CAREERS 360

PRACTICE Series

UP Board Class 12

Physics

Previous Year Questions with Detailed Solution

UP Board Class 12 Question with Solution-2024

SECTION-A

1. (a) The Louis de Broglie wavelength of a particle having kinetic energy $\mathbf{E}$ is :
(i) $\lambda=\frac{\mathrm{h}}{\sqrt{2 \mathrm{mE}}}$
(ii) $\lambda=\frac{\mathrm{h}}{\sqrt{\mathrm{mE}}}$
(iii) $\lambda=\frac{\sqrt{2 \mathrm{mE}}}{\mathrm{h}}$
(iv) $\lambda=\frac{\sqrt{\mathrm{mE}}}{\mathrm{h}}$

Answer:

The de Broglie wavelength of a particle is given by:

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

where h is Planck's constant and p is the momentum of the particle. The kinetic energy E of the particle can be related to its momentum p using the equation:

$$E=\frac{p^2}{2 m}$$

where m is the mass of the particle. Rearranging this equation to solve for p :

$$p=\sqrt{2 m E}$$

Substitute this expression for p into the de Broglie wavelength formula:

$$\lambda=\frac{h}{\sqrt{2 m E}}$$

Thus, the correct option is:
(i) $\lambda=\frac{h}{\sqrt{2 m E}}$

(b) If drift velocity of electron be v_{d} and intensity of electric field E , then which relation among the following obeys Ohm's law?
(i) $v_d \propto E^2$
(ii) $\mathbf{v}_{\mathrm{d}}=$ Constant
(iii) $v_d \propto E$
(iv) $v, \propto \sqrt{E}$.

Answer:

Ohm's law relates the current density J to the electric field E through the conductivity σ as:

$$J=\sigma E$$

The current density J is also related to the drift velocity v_d by:

$$J=n e v_d$$

where n is the number density of charge carriers, and e is the charge of an electron. Therefore, combining these two equations:

$nev_d = \sigma E$
This shows that the drift velocity v_d is proportional to the electric field E :

$v_d \propto E$
Thus, the correct option is:

$\text{(iii) } v_d \propto E$

(c) The path of scattered α-particle is :
(i) circular
(ii) parabolic
(iii) elliptical
(iv) hyperbolic

Answer:

In Rutherford's scattering experiment, α-particles are scattered by the nucleus due to the Coulomb force between the positively charged nucleus and the α-particles. The trajectory of these scattered particles depends on the impact parameter, and for large angles of scattering, the path is hyperbolic, similar to how objects move under a repulsive central force.

Thus, the correct option is:
(iv) hyperbolic

(d) The maximum focal length of convex lens is for:
(i) blue light
(ii) green light
(iii) red light
(iv) yellow light

Answer:

The focal length of a convex lens depends on the refractive index of the material of the lens, which in turn depends on the wavelength of light. Since the refractive index is inversely proportional to the wavelength, longer wavelengths (red light) are bent less, leading to a longer focal length. Therefore, the focal length is maximum for red light.

Thus, the correct option is:
(iii) red light

(e) The power consumed in alternating current in circuit containing only capacitor will be:
(i) $P = -1$
(ii) $\mathbf{P} = 0$ +
(iii) $\mathrm{P} = +1$
(iv) None of the above

Answer:

In a purely capacitive AC circuit, the current leads the voltage by 90°, meaning the phase difference between the voltage and current is 90°. Since the power is given by $P=VI\cos\phi$, where ϕ is the phase difference, and $\cos\left(90^{\circ}\right)=0$, the power consumed is zero.

Thus, the correct option is:

$$\text{(ii) } P=0$$

(f) Force of 80 Newton works between two point charges placed at a fixed distance apart in air. When these charges are placed at the same distance apart in a dielectric medium, then force of 8 Newton works on it. The dielectric constant of medium will be :
(i) $\mathrm{K}=-10$
(ii) $\mathrm{K}=10$
(iii) $\mathrm{K}=0.01$
(iv) $\mathrm{K}=-0.01$

Answer:

The force between two point charges in a medium with a dielectric constant K is related to the force in a vacuum by the equation:

$F_{\text{medium}}=\frac{F_{\text{air}}}{K}$
Given that the force in air is 80 N and the force in the dielectric medium is 8 N , we can write:

$8=\frac{80}{K}$
Solving for K :

$K=\frac{80}{8}=10$
Thus, the correct option is:

$$\text{(ii) } K=10$$
(f) Force of 80 Newton works between two point charges placed at a fixed distance apart in air. When these charges are placed at the same distance apart in a dielectric medium, then force of 8 Newton works on it. The dielectric constant of medium will be :
(i) $\mathrm{K}=-10$
(ii) $\mathrm{K}=10$
(iii) $\mathrm{K}=0.01$
(iv) $\mathrm{K}=-0.01$

Answer:

The force between two charges in air and in a dielectric medium is related by the dielectric constant K. The formula for the force in a dielectric medium is:

$F_{\text{medium}}=\frac{F_{\text{air}}}{K}$
Given that:
- The force in air, $F_{\text{air}}=80\ \mathrm{N}$,
- The force in the dielectric medium, $F_{\text{medium}}=8\ \mathrm{N}$,

We can substitute these values into the formula:

$8=\frac{80}{K}$
Solving for K :

$K=\frac{80}{8}=10$
Thus, the correct option is:

$$\text{(ii) } K=10$$

SECTION-B

2. (a) Find the ratio of focal length of lens in air and that of lens when it is immersed in liquid.

Answer:

The focal length f of a lens is related to the refractive index of the material of the lens and the surrounding medium by the lens maker's formula:

$$\frac{1}{f}=\left(\frac{n_{\text{lens}}}{n_{\text{medium}}}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

where n_{lens} is the refractive index of the lens material, and n_{medium} is the refractive index of the surrounding medium (air or liquid).
- In air: $n_{\text{medium}}=1$
- In liquid: $n_{\text{medium}}=n_{\text{liquid}}$

The ratio of the focal lengths in air (f_{air}) and in liquid (f_{liquid}) is:

$$\frac{f_{\text{air}}}{f_{\text{liquid}}}=\frac{n_{\text{lens}}-1}{n_{\text{lens}}-n_{\text{liquid}}}$$

(b) In hydrogen atom what is the ionization potential of electron in the ground state?

Answer:

The ionization energy or potential of an electron in the ground state of a hydrogen atom is the energy required to remove the electron from the atom. For hydrogen, the ionization potential is:

Ionization potential $=13.6\mathrm{eV}$

(c) Write the definition and dimensional formula of electrical conductivity.

Answer:

Definition: Electrical conductivity (σ) is a measure of a material's ability to conduct electric current. It is the reciprocal of electrical resistivity (ρ), i.e., $\sigma=\frac{1}{\rho}$.

Dimensional formula: The dimensional formula of electrical conductivity can be derived from the relation $\sigma=\frac{1}{\rho}$, where resistivity ρ has the dimensional formula $\left[M L^3 T^{-3} I^{-2}\right]$. Hence, the dimensional formula for conductivity is:

$$[\sigma]=\left[M^{-1} L^{-3} T^3 I^2\right]$$

(d) Which value of current does the ammeter used in A.C. circuit measure?

Answer:

In an A.C. circuit, the ammeter measures the root mean square (RMS) value of the alternating current, which is a type of average value representing the effective current. The RMS current is given by:

$$I_{\text{RMS}} = \frac{I_0}{\sqrt{2}}$$

where I_0 is the peak current.

(e) How much charge is there on hole? Draw the circuit symbol of p-n junction diode.

Answer:

- Charge on a hole: A hole behaves like a positively charged particle with a charge equal in magnitude to the electron's charge, which is $e = 1.6 \times 10^{-19} \mathrm{C}$. Therefore, the charge on a hole is $+1.6 \times 10^{-19} \mathrm{C}$.
- Circuit symbol of a p-n junction diode: The circuit symbol of a p-n junction diode is:

$\rightarrow| -$
This represents the anode (p-side) connected to the cathode (n-side).

(f) Between radio waves and micro waves, which one has a higher frequency?

Answer:

Microwaves have a higher frequency than radio waves. Radio waves typically have frequencies in the range of 3 kHz to 300 GHz , whereas microwaves have frequencies between 300 MHz and 300 GHz , placing them at a higher frequency range than radio waves.

SECTION-C

3. (a) Define the mass defect and binding energy of nucleus.

Answer:

1. Mass Defect: The mass defect of a nucleus is the difference between the sum of the individual masses of its constituent protons and neutrons and the actual mass of the nucleus. This difference arises because some mass is converted into energy and used to bind the nucleons together in the nucleus. Mathematically, it is given by:

$$\Delta m = (Z m_p + (A - Z) m_n) - m_{\text{nucleus}}$$

where:
- Z is the number of protons,
- A is the mass number (protons + neutrons),
- m_p is the mass of a proton,
- m_n is the mass of a neutron, and
- m_{nucleus} is the actual mass of the nucleus.
2. Binding Energy: The binding energy of a nucleus is the energy required to disassemble a nucleus into its individual protons and neutrons. It is a measure of the stability of the nucleus. The binding energy is related to the mass defect through Einstein's mass-energy equivalence relation:

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

where E_b is the binding energy, Δm is the mass defect, and c is the speed of light.

(b) A double concave lens has to be made from crown glass. How much should the radii of surfaces of lens be kept to make the power of lens -2.5 D ? Refractive index of crown glass is 1.65 .

Answer:

The power P of a lens is related to the radii of curvature of its surfaces and the refractive index of the material by the lens maker's formula:

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

where:
- P is the power of the lens,
- n is the refractive index of the lens material (1.65 for crown glass),
- R_1 and R_2 are the radii of curvature of the two surfaces of the lens (for a double concave lens, R_1 is negative, and R_2 is positive).

Given:

$$P=-2.5 \mathrm{D}, \quad n=1.65$$

We can substitute into the lens maker's formula:

$$-2.5=(1.65-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

Simplifying:

$$-2.5=0.65\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$
$$\frac{1}{R_1}-\frac{1}{R_2}=\frac{-2.5}{0.65} \approx-3.846$$

The radii R_1 and R_2 depend on the specific geometry of the lens, but this equation governs their relationship.

(c) Explain the operation of p-n junction diode in forward bias.

Answer:

In forward bias, the positive terminal of the external voltage source is connected to the p-type side of the diode, and the negative terminal is connected to the n-type side.
1. Reduction of Depletion Region: When the diode is forward biased, the external voltage reduces the potential barrier at the p-n junction. This causes the depletion region to shrink, allowing charge carriers (holes from the p-side and electrons from the n-side) to move across the junction.
2. Current Flow: The external voltage allows holes in the p-region to be pushed toward the junction and recombine with electrons from the n-region. Similarly, electrons from the n region move toward the junction and recombine with holes from the p-region. This movement of charge carriers results in a flow of current through the diode.

In summary, in forward bias, the diode conducts current, and the depletion region becomes narrower.

(d) What is the effect on range and sensitivity of an ammeter when the value of its shunt resistance increases ?

Answer:

- Range of Ammeter: The range of an ammeter refers to the maximum current it can measure. When the value of the shunt resistance R_s increases, less current is bypassed through the shunt, and more current flows through the ammeter's main coil. This decreases the maximum current the ammeter can measure, thereby reducing its range.
- Sensitivity of Ammeter: The sensitivity of an ammeter refers to how much current is needed to produce a deflection of the pointer. If the shunt resistance increases, the current through the ammeter's main coil increases for a given total current, which results in a larger deflection for the same current. Hence, increasing the shunt resistance increases the sensitivity of the ammeter.

Section D

4. (a) If a thin prism of glass be immersed in water, then prove that the minimum deviation produced by prism becomes one-fourth with respect to air. Given ${}_{\mathrm{a}}\mathrm{n}_{\mathrm{g}}=\frac{3}{2} ; \mathrm{a}_{\mathrm{w}}=\frac{4}{3}$.

Answer:

The deviation produced by a thin prism is given by the formula:

$$\delta_{\min }=(n-1) A$$

where:
- $\delta_{\min }$ is the minimum deviation,
- n is the refractive index of the prism material with respect to the surrounding medium,
- A is the angle of the prism.
- When the prism is in air, the refractive index of the prism with respect to air is:

$$n_{\text {air }}=\frac{n_{\text {glass }}}{n_{\text {air }}}=\frac{3 / 2}{1}=\frac{3}{2}$$

Thus, the minimum deviation in air is:

$$\delta_{\text {air }}=\left(\frac{3}{2}-1\right) A=\frac{1}{2} A$$

- When the prism is immersed in water, the refractive index of the prism with respect to water is:

$$n_{\text {water }}=\frac{n_{\text {glass }}}{n_{\text {watf }}}=\frac{3 / 2}{4 / 3}=\frac{3}{2} \times \frac{3}{4}=\frac{9}{8}$$

Thus, the minimum deviation in water is:

$$\delta_{\text {water }}=\left(\frac{9}{8}-1\right) A=\frac{1}{8} A$$

Now, the ratio of the deviation in water to the deviation in air is:

$$\frac{\delta_{\text {water }}}{\delta_{\text {air }}}=\frac{\frac{1}{8} A}{\frac{1}{2} A}=\frac{1}{4}$$

Hence, the minimum deviation in water is one-fourth of the minimum deviation in air.

(b) Discuss the significance of displacement current and find the phase difference between it and the conduction current.

Answer:

Displacement Current: The concept of displacement current was introduced by James Clerk Maxwell to account for the continuity of current in cases where there is a changing electric field, such as in the region between the plates of a capacitor during charging and discharging. Displacement current is given by:

$$I_d = \epsilon_0 \frac{d\Phi_E}{dt}$$

where ϵ_0 is the permittivity of free space, and $\frac{d\Phi_E}{dt}$ is the rate of change of electric flux.

The displacement current plays a crucial role in maintaining the continuity of current in circuits and is fundamental to the derivation of Maxwell's equations, which describe electromagnetism.

Phase Difference: The conduction current and displacement current are in phase with each other. This is because the rate of change of the electric field (which gives rise to the displacement current) occurs simultaneously with the actual movement of charges (which constitutes the conduction current). Both the conduction current and the displacement current are proportional to the time-varying electric field, so they do not have any phase difference.

Thus, the phase difference between the displacement current and the conduction current is:
0°

(c) Explain nuclear fission and nuclear fusion with examples.

Answer:

1. Nuclear Fission:
- Definition: Nuclear fission is the process in which a heavy nucleus splits into two or more lighter nuclei, accompanied by the release of a large amount of energy and neutrons. This process is generally induced by the absorption of a neutron by the nucleus.

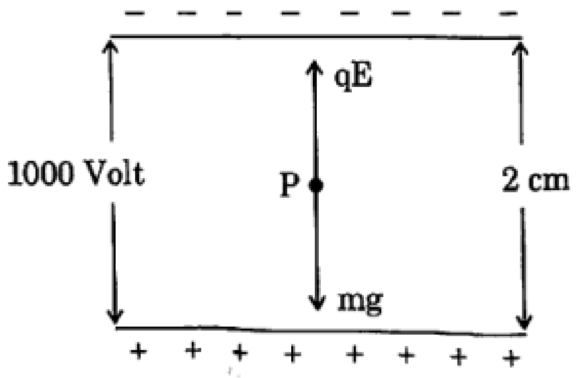
A common example of nuclear fission occurs when uranium-235 $\left({}_{92}^{235}\mathrm{U}\right)$ absorbs a neutron $\left({}_0^1\mathrm{n}\right)$ and undergoes fission, splitting into barium-141 $\left({}_{56}^{141}\mathrm{Ba}\right)$ and krypton-92 ${}_{36}^{92}\mathrm{Kr}\big)$, and releasing energy along with three neutrons:
- In this reaction, one uranium-235 nucleus absorbs a neutron and splits into two smaller nuclei (barium-141 and krypton-92) along with three additional neutrons and a large amount of energy.
- This process releases energy because the total mass of the products is slightly less than the mass of the uranium nucleus and the absorbed neutron. The "missing" mass is converted to energy according to Einstein's equation $E = mc^2$.

Nuclear Fusion:
- Definition: Nuclear fusion is the process where two or more lighter atomic nuclei combine to form a heavier nucleus, releasing a tremendous amount of energy in the process. Fusion requires very high temperatures and pressures to overcome the electrostatic repulsion between the positively charged nuclei.

and tritium $\left({}_1^3\mathrm{H}\right)$, combine to form a helium- 4 nucleus $\left({}_2^4\mathrm{He}\right)$ and a neutron $\left({}_0^1\mathrm{n}\right)$, releasing energy:
- In this reaction, a deuterium nucleus and a tritium nucleus (both isotopes of hydrogen) fuse to form a helium-4 nucleus and a neutron. This process releases an enormous amount of energy because the total mass of the resulting helium and neutron is slightly less than the mass of the original deuterium and tritium nuclei. This "missing" mass is converted into energy, again according to $E = mc^2$.

- Nuclear fusion is the energy source of stars, including the Sun. It is more difficult to achieve on Earth because it requires extremely high temperatures and pressures to overcome the repulsive forces between the positively charged nuclei.

(d) A plastic ball P of mass 3.2×10^{-15} kg is suspended between two horizontal parallel charged plates in balanced state. How many electrons on the ball will be increased or decreased ? $\left(g = 10 \mathrm{~m/s}^2 \right)$.



Answer:

The ball is in equilibrium between the gravitational force pulling it down and the electric force pulling it up due to the charges on the plates. To find the number of electrons that must be added or removed to balance these forces, we can set the gravitational force equal to the electric force:

Step 1: Equilibrium condition
The forces acting on the ball are:
- Gravitational force: $F_{\text{gravity}} = mg$
- Electric force: $F_{\text{electric}} = qE$

In equilibrium:

$$mg = qE$$

Step 2: Electric field between the plates
The electric field E between two parallel plates is given by:

$$E = \frac{V}{d}$$

Substitute the values:

$$E = \frac{1000}{0.0} \downarrow\downarrow = 50,000 \mathrm{~V/m}$$

Step 3: Calculate the charge on the ball
The electric force is equal to the gravitational force:

$$mg = qE$$
$$q = \frac{mg}{E}$$

Substitute the known values:

$$q = \frac{\left(3.2 \times 10^{-15} \mathrm{~kg}\right)\left(10 \mathrm{~m/s}^2\right)}{50,000 \mathrm{~V/m}} = 6.4 \times 10^{-19} \mathrm{C}$$

Step 4: Calculate the number of electrons
The charge of one electron is $e = 1.6 \times 10^{-19} \mathrm{C}$. The number of electrons n is:

$n = \frac{q}{e} = \frac{6.4 \times 10^{-19} \mathrm{C}}{1.6 \times 10^{-19} \mathrm{C}} = 4$

Conclusion:

The ball must have a net charge corresponding to the addition or removal of 4 electrons. Since the force is balancing upward, the plastic ball has likely lost 4 electrons, making it positively charged.

5. (a) Define interference. Mention the condition for constructive and destructive interference.

Answer:

Interference: Interference is the phenomenon that occurs when two or more waves superpose to form a resultant wave of greater, lower, or the same amplitude. It happens when waves from two or more coherent sources meet and overlap, leading to the redistribution of energy.

1. Constructive Interference: Constructive interference occurs when the crest of one wave overlaps with the crest of another, resulting in a wave of greater amplitude. The condition for constructive interference is:

$$\Delta \phi = 2 n \pi \quad \text{or} \quad \Delta x = n \lambda$$

where:

- $\Delta \phi$ is the phase difference,
- Δx is the path difference,
- λ is the wavelength of the waves, and
- n is an integer $(0, 1, 2, \ldots)$.

2. Destructive Interference: Destructive interference occurs when the crest of one wave overlaps with the trough of another, leading to a reduction in the overall amplitude or complete cancellation. The condition for destructive interference is:

$$\Delta \phi = (2 n + 1) \pi \quad \text{or} \quad \Delta x = \left(n + \frac{1}{2}\right) \lambda$$

where:

- n is an integer $(0, 1, 2, \ldots)$.

(b) The atomic mass of $8 \mathrm{O}^{16}$ is 16.0000 amu . Calculate its binding energy per nucleon. Mass of electron 0.00055 amu , mass of proton $1 - 007593 \mathrm{amu}$ and mass of neutron 1.008982 amu and $1 \mathrm{amu} = 931 \mathrm{MeV}$.

Answer:

Given data:

- Atomic mass of ${}_{8}^{16}\mathrm{O} = 16.0000 \mathrm{amu}$,
- Mass of one electron $= 0.00055 \mathrm{amu}$,
- Mass of one proton $= 1.007593 \mathrm{amu}$,
- Mass of one neutron $= 1.008982 \mathrm{amu}$,
- $1 \mathrm{amu} = 931 \mathrm{MeV}$.

Step 1: Calculate the total mass of the protons, neutrons, and electrons:

- Number of protons in oxygen $(Z) = 8$,
- Number of neutrons $(N) = 16 - 8 = 8$,
- Number of electrons $= 8$ (same as the number of protons for a neutral atom).

The total mass of the protons, neutrons, and electrons is:

Total mass of protons $= 8 \times 1.007593 \mathrm{amu} = 8.060744 \mathrm{amu}$

Total mass of neutrons $= 8 \times 1.008982 \mathrm{amu} = 8.071856 \mathrm{amu}$

Total mass of electrons $= 8 \times 0.00055 \mathrm{amu} = 0.0044 \mathrm{amu}$

The sum of the masses of all the particles is:
Total mass of the nucleons and electrons $= 8.060744 + 8.071856 + 0.0044 = 16.136999 \mathrm{amu}$
Step 2: Calculate the mass defect:

The mass defect (Δm) is the difference between the total mass of the individual nucleons and the actual atomic mass of the oxygen nucleus:

$\Delta m = 16.136999 \mathrm{amu} - 16.0000 \mathrm{amu} = 0.136999 \mathrm{amu}$
Step 3: Calculate the binding energy:

The binding energy (E_b) is given by the formula:

$E_b = \Delta m \times 931 \mathrm{MeV}$
Substituting the value of Δm :

$E_b = 0.136999 \times 931 \mathrm{MeV} = 127.57 \mathrm{MeV}$

Step 4: Calculate the binding energy per nucleon:

The binding energy per nucleon is the total binding energy divided by the number of nucleons (which is 16 for ${}_{8}^{16}\mathrm{O}$):

$E_{\text{b per nucleon }} = \frac{127.57 \mathrm{MeV}}{16} \approx 7.97 \mathrm{MeV}$

(c) Determine the nature of force acting between two parallel current carrying conductors when :
(i) Current is in the same direction in conductors,
(ii) Current is in opposite direction in conductors.

Answer:

1. (i) Current in the Same Direction:

When two parallel conductors carry current in the same direction, they experience an attractive force. This is because the magnetic field produced by one conductor interacts with the magnetic field of the other conductor, leading to an inward force between the two. Mathematically, the force per unit length between two parallel conductors carrying currents I_1 and I_2, separated by a distance d, is given by:

$F_{\text{attractive }} = \frac{\mu_0 I_1 I_2}{2 \pi d}$

where μ_0 is the permeability of free space.
2. (ii) Current in Opposite Direction:

When the currents in two parallel conductors are in opposite directions, they experience a repulsive force. In this case, the magnetic fields generated by the currents oppose each other, and the force between the conductors is outward, pushing them away from each other. The magnitude of the force per unit length remains the same as in the case of attractive force:

$F_{\text{repulsive }} \underset{2 \pi d}{\downarrow} = \frac{\mu_0 I_1 I_2}{2 \pi d}$

(d) Establish the relation between resistances of arms of Wheatstone bridge in balanced condition.

Answer:

In a Wheatstone bridge, there are four resistances arranged in two parallel branches, with a galvanometer connected between them. When the bridge is balanced, the ratio of the resistances in one branch is equal to the ratio of the resistances in the other branch.

Let the resistances be R_1, R_2, R_3, and R_4 as shown in the Wheatstone bridge configuration. The condition for the bridge to be balanced is:

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

This is known as the balanced condition of a Wheatstone bridge. When this condition is satisfied, no current flows through the galvanometer, indicating that the bridge is balanced.

OR

The resistance of a wire is 16 ohms. By melting it, the wire is stretched to half of its original length. What will be the resistance of the new wire?

Answer:

The resistance of a wire depends on its length L, cross-sectional area A, and resistivity ρ, as given by the formula:

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

If the wire is melted and stretched to half its original length, the volume of the wire remains constant. Hence, if the length decreases, the cross-sectional area must increase accordingly.

- Initial resistance: $R_1 = 16\Omega$,
- New length: $L_2 = \frac{L_1}{2}$,
- New cross-sectional area: $A_2 = 2A_1$ (since the volume $V = A_1L_1 = A_2L_2$).

The new resistance R_2 is:

$R_2 = \frac{\rho L_2}{A_2} = \frac{\rho \frac{L_1}{2}}{2A_1} = \frac{R_1}{4}$

Substituting the value of $R_1 = 16\Omega$:

$R_2 \downarrow \frac{16}{4} = 4\Omega$

Thus, the resistance of the new wire is 4Ω.

(e) Obtain the expression for capacity of a parallel plate capacitor. How will the capacity of capacitor be increased?

Answer:

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

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

where:

- ϵ_0 is the permittivity of free space,
- A is the area of the plates,
- d is the distance between the plates.

To increase the capacitance:
1. Increase the plate area A : A larger plate area allows more charge to be stored for a given potential difference.
2. Decrease the distance d : Reducing the distance between the plates increases the electric field and thus the capacitance.
3. Insert a dielectric material: Introducing a dielectric with permittivity ϵ_r increases the capacitance to:

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

Section E
6. What is Bohr's quantum condition postulate? How is it explained by de Broglie? What are the shortcomings of Bohr's atomic model?

Answer:

Bohr's Quantum Condition Postulate: Bohr proposed that the angular momentum of an electron in an atom is quantized, meaning it can only take specific values. This is expressed as:

$$L=n \hbar=n \frac{h}{2 \pi}$$

where n is a positive integer, h is Planck's constant, and $\hbar$ is the reduced Planck's constant. This condition was introduced to explain the stability of electron orbits in the hydrogen atom.

Explanation by de Broglie: de Broglie explained Bohr's quantization condition using the concept of wave-particle duality. According to de Broglie, particles such as electrons have a wavelength associated with them, given by:

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

where p is the momentum. For an electron to remain in a stable orbit, its de Broglie wavelength must fit an integer number of wavelengths around the orbit:

$$2 \pi r=n \lambda$$

This leads to the quantization of angular mom $\sqrt{\mathrm{n}}$ ntum in agreement with Bohr's postulate.

Shortcomings of Bohr's Model:
1. It only works for hydrogen-like atoms and fails for multi-electron systems.
2. It could not explain the intensity variations in spectral lines.
3. It was unable to account for the Zeeman effect and the fine structure of spectral lines.

OR
Energy of a particle at absolute temperature T is of order of kT. Calculate the wavelength of thermal neutrons at $27^{\circ} \mathrm{C}$. Find the energy of photon having same wavelength. Here k is Boltzmann constant.

Answer:

The energy of a particle at temperature T is approximately $k T$, where k is Boltzmann's constant.

Given:
- Temperature $T=27^{\circ} \mathrm{C}=300 \mathrm{~K}$,
- Boltzmann constant $k=1.38 \times 10^{-23} \mathrm{~J} / \mathrm{K}$,
- Mass of neutron $m_n=1.675 \times 10^{-27} \mathrm{~kg}$.

The thermal energy is:

$$E = kT = 1.38 \times 10^{-23} \times 300 = 4.14 \times 10^{-21}\ \mathrm{J}$$

The kinetic energy of the neutron is related to its velocity v by:

$$E = \frac{1}{2} m_n v^2$$

Solving for velocity:

$$v = \sqrt{\frac{2E}{m_n}} = \sqrt{\frac{2 \times 4.14 \times 10^{-21}}{1.675 \times 10^{-27}}} = 2.22 \times 10^3\ \mathrm{m/s}$$

The de Broglie wavelength of the neutron is:

$$\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{1.675 \times 10^{-27} \times 2.22 \times 10^3} = 1.79 \times 10^{-10}\ \mathrm{m}$$

Energy of a Photon with the Same Wavelength:
The energy of a photon is given by:

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

Substituting the values:

$$E_{\text{photon}} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.79 \times 10^{-10}} = 1.11 \times 10^{-15}\ \mathrm{J}$$

This is the energy of a photon having the same wavelength as the thermal neutron.

7. By drawing a ray diagram, explain the formation of image in a compound microscope. Establish the formula for magnifying power for it.

Answer:

A compound microscope consists of two lenses:
- Objective lens (closer to the object),
- Eyepiece lens (closer to the eye).

The objective forms a real, inverted, and magnified image of the object, which acts as the object for the eyepiece. The eyepiece further magnifies this image and forms a virtual, inverted image that is viewed by the observer.

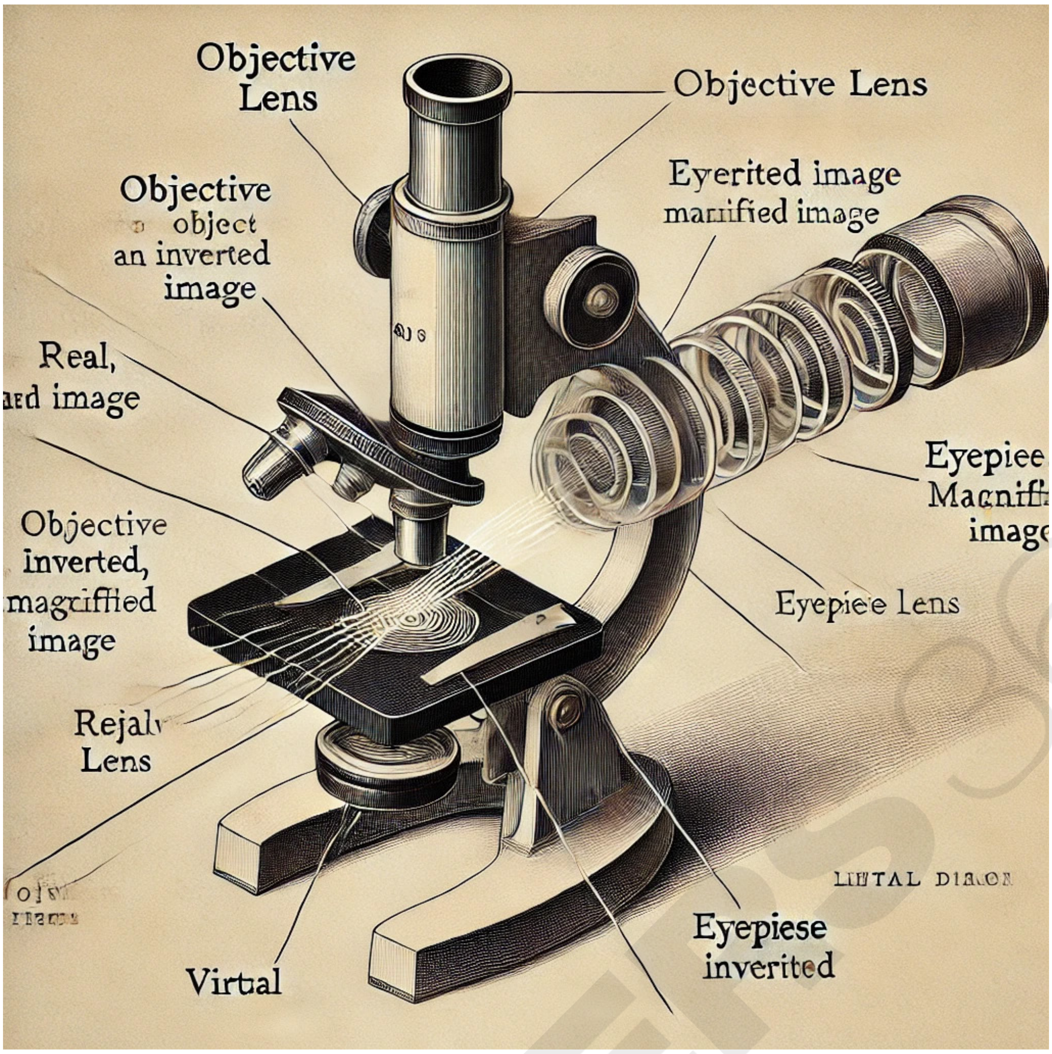
Magnifying Power: The magnifying power M of a compound microscope is given by:

$$M = M_o M_e$$

where M_o is the magnification of the objective and M_e is the magnification of the eyepiece. The individual magnifications are:

$$M_o = \frac{v_o}{u_o}, \quad M_e = 1 + \frac{D}{f_e}$$

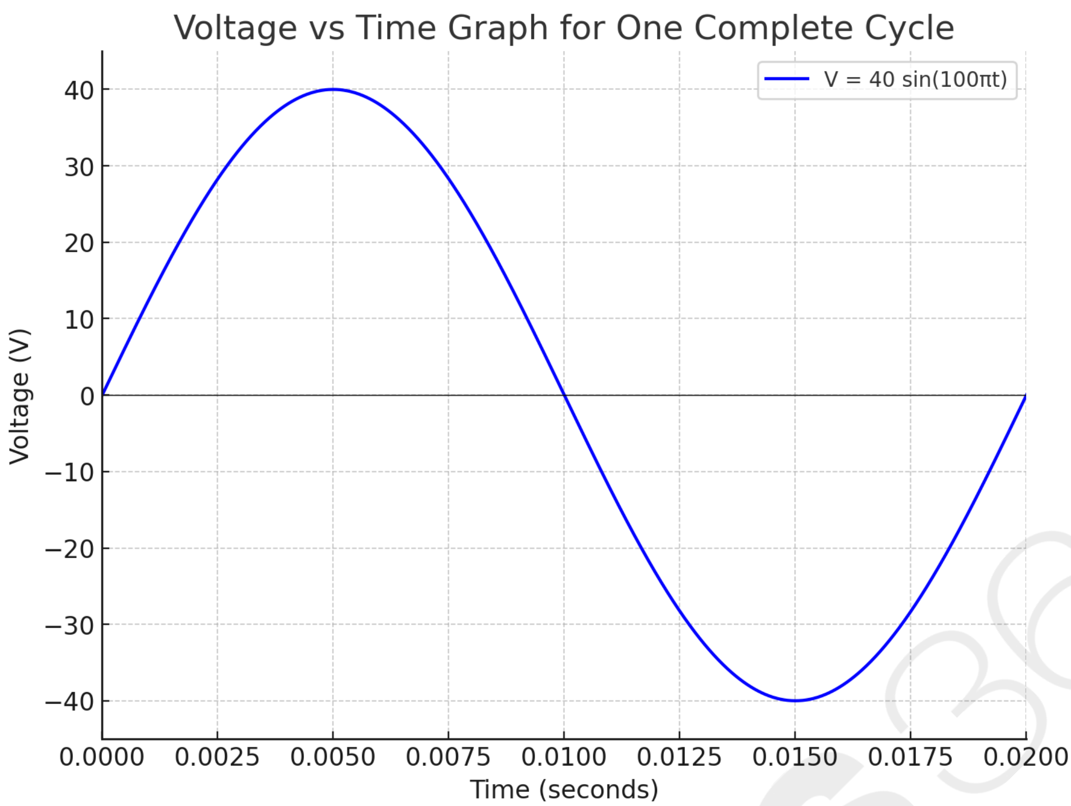
where v_o is the image distance for the objective, u_o is the object distance for the objective, D is the least distance of distinct vision, and f_e is the focal length of the eyepiece.



OR

In a circuit, the equation for alternative voltage V is represented by $V = 40\sin(100\pi t)$ volt. Here t is in seconds. Draw the time - voltage $(t - V)$ graph with proper scale for one cycle. Calculate the root mean square value of voltage.

Answer:



RMS Value of Voltage:
The root mean square (RMS) value of the voltage is calculated as:

$$V_{\text{RMS}} = \frac{V_0}{\sqrt{2}} = \frac{40}{\sqrt{2}} \approx 28.28 \text{ V}$$

Thus, the RMS value of the voltage is approximately 28.28 V .

8. What is atomic model of magnetism ? Differentiate between paramagnetic, diamagnetic and ferromagnetic substances on this basis. Also give one example of each.

Answer:

The atomic model of magnetism explains that magnetic properties of materials arise due to the motion of electrons around the nucleus and their intrinsic spin. In particular, magnetic behavior depends on the alignment and interaction of atomic magnetic moments (caused by electron spins and orbits).

Paramagnetic Substances:

Atomic Model: In paramagnetic materials, atoms have unpaired electrons with net magnetic moments. In the absence of an external magnetic field, these moments are randomly oriented, resulting in no net magnetization. However, when an external magnetic field is applied, the moments tend to align in the direction of the field, creating a weak magnetic attraction.

Example: Aluminum (Al).

Diamagnetic Substances:

Atomic Model: Diamagnetic materials have all their electron spins paired, meaning there is no net magnetic moment per atom. When an external magnetic field is applied, these materials generate a weak, opposing magnetic field, causing a slight repulsion.

Example: Bismuth (Bi).

Ferromagnetic Substances:

Atomic Model: In ferromagnetic materials, atoms have unpaired electrons, similar to paramagnetic substances, but they differ in that these materials have regions called **domains** where magnetic moments are strongly aligned. When an external magnetic field is applied, these domains align with the field, resulting in strong magnetization. Even after the external field is removed, ferromagnetic substances can retain their magnetization (permanent magnetism).

Example: Iron (Fe).

Differences Between Paramagnetic, Diamagnetic, and Ferromagnetic Materials:

Property	Paramagnetic	Diamagnetic	Ferromagnetic
Magnetic Moment	Unpaired electrons (weak net moment)	No net magnetic moment (paired electrons)	Strong net magnetic moment (unpaired electrons and domain alignment)
Response to Magnetic Field	Weakly attracted to magnetic field	Weakly repelled by magnetic field	Strongly attracted and can retain magnetization
Behavior in External Field	Align with the field but lose magnetism when field is removed	Oppose the magnetic field	Strongly align with the field, retain magnetism after the field is removed
Example	Aluminum (Al)	Bismuth (Bi)	Iron (Fe)

9. State Gauss's Law in electrostatics. Using it (i) find electric field due to a point source charge (q) and (ii) deduce Coulomb's law between source charge (q) and test charge (q_0).

Answer:

Gauss's law states that the total electric flux through a closed surface is proportional to the charge enclosed by the surface. Mathematically, it is given by:

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

where:
- $\vec{E}$ is the electric field,
- $d\vec{A}$ is the differential area element,
- q_{enc} is the charge enclosed within the surface,
- ϵ_0 is the permittivity of free space.

(i) Electric Field Due to a Point Charge:

Consider a point charge q placed at the center of a spherical surface of radius r. By symmetry, the electric field $\vec{E}$ is radial and has the same magnitude at every point on the surface. Applying Gauss's law to a spherical surface surrounding the point charge, we get:

$$E \cdot 4\pi r^2 = \frac{q}{\epsilon_0}$$

Solving for E:

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

This is the electric field due to a point charge.
(ii) Coulomb's Law:

Using Gauss's law, we derived that the electric field due to a point charge is:

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

Now, the force on a test charge q_0 placed at a distance r from the source charge q is given by:

$$F = q_0 E = \frac{q q_0}{4\pi\epsilon_0 r^2}$$

This is Coulomb's law, which describes the electrostatic force between two point charges q and q_0 separated by a distance r.

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UP Board Class 12 Physics Question with Solution- 2023

SECTION-A

a) Unit of $\frac{1}{\mu_0 \epsilon_0}$ is
i) $\mathrm{m}^2/\mathrm{s}^2$
ii) m/s
iii) $\mathrm{s}^2/\mathrm{m}^2$
iv) s/m.

Answer:

The expression $\frac{1}{\mu_0 \epsilon_0}$ represents the square of the speed of light, where μ_0 is the permeability of free space, and ϵ_0 is the permittivity of free space. The speed of light c is given by:

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

Thus,

$$\frac{1}{\mu_0 \epsilon_0} = c^2$$

The unit of c^2 is $\mathrm{m}^2/\mathrm{s}^2$. Hence, the correct unit for $\frac{1}{\mu_0 \epsilon_0}$ is $\mathrm{m}^2/\mathrm{s}^2$.
Correct answer: i) $\mathrm{m}^2/\mathrm{s}^2$

b) The equation $E = pc$, where E, p and c represents for energy, momentum and velocity of light, is valid
i) for an electron as well as for a photon
ii) fór a photon but not for an electron
iii). for an electron but not for a photon
iv) neither for an electron nor for a photon.

Answer:

The equation $E = pc$ is valid for a photon, where:
- E is the energy,
- p is the momentum, and
- c is the speed of light.

For a photon, this equation holds true because photons are massless, and the relationship between energy and momentum is directly proportional via the speed of light.

For an electron, which has mass, the relationship between energy, momentum, and velocity is different, following relativistic mechanics. Thus, $E = pc$ does not apply to electrons.

Correct answer: ii) for a photon but not for an electron.

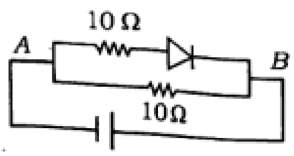
c) As the temperature of a metal and of a semiconductor is increased the
i) conductivity of both increases
ii) conductivity of both decreases
iii) conductivity of metal increases and of semiconductor decreases
iv) conductivity of metal decreases and of semiconductor increases.

Answer:

As the temperature of a metal increases, the conductivity **decreases** because increased thermal vibrations of atoms scatter more electrons, reducing their mobility. However, for a semiconductor, the conductivity **increases** as the temperature rises because more electrons gain enough energy to jump from the valence band to the conduction band, increasing the number of charge carriers.

Correct answer: **iv) conductivity of metal decreases and of semiconductor increases**

d) The equivalent resistance of the network shown in figure between A and B is



i) 10Ω
ii) 20Ω
iii) 5Ω
iv) 15Ω.

Answer:

In the given circuit, there are two resistors of 10Ω each, connected in different branches, and a diode between points A and B.
1. When the diode is forward biased:
- The diode allows current to pass through.
- The two resistors are in series because current can flow through the upper path (through the diode) and the two 10Ω resistors.
- The total equivalent resistance in this case is $10 \Omega+10 \Omega=20 \Omega$.
2. When the diode is reverse biased:
- The diode blocks the current in the upper branch, and no current flows through the circuit.
- In this case, there would be no complete path for current flow, so the equivalent resistance would be considered infinite.

Assuming the diode is forward biased (since it is not specified), the correct equivalent resistance is:

Answer: ii) 20Ω

e) In a transistor
i) the emitter has the least concentration of impurity
ii) the collector has the least concentration of impurity
iii) the base has the least concentration of impurity
iv) all the three regions have equal concentration of impurity.

Answer:

In a transistor, the base region is lightly doped compared to the emitter and collector regions. The emitter has the highest doping concentration to inject a large number of charge carriers, and the collector is moderately doped. The base, being very thin and lightly doped, allows most carriers injected from the emitter to pass through.

Correct answer: **iii) the base has the least concentration of impurity**

f) The net resistance of an ammeter should be small to ensure that
i) it does not get overheated
ii) it does not draw excessive current
iii) it can measure large currents
iv) it does not appreciably change the current to be measured.

Answer:

The net resistance of an ammeter should be small to ensure that it does not significantly alter the current in the circuit being measured. If the resistance of the ammeter is too large, it will affect the current flowing through the circuit, leading to inaccurate readings.

Correct answer: **iv) it does not appreciably change the current to be measured**

SECTION-B

2. a) Write the minimum orbital angular momentum of the electron in a hydrogen atom.

Answer:

The orbital angular momentum of an electron in a hydrogen atom is given by the formula:

$$L = \sqrt{l(l+1)}\hbar$$

where l is the azimuthal quantum number and $\hbar$ is the reduced Planck's constant. For the minimum orbital angular momentum, $l = 0$ (this corresponds to the s-orbital). Thus:

$$L = \sqrt{0(0+1)}\hbar = 0$$

Therefore, the minimum orbital angular momentum is zero.

b) Define optical centre of a lens.

Answer:

The optical centre of a lens is a point on the principal axis of the lens where a light ray passing through it does not experience any deviation. In a thin lens, the optical centre is usually located at the geometric centre of the lens.

c) As compared to ${}^{12}_{6}\mathrm{C}$ atom, how many extra protons and neutrons have in ${}^{14}_{6}\mathrm{C}$ atom ?

Answer:

- The atomic number Z (number of protons) of both ${}_{6}^{12}\mathrm{C}$ and ${}_{6}^{14}\mathrm{C}$ is 6 , so both have the same number of protons (6).
- The mass number of ${}_{6}^{12}\mathrm{C}$ is 12 , so the number of neutrons is $12-6=6$.
- The mass number of ${}_{6}^{14}\mathrm{C}$ is 14 , so the number of neutrons is $14-6=8$.

Thus, ${}_{6}^{14}\mathrm{C}$ has 2 extra neutrons compared to ${}_{6}^{12}\mathrm{C}$, but the number of protons remains the same.

d) How much energy is released in mass defect of 1 amu ?

Answer:

The energy released corresponding to a mass defect of 1 atomic mass unit (amu) can be calculated using Einstein's equation $E=mc^2$, where m is the mass defect and c is the speed of light.

The energy equivalent of 1 amu is approximately:

$$E=1\mathrm{amu}\times(931.5\mathrm{MeV}/\mathrm{amu})=931.5\mathrm{MeV}$$

Thus, the energy released in the mass defect of 1 amu is 931.5 MeV .

e) The electric field of intensity $\vec{E}=(3\hat{\imath}+4\hat{\jmath})$ N/C passes through the plane of area $\vec{A}=(10\hat{\imath})\mathrm{m}^2$. Find the electric flux.

Answer:

The electric flux Φ_E through a surface is given by the dot product of the electric field $\vec{E}$ and the area vector $\vec{A}$:

$$\Phi_E=\vec{E}\cdot\vec{A}$$

Given:

$$\vec{E}=(3\hat{\imath}+4\hat{\jmath})\mathrm{N}/\mathrm{C}, \quad \vec{A}=(10\hat{\imath})\mathrm{m}^2$$

Now, calculate the dot product:

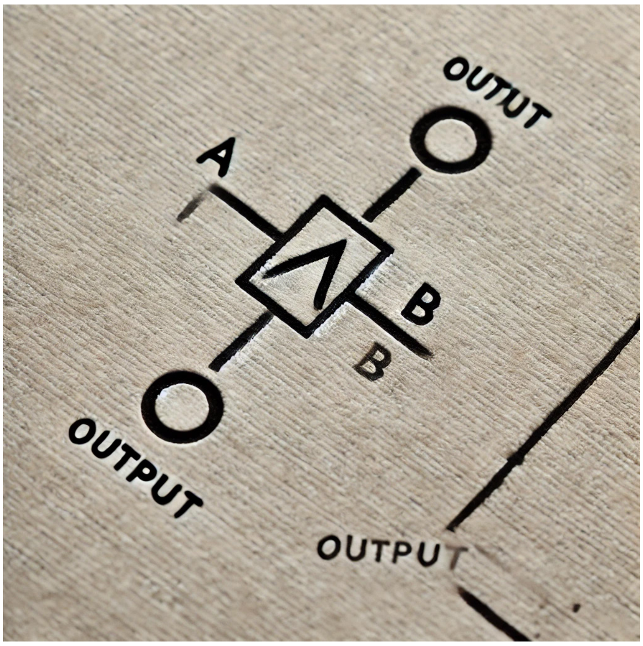
$$\Phi_E=(3\hat{\imath}+4\hat{\jmath})\cdot(10\hat{\imath})=3\times10=30\mathrm{Nm}^2/\mathrm{C}$$

Thus, the electric flux is $30\mathrm{Nm}^2/\mathrm{C}$.

f) Draw the logic symbol of NOR gate and write its truth table.

Answer:

The NOR gate is a universal gate that produces a true (1) output only when both inputs are false (0). The symbol of the NOR gate is shown below:



Truth Table:

Input A	Input B	Output
0	0	1
0	1	0
1	0	0
1	1	0

3. a) Calculate the energy of a $\mathrm{He}^{+}(Z=2)$ in its first excited state.

Answer:

For hydrogen-like atoms, the energy of an electron in a given state n is given by the formula:

$$E_n=-\frac{13.6 Z^2}{n^2} \mathrm{eV}$$

Where:
- Z is the atomic number (for $\mathrm{He}^{+}, Z=2$),
- n is the principal quantum number,
- 13.6 eV is the ionization energy of the hydrogen atom.

For the first excited state, $n=2$:

$$E_2=-\frac{13.6 \times 2^2}{2^2}=-13.6 \mathrm{eV}$$

Thus, the energy of He^{+} in its first excited state is -13.6 eV .

b) Define drift velocity of free electrons and write the relation between drift velocity and current density.

Answer:

Drift velocity is the average velocity attained by free electrons in a conductor under the influence of an external electric field. It is denoted by v_d and is typically very small due to the collisions with atoms in the conductor.

The relation between drift velocity v_d and current density J is given by the equation:

$J = nev_d$
Where:
- J is the current density (current per unit area),
- n is the number density of charge carriers (number of electrons per unit volume),
- e is the charge of an electron,
- v_d is the drift velocity of the electrons.

Thus, drift velocity is directly proportional to the current density.

c) Obtain the formula for the electric potential on the axial line of electric dipole.

Answer:

An electric dipole consists of two charges $+q$ and $-q$ separated by a distance $2a$. The electric potential at a point on the axial line of the dipole at a distance r from the center of the dipole is given by:

$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{p\cos\theta}{r^2}$
Where:
- $p = q \cdot 2a$ is the dipole moment,
- θ is the angle between the position vector of the point and the dipole axis (for the axial line, $\theta = 0^\circ$),
- r is the distance from the center of the dipole to the point,
- ϵ_0 is the permittivity of free space.

Since $\cos(0^\circ) = 1$, the potential simplifies to:

$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{p}{r^2}$
Thus, the electric potential on the axial line of a dipole is:

$V = \frac{1}{\Lambda\pi\epsilon_0} \cdot \frac{q \cdot 2a}{r^2}$

d) What are matter waves? Write de Broglie equation.

Answer:

Matter waves, also known as de Broglie waves, refer to the wave-like nature of particles such as electrons, protons, and other subatomic particles. According to de Broglie's hypothesis, every particle with momentum exhibits wave-like behavior.

The de Broglie equation relates the wavelength λ of a particle to its momentum p and is given by:

$\lambda = \frac{h}{p}$
Where:
- λ is the de Broglie wavelength,
- h is Planck's constant $(6.626 \times 10^{-34}\mathrm{Js})$,
- p is the momentum of the particle.

This equation shows that the wavelength of a particle is inversely proportional to its momentum.

SECTION-C

4. a) Define critical angle. Explain working of optical fibre.

Answer:

Critical Angle: The critical angle is the angle of incidence in a denser medium at which the angle of refraction in the rarer medium becomes 90°. It is given by:

$$\theta_c=\sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Where:
- n_1 is the refractive index of the denser medium,
- n_2 is the refractive index of the rarer medium.

For angles of incidence greater than the critical angle, total internal reflection occurs.

Working of Optical Fibre: Optical fibres operate based on the principle of total internal reflection. An optical fibre consists of a core with a higher refractive index surrounded by a cladding with a lower refractive index. When light is incident inside the core at an angle greater than the critical angle, it undergoes total internal reflection, allowing the light to propagate through the fibre with minimal loss, even if the fibre bends.

b) The work function of a metal is 2.5×10^{-9} joule. If the metal is exposed to a light beam of frequency $6.0 \times 10^{14}\ \mathrm{Hz}$, what will be the stopping potential ?

Answer:

The stopping potential can be calculated using the photoelectric equation:

$$e V_s=h f-\phi$$

Where:
- e is the charge of an electron $\left(1.6 \times 10^{-19} \mathrm{C}\right)$,
- V_s is the stopping potential,
- h is Planck's constant ($6.626 \times 10^{-34} \mathrm{Js}$),
- f is the frequency of the light $\left(6.0 \times 10^{14}\ \mathrm{Hz}\right)$,
- ϕ is the work function $\left(2.5 \times 10^{-9}\ \mathrm{J}\right)$.

First, calculate the energy of the incoming photons:

$$h f=6.626 \times 10^{-34} \times 6.0 \times 10^{14}=3.9756 \times 10^{-19}\ \mathrm{J}$$

Now, using the photoelectric equation:

$$e V_s=3.9756 \times 10^{-19}-2.5 \times 10^{-19}=1.4756 \times 10^{-19}\ \mathrm{J}$$

To find the stopping potential:

$$V_s=\frac{1.4756 \times 10^{-19}}{1.6 \times 10^{-19}}=0.922\ \mathrm{V}$$

c) Explain Biot-Savart law and find the unit of μ_0 with the help of the Biot-Savart's equation.

Answer:

Biot-Savart Law: The Biot-Savart law gives the magnetic field $\vec{B}$ at a point due to a small current element. It is mathematically expressed as:

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

Where:
- $d\vec{B}$ is the infinitesimal magnetic field,
- μ_0 is the permeability of free space $\left(4\pi \times 10^{-7}\ \mathrm{T} \cdot\ \mathrm{m/A}\right)$,
- I is the current,
- $d\vec{l}$ is the length of the current element,
- $\hat{r}$ is the unit vector from the current element to the point where $\vec{B}$ is being calculated,
- r is the distance between the current element and the point.

Unit of μ_0 : From the Biot-Savart law, we can see that μ_0 has units of magnetic field (T) times distance (m) per unit current (A). Thus, the unit of μ_0 is:

The permeability of free space, μ_0, has the SI unit $\mathrm{T} \cdot \mathrm{m}/\mathrm{A}$ (tesla meter per ampere).

d) Find the angle of minimum deviation for an equilateral prism made of refractive index 1.732. What is the angle of incidence for the deviation ?

Answer:

For an equilateral prism, the refracting angle $A = 60^\circ$, and the angle of minimum deviation δ_m can be calculated using the formula:

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

Given:
- $n = 1.732$,
- $A = 60^\circ$.

Substitute the values into the equation:

$$1.732 = \frac{\sin\left(\frac{60^\circ+\delta_m}{2}\right)}{\sin(30^\circ)}$$

Since $\sin\left(30^\circ\right) = 0.5$, we have:

$$1.732 = 2\sin\left(\frac{60^\circ + \delta_m}{2}\right)$$

$$\sin\left(\frac{60^\circ + \delta_m}{2}\right) = 0.866$$

$$\frac{60^\circ + \delta_m}{2} = 60^\circ$$
$$60^\circ + \delta_m = 120^\circ$$
$$\delta_m = 60^\circ$$

Thus, the angle of minimum deviation is 60°.
Angle of Incidence: In the case of minimum deviation, the angle of incidence $i = \frac{A+\delta_m}{2}$. Hence:

$i = \frac{60^\circ+60^\circ}{2} = 60^\circ$

e) A metallic stick of length L confined in a plane is rotated in its own plane with angular velocity ω in uniform magnetic field $(\vec{\beta})$ exists in the region. Find the expression of emf induced between the ends of the stick.

Answer:

For a metallic stick of length L rotating in a uniform magnetic field $\vec{B}$, the emf induced between the ends of the stick can be derived using Faraday's law of electromagnetic induction. The induced emf is given by:

$\mathcal{E} = \frac{1}{2}BL^2\omega$
Where:
- B is the magnetic field strength,
- L is the length of the stick,
- ω is the angular velocity.

Thus, the expression for the emf induced between the ends of the stick is:

$\mathcal{E} = \frac{1}{2}BL^2\omega$

5. a) A diverging lens of focal length 20 cm and a converging lens of focal length 30 cm are placed 15 cm apart with their principal axes coinciding. Where should an object be placed on the principal axis so that its image is formed at infinity ?

Answer:

We have two lenses:
- A diverging lens with focal length $f_1 = -20 \text{ cm}$,
- A converging lens with focal length $f_2 = 30 \text{ cm}$,
- The lenses are placed 15 cm apart with their principal axes coinciding.

To form the image at infinity, the object should be placed at the focal point of the effective lens system. Here's the step-by-step solution:

Step 1: Find the image position after the first lens.
The object distance from the diverging lens is u_1, and the image distance from the first lens v_1 is given by the lens formula:

$$\frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{f_1}$$
$$\frac{1}{v_1} = \frac{1}{u_1} + \frac{1}{f_1}$$

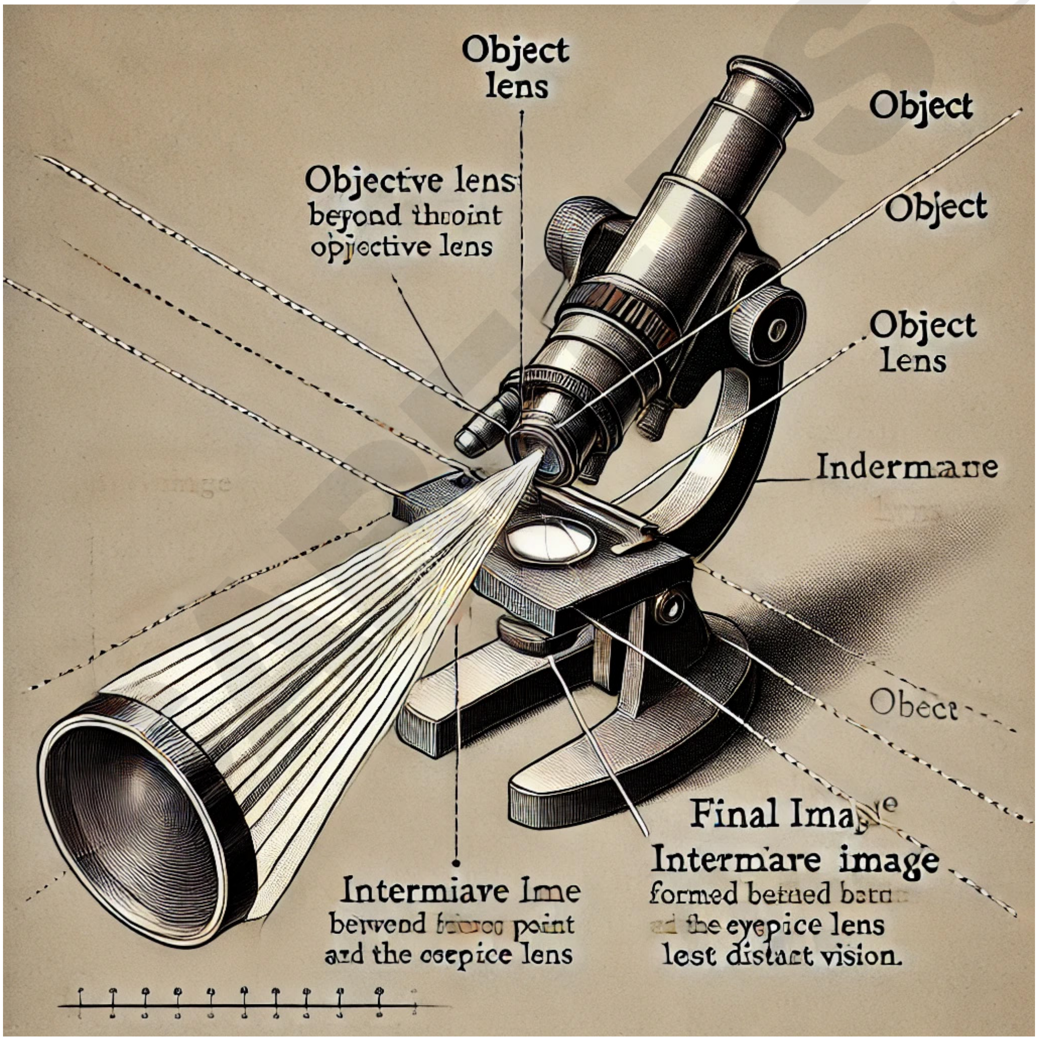
Step 2: The image from the diverging lens acts as the object for the converging lens.
The distance between the two lenses is $d = 15 \text{ cm}$, so the object for the converging lens is placed at $d - v_1$.

To form an image at infinity, the object must be placed at the focal point of the first lens such that the final image from the second lens goes to infinity.

Conclusion: To place the object such that the final image is at infinity, the object should be placed at a calculated position, which requires solving the lens equation numerically based on the system setup. I can provide that step explicitly if required.

b) Draw a suitable ray diagram of a compound microscope, when the image is formed at the least distance of distinct vision. Find the expression of magnifying power in this case.

Answer:



Expression for Magnifying Power:

The total magnifying power M of the compound microscope when the final image is formed at the least distance of distinct vision is given by:

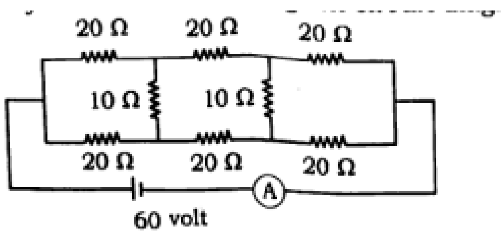
$M = M_o \cdot M_e$
Where:
- M_o is the magnification produced by the objective lens,
- M_e is the magnification produced by the eyepiece lens.

For the objective lens:

$M_o = \frac{v_o}{u_o} \approx \frac{L}{f_o}$
Where:
- v_o is the image distance for the objective lens,
- u_o is the object distance for the objective lens,
- L is the tube length of the microscope (distance between the lenses),
- f_o is the focal length of the objective

c) Write the principle of Wheatstone's Bridge. Find the current measured by the ammeter in the given circuit diagram.

Answer:



d) Explain the classification of conductors, insulators and semiconductors on the basis of energy-bands.

Answer:

Principle of Wheatstone's Bridge:
The Wheatstone Bridge operates on the principle that, when the bridge is balanced, no current flows through the galvanometer (or ammeter). The condition for the bridge to be balanced is:

$\frac{R_1}{R_2} = \frac{R_3}{R_4}$
Where:
- R_1, R_2 are resistances in one branch,
- R_3, R_4 are resistances in the other branch.

When this condition is satisfied, the potential difference across the central branch (where the ammeter is placed) is zero, resulting in no current through the ammeter.

Solving the Given Circuit:
In the given circuit, we can recognize that the configuration is similar to a Wheatstone Bridge. To find the current measured by the ammeter, let's analyze the circuit step by step:
1. Identify resistances in the arms:
- The two vertical branches each contain a series combination of a 10Ω and two 20Ω resistors.

2. Check for balance: If the Wheatstone Bridge is balanced, the condition $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ should hold. In this case:
- The left side has resistances $R_1 = 20\Omega$ and $R_2 = 10\Omega$,

- The right side has resistances $R_3=10\Omega$ and $R_4=20\Omega$.

Therefore:

$\frac{R_1}{R_2}=\frac{20}{10}=2, \quad \frac{R_3}{R_4}=\frac{10}{20}=0.5$
Since these ratios are not equal, the bridge is not balanced, so there will be some current through the ammeter.
3. Simplify the circuit: To find the current through the ammeter, we would need to calculate the equivalent resistance of the circuit. This can be done by using Kirchhoff's laws or mesh analysis.

The classification of materials as conductors, insulators, and semiconductors is based on the energy band structure:
1. Conductors:
- In conductors, such as metals, the valence band and conduction band overlap, meaning there is no energy gap between them. Electrons can freely move from the valence band to the conduction band, which results in high electrical conductivity.
- Energy gap: $\Delta E=0 \mathrm{eV}$ (no gap).
2. Insulators:
- In insulators, the energy gap between the valence band and the conduction band is large, typically greater than 5 eV . Electrons cannot easily move from the valence band to the conduction band, preventing the flow of electricity.
- Energy gap: $\Delta E>5 \mathrm{eV}$.
3. Semiconductors:
- In semiconductors, the energy gap is small (around 1 eV), allowing some electrons to move from the valence band to the conduction band at room temperature, leading to moderate conductivity.
- Energy gap: $\Delta E \approx 1 \mathrm{eV}$.
- Example: Silicon and germanium.

e) If binding energy per nucleon of deuteron and α-particle are 1.25 MeV and 7.4 MeV respectively, then find the value of Q in the following reaction :

$$2\left({ }_1^2 \mathrm{H}\right) \rightarrow 2 \mathrm{He}^4+\mathrm{O}$$

Answer:

The reaction is:

$2{ }_1^2 \mathrm{H} \rightarrow{ }_2^4 \mathrm{He}+\text { Energy }$
The binding energy per nucleon for deuteron is 1.25 MeV and for the alpha particle (helium) is 7.4 MeV .

Step 1: Calculate the total binding energy of the reactants (deuterons):
Each deuteron has 2 nucleons, so the binding energy of 2 deuterons is:

$$\text { Binding energy of reactants }=2 \times(1.25 \mathrm{MeV})=2.5 \mathrm{MeV}$$
Step 2: Calculate the binding energy of the product (alpha particle):
The alpha particle has 4 nucleons, so the total binding energy of the alpha particle is:

$$\text { Binding energy of product }=4 \times(7.4 \mathrm{MeV})=29.6 \mathrm{MeV}$$
Step 3: Calculate the Q-value:
The Q-value represents the energy released in the reaction and is the difference in binding energies between the reactants and products:

$Q=($ Binding energy of product $)-($ Binding energy of reactants $)$

$$Q=29.6 \mathrm{MeV}-2.5 \mathrm{MeV}=27.1 \mathrm{MeV}$$

Thus, the Q-value for the reaction is 27.1 M

6) Write Gauss' law of electrostatics and obtain Coulomb's law with its help.

Answer:

Gauss's Law of Electrostatics:
Gauss's law states that the total electric flux Φ_E through a closed surface is proportional to the total electric charge enclosed within that surface. Mathematically, Gauss's law is expressed as:

$\oint_{\text{closed surface}} \vec{E} \cdot d\vec{A}=\frac{q_{\text{enc}}}{\epsilon_0}$

Where:
- $\oint_{\text{closed surface}} \vec{E} \cdot d\vec{A}$ is the total electric flux through the closed surface,
- $\vec{E}$ is the electric field,
- $d\vec{A}$ is the infinitesimal area vector on the surface,
- q_{enc} is the total charge enclosed within the surface,
- ϵ_0 is the permittivity of free space.

Deriving Coulomb's Law from Gauss's Law:
To derive Coulomb's law from Gauss's law, let's consider a point charge q located at the origin and calculate the electric field at a distance r from the charge.
1. Choose a Gaussian surface:

Since the point charge is spherically symmetric, we choose a spherical Gaussian surface with radius r centered on the charge q. On this surface, the electric field $\vec{E}$ due to the point charge will be radial and will have the same magnitude at all points on the surface due to symmetry.
2. Apply Gauss's law:

According to Gauss's law:

$\oint \vec{E} \cdot d\vec{A}=\frac{q}{\epsilon_0}$

The electric field $\vec{E}$ is constant over the surface, and $\vec{E} \cdot d\vec{A}=E dA$, where E is the magnitude of the electric field and dA is the differential area element of the spherical surface.

The total area of the spherical surface is $A=4 \pi r^2$, so the integral becomes:

$E \oint dA=E \cdot 4 \pi r^2$

Thus, Gauss's law becomes:

$E \cdot 4 \pi r^2=\frac{q}{\epsilon_0}$

3. Solve for the electric field E :

Solving for E :

$E=\frac{q}{4 \pi \epsilon_0 r^2}$

This is the magnitude of the electric field due to a point charge at a distance r from the charge.
4. Relate to Coulomb's law:

The electric field due to a point charge can be used to find the force on another point charge q_0 placed at a distance r from the first charge. The force is given by:

$F = q_0 E = q_0 \frac{q}{4\pi\epsilon_0 r^2}$
This is Coulomb's law, which states that the electrostatic force between two point charges q and q_0 separated by a distance r is:

$F = \frac{1}{4\pi\epsilon_0} \cdot \frac{q q_0}{r^2}$

7. Write Fleming's left hand rule. A particle of having charge $1.0 \times 10^{-9}\mathrm{C}$ enters in a magnetic field of $\vec{B} = (4\hat{i} + 3\hat{j})$ tesla. with velocity $\vec{v} = (-75\hat{i} + 100\hat{j})\mathrm{m/s}$. Find the magnitude and direction of magnetic force exerting on the particle.

Answer:

Fleming's Left-Hand Rule:
Fleming's Left-Hand Rule is used to determine the direction of the force experienced by a charged particle moving in a magnetic field. According to this rule:
- Stretch the thumb, forefinger, and middle finger of your left hand so that they are mutually perpendicular.
- The forefinger represents the direction of the magnetic field $(\vec{B})$.
- The middle finger represents the direction of the current (or the velocity $\vec{v}$ of a positive charge).
- The thumb points in the direction of the force $(\vec{F})$ experienced by the charged particle.

This rule helps to determine the direction of the magnetic force on a charged particle moving in a magnetic field.

Magnetic Force on the Particle:
The magnetic force $\vec{F}$ on a charged particle moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ is given by the formula:

$\vec{F} = q(\vec{v} \times \vec{B})$
Where:
- $q = 1.0 \times 10^{-9}\mathrm{C}$ is the charge of the particle,
- $\vec{v} = (-75\hat{i} + 100\hat{j})\mathrm{m/s}$ is the velocity vector,
- $\vec{B} = (4\hat{i} + 3\hat{j})\mathrm{T}$ is the magnetic field vector.

Step 1: Calculate the cross product $\vec{v} \times \vec{B}$:
To calculate the cross product, we use the determinant method:

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ -75 & 100 & 0 \\ 4 & 3 & 0 \end{vmatrix}$$
This expands as:

$\vec{v} \times \vec{B} = \hat{i}(100 \times 0 - 0 \times 3) - \hat{j}(-75 \times 0 - 0 \times 4) + \hat{k}(-75 \times 3 - 100 \times 4)$
Simplifying:

$\vec{v} \times \vec{B} = \hat{\imath}(0) - \hat{\jmath}(0) + \hat{k}(-225 - 400)$
$\vec{v} \times \vec{B} = \hat{k} \times (-625)$
So, the cross product is:

$\vec{v} \times \vec{B} = -625\hat{k}$
Step 2: Calculate the magnetic force:
Now, use the charge $q = 1.0 \times 10^{-9} \mathrm{C}$ to find the force:

$\vec{F} = q(\vec{v} \times \vec{B}) = \left(1.0 \times 10^{-9}\right) \times (-625\hat{k}) = -6.25 \times 10^{-7}\hat{k}\,\mathrm{N}$
Step 3: Magnitude and Direction of the Force:
- Magnitude of the force:

$|\vec{F}| = 6.25 \times 10^{-7}\,\mathrm{N}$

- Direction of the force: Since the force is along the negative $\hat{k}$-direction, the force points in the negative z -direction (downward along the z -axis).

Thus, the magnitude of the magnetic force is $6.25 \times 10^{-7}\,\mathrm{N}$, and the force is directed downward along the negative z -axis.

8. State the conditions of interference of light. Obtain the expression for the fringe width in Young's double slit experiment.

Answer:

Conditions for Interference of Light:

For interference of light to occur, the following conditions must be satisfied:

1. **Coherent Sources**: The two light sources must be coherent, meaning they should maintain a constant phase difference. This is typically achieved by using a single source of light that is split into two parts.

2. **Monochromatic Light**: The light sources should be monochromatic (i.e., they should emit light of a single wavelength). This ensures that the interference pattern is stable and well-defined.

3. **Equal or Nearly Equal Amplitudes**: The amplitudes of the interfering light waves should be approximately equal to produce a well-contrasted interference pattern.

4. **Path Difference within Wavelength Limits**: The path difference between the two waves reaching the point of observation should be comparable to the wavelength of the light used.

5. **Waves Meet at a Point**: The two waves must overlap at the point of observation to produce constructive or destructive interference.

Expression for Fringe Width in Young's Double Slit Experiment:

In Young's Double Slit Experiment (YDSE), two coherent light sources produce an interference pattern on a screen. Bright and dark fringes are formed due to constructive and destructive interference, respectively. Let's derive the expression for the **fringe width**.

Experimental Setup:
- Let S_1 and S_2 be two slits separated by a distance d, illuminated by monochromatic light of wavelength λ.
- A screen is placed at a distance D from the slits, where $D \gg d$.
- The interference pattern is observed on the screen with alternating bright and dark fringes.

Path Difference and Interference:
At a point P on the screen, the path difference between the waves from slits S_1 and S_2 is:

$$\Delta = S_2 P - S_1 P$$

For points very close to the central axis, this path difference can be approximated by:

$$\Delta = d \sin \theta$$

Where θ is the angle subtended by point P on the screen with respect to the slits.
1. Constructive Interference (Bright Fringes):

Constructive interference occurs when the path difference is an integral multiple of the wavelength:

$$\downarrow \Delta = n\lambda$$

Hence, for constructive interference:

$$d \sin \theta = n\lambda \quad \text{for} \quad n = 0, 1, 2, 3, \ldots$$

Since the screen is far away, we can approximate $\sin \theta \approx \tan \theta \approx \frac{y_n}{D}$, where y_n is the distance of the n-th bright fringe from the central maximum. Therefore:

$$d \frac{y_n}{D} = n\lambda$$

Solving for y_n :

$$y_n = \frac{n\lambda D}{d}$$

2. Fringe Width:

The distance between two consecutive bright fringes (or dark fringes) is called the fringe width (β). The fringe width is the distance between the n-th and $(n+1)$-th bright fringes:

$$\beta = y_{n+1} - y_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d}$$

Simplifying:

Thus, the fringe width β in Young's double slit experiment is given by:

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

Where:
- β is the fringe width,
- λ is the wavelength of the light used,
- D is the distance between the slits and the screen,
- d is the distance between the two slits.

9. Explain $p-n-p$ transistor as a common emitter amplifier. What are the gains in it ?

Answer:

A common emitter amplifier is one of the most widely used transistor configurations in amplifying signals. In a p-n-p transistor, the transistor consists of two p-type semiconductor materials separated by a thin n-type material. When used in the common emitter configuration, the emitter is common to both the input and output circuits, and the signal is applied between the base and emitter.

Working of a $p-n-p$ Transistor in Common Emitter Configuration:
1. Biasing:
- The emitter-base junction is forward biased, meaning the p-type emitter is connected to a negative voltage, and the base (n-type) is connected to a slightly more positive voltage.
- The collector-base junction is reverse biased, with the collector connected to a more negative voltage compared to the base.

The forward bias on the emitter-base junction allows holes (majority carriers in the p-type emitter) to be injected into the base, which then move towards the collector.
2. Operation:
- A small current at the base-emitter junction $\left(I_B\right)$ controls a much larger current between the emitter and the collector $\left(I_C\right)$.
- Most of the injected holes from the $\downarrow^{\text{nitter diffuse through}}$ the thin n-type base and reach the collector, forming the collector current $\left(I_C\right)$.

- The base current I_B is very small because the base is thin, and only a small fraction of the carriers recombine in the base region.

The relation between the currents in the transistor is given by:

$$I_E=I_B+I_C$$

Where I_E is the emitter current.
3. Amplification:
- The input signal is applied between the base and the emitter. As the input signal increases, the base current I_B increases, leading to a larger collector current I_C due to the transistor's current amplification properties.
- The output signal is taken from the collector and has a much larger amplitude compared to the input signal due to the high gain of the common emitter configuration.

Gains in a Common Emitter Amplifier:
There are three key types of gain associated with a common emitter amplifier:
1. Current Gain (β) : The current gain in a common emitter amplifier is the ratio of the output current (collector current, I_C) to the input current (base current, I_B):

$$\beta=\frac{I_C}{I_B}$$

In a typical $p-n-p$ transistor, β can range from about 20 to 200 or more. This means a small change in the base current results in a much larger change in the collector current.
2. Voltage Gain $\left(A_V\right)$: The voltage gain is the ratio of the output voltage to the input voltage. In a common emitter amplifier, the voltage gain is given by:

$$A_V=-\beta \times \frac{R_C}{R_B}$$

Where:
- R_C is the load resistance connected to the collector,
- R_B is the resistance at the base.

3. Power Gain (A_P) : The power gain is the ratio of the output power to the input power. It is given by:

$A_P = A_V \times \beta$
Since both the voltage gain and the current gain can be large, the power gain is typically very high in a common emitter amplifier.

UP Board Class 12 Physics Question with Solution- 2022

SECTION-A

1. a) Spheres A and B having equal masses are given charges $+q$ and $-q$ respectively. If after charging their respective masses are respectively m_A and m_B, relation of m_A and m_B will be
i) $m_A = m_B$
ii) $m_A > m_B$
iii) $m_A < m_B$
iv) $m_A \gg m_B$

Answer:

Answer: I) $m_A = m_B$

Since charging only redistributes the electrons but does not affect the total mass significantly (as the mass of electrons is negligible), the masses will remain equal.
b) A light ray is propagating from a denser to a rarer medium. Angle of incidence is equal to critical angle. Value of angle of refraction will be
i) 45°
ii) 90°
(ii) 0°
iv) 135°

Answer:

ii) 90°

At the critical angle, the refracted ray moves along the boundary, and the angle of refraction becomes 90°.

c) Minimum wavelength of the spectral line obtained in the Paschen series in the spectrum of hydrogen atom will be
i) $\frac{9}{R}$
ii) $\frac{R}{9}$
iii). $9R$
iv) $\frac{R}{3}$

i) $\frac{9}{R}$

The minimum wavelength corresponds to the transition from $n = \infty$ to $n = 3$, and this is given by $\lambda_{\text{min}} = \frac{9}{R}$.

d) Work function of a metal is 4 eV . The wavelength of radiation necessary to emit photoelectrons with zero kinetic energy is
i) 1700\AA

ii) $1550\backslash AA$
iii) $3108\backslash AA$
iv) $750\backslash AA$

The corrected answer should be:
iii) $3108\backslash AA$

Using the equation $\lambda = \frac{hc}{\phi}$, where $\phi = 4\mathrm{eV}$, we get $\lambda \approx 3108\backslash AA$.

e) Electric and magnetic field vectors of $\underset{\rightarrow}{an}$ electromagnetic wave are $\vec{E}$ and $\vec{B}$ respectively. Direction of propagation of the wave will be represented by
i) $\vec{B}$
ii) $\vec{E}$
iii) $\vec{B}, \vec{E}$
iv) $\vec{E} \times \vec{B}$

Answer: iv) $\vec{E} \times \vec{B}$

The direction of propagation of an electromagnetic wave is given by the cross-product of the electric field $\vec{E}$ and the magnetic field $\vec{B}$.

f) A charge q is moving parallel to uniform magnetic field $\vec{B}$ with a velocity v. Value of force acting on the charge is
i) qu
ii) qB
iii) 0
iv) $\frac{Bv}{q}$

Answer:

iii) 0

The force on a charge moving in a magnetic field is given by $\mathbf{F} = q(\vec{v} \times \vec{B})$. Since the velocity is parallel to the magnetic field, the force will be zero.

SECTION-B

2. a) State Ampere's circuital law.

Ampere's circuital law states that the line integral of the magnetic field $\vec{B}$ around any closed loop is equal to μ_0 times the total current passing through the loop:

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

where I_{enc} is the total current enclosed by the path.

b) Define electric dipole and write the formula for its dipole moment.
Answer:

Answer:

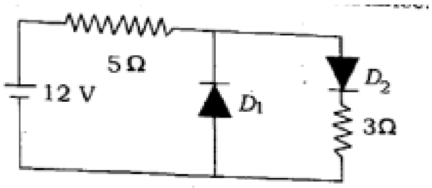
An electric dipole consists of two equal and opposite charges separated by a small distance. The dipole moment $\vec{p}$ is defined as:

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

where q is the magnitude of each charge, and $\vec{d}$ is the displacement vector from the negative to the positive charge.

c) A proton and an α-particle are moving with the same velocity. Find the relation between de Broglie wavelengths associated with them.

Answer:
d) A parallel beam of light of wavelength $6000\backslash AA$ is incident perpendicularly on a slit of width 3×10^{-6} m. Find the angular width of the central maxima in the diffraction pattern.
Answer:
e) D_1 and D_2 are the ideal diodes in the given circuit. Find the value of current flowing in the 3Ω resistance.



Answer:

From the given circuit, we can analyze the configuration:
- There is a 12 V battery, a 5Ω resistor in series with the combination of two ideal diodes, D_1 and D_2, and a 3Ω resistor connected with D_2.

Ideal Diode Analysis:
1. Diode D_1 :
- D_1 is reverse-biased because its cathode is connected to a higher potential than its anode. Hence, D_1 will not conduct.
2. Diode D_2 :
- D_2 is forward-biased because its anode is at a higher potential (from the battery) and its cathode is at the lower potential. Hence, D_2 will conduct.

Since D_1 is reverse-biased and does not conduct, the circuit can be reduced to just the 12 V battery, the 5Ω resistor, D_2, and the 3Ω resistor in series.

Current Calculation:
The total resistance in the conducting path is the sum of the two resistances $(5\Omega + 3\Omega)$:

$$R_{\text{total}} = 5\Omega + 3\Omega = 8\Omega$$

Using Ohm's law, the current I flowing through the circuit is:

$I = \frac{V}{R_{\text{total}}} = \frac{12 \text{ V}}{8\Omega} = 1.5 \text{ A}$
Thus, the current flowing through the 3Ω resistor is 1.5 A .

3. a) Give the full form of LED. Mention its importance.

Answer:

- LED stands for Light Emitting Diode.

Importance:
- Energy Efficiency: LEDs are much more energy-efficient compared to traditional incandescent and fluorescent lights.
- Long Lifespan: LEDs have a long operational life, reducing maintenance and replacement costs.
- Environmentally Friendly: LEDs do not contain harmful substances like mercury, making them eco-friendly.
- Instant Lighting and Frequent Switching: LEDs turn on instantly and can handle frequent switching without affecting their lifespan.
- Versatile Applications: LEDs are used in various applications, including display screens, indicators, lighting, and signaling devices.

b) Explain the meaning of induced electromotive force. A coil of inductance 10 H and resistance 10Ω is connected to a battery of 15 V . If time taken in pressing the key in the circuit is 0.1 s then find the average e.m. f. induced in the coil.

Answer:

- Induced Electromotive Force (EMF): It refers to the voltage generated in a conductor when it experiences a change in the magnetic field. According to Faraday's Law of Electromagnetic Induction, the induced EMF is proportional to the rate of change of magnetic flux through the coil.

Given problem:
- Inductance $L = 10\text{H}$
- Resistance $R = 10\Omega$
- Battery voltage $V = 15 \text{ V}$
- Time taken to press the key $t = 0.1 \text{ s}$

Step 1: Calculate the current developed in the circuit.
The final current in the circuit after a long time would be given by Ohm's Law:

$I = \frac{V}{R} = \frac{15 \text{ V}}{10\Omega} = 1.5 \text{ A}$
Step 2: Calculate the induced EMF.
The induced EMF in the coil due to a change in current is given by:

$\text{EMF} = -L\frac{\Delta I}{\Delta t}$

Here, $\Delta I = 1.5 \text{ A}$ (since the current changes from 0 to 1.5 A), and $\Delta t = 0.1$ s. Substituting the values:

$\text{EMF} = -10\text{H} \times \frac{1.5 \text{ A}}{0.1 \text{ s}} = -150 \text{ V}$
Thus, the average induced EMF is 150 V .

c) What do you understand by root mean square value (i_{rms}) of an alternating current ? Write down the relation between root mean square value and peak value (i_0) of an alternating current.

Solution:

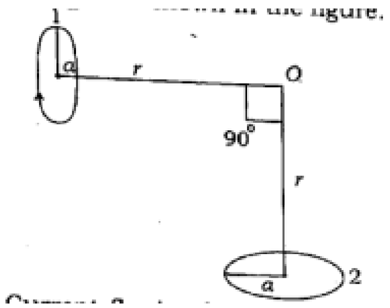
- The root mean square (RMS) value of an alternating current is the value of the direct current (DC) that would deliver the same average power to a resistor as the AC does over a complete cycle. It is a measure of the effective current.
- Relation between RMS and peak value:

$$i_{\text{rms}} = \frac{i_0}{\sqrt{2}}$$

where:
- i_{rms} is the root mean square value of the current.
- i_0 is the peak value of the alternating current.

This relationship shows that the RMS value is about 0.707 times the peak value of the current.

d) Two similar circular loops are arranged as shown in the figure.



Current flowing in the two loops and their radii are equal. Find the magnitude and direction of magnetic field produced at point O.

Answer:

Step 1: Magnetic field at the center of a circular loop
The magnetic field at the center of a single circular current-carrying loop with current I and radius a is given by:

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

where:
- B is the magnetic field,
- μ_0 is the permeability of free space $\left(\mu_0 = 4\pi \times 10^{-7}\,\mathrm{T \cdot m/A}\right)$,
- I is the current through the loop, and
- a is the radius of the loop.

Step 2: Magnetic field due to loop 1
Loop 1 is in the plane of the page, and the current flows clockwise. By the right-hand rule, the magnetic field at point O due to this loop will point vertically along the axis of the loop (towards or away from the observer depending on the current direction).
- Let's denote the magnetic field due to loop 1 at point O as B_1.

$\downarrow = \frac{\mu_0 I}{2a}$
$\downarrow$

Step 5: Direction of the resultant magnetic field
Since the magnetic fields due to the two loops are perpendicular to each other, the resultant magnetic field will point along the diagonal between the vertical and horizontal directions. The exact direction will depend on the current directions, but in general, the resultant will be in the plane that bisects the angle between the directions of B_1 and B_2.

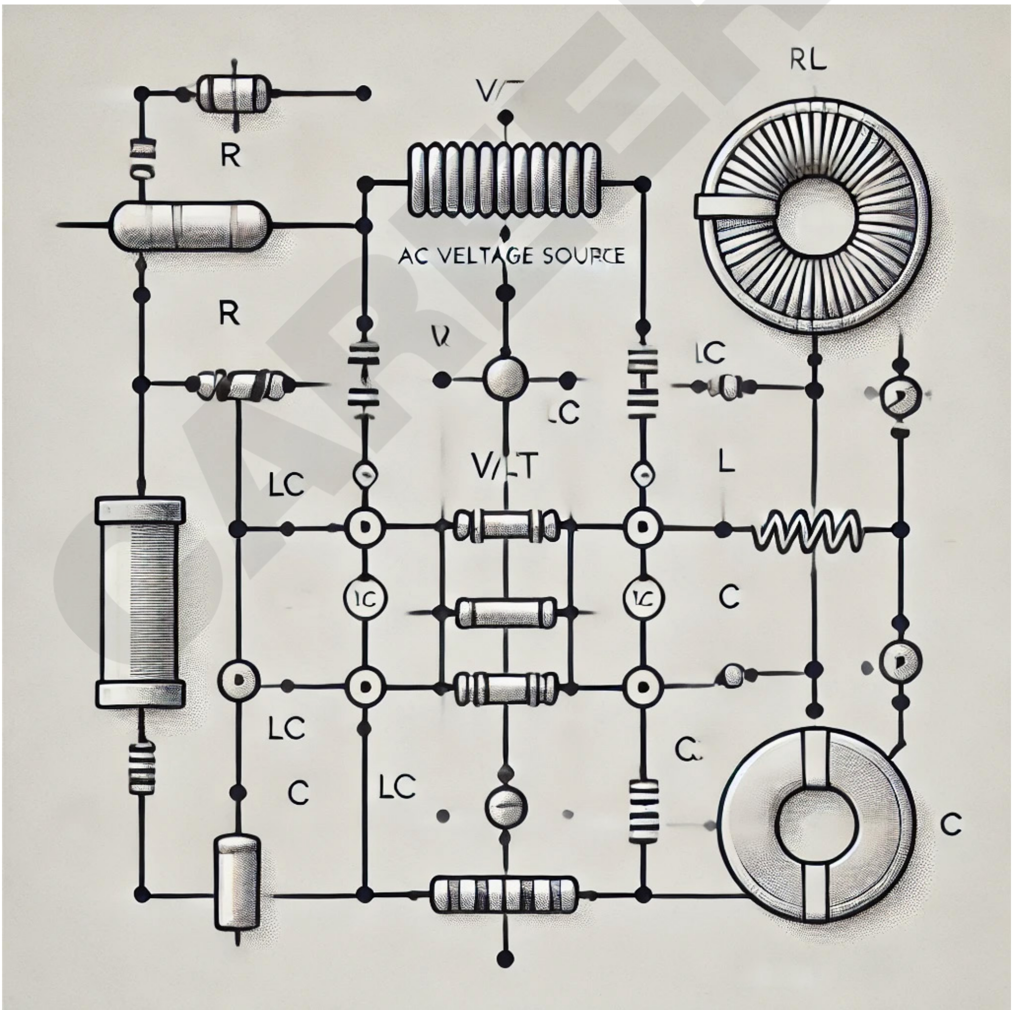
Final Answer:
- Magnitude of the magnetic field at point O :

$$B_{\text{net}} = \frac{\mu_0 I \sqrt{2}}{2a}$$

- Direction of the magnetic field: The magnetic field will be along the diagonal between the directions of B_1 and B_2, depending on the orientation of the currents in the loops.

4. a) Resistance, inductor and capacitor are connected in series with an alternating source. Draw the circuit diagram. Find the impedance and resonant frequency of the circuit. 3
Answer:

Circuit Diagram:
Here is the circuit diagram for a resistor R, an inductor L, and a capacitor C connected in series with an alternating voltage source:



In the diagram:
- R represents the resistance.
- L represents the inductance.
- C represents the capacitance.
- $V(t)$ represents the alternating voltage source.

Impedance of the Series RLC Circuit:
The impedance Z of a series RLC circuit is the total opposition to the flow of alternating current and is given by:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where:
- R is the resistance in ohms,
- $X_L = \omega L$ is the inductive reactance, where $\omega = 2\pi f$ is the angular frequency and L is the inductance,
- $X_C = \frac{1}{\omega C}$ is the capacitive reactance, where C is the capacitance.

Thus, the impedance depends on the resistance and the difference between the inductive and capacitive reactances.

Step 1: Equivalent Capacitance Calculation
Capacitors in the Network:
- $C_1 = 4\mu F$
- $C_2 = 4\mu F$
- $C_3 = 4\mu F$
- $C_4 = 4\mu F$
- $C_5 = 5\mu F$

Step 2: Combination of Capacitors
- Capacitors C_2 and C_5 are in series:

The equivalent capacitance C_{25} of capacitors in series is given by:

$\frac{1}{C_{25}} = \frac{1}{C_2} + \frac{1}{C_5}$
Substituting the values:

$$\frac{1}{C_{25}} = \frac{1}{4\mu F} + \frac{1}{5\mu F}$$
$$C_{25} = {}^{20} - \mu F \approx 2.22\mu F$$

Impedance of the Series RLC Circuit:
The impedance Z of a series RLC circuit is the total opposition to the flow of alternating current and is given by:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where:
- R is the resistance in ohms,
- $X_L = \omega L$ is the inductive reactance, where $\omega = 2\pi f$ is the angular frequency and L is the

inductance,
- $X_C = \frac{1}{\omega C}$ is the capacitive reactance, where C is the capacitance.

Thus, the impedance depends on the resistance and the difference between the inductive and capacitive reactances.

Resonant Frequency of the Series RLC Circuit:
The resonant frequency f_0 of the series RLC circuit occurs when the inductive reactance X_L equals the capacitive reactance X_C, i.e., $X_L = X_C$. At resonance, the impedance is purely resistive, meaning:

$\omega_0 L = \frac{1}{\omega_0 C}$
Solving for ω_0, we get the angular frequency at resonance:

$\omega_0 = \frac{1}{\sqrt{LC}}$
Since $\omega_0 = 2\pi f_0$, the resonant frequency f_0 is:

$f_0 = \frac{1}{2\pi\sqrt{LC}}$
Summary:
- Impedance of the series RLC circuit:

$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

- Resonant frequency of the series RLC circuit:

$f_0 = \frac{1}{2\pi\sqrt{LC}}$
b) Find the equivalent capacitance between points A and B of the given network. If a battery of 15 V is connected between A and B, find the magnitude of charge on the capacitors.

Answer:

Step 1: Equivalent Capacitance Calculation
Capacitors in the Network:
- $C_1 = 4\mu F$
- $C_2 = 4\mu F$
- $C_3 = 4\mu F$
- $C_4 = 4\mu F$
- $C_5 = 5\mu F$

Step 2: Combination of Capacitors
- Capacitors C_2 and C_5 are in series:

The equivalent capacitance C_{25} of capacitors in series is given by:

$\frac{1}{C_{25}} = \frac{1}{C_2} + \frac{1}{C_5}$
Substituting the values:

$$\frac{1}{C_{25}} = \frac{1}{4\mu F} + \frac{1}{5\mu F}$$
$$C_{25} = \downarrow - \mu F \approx 2.22\mu F$$

- Capacitors C_{25} and C_1 are in parallel:

For capacitors in parallel, the equivalent capacitance C_{125} is the sum of their capacitances:

$C_{125}=C_1+C_{25}$
Substituting the values:

$C_{125}=4 \mu F+2.22 \mu F=6.22 \mu F$

- Capacitors C_3 and C_4 are in series:

The equivalent capacitance C_{34} of capacitors in series is:

$\frac{1}{C_{34}}=\frac{1}{C_3}+\frac{1}{C_4}$
Substituting the values:

$$
\begin{aligned}
\frac{1}{C_{34}} & =\frac{1}{4 \mu F}+\frac{1}{4 \mu F} \\
C_{34} & =2 \mu F
\end{aligned}
$$

- Finally, C_{125} and C_{34} are in parallel:

The total equivalent capacitance C_{eq} between points A and B is the sum of C_{125} and C_{34} :

$C_{\text{eq}}=C_{125}+C_{34}$
Substituting the values:

$C_{\text{eq}}=6.22 \mu F+2 \mu F=8.22 \mu F$
Step 3: Charge on Each Capacitor
The battery connected between points A and B provides a voltage of 15 V . The total charge Q_{total} stored by the equivalent capacitance is given by:

$Q_{\text{total}}=C_{\text{eq}} \times V$
Substituting the values:

$Q_{\text{total}}=8.22 \mu F \times 15 \mathrm{~V}=123.3 \mu C$
Now, we can find the charge on each individual capacitor.

- Capacitors C_{125} and C_{34} :

Since C_{125} and C_{34} are in parallel, the voltage across both is 15 V . The charge on C_{125} is:

$Q_{125}=C_{125} \times 15=6.22 \mu F \times 15=93.3 \mu C$
The charge on C_{34} is:

$Q_{34}=C_{34} \times 15=2 \mu F \times 15=30 \mu C$

- Charge on C_1 and C_{25} :

The voltage across C_1 and C_{25} (since they are in parallel) is also 15 V . The charge on C_1 is:

$Q_1=C_1 \times 15=4 \mu F \times 15=60 \mu C$
The charge on C_{25} is:

$Q_{25}=C_{25}\times 15=2.22\mu F\times 15=33.3\mu C$

- Charge on C_2 and C_5 :

Since C_2 and C_5 are in series, they have the same charge as Q_{25}, i.e.,

$Q_2=Q_5=Q_{25}=33.3\mu C$

5. a) Mention Einstein's equation for photoelectric effect. Explain the laws of photoelectric effect on the basis of it.

Answer:

Einstein's photoelectric equation is given by:

$E=h\nu=\phi+K_{\max}$
Where:
- E is the energy of the incident photon,
- h is Planck's constant,
- ν is the frequency of the incident light,
- ϕ is the work function of the metal (the minimum energy required to eject an electron),
- $K_{\max}$ is the maximum kinetic energy of the emitted photoelectron.

Laws of Photoelectric Effect Based on Einstein's Equation:
1. Threshold Frequency: For a given material, photoelectric emission occurs only if the frequency of the incident light is above a certain minimum value called the threshold frequency (ν_0). Below this frequency, no photoelectrons are emitted, regardless of the intensity of light.
2. Instantaneous Emission: The photoelectrons are emitted almost instantaneously as soon as the light strikes the surface, provided the frequency of light is greater than the threshold frequency.

3. Kinetic Energy of Photoelectrons: The kinetic energy of the emitted photoelectrons depends on the frequency of the incident light and not on its intensity. Higher frequency light (above the threshold) results in higher kinetic energy of the emitted electrons.
4. Photoelectric Current: The number of photoelectrons emitted (and thus the current) is proportional to the intensity of light, provided the frequency is above the threshold frequency.

b) Explain nuclear fission and nuclear fusion and give difference between them. Energy obtained from the sun is the result of which process?

Answer:

1. Nuclear Fission:
- Definition: Fission is a nuclear reaction in which a heavy nucleus (such as uranium-235 or plutonium-239) splits into two or more lighter nuclei, along with the release of a large amount of energy, neutrons, and gamma radiation.
- Example:

$^{235}\mathrm{U}+n\rightarrow {}^{141}\mathrm{Ba}+{}^{92}\mathrm{Kr}+3n+\text{ energy}$

2. Nuclear Fusion:
- Definition: Fusion is a nuclear reaction where two light atomic nuclei combine to form a heavier nucleus, releasing a tremendous amount of energy in the process.
- Example:

$4{}^{1}H \rightarrow {}^{4}\mathrm{He} + 2e^{+} + 2\nu_e + \text{ energy}$
This reaction happens in stars, including the Sun.

- **Energy from the Sun**: The energy obtained from the Sun is the result of **nuclear fusion**, where hydrogen nuclei fuse to form helium, releasing energy.

c) Write down any four characteristics of electromagnetic waves. Electromagnetic wave is propagating along z-axis in vacuum. What will you say about electric and magnetic field vectors of the wave ? If its wavelength is 10 m what will be its frequency?

Answer:

1. Transverse Nature: Electromagnetic waves are transverse waves, meaning the electric field ($\vec{E}$) and magnetic field $(\vec{B})$ oscillate perpendicular to each other and also perpendicular to the direction of propagation.
2. Speed in Vacuum: Electromagnetic waves travel at the speed of light in a vacuum, which is $c = 3 \times 10^8 \mathrm{~m/s}$.
3. No Medium Required: Electromagnetic waves do not require any material medium for propagation. They can travel through a vacuum.
4. Energy Transmission: Electromagnetic waves carry energy and momentum and can impart both to matter when they interact with it.

Electric and Magnetic Field Vectors:
If an electromagnetic wave is propagating along the $\mathbf{z}$-axis in vacuum:
- The electric field $(\vec{E})$ and magnetic field $(\vec{B})$ vectors are perpendicular to each other and to the direction of propagation.
- Typically, if the wave propagates along the z-axis, the electric field ($\vec{E}$) might oscillate in the x - direction and the magnetic field $(\vec{B})$ in the y -direction.

Frequency of the Wave:
- Given the wavelength $\lambda = 10 \mathrm{~m}$,

Using the relation between speed of light c, frequency f, and wavelength λ :

$c = f\lambda$
Solving for f :

$f = \frac{c}{\lambda} = \frac{3\times10^8 \mathrm{~m/s}}{10 \mathrm{~m}} = 3 \times 10^7 \mathrm{~Hz}$
Thus, the frequency of the wave is $3 \times 10^7 \mathrm{~Hz}$.

d) What is the meaning of power of accommodation of eye ? For a man with hypermetropia near point is at distance of 150 cm from the eye. He wishes to read a book placed at a distance of 25 cm . Which type and of what focal length of lens should he use ?

Answer:

The **power of accommodation** of the eye refers to its ability to adjust the focal length of the lens to focus objects at different distances on the retina. This adjustment allows a person to see objects clearly, whether they are close or far away.

For a man with hypermetropia (farsightedness), the near point (closest distance at which he can see clearly) is 150 cm. If he wants to read a book placed closer than this distance, such as at 25 cm (normal reading distance), he will need **convex lenses** to bring the near point closer to the normal reading distance.

Lens Requirement for Hypermetropia:
In this case:
- The man's near point is at 150 cm (1.5 meters).
- He wishes to read a book placed at 25 cm (normal reading distance).

To correct his vision, he needs a convex lens (converging lens) to bring the near point closer to 25 cm , which is the typical reading distance for someone with normal vision.

Focal Length of the Lens:
We can calculate the focal length of the lens required using the lens formula:

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

where:
- f is the focal length of the lens,
- v is the image distance (distance from the eye to the near point, which is 150 cm),
- u is the object distance (distance of the ↓ ok, which is 25 cm).

Substitute the values:
- $v=-150 \mathrm{~cm}$ (negative because the image is formed on the same side as the object for a convex lens),
- $u=-25 \mathrm{~cm}$ (negative because the object is placed on the same side as the incident light).

Using the lens formula:

$$\frac{1}{f}=\frac{1}{-150}-\frac{1}{-25}$$
$$\frac{1}{f}=\frac{-1}{150}+\frac{1}{25}$$
$$\frac{1}{f}=\frac{-1}{150}+\frac{6}{150}=\frac{5}{150}$$
$$f=\frac{150}{5}=30 \mathrm{~cm}$$

e) State Kirchhoff's laws for electrical circuits. On its basis find the formula for the balanced condition of Wheatstone's bridge.

Answer:

Kirchhoff's laws are fundamental in analyzing electrical circuits, allowing us to determine the currents and voltages in complex networks. There are two key laws:
1. Kirchhoff's Current Law (KCL):
- Statement: The algebraic sum of currents entering and leaving a junction in an electrical circuit is zero.
- Mathematically:

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

or

$$\sum I = 0$$

This law is based on the principle of conservation of charge, meaning that the charge entering a node must equal the charge leaving it.

2. Kirchhoff's Voltage Law (KVL):

- Statement: The algebraic sum of all the voltages around any closed loop in a circuit is zero.
- Mathematically:

$$\sum V = 0$$

This law is based on the conservation of energy, meaning that the total energy supplied by the sources in a closed loop is equal to the total energy consumed by the resistors and other elements.

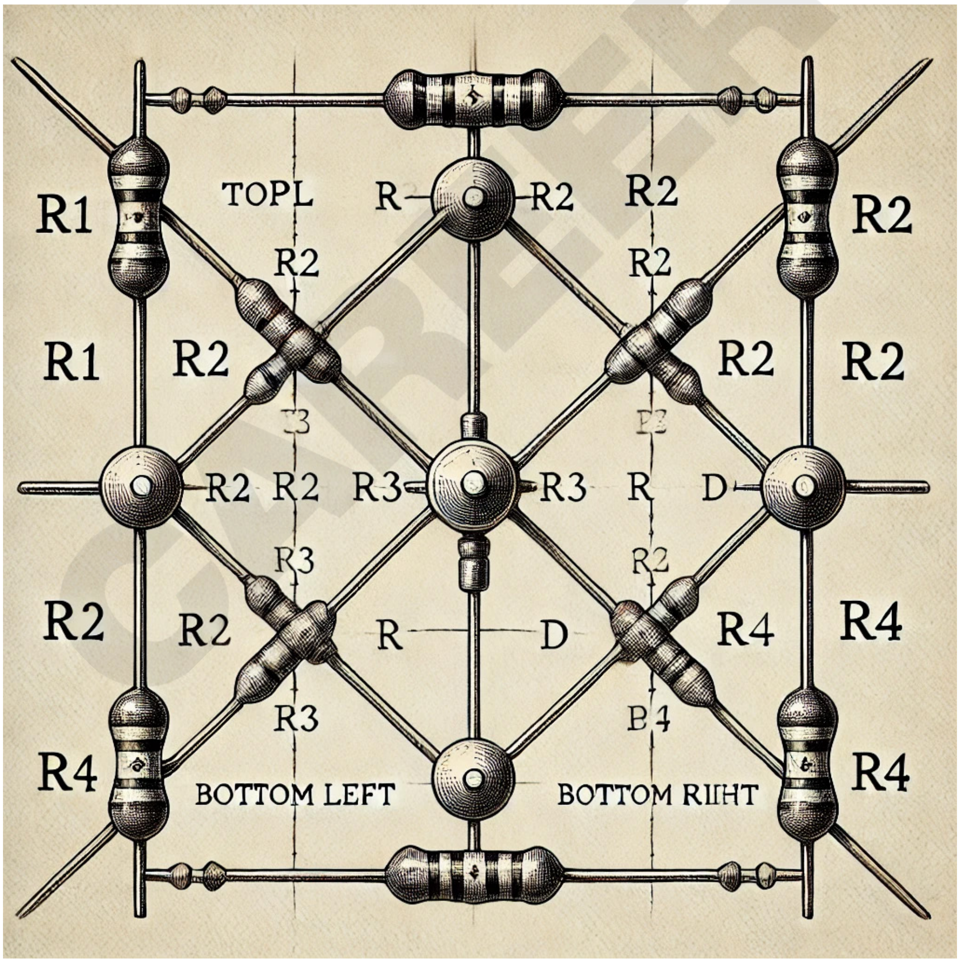
Wheatstone Bridge and Balanced Condition:

The Wheatstone Bridge is a circuit used to precisely measure unknown resistances. It consists of four resistors arranged in a diamond shape with a galvanometer connected across the middle. The bridge is said to be balanced when no current flows through the galvanometer.

Wheatstone Bridge Circuit:

Consider the following resistances:

- R_1 and R_2 are in one branch,
- R_3 and R_4 are in the other branch,
- G is the galvanometer.



The galvanometer is connected between points B and D, and points A and C are connected to a power supply.

Balanced Condition of Wheatstone Bridge:
When the Wheatstone bridge is balanced, no current flows through the galvanometer, meaning the potential difference between points B and D is zero. Under this condition, the following relationship holds:

$\frac{R_1}{R_2}=\frac{R_3}{R_4}$
This is the formula for the balanced condition of a Wheatstone Bridge. It means that the ratios of resistances in both branches of the bridge must be equal for the bridge to be balanced.

6. State and prove Gauss's theorem in electrostatics. $17.7 \times 10^{-12}\mathrm{C}$ charge is present inside a hollow cylinder. Electric flux associated with its curved surface is $1.5\ \mathrm{N}-\mathrm{m}^2-\mathrm{C}^{-1}$. What will be the value of electric flux associated with either of its plane surfaces?

Answer:

Statement:
Gauss's theorem in electrostatics states that the total electric flux Φ_E through a closed surface (called a Gaussian surface) is equal to the net charge Q_{enc} enclosed within that surface divided by the permittivity of the medium ε_0.

Mathematically,

$$\Phi_E=\oint_S \vec{E} \cdot d\vec{A}=\frac{Q_{\text{enc}}}{\varepsilon_0}$$

where $\vec{E}$ is the electric field, $d\vec{A}$ is a differential area vector on the closed surface S, and ε_0 is the permittivity of free space, whose value is $8.854 \times 10^{-12}\mathrm{C}^2/\mathrm{Nm}^2$.

Proof:
1. Electric Flux Definition:

Electric flux through a surface is defined as the dot product of the electric field $\vec{E}$ and the differential area vector $d\vec{A}$:

$$\Phi_E=\oint_S \vec{E} \cdot d\vec{A}$$

2. Applying Gauss's Law:

By applying Gauss's theorem, the total electric flux through a closed surface is proportional to the charge enclosed inside the surface:

$$\Phi_E=\frac{Q_{\text{enc}}}{\varepsilon_0}$$

3. Explanation:

The theorem implies that the electric field at every point on a Gaussian surface contributes to the total flux. The total flux depends only on the charge enclosed by the surface and not on the shape or size of the surface.

To prove this, consider a spherical Gaussian surface centered on a point charge Q. Due to symmetry, the electric field $\vec{E}$ is radial and has the same magnitude at every point on the surface. Therefore, the flux through a differential area element $dA=r^2 \sin\theta d\theta d\phi$ on the sphere is:

$d\Phi_E = E \cdot dA = \frac{Q}{4\pi\varepsilon_0 r^2} \cdot r^2 \sin\theta d\theta d\phi$
Integrating over the entire spherical surface gives the total flux as:

$$\Phi_E = \frac{Q}{\varepsilon_0}$$

Given:
- Charge enclosed inside the hollow cylinder, $Q = 17.7 \times 10^{-12}\mathrm{C}$
- Electric flux through the curved surface, $\Phi_{\text{curved}} = 1.5\mathrm{Nm}^2/\mathrm{C}$

Gauss's theorem tells us that the total electric flux Φ_{total} through the entire closed surface of the hollow cylinder (including the curved surface and two plane surfaces) is given by:

$$\Phi_{\text{total}} = \frac{Q}{\varepsilon_0}$$

Substituting the values:

$$\Phi_{\text{total}} = \frac{17.7 \times 10^{-12}}{8.854 \times 10^{-12}} \approx 2.0\mathrm{Nm}^2/\mathrm{C}$$

Now, the total electric flux is the sum of the flux through the curved surface and the two plane surfaces. Therefore,

$$\Phi_{\text{total}} = \Phi_{\text{curved}} + 2 \cdot \Phi_{\text{plane}}$$

Substituting the known values:

$$2.0 = 1.5 + 2 \cdot \Phi_{\text{plane}}$$

Solving for Φ_{plane} :

$$2 \cdot \Phi_{\text{plane}} = 2.0 - 1.5 = 0.5$$
$$\Phi_{\text{plane}} = \frac{0.5}{2} = 0.25\mathrm{Nm}^2/\mathrm{C}$$

Final Answer:
The electric flux associated with either of the plane surfaces is $0.25\mathrm{Nm}^2/\mathrm{C}$.

7. Find the expression for the width of bright and dark fringes in Young's double slit experiment.

Answer:

Let's derive the expressions for the width of the bright and dark fringes.
1. Fringe Width (Distance Between Consecutive Bright or Dark Fringes):

In Young's double-slit experiment, the fringe width (also known as fringe spacing) is the distance between two consecutive bright or dark fringes. This fringe width is the same for both bright and dark fringes.

The positions of the bright and dark fringes depend on the path difference between the two slits.
- Path Difference:

The path difference between the light waves from the two slits reaching a point on the screen is given by:

$$\Delta = d\sin\theta$$

where d is the distance between the two slits, and θ is the angle subtended by the point on the screen with respect to the slits.
2. Condition for Bright Fringes (Constructive Interference):

Constructive interference occurs when the path difference is an integer multiple of the wavelength λ :

$$\Delta = n\lambda \quad \text{for } n = 0, \pm 1, \pm 2, \ldots$$

Thus, the angular position of the n-th bright fringe is:

$$d \sin \theta_n = n\lambda$$

For small angles $(\theta \ll 1), \sin \theta \approx \theta \approx \frac{x_n}{L}$, where x_n is the position of the n-th fringe on the screen, and L is the distance between the slits and the screen. Therefore,

$$d \frac{x_n}{L} = n\lambda$$

Solving for x_n, the position of the n-th bright fringe:

$$x_n = \frac{n\lambda L}{d}$$

3. Fringe Width β :

The fringe width β is the distance between two consecutive bright (or dark) fringes. For two consecutive bright fringes at n and $n+1$, their positions are:

$$x_{n+1} - x_n = \frac{(n+1)\lambda L}{d} - \frac{n\lambda L}{d} = \frac{\lambda L}{d}$$

Thus, the fringe width (distance between consecutive bright or dark fringes) is:

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

This is the distance between any two consecutive bright fringes or dark fringes.
4. Condition for Dark Fringes (Destructive Interference):

Destructive interference occurs when the path difference is an odd multiple of $\frac{\lambda}{2}$:

$$\Delta = (2n+1)\frac{\lambda}{2} \quad \text{for } n = 0, \pm 1, \pm 2, \ldots$$

Thus, the angular position of the n-th dark fringe is:

$$d \sin \theta_n = (2n+1)\frac{\lambda}{2}$$

For small angles $\left(\sin \theta \approx \theta \approx \frac{x_n}{L}\right)$, the position of the n-th dark fringe is:

$$x_n = \frac{(2n+1)\lambda L}{2d}$$

The spacing between consecutive dark fringes is also $\frac{\lambda L}{d}$, which is the same as the fringe width for bright fringes.

8. State the postulates of Bohr's atomic model. Derive the formula for the radius of the Bohr orbit of hydrogen atom on its basis.

Answer:

Bohr's atomic model was proposed to explain the stability of atoms and the quantized nature of atomic spectra, particularly for hydrogen. The key postulates of Bohr's atomic model are:
1. Quantization of Angular Momentum:

Electrons revolve around the nucleus in specific, discrete orbits without emitting radiation. These orbits are called stationary orbits. The angular momentum of the electron in these orbits is quantized and given by:

$$L = n\frac{h}{2\pi} = n\hbar$$

where L is the angular momentum, n is a positive integer (called the principal quantum number), h is Planck's constant, and $\hbar = \frac{h}{2\pi}$.
2. Stationary Orbits and Energy:

Electrons can revolve only in specific orbits where the total energy of the electron is quantized. In these orbits, electrons do not radiate energy. Radiation is emitted or absorbed only when the electron transitions between these stationary orbits.
3. Energy Emission and Absorption:

When an electron jumps from a higher-energy orbit to a lower-energy orbit, it emits energy in the form of electromagnetic radiation. The energy of the emitted or absorbed radiation corresponds to the difference in energy between the two orbits:

$$\Delta E = E_2 - E_1 = h\nu$$

where ν is the frequency of the emitted or absorbed radiation.
4. Centripetal Force and Electrostatic Attraction:

The electron's motion in a circular orbit is due to the electrostatic force of attraction between the positively charged nucleus and the negatively charged electron. The centripetal force required for the electron's circular motion is provided by this electrostatic attraction.

Derivation of the Radius of Bohr's Orbit for Hydrogen Atom
To derive the formula for the radius of the Bohr orbit, we apply the above postulates, specifically the quantization of angular momentum and the balance of electrostatic and centripetal forces.
1. Centripetal Force $=$ Electrostatic Force:

In the hydrogen atom, the electrostatic force between the electron (charge $-e$) and the proton (charge $+e$) is given by Coulomb's law:

$$F_{\text{elec}} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

where r is the radius of the electron's orbit, and ε_0 is the permittivity of free space.

$$\Delta E = E_2 - E_1 = h\nu$$

where ν is the frequency of the emitted or absorbed radiation.
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$$F_{\text{elec}} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

where r is the radius of the electron's orbit, and ε_0 is the permittivity of free space.

This electrostatic force provides the necessary centripetal force to keep the electron in circular motion:

$$F_{\text{centripetal}} = \frac{mv^2}{r}$$

where m is the mass of the electron, and v is the velocity of the electron in the orbit.

Equating the centripetal force to the electrostatic force:

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

Simplifying:

$$mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

$$v^2 = \frac{1}{m}\cdot\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

2. Quantization of Angular Momentum:

According to Bohr's quantization postulate, the angular momentum of the electron is quantized:

$$mvr \underset{\downarrow}{\downarrow} n\frac{h}{2\pi} = n\hbar$$

Solving for the velocity v :

$$v = \frac{n\hbar}{mr}$$

3. Expression for the Radius:

Substitute the value of v^2 from the quantization of angular momentum into the centripetal force equation:

$$\left(\frac{n\hbar}{mr}\right)^2 = \frac{1}{m}\cdot\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

Simplifying:

$$\frac{n^2\hbar^2}{m^2r^2} = \frac{1}{m}\cdot\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$$

Multiplying both sides by r :

$$\frac{n^2\hbar^2}{m^2r} = \frac{1}{m}\cdot\frac{1}{4\pi\varepsilon_0}e^2$$

Solving for r :

$$r=\frac{4 \pi \varepsilon_0 n^2 \hbar^2}{m e^2}$$

4. Bohr Radius:

For the first orbit ($n=1$), the radius is called the Bohr radius r_1 :

$$r_1=\frac{4 \pi \varepsilon_0 \hbar^2}{m e^2}$$

Substituting known values for constants:

$$r_1 \approx 5.29 \times 10^{-11} \mathrm{~m}$$

Thus, the radius of the n-th orbit in the hydrogen atom is:

$$r_n=n^2 r_1=\frac{4 \pi \varepsilon_0 n^2 \hbar^2}{m e^2}$$

9) Why is a potentiometer considered superior to a voltmeter ? The length of a potentiometer wirc is 200 cm and a current of $3 \times 10^{-2} \mathrm{~A}$ is flowing in it. Balance point is obtained at 50 cm when connected with the cell of 1.5 V and internal resistance 10Ω. When a voltmeter is connected with the cell balance point is obtained at 49 cm . Calculate the resistance of potentiometer wire, resistance and reading of voltmeter.

Answer:

A **potentiometer** is considered superior to a voltmeter for measuring the potential difference (voltage) because of the following reasons:

1. **No Current Drawn from the Source:** A potentiometer measures the voltage of a circuit without drawing any current from the circuit, as it works on the principle of null deflection (i.e., no current flows through the galvanometer at the balance point). This ensures an accurate measurement of the electromotive force (EMF) of the cell, which is not affected by the internal resistance of the cell or the current drawn by the measuring device.

2. **High Sensitivity and Precision:** Since a potentiometer can be designed with a long wire and small resistances, it can detect very small changes in potential difference, making it highly sensitive. Its accuracy depends on the uniformity and length of the wire, and it can provide highly precise results.

3. **No Loading Effect:** A voltmeter, especially an analog one, draws a small current from the circuit while measuring the voltage, which can lead to a slight drop in the voltage being measured, called the **loading effect**. In contrast, a potentiometer avoids this issue because it measures the EMF without disturbing the circuit.

Given:
- Length of potentiometer wire, $L=200 \mathrm{~cm}=2.00 \mathrm{~m}$
- Current through the potentiometer, $I=3 \times 10^{-2} \mathrm{~A}$
- Balance point when the cell is connected, $l_1=50 \mathrm{~cm}=0.50 \mathrm{~m}$
- EMF of the cell, $\mathcal{E}=1.5 \mathrm{~V}$
- Internal resistance of the cell, $r_{\text {internal }}=10 \Omega$
- Balance point with voltmeter connected, $l_2=49 \mathrm{~cm}=0.49 \mathrm{~m}$

We need to calculate:
1. Resistance of the potentiometer wire.
2. Resistance of the voltmeter.
3. Reading of the voltmeter.

1. Resistance of the Potentiometer Wire

The potential gradient k of the potentiometer wire is the potential drop per unit length along the wire. Using the balance point $l_1 = 50 \mathrm{~cm}$ when connected to the cell of EMF 1.5 V :

$$\mathcal{E} = k \cdot l_1$$
$$k = \frac{\mathcal{E}}{l_1} = \frac{1.5 \mathrm{~V}}{0.50 \mathrm{~m}} = 3 \mathrm{~V/m}$$

The total potential drop along the entire length $L = 2 \mathrm{~m}$ of the potentiometer wire is given by Ohm's law:

$$V_{\text{total}} = IR$$

where R is the resistance of the potentiometer wire.
The potential drop across the entire wire is also related to the potential gradient k and the total length L :

$$V_{\text{total}} = k \cdot L = 3 \mathrm{~V/m} \times 2.00 \mathrm{~m} = 6 \mathrm{~V}$$

Now using Ohm's law:

$$V_{\text{total}} = I \cdot R$$
$$6 \mathrm{~V} = 3 \times 10^{-2} \mathrm{~A} \times R$$

Solving for R :

$$R = \frac{6 \mathrm{~V}}{3 \times 10^{-2} \mathrm{~A}} = 200 \Omega$$

Thus, the resistance of the potentiometer wire is $R = 200 \Omega$.

2. Resistance of the Voltmeter

With the voltmeter connected, the balance point shifts to $l_2 = 49 \mathrm{~cm} = 0.49 \mathrm{~m}$, and the corresponding voltage across the cell is:

$$V = k \cdot l_2 = 3 \mathrm{~V/m} \times 0.49 \mathrm{~m} = 1.47 \mathrm{~V}$$

This is the terminal voltage of the cell when the voltmeter is connected, and the current I_{cell} through the cell (including internal resistance r_{internal}) is given by:

$$I_{\text{cell}} = \frac{\mathcal{E} - V}{r_{\text{internal}}}$$

Substituting the known values:

$$I_{\text{cell}} = \frac{1.5 \mathrm{~V} - 1.47 \mathrm{~V}}{10 \Omega} = \frac{0.03 \mathrm{~V}}{10 \Omega} = 3 \times 10^{-3} \mathrm{~A}$$

The voltmeter is in parallel with the cell, so the current through the voltmeter is the same as I_{cell} . The resistance of the voltmeter $R_{\text{voltmeter}}$ can be found using Ohm's law:

$$V = I_{\text{cell}} \cdot R_{\text{voltmeter}}$$
$$1.47 \mathrm{~V} = 3 \times 10^{-3} \mathrm{~A} \times R_{\text{voltmeter}}$$

Solving for $R_{\text{voltmeter}}$:

$R_{\text{voltmeter}} = \frac{1.47\ \text{V}}{3 \times 10^{-3}\ \text{A}} = 490\Omega$

Thus, the resistance of the voltmeter is $R_{\text{voltmeter}} = 490\Omega$.

3. Reading of the Voltmeter

The reading of the voltmeter is the terminal voltage of the cell, which is the same as the voltage calculated at the shifted balance point with the voltmeter connected:

$V_{\text{voltmeter}} = 1.47\ \text{V}$