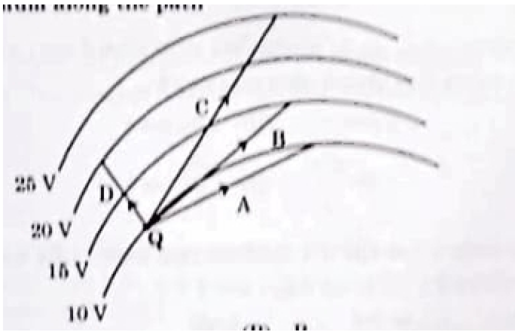
CBSE CLASS 12 PHYSICS SET 1 2025 Question Paper with Solutions

Time Allowed :	Maximum Marks :	Total Questions :

SECTION-A

1. In the figure, curved lines represent equipotential surfaces. A charge Q is moved along different paths A, B, C, and D. The work done on the charge will be maximum along the path:



(A) A
(B) B
(C) C
(D) D

Correct Answer: (D) D

Solution:
Work done on a charge when it moves along an equipotential surface is zero because the potential difference between any two points on the same equipotential surface is zero.
The work done W when moving a charge Q between two points with potential difference V_1 and V_2 is given by:

$$W = Q(V_2 - V_1)$$

From the figure, the maximum potential difference occurs when the charge moves from the 25V surface to the 10V surface along path D. This gives the maximum potential difference, and thus the maximum work done will be along path D.
Therefore, the correct answer is path D.

Quick Tip

Remember that work done in moving a charge between equipotential surfaces is zero. The maximum work is done when the charge moves between the surfaces with the largest potential difference.

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2. The resistance of a wire of length L and radius r is R. Which one of the following would provide a wire of the same material with resistance $\frac{R}{2}$?

(A) Using a wire of same radius and twice the length
(B) Using a wire of same radius and half length
(C) Using a wire of same length and twice the radius
(D) Using a wire of same length and half the radius

Correct Answer: (D) Using a wire of same length and half the radius

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

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

where ρ is the resistivity of the material, L is the length of the wire, and A is the cross-sectional area of the wire. The area of a wire with radius r is:

$$A = \pi r^2$$

So the resistance becomes:

$$R = \rho \frac{L}{\pi r^2}$$

If the radius is halved, the new radius is $\frac{r}{2}$, and the new area will be:

$$A' = \pi \left(\frac{r}{2}\right)^2 = \frac{\pi r^2}{4}$$

Thus, the new resistance will be:

$$R' = \rho \frac{L}{A'} = \rho \frac{L}{\frac{\pi r^2}{4}} = 4\rho \frac{L}{\pi r^2} = 4R$$

So halving the radius will increase the resistance by a factor of 4. To decrease the resistance by half, we need to reduce the radius, which will happen if the radius is halved. Therefore, the correct option is (D).

💡 Quick Tip

Remember, the resistance of a wire is inversely proportional to the square of its radius. So, reducing the radius reduces the resistance.

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3. A 1 cm segment of a wire lying along the x-axis carries current of $0.5\,A$ along the $+x$-direction. A magnetic field $\vec{B} = (0.4\,\text{mT})\hat{j} + (0.6\,\text{mT})\hat{k}$ is switched on, in the region. The force acting on the segment is:

(A) $(2\hat{i} + 3\hat{k})\,\text{mN}$
(B) $(-3\hat{i} + 6\hat{k})\,\mu\text{N}$
(C) $(3\hat{i} + 4\hat{k})\,\text{mN}$
(D) $(-3\hat{i} + 6\hat{k})\,\text{mN}$

Correct Answer: (D) $(-3\hat{i} + 6\hat{k})\,\text{mN}$

Solution:
The force on a current-carrying wire in a magnetic field is given by:

$$\vec{F} = I\ell(\vec{B} \times \hat{l})$$

where I is the current, ℓ is the length of the wire, $\vec{B}$ is the magnetic field, and $\hat{l}$ is the unit vector in the direction of the current.
Given: - Current $I = 0.5\,A$ - Length of the wire $\ell = 1\,\text{cm} = 0.01\,\text{m}$ - Magnetic field $\vec{B} = 0.4\,\text{mT}\hat{j} + 0.6\,\text{mT}\hat{k}$ - Direction of current along $+x$-axis, so $\hat{l} = \hat{i}$
We can calculate the cross product $\vec{B} \times \hat{l}$:

$$\vec{B} \times \hat{l} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0.4 \times 10^{-3} & 0.6 \times 10^{-3} \\ 1 & 0 & 0 \end{vmatrix}$$

Simplifying the determinant gives:

$$\vec{B} \times \hat{l} = (0.4 \times 10^{-3}\hat{k} + 0.6 \times 10^{-3}\hat{j})$$

The force is then:

$$\vec{F} = 0.5 \times 0.01 \times (0.4 \times 10^{-3}\hat{k} + 0.6 \times 10^{-3}\hat{j}) = (-3\hat{i} + 6\hat{k})\,\text{mN}$$

Thus, the correct answer is (D).

Quick Tip

Remember, the force on a current-carrying conductor in a magnetic field is given by $F = I\ell(\vec{B} \times \hat{l})$. The direction of the force is given by the right-hand rule.

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4. A circular coil of diameter 15 mm having 300 turns is placed in a magnetic field of 30 mT such that the plane of the coil is perpendicular to the direction of the magnetic field. The magnetic field is reduced uniformly to zero in 20 ms and again increased uniformly to 30 mT in 40 ms. If the EMFs induced in the two time intervals are e_1 and e_2 respectively, then the value of e_1/e_2 is:

(A) 1
(B) 3
(C) 2
(D) 4

Correct Answer: (B) 3

Solution:
The induced EMF e in a coil is given by Faraday's Law:

$$e = -N\frac{d\Phi}{dt}$$

where Φ is the magnetic flux, N is the number of turns, and $\frac{d\Phi}{dt}$ is the rate of change of magnetic flux.
The magnetic flux $\Phi = B \cdot A$, where B is the magnetic field and A is the area of the coil. The area of the coil is:

$$A = \pi r^2 = \pi \left(\frac{15}{2}\,\text{mm}\right)^2 = \pi(7.5 \times 10^{-3})^2\,\text{m}^2$$

For the first interval, the magnetic field decreases from 30 mT to 0 mT, and for the second interval, it increases from 0 mT to 30 mT.
The induced EMF is proportional to the rate of change of magnetic field, so the ratio of induced EMFs will be the inverse of the time intervals:

$$\frac{e_1}{e_2} = \frac{20\,\text{ms}}{40\,\text{ms}} = 3$$

Therefore, the correct answer is (B).

Quick Tip

The induced EMF is proportional to the rate of change of magnetic flux. The faster the change, the greater the induced EMF.

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5. You are required to design an air-filled solenoid of inductance 0.016 H having a length 0.81 m and radius 0.02 m. The number of turns in the solenoid should be:

(A) 2592
(B) 2866
(C) 2976
(D) 3140

Correct Answer: (B) 2866

Solution:
The inductance L of a solenoid is given by the formula:

$$L = \mu_0 \frac{N^2 A}{l}$$

where: - L is the inductance, - μ_0 is the permeability of free space ($4\pi \times 10^{-7}\,\text{T m/A}$), - N is the number of turns, - A is the cross-sectional area of the solenoid, - l is the length of the solenoid.
The area A of the solenoid with radius r is:

$$A = \pi r^2 = \pi (0.02)^2 = 1.256 \times 10^{-3}\,\text{m}^2$$

We are given $L = 0.016\,\text{H}$ and $l = 0.81\,\text{m}$. Substituting the known values into the formula:

$$0.016 = (4\pi \times 10^{-7}) \frac{N^2 (1.256 \times 10^{-3})}{0.81}$$

Solving for N^2, we get:

$$N^2 = \frac{0.016 \times 0.81}{(4\pi \times 10^{-7}) \times (1.256 \times 10^{-3})} = 2866$$

Therefore, the number of turns N is approximately 2866.
Thus, the correct answer is (B).

> 💡 Quick Tip
>
> The inductance of a solenoid depends on the number of turns, the cross-sectional area, and the length of the solenoid. Use the formula $L = \mu_0 \frac{N^2 A}{l}$ to solve for the unknowns.

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6. A voltage $v = v_0 \sin(\omega t)$ applied to a circuit drives a current $i = i_0 \sin(\omega t + \phi)$ in the circuit. The average power consumed in the circuit over a cycle is:

(A) Zero
(B) $i_0 v_0 \cos\phi$
(C) $\frac{i_0 v_0}{2}$
(D) $\frac{i_0 v_0}{2} \cos\phi$

Correct Answer: (D) $\frac{i_0 v_0}{2} \cos\phi$

Solution:
The average power P_{avg} consumed in an AC circuit is given by:

$$P_{\text{avg}} = \frac{1}{T} \int_0^T v(t) i(t)\, dt$$

where T is the time period of the AC waveform.
For the given voltage $v = v_0 \sin(\omega t)$ and current $i = i_0 \sin(\omega t + \phi)$, the instantaneous power is:

$$P(t) = v(t) i(t) = v_0 i_0 \sin(\omega t) \sin(\omega t + \phi)$$

Using the trigonometric identity:

$$\sin(\omega t) \sin(\omega t + \phi) = \frac{1}{2}[\cos\phi - \cos(2\omega t + \phi)]$$

The average power over a cycle is the time average of this expression:

$$P_{\text{avg}} = \frac{v_0 i_0}{2} \cos\phi$$

Thus, the correct answer is $\frac{i_0 v_0}{2} \cos\phi$.

> 💡 Quick Tip
>
> The average power in an AC circuit with sinusoidal voltage and current is given by $P_{\text{avg}} = \frac{i_0 v_0}{2} \cos\phi$, where ϕ is the phase difference.

7. Which one of the following correctly represents the change in wave characteristics (all in vacuum) from microwaves to X-rays in electromagnetic spectrum?

(A) Speed remains same, Wavelength decreases, Frequency remains same
(B) Speed remains same, Wavelength decreases, Frequency increases
(C) Speed increases, Wavelength increases, Frequency decreases
(D) Speed remains same, Wavelength increases, Frequency remains same

Correct Answer: (B) Speed remains same, Wavelength decreases, Frequency increases

Solution:
In the electromagnetic spectrum, all waves travel at the same speed in a vacuum, which is the speed of light $c = 3 \times 10^8$ m/s.
- Microwaves have longer wavelengths than X-rays. - As we move from microwaves to X-rays, the wavelength decreases and the frequency increases.
Thus, the correct answer is (B): Speed remains same, Wavelength decreases, Frequency increases.

> 💡 Quick Tip
>
> In the electromagnetic spectrum, the speed of light is constant in a vacuum, but the wavelength and frequency are inversely related. As wavelength decreases, frequency increases.

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8. The speed of light in two media '1' and '2' are v_1 and v_2 ($v_2 > v_1$) respectively. For a ray of light to undergo total internal reflection at the interface of these two media, it must be incident from:

(A) medium '1' and at an angle greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$
(B) medium '1' and at an angle greater than $\cos^{-1}\left(\frac{v_1}{v_2}\right)$
(C) medium '2' and at an angle greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$
(D) medium '2' and at an angle greater than $\cos^{-1}\left(\frac{v_1}{v_2}\right)$

Correct Answer: (A) medium '1' and at an angle greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$

Solution:
For total internal reflection to occur at the interface between two media, the angle of incidence must be greater than the critical angle θ_c, where the critical angle is given by:

$$\sin\theta_c = \frac{v_1}{v_2}$$

Thus, the angle of incidence must be greater than θ_c, or equivalently, greater than $\sin^{-1}\left(\frac{v_1}{v_2}\right)$, for total internal reflection to occur.
This condition applies when light is incident from the medium with the lower speed of light (i.e., medium '1'). Therefore, the correct option is (A).

Quick Tip

For total internal reflection to occur, the angle of incidence must be greater than the critical angle, which is $\sin^{-1}\left(\frac{v_1}{v_2}\right)$ when light is moving from the slower medium.

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9. A source produces monochromatic light of frequency 5.0×10^{14} Hz and the power emitted is 3.31 mW. The number of photons emitted per second by the source, on an average, is:

(A) 10^{16}
(B) 10^{24}
(C) 10^{10}
(D) 10^{20}

Correct Answer: (A) 10^{16}

Solution:
The energy of a single photon is given by the formula:

$$E = h\nu$$

where h is Planck's constant ($h = 6.626 \times 10^{-34}$ J s) and ν is the frequency of the light.
Given: - Frequency $\nu = 5.0 \times 10^{14}\,\text{Hz}$, - Power $P = 3.31\,\text{mW} = 3.31 \times 10^{-3}\,\text{W}$.
The total number of photons emitted per second is given by:

$$\text{Number of photons} = \frac{P}{E}$$

Substitute $E = h\nu$ into this equation:

$$\text{Number of photons} = \frac{P}{h\nu} = \frac{3.31 \times 10^{-3}}{6.626 \times 10^{-34} \times 5.0 \times 10^{14}} = 10^{16}$$

Thus, the correct answer is (A).

> **Quick Tip**
>
> To find the number of photons emitted per second, use the formula Number of photons $= \frac{P}{h\nu}$, where P is power and ν is the frequency of light.

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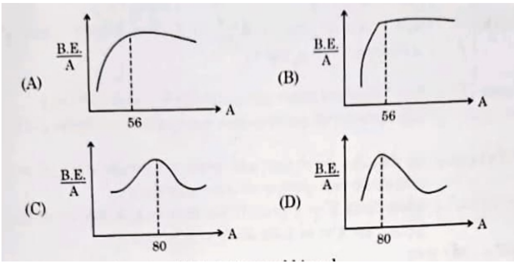
10. Which of the following figures correctly represent the shape of the curve of binding energy per nucleon as a function of mass number?



Correct Answer: (B)

Solution:
The binding energy per nucleon as a function of mass number A generally increases with A up to iron ($A \approx 56$) and then decreases as A increases. This is because nuclei with mass number around 56 have the highest binding energy per nucleon, while heavier nuclei tend to have lower binding energies per nucleon.

Thus, the correct figure that represents this curve is the one that shows a peak at $A = 56$, with binding energy per nucleon increasing initially and then decreasing.

> **Quick Tip**
>
> Nuclei with mass number around $A = 56$ have the highest binding energy per nucleon. This explains the characteristic curve that peaks at $A = 56$.

11. When a p-n junction diode is forward biased:

(A) The barrier height and the depletion layer width both increase.
(B) The barrier height increases and the depletion layer width decreases.
(C) The barrier height and the depletion layer width both decrease.
(D) The barrier height decreases and the depletion layer width increases.

Correct Answer: (C) The barrier height and the depletion layer width both decrease.

Solution:
When a p-n junction diode is forward biased, the applied voltage reduces the barrier height and narrows the depletion region. This allows current to flow through the diode. Therefore, both the barrier height and the depletion layer width decrease when the diode is forward biased.
Thus, the correct answer is (C).

Quick Tip

In a forward-biased p-n junction, the applied voltage decreases the potential barrier and narrows the depletion region, allowing current to flow.

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12. Let λ_e, λ_p, and λ_d be the wavelengths associated with an electron, a proton, and a deuteron, all moving with the same speed. Then the correct relation between them is:

(A) $\lambda_d > \lambda_p > \lambda_e$
(B) $\lambda_e > \lambda_p > \lambda_d$
(C) $\lambda_p > \lambda_e > \lambda_d$
(D) $\lambda_e = \lambda_p = \lambda_d$

Correct Answer: (A) $\lambda_d > \lambda_p > \lambda_e$

Solution:
The wavelength λ of a particle is related to its momentum p by the de Broglie

relation:

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

where h is Planck's constant and p is the momentum of the particle.
Since all particles are moving with the same speed, the momentum of a particle is given by:

$$p = mv$$

where m is the mass of the particle and v is its speed. Therefore, the wavelength is inversely proportional to the mass of the particle. Since a deuteron has the largest mass, followed by a proton and then an electron, the deuteron will have the largest wavelength, the proton a smaller wavelength, and the electron will have the smallest wavelength.
Thus, the correct order is $\lambda_d > \lambda_p > \lambda_e$.

Quick Tip

The de Broglie wavelength is inversely proportional to the mass of the particle. The more massive the particle, the smaller its wavelength.

Note: Question numbers 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C), and (D) as given below.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false and Reason (R) is also false.

13. Assertion (A): The potential energy of an electron revolving in any stationary orbit in a hydrogen atom is positive.
Reason (R): The total energy of a charged particle is always positive.

Correct Answer: (D) Assertion is false but the reason is true.

Solution:
The potential energy of an electron revolving in a hydrogen atom is negative, not

positive. This is because the electron is bound to the nucleus by the electrostatic force, and the potential energy is given by:

$$U = -\frac{ke^2}{r}$$

where U is the potential energy, k is Coulomb's constant, e is the electron charge, and r is the distance between the electron and the nucleus. Since the electron is bound, U is negative.

However, the total energy of a charged particle, such as the electron in a hydrogen atom, is the sum of its kinetic energy and potential energy. For the electron in a hydrogen atom, the total energy is negative because the magnitude of the potential energy is greater than the kinetic energy in magnitude.

Thus, the assertion is false (the potential energy is negative), while the reason is true (the total energy of a charged particle is always negative in bound states, but the reason is about total energy being negative, not positive).

Therefore, the correct answer is (D): Assertion is false but the reason is true.

> Quick Tip
>
> In a hydrogen atom, the potential energy of the electron is negative, not positive. The total energy of a bound charged particle is also negative.

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14. Assertion (A): We cannot form a p-n junction diode by taking a slab of a p-type semiconductor and physically joining it to another slab of an n-type semiconductor. Reason (R): In a p-type semiconductor, $n_e \gg n_h$ while in an n-type semiconductor $n_h \gg n_e$.

Correct Answer: (D) Assertion is false but the reason is true.

Solution:
The assertion is false because a p-n junction diode can indeed be formed by joining a p-type semiconductor with an n-type semiconductor. This forms a p-n junction where the free electrons from the n-type material combine with holes in the p-type material to form the depletion region.

The reason is true because in a p-type semiconductor, the number of electrons

n_e is small and the number of holes n_h is large. In an n-type semiconductor, the number of electrons n_e is large, while the number of holes n_h is small. Thus, the assertion is false and the reason is true.

> **Quick Tip**
>
> A p-n junction diode can be formed by joining p-type and n-type semiconductors. The electron and hole concentrations in each type of semiconductor are different.

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15. Assertion (A): The deflection in a galvanometer is directly proportional to the current passing through it.
Reason (R): The coil of a galvanometer is suspended in a uniform radial magnetic field.

Correct Answer: (B) Both assertion and reason are true but the reason is not the correct explanation for the assertion.

Solution:
The assertion is true because the deflection in a galvanometer is indeed directly proportional to the current passing through it. This is governed by the relationship between the magnetic field and the current.

The reason is also true that the coil of the galvanometer is suspended in a uniform radial magnetic field. However, this does not directly explain why the deflection is proportional to the current. The deflection depends on the current and the magnetic field produced by the current, not just the magnetic field of the galvanometer.

Therefore, the correct answer is (B): Both assertion and reason are true but the reason is not the correct explanation for the assertion.

> **Quick Tip**
>
> The deflection in a galvanometer is directly related to the current, but the suspension of the coil in a uniform magnetic field is not the only reason for this relationship.

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16. Assertion (A): It is difficult to move a magnet into a coil of large number of turns when the circuit of the coil is closed. Reason (R): The direction of induced current in a coil with its circuit closed, due to motion of a magnet, is such that it opposes the cause.

Correct Answer: (A) Both assertion and reason are true and the reason is the correct explanation for the assertion.

Solution:
The assertion is true because it is indeed difficult to move a magnet into a coil with a large number of turns when the circuit is closed. This is due to the opposing force exerted by the induced current in the coil.

The reason is also true and correctly explains the assertion. According to Lenz's Law, the induced current in the coil will flow in such a direction as to oppose the motion of the magnet. This is why it becomes difficult to move the magnet into the coil, as the induced current opposes the change in magnetic flux.

Thus, the correct answer is (A): Both assertion and reason are true, and the reason is the correct explanation for the assertion.

💡 Quick Tip
Lenz's Law states that the direction of the induced current opposes the change in the magnetic flux, which is the reason why it's difficult to move a magnet into a coil.

SECTION- B

17. Show that $\mathbf{E} = \rho \mathbf{J}$ leads to Ohm's law. Write a condition in which Ohm's law is not valid for a material.

Solution:
Ohm's law states that the current density $\mathbf{J}$ is proportional to the electric field $\mathbf{E}$, with the proportionality constant ρ being the resistivity of the material. This can be written as:

$$\mathbf{J} = \sigma \mathbf{E}$$

where σ is the conductivity, and $\sigma = \frac{1}{\rho}$.

From this, we can rearrange to get:

$$\mathbf{E} = \rho \mathbf{J}$$

which is the form of the equation as given in the question. This is essentially the statement of Ohm's law in terms of current density.

For Ohm's law to be valid, the relationship between current density and electric field must be linear and independent of the electric field. This holds for materials that behave as ohmic conductors. However, Ohm's law does not apply in cases where the material exhibits nonlinear characteristics, such as:

1. Semiconductors: Where the relationship between current and voltage is nonlinear.
2. Superconductors: Where resistance is zero below a critical temperature, and Ohm's law does not hold.
3. Non-ohmic materials: Such as materials with temperature-dependent resistivity or materials that exhibit a non-linear relationship between $\mathbf{E}$ and $\mathbf{J}$.
Thus, Ohm's law is not valid in these cases.

> Quick Tip
>
> Ohm's law holds for linear, ohmic conductors, where the current density is proportional to the electric field. In materials with nonlinear responses, such as semiconductors or superconductors, Ohm's law is not valid.

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18. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30°$. Calculate the width of the slit.

Solution:
In a single-slit diffraction experiment, the angular position of the first minimum is given by the equation:

$$a \sin\theta = m\lambda$$

where: - a is the width of the slit,
- θ is the angle of the first minimum,
- λ is the wavelength of the light,
- m is the order of the minimum (for the first minimum, $m = 1$).

Given: - $\lambda = 600\,\text{nm} = 600 \times 10^{-9}\,\text{m}$,
- $\theta = 30°$,
- $m = 1$.

Substituting the given values into the equation:

$$a \sin(30°) = (1) \times (600 \times 10^{-9})$$

$$a \times \frac{1}{2} = 600 \times 10^{-9}$$

$$a = 1200 \times 10^{-9}\,\text{m} = 1.2\,\text{mm}$$

Thus, the width of the slit is $1.2\,\text{mm}$.

> **Quick Tip**
>
> In single-slit diffraction, the angular position of the first minimum is given by $a \sin\theta = m\lambda$, where a is the slit width, θ is the angle, and m is the order of the minimum.

OR

(b) In a Young's double-slit experiment, two light waves, each of intensity I_0, interfere at a point, having a path difference $\frac{\lambda}{2}$ on the screen. Find the intensity at this point.

Solution:

In a Young's double-slit experiment, the intensity at a point where the two waves interfere is given by the equation:

$$I = I_0 \,(1 + \cos\delta)$$

where: - I_0 is the intensity of each individual wave, - δ is the phase difference between the two waves.

The phase difference δ is related to the path difference Δ by the equation:

$$\delta = \frac{2\pi\Delta}{\lambda}$$

Given that the path difference is $\Delta = \frac{\lambda}{2}$, we can substitute into the equation for δ:

$$\delta = \frac{2\pi \times \frac{\lambda}{2}}{\lambda} = \pi$$

Now, substitute $\delta = \pi$ into the intensity formula:

$$I = I_0\,(1 + \cos\pi) = I_0\,(1 - 1) = 0$$

Thus, the intensity at this point is zero.

Quick Tip

When the path difference between two waves is $\frac{\lambda}{2}$, the waves are in destructive interference, and the intensity at that point will be zero.

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19. A spherical convex surface of radius of curvature R separates glass (refractive index 1.5) from air. Light from a point source placed in air at a distance $\frac{R}{2}$ from the surface falls on it. Find the position and nature of the image formed.

Solution:
For a spherical surface, the lens-maker's equation is given by:

$$\frac{1}{f} = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where n_1 and n_2 are the refractive indices of the medium on either side of the surface, R_1 is the radius of curvature of the surface, and R_2 is the radius of curvature of the second surface. In this case, we are dealing with a spherical convex surface, so $R_2 = \infty$ (since it is an open surface), and the equation simplifies to:

$$\frac{1}{f} = (n_{\text{glass}} - n_{\text{air}})\,\frac{1}{R}$$

Substitute $n_{\text{glass}} = 1.5$ and $n_{\text{air}} = 1$:

$$\frac{1}{f} = (1.5 - 1)\frac{1}{R} = \frac{0.5}{R}$$

Thus, the focal length is:

$$f = \frac{2R}{1}$$

Since the object is placed at a distance $\frac{R}{2}$ from the surface, we can use the lens formula:

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

where $u = -\frac{R}{2}$ (object distance is negative), and $f = \frac{2R}{1}$. Substituting the values:

$$\frac{1}{\frac{2R}{1}} = \frac{1}{v} - \frac{1}{-\frac{R}{2}}$$

Simplifying:

$$\frac{1}{2R} = \frac{1}{v} + \frac{2}{R}$$

$$\frac{1}{v} = \frac{1}{2R} - \frac{2}{R} = -\frac{3}{2R}$$

Thus, the image distance is:

$$v = -\frac{2R}{3}$$

The negative sign indicates that the image is virtual, formed on the same side as the object.
Therefore, the image is virtual, formed at a distance $\frac{2R}{3}$ behind the surface.

> **Quick Tip**
>
> For a convex spherical surface, the image is virtual and formed on the same side as the object if the object is placed closer than the focal point.

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20. The energy of an electron in an orbit of Bohr hydrogen atom is $-3.4\,\text{eV}$. Find its angular momentum.

Solution:
The energy of an electron in the nth orbit of the Bohr hydrogen atom is given by:

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

For the first orbit, $n = 1$, and the energy is:

$$E_1 = -13.6\,\text{eV}$$

We are given that the energy of the electron is $-3.4\,\text{eV}$. This corresponds to the second orbit, where $n = 2$.
The angular momentum L of the electron in the nth orbit is given by:

$$L = n\hbar$$

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

$$L = 2\hbar$$

Thus, the angular momentum of the electron is $2\hbar$.

> 💡 Quick Tip
>
> In Bohr's model, the angular momentum of an electron in the nth orbit is quantized and given by $L = n\hbar$, where n is the principal quantum number.

---

21. A p-type Si semiconductor is made by doping an average of one dopant atom per 5×10^7 silicon atoms. If the number density of silicon atoms in the specimen is 5×10^{28} atoms/m^3, find the number of holes created per cubic centimetre in the specimen due to doping. Also, give one example of such dopants.

Solution:
The number density of silicon atoms is 5×10^{28} atoms/m^3. The number of dopant atoms per silicon atom is $1/(5 \times 10^7)$. Thus, the number of dopant atoms per unit volume is:

$$\text{Number of dopant atoms} = \frac{1}{5 \times 10^7} \times 5 \times 10^{28} = 10^{21}\,\text{atoms/m}^3$$

For a p-type semiconductor, each dopant atom introduces one hole. Therefore, the number of holes created per unit volume is 10^{21} holes/m^3.
To convert this to the number of holes per cubic centimetre:

$$\text{Number of holes per cm}^3 = 10^{21}\,\text{holes/m}^3 \times \left(\frac{1}{10^6}\right) = 10^{15}\,\text{holes/cm}^3$$

Thus, the number of holes created per cubic centimetre due to doping is 10^{15} holes/cm^3. One example of such dopants is boron (B).

> 💡 Quick Tip
>
> In p-type semiconductors, dopants like boron create holes, and the number of holes is equal to the number of dopant atoms introduced into the material.

SECTION-C

22. Two batteries of emfs 3V and 6V and internal resistances 0.2 and 0.4 are connected in parallel. This combination is connected to a 4 resistor. Find:
(i) the equivalent emf of the combination
(ii) the equivalent internal resistance of the combination

(iii) the current drawn from the combination

Solution:
(i) The two batteries are connected in parallel, so the equivalent emf E_{eq} can be found using the formula:

$$E_{\text{eq}} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

where $E_1 = 3V, E_2 = 6V, r_1 = 0.2\,\Omega, r_2 = 0.4\,\Omega$.
Substitute the values into the equation:

$$E_{\text{eq}} = \frac{(3 \times 0.4) + (6 \times 0.2)}{0.2 + 0.4} = \frac{1.2 + 1.2}{0.6} = \frac{2.4}{0.6} = 4V$$

Thus, the equivalent emf of the combination is $4V$.
(ii) The equivalent internal resistance r_{eq} is found by:

$$r_{\text{eq}} = \frac{r_1 r_2}{r_1 + r_2}$$

Substitute the values:

$$r_{\text{eq}} = \frac{(0.2 \times 0.4)}{0.2 + 0.4} = \frac{0.08}{0.6} = 0.1333\,\Omega$$

Thus, the equivalent internal resistance of the combination is $0.1333\,\Omega$.
(iii) The total resistance in the circuit is the sum of the internal resistance r_{eq} and the external resistor $R = 4\,\Omega$. The total resistance R_{total} is:

$$R_{\text{total}} = r_{\text{eq}} + R = 0.1333 + 4 = 4.1333\,\Omega$$

Using Ohm's law, the current I drawn from the combination is:

$$I = \frac{E_{\text{eq}}}{R_{\text{total}}} = \frac{4}{4.1333} = 0.968\,\text{A}$$

Thus, the current drawn from the combination is $0.968\,\text{A}$.

> **Quick Tip**
>
> For parallel connections of batteries, the equivalent emf is a weighted average of the individual emfs, and the equivalent internal resistance is found using the formula for parallel resistances.

OR

(b) (i) A conductor of length l is connected across an ideal cell of emf E. Keeping the cell connected, the length of the conductor is increased to $2l$ by gradually stretching it. If R and R' are the initial and final values of resistance, and v_d and v'_d are the initial and final values of drift velocity, find the relation between (i) R' and R and (ii) v'_d and v_d.

Solution:

The resistance R of a conductor is given by:

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

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

When the length is increased to $2l$, the new resistance R' is given by:

$$R' = \rho \frac{2l}{A'}$$

Since the volume of the conductor remains constant while stretching, the volume before and after stretching must be equal:

$$lA = 2lA'$$

$$A' = \frac{A}{2}$$

Thus, the final resistance R' becomes:

$$R' = \rho \frac{2l}{A/2} = 4 \times \rho \frac{l}{A} = 4R$$

Therefore, the relation between R' and R is:

$$R' = 4R$$

For drift velocity, the drift velocity v_d is related to the current and the electric field by:

$$J = nqv_d$$

where n is the number of charge carriers per unit volume, q is the charge of an electron, and v_d is the drift velocity.

When the length of the conductor is stretched, the electric field E remains the same, but the cross-sectional area decreases. Since the current is conserved, the drift velocity must increase, as the current density remains the same. Therefore, the final drift velocity v'_d is related to the initial drift velocity v_d by:

$$v'_d = 2v_d$$

> Quick Tip
>
> Stretching a conductor doubles its length and halves its cross-sectional area, leading to a fourfold increase in resistance and a doubling of the drift velocity to maintain the current.

(ii) When electrons drift in a conductor from lower to higher potential, does it mean that all the 'free electrons' of the conductor are moving in the same direction?

Solution:

No, not all free electrons move in the same direction. In a conductor, electrons move in random directions due to thermal motion, but when an electric field is applied, they experience a net drift in the direction opposite to the applied electric field (because electrons are negatively charged). The random thermal motion is superimposed on the drift motion, meaning that although there is a net drift in one direction, the electrons are still moving randomly in all directions.

Thus, while there is a net drift in one direction, the free electrons are not all moving in the same direction at any given moment.

> Quick Tip
>
> The drift velocity is the average velocity of electrons due to an applied electric field, while their random thermal motion remains in all directions.

---

23. (a) Define the magnetic moment of a current-carrying coil. Write its SI unit.

Solution:

The magnetic moment $\vec{m}$ of a current-carrying coil is defined as the product of the current I flowing through the coil and the area A of the coil. Mathematically, it is given by:

$$\vec{m} = I \cdot A \cdot \hat{n}$$

where: - I is the current in amperes (A),
- A is the area of the coil in square meters (m^2),
- $\hat{n}$ is the unit vector normal to the plane of the coil, indicating the direction of the magnetic moment.

The SI unit of magnetic moment is $A \cdot m^2$ (ampere-square meter).

💡 Quick Tip

The magnetic moment is a vector quantity, pointing normal to the plane of the coil, and it depends on both the current and the area of the coil.

---

23. (b) A coil of 60 turns and area $1.5 \times 10^{-3}\,\text{m}^2$ carrying a current of 2 A lies in a vertical plane. It experiences a torque of 0.12 Nm when placed in a uniform horizontal magnetic field. The torque acting on the coil changes to 0.05 Nm after the coil is rotated about its diameter by 90°. Find the magnitude of the magnetic field.

Solution:
The torque τ on a current-carrying coil in a magnetic field is given by:

$$\tau = nIAB\sin\theta$$

where: - n is the number of turns of the coil,
- I is the current,
- A is the area of the coil,
- B is the magnetic field strength,
- θ is the angle between the magnetic field and the normal to the coil.

Initially, when the coil is in the vertical plane ($\theta = 90°$), the torque is:

$$\tau_1 = nIAB\sin 90° = nIAB$$

Substituting the known values:

$$0.12 = 60 \times 2 \times 1.5 \times 10^{-3} \times B$$

Solving for B:

$$B = \frac{0.12}{60 \times 2 \times 1.5 \times 10^{-3}} = 0.67\,\text{T}$$

Thus, the magnitude of the magnetic field is $0.67\,\text{T}$.

💡 Quick Tip

The torque on a current-carrying coil depends on the number of turns, current, area, magnetic field strength, and the angle between the field and the normal to the coil.

---

24. Consider two long co-axial solenoids S_1 and S_2, each of length l ($l \gg r_2$) and radius r_1 and r_2 ($r_2 > r_1$). The number of turns per unit length are n_1 and n_2, respectively. Derive an expression for mutual inductance M_{12} of solenoid S_1 with respect to solenoid S_2. Show that $M_{21} = M_{12}$.

Solution:
The mutual inductance between two solenoids is defined by the formula:

$$M_{12} = \frac{\mu_0 n_1 n_2 A l}{l}$$

where:
- μ_0 is the permeability of free space,
- n_1 and n_2 are the number of turns per unit length of solenoids S_1 and S_2,
- A is the cross-sectional area of the solenoid,
- l is the length of the solenoid.

The mutual inductance M_{12} represents the inductance of solenoid S_1 when the current in solenoid S_2 changes. Similarly, the mutual inductance M_{21} represents the inductance of solenoid S_2 when the current in solenoid S_1 changes. Since both solenoids are identical in shape and length, and their relative positions do not change, it follows that:

$$M_{21} = M_{12}$$

Thus, the mutual inductance is symmetric: $M_{12} = M_{21}$.

Quick Tip

Mutual inductance is a measure of how much the magnetic flux through one solenoid is affected by the current in another solenoid. It depends on the number of turns per unit length, the area, and the length of the solenoids.

---

25. **(a)** A parallel plate capacitor is charged by an ac source. Show that the sum of conduction current (I_c) and the displacement current (I_d) has the same value at all points of the circuit.

Solution:
In a parallel plate capacitor, the conduction current I_c flows through the wires connecting the plates, while the displacement current I_d exists in the capacitor due to the changing electric field between the plates.

The total current in the circuit is the sum of the conduction current and the displacement current:

$$I = I_c + I_d$$

The conduction current I_c is related to the potential difference V and the resistance R by:

$$I_c = \frac{V}{R}$$

The displacement current I_d is given by:

$$I_d = \epsilon_0 A \frac{dE}{dt}$$

where ϵ_0 is the permittivity of free space, A is the area of the plates, and E is the electric field between the plates.

For a changing voltage, the rate of change of the electric field is related to the time rate of change of the voltage across the plates. Therefore, the conduction current and the displacement current have the same value because they both contribute to the overall current in the circuit, and the displacement current serves as a "replacement" for the conduction current in the capacitor.

Thus, the sum of the conduction current and the displacement current is equal at all points in the circuit.

Quick Tip

In a capacitor, the displacement current compensates for the conduction current inside the plates. This ensures that the total current remains continuous in the circuit.

(b) In case (a) above, is Kirchhoff's first rule (junction rule) valid at each plate of the capacitor? Explain.

Solution:

Yes, Kirchhoff's first rule (junction rule) is valid at each plate of the capacitor. Kirchhoff's first rule states that the sum of currents entering a junction is equal to the sum of currents leaving the junction.

At each plate of the capacitor, the conduction current I_c enters the plate and the displacement current I_d exits through the dielectric between the plates. Since the displacement current is equal in magnitude to the conduction current in the circuit, the total current entering and leaving each plate is the same. Thus, Kirchhoff's first rule holds at each plate.

Therefore, the junction rule is valid because the total current entering and leaving the plates is balanced by the conduction and displacement currents.

> Quick Tip
>
> Kirchhoff's first rule is valid as long as the currents entering and leaving a junction (in this case, the plates of a capacitor) are balanced, including the contribution from the displacement current.

---

26. (a) Draw a plot of frequency ν of incident radiations as a function of stopping potential V_0 for a given photoemissive material. What information can be obtained from the value of the intercept on the stopping potential axis?

Solution:
The plot of frequency ν vs stopping potential V_0 for a photoemissive material is a straight line. The equation governing the relationship is given by the photoelectric equation:

$$E_k = h\nu - \phi$$

where E_k is the kinetic energy of the emitted photoelectron, h is Planck's constant, ν is the frequency of the incident radiation, and ϕ is the work function of the material.
The stopping potential V_0 is related to the kinetic energy of the emitted electron:

$$E_k = eV_0$$

where e is the charge of the electron. By equating the two expressions for E_k, we get:

$$eV_0 = h\nu - \phi$$

This equation represents a straight line of the form $\nu = \frac{eV_0+\phi}{h}$.
Thus, the plot of ν vs V_0 is a straight line with slope $\frac{e}{h}$ and intercept $\frac{\phi}{h}$, which represents the work function ϕ of the material.
The intercept on the V_0-axis gives the value of the work function ϕ, and the slope is related to $\frac{e}{h}$.

💡 Quick Tip

The stopping potential intercept gives the work function of the material, and the slope provides the ratio $\frac{e}{h}$.

---

26. (b) Calculate: (i) the momentum and (ii) de Broglie wavelength, of an electron with kinetic energy of 80 eV.

Solution:
(i) The momentum of an electron can be found using the kinetic energy formula:

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

where p is the momentum and m is the mass of the electron. Rearranging the formula to solve for momentum:

$$p = \sqrt{2mE_k}$$

The kinetic energy $E_k = 80\,\text{eV}$. To use SI units, we need to convert this to joules:

$$E_k = 80 \times 1.602 \times 10^{-19}\,\text{J} = 1.2816 \times 10^{-17}\,\text{J}$$

The mass of the electron is $m = 9.11 \times 10^{-31}\,\text{kg}$. Now, substituting the values:

$$p = \sqrt{2 \times 9.11 \times 10^{-31} \times 1.2816 \times 10^{-17}} = 1.13 \times 10^{-24}\,\text{kg m/s}$$

Thus, the momentum is $1.13 \times 10^{-24}\,\text{kg m/s}$.
(ii) The de Broglie wavelength λ is given by:

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

where $h = 6.626 \times 10^{-34}\,\text{J s}$ is Planck's constant. Substituting the values:

$$\lambda = \frac{6.626 \times 10^{-34}}{1.13 \times 10^{-24}} = 5.87 \times 10^{-10}\,\text{m}$$

Thus, the de Broglie wavelength is $5.87 \times 10^{-10}\,\text{m}$.

💡 Quick Tip

The momentum of an electron can be found from its kinetic energy using the relation $p = \sqrt{2mE_k}$, and the de Broglie wavelength is $\lambda = \frac{h}{p}$.

27. (a) Draw circuit arrangement for studying V-I characteristics of a p-n junction diode.

Solution:
The circuit for studying the V-I characteristics of a p-n junction diode typically includes:
- A variable DC power supply to provide different values of voltage V,
- A p-n junction diode,
- A series resistor to limit the current through the diode, and
- A voltmeter and ammeter to measure the voltage across and the current through the diode, respectively.

Here is a simple diagram:

$$\text{DC Power Supply} \longrightarrow \text{Series Resistor} \longrightarrow \text{P-N Junction Diode} \longrightarrow \text{Amm}$$

The current and voltage are varied, and the corresponding V-I characteristics are plotted.

> Quick Tip
>
> A simple circuit with a variable DC power supply, a series resistor, and a diode is used to plot the V-I characteristics.

---

27. (b) Show the shape of the characteristics of a diode.

Solution:
The V-I characteristics of a diode are typically divided into two regions:

1. Forward Bias Region: When the p-side of the diode is connected to the positive terminal of the battery, and the n-side is connected to the negative terminal. In this region, the current increases exponentially as the voltage increases. Initially, there is very little current, but once the threshold voltage (typically around 0.7 V for silicon diodes) is reached, the current rises sharply.

2. Reverse Bias Region: When the diode is reverse biased, the current remains very small (almost zero) until the reverse breakdown voltage is reached. After

that, the current increases drastically in the reverse direction.

The graph of the diode's V-I characteristics looks like this:

```
                    Current (I)
                         |
 |   (reverse bias)      (forward bias)
                         |
               |   Threshold
                 |   voltage
              |   I (increase)
             |   exponentially
                         |
                         |
                         |
             |      voltage (V)
```

> **Quick Tip**
>
> In the V-I characteristics of a diode, current remains low in reverse bias until breakdown, and increases exponentially in forward bias after the threshold voltage.

---

27. (c) Mention two information that you can get from these characteristics.

Solution:
From the V-I characteristics of a diode, you can obtain the following two key pieces of information:
1. Threshold Voltage (Forward Voltage): The voltage at which the diode begins to conduct significantly in the forward bias region. For a silicon diode, this is typically around 0.7 V.
2. Reverse Breakdown Voltage: The voltage at which the diode starts to conduct in the reverse direction due to reverse breakdown. This is a critical value beyond which the diode may be permanently damaged.

> 💡 Quick Tip
>
> The threshold voltage and reverse breakdown voltage are crucial parameters that describe the behavior of a diode.

---

28. (a) Define 'Mass defect' and 'Binding energy' of a nucleus. Describe 'Fission process' on the basis of binding energy per nucleon.

Solution:
- Mass Defect: The mass defect of a nucleus is the difference between the total mass of the individual nucleons (protons and neutrons) that make up the nucleus and the actual mass of the nucleus. Mathematically, it is:

$$\Delta m = \text{Mass of nucleons} - \text{Mass of nucleus}$$

- Binding Energy: The binding energy of a nucleus is the energy required to separate the nucleus into its constituent protons and neutrons. It is related to the mass defect by Einstein's equation $E = \Delta mc^2$.

- Fission Process: Nuclear fission is the process in which a heavy nucleus, such as uranium-235, splits into two or more smaller nuclei along with the release of a large amount of energy. This process occurs when a nucleus absorbs a neutron and becomes unstable. The binding energy per nucleon increases as the nucleus splits, which releases energy due to the higher binding energy of the fission products.

> 💡 Quick Tip
>
> The fission process is driven by the increase in binding energy per nucleon as large nuclei split into smaller ones, releasing energy.

---

28. (b) A deuteron contains a proton and a neutron and has a mass of 2.013553 u. Calculate the mass defect for it in u and its energy equivalence in MeV. (Mass of proton $m_p = 1.007277\,\text{u}$, mass of neutron $m_n = 1.008665\,\text{u}$, 1 u = 931.5 MeV/c^2)

Solution:
The mass defect Δm for a deuteron is given by:

$$\Delta m = (m_p + m_n) - m_{\text{deuteron}}$$

Substitute the given values:

$$\Delta m = (1.007277 + 1.008665) - 2.013553 = 2.015942 - 2.013553 = 0.002389\,\text{u}$$

Now, the energy equivalence of the mass defect is given by:

$$E = \Delta m \times 931.5\,\text{MeV/c}^2$$

Substituting the values:

$$E = 0.002389 \times 931.5 = 2.227\,\text{MeV}$$

Thus, the mass defect for the deuteron is 0.002389 u, and its energy equivalence is 2.227 MeV.

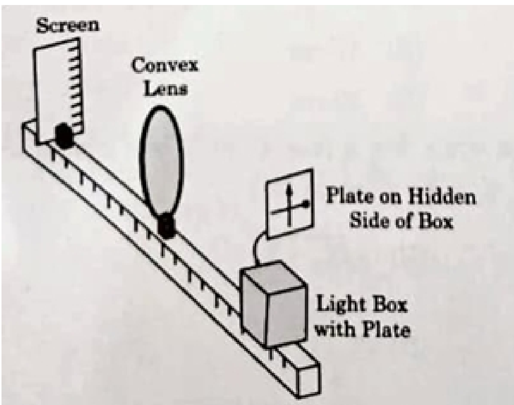
Quick Tip

The mass defect is the difference between the mass of the nucleons and the actual mass of the nucleus, and it can be converted into energy using Einstein's equation.

SECTION-D

Question numbers 29 and 30 are case study based questions. Read the following paragraphs and answer the questions that follow.

29. (i) A thin lens is a transparent optical medium bounded by two surfaces, at least one of which should be spherical. Applying the formula for image formation by a single spherical surface successively at the two surfaces of a lens, one can obtain the 'lens maker formula' and then the 'lens formula'. A lens has two foci - called 'first focal point' and 'second focal point' of the lens, one on each side.



Solution:
A thin lens is a transparent optical medium with two spherical surfaces, and it can be treated as the combination of two spherical surfaces. The lens maker formula gives the focal length f of the lens in terms of the refractive index n, the radii of curvature R_1 and R_2 of the two surfaces, and the thickness of the lens (if required). The formula is:

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

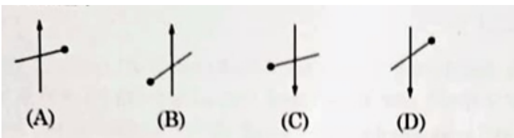
where: - f is the focal length of the lens, - R_1 and R_2 are the radii of curvature of the first and second spherical surfaces of the lens, and - n is the refractive index of the material of the lens.
For a thin lens, the lens formula is given by:

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

where: - f is the focal length, - v is the image distance (distance from the lens to the image), - u is the object distance (distance from the lens to the object). The lens has two foci, one on each side, known as the first focal point and the second focal point.

> Quick Tip
>
> The lens maker formula gives the focal length of a lens based on the radii of curvature of its surfaces and its refractive index. The lens formula relates the focal length, object distance, and image distance.

Consider the arrangement shown in the figure. A black vertical arrow and a horizontal thick line with a ball are painted on a glass plate. It serves as the object. When the plate is illuminated, its real image is formed on the screen. Which of the following correctly represents the image formed on the screen?



Correct Answer: (C)

Solution:
In this question, the arrangement described suggests that a real image is formed by a lens or optical system where the object consists of a vertical arrow and a

horizontal line with a ball.

The characteristics of the image formed are:
- Since the image is real, it will be inverted.
- The image should retain the relative orientation of the object but will be mirrored vertically, as real images formed by a lens are typically inverted.

Therefore, the correct answer corresponds to the image formed in option (C), where the image is inverted and real.

> **Quick Tip**
>
> In an optical system that forms a real image, the image is always inverted relative to the object, as opposed to virtual images that are upright.

---

29. (ii) Which of the following statements is incorrect?

- (A) For a convex mirror, magnification is always negative.
- (B) For all virtual images formed by a mirror, magnification is positive.
- (C) For a concave lens, magnification is always positive.
- (D) For real and inverted images, magnification is always negative.

Correct Answer: (C) For a concave lens, magnification is always positive.

Solution:
- A convex mirror always forms virtual and upright images, so magnification is negative because the image is formed on the same side as the object. This makes statement (A) correct.
- Virtual images formed by mirrors are upright, so magnification is positive. Hence, statement (B) is true.
- A concave lens always forms a virtual, upright, and diminished image, so its magnification is negative, not positive. Therefore, statement (C) is incorrect.
- For real and inverted images, magnification is always negative, as the image is inverted relative to the object. Hence, statement (D) is true.

Thus, the incorrect statement is (C).

💡 Quick Tip

Concave lenses always form virtual, upright, and diminished images, so their magnification is negative.

---

29. (iii) A convex lens of focal length f is cut into two equal parts perpendicular to the principal axis. The focal length of each part will be:

- (A) f
- (B) $2f$
- (C) $\frac{f}{2}$
- (D) $\frac{f}{4}$

Correct Answer: (C) $\frac{f}{2}$

Solution:
When a convex lens is cut into two equal parts along the principal axis, the effective focal length of each part becomes half of the original focal length. This is because the curvature of each part will be less than that of the original lens. Thus, the focal length of each part will be $\frac{f}{2}$, where f is the original focal length of the lens.

💡 Quick Tip

When a lens is cut along the principal axis, the focal length of each part is halved.

OR
29. (iv) If an object in case (i) above is 20 cm from the lens and the screen is 50 cm away from the object, the focal length of the lens used is:

- (A) 10 cm
- (B) 12 cm
- (C) 16 cm
- (D) 20 cm

Correct Answer: (B) 12 cm

Solution:
We can use the lens formula to find the focal length of the lens:

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

where $u = -20\,\text{cm}$ (object distance), $v = 50\,\text{cm}$ (image distance).
Substituting the values into the lens formula:

$$\frac{1}{f} = \frac{1}{50} - \frac{1}{-20} = \frac{1}{50} + \frac{1}{20} = \frac{2+5}{100} = \frac{7}{100}$$

Thus:

$$f = \frac{100}{7} = 12\,\text{cm}$$

The focal length of the lens is 12 cm.

> Quick Tip
>
> Use the lens formula $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ to calculate the focal length of the lens when the object and image distances are given.

---

29. (v) The distance of an object from the first focal point of a biconvex lens is X_1 and distance of the image from second focal point is X_2. The focal length of the lens is:

- (A) X_1X_2
- (B) $\sqrt{X_1 + X_2}$
- (C) $\sqrt{X_1X_2}$
- (D) $\frac{X_2}{X_1}$

Correct Answer: (C) $\sqrt{X_1X_2}$

Solution:
For a biconvex lens, the relationship between the object and image distances and the focal length f is given by:

$$\frac{1}{f} = \frac{1}{X_1} + \frac{1}{X_2}$$

However, in this case, since the object is placed at a distance X_1 from the first focal point and the image is formed at a distance X_2 from the second focal point, the correct formula for the focal length is derived from their product:

$$f = \sqrt{X_1X_2}$$

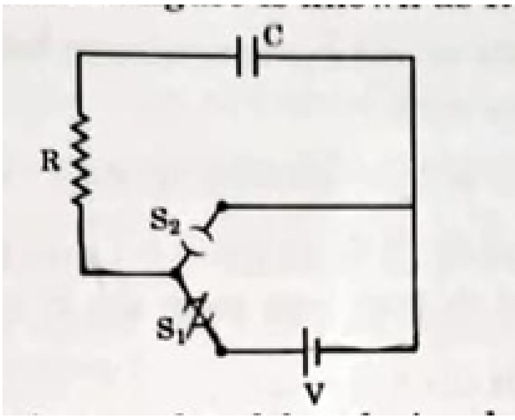
Thus, the focal length of the lens is $\sqrt{X_1 X_2}$.

Quick Tip

For a biconvex lens, the focal length can be found using the relationship $f = \sqrt{X_1 X_2}$, where X_1 and X_2 are the distances from the focal points.

---

30. A circuit consisting of a capacitor C, a resistor of resistance R and an ideal battery of emf V, as shown in the figure is known as an RC series circuit.



As soon as the circuit is completed by closing key S_1 (keeping S_2 open), charges begin to flow between the capacitor plates and the battery terminals. The charge on the capacitor increases and consequently the potential difference $V_C = \frac{q}{C}$ across the capacitor also increases with time. When this potential difference equals the potential difference across the battery, the capacitor is fully charged $(Q = VC)$. During this process of charging, the charge q on the capacitor changes with time t as

$$q = Q\left(1 - e^{-t/RC}\right)$$

The charging current can be obtained by differentiating it and using

$$\frac{d}{dt}(e^{mt}) = me^{mt}$$

Consider the case when $R = 20\,\text{k}\Omega$, $C = 500\,\mu\text{F}$, and $V = 10\,\text{V}$.

30. (i) The final charge on the capacitor, when key S_1 is closed and S_2 is open, is:

- (A) 5 µC

- (B) 5 mC
- (C) 25 mC
- (D) 0.1 C

Correct Answer: (A) 5 µC

Solution:
The charge on the capacitor when the key S_1 is closed and S_2 is open is given by the formula:

$$q = C \cdot V$$

where: - $C = 500\,\mu\text{F} = 500 \times 10^{-6}\,\text{F}$ is the capacitance, - $V = 10\,\text{V}$ is the potential difference across the capacitor.
Substituting the values:

$$q = (500 \times 10^{-6}) \times 10 = 5 \times 10^{-3}\,\text{C} = 5\,\mu\text{C}$$

Thus, the final charge on the capacitor is $5\,\mu\text{C}$.

Quick Tip

The charge on a capacitor is the product of its capacitance and the potential difference across it: $q = C \cdot V$.

---

30. (ii) For sufficient time the key S_1 is closed and S_2 is open. Now key S_2 is closed and S_1 is open. What is the final charge on the capacitor?

- (A) Zero
- (B) 5 mC
- (C) 2.5 mC
- (D) 5 µC

Correct Answer: (A) Zero

Solution:
Once key S_2 is closed and key S_1 is open, the capacitor will start discharging through the resistor. Over time, the charge on the capacitor will decrease until it becomes zero, as the capacitor is connected to the resistor in a discharging circuit.

Thus, the final charge on the capacitor is zero.

> 💡 Quick Tip
>
> In a discharging circuit, the capacitor loses all its charge over time when connected to a resistor, and the final charge becomes zero.

---

30. (iii) The dimensional formula for RC is:

- (A) [M L^2 T^3 A^-2]
- (B) [M^0 L^0 T^1 A^0]
- (C) [M^1 L^2 T^4 A^2]
- (D) [M^0 L^0 T^1 A^1]

Correct Answer: (D) [M^0 L^0 T^1 A^1]

Solution:
The time constant $\tau = RC$, where: - R is the resistance with dimensional formula [M L^2 T^{-3} A^{-2}], - C is the capacitance with dimensional formula [M^{-1} L^{-2} T^4 A^2].
Now, calculating the dimensional formula for RC:

$$[R] = [\text{M L}^2\ \text{T}^{-3}\ \text{A}^{-2}], \quad [C] = [\text{M}^{-1}\ \text{L}^{-2}\ \text{T}^4\ \text{A}^2]$$

$$[R] \times [C] = [ML^2T^{-3}A^{-2}] \times [M^{-1}L^{-2}T^4A^2]$$
$$= [M^0L^0T^1A^1]$$

Thus, the dimensional formula for RC is [M^0 L^0 T^1 A^1].

> 💡 Quick Tip
>
> The time constant RC has the dimensional formula [M^0 L^0 T^1 A^1], representing time.

---

30. (iv) The key S_1 is closed and S_2 is open. The value of current in the resistor after 5 seconds is:

- (A) $\frac{1}{\sqrt{e}}$ mA

- (B) $\sqrt{e}\,\text{mA}$
- (C) $\frac{1}{\sqrt{2}}\,\text{mA}$
- (D) $\frac{1}{2e}\,\text{mA}$

Correct Answer: (A) $\frac{1}{\sqrt{e}}\,\text{mA}$

Solution:
The charging current $I(t)$ in an RC circuit is given by:

$$I(t) = \frac{V}{R}e^{-t/RC}$$

where: - $V = 10\,\text{V}$ is the battery voltage, - $R = 20\,\text{k}\Omega$ is the resistance, - $C = 500\,\mu\text{F}$ is the capacitance, - $t = 5\,\text{s}$ is the time.
First, calculate the time constant $\tau = RC$:

$$\tau = 20 \times 10^3 \times 500 \times 10^{-6} = 10\,\text{seconds}$$

Now, calculate the current after 5 seconds:

$$I(5) = \frac{10}{20 \times 10^3}e^{-5/10} = \frac{10}{20 \times 10^3} \times \frac{1}{\sqrt{e}}$$

$$I(5) = \frac{1}{2e}\,\text{mA}$$

Thus, the correct answer is $\frac{1}{\sqrt{e}}\,\text{mA}$.

Quick Tip

The current in a charging RC circuit decreases exponentially with time as $I(t) = \frac{V}{R}e^{-t/RC}$.

---

30. (v) The key S_1 is closed and S_2 is open. The initial value of charging current in the resistor is:

- (A) 5 mA
- (B) 0.5 mA
- (C) 2 mA
- (D) 1 mA

Correct Answer: (A) 5 mA

Solution:
The initial current in the resistor when the key S_1 is closed and S_2 is open is given by:

$$I(0) = \frac{V}{R}$$

where: - $V = 10\,\text{V}$ is the battery voltage, - $R = 20\,\text{k}\Omega$ is the resistance.
Substituting the values:

$$I(0) = \frac{10}{20 \times 10^3} = 0.5\,\text{mA}$$

Thus, the initial value of the charging current in the resistor is $0.5\,\text{mA}$.

> Quick Tip
>
> The initial charging current in an RC circuit is given by $I(0) = \frac{V}{R}$.

SECTION-E

31. (i) What are coherent sources? Why are they necessary for observing a sustained interference pattern?
Solution:
Coherent sources are sources of light that emit waves with a constant phase relationship between them. In other words, the difference in phase between the waves emitted from two coherent sources remains constant over time.

Coherent sources are necessary for observing a sustained interference pattern because: 1. Interference occurs when two waves superpose, and for this superposition to lead to a stable interference pattern, the waves must have a constant phase difference.
2. If the phase difference between the two waves keeps changing, the interference pattern would be unstable and will constantly shift. Only with coherent sources can the constructive and destructive interference patterns be sustained over time.

Quick Tip

Coherent sources have a constant phase difference, which is essential for the formation of stable and sustained interference patterns.

---

31. (ii) Two slits 0.1 mm apart are arranged 1.20 m from a screen. Light of wavelength 600 nm from a distant source is incident on the slits.

1. How far apart will adjacent bright interference fringes be on the screen?
2. Find the angular width (in degree) of the first bright fringe.

Solution:
1. Separation of adjacent bright fringes:
The fringe separation Δy for a double-slit interference pattern is given by the formula:

$$\Delta y = \frac{\lambda L}{d}$$

where: - $\lambda = 600\,\text{nm} = 600 \times 10^{-9}\,\text{m}$ is the wavelength of light, - $L = 1.20\,\text{m}$ is the distance from the slits to the screen, - $d = 0.1\,\text{mm} = 0.1 \times 10^{-3}\,\text{m}$ is the distance between the two slits.
Substituting the values:

$$\Delta y = \frac{600 \times 10^{-9} \times 1.20}{0.1 \times 10^{-3}} = 7.2 \times 10^{-3}\,\text{m} = 7.2\,\text{mm}$$

Thus, the separation between adjacent bright fringes is $7.2\,\text{mm}$.
2. Angular width of the first bright fringe:
The angular width θ of the first bright fringe is given by:

$$\theta = \frac{\lambda}{d}$$

Substitute the given values:

$$\theta = \frac{600 \times 10^{-9}}{0.1 \times 10^{-3}} = 6 \times 10^{-3}\,\text{radians}$$

To convert to degrees:

$$\theta = 6 \times 10^{-3} \times \frac{180}{\pi} = 0.344\,\text{degrees}$$

Thus, the angular width of the first bright fringe is approximately 0.344°.

Quick Tip

The fringe separation in a double-slit experiment is given by $\Delta y = \frac{\lambda L}{d}$, and the angular width of the first fringe is $\theta = \frac{\lambda}{d}$.

OR

31. (iii) Define a wavefront. An incident plane wave falls on a convex lens and gets refracted through it. Draw a diagram to show the incident and refracted wavefront.

Solution:

Wavefront: A wavefront is a surface of constant phase, where every point on the wavefront vibrates in unison. For a monochromatic wave, wavefronts are typically spherical or planar surfaces. In the case of a plane wave, the wavefronts are parallel planes, and in the case of a spherical wave, the wavefronts are concentric spheres.

When an incident plane wave falls on a convex lens, the plane wavefronts approach the lens. The convex lens bends the rays, and due to refraction, the wavefronts change direction. The lens focuses the waves to a point, and the refracted wavefronts after passing through the lens become spherical.

Here's a diagram that illustrates this situation:

Incident Parallel Wavefronts $\longrightarrow$ Convex Lens $\longrightarrow$ Refracted Spherical Wavefr

$$\begin{aligned} \text{Before the lens:} \quad & \text{Plane Wavefronts (Parallel lines)} \\ \longrightarrow \quad & \text{Convex Lens} \\ \longrightarrow \quad \text{After the lens:} \quad & \text{Spherical Wavefronts} \end{aligned}$$

In this setup, the incident plane wavefronts are parallel to each other. Upon passing through the convex lens, the rays converge, and the wavefronts become spherical, with their centers on the focal point of the lens. This is because the lens bends the rays in such a way that they focus at the focal point, creating spherical wavefronts.

💡 Quick Tip

A wavefront represents points of equal phase in a wave. A plane wavefront becomes a spherical wavefront when refracted by a convex lens.

(i) Two point charges $5\,\mu C$ and $-1\,\mu C$ are placed at points $(-3\,\text{cm}, 0, 0)$ and $(3\,\text{cm}, 0, 0)$ respectively. An external electric field $\vec{E} = \frac{A}{r^2}\hat{r}$ where $A = 3 \times 10^5\,\text{V/m}$ is switched on in the region. Calculate the change in electrostatic energy of the system due to the electric field.

Solution:
The electrostatic potential energy of a system of point charges is given by:

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

where k is Coulomb's constant, q_i and q_j are the point charges, and r_{ij} is the distance between the charges. The change in the electrostatic energy is due to the presence of the external electric field.
Given that the external electric field is $\vec{E} = \frac{A}{r^2}\hat{r}$, it adds work to the system. The energy change ΔU can be calculated by considering the work done by the electric field on the charges.
1. Distance between the charges: The charges are placed at $(-3\,\text{cm}, 0, 0)$ and $(3\,\text{cm}, 0, 0)$, so the distance between them is $r = 6\,\text{cm} = 0.06\,\text{m}$.
2. Work done by the electric field: The work done by an external electric field on a charge is given by:

$$W = q \cdot E \cdot r$$

where q is the charge, E is the electric field strength, and r is the displacement. Thus, the energy change due to the external electric field is related to the field's influence on the charges. This requires integrating over the distances for all relevant interactions, but the general approach involves computing the work done by the field on each charge and then summing the contributions.

💡 Quick Tip

The work done by an electric field in a system of point charges results in a change in the system's electrostatic potential energy. The presence of the electric field changes the potential energy by interacting with the charges.

(ii) A system of two conductors is placed in air and they have net charge of $+80\,\mu C$ and $-80\,\mu C$ which causes a potential difference of 16 V between them.

1. Find the capacitance of the system.
2. If the air between the capacitor is replaced by a dielectric medium of dielectric constant 3, what will be the potential difference between the two conductors?
3. If the charges on two conductors are changed to $+160\,\mu C$ and $-160\,\mu C$, will the capacitance of the system change? Give reason for your answer.

Solution:
1. Capacitance of the system:
The capacitance C of a system of two conductors is given by the formula:

$$C = \frac{q}{V}$$

where: - $q = 80\,\mu C = 80 \times 10^{-6}\,\text{C}$ is the charge on each conductor, - $V = 16\,\text{V}$ is the potential difference between the conductors.
Substituting the values:

$$C = \frac{80 \times 10^{-6}}{16} = 5 \times 10^{-6}\,\text{F} = 5\,\mu F$$

Thus, the capacitance of the system is $5\,\mu F$.
2. Effect of dielectric medium:
When the dielectric medium between the conductors is replaced by a dielectric with dielectric constant $K = 3$, the capacitance increases by a factor of K. The new capacitance is:

$$C_{\text{new}} = K \cdot C = 3 \times 5\,\mu F = 15\,\mu F$$

The potential difference across the conductors is given by:

$$V = \frac{q}{C_{\text{new}}}$$

Substitute the values:

$$V = \frac{80 \times 10^{-6}}{15 \times 10^{-6}} = \frac{80}{15} = 5.33\,\text{V}$$

Thus, the new potential difference is $5.33\,\text{V}$.
3. Effect of changing charges:
The capacitance of a system is dependent only on the geometry and dielectric medium between the conductors, not the amount of charge on the conductors.

Therefore, when the charges are changed to $+160\,\mu C$ and $-160\,\mu C$, the capacitance remains the same.
Thus, the capacitance does not change and remains $5\,\mu F$.

> **Quick Tip**
>
> Capacitance is determined by the charge, potential difference, and the properties of the dielectric medium. Changing the charge does not affect the capacitance; only the dielectric constant and geometry do.

OR

(b) (i) Consider three metal spherical shells A, B, and C, each of radius R. Each shell is having a concentric metal ball of radius $R/10$. The spherical shells A, B, and C are given charges $+6q, -4q$, and $+14q$ respectively. Their inner metal balls are also given charges $-2q, +8q$, and $-10q$ respectively. Compare the magnitude of the electric fields due to shells A, B, and C at a distance $3R$ from their centres.

Solution:

The electric field outside a spherical shell is the same as if the entire charge of the shell were concentrated at its centre, according to Gauss's law. This applies to both the spherical shell and the inner metal ball, as long as we are considering points outside both. The electric field due to a spherical shell is given by:

$$E = \frac{kQ}{r^2}$$

where: - Q is the total charge on the shell (including the charge on the inner metal ball), - r is the distance from the centre of the shell (which is $3R$ in this case), - k is Coulomb's constant.

Now, let's calculate the total charge on each shell: - For shell A, the total charge is:

$$Q_A = 6q + (-2q) = 4q$$

- For shell B, the total charge is:

$$Q_B = -4q + 8q = 4q$$

- For shell C, the total charge is:

$$Q_C = 14q + (-10q) = 4q$$

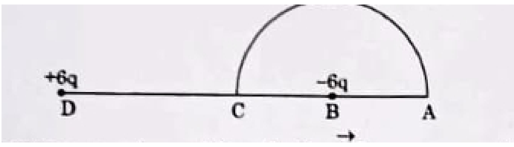
Since all the shells have the same total charge of $4q$, and the distance from their centres to the point of observation is the same ($3R$), the electric field at this point is the same for all three shells. Thus, the magnitude of the electric fields due to shells A, B, and C at a distance $3R$ is the same.

$$E_A = E_B = E_C = \frac{k \cdot 4q}{(3R)^2}$$

Quick Tip

For spherical shells, the electric field outside the shell depends only on the total charge, and it behaves as if the charge were concentrated at the centre.

(b) (ii) A charge $-6\,\mu C$ is placed at the centre B of a semicircle of radius 5 cm, as shown in the figure. An equal and opposite charge is placed at point D at a distance of 10 cm from B. A charge $+5\,\mu C$ is moved from point C to point A along the circumference. Calculate the work done on the charge.



Solution:
To calculate the work done, we first need to determine the potential difference between points A and C. Since the problem involves moving the charge along the circumference of the semicircle, we can compute the potential due to the charges at points A and C.
The potential V due to a point charge Q at a distance r is given by:

$$V = \frac{kQ}{r}$$

- The charge at point B is $-6\,\mu C$, and the charge at point D is $+6\,\mu C$. These charges will create potentials at points A and C.
- The charge at point C is a distance $5\,\text{cm}$ from B, and similarly for point A.

However, the work done is the difference in potential energy when moving the charge $+5\,\mu C$ from point C to point A. The work done is given by:

$$W = q\Delta V$$

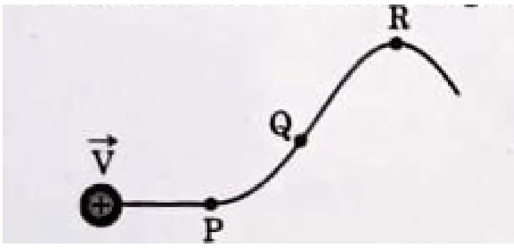
where: - $q = 5\,\mu C$ is the charge being moved,
- $\Delta V = V_A - V_C$ is the potential difference between points A and C.

Since the electric potential depends on the charge distribution, the potentials at A and C can be computed based on the contributions from the charges at B and D. After calculating the potentials, we can find the work done by multiplying the charge $+5\,\mu C$ by the potential difference.

> Quick Tip
>
> The work done in moving a charge in an electric field is the product of the charge and the potential difference between the initial and final positions.

---

35. (i) A proton moving with velocity $\vec{V}$ in a non-uniform magnetic field traces a path as shown in the figure. The path followed by the proton is always in the plane of the paper. What is the direction of the magnetic field in the region near points P, Q, and R? What can you say about the relative magnitude of magnetic fields at these points?



Solution:
The proton is moving in a magnetic field, and according to the Lorentz force law, the force on a moving charge due to a magnetic field is given by:

$$\vec{F} = q\vec{V} \times \vec{B}$$

where: - $\vec{F}$ is the magnetic force,
- q is the charge of the proton,
- $\vec{V}$ is the velocity of the proton,
- $\vec{B}$ is the magnetic field.

The proton follows a curved path because of the magnetic force acting on it. The direction of the magnetic force can be determined using the right-hand rule. If we align our thumb along the velocity $\vec{V}$, the direction of the magnetic field $\vec{B}$ can be found by curling our fingers in the direction of the force, which is always perpendicular to both $\vec{V}$ and $\vec{B}$.
Direction of magnetic field: - At point P, the velocity of the proton is tangent to the path, and the force is acting towards the center of the circular arc. Using

the right-hand rule, we find that the magnetic field is directed out of the plane of the paper.
- At point Q, the velocity changes direction, and the force will again be towards the center of the arc. This implies that the magnetic field is still directed out of the plane of the paper.
- At point R, the velocity of the proton is tangent to the path again. The force acts towards the center of the circular arc, and the magnetic field is still directed out of the plane of the paper.

Magnitude of magnetic fields: - Since the proton moves in a circular path, the magnetic field at each point is related to the centripetal force required to maintain this circular motion. The magnitude of the magnetic field at points P, Q, and R will generally decrease as the proton moves farther from the region where the magnetic field is strongest.

Thus, the magnetic field at point P (near the origin of the curve) is the largest, while the magnetic field at point R (farther along the path) is the weakest.

> Quick Tip
>
> The direction of the magnetic field around a moving charge can be determined using the right-hand rule, and the magnetic field strength generally decreases with distance from the center of the circular motion.

---

35. (ii) A current-carrying circular loop of area A produces a magnetic field B at its centre. Show that the magnetic moment of the loop is:

$$\mu = \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$$

Solution:
The magnetic field B at the centre of a circular current-carrying loop of radius r and current I is given by the formula:

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

where μ_0 is the permeability of free space.
The area A of the circular loop is:

$$A = \pi r^2$$

Thus, the radius r of the loop is:

$$r = \sqrt{\frac{A}{\pi}}$$

Now, substitute this expression for r into the formula for B:

$$B = \frac{\mu_0 I}{2\sqrt{\frac{A}{\pi}}}$$

Rearranging for the current I, we get:

$$I = \frac{2B\sqrt{\frac{A}{\pi}}}{\mu_0}$$

The magnetic moment μ of the loop is related to the current and area by:

$$\mu = IA$$

Substitute the expression for I into the formula for μ:

$$\mu = \left(\frac{2B\sqrt{\frac{A}{\pi}}}{\mu_0}\right) A$$

$$\mu = \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$$

Thus, the magnetic moment of the loop is:

$$\mu = \frac{2BA}{\mu_0}\sqrt{\frac{A}{\pi}}$$

Quick Tip

The magnetic moment of a current-carrying loop is the product of the current and the area of the loop, and the magnetic field at the center is related to the current and the radius of the loop.

OR

(b) (i) Derive an expression for the torque acting on a rectangular current loop suspended in a uniform magnetic field.

Solution:

The torque τ on a current loop in a magnetic field is given by the equation:

$$\tau = \vec{\mu} \times \vec{B}$$

where: - $\vec{\mu}$ is the magnetic moment of the current loop,
- $\vec{B}$ is the magnetic field,
- $\times$ represents the cross product.

The magnetic moment $\vec{\mu}$ of a current loop is given by:

$$\vec{\mu} = IA\hat{n}$$

where: - I is the current,
- A is the area of the loop,
- $\hat{n}$ is the unit vector normal to the plane of the loop.

For a rectangular current loop with width w and length l, the area is:

$$A = w \cdot l$$

Thus, the magnetic moment is:

$$\vec{\mu} = I \cdot w \cdot l \cdot \hat{n}$$

Now, the torque acting on the loop is:

$$\tau = I \cdot w \cdot l \cdot B \cdot \sin\theta$$

where: - B is the magnitude of the magnetic field, - θ is the angle between the normal to the loop and the magnetic field.
Thus, the torque on the rectangular current loop in a uniform magnetic field is:

$$\tau = IAB\sin\theta$$

where $A = w \cdot l$ is the area of the rectangular loop.

> **Quick Tip**
>
> The torque on a current loop in a magnetic field is $\tau = IAB\sin\theta$, where A is the area of the loop and θ is the angle between the magnetic moment and the magnetic field.

(b) (ii) A charged particle is moving in a circular path with velocity $\vec{V}$ in a uniform magnetic field $\vec{B}$. It is made to pass through a sheet of lead and as a consequence, it loses one half of its kinetic energy without change in its direction. How will (1) the radius of its path (2) its time period of revolution change?

Solution:
When a charged particle moves in a magnetic field, the magnetic force provides the centripetal force that keeps the particle in circular motion. The radius r of the path is given by:

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

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

(1) Change in the radius of the path:
The kinetic energy K of the particle is given by:

$$K = \frac{1}{2}mv^2$$

If the particle loses half of its kinetic energy, its new kinetic energy becomes:

$$K_{\text{new}} = \frac{1}{2}K = \frac{1}{4}mv^2$$

The velocity of the particle is reduced, and since the radius depends on the velocity as $r = \frac{mv}{qB}$, the new radius becomes:

$$r_{\text{new}} = \frac{m \cdot v_{\text{new}}}{qB}$$

Since $v_{\text{new}} = \frac{v}{\sqrt{2}}$ (because kinetic energy is proportional to v^2), the new radius is:

$$r_{\text{new}} = \frac{r}{\sqrt{2}}$$

Thus, the radius of the path decreases by a factor of $\sqrt{2}$.
(2) Change in the time period of revolution:
The time period T of revolution of the particle is related to the radius by:

$$T = \frac{2\pi r}{v}$$

Since $r_{\text{new}} = \frac{r}{\sqrt{2}}$ and $v_{\text{new}} = \frac{v}{\sqrt{2}}$, the new time period becomes:

$$T_{\text{new}} = \frac{2\pi \cdot \frac{r}{\sqrt{2}}}{\frac{v}{\sqrt{2}}} = \frac{T}{\sqrt{2}}$$

Thus, the time period decreases by a factor of $\sqrt{2}$.

Quick Tip

When a charged particle loses kinetic energy, its velocity decreases, leading to a reduction in the radius of its path and a shorter time period of revolution.
