CHAPTER 4

MOVING CHARGES AND MAGNETISM

CLASS 12TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS

4.1: A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil?

SOLUTION:

Given-number of turns (n) = 100, radius (r) = 8 cm = 0.08 m, Current (I) = 0.40 A.

Need to find - Magnetic field (B) at the centre of the coil.

Magnetic field (B) at the centre of the coil is given by,

$$B = \frac{\mu_0}{4\pi}\frac{2\pi nI}{r} = \frac{\mu_0}{2}\frac{nI}{r} \qquad (\therefore \mu_0 = 4\pi \times 10^{-7}\ \text{Tm/A})$$

$$B = \frac{4\pi \times 10^{-7}}{2} \times \frac{100 \times 0.4}{0.08}$$

$$B = 3.14 \times 10^{-4}\ \text{T}$$

Therefore, the magnetic field is 3.14×10^{-4} T.

4.2: A long straight wire carries a current of 35 A. What is the magnitude of the field B at a point 20 cm from the wire?

SOLUTION:

Given – Current (I) = 35 A, Distance (r) = 20 cm = 0.2 m.

Need to find – Magnetic field (B)

Magnetic field at a point due to a current carrying straight wire is:

$$B = \frac{\mu_0}{4\pi}\frac{2I}{r} \qquad (\therefore \mu_0 = 4\pi \times 10^{-7}\ \text{Tm/A})$$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 35}{4\pi \times 0.2}$$

$$B = 3.5 \times 10^{-5}\ \text{T}$$

Therefore, the magnetic field due to a current carrying straight wire is 3.5×10^{-5}T.

4.3: A long straight wire in the horizontal plane carries a current of 50 A in north to south direction. Give the magnitude and direction of B at a point 2.5 m east of the wire.

SOLUTION:

Given – Current (I) =50 A (direction – N to S), Distance of point from wire (r) = 2.5 m (direction – E)

Need to find – Magnetic field (B) (magnitude and direction both)

Magnetic field at a point due to a current carrying straight wire is:

$$B=\frac{\mu_0}{4\pi}\frac{2I}{r} \qquad (\because \mu_0 = 4\pi \times 10^{-7}\ \text{Tm/A})$$

$$B=\frac{4\pi\times10^{-7}\times2\times50}{4\pi\times2.5}$$

$$B=4\times10^{-6}\text{T}$$

Therefore, the magnetic field due to a current carrying straight wire is 4×10^{-6} T.

Direction: By using Maxwell's Right Hand Thumb Rule, the direction of magnetic field at a given point is vertically upward.

4.4 A horizontal overhead power line carries a current of 90 A in east to west direction. What is the magnitude and direction of the magnetic field due to the current 1.5 m below the line?

SOLUTION:

Given – Current (I) = 90 A (direction – E to W), Distance (r) = 1.5 m (below the power line)

Need to find – Magnetic field (B) (magnitude and direction both)

Magnetic field at a point is:

$$B=\frac{\mu_0}{4\pi}\frac{2I}{r} \qquad (\because \mu_0 = 4\pi \times 10^{-7}\ \text{Tm/A})$$

$$B=\frac{4\pi\times10^{-7}\times2\times90}{4\pi\times1.5}$$

$$B=1.2\times10^{-5}\ \text{T}$$

Therefore, the magnetic field due to a current carrying straight wire is 1.2×10^{-5} T.

Direction: By using Maxwell's Right Hand Thumb Rule, the direction of magnetic field at a given point is towards the south.

4.5 What is the magnitude of magnetic force per unit length on a wire carrying a current of 8 A and making an angle of 30 with the direction of a uniform magnetic field of 0.15 T?

SOLUTION:

Given – Current (I) = 8A, Angle (θ) = 30°, Magnetic field (B) = 0.15 T.

Need to find – Magnetic force per unit length (F' = F/l).

Magnetic force per unit length is given by,

$$F'=\frac{F}{l}=BI\sin\theta$$

$$F' = 0.15 \times 8 \times \sin 30^{\circ} = 0.15 \times 8 \times \frac{1}{2}$$

$$F' = 0.6 N/\text{m}$$

Therefore, the magnetic force per unit length is 0.6 N/m.

4.6 A 3.0 cm wire carrying a current of 10 A is placed inside a solenoid perpendicular to its axis. The magnetic field inside the solenoid is given to be 0.27 T. What is the magnetic force on the wire?

SOLUTION:

Given – Length of wire (L) = 3 m, Current (I) = 10 A, Magnetic field (B) = 0.27 T.

Need to find – Magnetic force (F) on the wire.

Magnetic force on the wire is given by,

$$F = BIL \sin\theta$$

$$F = (0.27) \times (10) \times (3) \times \sin 90^{\circ}$$

$$F = 8.1 \times 10^{-2} \text{ N}$$

Therefore, the magnetic force on the wire is 8.1×10^{-2} N.

4.7 Two long and parallel straight wires A and B carrying currents of 8.0 A and 5.0 A in the same direction are separated by a distance of 4.0 cm. Estimate the force on a 10 cm section of wire A.

SOLUTION:

Given – Current in wire A: I_A = 8 A and in wire B: I_B = 5 A, Distance between wires (d) = 4 cm = 0.04 m, Length of section of wire (l) = 10 cm = 0.1 m.

Need to find – Force (F)

Force (F) exerted on length l due to the magnetic field is given by,

$$B = \frac{\mu_0 2 I_A I_B l}{4\pi r}$$

$$B = \frac{4\pi \times 10^{-7} \times 2 \times 8 \times 5 \times 0.1}{4\pi \times 0.04}$$

$$B = 2 \times 10^{-5} \text{ N}$$

Therefore, the force exerted on length l is 2×10^{-5} N.

4.8 A closely wound solenoid 80 cm long has 5 layers of windings of 400 turns each. The diameter of the solenoid is 1.8 cm. If the current carried is 8.0 A, estimate the magnitude of B inside the solenoid near its centre.

SOLUTION:

Given – Length of solenoid (l) = 80 cm = 0.8 m, layers of windings = 5 (each of 400 turns), Diameter of solenoid (d) = 1.8 cm = 0.018 m, Current (I) = 8 A.

Need to find – Magnetic field (B) inside the solenoid near its centre.

Total number of turns in solenoid (N) = 5 × 400 = 2000

Magnetic field inside the solenoid near its centre is given by,

$$B = \frac{\mu_0 NI}{l} \qquad (0 = 4\ \text{Tm/A})$$

$$B = \frac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8}$$

$$B = 2.512 \times 10^{-2}\ \text{T}$$

Therefore, the magnetic field inside the solenoid near its centre is 2.512×10^{-2}T.

4.9 A square coil of side 10 cm consists of 20 turns and carries a current of 12 A. The coil is suspended vertically and the normal to the plane of the coil makes an angle of 30º with the direction of a uniform horizontal magnetic field of magnitude 0.80 T. What is the magnitude of torque experienced by the coil?

SOLUTION:

Given – side of square (a) = 10 cm = 0.1 m, Number of turns (n) = 20, Current (I) – 12 A,

Angle (θ) = 30, Magnetic field (B) = 0.80 T.

Need to find – Torque experienced by the coil.

Torque experienced by the coil in the magnetic field is given by,

$$\tau = nBIA\sin\theta$$

$\therefore$ A = (a × a) = (0.1) × (0.1) = 0.01m²

Now,

$$\tau = 20 \times 0.8 \times 12 \times 0.01 \times \sin 30^\circ$$

$$\tau = 20 \times 0.8 \times 12 \times 0.01 \times \frac{1}{2}$$

$$\tau = 0.96\text{N-m}$$

Therefore, the torque experienced by the coil in the magnetic field is 0.96N-m.

4.10 Two moving coil meters, M_1 and M_2 have the following particulars:

$R_1 = 10\Omega$, $N_1 = 30$,

$A_1 = 3.6 \times 10^{-3}\ m^2$, $B_1 = 0.25$ T

$R_2 = 14\Omega$, $N_2 = 42$,

$A_2 = 1.8 \times 10^{-3}\ m^2$, $B_2 = 0.50$ T

(The spring constants are identical for the two meters). Determine the ratio of (a) current sensitivity and (b) voltage sensitivity of M_2 and M_1.

SOLUTION:

(a) Current sensitivity of M1 is given by,

$$I_{M1} = \frac{N_1 B_1 A_1}{K_1}$$

Current sensitivity of M_2 is given by,

$$I_{M2} = \frac{N_2 B_2 A_2}{K_2}$$

Ration of current sensitivity is given by,

$$\frac{I_{M2}}{I_{M1}} = \frac{N_2 B_2 A_2 K_1}{K_2 N_1 B_1 A_1}$$

$$\frac{I_{M2}}{I_{M1}} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times K}{K \times 30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$\frac{I_{M2}}{I_{M1}} = 1.4$$

Therefore, the ratio of current sensitivity of M_2 to M_1 is 1.4.

(b) Voltage sensitivity of M_1 is given by,

$$V_{M1} = \frac{N_1 B_1 A_1}{K_1 R_1}$$

Voltage sensitivity of M_2 is given by,

$$V_{M2} = \frac{N_2 B_2 A_2}{K_2 R_2}$$

Ration of voltage sensitivity is given by,

$$\frac{V_{M2}}{V_{M1}} = \frac{N_2 B_2 A_2 K_1 R_1}{K_2 R_2 N_1 B_1 A_1}$$

$$\frac{V_{M2}}{V_{M1}} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times 10 \times K}{K \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$\frac{V_{M2}}{V_{M1}} = 1$$

Therefore, the ratio of voltage sensitivity of M_2 to M_1 is 1.

4.11 In a chamber, a uniform magnetic field of 6.5 G (1 G = 10^{-4} T) is maintained. An electron is shot into the field with a speed of 4.8 × 10^6 m/s normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit. (e = 1.5 × 10^{-19} C, me = 9.1 × 10^{-31} kg)

SOLUTION:

Given – Magnetic field (B) = 6.5 G (1 G = 10^{-4} T), Speed of electron (v) = 4.8 × 10^6 m/s,
e = 1.5 × 10^{-19} C, m_e = 9.1 × 10^{-31} kg, Angle (θ) = 90°.

Need to find – Why the path is circular and radius or circular orbit.

Magnetic force exerted on the electron in the magnetic field is given by,

$$F = evB\sin\theta$$

This force provides necessary centripetal force to the moving electron; that means the electron starts moving in a circular orbit of radius r.

In equilibrium condition,

$$\text{Centripetal force} = \text{Magnetic force}$$

$$\left(\mathrm{F} = \frac{mv^2}{r}\right) = (F = evB\sin\theta)$$

$$r = \frac{mv}{Be\sin\theta}$$

$$r = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times\sin 90^{\circ}}$$

$$r = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times1}$$

$$r = 4.2\times10^{-2}\,\mathrm{m} = 4.2cm$$

Therefore, the radius of the circular orbit is 4.2 cm.

4.12 In Exercise 4.11 obtain the frequency of revolution of the electron in its circular orbit. Does the answer depend on the speed of the electron? Explain.

SOLUTION:

Given – Data from previous question

Need to find – Frequency of revolution of the electrons.

We know that,

$$\left(\mathrm{F} = \frac{mv^2}{r}\right) \cdot = \cdot (F = evB\sin\theta)$$

$\therefore \theta = 90° \Rightarrow$ Sin 90° = 1, v = rω, and ω = 2πν

So
$$eB = \frac{m}{r}(r\omega) = \frac{m}{r}(r2\pi\nu)$$

$$\nu = \frac{eB}{2\pi m}$$

This formula shows that the frequency is independent of the speed of the electron.

Magnitude of frequency is:

$$\nu = \frac{6.5\times10^{-4}\times1.6\times10^{-19}}{2\times3.14\times9.1\times10^{-31}} = 18.2\times10^{6}\,Hz$$

$$\nu \approx 18MHz$$

Therefore, the frequency of revolution of the electrons is around 18 MHz and independent of the speed of electron.

4.13 (a) A circular coil of 30 turns and radius 8.0 cm carrying a current of 6.0 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.0 T. The field lines make an angle of 60° with the normal of the coil. Calculate the magnitude of the counter torque that must be applied to prevent the coil from turning.

(b) Would your answer change, if the circular coil in (a) were replaced by a planar coil of some irregular shape that encloses the same area? (All other particulars are also unaltered.)

SOLUTION:

Given – Number of turns (n) = 30, Radius (r) = 8 cm = 0.08 m, Current (I) = 6 A, Magnetic field (B) = 1 T, Angle (θ) = 60°.

(a) Counter torque to prevent coil from turning is given by,

$$\tau = nBIA\sin\theta$$

∴ Area of coil (A) = $\pi r^2 = (3.14)\times(0.08)^2 = 0.0201\text{m}^2$

Now,

$$\tau = 30\times 6\times 1\times 0.0201\times \sin 60^{\circ}$$

$$\tau = 30\times 6\times 1\times 0.0201\times \frac{\sqrt{3}}{2}$$

$$\tau = 3.133 N-m$$

Therefore, counter torque to prevent coil from turning is 3.133 N-m.

(b) From part (a), we can conclude that the magnitude of the applied torque does not depend on the shape of the coil.

If the circular coil in part (a) is replaced by a planar coil of some irregular shape enclosing the same area (with all other conditions remaining unchanged), the answer remains the same.