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Ch - 4

NCERT Exercise :-

Ans 1) The no of turns on the coil (n) is 100.

The radius of each turn (r) is 8 cm or 0.08 m.

The magnitude of the magnetic field at the center of the coil can be obtained by the coil can be obtained by the following relation.

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

where μ_0 is permeability of free

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

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

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

Ans 2) The magnitude of the current flowing in the wire (I) is 35 A.

The distance of the point from the wire (r) is 20 cm or 0.2 m

At this point, the magnitude of the magnetic field is given by the relation:

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

where, μ_0 = permeability of free space.

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

Substituting the values in the eq^n,

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

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

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

Ans 6) The length of the wire = 3 cm or 0.03 m.
The magnitude of the current flowing the wire (I) = 10 A.

Strength of the magnetic field (B) = 0.27 T.

The angle bet^n the current & the magnetic field is $\theta = 90°$.

The magnetic force exerted on the wire is calculated as follows.

$$F = BIl \sin\theta.$$
$$= 0.27 \times 10 \times 0.03 \times \sin 90°$$
$$= 8.1 \times 10^{-2}\ N.$$

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

Ans 7) Magnitude of the current flowing in the wire A (I_A) = 8 A.
Magnitude of the current flowing in the wire B (I_B) = 5 A.
Distance betⁿ two wires (r) = 4 cm or 0.04 m.
Length of the section of wire A (l) = 10 cm or 0.1 m

$$F = \frac{\mu_0 I_A I_B L}{2\pi r}$$ (μ_0 = permeability of free space = $4\pi \times 10^{-7}\ TmA^{-1}$)

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

∴ The magnitude of force is 2×10^{-5} N.

Ans 8) Solenoid length (l) = 80 cm or 0.8 m.

Total no. of turns on the solenoid $N = 5 \times 400 = 2000$.

Solenoid diameter (D) = 1.8 cm = 0.018 m.
Current carried by the solenoid (I) = 8.0 A.

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

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

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

∴ Magnitude of B inside the solenoid near its center is 2.5×10^{-2} T.

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Ans 11) Magnetic field strength (B) $= 6.5\,G$
$= 6.5 \times 10^{-4}\ T$

Speed of 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 betn the shot electron & magnetic field, $\theta = 90$

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

$$F_c = F$$

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

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

So,

$$r = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{6.5 \times 10^{-4} \times 1.6 \times 10^{-19} \times \sin 90^\circ} = 4.2 \times 10^{-2} = 4.2\ cm.$$

$\therefore$ 4.2 cm is the radius of the circular orbit of the circular orbit of the electron.

Ans 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 $= \nu$.
Angular frequency of the electron $= \omega = 2\pi\nu$.

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

In the circuit orbit, the magnetic force on the electron is balaced by the centripetal force.

Hence, we can write :

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

$$\Rightarrow eB = \frac{mv}{r} = \frac{m(r\omega)}{r} = \frac{m(r \cdot 2\pi\nu)}{r}$$

$$\Rightarrow \nu = \frac{Be}{2\pi m}$$

This expression for frequency is independent of the speed of the electron

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

Ans13) a) No. of turns on the circular coil (n) = 30

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
The angle betn the field lines & normal with the coil surface, $\theta = 60°$

$$\tau = nIBA \sin\theta$$
$$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60°$$
$$= 3.133\ Nm.$$

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.

Ans 14) Radius of the coil X, r_1 = 16 cm = 0.16 m.
No of turns in coil X, n_1 = 20.
Current in the coil, X, I_1 = 16 A.
Radius of the coil Y, r_2 = 10 cm = 0.1 m
No. of turns in coil Y, n_2 = 25.
Current in the coil, Y, I_2 = 18 A.

$$B_1 = \frac{\mu_0 N_1 I_1}{2r_1}$$

$\mu_0 = 4\pi \times 10^{-7}$ Tm/A.

$$B_1 = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16}$$
$= 4\pi \times 10^{-4}$ T (Towards east)

∴ Magnetic field is given as,

$B = B_2 - B_1 = 9\pi \times 10^{-4}$ T $- 4\pi \times 10^{-4}$ T.
$= 5\pi \times 10^{-4}$ T
$= 5 \times 3.14 \times 10^{-4}$
$= 1.57 \times 10^{-3}$ T (Towards west).

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Ans 15) Magnetic field strength, $B = 100\,G = 100 \times 10^{-4}$ T.
No. of turns per unit length, $N = 1000$ turns/m
Current carrying capacity of the coil $= 15$ A.
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}.
Magnetic field is given as,

$$B = \mu_0 NI / l$$
$$= NI/l = B/\mu_0$$
$$= (100 \times 10^{-4}) \; (4\pi \times 10^{-7})$$
$$= NI/l = 7961$$

Let, the current, $I = 10$ A.
length of the solenoid $= 0.5$ m.

So, we get
$(N \times 10) / 0.5 = 7961$
$N = 398$ turns ≈ 400 turns

Ans 16) a) $B = \dfrac{\mu_0 I R^2 N}{2(x^2 + R^2)^{3/2}}$

At the center of the coil, $x = 0$
$\therefore$ the magnetic field at the centre is $B = \dfrac{\mu_0 I R^2 N}{2R^3}$

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

b) Let the small distance be^n the point P & O be d.

for the coil, C, the distance $O_1 P = x_1 = (R/2) + d$
for the coil d, the distance $O_2 P = x_2 = (R/2) - d$

$$B = \frac{\mu_0 \; 2\pi n I a^2}{4\pi (x^2 + a^2)^{3/2}}$$

$$B_1 = \frac{\mu_0}{2} \frac{NIR^2}{(x_1^2 + R^2)^{3/2}}$$

$$B_1 = \frac{\mu_0}{2} \frac{NIR^2}{\left(\left(\frac{R^2}{4} + d^2 + Rd\right) + R^2\right)^{3/2}}.$$

d^2 can be neglected when compared to R^2.

$$B_1 = \frac{\mu_0 NIR^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 + \frac{4d}{5R}\right)^{-3/2}\right]$$

$$B_2 = \frac{\mu_0}{2} \frac{NIR^2}{(x_2^2 + R^2)^{3/2}}$$

$$B_2 = \frac{\mu_0 NIR^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 - \frac{4d}{5R}\right)^{-3/2}\right].$$

The total magnetic field at the point P due to the current through the coils $B = B_1 + B_2$

$$B = \frac{\mu_0 NIR^2}{2} \frac{1}{\left(\frac{5R^2}{4}\right)^{3/2}} \left[\left(1 + \frac{4d}{5R}\right)^{-3/2} + \left(1 - \frac{4d}{5R}\right)^{-3/2}\right]$$

$$B = \frac{\mu_0 NIR^2}{2\left(\frac{5R^2}{4}\right)^{3/2}} \left[1 - \frac{6d}{5R} + 1 + \frac{6d}{5R}\right].$$

$$B = \frac{\mu_0 NIR^2}{2\left(\frac{5R^2}{4}\right)^{3/2}} \times 2$$

$$B = \frac{\mu_0 NI}{R} \left(\frac{4}{5}\right)^{3/2}$$

$$B = (0.72) \frac{\mu_0 NI}{R}$$

c) Magnetic field should be in a vertically downward direction.

Ans 19) Magnetic field, $B = 0.15\ T$
Potential difference, $V = 2.0\ kV$.

An electron gains kinetic energy which is given by,

$$E = \frac{1}{2} mv^2$$
$$eV = \frac{1}{2} mv^2$$

$$v = \sqrt{\frac{2eV}{m}} \quad v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^3}{9.1 \times 10^{-31}}}$$
$$= 2.652 \times 10^7\ m/s.$$

a) The forces F_1 and F_2 are equal.

$$F_1 = evB$$
$$F_2 = mv^2/r$$
$$F_1 = F_2$$
$$evB = mv^2/r$$
$$\Rightarrow r = mv/eB$$
$$r = \frac{9.1 \times 10^{-31} \times 2.652 \times 10^7}{0.15 \times 1.6 \times 10^{-19}}$$

$$= 10^{-3}\ m = 1mm.$$

b) $r = mv \sin\theta / Be$

$$r = \frac{9.1 \times 10^{-31} \times 2.652 \times 10^7 \times \sin 30^\circ}{0.15 \times 1.6 \times 10^{-19}}$$

$$= 50.25 \times 10^{-5} m$$

$\therefore r = 0.5\ mm$

Ans17) Inner radius of the core, $r_1 = 25\ cm = 0.25\ m$.
Outer radius of the core, $r_2 = 26\ cm = 0.26\ m$
No of turns of the wire, $N = 3500$ turns.
Current in the wire, $I = 11\ A$

a) The magnetic field outside the toroid is zero.
b) Inside the core of the toroid, the magnetic field induction is:

$B = \mu_0 N I / l$

Mean length of the toroid,

$$l = 2\pi\left(\frac{r_1 + r_2}{2}\right)$$

$$= \pi(r_1 + r_2) = \pi(0.25 + 0.26) = \pi \times 0.51$$

So, $B = \mu_0 N I / l$

$$B = \frac{(4\pi \times 10^{-7}) \times 3500 \times 11}{\pi \times 0.51} = 3.02 \times 10^{-2}\ T.$$

c) The magnetic field in the empty space surrounded by the toroid is zero.

Ans18) a) Initial velocity is either parallel or anti-parallel to the magnetic field. There is no magnetic force acting on the particle when it is parallel or anti-parallel and it moves undeflected.

b) Yes, because magnetic force can change the direction of velocity but not its magnitude.

Ans 20) Magnetic field , $B = 0.75$ T.
Accelerating voltage , $V = 15$ KV $= 15 \times 10^3$ V.
Electrostatic field , $E = 9.0 \times 10^{-5}$ V m^{-1}.
Kinetic energy of the electron , $E = \frac{1}{2} mv^2$.
Therefore, $e/m = v^2/2V$.

Here, mass of the electron = m
charge of the electron = e
Velocity of the electron = v

$$eE = evB$$
$$\Rightarrow v = E/B$$
$$\therefore (1/2) m (E/B)^2 = eV$$
$$e/m = E^2/2VB^2$$

$$= \frac{(9.0 \times 105)^2}{2 \times 15000 \times (0.75)^2} = 4.8 \times 10^7 \text{ C/kg}.$$

The answer is not unique because only the ratio of charge to mass is determined. Other possible answers are He^{++}, Li^{++}, etc.

Ans 24) Magnetic field strength , $B = 3000$ G $= 0.3$ T.
Area of the loop , $A = 10 \times 5 = 50$ $cm^2 = 50 \times 10^{-4}$ m^2
Current in the loop , $I = 12$ A.

a) Torque, $\vec{\tau} = I\vec{A} \times \vec{B}$

$$\vec{A} = 50 \times 10^{-4} \hat{i}$$
$$\vec{B} = 0.3 \hat{k}$$
$$= 1.8 \times 10^{-2} \hat{j} \text{ Nm}$$

d) $\vec{\tau} = I\vec{A} \times \vec{B}$

$\tau = 12 \times 50 \times 10^{-4} \times 0.3$

$= 1.8 \times 10^{-2}$ Nm.

The direction of torque is $(90^\circ + 30^\circ)$ from -ve x-axis or $360^\circ - 120^\circ = 240^\circ$ from +ve x-axis
The net force on the loop is zero.

b) This is same as (a). Therefore, the torque is 1.8×10^{-2} N m ~~tom~~ along the negativity y-direction. The net force is zero. Ans

(c) $\vec{A} = -50 \times 10^{-4}\,\hat{j}$

$\vec{B} = 0.3\,\hat{k}$

$\vec{\tau} = 12 \times (-50 \times 10^{-4})\,\hat{j} \times 0.3\,\hat{k}$

$= -1.8 \times 10^{-2}\,\hat{i}$ Nm.

Therefore, the torque is 1.8×10^{-2} N m along the negativity x-direction. The net force is zero.

(e) $\cancel{\vec{\tau} = I\vec{A} \times \vec{B}}$ $\quad \vec{A} = 50 \times 10^{-4}\,\hat{k}$

$\cancel{\tau = 12 \times 50 \times 10^{-4} \times 0.3}$ $\quad \vec{B} = 0.3\,\hat{k}$

$\cancel{= 1.8 \times 10^{-2}\ \text{Nm}}$

Accordingly,

$\vec{\tau} = 12 \times (-50 \times 10^{-4})\,\hat{k} \times 0.3\,\hat{k}$

$= 0$

Hence, the torque is zero. The force is also zero.

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(f) $\vec{A} = -50 \times 10^{-4} \hat{k}$

$\vec{B} = 0.3 \hat{k}$

$\vec{\tau} = 12 \times (-50 \times 10^{-4})\hat{k} \times 0.3\hat{k}$

$= 0$

Case (e) corresponds to stable, and case (f) corresponds to unstable equilibrium.

Ans 27) Resistance of the galvanometer coil, $G = 12\ \Omega$

Current for which there is full scale deflection, $I = 3mA$.

A resistor with a resistance R is connected in series with the galvanometer to convert it into voltmeter. The resistance R is given as,

$$R = (V/I_g) - G$$

$$= \frac{18}{3 \times 10^{-3}} - 12 = 6000 - 12 = 5988\ \Omega.$$

A galvanometer can be converted into a voltmeter by connecting a resistor of $5988\ \Omega$.

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