NCERT Solutions for Class-XII Physics

Chapter-4

NCERT Physics Class 12

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?

1. Number of turns on the circular coil, n = 100
Radius of each turn, r = 8.0 cm = 0.08 m
Current flowing in the coil, I = 0.4 A
Magnitude of the magnetic field at the centre of coil is given by the relation,

$$|\vec{B}| = \frac{\mu_0}{4\pi}\frac{2\pi nI}{r}$$

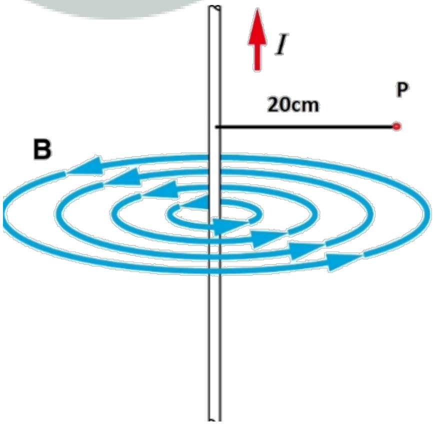
Where, μ_0 = Permeability of free space = $4\pi \times 10^{-7}$ T m A^{-1}
So,

$$|\vec{B}| = \frac{4\pi\times10^{-7}}{4\pi}\times\frac{2\pi\times100\times0.4}{r} = 3.14\times10^{-4}T$$

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

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?

2. **Given:**
Current through the wire, I = 35 A
Distance of point P from the wire, d = 20 cm



Using Biot Savart law we can find magnetic field at a distance d from a current carrying conductor.
It is given by:

$$|B| = \frac{\mu_0 I}{2\pi\times d} \quad ....(1)$$

Where,
B = Magnetic field strength
I = current through the coil
μ_0 is the permeability of free space.
$\mu_0 = 4 \times \pi \times 10^{-7}$ TmA^{-1}
d = distance of point P
By plugging the values in the equation (1), we get

$$\Rightarrow |B| = \frac{4\pi \times 10^{-7} \text{TmA}^{-1} \times 35\text{A}}{2\pi \times .20 \text{ m}}$$

$\Rightarrow |B| = 3.5 \times 10^{-5}$T
In this case the magnetic field at 20 cm away from a current carrying conductor is found to be 3.5×10^{-5}T.

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.

3. Current in the wire, I = 50 A
A point is 2.5 m away from the East of the wire.
∴ 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,

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

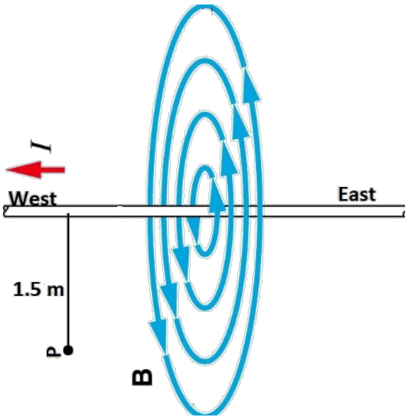
Where, μ_0 = Permeability of free space = $4\pi \times 10^{-7}$ T m A^{-1}

$$|\vec{B}| = \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2 \times 50}{2.5} = 4 \times 10^{-6} \text{T}$$

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.

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?

4. **Given:**
Current through the wire, I = 90 A (East to West)
Distance of point P below the wire, d = 1.5 m



Using Biot Savart law we can find magnetic field at a distance d from a current carrying conductor.

It is given by:

$$|B| = \frac{\mu_0 I}{2\pi \times d} \qquad ...(1)$$

Where,

B = Magnetic field strength

I = current through the coil

μ_0 is the permeability of free space.

$\mu_0 = 4 \times \pi \times 10^{-7}\ TmA^{-1}$

d = distance of point P

By plugging the values in the equation (1), we get

$$\Rightarrow |B| = \frac{4\pi \times 10^{-7}\ TmA^{-1} \times 90A}{2\pi \times 1.5\ m}$$

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

Direction of Magnetic Field:

We know that wire carries current in east to west direction. Using Right hand thumb rule, we can conclude that the direction of magnetic field is from north to south as indicated in the figure.

The magnitude of the magnetic field is 1.2×10^{-5} T and its direction is from north to south.

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?

5. Current in the wire, I = 8 A

Magnitude of the uniform magnetic field, B = 0.15 A Angle between the wire and magnetic field, θ = 30°. Magnetic force per unit length on the wire is given as: f = BI sinθ = 0.15 × 8 × 1 × sin30° = 0.6 N m^{-1}

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

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?

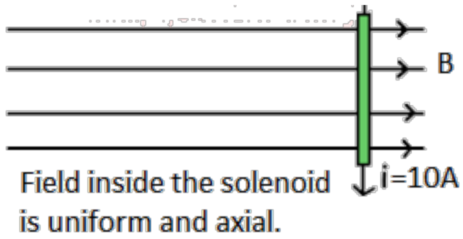
6. **Given:**

Current through the wire, I = 10 A

Strength of magnetic field inside the solenoid = 0.27 T

Angle between direction of magnetic field and current, $\theta = 90°$

Length of the wire = 3 cm



Force on a current carrying conductor of length L carrying current I, due to a uniform magnetic field of strength B is given by,

$F = IL \times B$ … (1)

Now by plugging the values in the equation (1), we get

$F = 10\text{ A} \times 0.03\text{ m} \times 0.27\text{ T} \times \sin 90°$

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

Hence, the magnitude of force per unit length of the wire is 8.1×10^{-2} N.

Note: The direction of magnetic field inside the solenoid is parallel to its axis.

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.

7. Current flowing in wire A, $I_A = 8.0$ A

Current flowing in wire B, $I_B = 5.0$ A

Distance between the two wires, r = 4.0 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:

$$F = \frac{\mu_0 I_A I_B L}{2\pi r}$$

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

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

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

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.

8. **Given:**

Length of solenoid, L = 80 cm

Number of turns = number of layers × number of turns per layer

Number of turns, n = 5 × 400 = 2000

Radius of solenoid, r = Diameter/2 = 0.9 cm

Current through the solenoid = 8.0 A

We know that, magnetic field strength near the centre of solenoid is given by,

$$B = \frac{\mu_0 \times n \times I}{L} \quad ....(1)$$

Where,

B = Magnetic field strength

n = total number of turns

I = current through the coil

μ_0 is the permeability of free space.

$\mu_0 = 4 \times \pi \times 10^{-7}\ TmA^{-1}$

r = radius of coil

Now, by plugging the values In equation (1), we get,

$$|B| = \frac{4\pi \times 10^{-7}\ TmA^{-1} \times 2000 \times 8A}{.80\ m}$$

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

Hence the magnetic field strength at the centre of the solenoid is 2.512×10^{-2} T.

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 30° with the direction of a uniform horizontal magnetic field of magnitude 0.80 T. What is the magnitude of torque experienced by the coil?

9. Length of a side of the square coil, I = 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 magnetic field, θ = 30°

Strength of magnetic field, B = 0.80 T

Magnitude of the magnetic torque experienced by the coil in the magnetic field is given by the relation,

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

Where, A = Area of the square coil

= 1 × 1 = 0.1 × 0.1

$= 0.01\ m^2$

So,

$\tau = 20 \times 0.8 \times 12 \times 0.01 \times \sin 30°$

$= 0.96$ N m

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

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.

10. Given:

For moving coil meter M_1

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

Number of turns, $N_1 = 30$

Area of cross-section, $A_1 = 3.6 \times 10^{-3}\ m^2$

Magnetic field strength, $B_1 = 0.25$ T

For moving coil meter M_2

Resistance of wire, $R_2 = 14\ \Omega$

Number of turns, $N_2 = 42$

Area of cross-section, $A_2 = 1.8 \times 10^{-3}\ m^2$

Magnetic field strength, $B_2 = 0.50$ T

Spring constant, $K_1 = K_2 = K$

(a) Current sensitivity is given by,

For M_1,

$$I_{S1} = \frac{N_1 B_1 A_1}{K_1} \qquad ...(1)$$

By putting the values in equation 1, we have

$$\Rightarrow I_{S1} = \frac{30 \times 0.25T \times 3.6 \times 10^{-3} m^2}{K}$$

For M_2

$$I_{S2} = \frac{N_2 B_2 A_2}{K_2} \qquad ...(2)$$

By putting the values in equation 2, we have

$$\Rightarrow I_{S2} = \frac{42 \times 0.5T \times 1.8 \times 10^{-3} m^2}{K}$$

Now finding the ration of I_1 and I_2

$$\frac{I_{S1}}{I_{S2}} = \frac{30 \times 0.25T \times 3.6 \times 10^{-3} m^2}{42 \times 0.5T \times 1.8 \times 10^{-3} m^2}$$

$$\Rightarrow \frac{I_{S1}}{I_{S2}} = 1.4$$

Hence, the ratio of current sensitivities is 1.4.

(b) Voltage sensitivity is given by,

For M_1,

$$V_{S1} = \frac{N_1 B_1 A_1}{K_1 R_1}$$

$$\Rightarrow V_{S1} = \frac{30 \times 0.25T \times 3.6 \times 10^{-3} m^2}{K \times 10\,\Omega} \quad ...(3)$$

For M_2

$$V_{S2} = \frac{N_2 B_2 A_2}{K_2 R_2}$$

$$\Rightarrow V_{S2} = \frac{42 \times 0.5\,T \times 1.8 \times 10^{-3} m^2}{K \times 14\,\Omega} \quad ...(4)$$

By dividing equation 3 by 4, we get

$$\Rightarrow \frac{V_{S1}}{V_{S2}} = 1$$

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

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^{-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)

11. Magnetic field strength, B = 6.5 G = 6.5×10^{-4} T
Speed of the electron, v = 4.8×10^6 m/s
Charge on the electron, e = 1.6×10^{-19} C
Mass of the electron, $m_e = 9.1 \times 10^{-31}$ kg
Angle between the shot electron and magnetic field, $\theta = 90°$
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.,

$F_e = F$

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

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

So,

$$r = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times\sin 90^\circ} = 4.2\times10^{-2}\,\text{m} = 4.2\text{ m}$$

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

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.

12. **Given:**

Magnetic field strength, B = 6.5 G = 6.5×10^{-4} T

Initial velocity of electron = $4.8 \times 10^{6}\ \text{ms}^{-1}$

Angle between the initial velocity of electron and magnetic field, θ = 90°

We can relate the velocity of the electron to its angular frequency by the relation,

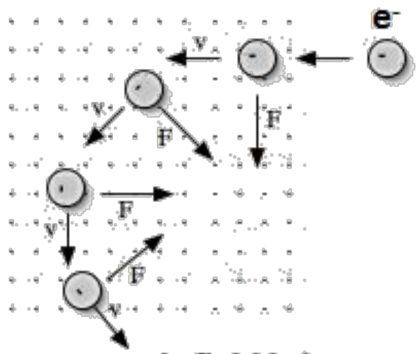
V = rω … (1)

Where,

V = velocity of electron

r = radius of path

ω = angular frequency



magnetic field is in outward direction

We understand that, magnetic force on the electron is equal to the centripetal force on it, hence we can write,

$F_e = F_c$

$e \times V \times B = mV^2/r$ … (2)

From equation (2) we can write,

$\Rightarrow eB = mV/r$ … (3)

Now, by putting value of V from equation (1) in equation (3)

$$e \times B = \frac{m \times r \times \omega}{r}$$

$\Rightarrow e \times B = m \times \omega$ … (4)

We know that, $\omega = 2\pi\nu$

Putting in equation (4), we have

$$\nu = \frac{B \times e}{2 \times \pi \times m} \quad ...(5)$$

Now, by putting the values in equation (5) we get,

$$\Rightarrow \nu = \frac{6.5 \times 10^{-4} T \times 1.6 \times 10^{-19} C}{2 \times \pi \times 9.1 \times 10^{-31}}$$

$\Rightarrow \nu = 18.2 \times 10^6$ Hz

Hence, the frequency of rotation is 18.2×10^6 Hz.

Note: The frequency of rotation is independent of the initial velocity of the electron.

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 plane coil of some irregular shape that encloses the same area? (All other particulars are also unaltered).

13. (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

Magnetic field strength, B = 1T

Angle between the filed lines and normal with the coil surface, $\theta = 60°$

The coil experiences a torque in the magnetic field.

Hence, in turns.

The counter torque applied to prevent the coil from turning is given by the relation,

$\tau = n\ IBA \sin\theta$ …………… (i)

$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60°$

= 3.133 Nm

(b) It can be inferred from relation (i) 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.