# CH-4

4.1) $n = 100$

$r = 8.0\,cm = 0.08\,m$

$I = 0.4\,A$

$B = \dfrac{\mu_0 n I}{2r}$ $\qquad \mu_0 = 4\pi \times 10^{-7}\, T\,m\,A^{-1}$

$B = \dfrac{4\pi \times 10^{-7} \times 100 \times 0.4}{2 \times 0.08} = 3.14 \times 10^{-4}\, T$

4.2) $I = 35\,A$

$r = 20\,cm = 0.2\,m$

$B = \dfrac{\mu_0 I}{2\pi r} = \dfrac{4\pi \times 10^{-7} \times 2 \times 35}{4\pi \times 0.2} = 35 \times 10^{-5}\, T$

4.3) $r = 2.5\,m$

$I = 50\,A$

$|B| = \dfrac{\mu_0 2I}{4\pi r} = \dfrac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 2.5} = 4 \times 10^{-6}\, T$

$\therefore$ vertically upward

4.4) $I = 90\,A$

$r = 1.5\,m$

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

$B = \dfrac{4\pi \times 10^{-7} \times 2 \times 90}{4\pi \times 1.5} = 1.2 \times 10^{-5}\, T$

$\therefore$ Towards South.

4.5) $I = 8A$

$B = 0.15T$

$\theta = 30°$

$F = BI\sin\theta = 0.15 \times 8 \times \sin 30° = 0.6\,Nm^{-1}$

4.6) $l = 3\,cm = 0.03m$

$I = 10A$

$B = 0.27T$

$\theta = 90°$

$F = BIL\sin\theta = 0.27 \times 10 \times 0.03 \times \sin 90° = 81 \times 10^{-3} N$

4.7) $I_A = 8.0A$

$I_B = 5.0A$

$r = 4\,cm = 0.04m$

$L = 10cm = 0.1m$

$F = \dfrac{\mu_0 I_A I_B L}{2\pi r}$

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

4.8) $l = 80cm = 0.8m$

$N = 5 \times 400 = 2000$

$D = 1.8cm = 0.018m$

$I = 8.0A$

$|B| = \dfrac{\mu_0 NI}{l} = \dfrac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8} = 2.5 \times 10^{-2} T$

4.9) $L = 10\,cm = 0.1\,m$

$I = 12A$

$n = 20$

$\theta = 30^\circ$

$B = 0.80T$

$A = .1 \times .1 = 0.01\,m^2$

$T = nBIA\sin\theta$

$= 20 \times 0.8 \times 12 \times 0.01 \times \sin 30^\circ$

$= 0.96\,Nm$

4.10) $M_1$

$R_1 = 10\Omega$

$N_1 = 30$

$A_1 = 3.6 \times 10^{-3}\,m^2$

$B_1 = 0.25T$

$K_1 = K$

$M_2$

$R_2 = 14\Omega$

$N_2 = 42$

$A_2 = 1.8 \times 10^{-3}\,m^2$

$B_2 = 0.50T$

$K_2 = K$

a) $I_{s_1} = \dfrac{N_1 B_1 A_1}{K_1}$ $\quad I_{s_2} = \dfrac{N_2 B_2 A_2}{K_2}$

$\dfrac{I_{s1}}{I_{s2}} = \dfrac{42 \times 0.5 \times 1.8 \times 10^{-3}}{30 \times 0.25 \times 3.6 \times 10^{-3}} = 1.4$

b) $V_{s_2} = \dfrac{N_2 B_2 A_2}{K_2 R_2}$ $\quad V_{s1} = \dfrac{N_1 B_1 A_1}{K_1 R_1}$

$\dfrac{V_{s2}}{V_{s1}} = \dfrac{42 \times 0.5 \times 1.8 \times 10^{-3} \times K}{K \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}} = 1$

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

$v = 4.8 \times 10^{6}\,m/s$

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

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

$\theta = 90^\circ$

$F = evB\sin\theta$

Electron is moving around a circular path. To rotate in a circular path, electron needs a centripetal force. centripetal force is provided by the magnetic force. Hence, the centripetal force exerted on the electron

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

For equillibrium,

$$F_e = F$$

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

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

$$\Rightarrow r = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times\sin 90^\circ} = 4.2\text{ cm}$$

4.12) Assume frequency of revolution of $\bar{e}$ is $V$.
Angular frequency of $\bar{e}$ = $\omega = 2\pi V$

Rel$^n$ bet$^w$ $v$ of $\bar{e}$ & angular frequency is $v = r\omega$
Hence,

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

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

$$\Rightarrow V = \frac{eB}{2\pi m} = \frac{6.5\times10^{-4}\times1.6\times10^{-19}}{2\times3.14\times9.1\times10^{-31}} = 1.82\times10^{7}\text{ Hz}$$

$\approx$ 18 MHz

4.13 a) $N = 30$

$r = 0.08m$

$A = \pi r^2 = 0.0201 m^2$

$I = 6.0A$

$B = 1T$

$\theta = 60°$

$Torque = nBIA \sin\theta$

$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60°$

$= 3.1333 Nm$

b) From the formula of Torque, we can say that magnitude of applied Torque is independent of shape of the coil. It depends on Area of coil. Hence, Torque will not change if the circular coil in the above case is replaced by planar coil that encloses same area.

4.14) X

$r_1 = 16cm = 0.16m$

$N_1 = 20$

$I_1 = 16A$

Y

$R_2 = 0.1m$

$N_2 = 25$

$I_2 = 18A$

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

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

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

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

$B = B_2 - B_1$

$= 1.57 \times 10^{-3} T$ (Towards West)

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

$n = 1000$ turns $m^{-1}$

$I = 15A$

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

$B = \mu_0 n I$

$\Rightarrow nI = \frac{B}{\mu_0} = \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74 \approx 8000\ Am^{-1}$

4.16) Given

Radius $= R$

No. of turns $= N$

Current $= I$

$$B = \frac{\mu_0 I R^2 N}{2(x^2+R^2)^{3/2}}$$

(a) $x = 0$

$B = \frac{\mu_0 N I}{2R}$ This is the expression for the magnetic field at the centre of coil.

(b) Radii $= R$

No. of turns $= N$

Current $= I$

distance betw both coils $= R$

Let Q at distance d from centre.

Then,

One coil is at distance of $\frac{R}{2} + d$ from point Q.

Magnetic field at Q $\Rightarrow B_1 = \frac{\mu_0 N I R}{2\left[\left(\frac{R}{2}+d\right)^2 + R^2\right]^{3/2}}$

Also, another coil is at distance $\frac{R}{2}-d$ from O

$$B_2 = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2}-d\right)^2 + R^2\right]^{3/2}}$$

Total magnetic field :

$$B = B_1 + B_2$$

$$= \frac{\mu_0 I R^2}{2}\left[\left\{\left(\frac{R}{2}-d\right)^2+R^2\right\} + \left\{\left(\frac{R}{2}+d\right)^2 + R^2\right\}^{3/2}\right]$$

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

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

For $d << R$

so

$$\approx \frac{\mu_0 I R^2}{2} \times \left(\frac{5R^2}{4}\right)^{3/2} \times \left[\left(1-\frac{4d}{5R}\right)^{3/2} + \left(1+\frac{4d}{5R}\right)^{3/2}\right]$$

$$\approx \frac{\mu_0 I R^2 N}{2R^3} \times \left(\frac{4}{5}\right)^{3/2}\left[1 - \frac{6d}{5R} + 1 + \frac{6d}{5R}\right]$$

$$B = \left(\frac{4}{5}\right)^{3/2}\frac{\mu_0 I N}{R} = 0.72\left(\frac{\mu_0 I N}{R}\right)$$

Hence proved that field on the axis around the mid-point betw the coils is uniform.

4.17) $r_i = 25\text{cm} = 0.25\text{m}$

$r_o = 26\text{cm} = 0.26\text{m}$

$N = 3500$

$I = 11A$

(a) Magnetic field outside a toroid is 0 but for inside the core of toroid magnetic field will be nonzero.

(b) $|B| = \frac{\mu_0 NI}{l}$

$l = 2\pi \frac{r_i + r_o}{2} = 0.51\pi$

$B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi} = 3 \times 10^{-2}\ T$

4.19) $B = 0.15T$

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

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

$V = 2.0 kV = 2 \times 10^{3} V$

$K.E. = eV$

$\Rightarrow eV = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2eV}{m}}$ — (1)

(a) Let radius $= r$

Magnetic force on the electron $= Bev$

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

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

$\Rightarrow r = \frac{mv}{Be}$ — (2)

From eqn ① & ②

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

$$= \frac{9.1\times10^{-31}}{0.15\times1.6\times10^{-19}} \times \left(\frac{2\times1.6\times10^{-19}\times2\times10^{3}}{9.1\times10^{-31}}\right)^{1/2}$$

$$= 1.01\times10^{-3}\,m = 1\,mm.$$

∴ Hence, the electron has a circular trajectory of 1mm normal to the magnetic field.

(b) $V_1 = V\sin\theta$

From eqn ②

$$r_1 = \frac{mV_1}{Be}$$

$$= \frac{mV\sin\theta}{Be}$$

$$= \frac{9.1\times10^{-11}}{0.15\times1.6\times10^{-19}}\left[\frac{2\times1.6\times10^{-19}\times2\times10^{3}}{9\times10^{-31}}\right]^{1/2}\times\sin 30°$$

$$= 0.5\times10^{-3}\,m = 0.5\,mm$$

4.20) $B = 0.75T$

$V = 15\,kV = 15\times10^{3}\,V$

$E = 9\times10^{-5}\,Vm^{-1}$

$m, e, v$ $\quad KE = eV$

$$\Rightarrow \frac{1}{2}mv^2 = eV \Rightarrow \frac{e}{m} = \frac{v^2}{2V} \quad \text{— ①}$$

∴ $eE = evB$

$$\Rightarrow v = \frac{E}{B} \quad \text{— ②}$$

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

$$= \frac{(9.0\times 10^{5})^2}{2\times 15000\times (0.75)^2} = 4.8\times 10^{13}\ C/kg.$$

4.21) $l = 0.45m$

$m = 60g = 60\times 10^{-3}\ kg$

$g = 9.8\ m/s^2$

(a) $BIl = mg$

$\Rightarrow B = \frac{60\times 9.8\times 10^{-3}}{5\times 0.45} = 0.26T$

Magnetic force will be in upward direction.

(b) Now, if I direction is reversed.

Total tension in wire.

$= BIl + mg$

$= 0.26\times 5\times \cancel{0.45}\,0.45 + (60\times 10^{-3})\times 9.8 = 1.176N$

4.22) $I = 300A$

$r = 1.5cm = 0.015m$

$l = 70cm = 0.7m$

$F = \frac{\mu_0 I^2}{2\pi r}$

$= \frac{4\pi\times 10^{-7}\times 300\times 300}{2\pi\times 0.015} = \cancel{1.2\ N/m}\ 1.2\ N/m$

Since the direction of the current in the wires is opposite so, repulsive force will be generated betw them.

4.23) $B = 1.5T$

$r = 10cm = 0.1m$

$I = 7A$

(a) $l = 2r = 0.2m$

$\theta = 90^\circ$

$F = BIl\sin\theta = 1.5 \times 7 \times 0.2 \times \sin 90^\circ = 2.1N$

Hence,

magnitude of force 2.1N acts on the wire vertically downward direction.

(b) $l_1 = \frac{l}{\sin\theta}$

Now $\theta = 45^\circ$

Force on wire =

$= BIl\sin\theta = 1.5 \times 7 \times 0.2 = 2.1N$

(c) $d = 6.0m$

Let $l_2$ = new length

$\therefore \left(\frac{l_2}{2}\right)^2 = 4(d+r)$

$= 4(10+6) = 4(16)$

$\therefore l_2 = 8+2 = 16cm = 0.16m$

$F_2 = BIl_2$

$= 1.5 \times 7 \times 0.16$

$= 1.68N$

$\therefore$ Force of magnitude acts vertically downward.

4.24) $B = 0.3 T$

$l = 10 cm$

$b = 5 cm$

$A = l \times b \times 3 = 50 \times 10^{-4} m^2$

$I = 12 A$

Assume, that ACM direction of the current is Positive & vice-versa.

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

$\vec{B} = 0.3 \hat{k}, \vec{A} = 50 \times 10^{-4} \hat{i}$

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

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

Hence, force will be in loop

(b) Direction same as (a) so, answer is same as (a)

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

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

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

(d) $|\tau| = I \times A \times B$

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

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

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

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

$= 0$

$\therefore$ Hence torque is 0, force 0

(f) torque 0, force 0.

4.25) $r = 10cm = 0.1m$

$B = 0.10T$

$n = 20$

$I = 5.0A$

(a) Because of uniform magnetic field, The total torque on the coil will be 0.

(b) Because of uniform magnetic field, total force on the coil is 0.

(c) $A = 10^{-5} m^2$

$N = 10^{29} m^3$

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

$F = BeV_d$

$V_d = \frac{I}{NeA}$

$\therefore F = \frac{BeI}{NeA}$

$= \frac{0.10 \times 0.50}{10^{29} \times 10^{-5}} = 5 \times 10^{-25} N$

4.26) $r = 0.04m$

$L = 0.6m$

$n = 3 \times 300 = 900$

$l = 0.02m$

$m = 2.5 \times 10^{-3} kg$

$i = 6A$

$g = 9.8 m/s^2$

$B = \frac{\mu_0 n I}{L}$

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

$F = Bil$

$= \frac{\mu_0 n I}{L} \times il$

$\therefore mg = \frac{\mu_0 n I i l}{L}$

$\Rightarrow I = \frac{mgL}{\mu_0 n i l}$

$= \frac{2.5 \times 10^{-3} \times 9.8 \times 0.6}{4\pi \times 10^{-7} \times 900 \times 0.02 \times 6} = 108\ A$

4.27) $G = 12\ \Omega$

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

$V = 18\ V$

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

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

4.28) $G = 15\ \Omega$ $I_g = 4 mA = 4 \times 10^{-3}\ A$

$I = 6A$

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

$= \frac{4 \times 15 \times 10^{-3}}{6 - 4 \times 10^{-3}} = 0.01\ \Omega$

$\therefore$ A shunt resistor of $0.01\ \Omega$ is to be connected in $\parallel$ with the galvanometer