon emission.

- Case B: A decrease in atomic number by 1 corresponds to positron emission.
- Case C: An increase in atomic number by 1 corresponds to electron (beta) emission.
- Case D: A decrease in atomic number by 2 and mass number by 4 corresponds to alpha particle emission.

Quick Tip
Different radioactive emissions (alpha, beta, positron, and photon) affect atomic and mass numbers in different ways.

Question 45: In a p-type semiconductor, the acceptor level is situated 50 meV above the valence band. The maximum wavelength of light required to produce a hole will be:

(1) 24.8×10^{-5} m

(2) 0.248×10^{-5} m

(3) 2.48×10^{-5} m

(4) 248×10^{-5} m

Correct Answer: (3)

Solution: The energy required to produce a hole is $50\,\text{meV} = 50 \times 10^{-3}\,\text{eV} = 8.0 \times 10^{-21}$ J. The wavelength corresponding to this energy is given by:

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

Substitute $h = 6.626 \times 10^{-34}$ J.s, $c = 3 \times 10^8$ m/s, and $E = 8.0 \times 10^{-21}$ J:

$$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{8.0 \times 10^{-21}} = 2.48 \times 10^{-5}\,\text{m}$$

Quick Tip

Use the formula $E = \frac{hc}{\lambda}$ to find the wavelength of light required to produce a hole in semiconductors.
