Moving Charges & Magnetism

NCERT Questions

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4.1 No. of turns, $n = 100$, $r = 0.08\,m$, $I = 0.4\,A$

$|B| = \frac{\mu_0}{4\pi}\frac{2\pi nI}{r} = \frac{4\pi \times 10^{-7} \times 2\pi \times 100 \times 0.4}{4\pi \times 0.08} = 3.14 \times 10^{-4}\,T$

4.2 $I = 35\,A$, $r = 0.2\,m$, $B = \frac{\mu_0}{4\pi}\frac{2I}{r}$

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

4.6 length (l) $= 0.03\,m$, $B = 0.27\,T$, $\theta = 90^\circ$

$I = 10\,A$

$\therefore F = IBl\sin\theta = 0.27 \times 10 \times 0.03 \times \sin 90^\circ = 8.1 \times 10^{-2}\,N$

4.7 $I_A = 8.0\,A$, $r = 0.04\,m$

$I_B = 5.0\,A$, $l = 0.1\,m$

$\therefore B = \frac{\mu_0 2 I_A I_B l}{4\pi r} = \frac{4\pi \times 10^{-7} \times 2 \times 8 \times 5 \times 0.1}{4\pi \times 0.04} = 2 \times 10^{-5}\,N$

4.8 length (l) $= 0.8\,m$

No. of turns (nl) $= 5 \times 400 = 2000$

Diameter (D) $= 1.8\,cm = 0.018\,m$

$I = 8.0\,A$

$B = \frac{\mu_0 NI}{l} = \frac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8} = 8\pi \times 10^{-3}$

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

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

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

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

Mass of electron (m_e) $= 9.1 \times 10^{-31}\,kg$

$F = evB\sin\theta$

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

$\therefore r = \frac{mv}{Be\sin\theta} = \frac{9.1\times10^{-31}\times4.8\times10^{6}}{6.5\times10^{-4}\times1.6\times10^{-19}\times\sin 90^\circ} = 4.2\times10^{-2}\,m$

$\therefore$ Radius of circular orbit = 4.2 cm

4.12

$B = 6.5\times10^{-4}\,T$ $\quad$ $r = 4.2\,cm = 0.042\,m$

$e = 1.6\times10^{-19}\,C$ $\quad$ Frequency = ν

$m_e = 9.1\times10^{-31}\,kg$ $\quad$ Angular frequency = $\omega = 2\pi\nu$

$v = 4.8\times10^{6}$

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

$\Rightarrow \nu = \frac{Be}{2\pi m} = \frac{6.5\times10^{-4}\times1.6\times10^{-19}}{2\times3.14\times9.1\times10^{-31}} \approx 18\,MHz$

$\therefore$ Frequency = 18 MHz

4.13

$n = 30$ $\quad$ $I = 6.0\,A$

$r = 8.0\,cm = 0.08\,m$ $\quad$ $B = 1\,T$

Area $= \pi r^2 = 0.0201\,m^2$ $\quad$ $\theta = 60^\circ$

$\tau = nIBA\sin\theta = 30\times6\times1\times0.0201\times\sin 60^\circ = 3.133\,Nm$

(b) The magnitude of the 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.

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4.14 $r_1 = 0.16m$, $n_1 = 20$, $I_1 = 16A$
$r_2 = 0.1m$, $n_2 = 25$, $I_2 = 18A$

$B_1 = \frac{\mu_0 n_1 I_1}{2r_1} = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16} = 4\pi \times 10^{-4}\,T$ (towards East)

$B_2 = \frac{\mu_0 n_2 I_2}{2r_2} = \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10} = 9\pi \times 10^{-4}\,T$ (toward West)

$\therefore B_{net} = B_2 - B_1$
$= 9\pi \times 10^{-4} - 4\pi \times 10^{-4}$
$= 5\pi \times 10^{-4}\,T = 1.57 \times 10^{-3}\,T$ (towards West)

4.15 $B = 100 \times 10^{-4}\,T$
$n = 1000$ turns m^{-1}
$I = 15A$
$B = \mu_0 n I$
$\Rightarrow nI = \frac{B}{\mu_0} = \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}} = 7957.74 \approx 8000\,A/m$

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 possibility of some adjustments with limits.

4.17 Inner radius $(r_1) = 0.25m$ $I = 11\,A$
Outer radius $(r_2) = 0.26m$
$N = 3500$
$\therefore B = \frac{\mu_0 NI}{l}$, ~~$\Rightarrow l = \frac{\mu_0 NI}{B} = 2\pi$~~

Now, $l = 2\pi \left[\frac{r_1 + r_2}{2}\right] = 0.51\pi$

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$\therefore B = \frac{4\pi \times 10^{-7} \times 3500 \times 11}{0.51\pi} = 3.0 \times 10^{-2}\, T$

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

4.18 The initial velocity of the particle is either parallel or antiparallel to the magnetic field. Hence, it travels along a straight line without suffering any deflection in the field.

Yes, the final speed of the charged particle will be equal to its initial speed.

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.

4.19 $B = 0.15\, T$ $m = 9.1 \times 10^{-31}\, kg$

$e = 1.6 \times 10^{-19}\, C$ $V = 2.0\, kV$

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

$r = \frac{mv}{Be} = \frac{m}{Be}\left[\frac{2eV}{m}\right]^{\frac{1}{2}} = \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \left(\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9.1 \times 10^{-31}}\right)^{\frac{1}{2}}$

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

$= 1\, mm$

$v_1 = v \sin\theta \Rightarrow r_1 = \frac{mv_1}{Be} = 0.5\, mm$

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

4.20 $B = 0.75T$, $V = 15\times10^3 V$, $E = 9\times10^5 Vm^{-1}$

Since,

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

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

$$\therefore \frac{e}{m} = \frac{1}{2}\frac{\left(\frac{E}{B}\right)^2}{V} = \frac{E^2}{2VB^2} = \frac{(9.0\times10^5)^2}{2\times15000\times(0.75)^2} = 4.8\times10^7 C/kg.$$

This value of specific charge e/m is equal to the value of deuteron ions. Other possible answers are He^{++}, Li^{++}, etc.

4.24 (a) $B = 0.3\,T$

$l = 10\,cm$

$b = 5\,cm$

$Area = l\times b = 50\times10^{-4}\,m^2$

$I = 12A$

$$\vec{\tau} = I\vec{A}\times\vec{B} = 12\times(50\times10^{-4})\hat{i}\times0.3\hat{k} = -1.8\times10^{-2}\hat{j}\,Nm$$

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

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

$$\tau = -12\times(50\times10^{-4})\hat{j}\times0.3\hat{k}$$
$$= -1.8\times10^{-2}\hat{i}\,Nm$$

Here, force is zero

(c) (d) Torque, $\tau = I\vec{A}\times\vec{B} = (50\times10^{-4}\times12)\hat{k}\times0.3\hat{k} = 0$

Here, Torque is zero and force is also zero.

(d) Torque $= \tau = I\vec{A}\times\vec{B} = 0$

Here, torque is zero and force is also zero.

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(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.

(f) The direction of $I\vec{A}$ and $\vec{B}$ is opposite. The angle between them is 180°. Therefore, it is in unstable equilibrium.