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Moving charge & Magnetism

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Date ____
Page ____

(1)

N.C.E.R.T Excercise

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

$\therefore B = \dfrac{\mu_0 N I}{2r} = \dfrac{4\pi \times 10^{-7} \times 100 \times 0.40}{2 \times 0.08}$

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

4.2) Here, $I = 35A$, $r = 20cm = 0.20\,m$,

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

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

4.6) Given, $l = 3.0\,Cm = 0.03\,m$, $I = 10A$

$\theta = 90^\circ$, $B = 0.27\,T$

$F = IlB \sin\theta = 10 \times 0.03 \times 0.27 \times \sin 90^\circ$

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

4.7) Force per unit length of each wire is

$f = \dfrac{\mu_0 I_1 I_2}{2\pi r} = \dfrac{\cancel{4}^{2}\cancel{\pi} \times 10^{-7} \times \cancel{8}^{2} \times 5}{\cancel{2}\cancel{\pi} \times \cancel{4} \times 10^{-2}}$

$= 2 \times 10^{-4}\,N\,m^{-1}$

Force on 10 cm section of wire A is

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

4.8) Number of turns per unit length of the solenoid is :-

$n = \dfrac{\text{No. of turns per layer} \times \text{No. of layers}}{\text{Length of solenoid.}}$

$= \dfrac{400 \times 5}{0.80} = \dfrac{\cancel{40}^{5} \times 5 \times 100}{\cancel{8}} = 2500\,m^{-1}.$

Magnetic field inside the solenoid is

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

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

4.11) The perpendicular magnetic field exerts a force on the electron perpendicular to its path. This force continuously defects the electron from its path and makes it move along a circular path.
∴ Magnetic force on the electron = Centripetal force.

$$\Rightarrow evB\sin 90^\circ = \frac{m_e V^2}{r}$$

$$\Rightarrow r = \frac{m_e V}{eB}$$

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

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

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

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

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

$$= 18.18 \times 10^6 Hz = 18MHz$$

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

4.13)(a) $N = 30$, $r = 8.0\ cm = 0.08m$, $I = 6.0A$
$B = 1T$, $\theta = 60^\circ$

Magnitude of counter torque
= Magnitude of deflecting torque
$= NIBA\sin\theta$
$= 30 \times 6 \times 1 \times (3.14 \times 0.08 \times 0.08)\sin 60^\circ$
$= 30 \times 6 \times 3.14 \times 64 \times 10^{-4} \times 0.866$
$= 3.1 Nm$

(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: $r_x = 16\text{ cm} = 0.16\text{ m}$, $N_x = 20$, $I_x = 16\text{A}$

∴ Magnetic field at the centre of coil x is

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

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

As the current in the coil X is anti-clockwise, the field is directed towards east.

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

∴ Magnetic field at the centre of coil Y is

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

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

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 & its magnitude is

$$B = B_y - B_x = 5\pi \times 10^{-4}$$

$$\simeq 1.6 \times 10^{-3}\ T.$$

4.15) Here $B = 100\,G = 10^{-2}\ T$, $I = 15\text{A}$

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

Magnetic field inside a solenoid,

$$B = \mu_0 n I$$

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

We may take $I = 10A$, then $n = 800$

The solenoid may have length 60 cm & area of cross-section 5×10^{-2} m^2 (five times the given value) so as to avoid edge effects, etc.

4.17) Here, $I = 11A$, total number of turns $= 3500$

Mean radius of toroid,

$r = \frac{25+26}{2} = \frac{51}{2} = 25.5$ cm

$= 25.5 \times 10^{-2}$ m.

Total length (circumference) of the toroid

$= 2\pi r = 2\pi \times 25.5 \times 10^{-2} = 51.0 \times 10^{-2} \pi$ m

$\therefore$ No. 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,

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

$\simeq 3.02 \times 10^{-2}$ T

4.18(a) 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 or the particle will remain undeflected if

$\sin\theta = 0$

or $\theta = 0°, 180°$

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 & 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 ~~force~~ 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

4.20) $B = 0.75\,T$, $E = 9.0\times10^5\,Vm^{-1}$,
$V = 15\,kV = 15\times10^3\,V$

For undeflected beam, velocity of charged particles must be

$$v = \frac{E}{B} = \frac{9.0\times10^5}{0.75}\,ms^{-1}$$
$$= 12\times10^5\,ms^{-1}$$

But the kinetic energy of the charged particles is given by

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

$$\therefore \frac{q}{m} = \frac{1}{2}\cdot\frac{v^2}{V^2} = \frac{1}{2}\times\frac{(12\times10^5)^2}{15\times10^3}\,Ckg^{-1}$$

Now for deutrons,

$$\frac{q}{m} = \frac{1.60\times10^{-19}}{\cancel{2}\times1.67\times10^{-27}} = 4.8\times10^7\,Ckg^{-1}$$

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

4.27) Here, $R_g = 12\,\Omega$

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

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

$$= 6000 - 12 = 5988\,\Omega$$

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

4.28) Here, $R_g = 15\,\Omega$, $I_g = 4\,mA = 0.004\,A$, $I = 6\,A$

$$R_s = \frac{I_g}{I - I_g} \times R_g = \frac{0.004}{6 - 0.004} \times 15$$

$$= 0.010\,\Omega = 10\,m\Omega$$

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