24/07/21

CHAPTER - 4
Exercise

Q4.1) Ans) No. of turns on the circular coil, n = 100
Radius of each turn, r = 8.0 cm = 0.08 m
Current flowing through the coil, I = 0.4 A

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

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

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

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

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

4.2) Current in the wire, I = 35 A.
Distance of a point from the wire, r = 20 cm = 0.2 m

$$B = \frac{\cancel{4\pi} \times 10^{-7} \times \cancel{2} \times 35}{\cancel{4\pi} \times \frac{\cancel{0.2}\ 10^{-1}}{}}$$

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

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

4.3) Length of the wire, l = 3 cm = 0.03 m
Current flowing, I = 10 A.
Magnetic field, B = 0.27 T
Angle between the current and magnetic field $\theta = 90°$

$$F = BIl\sin\theta$$

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

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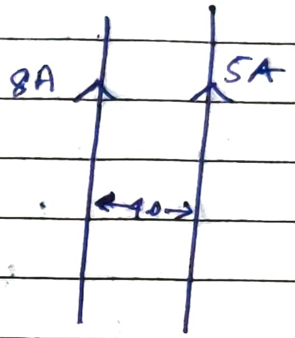
Direction of force can be obtained from Flemings left hand rule.

Q4.7 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, $l = 10\,cm = 0.01\,m$

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



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

$$= 2 \times 10^{-5}\,N.$$

This is an attractive force normal to A and towards B because the direction of the currents in the wires is the same.

Q4.8 length of the solenoid, $l = 80\,cm = 0.8\,m$
There are 5 layers of windings of 400 turns each on the solenoid.
∴ Total no. of turns, $N = 5 \times 400 = 2000$
Diameter, $D = 1.8\,cm = 0.018\,m$.
Current carried, $I = 8.0\,A$.

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

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

$$= 8\pi \times 10^{-3} = 2.512 \times 10^{-2}\,T$$

Hence the magnitude of the magnetic field inside the solenoid near its centre is 2.512×10^{-2} T

Q4.11 Magnetic field strength, $B = 6.5G = 6.5 \times 10^{-4}$ T
Speed of electron, $v = 4.8 \times 10^{6}$ m/s
Charge of 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, $\theta = 90°$

$$F = evB\sin\theta$$

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

Centripetal force,

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

In Equilibrium,

$$F_c = F$$

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

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

$$= \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{6.5 \times 10^{-4} \times 1.6 \times 10^{-19} \times \sin 90°}$$

$$= 4.2 \times 10^{-2}\ \text{m} = 4.2\ \text{cm}$$

Q4.12 Magnetic field strength, $B = 6.5 \times 10^{-4}$ T
Charge of the electron, $e = 1.6 \times 10^{-19}$ C
Mass of electron, $m_e = 9.1 \times 10^{-31}$ kg
Velocity, $v = 4.8 \times 10^{6}$ m/s
Radius of the orbit, $r = 4.2$ cm $= 0.042$ m
Angular frequency.

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We know,

$v = r\omega$

We also know that,

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

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

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

$$\Rightarrow \nu = \frac{6.5 \times 10^{-4} \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}}$$

$$= 18.2 \times 10^{6}\,Hz \approx 18.2\,MHz$$

It is independent of the speed of electron.

Q4.13 Number of turns on the circular coil, $n = 30$.
Radius of the coil. $r = 8\,cm = 0.08\,m$

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 coil surface, $\theta = 60^\circ$

$$\tau = nIAB\sin\theta \longrightarrow (1)$$

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

$$= 3.133\,Nm.$$

b) It can be inferred from relation (1) that the magnitude of the applied torque is not dependant on the shape of the coil. It depends on the area of the coil, Hence, the answer would not change if the

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circular coil in the above case is replaced by a planar coil of some irregular shape that encloses the same area.

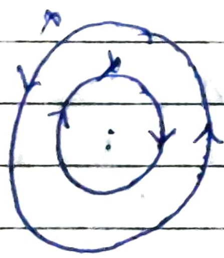
Q4.14 Radius of coil X, r_1 = 16 cm = 0.16 m
Radius of coil Y, r_2 = 10 cm = 0.1 m.
No. of turns on coil X, n_1 = 20
No. of turns on coil Y, n_2 = 25
Current in coil X, I_1 = 16 A
Current in coil Y, I_2 = 18 A

$$B_1 = \frac{\mu_0 n_1 I_1}{2r_1}$$

$$= \cancel{4.0\times10^{-7}}\ \frac{4\pi\times10^{-7}\times\cancel{20}^{10}\times\cancel{16}}{\cancel{2}\times\cancel{0.16}\times10^{-2}}$$

$$= 4\pi\times10^{-4}\,T \text{ (towards east)}$$

observer



$$B_2 = \frac{4\pi\times10^{-7}\times25\times18}{2\times0.10}$$

$$= 9\pi\times10^{-4}\,T \text{ (Towards west)}$$

Hence net force.

$$B = B_2 - B_1$$

$$= 9\pi\times10^{-4} - 4\pi\times10^{-4}$$

$$= 5\pi\times10^{-4}\,T$$

$$= 1.57\times10^{-3}\,T \text{ (towards west)}$$

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Q4.15 Magnetic field strength $B = 100\,G = 100 \times 10^{-4} T$.
No. of turns per unit length, $n = 1000$ turns m^{-1}
Current flowing in the coil, $I = 15A$.

$$\therefore nI = \frac{B}{\mu_0}$$

$$= \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74 \approx 8000\ A/m.$$

If the length of the coil is taken as 50 cm, radius 4 cm, number of turns 400 and current 10 A, then these values are not unique for the given purpose.

Q4.17 Inner radius of the toroid, $r_1 = 0.25\,m$
Outer radius of the toroid, $r_2 = 0.26\,m$
No. of turns on the coil, $N = 3500$.
Current in the coil, $I = 11A$

a) Magnetic field outside a toroid is zero. It is non-zero only inside the core of a toroid.

b) Magnetic field inside the core of a toroid

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

Here length of toroid $= l$

$$= 2\pi \left[\frac{r_1 + r_2}{2}\right]$$

$$= \pi (0.25 + 0.26)$$

$$= 0.51\pi$$

$$\therefore B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi} \approx 3.0 \times 10^{-2} T$$

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

4.18 a) The initial velocity of the particle is either parallel or anti-parallel to the magnetic field. Hence, it travels along a straight path without suffering any deflection in the field.

b) Yes, the final speed of the charged particle will be equal to its initial speed. This is because magnetic force can change the direction of velocity, but not its magnitude.

c) An electron travelling from west to east enters a chamber having a uniform electrostatic field in the North south direction. This moving electron will remain undeflected if the electric force acting on it is equal and opposite of magnetic field. Magnetic force is directed towards the south. According to flemings left hand rule magnetic field should be applied in a vertically downward direction.

4.19) magnetic field strength, $B = 0.15T$

charge on the electron, $e = 1.6 \times 10^{-19} C$

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

potential difference, $V = 2.0 kV = 2 \times 10^3 V$

Thus, kinetic energy of the electron $= eV$

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

$v = \sqrt{\frac{2eV}{m}}$ ——— (i)

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a) Magnetic force on the electron provides the required centripetal force of the electron. Hence, the electron traces a circular path of radius 'r'

Magnetic force on the electron,

$$F = Bev$$

Centripetal force $= \frac{mv^2}{r}$

$$\therefore Bev = \frac{mv^2}{r}$$

$$\Rightarrow r = \frac{mv}{Be} \quad \text{——— (ii)}$$

From equation 1 & 2 ~~...~~ we get.

$$r = \frac{m}{Be}\left[\frac{2eV}{m}\right]^{\frac{1}{2}}$$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left(\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.1 \times 10^{-31}}\right)^{\frac{1}{2}}$$

$$= 100.55 \times 10^{-5}$$

$$= 1.01 \times 10^{-3} \text{ m}$$

$$= 1 \text{ mm}$$

Hence, the electron has a circular trajectory of radius 1.0 mm normal to the magnetic field.

b) when the field makes an angle ~~θ~~ of 30° with initial velocity, the initial velocity

$$v_1 = v \sin\theta$$

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From eq (ii) we can write the expression for radius

$$r_1 = \frac{m v_1}{Be}$$

$$= \frac{m v \sin\theta}{Be}$$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left[\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9 \times 10^{-31}}\right]^{\frac{1}{2}} \times \sin$$

$$= 0.5 \times 10^{-3} \text{ m}$$

$$= 0.5 \text{ mm}$$

Hence, the electron has helical trajectory of radius 0.5 mm along the magnetic field direction.

4.20) $B = 0.75T$

$V = 15kV = 15 \times 10^{3}$ V

$E = 9 \times 10^{5}$ V m^{-1}

~~KE of ex~~ Kinetic energy of electron = eV

$$\Rightarrow \frac{1}{2} m v^2 = eV$$

$$\therefore \frac{e}{m} = \frac{v^2}{2V} \quad \text{—— (i)}$$

Since the particle remains undeflected by electric and magnetic field.

$$\therefore eE = evB$$

$$v = \frac{E}{B} \quad \text{—— (ii)}$$

Putting eq (2) in (1).

$$\frac{e}{m} = \frac{\frac{1}{2}\left(\frac{E}{B}\right)^2}{V} = \frac{E^2}{2VB^2}$$

$$= \frac{(9.0\times 10^5)^2}{2\times 15000\times(0.75)^2} = 4.8\times 10^7 \, C/kg$$

This value of specific charge e/m is equal to the value of deutron or deuterium ions. This is not a unique answer. Other possible answers are He^{++}, Li^{++} etc.

Q4.24) $B = 3000\,G = 3000\times 10^{-4}\,T = 0.3\,T$

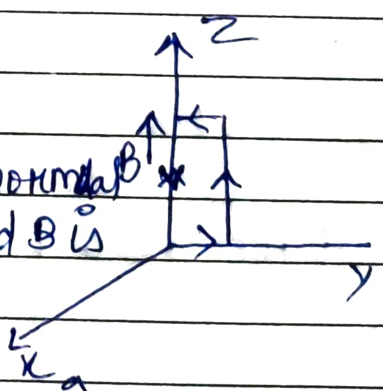
$l = 10\,cm$

$b = 5\,cm$

$A = l\times b = 50\,cm^2 = 50\times 10^{-4}\,m^2$

Now, taking anti-clockwise direction as +ve.

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



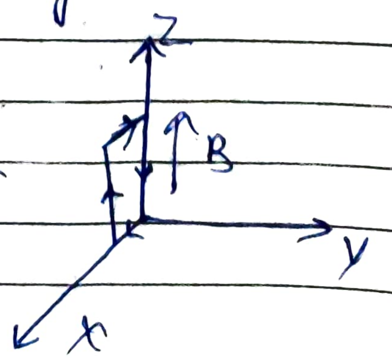
From fig, we observe A is normal to the y-z plane and B is directed along z axis.

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

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

The torque is in negative y direction. Force on the loop is zero as angle between A and B is zero.

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



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

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

Negative of x-axis

force is zero

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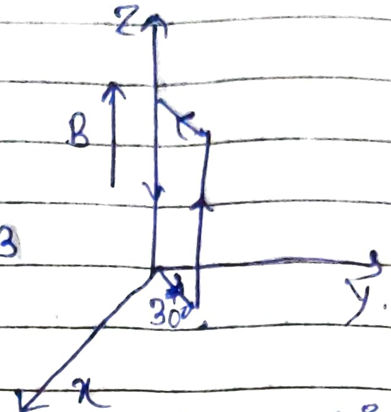
d) Magnitude of torque

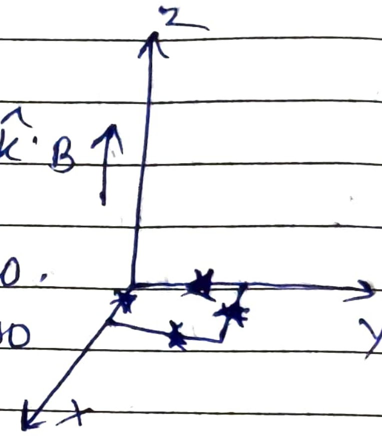


$|\tau| = IAB$
$= 12 \times 50 \times 10^{-4} \times 0.3$
$= 1.8 \times 10^{-2}$ N m

torque is 1.8×10^{-2} N m at an angle of 240° with positive x- direction

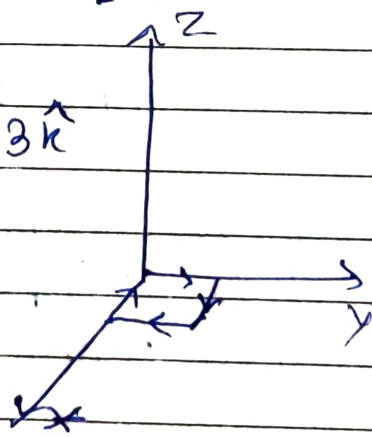
e) Torque $\tau = I\vec{A} \times \vec{B}$
$= (50 \times 10^{-4} \times 12)\hat{k} \times 0.3\hat{k}$
$= 0$

Hence, the torque is zero. the ~~brow~~ force is also zero.



(f) torque, $\tau = I\vec{A}\,\vec{B}$
$= (50 \times 10^{-4} \times 12)\hat{k} \times 0.3\hat{k}$
$= 0$

Here also $\tau = 0$
$f = 0$



Q4.27) Resistance of the galvanometer coil, $G = 12\,\Omega$
Current for which there is full scale deflection
$I_g = 3\,mA = 3 \times 10^{-3}$ A
Range of voltmeter is 0, which needs to be converted to 18 V.
$\therefore V = 18$ V
In series connection.
$R = \frac{V}{I_g} - G$

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$= \frac{18}{3\times10^{-3}} - 12 = 6000 - 12 = 5988\ \Omega$

9.28 $G = 15\ \Omega$

$I_g = 4\,mA = 4\times10^{-3} A$

Range of the ammeter is 0, which needs to be converted to 6A.

$\therefore$ Current, $I = 6A$.

A shunt resistor of resistance S to be connected in parallel with Galvanometer to convert it into an ammeter.

$$S = \frac{I_g G}{I - I_g}$$

$$= \frac{4\times10^{-3}\times15}{6-4\times10^{-3}}$$

$$S = \frac{6\times10^{-2}}{6-0.004} = \frac{0.06}{5.996} \approx 0.01\ \Omega = 10\,m\Omega$$

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