

### NCERT Exercise :

4.1 Given  $N = 100$ ,  $r = 8 \text{ cm} = 0.08 \text{ m}$ ,  $I = 0.40 \text{ A}$

$$\therefore B = \frac{\mu_0 NI}{2r} = \frac{4\pi \times 10^{-7} \times 100 \times 0.40}{2 \times 0.08} = \pi \times 10^{-4} = 3.1 \times 10^{-4} \text{ T}$$

4.2 Here  $I = 35 \text{ A}$ ,  $r = 20 \text{ cm} = 0.20 \text{ m}$ ,  $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 35}{2\pi \times 0.20} = 3.5 \times 10^{-5} \text{ T}$$

4.6 Given  $l = 3.0 \text{ cm} = 0.03 \text{ m}$ ,  $I = 10 \text{ A}$ ,  $\theta = 90^\circ$ ,  $B = 0.27 \text{ T}$

$$F = IlB \sin \theta = 10 \times 0.03 \times 0.27 \times \sin 90^\circ = 8.1 \times 10^{-2} \text{ N}$$

The direction of the force is given by Fleming's left hand rule.

4.7 Force per unit length of each wire is

$$f = \frac{\mu_0 I_1 I_2}{2\pi r} = \frac{4\pi \times 10^{-7} \times 8 \times 5}{2\pi \times 4 \times 10^{-2}} = 2 \times 10^{-4} \text{ N m}^{-1}$$

Force on 10 cm section of wire A is

$$F = fl = 2 \times 10^{-4} \times 10 \times 10^{-2} = 2 \times 10^{-5} \text{ N}$$

4.8 Number of turns per unit length of the solenoid

$$n = \frac{\text{Number of turns per layer} \times \text{Number of layers}}{\text{Length of solenoid}}$$

$$= \frac{400 \times 5}{0.80} = 2500 \text{ m}^{-1}$$

Magnetic field inside the solenoid is

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times 2500 \times 8 = 8\pi \times 10^{-3} \text{ T} \\ = 2.5 \times 10^{-2} \text{ T}$$

4.11 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.

$\therefore$  Magnetic force on the electron = Centripetal force

$$e v B \sin 90^\circ = \frac{m_e v^2}{r}$$

$$\Rightarrow r = \frac{m_e v}{e B}$$

$$\text{Now, } B = 6.5 \text{ G} = 6.5 \times 10^{-4} \text{ T}, \quad v = 4.8 \times 10^6 \text{ m s}^{-1}$$

$$\therefore r = \frac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2 \times 10^{-2} \text{ m} = 4.2 \text{ cm}$$

4.12 Frequency of revolution of the electron in its circular orbit,

$$f = \frac{eB}{2\pi m} = \frac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18.18 \times 10^6 \text{ Hz} = 18 \text{ MHz}$$

No, the frequency  $f$  does not depend on the speed  $v$  of the electron.

4.13 a)  $N = 30$ ,  $r = 80 \text{ cm} = 0.8 \text{ m}$ ,  $I = 6.0 \text{ A}$ ,  $B = 1 \text{ T}$ ,  $\theta = 60^\circ$

Magnitude of counter torque = Magnitude of deflecting torque

$$= NIBA \sin \theta$$

$$= 30 \times 6 \times 1 \times (3.14 \times 0.8 \times 0.8) \times \sin 60^\circ$$

$$= 30 \times 6 \times 3.14 \times 64 \times 10^{-4} \times 0.866$$

$$= 3.1 \text{ Nm}$$

b) No, the answer would not change because the above formula for the torque is true for a planar loop of any shape.

4.14 For coil X:  $r_x = 16 \text{ cm} = 0.16 \text{ m}$ ,  $N_x = 20$ ,  $I_x = 16 \text{ A}$

$\therefore$  Magnetic field at the centre of coil X is

$$B_x = \frac{\mu_0 I_x N_x}{2 r_x} = \frac{4\pi \times 10^{-7} \times 16 \times 20}{2 \times 0.16} = 4\pi \times 10^{-4} \text{ T}$$

As the current in the coil X is anticlockwise, the field is directed towards east.

For coil  $Y = r_y = 10\text{cm} = 0.10\text{m}$ ,  $N_y = 25$ ,  $I_y = 18\text{A}$

$\therefore$  Magnetic field at the centre of coil  $Y$  is

$$B_y = \frac{\mu_0 I_y N_y}{2r_y} = \frac{4\pi \times 10^{-7} \times 18 \times 25}{2 \times 0.10} = 9\pi \times 10^{-4}\text{T}$$

As the current in the coil  $Y$  is clockwise, the field  $B_y$  is directed towards west.

Since  $B_y > B_x$ , therefore, the net field is directed towards west and its magnitude is

$$B = B_y - B_x = 5\pi \times 10^{-4} = 1.6 \times 10^{-3}\text{T}$$

4.15 Here  $B = 100\text{G} = 10^{-2}\text{T}$ ,  $I = 15\text{A}$ ,  $n = 1000\text{ turns m}^{-1}$

Magnetic field inside a solenoid,

$$B = \mu_0 n I$$

$$\therefore n I = \frac{B}{\mu_0} = \frac{10^{-2}}{4\pi \times 10^{-7}} = 7955 \approx 8000$$

We may take  $I = 10\text{A}$ , then  $n = 800$

The solenoid may have length  $50\text{cm}$  and area of cross-section  $5 \times 10^{-2}\text{m}^2$  (five times the given value) so as to avoid edge effects, etc.

4.17 Here  $I = 11\text{A}$ , total number of turns = 3500

mean radius of toroid,

$$r = \frac{25+26}{2} = 25.5\text{cm} = 25.5 \times 10^{-2}\text{m}$$

$$\begin{aligned} \text{Total length (circumference) of the toroid} &= 2\pi r \\ &= 2\pi \times 25.5 \times 10^{-2} = 51.0 \times 10^{-2}\pi\text{m} \end{aligned}$$

∴ Number of turns per unit length,

$$n = \frac{3500}{51.0 \times 10^{-2}\pi}$$

a The field outside the toroid is zero.

b The field inside the core of the toroid,

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times \frac{3500}{51.0 \times 10^{-2}} \times 11 = 3.02 \times 10^{-2}\text{T}$$

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

4.18a) The force on a charged particle moving in a magnetic field is given by

$$F = qvB \sin \theta$$

The force on a charged particle will be zero if the particle will remain undeflected if

$$\sin \theta = 0 \text{ or } \theta = 0^\circ, 180^\circ$$

i.e., initial velocity  $\vec{v}$  is either parallel or antiparallel to  $\vec{B}$ .

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 particle will have its final speed equal to its initial speed.

c) The electron travelling west to east experiences a force towards north due to the electrostatic field. It will remain undeflected if it experiences an equal force towards south due to the magnetic field. According to Fleming's left hand rule, the magnetic field must act in the vertically downward direction.

$$4.19 \quad V = 2.0 \text{ kV} = 2 \times 10^3 \text{ V}, \quad B = 0.15 \text{ T}, \quad e = 1.6 \times 10^{-19} \text{ C}, \\ m = 9.1 \times 10^{-31} \text{ kg}$$

Potential difference  $V$  imparts kinetic energy to the electron given by

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

or, velocity gained by electron,

$$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^3}{9.1 \times 10^{-31}}} \text{ ms}^{-1}$$

$$= 2.65 \times 10^7 \text{ ms}^{-1}$$

a When field  $\vec{B}$  is transverse to the initial velocity  $\vec{v}$ ,

$$e v B \sin 90^\circ = \frac{mv^2}{r}$$

$$\therefore r = \frac{mv}{eB} = \frac{9.1 \times 10^{-31} \times 2.65 \times 10^7}{1.6 \times 10^{-19} \times 0.15} = 10^{-3} \text{ m} = 1 \text{ mm}$$

Thus the electron follows a circular path trajectory of radius 1mm normal to the field B.

b When field  $\vec{B}$  makes an angle of  $30^\circ$  to the initial velocity  $\vec{v}$ ,

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

$$v_{\parallel} = v \cos 30^\circ = 2.65 \times 10^7 \times 0.866 = 2.3 \times 10^7 \text{ ms}^{-1}$$

The radius of the helical path is given by

$$r = \frac{mv_{\perp}}{eB} = \frac{mv \sin 30^\circ}{eB} = \frac{9.1 \times 10^{-31} \times 1.33 \times 10^7}{1.6 \times 10^{-19} \times 0.15} = 50.4 \times 10^{-5}$$

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$$= 0.50 \text{ mm}$$

$$4.20 \quad B = 0.75 \text{ T}, E = 9 \times 10^5 \text{ Vm}^{-1}, V = 15 \text{ kV} = 15 \times 10^3 \text{ V}$$

For undeflected beam, velocity of charged particles must be

$$v = \frac{E}{B} = \frac{9.0 \times 10^5 \text{ ms}^{-1}}{0.75} = 12 \times 10^5 \text{ ms}^{-1}$$

But the kinetic energy of the charged particles is given by

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

$$\therefore \frac{q}{m} = \frac{1}{2} \frac{v^2}{V} = \frac{1}{2} \times \frac{(12 \times 10^5)^2}{15 \times 10^3}$$

$$= 4.8 \times 10^7 \text{ C kg}^{-1}$$

Now for deuterons,

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

which means that the particles may be deuterons, each of which contains one proton and one neutron. The answer is not unique because we have determined only the ratio of charge to mass. Other possible answers are  $\text{He}^{2+}$  and  $\text{Li}^{3+}$ , etc.



4.24 Here  $B = 3000 \text{ G} = 3000 \times 10^{-4} \text{ T} = 0.3 \text{ T}$ ,  $A = 10 \times 5 = 50 \text{ cm}^2 = 5.0 \times 10^{-4} \text{ m}^2$ ,  $I = 12 \text{ A}$

Magnetic moment,

$$m = IA = 12 \times 5.0 \times 10^{-4} = 0.06 \text{ Am}^2$$

We apply right hand rule to various current loops to decide the direction of  $\vec{m}$ .

a) Here  $\vec{m} = 0.06 \hat{i} \text{ Am}^2$ ,  $B = 0.3 \hat{k} \text{ T}$

$$\therefore \vec{\tau} = \vec{m} \times \vec{B} = 0.06 \hat{i} \times 0.3 \hat{k} = -1.8 \times 10^{-2} \hat{j} \text{ Nm}$$

Thus a torque of  $1.8 \times 10^{-2} \text{ Nm}$  acts along negative  $y$ -axis.

b) Here  $\vec{m} = 0.06 \hat{i} \text{ Am}^2$ ,  $B = 0.3 \hat{k} \text{ T}$

Clearly,  $\vec{m}$  and  $\vec{B}$  are same as in case (a). In this case also, a torque of  $1.8 \times 10^{-2} \text{ Nm}$  acts along negative  $y$ -axis.

c) Here  $\vec{m} = -0.06 \hat{j} \text{ Am}^2$ ,  $B = 0.3 \hat{k} \text{ T}$

$$\vec{\tau} = \vec{m} \times \vec{B} = -0.06 \hat{j} \times 0.3 \hat{k} = -1.8 \times 10^{-2} \hat{i} \text{ Nm}$$

Thus a torque of  $1.8 \times 10^{-2} \text{ Nm}$  acts along negative  $x$ -axis.

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d) This case is similar to case (c). But here the direction of the torque is  $60^\circ$  anticlockwise with negative x-direction, i.e.,  $240^\circ$  with positive x-direction.

e) Here  $\vec{m} = 0.06 \hat{k} \text{ Am}^2$ ,  $\vec{B} = 0.3 \hat{k} \text{ T}$

$$\therefore \vec{\tau} = \vec{m} \times \vec{B} = 0.06 \hat{k} \times 0.3 \hat{k} = 0$$

f) Here  $\vec{m} = -0.06 \hat{k} \text{ Am}^2$ ,  $\vec{B} = 0.3 \hat{k} \text{ T}$

$$\therefore \vec{\tau} = \vec{m} \times \vec{B} = -0.06 \hat{k} \times 0.3 \hat{k} = 0$$

40.27 Here  $R_g = 12 \Omega$

$$I_g = 3 \text{ mA} = 3 \times 10^{-3} \text{ A}, V = 18 \text{ V}$$

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

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

40.28 Here  $R_g = 15 \Omega$ ,  $I_g = 4 \text{ mA} = 0.004 \text{ A}$ ,  $I = 6 \text{ A}$

$$R_g = \frac{I_g}{I - I_g} \times R_g = \frac{0.004}{6 - 0.004} \times 15 = 0.010 \Omega = 10 \text{ m}\Omega$$

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