Moving Charges and Magnetism

4.1) No. of turns on the circular coil, $n = 100$
Radius of each turn, $r = 8.0\,cm = 0.08\,m$
$I = 0.4\,A$.

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

$$\mu_0 = 4\pi \times 10^{-7}\, T\,m\,A^{-1}$$

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

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

4.2) $I = 35\,A$
Distance of a point from wire, $r = 20\,cm = 0.2\,m$.

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

$$= \frac{4\pi \times 10^{-7} \times 2 \times 35}{4\pi \times 0.2} = \boxed{3.5 \times 10^{-5}\,T}$$

∴ The ~~magnetic~~ magnitude of magnetic field is $\boxed{3.5 \times 10^{-5}\,T}$.

4.6) Length of the wire, $l = 3\,cm = 0.03\,m$
$I = 10\,A$
$B = 0.27\,T$
$\theta = 90°$
$F = BIl\sin\theta = 0.27 \times 10 \times 0.03 \sin 90°$
$= \boxed{8.1 \times 10^{-2}\,N}$

∴ The magnetic field on the wire is $8.1 \times 10^{-2}\,N$.

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4.7) $I_A = 8A$

$I_B = 5A.$

$r = 4cm = 0.04m$

Length of a section of wire A, $l = 0.1m$

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

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

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

The magnitude of force on a 10cm section of wire A is $2 \times 10^{-5} N$.

4.8) Length of the solenoid, $l = 80cm = 0.8m.$

Total no. of turns on the solenoid, $N = 5 \times 400$
$= 2000$

Diameter of solenoid $= D = 1.8\ m = 0.018m$

$I = 8.0A.$

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

$$B = 4\pi \times 10^{-7} \times 2000 \times 8 / 0.8 = 8\pi \times 10^{-3}$$

$$= \boxed{2.512 \times 10^{-2} T}$$

∴ The magnetic of magnetic field inside the solenoid near its centre is $2.512 \times 10^{-2} T$.

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

$e = 1.6 \times 10^{-6}\ C.$

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

$V = 4.8 \times 10^{6}\ m/s.$

$r = 4.2\ cm = 0.042\ m$

Frequency of revolution of electron $= \nu$

Angular frequency of electron $= \omega = 2\pi\nu$

$v = r\omega$

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

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

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

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

$\cancel{= 18.2 \times 10^{6}\ Hz. = \boxed{18\ MHz}}$

4.12) $F = evB\sin\theta$

This force provides centripetal force to moving electron.

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

$F_c = F$

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

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

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

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

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4.12) $B = 6.5 \times 10^{-4}$ T.
$e = 1.6 \times 10^{-19}$ C
$m_e = 9.1 \times 10^{-31}$ kg
$v = 4.8 \times 10^{6}$ m/s.
$r = 4.2$ cm $= 0.042$ m

Frequency of revolution of electron $= \nu$.

$$\omega = 2\pi\nu$$
$$v = r\omega$$

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

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

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

$$\nu = \frac{6.5 \times 10^{-4} \times 1.6 \times 10^{-19}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18.2 \times 10^{6} \text{ Hz} = 18 \text{ MHz}.$$

4.13) (a) No. of turns on the circular coil, $n = 30$
Radius of the coil, $r = 8$ cm $= 0.08$ m

$= \pi r^2 = \pi(0.08)^2 = 0.0201 \text{ m}^2$

$I = 6$ A.
$B = 1$ T.
$\theta = 60°$
$\tau = nIBA\sin\theta$.
$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60° = 3.133$ Nm.

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

4.14) Radius of coil X, $r_1 = 16\,cm = 0.16\,m$
Radius of coil Y, $r_2 = 10\,m = 0.1\,m$

No. of turns of on coil X, $n_1 = 20$.
No. of turns of on coil Y, $n_2 = 25$

$I_1 = 16\,A$
$I_2 = 18\,A$.

$$B_1 = \frac{\mu_0 n_1 I_1}{2r_1} = \frac{4\pi\times10^{-7}\times20\times16}{2\times0.16} = \boxed{4\pi\times10^{-4}\,T}$$

$$B_2 = \frac{\mu_0 n_2 I_2}{2r_2} = \frac{4\pi\times10^{-7}\times25\times18}{2\times0.10}$$
$$= \boxed{9\pi\times10^{-4}\,T}$$

$$B = B_2 - B_1$$
$$= 9\pi\times10^{-4} - 4\pi\times10^{-4}$$
$$= 5\pi\times10^{-4}\,T = \boxed{1.57\times10^{-3}\,T}$$

4.15). Magnetic field strength $B = 100\,G = 100 \times 10^{-4}\,T$

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

$I = 15\,A$

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

$B = \mu_0 n I$.

$\therefore nI = \frac{B}{\mu_0} = \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = \boxed{7957.74} = \boxed{8000\,A/m}$.

4.17) $r_1 = 25\,cm = 0.25\,m$

$r_2 = 26\,cm = 0.26\,m$

$N = 3500$

$I = 11\,A$

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

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

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

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

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

$= 0.51\pi$

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

$= \boxed{3.0 \times 10^{-2}\,T}$

(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 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. The magnetic field should be applied in a vertically downward direction.

4.19) $B = 0.15\,T$

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

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

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

$K = eV$

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

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

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

$$\therefore Bev = mv^2/r$$

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

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

$$= \frac{0.91 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left(\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.1 \times 10^{-31}}\right)^{1/2}$$

$$= 100.55 \times 10^{-5} = 1.01 \times 10^{-3}\,m = 1\,mm.$$

(b) When the field makes an angle θ of 30^0 with initial velocity.

$$v_1 = \sin\theta$$

$$r_1 = mv_1/Be = \frac{mv\sin\theta}{Be} = \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times$$

$$\left[\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9 \times 10^{-3}}\right]^{1/2} \times \sin 30^0 =$$

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

$\therefore$ The electron has a helical trajectory of radius 0.5mm along the magnetic field direction.

4.20) $B = 0.75 T$.

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

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

Mass of electron = m

Charge of electron = e

~~Char~~

velocity of electron = v

$K = eV$

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

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

$\therefore eE = evB$.

$v = E/B$.

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

$$= \frac{(9 \times 10^5)^2}{2 \times 15000 \times (0.75)^2} = 4.8 \times 10^7 C/kg$$

→ This value of specific charge e/m is equal to the value of deuteron or deuterium ions. This is not a unique answer.

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

length of rectangular loop, $l = 10\,cm$
width of the loop, $b = 5\,cm$

Area of the loop,
$A = l \times b = 10 \times 5 = 50\,cm^2 = 50 \times 10^{-4}\,m^2$

$I = 12\,A$

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

$\therefore \tau = 12 \times (50 \times 10^{-4})\hat{i} \times 0.3\hat{k} = -1.8 \times 10^{-2}\hat{j}\,Nm.$

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

(b) This case is similar to case (a), Hence, the answer is same as (a).

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

$\therefore \tau = -12 \times (50 \times 10^{-4})\hat{j} \times 0.3\hat{k}$
$= -1.8 \times 10^{-2}\,\hat{i}\,Nm.$

$\therefore$ The torque is -1.8×10^{-2} N/m at an ~~angle of 240°~~ ~~with~~ positive x direction.

(d) $|\tau| = IAB = 12 \times 50 \times 10^{-4} \times 0.3$
$= 1.8 \times 10^{-2}$ Nm.

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

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

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

Hence, the torque is zero. The force is also zero.

→ In case (e), the direction of $I\vec{A}$ and $\vec{B}$ is the same and the angle between them is zero. Hence, its equilibrium is stable.

→ In case f, the direction of $I\vec{A}$ and $\vec{B}$ is opposite. The angle between them is 180°. Hence its equilibrium is unstable.

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

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

$V = 18\text{ V}$

Let resistance R be connected in series with the galvanometer.

$$R = \frac{V}{I_g} - G = \frac{18}{3 \times 10^{-3}} - 12 = 6000 - 12 = \boxed{5988\ \Omega}$$

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