Chapter-4 (Moving charges and Magnetism)

Excercise:

1) $N = 100$

$r = 8cm = 0.08\ m$

$I = 0.40\ A$

$$B_{at\ centre} = \frac{\mu_0 I N}{2r}$$

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

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

2) $I = 35\ A$

$r = 20\ cm = 0.2\ m$

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

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

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

6) $l = 3\ cm = 0.03\ m$

$I = 10\ A$

$B = 0.27\ T$

$\theta = 90^\circ$

$$F = BIl\sin\theta$$

$$= 0.27 \times 10 \times 0.03 \sin 90^\circ$$

$$= 8.1 \times 10^{-2}\ N.$$

7) $I_A = 8\,A$

$I_B = 5\,A$

$r = 4\,cm = 0.04\,m$

$l_A = 10\,cm = 0.1\,m$

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

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

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

8) $l = 80\,cm = 0.8\,m$

$N = 5 \times 400 = 2000$

$D = 1.8\,cm = 0.018\,m$

$I = 8\,A$

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

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

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

11) $B = 6.5\,G = 6.5 \times 10^{-4}\,T$

$v = 4.8 \times 10^6$

$\theta = 90^\circ$

$m_e = 9.1 \times 10^{-31}\,kg$

$e = 1.6 \times 10^{-19}\,C$

Magnetic force exerted on the electron is

$F = evB\sin\theta$.

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

$F_c = F$

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

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

$= \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times\sin 90^\circ}$

$= 4.2\times10^{-2}$ m

$= 4.2$ cm.

12) $B = 6.5\times10^{-4}$ T

$v = 4.8\times10^{6}$

$\theta = 90^\circ$

$m_e = 9.1\times10^{-31}$

$e = 1.6\times10^{-19}$

$r = 4.2$ cm $= 0.042$ m

Let frequency of the electron be f

Angular frequency $= \omega = 2\pi f$

Velocity is related to angular frequency as:

$v = r\omega$

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

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

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

$\therefore$ Frequency is independent of the speed of electron

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

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

$= 18$ MHZ

13) a) $N = 30$

$r = 8$ cm $= 0.08$ m

$I = 6$ A

$B = 1$ T

$\theta = 60^\circ$

$A = \pi r^2 = 3.14 \times (0.08)^2 = 0.0201$

$\tau = nIBA \sin\theta$

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

$= 3.133$ N m

b) As τ doesnot depend on shape so it will not change.

Additional Exercises:

14) $r_1 = 16$ cm $= 0.16$ m

$n_1 = 20$

$I_1 = 16$ A.

$r_2 = 0.1$ m

$n_2 = 25$

$I_2 = 18$ A

$B_{centre_1} = \frac{\mu_0 I_1 N_1}{2r_1}$

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

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$

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

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

$$B_{net} = B_2 - B_1$$

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

$$= 5\pi \times 10^{-4}\ T$$ (Towards west).

15) $B = 100\ G = 100 \times 10^{-4}\ T$

$N = 1000$ turns/m

$I = 15\ A$

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

$$\Rightarrow \frac{NI}{l} = \frac{B}{\mu_0}$$

$$\Rightarrow \frac{NI}{l} = \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}}$$

$$\Rightarrow \frac{NI}{l} = 7961$$

Let the current $= 10\ A$ and $l = 0.6\ m$.

So we get : $\frac{N \times 10}{0.6} = 7961$

$$\Rightarrow N = \frac{7961 \times 6}{100}$$

$$\Rightarrow N = 477.6$$

For length about 60 cm, no. of turns about 480, current about 10 A.

17) $r_1 = 25\,cm = 0.25\,m$
$r_2 = 26\,cm = 0.26\,m$
$N = 3500$
$I = 11\,A$

a) Outside the toroid, magnetic field is zero

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

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

$= \pi(r_1 + r_2)$

$= \pi \times 0.51$

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

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

$= 3.02 \times 10^{-2}\,T$

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

b) Yes as magnetic force can change the direction of velocity but not its magnitude

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

19) $B = 0.15\,T$
$V = 2\,kV$

gain in KE of an e^- $\Rightarrow E = (1/2)mv^2$

$\Rightarrow eV = (1/2)mv^2$

$\Rightarrow v = \sqrt{\frac{2eV}{m}}$.

$= \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.1 \times 10^{-31}}}$

$= 2.65 \times 10^{7}$ m/s

a) $F_1 = F_2$

$\Rightarrow F_1 = evB$

$\Rightarrow F_2 = \frac{mv^2}{r}$

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

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

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

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

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

$r = \frac{9.1 \times 10^{-31} \times 2.65 \times 10^{7} \times \sin 30°}{0.15 \times 1.6 \times 10^{-19}}$

$= 50.2 \times 10^{-5}$ m

$r = 0.5$ mm

20) $B = 0.75$ T

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

$E = 9.0 \times 10^{-5}$ V m^{-1}

$K = \frac{1}{2}mv^2$

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

$\Rightarrow \frac{e}{m} = \frac{v^2}{2V}$

∴ The particles are not deflected by $\vec{E}$ and $\vec{B}$.

$\Rightarrow eE = evB$

$\Rightarrow v = \frac{E}{B}$

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

$\Rightarrow \frac{e}{m} = \frac{E^2}{2VB^2}$

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

$\Rightarrow 4.8 \times 10^7$ C/kg.

∴ The answer is not unique as only the ratio of charge to mass is determined. The beam contains deutrons.

24) $B = 3000$ G $= 0.3$ T

$A = 10 \times 5 = 50 \times 10^{-4}$ m^2

$I = 12$ A.

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

$\vec{A} = 50 \times 10^{-4}\ \hat{i}$ (y-z plane)

$\vec{B} = 0.3\ \hat{k}$ (along z axis)

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

$= -1.8 \times 10^{-2}\ \hat{j}$ Nm (towards -ve y-direction)

b) It is same as a) in the -ve y direction.

$\tau_{net} = 0$.

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

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

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

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

∴ net force is zero.

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

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

∴ Net force is zero.

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

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

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

$= 0$

∴ $f_{net} = 0$.

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

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

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

$= 0$.

∴ $f = 0$

∴ case (e) and (f).

27) $G = 12 \Omega$

$I = 3$ mA

$R = \left(\frac{V}{I_g}\right) - G$

$\Rightarrow \frac{18}{3 \times 10^{-3}} - 12$

$\Rightarrow 6000 - 12$

$\Rightarrow 5988\ \Omega$

28) $G = 15\ \Omega$

$I_g = 4mA = 4 \times 10^{-3}\ A$

Ammeter range = 0 to 6 A.

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

$$= \frac{4 \times 10^{-3} \times 15}{6 - 0.004}$$

$$= 10 \times 10^{-3}\ A$$

$S = 10\ mA$

∴ 10 mA resistor must be connected in parallel.