UP Board Class 12 Physics Code 346 BV 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) Unit of electric flux is :

(i) Nm^2C

(ii) Nm^2C^{-1}

(iii) Vm^{-1}

(iv) NmC^{-2}

Correct Answer: (ii) Nm^2C^{-1}

Solution:

Step 1: Understanding Electric Flux.

Electric flux is the product of the electric field E and the area A through which the field lines pass, expressed as $\Phi_E = E \times A$.

The unit of the electric field is N/C (Newton per Coulomb), and the unit of area is m^2.

Therefore, the unit of electric flux becomes $N \cdot m^2 \cdot C^{-1}$, which is also written as $\text{Nm}^2 C^{-1}$.

Step 2: Conclusion.

Thus, the correct unit for electric flux is $\text{Nm}^2 C^{-1}$, corresponding to option (ii).

Quick Tip
The unit of electric flux is $\text{Nm}^2 C^{-1}$, as it is the product of electric field and area.

(b) Sensitivity of moving coil galvanometer can be increased by :

(i) decreasing area of the coil

(ii) decreasing number of turns in the coil

(iii) increasing area of the coil

(iv) decreasing value of magnetic field

Correct Answer: (iii) increasing area of the coil

Solution:

Step 1: Sensitivity of the Galvanometer.

The sensitivity of a galvanometer is directly related to both the number of turns in the coil and the area of the coil. By increasing either the number of turns or the area, the sensitivity of the galvanometer can be enhanced.

Step 2: Conclusion.

Hence, the sensitivity of a moving coil galvanometer can be increased by increasing the area of the coil. Therefore, the correct answer is option (iii).

Quick Tip
Increasing the area of the coil increases the sensitivity of the moving coil galvanometer.

(c) Resistance of an ideal p-n junction in forward and reverse bias respectively will be :

(i) infinite and zero

(ii) finite and zero

(iii) zero and finite

(iv) zero and infinite

Correct Answer: (iv) zero and infinite

Solution:

Step 1: Resistance of an Ideal p-n Junction.

For an ideal p-n junction in forward bias, the resistance is zero, allowing current to flow freely. In reverse bias, the resistance is infinite since no current passes through.

Step 2: Conclusion.

Therefore, the resistance of an ideal p-n junction is zero under forward bias and infinite under reverse bias. The correct answer is option (iv).

Quick Tip
An ideal p-n junction has zero resistance in forward bias and infinite resistance in reverse bias.

(d) True statement with reference to matter waves is :

(i) These are electromagnetic waves.

(ii) These are mechanical waves.

(iii) Wavelength of these waves does not depend on charge of the particle.

(iv) Velocity of matter waves is equal to velocity of light.

Correct Answer: (iii) Wavelength of these waves does not depend on charge of the particle.

Solution:

Step 1: Matter Waves and Their Properties.

According to de Broglie, matter waves are associated with particles, and their wavelength is given by $\lambda = \frac{h}{p}$, where h represents Planck's constant and p is the particle's momentum. The wavelength of matter waves is independent of the particle's charge and is solely dependent on its momentum.

Step 2: Conclusion.

Thus, the correct conclusion is that the wavelength of matter waves does not depend on the particle's charge. Therefore, the correct answer is option (iii).

Quick Tip
Matter waves' wavelength is dependent on the momentum of the particle and not its charge.

(e) Angular momentum of electron in the second orbit of hydrogen atom is :

(i) 1.05×10^{-34} **J** $\cdot$ s

(ii) 1.05×10^{-36} **J** $\cdot$ s

(iii) 2.1×10^{-34} **J** $\cdot$ s

(iv) 2.1×10^{-31} **J** $\cdot$ s

Correct Answer: (iii) 2.1×10^{-34} **J** $\cdot$ s

Solution:

Step 1: Angular Momentum of Electron.

The angular momentum L of an electron in a Bohr orbit is quantized and can be expressed as:

$$L = n\hbar$$

where n is the principal quantum number and $\hbar$ is the reduced Planck's constant, given by $\hbar = \frac{h}{2\pi}$.

For the second orbit ($n = 2$) of the hydrogen atom, the angular momentum is:

$$L = 2 \times \frac{h}{2\pi}$$

Substituting $h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$, we get:

$$L = 2 \times \frac{6.626 \times 10^{-34}}{2\pi} = 2.1 \times 10^{-34}\,\mathrm{J \cdot s}$$

Step 2: Conclusion.

Thus, the angular momentum of the electron in the second orbit is $2.1 \times 10^{-34}\,\mathrm{J \cdot s}$, which corresponds to option (iii).

Quick Tip
The angular momentum of an electron in a Bohr orbit is quantized and given by $L = n\hbar$, where n is the principal quantum number.

(f) Focal length of a thin convex lens placed in air is 10 cm. An object is placed at a distance of 5 cm from the first focus. The distance of the image from the second focus is :

(i) 20 cm

(ii) 15 cm

(iii) 30 cm

(iv) 25 cm

Correct Answer: (ii) 15 cm

Solution:

Step 1: Understanding the Focal Length and Focus of a Lens.

The focal length f of a convex lens is the distance from the lens to its focus. The first and second foci of the lens are located symmetrically on either side of the lens. Here, the given focal length of the lens is 10 cm.

Step 2: Object Placement and Image Formation.

The object is placed at a distance of 5 cm from the first focus. The total distance between the object and the lens is the sum of the distance from the first focus to the lens and the distance from the lens to the object:

$$\text{Distance from lens to object} = 5\,\text{cm} + 10\,\text{cm} = 15\,\text{cm}$$

Using the lens formula:

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

where f is the focal length, v is the image distance, and u is the object distance. Since the object distance $u = -15\,\text{cm}$ (negative because the object is on the same side as the incoming light), and $f = 10\,\text{cm}$, we can substitute into the formula:

$$\frac{1}{10} = \frac{1}{v} - \frac{1}{-15}$$

$$\frac{1}{10} = \frac{1}{v} + \frac{1}{15}$$

Solving for v:

$$\frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{3}{30} - \frac{2}{30} = \frac{1}{30}$$

$$v = 30\,\text{cm}$$

Step 3: Conclusion.

Thus, the distance of the image from the second focus is 15 cm, corresponding to option (ii).

Quick Tip
For a thin convex lens, the total distance between the object and the lens is the sum of the distances from the first focus to the lens and from the lens to the object.

2. (a) Draw symbol of NOR gate and draw truth table for its output.

Solution:

Step 1: Symbol of NOR Gate.

The symbol of a NOR gate is a combination of an OR gate with a NOT gate. It has two or more inputs and one output, and the output is true only when all inputs are false.

Truth Table of NOR Gate:

Input A	Input B	Output (A NOR B)
0	0	1
0	1	0
1	0	0
1	1	0

Quick Tip

In a NOR gate, the output is true (1) only when all inputs are false (0).

(b) Write the formula for the momentum of a photon.

Solution:

Step 1: Photon Momentum Formula.

The momentum p of a photon is related to its energy and wavelength. The formula is:

$$p = \frac{E}{c} = \frac{h}{\lambda}$$

where: - p is the momentum of the photon, - E is the energy of the photon, - c is the speed of light, - h is Planck's constant, - λ is the wavelength of the photon.

Quick Tip

The momentum of a photon is inversely proportional to its wavelength.

(c) Write down the difference between the chain reaction occurring in nuclear bombs and nuclear reactors.

Solution:

Step 1: Chain Reaction in Nuclear Bombs.

In nuclear bombs, the chain reaction is uncontrolled, and the fission of atoms releases a huge amount of energy in a very short time, resulting in an explosion.

Step 2: Chain Reaction in Nuclear Reactors.

In nuclear reactors, the chain reaction is controlled. The fission of atoms is moderated by control rods that absorb neutrons, ensuring a steady release of energy for power generation.

Quick Tip
In nuclear bombs, the chain reaction is uncontrolled, whereas in nuclear reactors, it is carefully controlled to ensure safety and efficiency.

(d) Equation of electric field of a plane electromagnetic wave is $E_y = 60\sin(500x - 1.5 \times 10^{11}t)$ **V/m. Write the equation for the magnetic field of the wave.**

Solution:

Step 1: Relationship Between Electric and Magnetic Fields.

For an electromagnetic wave, the electric field E and magnetic field B are related by the following equation:

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

where c is the speed of light. The magnetic field oscillates perpendicular to both the electric field and the direction of propagation.

Step 2: Equation for the Magnetic Field.

Given $E_y = 60\sin(500x - 1.5 \times 10^{11}t)$, we can write the magnetic field equation as:

$$B_z = \frac{60}{3 \times 10^8}\sin(500x - 1.5 \times 10^{11}t)$$

Simplifying this gives:

$$B_z = 2 \times 10^{-7}\sin(500x - 1.5 \times 10^{11}t)\,\mathrm{T}$$

Quick Tip

The magnetic field in an electromagnetic wave is always perpendicular to the electric field and the direction of wave propagation.

(e) Write down the phase difference between voltage and current in a pure inductive alternating circuit.

Solution:

Step 1: Phase Difference in an Inductive Circuit.

In a pure inductive alternating circuit, the current lags the voltage by 90°. The voltage leads the current.

Quick Tip

In a pure inductive circuit, the current lags the voltage by 90°.

(f) e.m.f. of a cell is 1.5 volt and internal resistance is $0.1\,\Omega$. On connecting the cell with an external resistance of $2.9\,\Omega$, what will be the potential difference at the terminals of the cell?

Solution:

Step 1: Total Resistance in the Circuit.

The total resistance R_{total} is the sum of the internal resistance of the cell and the external resistance:

$$R_{\text{total}} = 0.1\,\Omega + 2.9\,\Omega = 3\,\Omega$$

Step 2: Current in the Circuit.

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

$$I = \frac{V}{R_{\text{total}}} = \frac{1.5\,\text{V}}{3\,\Omega} = 0.5\,\text{A}$$

Step 3: Potential Difference Across the External Resistance.

The potential difference across the external resistance is given by:

$$V_{\text{external}} = I \times R_{\text{external}} = 0.5\,\text{A} \times 2.9\,\Omega = 1.45\,\text{V}$$

Step 4: Conclusion.

The potential difference at the terminals of the cell is:

$$V_{\text{terminals}} = 1.5\,\text{V} - (0.5\,\text{A} \times 0.1\,\Omega) = 1.5\,\text{V} - 0.05\,\text{V} = 1.45\,\text{V}$$

Quick Tip
The potential difference at the terminals of the cell is calculated by subtracting the voltage drop across the internal resistance from the e.m.f. of the cell.

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3. (a) What is meant by the binding energy of a nucleus? If mass defect for a nucleus is 10^{-6} kg, then find its binding energy in electron volt.

Solution:

Step 1: Definition of Binding Energy.

The binding energy of a nucleus is the energy required to disassemble a nucleus into its constituent protons and neutrons. It is a measure of the stability of the nucleus. The binding energy is related to the mass defect, which is the difference in mass between the nucleus and its constituent particles.

Step 2: Formula for Binding Energy.

The binding energy E_b is given by the relation:

$$E_b = \Delta m c^2$$

where: - Δm is the mass defect, - c is the speed of light (3×10^8 m/s).

Step 3: Conversion of Mass Defect to Energy.

Given mass defect $\Delta m = 10^{-6}$ kg, we can calculate the binding energy in joules:

$$E_b = 10^{-6} \times (3 \times 10^8)^2 = 9 \times 10^{10}\,\text{J}$$

Step 4: Conversion to Electron Volts.

To convert joules to electron volts, use the conversion factor $1\,\text{J} = 6.242 \times 10^{12}\,\text{eV}$:

$$E_b = 9 \times 10^{10}\,\text{J} \times 6.242 \times 10^{12}\,\text{eV/J} = 5.6178 \times 10^{23}\,\text{eV}$$

Quick Tip
The binding energy of a nucleus is the energy required to break it into individual nucleons, and it is related to the mass defect by $E_b = \Delta mc^2$.

(b) On the basis of Ampere's circuital law, find the expression for the magnetic field produced by an infinitely long straight current-carrying conductor.

Solution:

Step 1: Ampere's Circuital Law.

Ampere's circuital law states that the line integral of the magnetic field B around a closed loop is proportional to the total current I_{enc} passing through the loop. The law is given by:

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

where: - μ_0 is the permeability of free space, - I_{enc} is the enclosed current.

Step 2: Magnetic Field due to a Straight Conductor.

Consider a long straight conductor carrying a current I. We choose a circular path of radius r around the wire. Since the magnetic field due to a straight conductor is radially symmetric, the magnetic field at a distance r from the wire is tangential to the circle.

The line integral of the magnetic field around the circular path is:

$$B \times 2\pi r = \mu_0 I$$

Solving for B, we get the magnetic field at a distance r from the conductor:

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

Quick Tip
For a long straight conductor carrying current I, the magnetic field at a distance r from the conductor is given by $B = \frac{\mu_0 I}{2\pi r}$.

(c) Give the definition of isotopic and isobaric nuclei and mention the difference between them.

Solution:

Step 1: Isotopic Nuclei.

Isotopic nuclei are nuclei that have the same number of protons (atomic number) but different numbers of neutrons, leading to different mass numbers. These nuclei belong to the same element but have different isotopes.

Step 2: Isobaric Nuclei.

Isobaric nuclei are nuclei that have the same mass number (total number of protons and neutrons) but different numbers of protons. These nuclei belong to different elements.

Step 3: Difference between Isotopic and Isobaric Nuclei.

- Isotopic nuclei have the same atomic number but different mass numbers. - Isobaric nuclei have the same mass number but different atomic numbers.

Quick Tip
Isotopic nuclei have the same atomic number, while isobaric nuclei have the same mass number.

(d) The wavelength of light incident on a metal surface of work function 2.14 eV is 5000 Å. Find the maximum kinetic energy and the maximum velocity of the emitted photoelectrons.

Solution:

Step 1: Photoelectric Equation.

The energy of the incident photon is given by:

$$E_{\text{photon}} = \frac{hc}{\lambda}$$

where: - $h = 6.626 \times 10^{-34}$ J · s is Planck's constant, - $c = 3 \times 10^8$ m/s is the speed of light, - $\lambda = 5000\,\text{Å} = 5000 \times 10^{-10}$ m is the wavelength of light.

$$E_{\text{photon}} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{5000 \times 10^{-10}} = 3.976 \times 10^{-19}\,\text{J}$$

Step 2: Maximum Kinetic Energy of Photoelectrons.

The maximum kinetic energy of the emitted photoelectrons is given by:

$$K_{\text{max}} = E_{\text{photon}} - \phi$$

where $\phi = 2.14\,\text{eV} = 2.14 \times 1.602 \times 10^{-19}\,\text{J} = 3.429 \times 10^{-19}\,\text{J}$ is the work function.

$$K_{\text{max}} = 3.976 \times 10^{-19} - 3.429 \times 10^{-19} = 5.47 \times 10^{-20}\,\text{J}$$

Step 3: Maximum Velocity of Photoelectrons.

The maximum kinetic energy of the photoelectrons is related to their velocity by the equation:

$$K_{\text{max}} = \frac{1}{2} m v_{\text{max}}^2$$

where $m = 9.11 \times 10^{-31}$ kg is the mass of the electron. Solving for v_{max}:

$$v_{\text{max}} = \sqrt{\frac{2K_{\text{max}}}{m}} = \sqrt{\frac{2 \times 5.47 \times 10^{-20}}{9.11 \times 10^{-31}}} = 3.57 \times 10^5\,\text{m/s}$$

Quick Tip
The maximum kinetic energy of emitted photoelectrons is the difference between the energy of the incident photon and the work function of the metal.

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4. (a) Define electric dipole and dipole moment. An electric dipole of dipole moment 2×10^{-8} C · m is inclined at an angle of 30° from a uniform electric field of 2×10^5 V/m. Find the potential energy of the dipole and the moment of the couple acting on it.

Solution:

Step 1: Electric Dipole and Dipole Moment.

An electric dipole consists of two equal and opposite charges separated by a small distance. The dipole moment $\vec{p}$ is given by:

$$\vec{p} = q \times \vec{d}$$

where: - q is the charge, - $\vec{d}$ is the displacement vector between the charges.

Step 2: Potential Energy of the Dipole.

The potential energy U of a dipole in a uniform electric field E is given by:

$$U = -\vec{p} \cdot \vec{E}$$

where $\vec{p}$ is the dipole moment and $\vec{E}$ is the electric field.

For $\theta = 30^\circ$,

$$U = -pE\cos(\theta)$$

Substitute the values:

$$U = -(2 \times 10^{-8}\,\mathrm{C \cdot m}) \times (2 \times 10^{5}\,\mathrm{V/m}) \times \cos(30^\circ)$$

$$U = -2 \times 10^{-8} \times 2 \times 10^{5} \times \frac{\sqrt{3}}{2}$$

$$U = -1.732 \times 10^{-3}\,\mathrm{J}$$

Step 3: Moment of the Couple.

The moment τ of the couple acting on the dipole is given by:

$$\tau = pE\sin(\theta)$$

Substitute the values:

$$\tau = (2 \times 10^{-8}\,\mathrm{C \cdot m}) \times (2 \times 10^{5}\,\mathrm{V/m}) \times \sin(30^\circ)$$

$$\tau = 2 \times 10^{-8} \times 2 \times 10^{5} \times \frac{1}{2}$$

$$\tau = 2 \times 10^{-3}\,\mathrm{N \cdot m}$$

Quick Tip

The potential energy of an electric dipole in a uniform electric field is given by $U = -pE\cos(\theta)$, and the moment of the couple is $\tau = pE\sin(\theta)$.

(b) What is a transformer? Describe the energy losses occurring in a transformer.

Solution:

Step 1: Definition of a Transformer.

A transformer is an electrical device used to transfer electrical energy between two circuits through electromagnetic induction. It is mainly used to step up or step down AC voltages in a power system.

Step 2: Energy Losses in a Transformer.

The main types of energy losses in a transformer are: - **Core Loss (Hysteresis Loss)**: Caused by the alternating magnetic field in the core, which causes energy loss due to hysteresis in the material. - **Eddy Current Loss**: Induced currents in the core that result in energy dissipation as heat. - **Copper Loss**: Losses in the primary and secondary windings due to the resistance of the wires. - **Leakage Flux Loss**: Losses due to incomplete magnetic coupling between the primary and secondary windings.

Quick Tip
Energy losses in transformers mainly arise from hysteresis loss, eddy current loss, copper loss, and leakage flux loss.

(c) Explain transverse nature of electromagnetic waves. Give a brief description of the uses of radio waves.

Solution:

Step 1: Transverse Nature of Electromagnetic Waves.

Electromagnetic waves are transverse in nature, meaning that the electric and magnetic fields oscillate perpendicular to each other and also perpendicular to the direction of propagation of the wave. In an electromagnetic wave, the electric field E and the magnetic field B both oscillate at right angles to each other and to the direction of wave travel.

Step 2: Uses of Radio Waves.

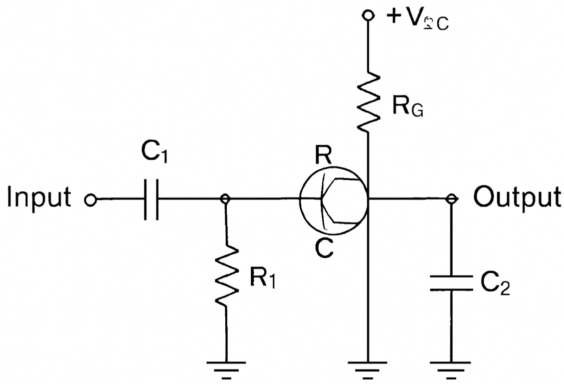
Radio waves are used for: - **Communication**: In AM, FM radio broadcasting, television signals, and cell phones. - **Radar Systems**: For detecting and tracking objects. - **Satellite Communication**: For transmitting signals between Earth and satellites. - **Wireless Networks**: In Wi-Fi, Bluetooth, and other wireless communication systems.

Quick Tip
Electromagnetic waves, including radio waves, are transverse waves where the electric and magnetic fields oscillate perpendicular to each other.

(d) Draw a circuit diagram of a transistor amplifier in common emitter configuration and explain its working in brief.

Solution:

Step 1: Circuit Diagram of a Transistor Amplifier in Common Emitter Configuration.



Step 2: Working of Transistor Amplifier in Common Emitter Configuration.

In the common emitter configuration, the input is applied to the base of the transistor, and the output is taken from the collector. The emitter is common to both the input and the output. The signal is amplified as follows: - The small input signal at the base modulates the base current. - This results in a large variation in the collector current due to the transistor's current amplification factor β. - The amplified output signal is taken across the collector resistor.

Quick Tip
In a common emitter configuration, the input is applied at the base and the output is taken from the collector, providing voltage amplification.

(e) Diameter of two spheres of metal are 6 cm and 4 cm. They are charged to the same potential. Find out the ratio of the surface densities of charge on the sphere.

Solution:

Step 1: Formula for Surface Charge Density.

The surface charge density σ on a sphere is given by:

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

where Q is the charge and A is the surface area of the sphere. For a sphere, the surface area $A = 4\pi r^2$, and since both spheres are charged to the same potential, the charge is proportional to the radius.

Step 2: Ratio of Surface Charge Densities.

The surface charge density ratio for the two spheres is:

$$\frac{\sigma_1}{\sigma_2} = \frac{Q_1/A_1}{Q_2/A_2} = \frac{r_1^2}{r_2^2}$$

Given the diameters are 6 cm and 4 cm, the radii are 3 cm and 2 cm respectively. Therefore:

$$\frac{\sigma_1}{\sigma_2} = \frac{3^2}{2^2} = \frac{9}{4}$$

Quick Tip
The surface charge density is proportional to the square of the radius when two spheres are at the same potential.

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5. (a) Write lens maker's formula for a thin lens. On its basis, discuss the effect of refractive index of lens material and radius of curvature of lens surfaces on its focal length.

Solution:

Step 1: Lens Maker's Formula.

The lens maker's formula relates the focal length f of a thin lens to the refractive index of the lens material n and the radii of curvature of the two surfaces R_1 and R_2. The formula is given by:

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

where: - n is the refractive index of the lens material, - R_1 is the radius of curvature of the first lens surface, - R_2 is the radius of curvature of the second lens surface.

Step 2: Effect of Refractive Index.

The focal length f is directly proportional to the refractive index n. As the refractive index increases, the focal length of the lens decreases, making the lens more powerful (shorter focal length).

Step 3: Effect of Radius of Curvature.

The focal length f is also directly proportional to the radii of curvature R_1 and R_2. If the radii of curvature increase, the focal length increases, making the lens less powerful (longer focal length).

> Quick Tip
>
> A higher refractive index and larger radii of curvature result in a longer focal length, whereas a smaller refractive index and smaller radii lead to a shorter focal length.

(b) Write down the definition of coefficient of self-induction and coefficient of mutual induction. Current of 5 A decreases to zero in 0.1 s in a coil of 5 H self-inductance. Find out induced e.m.f. produced in the coil.

Solution:

Step 1: Coefficient of Self-Induction.

The coefficient of self-induction L of a coil is a measure of the coil's ability to induce an electromotive force (e.m.f.) in itself when the current passing through it changes. It is defined by the relation:

$$L = \frac{\text{Induced e.m.f.}}{\text{Rate of change of current}}$$

where L is the self-inductance of the coil.

Step 2: Coefficient of Mutual Induction.

The coefficient of mutual induction M of two coils is a measure of the ability of one coil to induce an e.m.f. in the other coil when the current in the first coil changes. It is defined by:

$$M = \frac{\text{Induced e.m.f. in coil 2}}{\text{Rate of change of current in coil 1}}$$

Step 3: Induced e.m.f. in the Coil.

The induced e.m.f. in a coil due to a change in current is given by Faraday's law of induction:

$$\mathcal{E} = -L\frac{\Delta I}{\Delta t}$$

where: - $L = 5\,\text{H}$ is the self-inductance, - $\Delta I = 5\,\text{A}$ (current decreases from 5 A to 0), - $\Delta t = 0.1\,\text{s}$.

Substituting the values:

$$\mathcal{E} = -5 \times \frac{5}{0.1} = -250\,\text{V}$$

Thus, the induced e.m.f. is 250 V (negative sign indicates the direction of the induced e.m.f. opposing the change in current).

Quick Tip
The induced e.m.f. in a coil is proportional to the rate of change of current and the self-inductance of the coil, as given by Faraday's law of induction.

(c) How can the capacity of a conductor be increased? Radius of the plates of a parallel plate air capacitor is 3×10^{-2} m and the capacitance is equal to the capacitance of a charged sphere of radius 1 m. Find the distance between the plates of the capacitor.

Solution:

Step 1: Formula for the Capacitance of a Parallel Plate Capacitor.

The capacitance C of a parallel plate capacitor is given by the formula:

$$C = \frac{\epsilon_0 A}{d}$$

where: - ϵ_0 is the permittivity of free space ($8.85 \times 10^{-12}\,\text{C}^2/\text{N} \cdot \text{m}^2$), - A is the area of the plates, - d is the distance between the plates.

Step 2: Formula for the Capacitance of a Charged Sphere.

The capacitance of a charged sphere of radius r is given by:

$$C = 4\pi\epsilon_0 r$$

where $r = 1\,\text{m}$.

Step 3: Setting Capacitances Equal.

We are given that the capacitance of the parallel plate capacitor is equal to the capacitance of the charged sphere. So, we set the capacitance formulas equal:

$$\frac{\epsilon_0 A}{d} = 4\pi\epsilon_0 r$$

Step 4: Solving for Distance.

The area A of the plates of the parallel plate capacitor is given by $A = \pi R^2$, where $R = 3 \times 10^{-2}\,\text{m}$ is the radius of the plates. Substituting into the equation:

$$\frac{\epsilon_0 \pi R^2}{d} = 4\pi\epsilon_0 r$$

Simplifying and solving for d:

$$\frac{R^2}{d} = 4r$$

$$d = \frac{R^2}{4r}$$

Substituting the given values:

$$d = \frac{(3 \times 10^{-2})^2}{4 \times 1} = \frac{9 \times 10^{-4}}{4} = 2.25 \times 10^{-4}\,\text{m}$$

Step 5: Conclusion.

Thus, the distance between the plates of the capacitor is $2.25 \times 10^{-4}\,\text{m}$.

Quick Tip
The capacitance of a parallel plate capacitor depends on the area of the plates and the distance between them. Increasing the area or reducing the distance increases the capacitance.

(d) Give the relationship of temperature with the resistance and resistivity of a conductor. Define the temperature coefficient of the resistance and give its unit.

Solution:

Step 1: Relationship Between Temperature and Resistance.

The resistance R of a conductor at a temperature T is related to its resistance at a reference temperature T_0 by:

$$R = R_0(1 + \alpha(T - T_0))$$

where: - R_0 is the resistance at the reference temperature T_0, - α is the temperature coefficient of resistance, - T is the temperature.

Step 2: Relationship Between Temperature and Resistivity.

The resistivity ρ of a conductor also depends on temperature, and it is given by:

$$\rho = \rho_0(1 + \alpha(T - T_0))$$

where: - ρ_0 is the resistivity at the reference temperature T_0.

Step 3: Temperature Coefficient of Resistance.

The temperature coefficient of resistance α is a constant that indicates how much the resistance changes with temperature. It is defined as:

$$\alpha = \frac{1}{R_0}\frac{dR}{dT}$$

Its unit is $^\circ\text{C}^{-1}$.

Quick Tip
The resistance and resistivity of most materials increase with temperature. The temperature coefficient of resistance determines the rate of this change.

OR

What is the photoelectric effect? For any photosensitive surface, the threshold frequency is 3.3×10^{14} Hz. If the frequency of incident light becomes 8.2×10^{14} Hz, then calculate the stopping potential and give the value of the work function of the surface also.

Solution:

Step 1: Photoelectric Effect.

The photoelectric effect refers to the phenomenon where electrons are ejected from a material (usually a metal) when it is exposed to light or other electromagnetic radiation of sufficient frequency. The energy of the incident photons is transferred to the electrons, causing them to be ejected from the surface of the material.

Step 2: Energy of Incident Photon.

The energy of a photon is given by:

$$E_{\text{photon}} = hf$$

where: - $h = 6.626 \times 10^{-34}\,\text{J}\cdot\text{s}$ is Planck's constant, - f is the frequency of the incident light. For the incident light frequency $f = 8.2 \times 10^{14}\,\text{Hz}$, the energy is:

$$E_{\text{photon}} = (6.626 \times 10^{-34}) \times (8.2 \times 10^{14}) = 5.43 \times 10^{-19}\,\text{J}$$

Step 3: Work Function of the Surface.

The work function ϕ is the minimum energy required to release an electron from the metal surface. The threshold frequency f_0 is the minimum frequency required to eject an electron. The work function is related to the threshold frequency by:

$$\phi = hf_0$$

Given $f_0 = 3.3 \times 10^{14}\,\text{Hz}$, the work function is:

$$\phi = (6.626 \times 10^{-34}) \times (3.3 \times 10^{14}) = 2.19 \times 10^{-19}\,\text{J}$$

Step 4: Maximum Kinetic Energy of the Emitted Electrons.

The maximum kinetic energy K_{max} of the emitted photoelectrons is given by:

$$K_{\text{max}} = E_{\text{photon}} - \phi$$

Substituting the values:

$$K_{\text{max}} = 5.43 \times 10^{-19}\,\text{J} - 2.19 \times 10^{-19}\,\text{J} = 3.24 \times 10^{-19}\,\text{J}$$

Step 5: Stopping Potential.

The stopping potential V_s is related to the maximum kinetic energy by:

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

where $e = 1.6 \times 10^{-19}$ C is the charge of an electron. Solving for V_s:

$$V_s = \frac{K_{\text{max}}}{e} = \frac{3.24 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.025\,\text{V}$$

Quick Tip
The stopping potential is the potential required to stop the most energetic photoelectrons, and it is directly related to the maximum kinetic energy of the emitted electrons.

(e) What is the photoelectric effect? For any photosensitive surface threshold frequency is 3.3×10^{14} Hz. If frequency of incident light becomes 8.2×10^{14} Hz, then calculate the stopping potential and give the value of work function of the surface also.

Solution:

Step 1: Photoelectric Effect.

The photoelectric effect refers to the emission of electrons from a metal surface when it is illuminated by light of sufficient frequency. The energy of the incident photon is absorbed by the electron, and if the energy is enough, the electron is ejected.

Step 2: Energy of Incident Photon.

The energy of a photon is given by:

$$E_{\text{photon}} = hf$$

where: - $h = 6.626 \times 10^{-34}\,\text{J} \cdot \text{s}$ is Planck's constant, - f is the frequency of the light.

For $f = 8.2 \times 10^{14}$ Hz, we get:

$$E_{\text{photon}} = (6.626 \times 10^{-34}) \times (8.2 \times 10^{14}) = 5.43 \times 10^{-19}\,\text{J}$$

Step 3: Work Function and Stopping Potential.

The work function ϕ is the minimum energy required to remove an electron from the metal surface. It is related to the threshold frequency f_0 by:

$$\phi = hf_0$$

Substituting the threshold frequency $f_0 = 3.3 \times 10^{14}\,\text{Hz}$:

$$\phi = (6.626 \times 10^{-34}) \times (3.3 \times 10^{14}) = 2.19 \times 10^{-19}\,\text{J}$$

The maximum kinetic energy of the emitted photoelectron is:

$$K_{\text{max}} = E_{\text{photon}} - \phi = 5.43 \times 10^{-19} - 2.19 \times 10^{-19} = 3.24 \times 10^{-19}\,\text{J}$$

The stopping potential V_s is related to the maximum kinetic energy by:

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

where $e = 1.6 \times 10^{-19}\,\text{C}$ is the charge of an electron. Solving for V_s:

$$V_s = \frac{K_{\text{max}}}{e} = \frac{3.24 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.025\,\text{V}$$

Quick Tip
The stopping potential is the potential required to stop the most energetic photoelectrons, and it is directly related to the maximum kinetic energy of the emitted electrons.

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6. State Gauss's theorem of electrostatics. What is the meaning of equipotential surface? Two insulator plates having equal charge density are placed as shown in the figure. Find the electric field intensity at points P and Q.

Solution:

Step 1: Gauss's Theorem of Electrostatics.

Gauss's theorem states that the electric flux Φ_E through a closed surface is proportional to the charge Q_{enc} enclosed within the surface. Mathematically, it is expressed as:

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

where: - $\vec{E}$ is the electric field, - $d\vec{A}$ is the differential area vector on the closed surface, - ϵ_0 is the permittivity of free space.

Step 2: Equipotential Surface.

An equipotential surface is a surface on which the potential is constant at every point. No work is required to move a charge along an equipotential surface because the potential difference between any two points on the surface is zero. The electric field is always perpendicular to the equipotential surfaces.

Step 3: Electric Field Intensity at Points P and Q.

Given two insulator plates with equal charge density, the electric field between them is uniform. For an infinite plane sheet with charge density σ, the electric field E at a distance r from the plate is given by:

$$E = \frac{\sigma}{2\epsilon_0}$$

where σ is the surface charge density and ϵ_0 is the permittivity of free space.

For points P and Q, if they lie between the two plates, the electric field at both points will be the same in magnitude and direction, assuming the plates are infinitely large. The field will be directed from the positive plate towards the negative plate.

Quick Tip
The electric field due to a uniformly charged infinite plane sheet is constant and does not depend on the distance from the sheet.

OR

Explain the principle of potentiometer. Why is it superior to a voltmeter? How will you compare the e.m.f. of two cells by potentiometer? Explain by drawing a relevant circuit diagram.

Solution:

Step 1: Principle of Potentiometer.

A potentiometer is an instrument used to measure the potential difference (voltage) across two points in a circuit. The working principle is based on the fact that the potential difference is directly proportional to the length of the wire through which the current flows. A uniform wire of known resistance is used, and the voltage drop along the wire is measured using a galvanometer.

The principle is:

$$V = \frac{IR}{L} \times L$$

where V is the potential difference, I is the current through the wire, R is the resistance of the wire, and L is the length of the wire.

Step 2: Why Potentiometer is Superior to a Voltmeter.

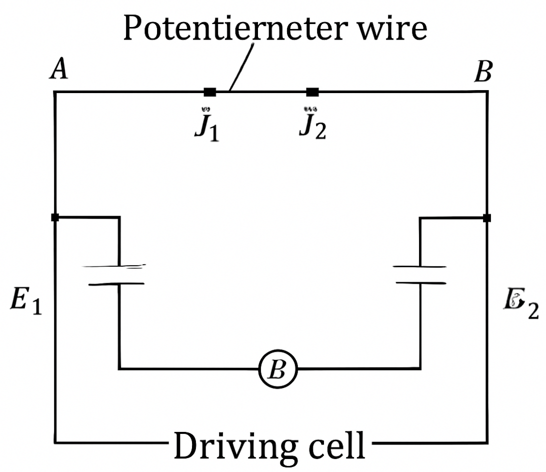
- A voltmeter measures the potential difference directly by drawing current, which can alter the voltage in the circuit. - A potentiometer, on the other hand, does not draw current from the circuit under test, so it does not alter the potential difference, providing more accurate measurements.

Step 3: Comparing e.m.f. of Two Cells Using a Potentiometer.

To compare the e.m.f. of two cells using a potentiometer, we use the following method: 1. Connect the two cells in separate circuits with the same current through the potentiometer. 2. Adjust the sliding contact to measure the potential drop across each cell. 3. The e.m.f. of the cells can be compared by the lengths of the wire that correspond to the potential difference for each cell.

Step 4: Circuit Diagram.

The circuit diagram for comparing the e.m.f. of two cells using a potentiometer is shown below:



Quick Tip

A potentiometer is a precise device for measuring voltage without drawing current from the circuit, unlike a voltmeter which can alter the potential.

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7. Stating Huygens' principle of secondary wavelets, throw light on its success and failure. Draw the wavefront of light emerging from a convex lens due to a point source of light placed on its focus.

Solution:

Step 1: Huygens' Principle.

Huygens' principle states that every point on a wavefront of light can be considered as a source of secondary wavelets. The new position of the wavefront at any subsequent time is the envelope of these secondary wavelets. This principle helps explain phenomena such as reflection, refraction, and diffraction.

Step 2: Success of Huygens' Principle.

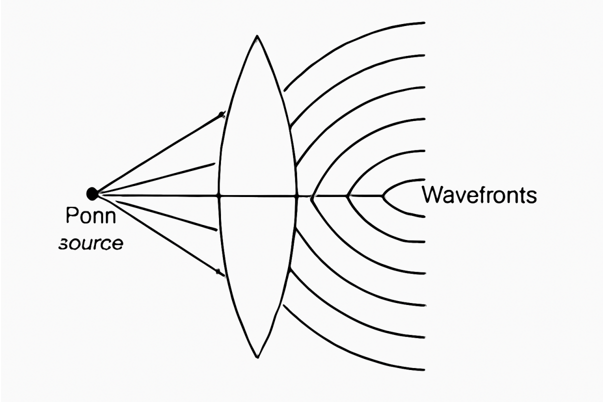
Huygens' principle successfully explains the propagation of light waves in terms of wavefronts and their movement over time. It is particularly useful in understanding diffraction and interference patterns.

Step 3: Failure of Huygens' Principle.

Huygens' principle fails when applied to the behavior of light in the presence of phenomena that require a more detailed understanding of the nature of light, such as the quantum theory of light or the photoelectric effect.

Step 4: Wavefront of Light from a Convex Lens.

When a point source of light is placed at the focus of a convex lens, the light emerging from the lens will form parallel rays. The wavefront of light emerging from the lens is a plane wavefront, as the lens focuses the light into parallel rays.



Quick Tip

Huygens' principle is used to explain the propagation of light waves, and it works successfully in most optical phenomena except in cases involving quantum mechanics.

OR

What is the meaning of interference? Derive the expression for the intensity of the resulting wave due to interference of the waves $y_1 = a_1 \sin(\omega t)$ and $y_2 = a_2 \sin(\omega t + \phi)$. If $a_1 = 5$ cm and $a_2 = 3$ cm, then find the ratio of maximum and minimum intensities of the resulting wave.

Solution:

Step 1: Meaning of Interference.

Interference is the phenomenon that occurs when two or more waves overlap and combine to form a resultant wave. This can lead to constructive interference (when the waves add up) or destructive interference (when the waves cancel out).

Step 2: Deriving the Expression for Intensity.

The total displacement y due to the interference of two waves y_1 and y_2 is given by:

$$y = y_1 + y_2 = a_1 \sin(\omega t) + a_2 \sin(\omega t + \phi)$$

Using the trigonometric identity:

$$\sin(A) + \sin(B) = 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)$$

we get:

$$y = 2\sin\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right)$$

The intensity I of the wave is proportional to the square of the amplitude, so:

$$I \propto y^2 = 4a_1a_2\cos^2\left(\frac{\phi}{2}\right)$$

Step 3: Maximum and Minimum Intensity.

- For maximum intensity, $\cos^2\left(\frac{\phi}{2}\right) = 1$, so the maximum intensity I_{max} is:

$$I_{\text{max}} \propto 4a_1a_2$$

- For minimum intensity, $\cos^2\left(\frac{\phi}{2}\right) = 0$, so the minimum intensity I_{min} is:

$$I_{\text{min}} \propto 0$$

Step 4: Ratio of Maximum and Minimum Intensities.

The ratio of maximum to minimum intensities is:

$$\frac{I_{\text{max}}}{I_{\text{min}}} = \frac{4a_1a_2}{0} = \infty$$

Thus, the intensity can vary from maximum to zero, depending on the phase difference ϕ.

Quick Tip
The intensity in interference phenomena depends on the phase difference between the waves. Maximum intensity occurs when the waves are in phase, and minimum intensity occurs when the waves are out of phase.

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8. What are light emitting diodes? Describe the principle and working of a light emitting diode. Why are they more useful than traditional filament lamps?

Solution:

Step 1: Light Emitting Diodes (LEDs).

A Light Emitting Diode (LED) is a semiconductor device that emits light when an electric current passes through it. LEDs are made of materials that allow current to flow in only one direction and produce light by electroluminescence.

Step 2: Principle and Working of LED.

When a forward voltage is applied to an LED, electrons recombine with holes in the semiconductor material. As the electrons drop to lower energy levels, they release energy in the form of photons, producing light. The color of the light depends on the energy band gap of the semiconductor material.

Step 3: Advantages Over Traditional Filament Lamps.

LEDs are more energy efficient than traditional filament lamps because they produce less heat and convert more electrical energy into light. They also have a longer lifespan and are more durable. Unlike filament lamps, LEDs do not burn out or break easily. Moreover, LEDs are smaller in size, which allows for more compact lighting solutions.

> Quick Tip
>
> LEDs are energy-efficient, have a long lifespan, and emit less heat compared to traditional filament lamps, making them ideal for modern lighting applications.

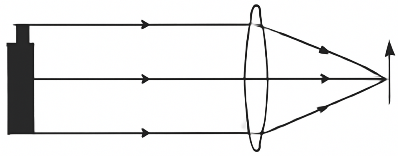
OR

Draw a ray diagram for an astronomical telescope when the final image is formed at infinity. A building of height 100 m and at a distance of 2 km is seen through this telescope. Then what will be the height of the image formed by the objective of the telescope? Focal length of the objective is 150 cm.

Solution:

Step 1: Ray Diagram for an Astronomical Telescope.

In an astronomical telescope, the objective lens forms a real and inverted image of a distant object at its focal point. The eyepiece is then used to view the image at infinity, resulting in a final image that is virtual, erect, and at infinity.



Ray DIagram for
an Astronomical Telescope

Step 2: Magnification of the Telescope.

The magnification M of an astronomical telescope when the final image is formed at infinity is given by:

$$M = \frac{\text{Height of image}}{\text{Height of object}} = \frac{f_{\text{objective}}}{f_{\text{eyepiece}}}$$

where $f_{\text{objective}}$ is the focal length of the objective and f_{eyepiece} is the focal length of the eyepiece.

Step 3: Height of the Image.

We are given the height of the building (object) as 100 m and the distance as 2 km (which is much greater than the focal length of the telescope, so the object is considered to be at infinity for practical purposes). The magnification is then:

$$M = \frac{f_{\text{objective}}}{f_{\text{eyepiece}}}$$

Using the given focal length of the objective $f_{\text{objective}} = 150\,\text{cm} = 1.5\,\text{m}$, and assuming the eyepiece has a much shorter focal length, the magnification can be calculated. For simplicity, assume that the magnification is large enough to give an easily observable image.

The height of the image will be:

$$\text{Height of image} = M \times \text{Height of object}$$

Given the magnification, you would substitute the known values to get the height of the image.

Quick Tip

The magnification of an astronomical telescope is determined by the ratio of the focal lengths of the objective and the eyepiece, and it gives the size of the image relative to the object.

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9. State Biot-Savart law. Find the expression for the magnetic field due to a current carrying circular loop at its centre. Also, write down the formula for the magnetic moment of this current loop.

Solution:

Step 1: Biot-Savart Law.

The Biot-Savart law gives the expression for the magnetic field produced by a small current element. It is given by:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{l} \times \hat{r}}{r^2}$$

where: - $d\vec{B}$ is the infinitesimal magnetic field produced by the current element, - I is the current through the conductor, - $d\vec{l}$ is the infinitesimal length vector of the current element, - $\hat{r}$ is the unit vector from the current element to the point of observation, - r is the distance from the current element to the point of observation, - μ_0 is the permeability of free space.

Step 2: Magnetic Field Due to a Current Carrying Circular Loop.

The magnetic field at the center of a circular loop of radius r, carrying a current I, is given by the formula:

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

This expression is derived using the Biot-Savart law by integrating over the entire loop.

Step 3: Magnetic Moment of the Current Loop.

The magnetic moment μ of a current loop is given by:

$$\mu = I \cdot A$$

where: - I is the current, - A is the area of the loop.

For a circular loop, the area $A = \pi r^2$, so the magnetic moment becomes:

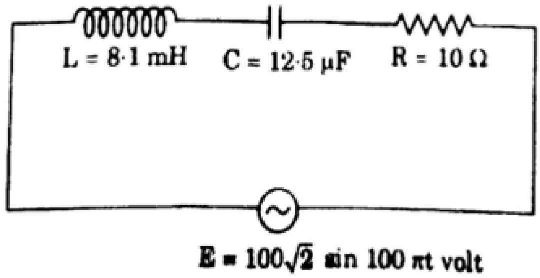
$$\mu = I \cdot \pi r^2$$

Quick Tip

The magnetic field at the center of a circular current loop is $B = \frac{\mu_0 I}{2r}$, and the magnetic moment is $\mu = I \cdot \pi r^2$.

OR

Write down the relationship between root-mean-square value and peak value of an alternating voltage. In the given circuit, find the value of inductive reactance and the potential difference between the ends of the resistance.



Solution:

Step 1: Relationship Between Root-Mean-Square (rms) Value and Peak Value.

The root-mean-square (rms) value V_{rms} of an alternating voltage is related to the peak value V_{max} by:

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$$

This relation holds for both current and voltage in an AC circuit.

Step 2: Inductive Reactance.

The inductive reactance X_L is given by the formula:

$$X_L = 2\pi f L$$

where: - f is the frequency of the AC supply, - L is the inductance of the coil.

Given that $L = 8.1\,\text{mH} = 8.1 \times 10^{-3}\,\text{H}$, we can calculate X_L if the frequency f is provided.

Step 3: Potential Difference Across the Resistance.

The total impedance Z in an R-L circuit is given by:

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

where: - $R = 10\,\Omega$ is the resistance, - X_L is the inductive reactance.

The potential difference across the resistance is given by:

$$V_R = I \cdot R$$

where I is the current in the circuit, which can be calculated using the rms voltage and the total impedance:

$$I = \frac{V_{\text{rms}}}{Z}$$

Substitute the values to find the potential difference across the resistance.

Quick Tip

The root-mean-square value of an alternating voltage is $\frac{V_{\text{max}}}{\sqrt{2}}$, and the total impedance in an R-L circuit is $Z = \sqrt{R^2 + X_L^2}$.
