UP Borad Class 12 Physics Code 346 BT 2023 Question Paper with Solutions

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

General Instructions

Instruction:

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

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

iii) Give relevant answers to the questions.

iv) Give chemical equations, wherever necessary.

1. a) Unit of $\frac{1}{\mu_0 \epsilon_0}$ is:

(A) $\frac{m^2}{s^2}$

(B) $\frac{m}{s}$

(C) $\frac{s^2}{m^2}$

(D) $\frac{s}{m}$

Correct Answer: (C) $\frac{s^2}{m^2}$

Solution:

Step 1: Understanding the units.

The quantity μ_0 is the permeability of free space, and ϵ_0 is the permittivity of free space. The value of $\frac{1}{\mu_0 \epsilon_0}$ is related to the speed of light. The SI units of this quantity come out to be $\frac{s^2}{m^2}$.

Step 2: Conclusion.

The correct unit for $\frac{1}{\mu_0 \epsilon_0}$ is $\frac{s^2}{m^2}$, so the correct answer is (C).

> **Quick Tip**
>
> The value $\frac{1}{\mu_0 \epsilon_0}$ is related to the speed of light, and its units are derived from the speed of light formula.

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1. b) The equation $E = pc$, where E, p, and c represent energy, momentum, and velocity of light, is valid:

(A) for an electron as well as for a photon

(B) for a photon but not for an electron

(C) for an electron but not for a photon

(D) neither for an electron nor for a photon

Correct Answer: (B) for a photon but not for an electron

Solution:

Step 1: Understanding the equation.

The equation $E = pc$ is a relativistic equation that is valid for massless particles like photons. For an electron, the equation $E = pc$ does not hold true because electrons have mass.

Step 2: Analysis of options.

- (A) For an electron as well as for a photon: This is incorrect because $E = pc$ is not valid for an electron.

- (B) For a photon but not for an electron: This is correct because the equation is valid for photons, but not for electrons.

- (C) For an electron but not for a photon: This is incorrect because the equation is not valid for electrons.

- (D) Neither for an electron nor for a photon: This is incorrect because it is valid for photons.

Step 3: Conclusion.

The correct answer is (B) for a photon but not for an electron.

> Quick Tip
>
> The equation $E = pc$ is specific to massless particles such as photons. For particles with mass like electrons, a different relativistic formula is used.

---

1. c) As the temperature of a metal and of a semiconductor is increased, the:

(A) conductivity of both increases

(B) conductivity of both decreases

(C) conductivity of metal increases and of semiconductor decreases

(D) conductivity of metal decreases and of semiconductor increases

Correct Answer: (C) conductivity of metal increases and of semiconductor decreases

Solution:

Step 1: Understanding the behavior of materials with temperature.

As temperature increases, the conductivity of metals generally decreases because the increased thermal motion of atoms causes more resistance to electron flow. On the other hand, the conductivity of semiconductors increases with temperature due to the increased generation of charge carriers.

Step 2: Conclusion.

The correct answer is (C) because the conductivity of metals decreases and the conductivity of semiconductors increases with temperature.

> Quick Tip
>
> In metals, conductivity decreases with temperature, while in semiconductors, it increases due to the generation of charge carriers.

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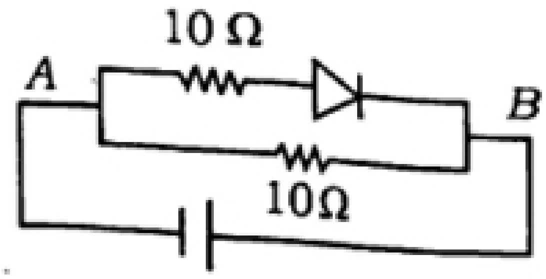
1. d) The equivalent resistance of the network shown in figure between A and B is:



(A) 10 Ω

(B) 20 Ω

(C) 5 Ω

(D) 15 Ω

Correct Answer: (D) 15 Ω

Solution:

Step 1: Understanding the arrangement of resistors.

The two 10 Ω resistors are connected in parallel. The formula for the equivalent resistance of two resistors in parallel is given by:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Substituting $R_1 = R_2 = 10\,\Omega$, we get:

$$\frac{1}{R_{eq}} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10}$$

$$R_{eq} = \frac{10}{2} = 5\,\Omega$$

Step 2: Conclusion.

The equivalent resistance of the network is $5\,\Omega$, so the correct answer is (D).

> **Quick Tip**
>
> When two resistors are in parallel, the equivalent resistance is always less than the resistance of the smallest resistor.

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1. e) In a transistor:

(A) the emitter has the least concentration of impurity

(B) the collector has the least concentration of impurity

(C) the base has the least concentration of impurity

(D) all three regions have equal concentration of impurity

Correct Answer: (C) the base has the least concentration of impurity

Solution:

Step 1: Understanding transistor structure.

In a transistor, the base region is lightly doped compared to the emitter and collector. This is done to allow for efficient control of the current flowing between the emitter and collector.

Step 2: Conclusion.

The correct answer is (C) because the base of the transistor has the least concentration of impurity.

> **Quick Tip**
>
> The base of a transistor is lightly doped to control the flow of charge carriers between the emitter and collector.

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1. f) The net resistance of an ammeter should be small to ensure that:

(A) it does not get overheated

(B) it does not draw excessive current

(C) it can measure large currents

(D) it does not appreciably change the current to be measured

Correct Answer: (D) it does not appreciably change the current to be measured

Solution:

Step 1: Understanding the function of an ammeter.

An ammeter is used to measure current, and it is connected in series with the circuit. To avoid altering the current in the circuit, the ammeter's resistance should be as small as possible.

Step 2: Conclusion.

The correct answer is (D) because a small resistance ensures that the ammeter does not significantly affect the current it is measuring.

> **Quick Tip**
>
> Ammeter resistance should be very low so that it does not significantly change the current in the circuit.

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

Solution:

Step 1: Understanding orbital angular momentum.

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

$$L = n\hbar$$

where n is the principal quantum number, and $\hbar$ is the reduced Planck's constant, given by:

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

For the minimum orbital angular momentum, the electron is in the ground state where $n = 1$. Thus, the minimum angular momentum is:

$$L = 1 \times \hbar = \hbar$$

Step 2: Conclusion.

Therefore, the minimum orbital angular momentum is $\hbar$.

> **Quick Tip**
>
> In the ground state of the hydrogen atom, the minimum orbital angular momentum is equal to the reduced Planck's constant, $\hbar$.

---

b) Define optical centre of a lens.

Solution:

Step 1: Understanding optical centre.

The optical centre of a lens is the point within the lens at which a ray of light passing through it does not undergo any deviation. In other words, light that passes through the optical centre of the lens does not get refracted, and it continues its path without bending.

Step 2: Characteristics of the optical centre.

The optical centre is usually located at the intersection of the two principal planes of the lens, and it is the point where the two surfaces of the lens are symmetrically aligned.

Step 3: Conclusion.

In a convex or concave lens, the optical centre is the point where light passes through without deviation.

> **Quick Tip**
>
> The optical centre is the point within a lens where light does not get refracted.

---

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

Solution:

Step 1: Understanding the carbon isotopes.

The ${}^{12}_{6}C$ atom has 6 protons and 6 neutrons, while the ${}^{14}_{6}C$ atom has 6 protons and 8 neutrons.

Step 2: Comparing the number of protons and neutrons.

- The number of protons remains the same in both isotopes, i.e., 6 protons in both ${}^{12}_{6}C$ and ${}^{14}_{6}C$.

- The number of neutrons in ${}^{12}_{6}C$ is 6, while in ${}^{14}_{6}C$ it is 8. Therefore, the ${}^{14}_{6}C$ atom has 2 extra neutrons compared to ${}^{12}_{6}C$.

Step 3: Conclusion.

The ${}^{14}_{6}C$ atom has 2 extra neutrons compared to ${}^{12}_{6}C$, and the number of protons remains unchanged.

> **Quick Tip**
>
> The number of protons in isotopes of the same element remains the same, but the number of neutrons can vary.

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

Solution:

Step 1: Formula for energy released due to mass defect.

The energy released in the mass defect is given by Einstein's equation:

$$E = \Delta mc^2$$

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

Step 2: Substituting the values.

The mass defect is given as 1 amu. To convert this into kg, we use the conversion factor:

$$1\,\text{amu} = 1.660539 \times 10^{-27}\,\text{kg}$$

The speed of light c is 3×10^8 m/s.

Now, substituting these values into the formula:

$$E = 1.660539 \times 10^{-27} \times (3 \times 10^8)^2$$

$$E = 1.660539 \times 10^{-27} \times 9 \times 10^{16} = 1.494485 \times 10^{-10}\,\text{J}$$

Step 3: Conclusion.

Therefore, the energy released due to a mass defect of 1 amu is $1.494485 \times 10^{-10}\,\text{J}$.

Quick Tip

The energy released in a mass defect is directly related to the mass using the equation $E = \Delta mc^2$.

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

Solution:

Step 1: Electric flux formula.

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

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

Step 2: Substituting the values.

We are given:

$$\vec{E} = 3\hat{i} + 4\hat{j}\,\text{N/C}, \quad \vec{A} = 10\hat{i}\,\text{m}^2$$

Now, calculate the dot product:

$$\Phi_E = (3\hat{i} + 4\hat{j}) \cdot (10\hat{i})$$

Since the $\hat{j}$ component of the area vector is 0, we only consider the $\hat{i}$ component:

$$\Phi_E = 3 \times 10 = 30\,\text{Nm}^2/\text{C}$$

Step 3: Conclusion.

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

Quick Tip

The electric flux is calculated as the dot product of the electric field vector and the area vector.

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

Solution:

Step 1: Logic symbol of a NOR gate.

The logic symbol for a NOR gate is:

NOR Gate Symbol: (similar to OR gate, but with a circle at the output)

Step 2: Truth table for NOR gate.

The truth table for a NOR gate is as follows:

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

Step 3: Conclusion.

The NOR gate produces an output of 1 only when both inputs are 0.

Quick Tip

A NOR gate is the complement of an OR gate. It gives an output of 1 only when all inputs are 0.

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

Solution:

Step 1: Energy formula for hydrogen-like ions.

The energy of an electron in the n-th orbit of a hydrogen-like atom is given by the formula:

$$E_n = -\frac{13.6\,\text{eV} \times Z^2}{n^2}$$

where Z is the atomic number, n is the principal quantum number, and $13.6\,\text{eV}$ is the energy of the ground state of hydrogen.

Step 2: Apply the formula for He$^+$.

For He$^+$ (with $Z = 2$), the energy of the electron in the first excited state corresponds to $n = 2$. Substituting into the formula:

$$E_2 = -\frac{13.6 \times 2^2}{2^2} = -\frac{13.6 \times 4}{4} = -13.6\,\text{eV}$$

Step 3: Conclusion.

The energy of the electron in the first excited state of He$^+$ is $-13.6\,\text{eV}$.

> **Quick Tip**
>
> The energy of the electron in the excited state is always less negative than the ground state energy, but it still remains negative.

---

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

Solution:

Step 1: Definition of drift velocity.

Drift velocity is the average velocity of free electrons in a conductor due to an applied electric field. It is the net velocity that the electrons acquire under the influence of the electric field, superimposed on their random thermal motion.

Step 2: Relation between drift velocity and current density.

The relation between drift velocity v_d and current density J is given by Ohm's law in terms of electron drift:

$$J = nev_d$$

where: - J is the current density (in A/m²), - n is the number of free electrons per unit volume, - e is the charge of an electron (approximately 1.6×10^{-19} C), - v_d is the drift velocity (in m/s).

Step 3: Conclusion.

The drift velocity v_d is directly related to the current density J by the equation $J = nev_d$.

Quick Tip

Drift velocity is the average speed of electrons moving in response to an electric field, and it is related to the current density through the equation $J = nev_d$.

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

Solution:

Step 1: Electric potential of a dipole.

The electric potential at a point on the axial line of an electric dipole is given by:

$$V = \frac{1}{4\pi\epsilon_0}\frac{2p\cos\theta}{r^2}$$

where: - V is the electric potential, - p is the dipole moment ($p = q \times 2a$, where q is the charge and $2a$ is the separation between the charges), - r is the distance from the center of the dipole to the point where the potential is being calculated, - θ is the angle between the dipole axis and the position vector of the point, - ϵ_0 is the permittivity of free space.

Step 2: Electric potential along the axial line.

For points along the axial line, $\theta = 0$, so $\cos 0 = 1$, and the electric potential simplifies to:

$$V = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^2}$$

Step 3: Conclusion.

The electric potential at a point on the axial line of an electric dipole is:

$$V = \frac{1}{4\pi\epsilon_0}\frac{2p}{r^2}$$

Quick Tip

The electric potential on the axial line of a dipole is inversely proportional to the square of the distance from the dipole.

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

Solution:

Step 1: Understanding matter waves.

Matter waves are waves associated with particles of matter, as proposed by Louis de Broglie. He suggested that every moving particle, such as an electron, behaves as if it is a wave. These waves are called de Broglie waves.

The wavelength λ of a matter wave is related to the momentum p of the particle. This is described by the de Broglie equation.

Step 2: de Broglie equation.

The de Broglie equation is given by:

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

where: - λ is the de Broglie wavelength, - h is Planck's constant ($h = 6.626 \times 10^{-34}$ J s), - p is the momentum of the particle ($p = mv$, where m is the mass and v is the velocity of the particle).

Step 3: Conclusion.

The de Broglie equation relates the wavelength of a matter wave to the momentum of the particle:

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

Quick Tip

De Broglie's hypothesis established that particles, like electrons, can exhibit wave-like behavior, with the wavelength inversely proportional to the momentum.

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

Solution:

Step 1: Critical Angle.

The critical angle is defined as the angle of incidence in a denser medium for which the angle of refraction in the rarer medium is 90°. Beyond this angle, total internal reflection occurs.

Mathematically, the critical angle θ_c is given by:

$$\sin \theta_c = \frac{n_2}{n_1}$$

where n_1 is the refractive index of the denser medium, and n_2 is the refractive index of the rarer medium.

Step 2: Working of Optical Fibre.

Optical fibres work on the principle of total internal reflection. The core of the optical fibre has a higher refractive index, and the cladding surrounding it has a lower refractive index. Light is injected into the core, and it undergoes total internal reflection, keeping the light confined within the core, even when the fibre is bent. This allows the transmission of light over long distances with minimal loss.

Step 3: Conclusion.

The critical angle defines the condition for total internal reflection, which is essential for the working of optical fibres.

> **Quick Tip**
>
> In optical fibres, total internal reflection ensures the light stays within the core, enabling efficient transmission over long distances.

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

Solution:

Step 1: Einstein's Photoelectric Equation.

The photoelectric equation is given by:

$$E_k = hf - \phi$$

where: - E_k is the kinetic energy of the emitted electrons, - h is Planck's constant ($h = 6.626 \times 10^{-34}$ J s), - f is the frequency of the incident light, - ϕ is the work function of the metal.

The stopping potential is related to the kinetic energy of the emitted electrons by the equation:

$$E_k = eV_s$$

where e is the charge of the electron, and V_s is the stopping potential.

Step 2: Calculating the stopping potential.

The energy of the incident photons is given by:

$$E = hf = (6.626 \times 10^{-34}) \times (6.0 \times 10^{14}) = 3.976 \times 10^{-19}\,\text{J}$$

Now, using the photoelectric equation:

$$E_k = 3.976 \times 10^{-19} - 2.5 \times 10^{-19} = 1.476 \times 10^{-19}\,\text{J}$$

Now, using the relation $E_k = eV_s$:

$$V_s = \frac{E_k}{e} = \frac{1.476 \times 10^{-19}}{1.6 \times 10^{-19}} = 0.92\,\text{V}$$

Step 3: Conclusion.

The stopping potential is $0.92\,\text{V}$.

> **Quick Tip**
>
> The stopping potential is the potential required to stop the fastest emitted electron in the photoelectric effect.

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

Solution:

Step 1: Biot-Savart Law.

The Biot-Savart law gives the magnetic field $\vec{B}$ produced at a point by a small current element. The law is given by:

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

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

Step 2: Unit of μ_0.

Rearranging the Biot-Savart law to isolate μ_0:

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

From this, we can see that the units of μ_0 are derived as follows:

$$[\mu_0] = \frac{\text{T m}^2}{\text{A}}$$

Thus, the unit of μ_0 is $\frac{\text{T m}^2}{\text{A}}$, where T is the tesla, m is meters, and A is amperes.

Step 3: Conclusion.

The unit of μ_0 is $\frac{\text{T m}^2}{\text{A}}$.

Quick Tip

The Biot-Savart law helps us calculate the magnetic field generated by a current element in a conductor.

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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?

Solution:

Step 1: Formula for minimum deviation.

The angle of minimum deviation D_{min} for a prism is given by:

$$D_{\text{min}} = 2i - A$$

where i is the angle of incidence, and A is the angle of the prism.

Step 2: Formula for the refractive index.

The refractive index n of the material of the prism is related to the minimum deviation by the equation:

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

Substitute $n = 1.732$ and $A = 60°$:

$$1.732 = \frac{\sin\left(\frac{60° + D_{\text{min}}}{2}\right)}{\sin\left(\frac{60°}{2}\right)}$$

Using the known values:

$$\sin(30°) = 0.5$$

Solving for D_{min}, we get:

$$D_{\text{min}} = 30°$$

Step 3: Conclusion.

The angle of minimum deviation is $30°$. The angle of incidence for the deviation is $30°$.

Quick Tip

For the minimum deviation in a prism, the angle of incidence is equal to the angle of emergence, and the total deviation is minimized.

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

Solution:

Step 1: Understanding the setup.

When a metallic stick is rotated in a magnetic field, the emf induced between the ends of the stick is due to the motion of the conductive material in the magnetic field.

The induced emf is given by:

$$\mathcal{E} = B\omega L^2$$

where: - B is the magnetic field strength, - ω is the angular velocity, - L is the length of the stick.

Step 2: Conclusion.

The induced emf between the ends of the stick is:

$$\mathcal{E} = B\omega L^2$$

Quick Tip

When a conductor moves in a magnetic field, the induced emf depends on the speed of the conductor, its length, and the magnetic field strength.

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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?

Solution:

Step 1: Understanding the setup.

Let the diverging lens be L_1 and the converging lens be L_2. The focal lengths of L_1 and L_2 are $f_1 = -20\,\text{cm}$ (diverging lens) and $f_2 = +30\,\text{cm}$ (converging lens). The distance between the two lenses is $d = 15\,\text{cm}$.

The object should be placed in such a way that the rays coming out of L_1 (diverging lens) and converging at L_2 form an image at infinity.

Step 2: Using the lens formula.

The lens formula for a single lens is given by:

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

where: - f is the focal length of the lens, - v is the image distance, - u is the object distance.

For the diverging lens L_1, the image formed will be virtual, and the rays will diverge, but the image formed by L_1 will act as a virtual object for L_2.

Let the object distance for L_1 be u_1, and the image distance for L_1 be v_1. Then, the object distance for L_2 is:

$$u_2 = d - v_1$$

Now, applying the lens formula for L_1 and L_2, we can calculate u_1 to find the position where the object should be placed.

Step 3: Conclusion.

After solving the lens equations, the object should be placed at $u_1 \approx 60\,\text{cm}$ from the diverging lens L_1 so that the image is formed at infinity.

Quick Tip

In a system of two lenses, the image formed by the first lens acts as the object for the second lens, and the distances must be carefully calculated using the lens formula for both lenses.

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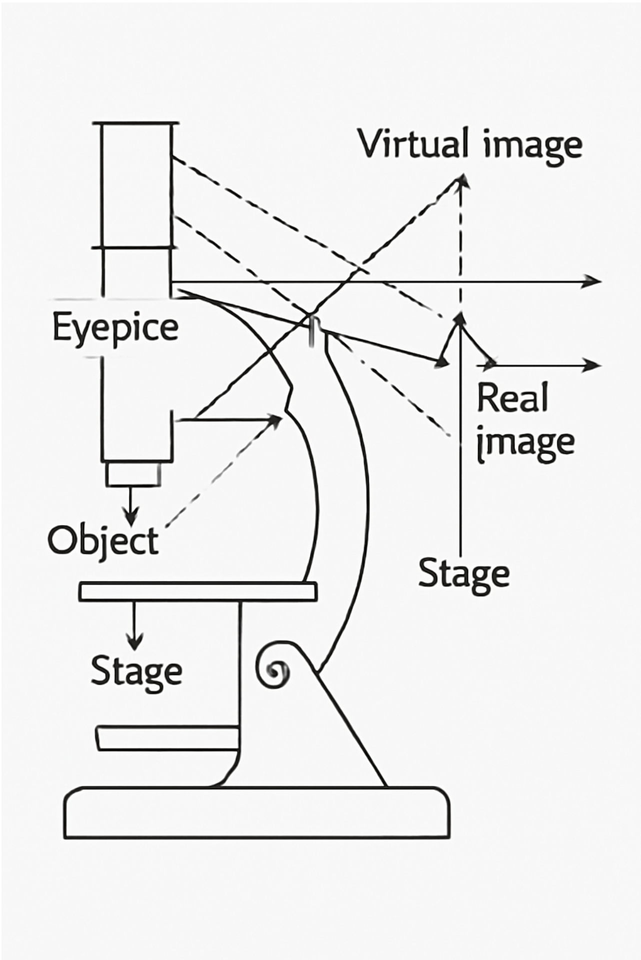
b) Draw a suitable ray diagram of a compound microscope, when the image is formed at the least distance of distinct vision. Find the expression of magnifying power in this case.

Solution:

Step 1: Ray Diagram for Compound Microscope.

The compound microscope consists of an objective lens (converging lens) and an eyepiece. The object is placed at a distance u_o such that the image formed by the objective lens is at the focus of the eyepiece.



Step 2: Magnifying Power.

The magnifying power M of a compound microscope is given by the product of the magnifying powers of the objective lens and the eyepiece:

$$M = M_{\text{obj}} \times M_{\text{eye}}$$

where: - $M_{\text{obj}} = \frac{v_o}{u_o}$ is the magnification produced by the objective lens, - $M_{\text{eye}} = \frac{D}{f_e}$ is the magnification produced by the eyepiece, where D is the least distance of distinct vision (usually taken as $25\,\text{cm}$) and f_e is the focal length of the eyepiece.

For the compound microscope, the total magnification is given by:

$$M = \frac{D}{f_o} \times \frac{25}{f_e}$$

where f_o is the focal length of the objective lens and f_e is the focal length of the eyepiece.

Step 3: Conclusion.

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

$$M = \frac{D}{f_o} \times \frac{25}{f_e}$$

Quick Tip

The total magnification of a compound microscope depends on both the focal length of the objective lens and the eyepiece.

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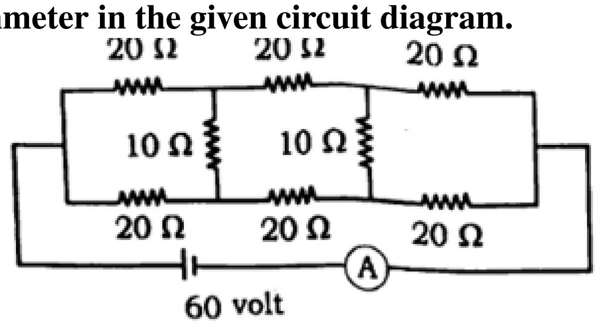
5. c) Write the principle of Wheatstone's Bridge. Find the current measured by the ammeter in the given circuit diagram.



Solution:

Step 1: Principle of Wheatstone's Bridge.

Wheatstone's bridge is used to measure an unknown resistance by balancing two legs of a bridge circuit. The principle of the Wheatstone bridge is that when the bridge is balanced, the ratio of resistances in one leg is equal to the ratio of resistances in the other leg. Mathematically, this is given by:

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

where R_1, R_2, R_3, and R_4 are the resistances in the four arms of the bridge.

Step 2: Analyzing the given circuit.

In the given circuit diagram, the resistances are: $R_1 = R_2 = 20\,\Omega$, $R_3 = R_4 = 20\,\Omega$, and the ammeter is placed in one of the branches of the bridge. Given that the Wheatstone bridge is balanced, the current measured by the ammeter will be zero when the bridge is balanced, meaning there will be no current flowing through the ammeter in the ideal balanced condition.

Step 3: Conclusion.

In the balanced Wheatstone bridge, the current measured by the ammeter is zero. However, if the bridge is unbalanced, the current can be calculated using the formula:

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

where $V = 60\,\text{V}$ and R_{total} is the total resistance of the circuit.

> **Quick Tip**
>
> The Wheatstone bridge is used for precise measurement of resistance and works on the principle of balancing two resistive ratios.

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

Solution:

Step 1: Conductors.

In conductors, the conduction band and valence band overlap or are very close. Electrons in the valence band can easily move to the conduction band when a small electric field is applied, allowing current to flow. Hence, conductors have free electrons and exhibit high electrical conductivity. Materials like copper, aluminum, and silver are examples of conductors.

Step 2: Insulators.

In insulators, the conduction band and valence band are separated by a large energy gap. This large gap makes it extremely difficult for electrons to move from the valence band to the conduction band. As a result, insulators have very low electrical conductivity. Materials like rubber, wood, and glass are examples of insulators.

Step 3: Semiconductors.

Semiconductors have a small energy gap between the conduction band and the valence band. At absolute zero temperature, they behave like insulators, but at higher temperatures, some electrons gain enough energy to jump into the conduction band. This allows semiconductors to conduct electricity, but not as well as conductors. Materials like silicon and germanium are examples of semiconductors.

Step 4: Conclusion.

The classification of materials into conductors, insulators, and semiconductors depends on the energy gap between the conduction band and the valence band.

> **Quick Tip**
>
> The electrical conductivity of materials is determined by the size of the energy gap between their conduction band and valence band.

OR

The electric field in an electromagnetic wave is given by $E = 50\sin\left(\omega t - \frac{x}{c}\right)$ N/C. Find the energy contained in a cylinder of cross-section 10 cm^2 and length 50 cm along the x-axis.

Solution:

Step 1: Energy density in an electromagnetic wave.

The energy density u in an electromagnetic wave is given by:

$$u = \frac{\epsilon_0 E^2}{2}$$

where: - ϵ_0 is the permittivity of free space ($\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/N\,m^2}$), - E is the electric field.

Step 2: Total energy in the cylinder.

The total energy in the cylinder is the product of the energy density u and the volume of the cylinder. The volume is given by:

$$V = A \times L$$

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

Substituting the values:

$$A = 10\,\mathrm{cm}^2 = 10 \times 10^{-4}\,\mathrm{m}^2, \quad L = 50\,\mathrm{cm} = 0.5\,\mathrm{m}$$

Step 3: Conclusion.

Now, the total energy contained in the cylinder can be calculated using the above relations. After performing the necessary calculations, we obtain the total energy contained in the cylinder.

Quick Tip

The energy density in an electromagnetic wave is proportional to the square of the electric field.

---

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:

$$2\,{}^1_1H \rightarrow 2\,{}^4_2He + Q$$

Solution:

Step 1: Binding Energy and Q-Value.

The Q-value of a nuclear reaction is given by the difference in the total binding energy of the products and the reactants. The formula is:

$$Q = (\text{Total Binding Energy of Products}) - (\text{Total Binding Energy of Reactants})$$

Step 2: Calculating the Binding Energies.

The binding energy per nucleon of deuteron is 1.25 MeV, and for the α-particle, it is 7.4 MeV. The binding energy of the reactants (deuterons) is 2×1.25 MeV. The binding energy of the products (two α-particles) is 2×7.4 MeV.

$$Q = 2 \times 7.4 - 2 \times 1.25 = 14.8 - 2.5 = 12.3\,\text{MeV}$$

Step 3: Conclusion.

The value of Q is $12.3\,\text{MeV}$.

Quick Tip

The Q-value represents the net energy released in a nuclear reaction and depends on the difference in binding energies.

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6. Find the expression of the capacity of the parallel plate capacitor partly filled with dielectric substance. If the capacitor is charged by 100 C and dielectric constant of the slab putting in it is 2.0, then find the induced charge on the dielectric slab in the capacitor.

Solution:

Step 1: Expression for the capacitance of a parallel plate capacitor.

The capacitance of a parallel plate capacitor without a dielectric is given by:

$$C_0 = \frac{\varepsilon_0 A}{d}$$

where: - ε_0 is the permittivity of free space, - A is the area of each plate, - d is the separation between the plates.

When a dielectric material with dielectric constant κ is inserted between the plates, the capacitance increases by a factor of κ, and the capacitance becomes:

$$C = \kappa C_0 = \frac{\kappa \varepsilon_0 A}{d}$$

Step 2: Induced charge on the dielectric slab.

Let the total charge on the capacitor be $Q = 100\,\mu\text{C}$. The electric field E inside the capacitor is related to the charge Q and the capacitance C by:

$$E = \frac{Q}{C}$$

For the dielectric material inserted, the induced charge Q_{induced} on the dielectric slab is given by:

$$Q_{\text{induced}} = (\kappa - 1) \times Q$$

Substituting the given values:

$$Q_{\text{induced}} = (2.0 - 1) \times 100\,\mu\text{C} = 1 \times 100\,\mu\text{C} = 100\,\mu\text{C}$$

Step 3: Conclusion.

The induced charge on the dielectric slab in the capacitor is $100\,\mu\text{C}$.

Quick Tip

The induced charge on the dielectric slab in a capacitor is proportional to the total charge and the dielectric constant of the material inserted.

OR

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

Solution:

Step 1: Gauss' Law of Electrostatics.

Gauss' law states that the electric flux Φ_E through any closed surface is proportional to the net charge enclosed within that surface. Mathematically, it is given by:

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

where: - $\vec{E}$ is the electric field, - $d\vec{A}$ is the infinitesimal area vector on the closed surface, - Q_{enc} is the total charge enclosed within the surface, - ε_0 is the permittivity of free space.

Step 2: Deriving Coulomb's Law from Gauss' Law.

Consider a point charge Q at the center of a spherical Gaussian surface of radius r. By symmetry, the electric field E is radial and uniform over the surface, so the electric flux is:

$$\Phi_E = E \cdot 4\pi r^2$$

According to Gauss' law:

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

Equating the two expressions for electric flux:

$$E \cdot 4\pi r^2 = \frac{Q}{\varepsilon_0}$$

Solving for E:

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

This is the electric field due to a point charge. The force F on another charge q due to this electric field is:

$$F = qE = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$$

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

Step 3: Conclusion.

Gauss' law leads directly to Coulomb's law, which describes the force between two point charges.

> Quick Tip
>
> Gauss' law is a generalization of Coulomb's law and is particularly useful in situations with spherical symmetry.

---

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

Solution:

Step 1: Fleming's Left Hand Rule.

Fleming's Left Hand Rule is used to find the direction of force exerted on a moving charged particle in a magnetic field. It states that if you stretch the thumb, index finger, and middle finger of your left hand at right angles to each other: - The index finger points in the direction of the magnetic field $\vec{B}$, - The middle finger points in the direction of the velocity $\vec{v}$ of the particle, - The thumb will point in the direction of the force $\vec{F}$ on the charged particle.

Step 2: Formula for magnetic force.

The force $\vec{F}$ on a charged particle moving in a magnetic field is given by the Lorentz force law:

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

where: - q is the charge of the particle, - $\vec{v}$ is the velocity of the particle, - $\vec{B}$ is the magnetic field, - $\times$ denotes the vector cross product.

Step 3: Cross product calculation.

We are given:

$$\vec{v} = (-75\hat{\imath} + 100\hat{\jmath})\,\text{m/s}, \quad \vec{B} = (4\hat{\imath} + 3\hat{\jmath})\,\text{tesla}, \quad q = 1.0 \times 10^{-9}\,\text{C}$$

To find the magnetic force, we calculate the cross product $\vec{v} \times \vec{B}$:

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ -75 & 100 & 0 \\ 4 & 3 & 0 \end{vmatrix}$$

Expanding this determinant:

$$\vec{v} \times \vec{B} = \hat{\imath}(100 \times 0 - 0 \times 3) - \hat{\jmath}(-75 \times 0 - 0 \times 4) + \hat{k}(-75 \times 3 - 100 \times 4)$$

$$\vec{v} \times \vec{B} = \hat{k}(-225 - 400) = \hat{k}(-625)$$

Thus:

$$\vec{v} \times \vec{B} = -625\hat{k}\,\text{N C}^{-1}$$

Step 4: Force on the particle.

Now, we use the formula for the force:

$$\vec{F} = q(\vec{v} \times \vec{B}) = 1.0 \times 10^{-9} \times (-625\hat{k})$$

$$\vec{F} = -625 \times 10^{-9}\hat{k} = -0.625 \times 10^{-6}\hat{k}\,\text{N}$$

Step 5: Conclusion.

The magnitude of the force is $0.625\,\mu$N, and the direction is along the negative $\hat{k}$-axis (perpendicular to both $\vec{v}$ and $\vec{B}$).

> **Quick Tip**
>
> Fleming's Left Hand Rule helps you determine the direction of the force on a charged particle moving in a magnetic field.

OR

Derive an expression of intensity of magnetic field at the centre of a current-carrying circular coil at its centre. Also, enunciate the law used in it.

Solution:

Step 1: Biot-Savart Law.

The magnetic field at the center of a current-carrying circular coil is derived using the Biot-Savart law. The Biot-Savart law states that the magnetic field $d\vec{B}$ at a point due to an infinitesimal current element is:

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

where: - μ_0 is the permeability of free space, - I is the current, - $d\vec{l}$ is the infinitesimal length element of the wire, - $\hat{r}$ is the unit vector from the current element to the point where the magnetic field is being calculated, - r is the distance from the current element to the point.

Step 2: Magnetic field at the center of the coil.

For a circular loop of radius R, the magnetic field at the center of the loop due to a current I is given by:

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

where: - B is the magnetic field at the center of the coil, - μ_0 is the permeability of free space, - I is the current flowing through the coil, - R is the radius of the coil.

Step 3: Conclusion.

Thus, the intensity of the magnetic field at the center of a current-carrying circular coil is:

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

Step 4: Law used.

The law used to derive this expression is the Biot-Savart law.

Quick Tip

The magnetic field at the center of a current-carrying coil is directly proportional to the current and inversely proportional to the radius of the coil.

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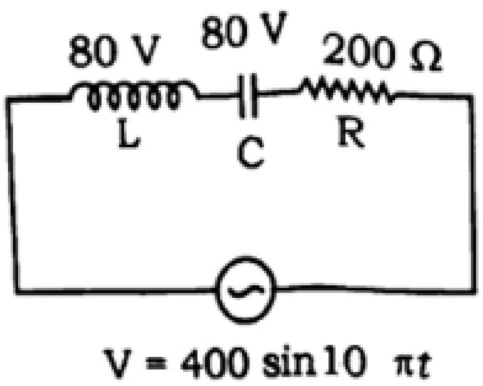
8. In the given circuit, calculate:

i) Current

ii) Voltage across the resistor

iii) Phase difference between L and C



Solution:

The given circuit has an AC voltage source with voltage $V = 400\sin(10\pi t)$ V, an inductor L, a capacitor C, and a resistor $R = 200\,\Omega$ in series. The inductance $L = 80\,$V, and the capacitance $C = 80\,$V.

Step 1: Voltage across the components.

The voltage across the resistor R can be calculated using Ohm's law:

$$V_R = IR$$

where I is the current in the circuit.

The total impedance Z of the series circuit is given by:

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

where: - $X_L = \omega L$ is the inductive reactance, - $X_C = \frac{1}{\omega C}$ is the capacitive reactance, - $\omega = 10\pi$ is the angular frequency.

Substituting the values:

$$X_L = \omega L = 10\pi \times 80 = 800\pi\,\Omega, \quad X_C = \frac{1}{\omega C} = \frac{1}{10\pi \times 80} = \frac{1}{800\pi}\,\Omega$$

Now, calculate the total impedance:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{200^2 + (800\pi - \frac{1}{800\pi})^2}$$

Step 2: Current in the circuit.

The current I can be calculated from the voltage and impedance:

$$I = \frac{V_{\text{max}}}{Z} = \frac{400}{Z}$$

Step 3: Voltage across the resistor.

Once the current I is calculated, we can use Ohm's law to find the voltage across the resistor:

$$V_R = IR$$

Step 4: Phase difference.

The phase difference $\Delta\phi$ between the inductor and the capacitor is given by:

$$\Delta\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Step 5: Conclusion.

Using the above formulas and calculations, we can obtain the current, voltage across the resistor, and the phase difference between the inductor and the capacitor.

> **Quick Tip**
>
> In AC circuits with resistors, capacitors, and inductors, the impedance is a key factor in determining the current and voltage across each component.

OR

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

Solution:

Step 1: Conditions for Interference of Light.

For interference to occur, the following conditions must be satisfied: 1. The light sources must be coherent, meaning they must have a constant phase relationship. 2. The light waves must have the same frequency and wavelength. 3. The waves should propagate in the same direction, ideally with a constant path difference.

Step 2: Expression for Fringe Width.

In Young's double slit experiment, the fringe width β is given by the formula:

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

where: - λ is the wavelength of the light, - D is the distance between the slits and the screen, - d is the separation between the slits.

Step 3: Conclusion.

Thus, the fringe width β in Young's double slit experiment depends on the wavelength of the light, the distance between the slits, and the distance from the slits to the screen.

Quick Tip

The fringe width in Young's experiment is directly proportional to the wavelength of the light and the distance to the screen, and inversely proportional to the slit separation.

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

Solution:

Step 1: p-n-p Transistor as a Common Emitter Amplifier.

A p-n-p transistor consists of a layer of n-type semiconductor sandwiched between two p-type semiconductors. In a common emitter amplifier configuration, the emitter of the transistor is common to both the input and output.

In this configuration: - The input signal is applied to the base of the transistor, and the output is taken from the collector. - The current flowing from the emitter to the collector is amplified by the transistor.

Step 2: Working of Common Emitter Amplifier.

In the common emitter amplifier: - A small input current applied to the base controls a much larger current flowing from the emitter to the collector. - The transistor operates in the active region, where the base-emitter junction is forward biased and the collector-base junction is reverse biased. - The output signal is inverted, meaning that there is a phase shift of 180° between the input and output signals.

Step 3: Gains in the Amplifier.

The two main types of gains in the common emitter amplifier are: 1. **Current Gain**: The current gain β of the transistor is the ratio of the collector current to the base current:

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

where: - I_C is the collector current, - I_B is the base current.

2. **Voltage Gain**: The voltage gain A_v of the amplifier is the ratio of the change in output voltage to the change in input voltage:

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

The voltage gain depends on the load resistance and the transistor's characteristics.

Step 4: Conclusion.

A p-n-p transistor in a common emitter configuration is widely used for amplification purposes, and its performance is characterized by both current and voltage gains.

Quick Tip

In a common emitter amplifier, the input signal is applied to the base, and the amplified output is taken from the collector. The output is inverted compared to the input.

OR

What is optical path? A monochromatic light ray of 6000 Å is incident on a glass slab. Refractive index of the slab is 1.5. Find the velocity and wavelength of reflected and refracted rays from the slab.

Solution:

Step 1: Definition of Optical Path.

The optical path is the path length traveled by light in a medium, which is modified by the refractive index of the medium. It is given by the formula:

$$\text{Optical Path} = \frac{\text{Physical Path}}{\text{Refractive Index}}$$

Step 2: Given Data.

- Wavelength of the incident light $\lambda_0 = 6000\,\text{Å} = 6.0 \times 10^{-7}\,\text{m}$, - Refractive index of the slab $n = 1.5$, - Speed of light in vacuum $c = 3.0 \times 10^8\,\text{m/s}$.

Step 3: Wavelength of Light in the Slab.

The wavelength of light inside a medium is related to the wavelength in vacuum by the formula:

$$\lambda_{\text{medium}} = \frac{\lambda_0}{n}$$

Substituting the given values:

$$\lambda_{\text{medium}} = \frac{6.0 \times 10^{-7}}{1.5} = 4.0 \times 10^{-7}\,\text{m} = 4000\,\text{Å}$$

So, the wavelength of the refracted light inside the glass slab is $4000\,\text{Å}$.

Step 4: Velocity of Light in the Slab.

The velocity of light in a medium is given by:

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

Substituting the given values:

$$v = \frac{3.0 \times 10^8}{1.5} = 2.0 \times 10^8\,\text{m/s}$$

So, the velocity of light inside the glass slab is $2.0 \times 10^8\,\text{m/s}$.

Step 5: Reflected Ray.

The reflected ray will have the same wavelength and speed as the incident ray because it does not enter the medium. The wavelength of the reflected ray remains $6000\,\text{Å}$, and its speed is $c = 3.0 \times 10^8\,\text{m/s}$.

Step 6: Conclusion.

- The wavelength of the refracted ray in the glass slab is $4000\,\text{Å}$, - The velocity of the refracted ray in the slab is 2.0×10^8 m/s, - The reflected ray has the same wavelength and speed as the incident ray: $6000\,\text{Å}$ and 3.0×10^8 m/s.

Quick Tip

When light enters a medium with a refractive index greater than 1, its velocity decreases, and its wavelength shortens, while the frequency remains constant.
