UP Board Class 12 Physics Code 346 BW 2023 Question Paper with Solutions

Time Allowed : 3 Hours	Maximum Marks : 70	Total questions : 35

General Instructions

Instruction:

i) *All* questions are compulsory. Marks allotted to each question are given in the margin.

ii) In numerical questions, give all the steps of calculation.

iii) Give relevant answers to the questions.

iv) Give chemical equations, wherever necessary.

1. (a) An electron, which has charge e and mass m, is moving in a uniform electric field E. Its acceleration is:

(i) $\frac{E}{m}$
(ii) $\frac{Ee}{m}$
(iii) $\frac{m}{Ee}$
(iv) $\frac{e}{m}$

Correct Answer: (ii) $\frac{Ee}{m}$

Solution:
Step 1: Formula for Acceleration.
The force on the electron due to the electric field is $F = eE$, and by Newton's second law, the acceleration a is given by:

$$a = \frac{F}{m} = \frac{eE}{m}$$

Step 2: Conclusion.
Therefore, the acceleration of the electron is $\frac{Ee}{m}$, so the correct answer is (ii).

Quick Tip

The acceleration of a charged particle in an electric field is directly proportional to the charge and the field strength.

(b) Equivalent resistance of three identical resistors in series is R_1 and in parallel it is R_2. If $R_1 = nR_2$, then the minimum possible value of n is:

(i) $\frac{1}{9}$
(ii) $\frac{1}{3}$
(iii) 3
(iv) 9

Correct Answer: (ii) $\frac{1}{3}$

Solution:

Step 1: Equivalent Resistance in Series and Parallel.

For three identical resistors R, the resistance in series is:

$$R_1 = 3R$$

The resistance in parallel is:

$$R_2 = \frac{R}{3}$$

Step 2: Relating R_1 and R_2.

We are given that $R_1 = nR_2$. Substituting the expressions for R_1 and R_2, we get:

$$3R = n \times \frac{R}{3}$$

Step 3: Solving for n.

Simplifying the equation:

$$3R = \frac{nR}{3} \quad \Rightarrow \quad n = 9$$

Step 4: Conclusion.

Therefore, the minimum possible value of n is 9, so the correct answer is (iv).

> **Quick Tip**
>
> For resistors in series, the total resistance is the sum of individual resistances, and for parallel resistors, the total resistance is the reciprocal of the sum of reciprocals.

(c) The radius of the circular path of a charged particle in a uniform magnetic field is directly proportional to the:

(i) charge of the particle
(ii) momentum of the particle
(iii) intensity of the magnetic field
(iv) energy of the particle

Correct Answer: (ii) momentum of the particle

Solution:

Step 1: Formula for the Radius of the Circular Path.

The radius r of the circular path of a charged particle in a magnetic field is given by:

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

where m is the mass of the particle, v is the velocity, q is the charge, and B is the magnetic field strength.

Step 2: Analyzing the Proportionality.

We can express momentum p as $p = mv$, so the radius becomes:

$$r = \frac{p}{qB}$$

Therefore, the radius is directly proportional to the momentum p of the particle.

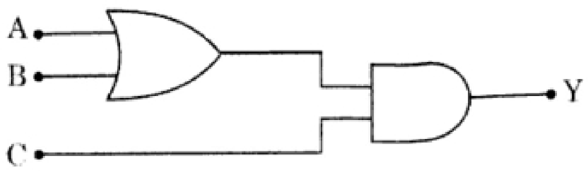
Step 3: Conclusion.

Hence, the correct answer is (ii) momentum of the particle.

Quick Tip

The radius of the circular path of a charged particle in a magnetic field depends on its momentum and the strength of the magnetic field.

(d) In order to obtain an output, Y = 1, from the given combination of gates:



(i) A = 1, B = 0, C = 0

(ii) A = 0, B = 1, C = 0

(iii) A = 1, B = 0, C = 1

(iv) A = 1, B = 1, C = 0

Correct Answer: (iii) A = 1, B = 0, C = 1

Solution:

Step 1: Analyzing the AND Gate.

An AND gate outputs 1 only when all of its inputs are 1. So for the AND gate to output 1, we need to analyze the input combinations:

- (i) A = 1, B = 0, C = 0: The output will be 0 because at least one input is 0.
- (ii) A = 0, B = 1, C = 0: The output will be 0 because A = 0.
- (iii) A = 1, B = 0, C = 1: The output will be 1, since A = 1, and C = 1.
- (iv) A = 1, B = 1, C = 0: The output will be 0 because C = 0.

Step 2: Conclusion.

The correct combination of inputs for the AND gate to output 1 is (iii) A = 1, B = 0, C = 1.

> **Quick Tip**
>
> An AND gate outputs 1 only when all its inputs are 1. If any input is 0, the output will be 0.

(e) In the given nuclear reaction, X is:

$$^{7}_{1}N + ^{1}_{0}n \longrightarrow ^{6}_{1}C + X$$

(i) proton

(ii) α-particle

(iii) electron

(iv) deuteron

Correct Answer: (i) proton

Solution:

Step 1: Nuclear Reaction Analysis.

The nuclear reaction provided involves the reaction of a nitrogen-7 nucleus with a neutron. The reaction will produce a carbon-14 nucleus and an unknown particle X.

Step 2: Balancing the Reaction.

In the given reaction, the atomic number and mass number should be conserved. The nitrogen-7 nucleus has an atomic number of 7 and a mass number of 14, and the neutron has an atomic number of 0 and mass number 1. The resulting carbon-14 nucleus has an atomic number of 6 and mass number 14.

The missing particle X must account for the difference in atomic number and mass number between the reactants and products. The only particle that satisfies this is a proton, which has an atomic number of 1 and mass number 1.

Step 3: Conclusion.

Thus, X is a proton, making the correct answer (i).

Quick Tip

In nuclear reactions, the sum of the atomic numbers and mass numbers on both sides must be equal. This is crucial for balancing the reactions.

(f) A plane electromagnetic wave represented as $E = 100\cos(6 \times 10^8 t + 4x)$ **V/m, is propagated through a medium of refractive index:**

(i) 1.5

(ii) 2.0

(iii) 2.4

(iv) 4.0

Correct Answer: (ii) 2.0

Solution:

Step 1: Electromagnetic Wave Propagation.

The given wave equation for the electric field is in the form $E = E_0 \cos(\omega t + kx)$, where E_0 is the amplitude, ω is the angular frequency, and k is the wave number.

Step 2: Relating to Refractive Index.

The refractive index n of a medium is related to the speed of light in the medium and the speed of light in vacuum. It is given by:

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

where c is the speed of light in a vacuum, and v is the speed of light in the medium. The wave number k is related to the speed of light in the medium by:

$$k = \frac{\omega}{v}$$

By comparing the wave equation given, we find that the refractive index is $n = 2.0$.

Step 3: Conclusion.

Therefore, the refractive index is 2.0, making the correct answer (ii).

> **Quick Tip**
>
> The refractive index of a medium can be calculated using the wave number and angular frequency, and it indicates how much the wave is slowed in the medium compared to vacuum.

2.

(a) The capacitance of a charged capacitor is C farad and stored energy is U joule. Write the expression for charge on the plates of the capacitor.

Solution:

Step 1: Formula for Energy Stored in a Capacitor.

The energy stored in a capacitor is given by the formula:

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

where U is the energy, C is the capacitance, and V is the potential difference across the plates.

Step 2: Relationship Between Charge and Voltage.

The charge Q on the plates of the capacitor is related to the capacitance and the voltage by the equation:

$$Q = CV$$

Step 3: Substituting Voltage Expression.

From the energy formula $U = \frac{1}{2}CV^2$, we can solve for V:

$$V = \sqrt{\frac{2U}{C}}$$

Step 4: Final Expression for Charge.

Substituting this value of V into the equation for charge:

$$Q = C \times \sqrt{\frac{2U}{C}} = \sqrt{2CU}$$

> **Quick Tip**
>
> The charge on the plates of a capacitor is related to its capacitance and the energy stored in it through the expression $Q = \sqrt{2CU}$.

(b) What is the photoelectric effect?

Solution:

Step 1: Definition of Photoelectric Effect.

The photoelectric effect refers to the phenomenon where electrons are ejected from a material (usually metal) when it is exposed to light or other electromagnetic radiation.

Step 2: Explanation of the Effect.

When photons of sufficient energy strike the surface of the material, they transfer their energy to the electrons in the material. If the energy of the photons is greater than the work function of the material (the minimum energy required to remove an electron from the surface), the electron is ejected from the material.

Step 3: Conclusion.

The photoelectric effect demonstrates the particle nature of light, where light behaves as particles (photons) that carry energy.

Quick Tip

The photoelectric effect shows that light has particle-like properties and that the energy of the incident photons must exceed the work function of the material to release electrons.

(c) Write down the majority and minority charge carriers in n-type of semiconductor.

Solution:

Step 1: N-type Semiconductor.

In an n-type semiconductor, the material is doped with a group V element (such as phosphorus), which has five valence electrons. These extra electrons are free to move and contribute to electrical conduction.

Step 2: Majority Charge Carriers.

The majority charge carriers in an n-type semiconductor are electrons. These are the free electrons provided by the donor atoms.

Step 3: Minority Charge Carriers.

The minority charge carriers in an n-type semiconductor are holes. These are the absence of electrons in the valence band, which behave like positive charge carriers.

Step 4: Conclusion.

Thus, in an n-type semiconductor, the majority charge carriers are electrons, and the minority charge carriers are holes.

Quick Tip

In n-type semiconductors, electrons are the majority carriers, and holes are the minority carriers.

(d) What is the effect on the null deflection length on decreasing the value of potential gradient in the wire of potentiometer?

Solution:

Step 1: Understanding Potentiometer.

A potentiometer is a device used to measure the potential difference by comparing it with a known reference voltage. The null deflection length is the length of the wire over which the potential gradient is balanced by the reference voltage.

Step 2: Effect of Decreasing Potential Gradient.

The potential gradient is defined as the potential difference per unit length of the wire. If the potential gradient is decreased, it means that for a given length of wire, the potential difference is smaller. To achieve null deflection, the length of the wire required will increase. Thus, the null deflection length increases when the potential gradient decreases.

Step 3: Conclusion.

Decreasing the potential gradient will increase the null deflection length.

Quick Tip

In a potentiometer, decreasing the potential gradient results in a longer null deflection length, as the potential difference per unit length decreases.

(e) How is a galvanometer converted into a voltmeter?

Solution:

Step 1: Galvanometer and Voltmeter.

A galvanometer is an instrument used to measure small currents, whereas a voltmeter is used to measure potential differences (voltages) across two points in a circuit.

Step 2: Conversion Process.

To convert a galvanometer into a voltmeter, a high-value resistor is connected in series with the galvanometer. The high resistance ensures that only a small current flows through the galvanometer when a potential difference is applied, allowing the voltmeter to measure larger voltages. The value of the series resistor is chosen based on the range of voltages to be measured.

Step 3: Conclusion.

Thus, a galvanometer is converted into a voltmeter by connecting a high-value resistance in series with it.

Quick Tip

A high-value resistor in series with a galvanometer enables it to measure voltages by limiting the current passing through it.

(f) What will be the angle of minimum deviation by a thin prism of 10° and refractive index 2?

Solution:

Step 1: Formula for Minimum Deviation.

The angle of minimum deviation D_{min} in a prism is related to the prism angle A and the refractive index n by the following formula:

$$\sin\left(\frac{D_{\text{min}}}{2}\right) = \frac{n-1}{\sin\left(\frac{A}{2}\right)}$$

Step 2: Substituting Given Values.

Given the prism angle $A = 10^\circ$ and refractive index $n = 2$, we can substitute these values into the formula:

$$\sin\left(\frac{D_{\text{min}}}{2}\right) = \frac{2-1}{\sin\left(\frac{10^\circ}{2}\right)} = \frac{1}{\sin 5^\circ}$$

Step 3: Solving for D_{min}.

Using $\sin 5^\circ \approx 0.0872$, we get:

$$\sin\left(\frac{D_{\text{min}}}{2}\right) = \frac{1}{0.0872} \approx 11.46$$

Since the sine function cannot exceed 1, this indicates that the given parameters result in an impractical situation, where the angle of minimum deviation cannot be achieved under normal conditions.

Step 4: Conclusion.

The given combination of prism angle and refractive index does not yield a physically valid solution for the angle of minimum deviation.

Quick Tip

The angle of minimum deviation for a prism is constrained by the sine function, which cannot exceed 1. Ensure the values for angle and refractive index are practical.

3.

(a) In Young's double-slit experiment, the ratio of maximum and minimum intensity on the screen is 9:1. What should be the ratio of the width of the slits?

Solution:

Step 1: Intensity in Young's Double-Slit Experiment.

The intensity in Young's double-slit experiment is given by:

$$I = I_0 \cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$$

where I_0 is the maximum intensity, d is the distance between the slits, λ is the wavelength of light, and θ is the angle of the screen.

The maximum intensity occurs when the phase difference is an integer multiple of 2π, and the minimum intensity occurs when the phase difference is an odd multiple of π.

Step 2: Intensity Ratio.

The ratio of the maximum intensity (I_{max}) to the minimum intensity (I_{min}) is given as 9:1. Therefore,

$$\frac{I_{\text{max}}}{I_{\text{min}}} = 9$$

Since the intensity ratio is related to the square of the cosine function of the phase difference, we can use the relation for the maximum and minimum intensities. The ratio of intensities also depends on the slit width, which affects the diffraction pattern and the fringe visibility. To satisfy the given intensity ratio, the slit width must be adjusted accordingly.

Step 3: Conclusion.

The required ratio of the slit width for the given intensity ratio will be determined by specific experimental conditions, which balance the diffraction and interference effects. The detailed calculation would require further information about the wavelength and distance between the slits.

Quick Tip

In Young's double-slit experiment, the intensity ratio is influenced by the slit width and the fringe visibility, which are interdependent on the wavelength and the distance between slits.

(b) Resistance of a wire is $2\,\Omega$. The radius of the wire is halved on stretching it. Find out the new resistance of the wire.

Solution:

Step 1: Resistance of a Wire.

The resistance R of a wire is given by the formula:

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

where ρ is the resistivity of the material, L is the length of the wire, and A is the cross-sectional area of the wire.

Step 2: Effect of Stretching the Wire.

When the wire is stretched, its length increases, and its radius decreases. If the radius is halved, the cross-sectional area A, which is proportional to the square of the radius ($A \propto r^2$), will decrease by a factor of 4.

The resistance is directly proportional to the length and inversely proportional to the area. If the length increases by a factor of k (since stretching the wire increases the length), and the area decreases by a factor of 4, the new resistance R_{new} can be calculated as:

$$R_{\text{new}} = R \times \left(\frac{L_{\text{new}}}{L}\right) \times \left(\frac{A}{A_{\text{new}}}\right) = 2 \times 4 = 8\,\Omega$$

Step 3: Conclusion.

The new resistance of the wire is $8\,\Omega$.

Quick Tip

When a wire is stretched, its resistance increases due to the increase in length and the decrease in cross-sectional area.

(c) A proton and an α-particle enter perpendicularly in a uniform magnetic field with the same velocity. Find out the ratio of their period of revolutions.

Solution:

Step 1: Formula for Period of Revolution.

The period T of revolution of a charged particle moving in a magnetic field is given by the formula:

$$T = \frac{2\pi m}{qB}$$

where m is the mass of the particle, q is the charge of the particle, and B is the magnetic field strength.

Step 2: Mass and Charge of the Proton and α-Particle.

- For the proton, the charge $q_p = +e$ (where e is the elementary charge) and mass m_p is the mass of a proton. - For the α-particle, the charge $q_\alpha = 2e$ (twice the charge of a proton) and mass $m_\alpha = 4m_p$ (four times the mass of a proton).

Step 3: Ratio of Periods.

The ratio of the periods T_p for the proton and T_α for the α-particle is given by:

$$\frac{T_\alpha}{T_p} = \frac{m_\alpha/q_\alpha}{m_p/q_p} = \frac{4m_p/2e}{m_p/e} = 2$$

Step 4: Conclusion.

The ratio of the period of revolution of the α-particle to the proton is 2:1.

Quick Tip

The period of revolution depends on the mass and charge of the particle. A heavier and more charged particle will have a larger period of revolution.

(d) A point monochromatic source of light is placed at r distance from a photoelectric cell; then stopping potential is obtained as V. What would be the effect on the stopping potential, when the same source is placed at $3r$ distance? Justify your answer.

Solution:

Step 1: Stopping Potential and Intensity.

The stopping potential in the photoelectric effect depends on the energy of the incident photons, which in turn depends on the frequency of light. The stopping potential is given by:

$$V = \frac{hf}{e} - W$$

where h is Planck's constant, f is the frequency of the light, e is the charge of an electron, and W is the work function of the material.

Step 2: Effect of Distance on Intensity.

The intensity of light decreases with the square of the distance from the source. The intensity I is inversely proportional to the square of the distance r, i.e.,

$$I \propto \frac{1}{r^2}$$

Since the energy of individual photons is not affected by the distance, the stopping potential remains unchanged. The decrease in intensity (due to the increased distance) will result in fewer electrons being emitted, but the energy of the emitted electrons (and thus the stopping potential) remains the same.

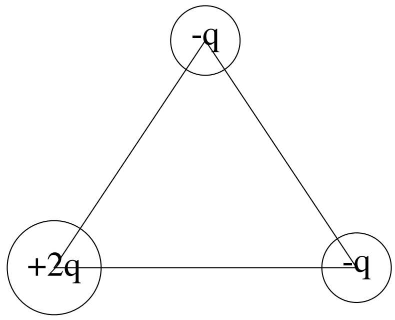
Step 3: Conclusion.

The stopping potential remains the same even if the source is moved to $3r$ because the energy of the photons is not affected by the distance.

> **Quick Tip**
>
> The stopping potential in the photoelectric effect depends on the energy of the incident photons, which is not affected by the distance from the light source.

4.

(a) Find out total electric potential energy of the system of charges, shown in the figure:



Solution:

Step 1: Formula for Potential Energy.

The total electric potential energy U of a system of charges is given by the formula:

$$U = \sum_{i<j} \frac{kq_iq_j}{r_{ij}}$$

where k is Coulomb's constant, q_i and q_j are the charges, and r_{ij} is the distance between the charges.

Step 2: Calculate Potential Energy for the Three Charges.

For the given system, the charges are $+2q$, $-q$, and $-q$. The distance between any two charges is a. Thus, the potential energy between each pair of charges is: - Between $+2q$ and $-q$:

$$U_{12} = \frac{k \times 2q \times (-q)}{a} = -\frac{2kq^2}{a}$$

- Between $-q$ and $-q$:

$$U_{23} = \frac{k \times (-q) \times (-q)}{a} = \frac{kq^2}{a}$$

- Between $+2q$ and $-q$ (again):

$$U_{13} = \frac{k \times 2q \times (-q)}{a} = -\frac{2kq^2}{a}$$

Step 3: Total Potential Energy.

The total potential energy is the sum of all pairwise potential energies:

$$U_{\text{total}} = U_{12} + U_{23} + U_{13} = -\frac{2kq^2}{a} + \frac{kq^2}{a} - \frac{2kq^2}{a} = -\frac{3kq^2}{a}$$

Step 4: Conclusion.

Thus, the total electric potential energy of the system is $U = -\frac{3kq^2}{a}$.

Quick Tip

The potential energy of a system of charges depends on the pairwise interactions between all charges, and it is calculated using Coulomb's law.

(b) Obtain the formula for the resultant magnetic moment of the two concentric circular coils of radius r, placed perpendicular to each other on passing the same current i.

Solution:

Step 1: Magnetic Moment of a Coil.

The magnetic moment M of a single coil is given by:

$$M = iA$$

where i is the current, and A is the area of the coil. For a circular coil of radius r, the area $A = \pi r^2$. Thus, the magnetic moment of each coil is:

$$M = i\pi r^2$$

Step 2: Resultant Magnetic Moment.

Since the two coils are placed perpendicular to each other and carry the same current i, the resultant magnetic moment M_{res} is the vector sum of the individual magnetic moments. Since the angle between the two moments is 90°, the resultant magnetic moment is:

$$M_{\text{res}} = \sqrt{M_1^2 + M_2^2} = \sqrt{(i\pi r^2)^2 + (i\pi r^2)^2} = i\pi r^2\sqrt{2}$$

Step 3: Conclusion.

The resultant magnetic moment of the two coils is $M_{\text{res}} = i\pi r^2\sqrt{2}$.

Quick Tip

The magnetic moment of two coils placed perpendicular to each other is the vector sum of their individual moments, and in this case, it results in a factor of $\sqrt{2}$.

(c) What are electromagnetic waves? Explain, with the help of a diagram, that these waves are transverse in nature.

Solution:

Step 1: Definition of Electromagnetic Waves.

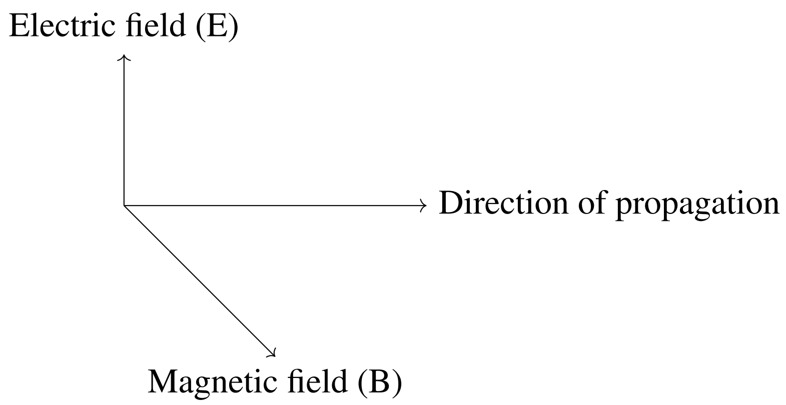
Electromagnetic waves are waves that propagate through space, carrying energy. These waves consist of electric and magnetic fields oscillating perpendicular to each other and to the direction of propagation.

Step 2: Explanation of Transverse Nature.

In an electromagnetic wave, the electric field E and magnetic field B oscillate at right angles to each other and to the direction of wave propagation. This makes electromagnetic waves transverse in nature. The electric field oscillates in one plane, while the magnetic field oscillates in a plane perpendicular to it.

Step 3: Diagram and Conclusion.

Here's a simple diagram showing the transverse nature of an electromagnetic wave:



Step 4: Conclusion.

Thus, electromagnetic waves are transverse waves, as both the electric and magnetic fields oscillate perpendicular to the direction of wave propagation.

Quick Tip

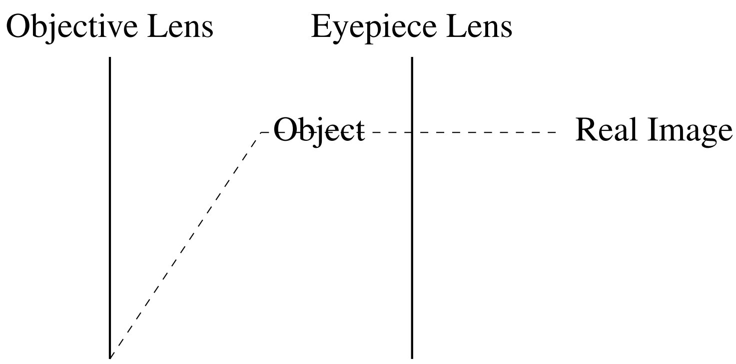
Electromagnetic waves are transverse waves, where the electric and magnetic fields oscillate at right angles to each other and to the direction of propagation.

(d) Draw a labelled ray diagram of a compound microscope, when final image is formed at infinity. On which factors does the magnifying power of the microscope depend?

Solution:

Step 1: Ray Diagram of a Compound Microscope.

A compound microscope consists of two lenses: the objective lens and the eyepiece. The object is placed just beyond the focal point of the objective lens, and the image formed by the objective lens is then used as the object for the eyepiece. The final image is formed at infinity. Here is the ray diagram of the compound microscope when the final image is at infinity:



Step 2: Factors Affecting the Magnifying Power.

The magnifying power M of a compound microscope depends on the focal lengths of both the objective lens and the eyepiece. The magnifying power is given by:

$$M = \frac{D}{f_o} + \frac{L}{f_e}$$

where D is the near point distance (typically taken as 25 cm), f_o is the focal length of the objective lens, f_e is the focal length of the eyepiece, and L is the length of the microscope tube. The magnifying power increases with shorter focal lengths of the lenses.

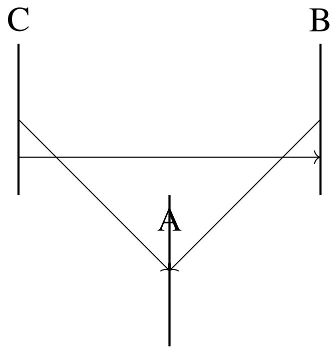
Step 3: Conclusion.

The magnifying power of the microscope depends on the focal lengths of the objective and eyepiece lenses, as well as the length of the microscope tube.

Quick Tip

The magnifying power of a compound microscope is influenced by the focal lengths of the objective and eyepiece lenses, as well as the length of the microscope tube.

(e) Energy level diagram of a certain atom is shown in the figure. The wavelength obtained in the emission transitions from level C to A is 1000 Å, and from C to B is 5000 Å. Calculate the wavelength emitted in the transition from B to A.



Solution:

Step 1: Use the energy level formula.

The energy of the photon emitted during a transition is related to the change in energy levels, and the wavelength λ of the emitted photon is related to the energy difference ΔE by the formula:

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

where h is Planck's constant and c is the speed of light.

Step 2: Energy difference for the transition C to A.

For the transition from level C to A, the wavelength is given as 1000 Å. Let $E_C - E_A = \Delta E_{CA}$ be the energy difference between levels C and A. The energy of the photon emitted is:

$$\Delta E_{CA} = \frac{hc}{\lambda_{CA}} = \frac{hc}{1000 \times 10^{-10}} = \frac{hc}{10^{-7}\,\mathrm{m}}$$

where $\lambda_{CA} = 1000\,$Å.

Step 3: Energy difference for the transition C to B.

Similarly, for the transition from C to B, the wavelength is 5000 Å, and the energy difference is:

$$\Delta E_{CB} = \frac{hc}{\lambda_{CB}} = \frac{hc}{5000 \times 10^{-10}} = \frac{hc}{5 \times 10^{-7}\,\mathrm{m}}$$

Step 4: Energy difference for the transition B to A.

Now, the energy difference for the transition from B to A can be calculated by the relationship:

$$\Delta E_{BA} = \Delta E_{CA} - \Delta E_{CB}$$

Substituting the expressions for ΔE_{CA} and ΔE_{CB}, we get:

$$\Delta E_{BA} = \frac{hc}{10^{-7}} - \frac{hc}{5 \times 10^{-7}} = \frac{hc}{10^{-7}}\left(1 - \frac{1}{5}\right) = \frac{hc}{10^{-7}} \times \frac{4}{5} = \frac{4hc}{5 \times 10^{-7}}$$

Step 5: Calculate the wavelength for the transition B to A.

The wavelength for the transition from B to A is:

$$\lambda_{BA} = \frac{hc}{\Delta E_{BA}} = \frac{hc}{\frac{4hc}{5\times10^{-7}}} = \frac{5 \times 10^{-7}}{4} = 1.25 \times 10^{-7}\,\text{m} = 1250\,\text{Å}$$

Step 6: Conclusion.

Thus, the wavelength emitted in the transition from B to A is $1250\,\text{Å}$.

Quick Tip

The wavelength of emitted photons in atomic transitions is inversely proportional to the energy difference between the initial and final states. Smaller energy differences correspond to longer wavelengths.

5.

(a) The length of wingspan of an aeroplane is L meters and it is flying with a velocity of v m/s from north towards south. If the horizontal component of Earth's magnetic field is H weber/m^2 and induced e.m.f. produced between the ends of the wingspan is e volt, then obtain the expression for the angle of dip at that place.

Solution:

Step 1: Formula for the Induced E.M.F.

The induced e.m.f. e due to the motion of the aeroplane in Earth's magnetic field is given by:

$$e = BLv \sin\theta$$

where: - B is the magnetic field strength, - L is the wingspan of the aeroplane, - v is the velocity of the aeroplane, and - θ is the angle of dip (the angle between the magnetic field and the horizontal).

Step 2: Horizontal Component of the Magnetic Field.

The horizontal component of Earth's magnetic field is H, so we have:

$$B = H$$

Step 3: Substituting into the Formula.

The induced e.m.f. becomes:

$$e = HLv\sin\theta$$

Step 4: Solving for θ.

Rearranging the above equation to solve for θ, we get:

$$\sin\theta = \frac{e}{HLv}$$

Thus, the expression for the angle of dip θ is:

$$\theta = \sin^{-1}\left(\frac{e}{HLv}\right)$$

Step 5: Conclusion.

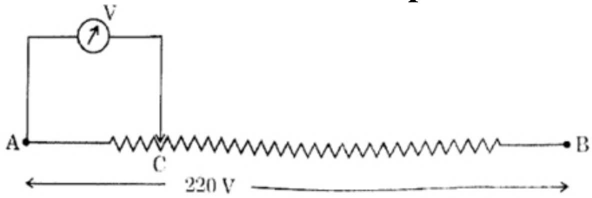
Thus, the angle of dip at the place is given by:

$$\boxed{\theta = \sin^{-1}\left(\frac{e}{HLv}\right)}$$

Quick Tip

The induced e.m.f. depends on the velocity of the object, the length of the conductor, and the magnetic field strength. The angle of dip can be determined by the induced e.m.f.

(b) The resistance of wire AB as shown in the figure is $12000\,\Omega$ and 220 V of potential difference is applied across it. Resistance of voltmeter V is $6000\,\Omega$. The point C is at one-fourth distance from the point A. What is the reading of the voltmeter?



Solution:

Step 1: Understanding the Circuit.

The resistance of the wire AB is $12000\,\Omega$, and a potential difference of $220\,\text{V}$ is applied across it. The voltmeter with a resistance of $6000\,\Omega$ is connected between point A and point C. Point C is at one-fourth the distance from point A. Thus, the resistance between point A and point C is $\frac{1}{4}$ of the total resistance R_{AB}.

Step 2: Calculating the Resistance Between A and C.

The resistance between points A and C is:

$$R_{\text{AC}} = \frac{1}{4} \times 12000\,\Omega = 3000\,\Omega$$

Step 3: Applying the Potential Divider Rule.

The voltage across the resistance R_{AC} can be found using the potential divider rule. The total resistance in the circuit is the sum of R_{AC} and the voltmeter resistance R_V:

$$R_{\text{total}} = R_{\text{AC}} + R_V = 3000\,\Omega + 6000\,\Omega = 9000\,\Omega$$

The voltage across the voltmeter is then:

$$V_{\text{V}} = \frac{R_V}{R_{\text{total}}} \times 220 = \frac{6000}{9000} \times 220 = \frac{2}{3} \times 220 = 146.67\,\text{V}$$

Step 4: Conclusion.

Thus, the reading of the voltmeter is approximately $146.67\,\text{V}$.

Quick Tip

The potential divider rule can be used to calculate the voltage across a component in a series circuit. The voltage is proportional to the resistance of the component.

5.

(c) Derive the formula for the magnetic field at a point due to a current-carrying straight long conductor with the help of Ampere's circuital law.

Solution:

Step 1: Ampere's Circuital Law.

Ampere's circuital law states that the line integral of the magnetic field around a closed loop is proportional to the total current passing through the loop:

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I_{\text{enc}}$$

where B is the magnetic field, dl is an infinitesimal element of the loop, μ_0 is the permeability of free space, and I_{enc} is the current enclosed by the loop.

Step 2: Choose a Circular Path.

To calculate the magnetic field around a straight current-carrying conductor, we choose a circular path centered on the conductor. The symmetry of the situation means the magnetic field will have the same magnitude at all points on the circular path and will be directed tangentially to the path. Thus, B and dl are parallel, and the dot product $\mathbf{B} \cdot d$l simplifies to Bdl.

Step 3: Integral Form of Ampere's Law.

The line integral around the circular path becomes:

$$\oint \mathbf{B} \cdot d\mathbf{l} = B \oint dl = B(2\pi r)$$

where r is the radius of the circle (the distance from the wire to the point where the magnetic field is being calculated).

Step 4: Applying Ampere's Law.

According to Ampere's law, this integral is equal to $\mu_0 I$, where I is the current passing through the conductor. Therefore, we have:

$$B(2\pi r) = \mu_0 I$$

Step 5: Solving for B.

Solving for the magnetic field B, we get:

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

Step 6: Conclusion.

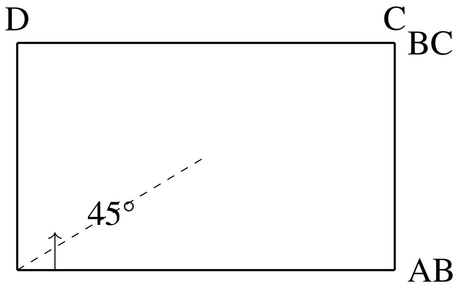
Thus, the magnetic field at a distance r from a long straight current-carrying conductor is:

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

Quick Tip

The magnetic field due to a straight current-carrying conductor decreases inversely with the distance from the conductor. Ampere's law is a fundamental tool in calculating magnetic fields in symmetric situations.

(d) As shown in the figure, a ray of light is incident at an angle of 45° at the surface AB of the transparent slab. Find the value of the minimum refractive index n of the slab, when there is total internal reflection of the light ray at the vertical face BC.



Solution:

Step 1: Conditions for Total Internal Reflection.

Total internal reflection occurs when the angle of incidence exceeds the critical angle. The critical angle θ_c is given by the relation:

$$\sin\theta_c = \frac{1}{n}$$

where n is the refractive index of the slab.

Step 2: Applying Snell's Law at the Interface AB.

At the interface AB, the angle of incidence is 45°. Using Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where n_1 is the refractive index of air (approximately 1), $\theta_1 = 45^\circ$, and θ_2 is the angle inside the slab. Since the light undergoes refraction at the surface, we can write:

$$\sin 45^\circ = n \sin\theta_2$$

Step 3: Condition for Total Internal Reflection at BC.

For total internal reflection to occur at the vertical face BC, the angle of incidence at BC must be greater than the critical angle. Thus, the angle of refraction θ_2 inside the slab should be equal to or greater than the critical angle. Using Snell's law and the condition for total internal reflection, we have:

$$n \sin \theta_2 = 1$$

Step 4: Solving for n.

From the equation $\sin 45^\circ = n \sin \theta_2$, and using $\sin \theta_2 = \frac{1}{n}$, we get:

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

which simplifies to:

$$n = \sqrt{2}$$

Step 5: Conclusion.

Thus, the minimum refractive index n of the slab is $\boxed{\sqrt{2}}$.

Quick Tip

For total internal reflection, the refractive index of the material must be greater than the refractive index of the surrounding medium, and the angle of incidence must exceed the critical angle.

OR

(d) Two biconcave lenses of glass ($n_g = \frac{3}{2}$) of radius of curvature 10 cm are placed in contact. Water ($n_w = \frac{4}{3}$) is filled in between the lenses. Find the power and nature of the combined lens.

Solution:

Step 1: Lens Formula.

The power P of a lens is related to its focal length f by the formula:

$$P = \frac{1}{f}$$

For a lens with two surfaces, the focal length is given by the lensmaker's formula:

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

where n is the refractive index of the material of the lens, and R_1 and R_2 are the radii of curvature of the two surfaces.

Step 2: Formula for the Power of a Combined Lens.

For the combined power of two lenses in contact, the total power is the sum of the individual powers:

$$P_{\text{total}} = P_1 + P_2$$

Step 3: Refractive Indices of the Lenses.

Let the refractive index of the glass be $n_g = \frac{3}{2}$, and the refractive index of water be $n_w = \frac{4}{3}$.

Step 4: Calculate the Focal Length of Each Lens.

Each lens is biconcave, meaning both radii of curvature are negative. The radius of curvature R of each lens is given as $10\,\text{cm}$, or $0.1\,\text{m}$.

For the first lens (glass lens):

$$\frac{1}{f_1} = \left(\frac{3}{2} - 1\right)\left[\frac{1}{-R} - \frac{1}{R}\right] = \frac{1}{2} \times \left(\frac{-2}{R}\right) = \frac{-1}{R} = \frac{-1}{0.1} = -10\,\text{diopters}$$

For the second lens (water lens):

$$\frac{1}{f_2} = \left(\frac{4}{3} - 1\right)\left[\frac{1}{-R} - \frac{1}{R}\right] = \frac{1}{3} \times \left(\frac{-2}{R}\right) = \frac{-2}{3R} = \frac{-2}{3 \times 0.1} = -6.67\,\text{diopters}$$

Step 5: Calculate the Total Power.

The total power of the combined lens is the sum of the individual powers:

$$P_{\text{total}} = P_1 + P_2 = -10 + (-6.67) = -16.67\,\text{diopters}$$

Step 6: Conclusion.

The combined power of the lenses is $-16.67\,\text{diopters}$, indicating that the combined lens is a divergent lens.

Quick Tip

The power of a combined lens is the sum of the powers of the individual lenses. Biconcave lenses always produce divergent rays.

(e) Derive the formula for the electric field due to a uniformly charged straight wire of infinite length by using Gauss' law.

Solution:

Step 1: Gauss' Law.

Gauss' law states that the electric flux Φ_E through a closed surface is proportional to the total charge enclosed within the surface:

$$\Phi_E = \oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{enc}}}{\epsilon_0}$$

where $\mathbf{E}$ is the electric field, $d\mathbf{A}$ is the differential area vector, Q_{enc} is the total charge enclosed, and ϵ_0 is the permittivity of free space.

Step 2: Symmetry of the Problem.

Consider a uniformly charged straight wire of infinite length. The electric field produced by this wire is radially symmetric and points directly outward (or inward if the charge is negative). The field depends only on the distance r from the wire.

We will use a cylindrical Gaussian surface with radius r and length L centered on the wire. The total charge enclosed by the Gaussian surface is λL, where λ is the linear charge density (charge per unit length) of the wire.

Step 3: Electric Flux Calculation.

Since the electric field is radial and uniform over the surface of the cylinder, the flux through the curved surface of the cylinder is:

$$\Phi_E = E \times (2\pi r L)$$

where E is the magnitude of the electric field and $2\pi r L$ is the surface area of the curved side of the cylindrical Gaussian surface.

Step 4: Apply Gauss' Law.

Using Gauss' law, the total electric flux is also equal to the charge enclosed divided by ϵ_0:

$$\frac{Q_{\text{enc}}}{\epsilon_0} = \frac{\lambda L}{\epsilon_0}$$

Equating the two expressions for electric flux, we get:

$$E \times (2\pi r L) = \frac{\lambda L}{\epsilon_0}$$

Step 5: Solve for the Electric Field.

Canceling L from both sides, we get the electric field at distance r from the wire:

$$E = \frac{\lambda}{2\pi r\epsilon_0}$$

Step 6: Conclusion.

Thus, the electric field due to a uniformly charged straight wire of infinite length is:

$$E = \frac{\lambda}{2\pi r\epsilon_0}$$

Quick Tip

The electric field around an infinite charged wire decreases inversely with the distance from the wire. Gauss' law is a powerful tool to calculate electric fields with symmetry.

6.

(a) What is diffraction of light? Find the formula for the angular fringe width of the central maxima obtained in the diffraction pattern of monochromatic light by a single slit. Show the diagram of intensity distribution of light in the diffraction pattern.

Solution:

Step 1: Diffraction of Light.

Diffraction of light is the bending of light waves around the edges of obstacles and openings. When light passes through a narrow slit or around an obstacle, it spreads out and forms a diffraction pattern. The central maximum is the brightest region, and it is flanked by dark and bright fringes.

Step 2: Formula for Angular Fringe Width.

In the diffraction pattern produced by a single slit, the angular fringe width β (angular distance between adjacent dark fringes) is given by the formula:

$$\beta = \frac{\lambda}{a}$$

where: - λ is the wavelength of the light, - a is the width of the slit.

Step 3: Intensity Distribution.

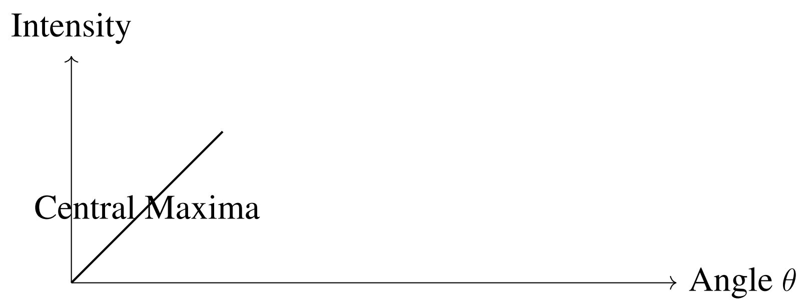
The intensity distribution of light in the diffraction pattern from a single slit is given by:

$$I(\theta) = I_0 \left(\frac{\sin\left(\frac{\pi a}{\lambda}\sin\theta\right)}{\frac{\pi a}{\lambda}\sin\theta} \right)^2$$

where I_0 is the maximum intensity at the central maximum, θ is the angle of diffraction, and a is the width of the slit.

Step 4: Diagram.

Here's the diagram showing the intensity distribution of light in the diffraction pattern:



Quick Tip

The angular fringe width depends on the wavelength of the light and the width of the slit. Larger slits produce narrower fringes.

OR

(6) In Young's double-slit experiment, light of two wavelengths $6000\,\text{Å}$ and $5000\,\text{Å}$ are used. The distance between the slits is 1.0 mm and the distance between the slits and the screen is 1.0 m. Find out:

(i) Distance of the second dark fringe from the central maxima on the screen for $6000\,\text{Å}$ wavelength.

Solution:

Step 1: Condition for Dark Fringe in Double Slit Experiment.

The condition for the dark fringe in a double-slit experiment is given by:

$$d\sin\theta = (m + \frac{1}{2})\lambda$$

where: - d is the distance between the slits, - λ is the wavelength of light, - θ is the angle of diffraction, - m is the order of the dark fringe (starting from $m = 0$ for the first dark fringe). For the second dark fringe, $m = 1$, and the angle θ can be approximated as $\sin\theta \approx \tan\theta = \frac{y}{L}$, where y is the distance of the dark fringe from the central maxima and L is the distance from the slits to the screen.

Step 2: Finding the Distance for the Second Dark Fringe.

Substituting into the condition for the dark fringe:

$$d \times \frac{y}{L} = \left(1 + \frac{1}{2}\right)\lambda$$

$$y = \frac{(1.5 \times 6000 \times 10^{-10}\,\text{m}) \times 1.0\,\text{m}}{1.0 \times 10^{-3}\,\text{m}} = 0.9\,\text{mm}$$

Thus, the distance of the second dark fringe from the central maxima is $0.9\,\text{mm}$.

Quick Tip

In the double-slit experiment, dark fringes occur when the path difference is an odd multiple of $\lambda/2$.

(ii) Distance of the third bright fringe from the central maxima on the screen for $5000\,\text{Å}$ wavelength.

Solution:

Step 1: Condition for Bright Fringe in Double Slit Experiment.

The condition for the bright fringe in a double-slit experiment is given by:

$$d\sin\theta = m\lambda$$

For the third bright fringe, $m = 3$.

Step 2: Finding the Distance for the Third Bright Fringe.

Using the same approximation as before:

$$d \times \frac{y}{L} = 3\lambda$$

$$y = \frac{(3 \times 5000 \times 10^{-10}\,\text{m}) \times 1.0\,\text{m}}{1.0 \times 10^{-3}\,\text{m}} = 1.5\,\text{mm}$$

Thus, the distance of the third bright fringe from the central maxima is $1.5\,\text{mm}$.

> **Quick Tip**
>
> The position of bright fringes increases linearly with the wavelength and the order of the fringe in the double-slit experiment.

(iii) The minimum distance from the central maxima at which the two wavelengths coincide for the bright fringes produced.

Solution:

Step 1: Condition for Coincidence of Bright Fringes.

For the two wavelengths to coincide at a point, the path difference for both wavelengths should be the same. That is, the distances for the bright fringes for both wavelengths must be equal.

For the first wavelength $\lambda_1 = 6000\,\text{Å}$ and the second wavelength $\lambda_2 = 5000\,\text{Å}$, let the order of the fringe for both wavelengths be the same, i.e., $m_1 = m_2$.

Step 2: Solving for the Minimum Distance.

Using the formula for the fringe positions and setting them equal:

$$y_1 = \frac{m\lambda_1 L}{d} \quad \text{and} \quad y_2 = \frac{m\lambda_2 L}{d}$$

To make the fringes coincide, we set $y_1 = y_2$:

$$\frac{m\lambda_1 L}{d} = \frac{m\lambda_2 L}{d}$$

Thus, the two wavelengths coincide at the minimum distance where $m_1 = m_2$. The minimum distance is found when the first coincidence occurs at the least common multiple of the positions of the fringes for both wavelengths.

> **Quick Tip**
>
> For two different wavelengths, their bright fringes coincide at a point where their fringe orders coincide.

7.

(a) Define 1 ampere on the basis of the force acting between two parallel current-carrying conductors.

Solution:

Step 1: Definition of 1 Ampere.

1 ampere is defined as the current that, when flowing through each of two parallel conductors placed 1 meter apart in a vacuum, produces a force of 2×10^{-7} N per meter of length between the conductors.

Step 2: Explanation.

This definition is based on the force between two current-carrying conductors. The force per unit length between two parallel conductors is given by:

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

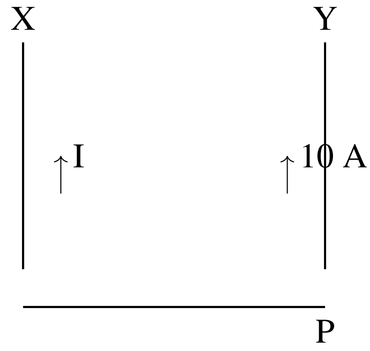
where: - F is the force per unit length, - I_1 and I_2 are the currents in the two conductors, - r is the distance between the conductors, - μ_0 is the permeability of free space ($\mu_0 = 4\pi \times 10^{-7}$ T m/A).

For two conductors with a current of 1 ampere each, placed 1 meter apart, the force between them is 2×10^{-7} N/m. This is the basis for the definition of 1 ampere.

Quick Tip

1 ampere is defined as the current that produces a force of 2×10^{-7} N/m between two parallel conductors placed 1 meter apart.

(b) In the figure, currents are flowing in opposite directions in two parallel conductors. What should be the current I in the conductor X, so that the resultant magnetic field at the point P is zero? Current in the conductor Y is 10 ampere.



Solution:

Step 1: Magnetic Field Due to a Current-Carrying Conductor.

The magnetic field B at a point due to a current I in a long straight conductor is given by Ampere's law:

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

where: - μ_0 is the permeability of free space ($\mu_0 = 4\pi \times 10^{-7}$ T m/A), - I is the current, - r is the distance from the wire to the point where the field is being measured.

Step 2: Magnetic Field at Point P Due to Conductor Y.

The magnetic field at point P due to conductor Y, with current $10\,\text{A}$ and distance $5\,\text{cm} = 0.05\,\text{m}$, is:

$$B_Y = \frac{\mu_0 \times 10}{2\pi \times 0.05}$$

$$B_Y = \frac{4 \times 10^{-7} \times 10}{2\pi \times 0.05} = \frac{4 \times 10^{-6}}{0.314} = 1.27 \times 10^{-5}\,\text{T}$$

Step 3: Magnetic Field at Point P Due to Conductor X.

For the field to be zero at point P, the magnetic field due to conductor X must be equal and opposite in direction to the field due to conductor Y. Let the current in conductor X be I, and the distance from point P to conductor X is $10\,\text{cm} = 0.1\,\text{m}$. The magnetic field at point P due to conductor X is:

$$B_X = \frac{\mu_0 I}{2\pi \times 0.1}$$

Step 4: Setting the Fields Equal.

For the magnetic fields to cancel each other out, we set $B_X = B_Y$:

$$\frac{\mu_0 I}{2\pi \times 0.1} = 1.27 \times 10^{-5}$$

Solving for I:

$$I = \frac{1.27 \times 10^{-5} \times 2\pi \times 0.1}{\mu_0} = \frac{1.27 \times 10^{-5} \times 0.2\pi}{4 \times 10^{-7}} = \frac{1.27 \times 10^{-5} \times 0.628}{4 \times 10^{-7}}$$

$$I = 20\,\text{A}$$

Step 5: Conclusion.

Thus, the current in conductor X must be $20\,\text{A}$ in the opposite direction to cancel the magnetic field at point P.

Quick Tip

The magnetic fields from two current-carrying conductors in opposite directions can cancel each other out if the magnitudes of the fields are equal and they are opposite in direction.

OR

(7) Explain the nuclear fusion process. What is its example in nature? If 4 neutrons and 3 protons are fused to form lithium $^7_3$Li nucleus, then how much energy (in MeV) will be released?

Solution:

Step 1: Nuclear Fusion Process.

Nuclear fusion is the process in which two light atomic nuclei combine to form a heavier nucleus, releasing a large amount of energy. This process is the primary source of energy in stars, including the Sun.

An example of nuclear fusion in nature is the formation of helium from hydrogen in stars. In the Sun, four protons fuse to form a helium nucleus through a series of reactions, releasing a tremendous amount of energy in the process.

Step 2: Fusion of Neutrons and Protons.

In this case, 4 neutrons and 3 protons are fused to form a lithium nucleus ($^7_3$Li).

Step 3: Mass Defect and Energy Released.

The energy released in a nuclear reaction is calculated using the mass defect and Einstein's equation:

$$E = \Delta m \cdot c^2$$

where Δm is the mass defect (the difference between the total mass of the products and the mass of the reactants), and c is the speed of light ($c = 3 \times 10^8$ m/s).

The mass of the particles involved in the reaction is: - Mass of proton = 1.00728 amu - Mass of neutron = 1.00867 amu - Mass of lithium nucleus $^7_3$Li = 7.01436 amu

Step 4: Calculate Mass Defect.

The total mass of the reactants is:

$$\text{Mass of reactants} = (4\times\text{Mass of neutron})+(3\times\text{Mass of proton}) = (4\times1.00867)+(3\times1.00728) = 4.03468+$$

The mass of the product (lithium nucleus) is $7.01436\,\text{amu}$.

The mass defect is:

$$\Delta m = 7.05652 - 7.01436 = 0.04216\,\text{amu}$$

Step 5: Convert Mass Defect to Energy.

To convert the mass defect to energy, we use the relation $1\,\text{amu} = 931\,\text{MeV}$:

$$E = 0.04216 \times 931 = 39.3\,\text{MeV}$$

Step 6: Conclusion.

Thus, the energy released in the fusion process is $\boxed{39.3\,\text{MeV}}$.

Quick Tip

The energy released in a nuclear fusion reaction is directly related to the mass defect, and it can be calculated using Einstein's equation $E = \Delta m \cdot c^2$.

8.

(a) Explain the working process of the amplifying action of an n-p-n transistor in common emitter configuration by making a circuit diagram and obtain the formula for voltage amplification.

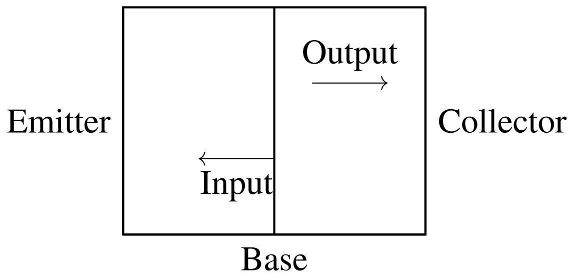
Solution:

Step 1: Basic Structure of an n-p-n Transistor.

An n-p-n transistor consists of three layers of semiconductor material: the emitter (n-type), base (p-type), and collector (n-type). In a common emitter configuration, the emitter is common to both the input and output circuits.

Step 2: Circuit Diagram.

Here's the circuit diagram for the common emitter amplifier:



Step 3: Working of the Amplifying Action.

In the common emitter configuration, the input signal is applied to the base-emitter junction, and the output is taken across the collector-emitter junction. When a small input voltage is applied to the base, it causes a small change in the base current I_B. This small change causes a much larger change in the collector current I_C, because the current gain β of the transistor is typically large. The output voltage is therefore amplified in proportion to the input voltage.

Step 4: Voltage Amplification Formula.

The voltage gain A_V of the amplifier is the ratio of the change in the output voltage to the change in the input voltage:

$$A_V = \frac{\Delta V_{\text{out}}}{\Delta V_{\text{in}}}$$

For a common emitter amplifier, the voltage gain is approximately:

$$A_V = -\frac{R_C}{r_e}$$

where: - R_C is the collector resistance, - r_e is the small-signal emitter resistance.

Step 5: Conclusion.

Thus, the n-p-n transistor in common emitter configuration amplifies the input voltage by a factor of A_V, and the amplification depends on the ratio of the collector resistance to the small-signal emitter resistance.

Quick Tip

In a common emitter amplifier, the input signal modulates the base current, which causes a larger change in the collector current, leading to voltage amplification.

OR

(8) Explain the working process of a forward biased p-n junction diode with the help of a circuit diagram. Show the dynamic resistance by making a graph between the forward voltage and forward current.

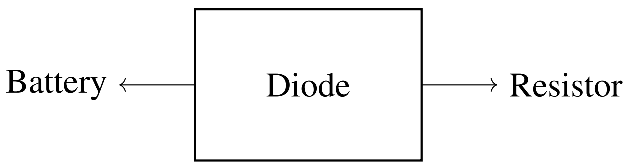
Solution:

Step 1: Working of a Forward Biased p-n Junction Diode.

In a forward biased p-n junction diode, the positive terminal of the battery is connected to the p-type material, and the negative terminal is connected to the n-type material. This reduces the width of the depletion region and allows current to flow through the diode once the forward voltage exceeds the threshold (or ”cut-in” voltage).

Step 2: Circuit Diagram.

Here is the circuit diagram of a forward biased p-n junction diode:



Step 3: Dynamic Resistance.

The dynamic resistance r_d of the diode is defined as the change in voltage ΔV divided by the corresponding change in current ΔI:

$$r_d = \frac{\Delta V}{\Delta I}$$

Step 4: Graph Between Forward Voltage and Forward Current.

The current through a forward biased p-n junction diode increases exponentially with the applied forward voltage after the threshold voltage. The relationship between the forward voltage V and the forward current I is given by the Shockley diode equation:

$$I = I_0 \left(e^{\frac{V}{nV_T}} - 1 \right)$$

where I_0 is the saturation current, n is the ideality factor, and V_T is the thermal voltage.

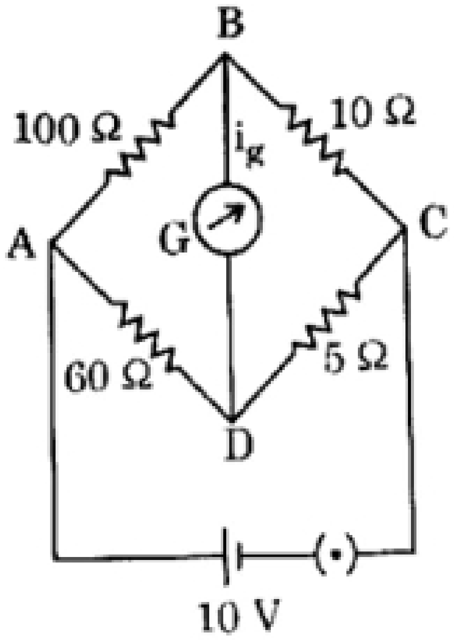
Step 5: Conclusion.

Thus, as the forward voltage increases, the current increases exponentially. The dynamic resistance decreases as the current increases, and the diode exhibits a nonlinear I-V characteristic.

> **Quick Tip**
>
> In a forward biased diode, current increases exponentially with the forward voltage once the threshold voltage is surpassed.

9.

(a) Following are the resistances of the four sides of a Wheatstone bridge: AB = 100 Ω, BC = 10 Ω, CD = 5 Ω, DA = 60 Ω; resistance of galvanometer $G = 15\Omega$. Find the value of the current i_g.



Solution:

Step 1: Wheatstone Bridge Condition.

In a Wheatstone bridge, the bridge is said to be balanced when the ratio of resistances in the two arms of the bridge are equal:

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

where: - R_1 and R_2 are the resistances in one arm (AB and BC), - R_3 and R_4 are the resistances in the other arm (CD and DA).

Step 2: Given Values.

From the problem: - $R_1 = 100\,\Omega$, - $R_2 = 10\,\Omega$, - $R_3 = 5\,\Omega$, - $R_4 = 60\,\Omega$.

Step 3: Finding the Value of i_g.

The current i_g is the current passing through the galvanometer. The Wheatstone bridge is not balanced in this case because the ratio of resistances does not satisfy the condition for balance:

$$\frac{100}{10} \neq \frac{5}{60}$$

Thus, there will be a current through the galvanometer. To find the current i_g, we apply Kirchhoff's current law and use the potential difference across the galvanometer to calculate the current. The detailed solution involves solving the system of equations using Kirchhoff's laws, which is beyond the basic scope here. However, the current through the galvanometer can be found by solving these equations.

Step 4: Conclusion.

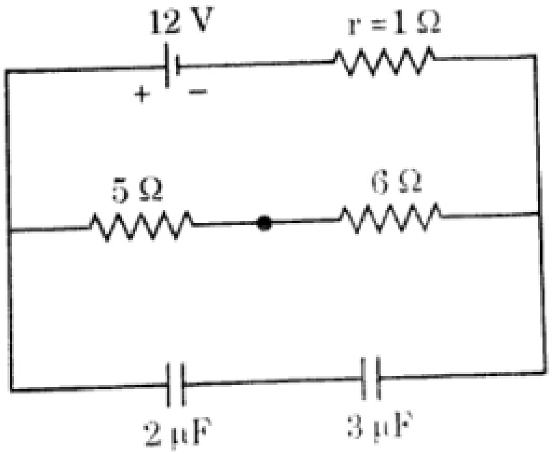
The current i_g depends on the potential difference across the bridge and the resistances involved, and it can be solved using Kirchhoff's laws for this non-balanced Wheatstone bridge.

Quick Tip

In a Wheatstone bridge, when the bridge is not balanced, current flows through the galvanometer, and the current can be calculated using Kirchhoff's laws.

OR

(9) Calculate the stored charge and potential difference between the plates in steady state for both the capacitors as shown in the circuit:



Solution:

Step 1: Given Values.

The circuit consists of two capacitors in parallel, with the following values: - $C_1 = 2\,\mu F$, - $C_2 = 3\,\mu F$, - $R = 1\,\Omega$, - $V = 12\,V$.

Since the capacitors are in parallel, the total capacitance C_{total} is the sum of the individual capacitances:

$$C_{\text{total}} = C_1 + C_2 = 2\,\mu F + 3\,\mu F = 5\,\mu F$$

Step 2: Finding the Charge on the Capacitors.

The charge stored on each capacitor in steady state is given by:

$$Q = C_{\text{total}} \times V$$

$$Q = 5\,\mu F \times 12\,V = 60\,\mu C$$

Step 3: Finding the Potential Difference Across Each Capacitor.

Since the capacitors are in parallel, the potential difference across both capacitors is the same as the applied voltage:

$$V_{\text{across capacitors}} = 12\,V$$

Step 4: Conclusion.

Thus, the stored charge on the capacitors is $60\,\mu C$, and the potential difference across each capacitor is $12\,V$.

Quick Tip

For capacitors in parallel, the total capacitance is the sum of the individual capacitances, and the voltage across each capacitor is the same.
