NCERT SOLUTIONS
CLASS-XII PHYSICS
CHAPTER-4
MOVING CHARGES AND MAGNETISM

Q 4.1) Determine the magnitude of the magnetic field B at the centre of the circular coil of wire carrying current of 0.4 A and having 100 turns with 8 cm being the radius of each turn.

Answer 4.1:

Number of turns on the coil (n) = 100

Radius of each turn (r) = 8 cm = 0.08 m

Current flowing in the coil (I) = 0.4 A

The following relation gives the magnitude of the magnetic field at the centre of the coil:

$|B| = \frac{\mu_0}{4\pi r} 2\pi n I$

Where,

μ_0 = Permeability of free space

= $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

So,

$|\bar{B}| = \frac{4\pi\times10^{-7}}{4\pi} \times \frac{2\pi\times100\times0.4}{r}$

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

Hence, the magnitude of the magnetic field is $3.14 \times 10^{-4}\ T$.

Q 4.2) Determine the magnitude of the field B at a point that is 20 cm away from the wire through which 35 A current flows.

Answer 4.2:

Current in the wire (I) = 35 A

Distance of a point from the wire (r) = 20 cm = 0.2 m

At this point the magnitude of the magnetic field is given as:

$|\bar{B}| = \frac{\mu_0}{4\pi} \frac{2I}{r}$

Where,

μ_0 = Permeability of free space

= $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

So,

$|\bar{B}| = \frac{4\pi\times10^{-7}}{4\pi} \times \frac{2\times35}{0.2}$

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

Hence, the magnitude of the magnetic field at a point 20 cm from the wire is $3.5 \times 10^{-5}\ T$.

Q 4.3) Determine the direction and magnitude of B at a point that is 2.5 m away in the east direction of the long straight wire that is in a horizontal plane carrying a current of 50 A in North to South direction.

Answer 4.3:

Current in the wire (I) = 50 A

A point is 2.5 m away from the East of the wire.

Therefore, Magnitude of the distance of the point from the wire (r) = 2.5 m

Magnitude of the magnetic field at that point is given by the relation:

$|\bar{B}| = \frac{\mu_0}{4\pi} \frac{2I}{r}$

Where,

μ_0 = Permeability of free space

= $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

$|B| = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2 \times 50}{2.5}$

= $4 \times 10^{-6}\ T$

The point is located normal to the wire length at a distance of 2.5 m. The direction of the current in the wire is vertically downward. Hence, according to the Maxwell's right hand thumb rule, the direction of the magnetic field at the given point is vertically upward.

Q 4.4) A flat overhead electrical cable carries a current of 90 A in east to west course. What is the direction and magnitude of the magnetic field due to the current 1.5 m below the line?

Answer 4.4:

Current in the power line (I) = 90 A

Point is located below the electrical cable at distance (r) = 1.5 m

Hence, magnetic field at that point is given by the relation,

$|\bar{B}| = \frac{\mu_0}{4\pi} \frac{2l}{r}$

Where,

μ_0 = Permeability of free space

= $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

$|\bar{B}| = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2 \times 90}{1.5}$

= $1.2 \times 10^{-5}\ T$

The current is flowing from East to West. The point is below the electrical cable.

Hence, according to Maxwell's right hand thumb rule, the direction of the magnetic field is towards the South.

Q 4.5) A wire carrying a current of 8 A makes an angle of 30^0 with the direction of a uniform magnetic field of 0.15 T. Find the magnitude of magnetic force per unit length on the wire.

Answer 4.5:

Current in the wire (I) = 8 A

Magnitude of the uniform magnetic field (B) = 0.15 T

Angle between the wire and magnetic field, $\theta = 30^\circ$.

Magnetic force per unit length on the wire is given as: F = $BI sin\theta$

= $0.15 \times 8 \times 1 \times sin 30^\circ$

= $0.6\ N\ m^{-1}$

Hence, the magnetic force per unit length on the wire is $0.6\ N\ m^{-1}$.

Q 4.6) Determine the magnetic force on a wire of 3 cm, carrying a current of 10 A and placed inside a solenoid normal to its axis. Inside the solenoid, the magnetic field is given as 0.27 T.

Answer 4.6:

Length of the wire (l) = 3 cm = 0.03 m

Current flowing in the wire (I) = 10 A

Magnetic field (B) = 0.27 T

Angle between the current and magnetic field, $\theta = 90^\circ$.

Magnetic force exerted on the wire is given as:

$F = BIl sin\theta$

= $0.27 \times 10 \times 0.03\ sin 90^\circ$

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

Hence, the magnetic force on the wire is $8.1 \times 10^{-2}\ N$. The direction of the force can be obtained from Fleming's left hand rule.

Q 4.7) Two long and parallel wires, wire A carrying current 8.0 A and wire B carrying current 5.0 A in the same direction are isolated by a distance of 4 cm. Calculate the force on a 10 cm section of wire A.

Answer 4.7:

Current flowing in wire A (I_A) = 8 A

Current flowing in wire B (I_B) = 5 A

Distance between the two wires (r) = 4 cm = 0.04 m

Length of a section of wire A (L) = 10 cm = 0.1 m

Force exerted on length L due to the magnetic field is given as:

$F = \frac{\mu_o I_A I_B L}{2\pi r}$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

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

The magnitude of force is $2 \times 10^{-5}\ N$. This is an attractive force normal to A towards B because the direction of the currents in the wires is the same.

Q 4.8) Find the magnitude of magnetic field B inside the solenoid carrying current of 8.0 A near its centre. Given Solenoid diameter as 1.8 cm, length as 80 cm and has 5 layers of windings of 400 turns each.

Answer 4.8:

Solenoid length (l) = 80 cm = 0.8 m

Five layers of windings of 400 turn each on the solenoid.

$\therefore$ Total number of turns on the solenoid, N = 5 x 400 = 2000

Solenoid Diameter (D) = 1.8 cm = 0.018 m

Current carried by the solenoid (I) = 8.0 A

The relation that gives the magnitude of magnetic field inside the solenoid near its centre is given below:

$B = \frac{\mu_0 N I}{l}$

Where,

μ_0 = Permeability of free space = $4\pi \times 10^{-7}\ T\ m\ A^{-1}$

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

= $2.5 \times 10^{-2}\ T$

Hence, The magnitude of B inside the solenoid near its centre is $2.5 \times 10^{-2}\ T$.

Q 4.9) Determine the magnitude of the torque experienced by the square coil when it is suspended vertically and the normal to the plane makes an angle of 30^0 with the direction of a uniform horizontal magnetic field of magnitude 0.8 T. Taking square coil of side 10 cm consisting of 20 turns and carrying a current of 12 A.

Answer 4.9:

Length of a side of the square coil (l) = 10 cm = 0.1 m

Current flowing in the coil (I) = 12 A

Number of turns on the coil (n) = 20

Angle made by the plane of the coil with B (Magnetic field), $\theta = 30^\circ$

Strength of magnetic field, B = 0.8 T

The following relation gives the magnitude of the magnetic torque experienced by the coil in the magnetic field:

$\tau = n\ BIA\ sin\theta$

Where,

A = Area of the square coil

= 1 x 1 = 0.1 x 0.1 = 0.01 m^2

So, $\tau = 20 \times 0.8 \times 12 \times 0.01 \times sin30^{\circ}$

= 0.96 N m

Hence, 0.96 N m is the magnitude of the torque experienced by the coil.

Q 4.10) Find the ratio of

(a) Current sensitivity of M_2 and M_1

(b) Voltage sensitivity of M_2 and M_1

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

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

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

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

$A_2 = 1.8 \times 10^{-3}\ m^2,\ B_2 = 0.5\ T$

(Note: Spring constants are identical for the two meters).

Answer 4.10:

Given data:

Moving coil meter M_1 Moving coil meter M_2

Resistance, $R_1 = 10\ \Omega$ Resistance, $R_1 = 10\ \Omega$

Number of turns, $N_1 = 30$ Number of turns, $N_2 = 42$

Area, $A_1 = 3.6 \times 10^{-3}\ m^2$ Area, $A_2 = 1.8 \times 10^{-3}\ m^2$

Magnetic field strength, B_1 = 0.25 T Magnetic field strength, B_2 = 0.5 T

Spring constant K_1 = K Spring constant K_2 = K

(a) Current sensitivity of M_1 is given as:

$I_{s1} = \frac{N_1 B_1 A_1}{K_1}$

And, Current sensitivity of M_2 is given as:

$I_{s2} = \frac{N_2 B_2 A_2}{K_2} \therefore Ratio \frac{I_{s2}}{I_{s1}} = \frac{N_2 B_2 A_2}{N_1 B_1 A_1} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times K}{K \times 30 \times 0.25 \times 3.6 \times 10^{-3}} = 1.4$

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

(b) Voltage sensitivity for M_2 is given as:

$V_{s2} = \frac{N_2 B_2 A_2}{K_2 R_2}$

And, voltage sensitivity for M_1 is given as:

$V_{s1} = \frac{N_1 B_1 A_1}{K_1 R_1} \therefore Ratio \frac{I_{s2}}{I_{s1}} = \frac{N_2 B_2 A_2 K_1 R_1}{N_1 B_1 A_1 K_2 R_2} = \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times 10 \times K}{K \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}} = 1$

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

Q 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 x 10^6 m s^{-1} normal to the field. Explain why the path of the electron is a circle. Determine the radius of the circular orbit. ($e = 1.6 \times 10^{-19}\ C,\ m_e = 9.1 \times 10^{-31}\ kg$)

Answer 4.11:

Magnetic field strength (B) = 6.5 G = $6.5 \times 10^{-4}\ T$

Speed of the electron (v) = $4.8 \times 10^6\ m/s$

Charge on the electron (e) = $1.6 \times 10^{-19}\ C$

Mass of the electron (m_e) = $9.1 \times 10^{-31}\ kg$

Angle between the shot electron and magnetic field, $\theta = 90^\circ$

The relation for Magnetic force exerted on the electron in the magnetic field is given as:

$F = evB\ sin\theta$

This force provides centripetal force to the moving electron. Hence, the electron starts moving in a circular path of radius r.

Hence, centripetal force exerted on the electron,

$F_e = \frac{mv^2}{r}$

In equilibrium, the centripetal force exerted on the electron is equal to the magnetic force i.e.,

$F_e = F$

=> $\frac{mv^2}{r} = evB\ sin\theta$

=> $r = \frac{mv}{eB\ sin\theta}$

So,

$r = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{6.5 \times 10^{-4} \times 1.6 \times 10^{-19} \times sin90^\circ} = 4.2 \times 10^{-2}\ m = 4.2cm$

Hence, 4.2 cm is the radius of the circular orbit of the electron.

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

Answer 4.12:

Magnetic field strength (B) = $6.5 \times 10^{-4}\ T$

Charge on the electron (e) = $1.6 \times 10^{-19}\ C$

Mass of the electron (m_e) = $9.1 \times 10^{-31}\ kg$

Speed of the electron (v) = $4.8 \times 10^6\ m/s$

Radius of the orbit, r = 4.2 cm = 0.042 m

Frequency of revolution of the electron = v

Angular frequency of the electron = $\omega = 2\pi v$

Velocity of the electron is related to the angular frequency as: $v = r\omega$

In the circular orbit, the magnetic force on the electron is balanced by the centripetal force.

Hence, we can write:

$\frac{mv^2}{r} = evB$

=> $eB = \frac{mv}{r} = \frac{m(r\omega)}{r} = \frac{m(r.2\pi v)}{r}$

=> $v = \frac{Be}{2\pi m}$

This expression for frequency is independent of the speed of the electron. On substituting the known values in this expression, we get the frequency as:

$v = \frac{6.5 \times 10^{-4} \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 1.82 \times 10^6\ Hz \approx 18\ MHz$

Hence, the frequency of the electron is around 18 MHz and is independent of the speed of the electron.

Q 4.13) (a) A circular coil having radius as 8.0 cm, number of turn as 30 and 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 60^0 with the normal of the coil. To prevent the coil from turning, determine the magnitude of the counter torque that must be applied.

(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.)

Answer 4.13:

(a) Number of turns on the circular coil (n) = 30

(a) Number of turns on the circular coil (n) = 30

Radius of the coil (r) = 8.0 cm = 0.08 m

Area of the coil = $\pi r^2 = \pi(0.08)^2 = 0.0201\ m^2$

Current flowing in the coil (I) = 6.0 A

Magnetic field strength, B = 1 T

Angle between the field lines and normal with the coil surface, $\theta = 60^\circ$

The coil experiences a torque in the magnetic field. Hence, it turns. The counter torque applied to prevent the coil from turning is given by the relation,

$\tau = nIBA\ sin\theta$

= $30 \times 6 \times 1 \times 0.0201 \times sin60^\circ$

= 3.133 N m

(b) It can be inferred from the relation $\tau = nIBA\ sin\theta$ that the magnitude of the applied torque is not dependent on the shape of the coil. It depends on the area of the coil. Hence, the answer would not change if the circular coil in the above case is replaced by a planar coil of some irregular shape that encloses the same area.