Moving Charges & Magnetism

Exercise NCERT

4.1 $N = 100 \quad r = 8\,cm = 0.08\,m \quad I = 0.4\,A$

$$\vec{B} = \frac{\mu_0 N I}{2R} = \frac{\mu_0 \times 100 \times 0.4}{2 \times 0.08} = \frac{4\pi \times 10^{-7} \times 100 \times \cancel{40}}{2 \times \cancel{8}}$$

$$= \pi \times 10^{-4} = \boxed{3.14 \times 10^{-4}\,T}$$ Ans

4.2 $I = 35\,A \quad d = 20\,cm = 0.02\,m \quad \mu_0 = 4\pi \times 10^{-7}$

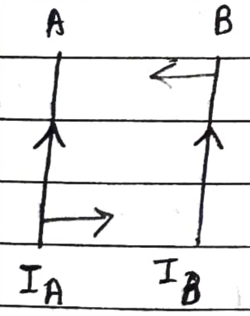
$$B = \frac{\mu_0 I}{2\pi r} = \frac{\cancel{4}\cancel{\pi} \times 10^{-7} \times 35}{\cancel{2} \times \cancel{\pi} \times \cancel{0.02}} = \boxed{3.5 \times 10^{-5}\,T}$$ Ans

4.6 $l = 3\,cm = 0.03\,m \quad I = 10\,A \quad B = 0.27\,T$

$$\vec{F} = IBL\sin\theta = 10 \times 0.27 \times 0.03 = 1\cancel{0} \times \frac{27}{100} \times \frac{3}{10\cancel{0}}$$

$$= \frac{81}{1000} = 81 \times 10^{-3} = \boxed{8.1 \times 10^{-2}\,N}$$ Ans

4.7



$I_A = 8\,A \quad I_B = 5\,A \quad d = 4\,cm = 0.04\,m$

Force per unit length of wire

$$F = \frac{\mu_0 I_A I_B}{2\pi r} = \frac{\mu_0 \times 8 \times 5}{2 \times \pi \times 0.04}$$

$$= \frac{\cancel{4}\cancel{\pi} \times 10^{-7} \times \cancel{8} \times 5}{\cancel{2} \times \cancel{\pi} \times \cancel{0.04}} = 20 \times 10^{-7} \times 100$$

$$= 2 \times 10^{-4}\,Nm^{-1}$$

Force on 10 cm section $= 2 \times 10^{-4} \times 0.1 = \boxed{2 \times 10^{-5}\,N}$ Ans

4.8

Solenoid: $l = 80\,cm = 0.8\,m \quad dia = 1.8\,cm \quad I = 8\,A$

$$n = \frac{N}{l} = \frac{5 \times 400}{0.8} = 2500\,m^{-1}$$

$$B = \mu_0 n I$$

$$= 4\pi \times 10^{-7} \times 2500 \times \frac{8}{1}$$

$$= 80000\pi \times 10^{-7}$$

$$= 8\pi \times 10^{4} \times 10^{-7} = 8\pi \times 10^{-3}\,T = \boxed{2.5 \times 10^{-2}\,T}$$ Ans

4.11 $\vec{B} = 6.5\,G = 6.5 \times 10^{-4}\,T \quad v = 4.8 \times 10^{6}\,ms^{-1}$

The perpendicular magnetic field exerts a force on the electron perpendicular to its path. This force continuously deflects the electron from its path and makes it move along a circular path.

Magnetic force on electron = Centripetal

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

$r = \frac{mv}{qB} = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}$

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

4.12) $F = \frac{qB}{2\pi m} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18.18 \times 10^6 Hz = \boxed{18 MHz}$ Ans

No frequency does not depend upon the speed of the electron.

4.13) $N = 30$ $r = 8cm = 0.08m$ $B = 1T$ $\theta = 60°$ $I = 6A$

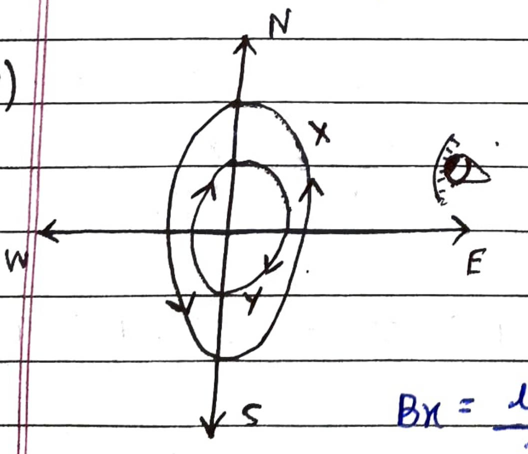
$\tau = IAB$

$= NIBA\sin\theta = 30 \times \cancel{6} \times 1 \times (3.14 \times 0.08 \times 0.08) \times \frac{\sqrt{3}}{2}$

$= \frac{9\cancel{0} \times \sqrt{3} \times 314 \times 8 \times 8}{100 \times 10\cancel{2}} = \boxed{3.1 Nm}$ Ans

b) No the answer would not change because the above formula is independed of shape.

4.14)



$r_x = 16 cm$ $r_Y = 10 cm$
$= 0.16m$ $= 0.1 m$
$N_x = 20$ $I_x = 16A$
$N_Y = 25$ $I_Y = 18A$

$B_x = \frac{\mu_0 I_x N}{2R_x} = \frac{4\pi \times 10^{-7} \times \cancel{16} \times \cancel{20}^{10}}{2 \times \cancel{0.16}\, 0.01}$

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

As the direction of current is anti clock wise its force direction is toward east.

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$B_y = \frac{\mu_0 I_y N}{2 r_y} = \frac{\overset{2}{\cancel{4}}\pi \times 10^{-7} \times 18 \times 25}{\cancel{2} \times 0.01} = 9\pi \times 10^{-4}\ T$

$\vec{B}$ is directed toward west.

$B_{net} = B_y - B_x = 4\pi \times 10^{-4} \approx \boxed{1.6 \times 10^{-3} T}$ Ans

4.15) $B = 100 G = 100 \times 10^{-4}$
$= 10^{-2} T$ $\quad I = 15 A \quad n = 1000$ turns m^{-1}

magnetic induction inside a tightly wounde solenoid

$B = \mu_0 n I$

$10^{-2} = 4\pi \times 10^{-7} \times nI$

$nI = \frac{10^{-2}}{4\pi \times 10^{-7}} = \frac{10^5}{4 \times 3.14} = 7955 \approx 8000$

For $n = 1000$ turns/s (upto 15A)

$I = 7.961 \approx 8 A$

4.17) Toroid $\quad r_i = 25 cm \quad r_o = 26 cm \quad N = 3500 \quad I = 11 A$

$r = \frac{25+26}{2} = \frac{51}{2} = 25.5 \times 10^{-2} M$

a) $\vec{B}$ outside.

Total length $= 2\pi r = 2 \times \pi \times 25.5 \times 10^{-2}$
$= 51 \times 10^{-2} \pi M$

$n = \frac{3500}{51 \times 10^{-2} \pi} =$

a) $\vec{B}$ outside : $\boxed{\text{Zero}}$

b) $\vec{B}$ inside the core : $B = \mu_0 n I = \cancel{\pi} \times 10^{-7} \times \frac{3500}{51 \times 10^{-2} \cancel{\pi}} \times 11$

$= \boxed{3.02 \times 10^{-3} T}$

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

4.18) a) The force on charge particle moving in a magnetic field is $F = q(vB)\sin\theta$

The force on a charged particle will be zero or the particle will remain undeflected $\sin\theta = 0$ or $\theta = 180°, \theta = 0°$
initial velocity $\vec{v}$ is either parallel or anti parallel.

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b) Yes, a magnetic field exerts force on a charged particle in a direction perpendicular to its direction of motion and hence does no work on it. So the charged particles will have its final speed equal to its initial speed.

c) It will remain undeflected if it experiences an equal force towards south due to magnetic field. According to fleming's left hand rule, the magnetic field must act in the vertically downward direction.

4.19) $V = 2\,KV = 2000\,V$ $B = 0.15\,T$

a) $\frac{1}{2}mv^2 = eV$

$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2000}{9.1 \times 10^{-31}}} = 2.65 \times 10^7\ ms^{-1}$

i) When field $\vec{B}$ is transverse to initial velocity

$Bev \sin 90° = \frac{mv^2}{r}$

$r = \frac{mv}{Be} = \frac{9.1 \times 10^{-31} \times 2.65 \times 10^7}{0.15 \times 1.6 \times 10^{-19}}$

$= 10^{-3} = 1\,mm$ (Ans)

Electron moves in a circular trajectory with radius 1 mm normal to the field.

ii) $v_\perp = v \sin 30° = 2.65 \times 10^7 \times \frac{1}{2} = 1.33 \times 10^7\ ms^{-1}$

$r = \frac{mv_\perp}{Be} = \frac{9.1 \times 10^{-31} \times 1.33 \times 10^7}{0.15 \times 1.6 \times 10^{-19}} = 0.50\,mm$ Ans

4.20) $B = 0.75\,T$ $V = 15000\,V$ $E = 9 \times 10^5\ Vm^{-1}$

$v = \frac{E}{B} = \frac{\cancel{9} \times 10^5}{5 \cancel{15} \times 10^{-2}} = \frac{3 \times \cancel{100000}}{5 \times \cancel{1000}} = \frac{9 \times 10^5}{75} \times 10^2 = 12 \times 10^5\ ms^{-1}$

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$\frac{1}{2}mv^2 = qV$ $\quad \frac{q}{m} = \frac{1}{2}\frac{V^2}{V} = \frac{1}{2}\frac{12 \times 10^5}{15 \times 10^3} = 4.8 \times 10^7 \ C kg^{-1}$

Now for deutrons,

$$\frac{q}{m} = \frac{1.6 \times 10^{-19}}{2 \times 1.67 \times 10^{-27}} = 4.8 \times 10^7 \ C \ kg^{-1}$$

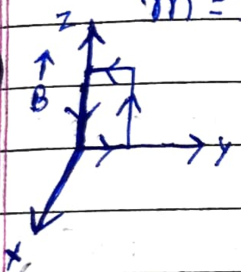
Which means that particle may be deutron (one proton and one neutron). Answer is not unquique because we have determined only the ratio of q/m. He^{2+} and Li^{3+} can be possible.

4.24) $\vec{B} = 3000 \, G = 3000 \times 10^{-4} = 0.3 \, T$ $\quad A = 10 \times 5 = 50 cm^2 = 50 \times 10^{-4} m^2$

$I = 12 A$ $\quad \tau = ?$ $\quad F = ?$

$m = IA = 12 \times 50 \times 10^{-4} = 600 \times 10^{-4} = 0.06 \, Am^2$

a)



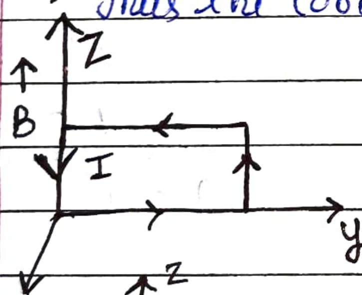
$\vec{m} = 0.06 \hat{i}$ $\quad \vec{B} = 0.3 \hat{k} \, T$

$\vec{\tau} = \vec{m} \times \vec{B} = 0.06 \times 0.3 \times \cancel{k}$

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

* Thus the torque of 1.8×10^{-2} Nm acts along −ve Y-axis

b)

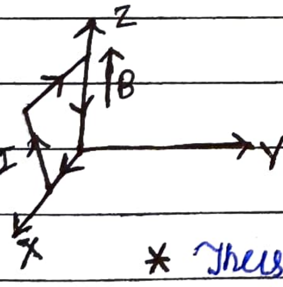


$\vec{m} = I \times A$.

* Cleary it is same case as (a)

Torque of 1.8×10^{-2} Nm acts along −ve Y-axis.

c)



$\vec{m} = -0.06 \hat{j}$ $\quad \vec{B} = 0.3 \hat{k}$

$\vec{\tau} = \vec{m} \times \vec{B} = -0.06 \hat{j} \times 0.3 \hat{k}$

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

* Thus a torque of -1.8×10^{-2} Nm acts along −ve X axis

d) This case is similar to case (c) but have the direction of the torque is 60° anticlockwise with −ve X-direction ie 240° with +ve X-direction.

e) $\vec{m} = 0.06 \hat{k} \, Am^2$ $\quad \vec{B} = 0.3 \hat{k}$ $\quad \vec{\tau} = \vec{m} \times \vec{B} = 0$

f) $\vec{m} = -0.06 \hat{k} \, Am^2$ $\quad \vec{B} = 0.3 \hat{k}$ $\quad \vec{\tau} = \vec{m} \times \vec{B} = 0$

The net force on the loop is zero in each case

Case (e) and (f) corresponds to stable equilibrium.

$\vec{m}$ parallel $\vec{B}$ $\vec{m}$ antiparallel to $\vec{B}$.

28) $R_G = 15\,\Omega$ $I_G = 4\,mA$ meter 0 - 6 A

$$i_g \times G = (i - i_g) \times S$$

$$0.004 \times 15 = (6 - 0.004) \times S$$

$$S = \frac{0.004}{6 - 0.004} \times 15 = 0.010\,\Omega = 10\,m\Omega$$

By connecting a shunt of $R = 10\,m\Omega$ across the given galvanometer, we get an ammeter of range 0 to 6A.

27) $R = 12\,\Omega$ $I = 3\,mA = 0.003\,A$ Voltmeter 0 to 18

$$V = i_g(G + R)$$

$$\frac{V}{i_g} = G + R$$

$$R = \frac{V}{i_g} - G = \frac{\cancel{18}\,6}{\cancel{0.003}\,0.001} - 12$$

$$= 6000 - 12$$

$$= \underline{\underline{5988\,\Omega}}$$

By connecting a resistance of 5988 in series with the given galvanoment, we get a voltmeter of range 0 to 18 V.