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Exercises

4.1 No. of turns on the circular coil, n = 100
Radius of each turn, r = 8.0 cm. = 0.08m
Current flowing in the coil, I = 0.4A
So,
Magnitude of the magnetic field =>

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

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

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

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

4.2 Current in the wire, I = 35 A
Distance of a point from the wire, r = 20cm = 0.2 m
So,
Magnitude of the magnetic field =>

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

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

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

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

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

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

Hence, the magnetic force on the wire is $8.1 \times 10^{-2}\,N$.

4.7. 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 of exerted on length~~
~~Magnetic field~~
~~Magnetic force~~

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

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

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

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.

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, $\theta = 90°$

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 ~~stro~~ starts moving in a circular path of radius r.
Hence, centripetal force exerted on the electron,

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

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

$$F_c = F.$$

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

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

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

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

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4.12 Magnetic field strength, $B = 6.5 \times 10^{-4}\,T$
Charge of the electron, $e = 1.6 \times 10^{-19}\,C$
Mass of the electron, $m_e = 9.1 \times 10^{-31}\,kg$
Velocity 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 $= \omega = 2\pi\nu$

Velocity of the electron $\Rightarrow v = r\omega$

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

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

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

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

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

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

$$= 18\,MHz$$

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

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4.13 a) No. 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,

$$\theta = 60^\circ$$

$\tau = nIBA\sin\theta$
$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60^\circ$
$= 3.133$ Nm

b) It can be inferred from relation 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 ~~it~~ of some irregular shape that encloses the same area.

4.14 Radius of coil X, $r_1 = 16$ cm $= 0.16$ m
Radium 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

Magnetic field due to coil X :-

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

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$\therefore$ $B_1 = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16}$

$= 4\pi \times 10^{-4} T$ (towards East)

Magnetic field due to coil Y :-

$B_2 = \frac{\mu_0 n_2 I_2}{2r_2}$

$= \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10}$

$= 9\pi \times 10^{-4} T$ (towards west)

Hence, net magnetic field can be obatined as:-

$B = B_2 - B_1$

$= 9\pi \times 10^{-4} - 4\pi \times 10^{-4}$

$= 5\pi \times 10^{-4} T$

$= 1.57 \times 10^{-3} T$ ~~towa~~ (towards west)

4.15 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, $I = 15A$

$B = \mu_0 n I$

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

$= \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74$

≈ 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. There is always a possiblity of some adjustments with limits.

4.17 Inner radius of the toroid, $r_1 = 25$ cm $= 0.25$ m
Outer radius of the toroid, $r_2 = 26$ cm $= 0.26$ m
No of turns on the coil, $N = 3500$
Current on coil, $I = 11$ A.

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 is given by,

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

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

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

$$l = 0.51\pi$$

$$\therefore \quad B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi}$$

$$\approx 3.0 \times 10^{-2} \text{ T}$$

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

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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 ~~first~~ 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 can 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 Fleming's 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, $m = 9.1 \times 10^{-31} kg$
Potential difference, $V = 2.0 KV = 2 \times 10^{3} V$
Thus,

K.E. of electron $= eV$

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

$$v = \sqrt{\frac{2eV}{m}} \quad \text{—— (1)}$$

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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 :-
BeV

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

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

$r = \frac{mv}{Be}$ —— (2)

From eq^n (1) & (2),

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

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

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

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

$= 1mm$

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 ~~init~~ initial velocity will be,

$v_1 = v\sin\theta$

From eq^n (2)

$r_1 = \frac{mv_1}{Be} = \frac{mv\sin\theta}{Be}$

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left[\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9 \times 10^{-31}}\right]^{\frac{1}{2}} \times \sin 30^\circ$$

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

$$= 0.5 \, mm$$

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

4.20. Magnetic field, $B = 0.75 T$

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

Electrostatic field, $E = 9 \times 10^{5} \, Vm^{-1}$

Mass of the electron $= m$

Charge of the electron $= e$

Velocity of electron $= v$

K.E. of electron $= eV$

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

$$\therefore \frac{e}{m} = \frac{v^2}{2V} \quad \text{——} \quad (1).$$

Since the particle remains undeflected by electric and magnetic field, we can infer that the electric field is balancing the magnetic field.

$$\therefore eE = evB$$

$$v = \frac{E}{B} \quad \text{——} \quad (2).$$

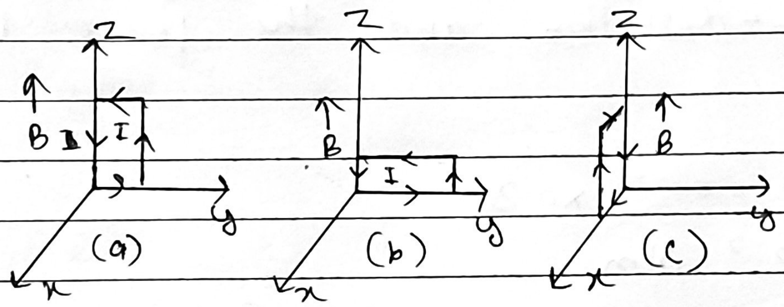
Putting eqⁿ (2) in eqⁿ (1).

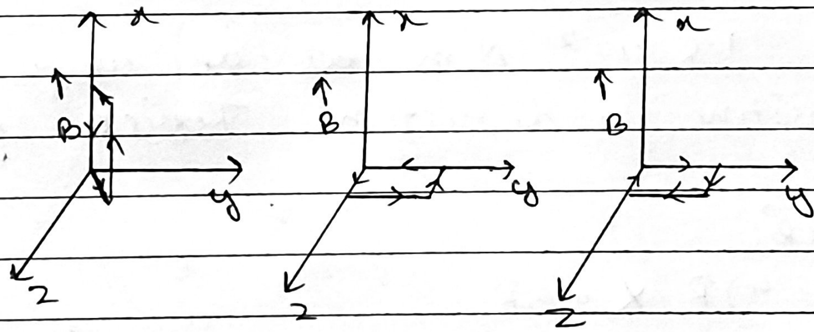
$$\frac{e}{m} = \frac{1}{2} \frac{\left(\frac{E}{B}\right)^2}{V} = \frac{E^2}{2VB^2}$$

$$= \frac{9.0 \times 10^5}{2 \times 15000 \times (0.75)^2}$$

$$= 4.8 \times 10^7 \ C/Kg$$

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

4.24. 



Magnetic field strength, B = 3000G = 0.3T
Length, l = 10 cm
Width, b = 5 cm
Area of loop, A = l×b = 10×5 = 50 cm² = $50 \times 10^{-4} m^2$
Current, I = 12A

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

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

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

The torque is 1.8×10^{-2} Nm along the negative y-direction. The force on the loop is zero because the angle between A and B is zero

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

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

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

The torque is 1.8×10^{-2} Nm along the negative x-direction and the force is zero.

d) $|\tau| = IAB$

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

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

Torque is 1.8×10^{-2} Nm at an angle of 240° with positive x-direction. Force is zero.

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

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

$= 0$

Hence, torque is zero. Force also zero.

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

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

$= 0$.

Hence, torque is zero. Force is also zero.

In case (e), the direction of $I\vec{A}$ and $\vec{B}$ are the same and the angle between them is zero. If displaced, they come back to an equilibrium. Hence, its equilibrium is stable.

Whereas, in case (f), the direction of $I\vec{A}$ and $\vec{B}$ is opposite. The angle between them is 180°. If disturbed, it does not come back to its original position. Hence, its equilibrium is unstable.

4.27. Resistance of the galvanometer coil, $G = 12\,\Omega$

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

Range of voltmeter is 0, which needs to be converted to 18V.

$\therefore$ $V = 18V$

$$R = \frac{V}{I_g} - G$$

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

$$R = 5988\,\Omega$$

Hence, a resistor of resistance $5988\,\Omega$ is to be connected in series with the galvanometer.

4.28. Resistance of the ~~gb galvanomeleter~~ galvanometer, $G = 15\Omega$

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

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

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

$$S = \frac{I_g G}{I - I_g} = \frac{4\times10^{-3}\times15}{6-4\times10^{-3}}$$

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