H.W

Ch-4 (Moving charges and Magnetism)

Exercises

Date 22/7/21

4.1) No. of turns on the circular coil, $n = 100$
Radius of each turn, $r = 8\ cm$
$= 0.08\ m$.

Current flowing in the coil, $I = 0.4A$
Magnitude of the magnetic field at the centre of the coil is given by the relation,

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

$$= \frac{4\pi \times 10^{-7}}{4\pi} \times \frac{2\pi \times 100 \times 0.4}{0.08} \quad \left[\because \mu_0 = 4\pi \times 10^{-7}\ TmA^{-1}\right]$$

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

Hence, the magnitude of the magnetic field is 3.14×10^{-4} T.

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

Magnitude of the magnetic field at this point is given as:

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

$$= \frac{4\pi \times 10^{-7} \times 2 \times 35}{4\pi \times 0.2}$$

$$= 3.5 \times 10^{-5}\ T.$$

Hence, the magnitude of the magnetic field at a point 20 cm from is 3.5×10^{-5} T.

4.3) Current in the wire, $I = 50\,A$

Magnitude of the distance of the point from the wire, $r = 2.5\,m$

Magnitude of the magnetic field at that point is given by the relation, $B = \frac{\mu_0 2I}{4\pi r}$

$$= \frac{4\pi \times 10^{-7} \times 2 \times 50}{4\pi \times 2.5}$$

$$= 4 \times 10^{-6}\,T.$$

The point is located normal to the wire length at a distance of 2.5 m. The direction of the current in the wire is outward. Hence, according to the Maxwell's right hand thumb rule, the direction of the magnetic field at the given point is vertically upward.

4.4) Current in the power line, $I = 90\,A$.

Distance of the point from the power line, $r = 1.5\,m$ below the power line

Hence, magnetic field at that point is given by the relation, $B = \frac{\mu_0 2I}{4\pi r}$

$$= \frac{4\pi \times 10^{-7} \times 2 \times 90}{4\pi \times 1.5}$$

$$= 1.2 \times 10^{-5}\,T.$$

The current is flowing from East to West. The point is below the power line. Hence, according to Maxwell's right hand thumb rule, the direction of the magnetic field is towards the south.

4.5) Current in the wire, $I = 8\,A$.
Magnitude of the uniform magnetic field, $B = 0.15\,T$.
Angle between the wire and the magnetic field, $\theta = 30°$.
Magnetic force per unit length on the wire is given as,

$$f = BI\sin\theta$$
$$= 0.15 \times 8 \times 1 \times \sin 30°$$
$$= 0.6\ N/m.$$

Hence, the magnetic force per unit length on the wire is 0.6 N/m.

4.6) Length of the wire, $l = 3\,cm$
$= 0.03\,m$
Current flowing in the wire, $I = 10\,A$.
Magnetic field, $B = 0.27\,T$.
Angle between the current and magnetic field, $\theta = 90°$
(Because magnetic field produced by a solenoid is along its axis and current carrying wire is kept perpendicular to the axis)

Magnetic force exerted on the wire is given as,

$$F = BIL\sin\theta$$
$$= 0.27 \times 10 \times 0.03 \times \sin 90°$$
$$= 8.1 \times 10^{-2}\ N.$$

Hence, the magnetic force on the wire is 8.1×10^{-2} N.

The direction of the force can be obtained from Fleming's left hand rule.

4.7) Current flowing in wire A, $I_A = 8$ A
Current flowing in wire B, $I_B = 5$ A.
Distance between the two wires, $r = 4$ cm
$= 0.04$ m.

Length of a section of wire A, $l = 10$ cm
$= 0.1$ m.

Force exerted on length l due to the magnetic field is,

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

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

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

The magnitude of force is 2×10^{-5} N. This is an attractive force normal to A ~~a~~ towards B because the direction of the currents in the wires is the same.

4.8) Length of the solenoid, $l = 80$ cm
$= 0.8$ m.
There are five layers of windings of 400 turns each on the solenoid.
Total number of turns on the solenoid,
$N = 5 \times 400 = 2000$
Diameter of the solenoid, $D = 1.8$ cm
$= 0.018$ m.
Current carried by the solenoid, $I = 8$ A.

Magnitude of the magnetic field inside the solenoid near its centre is given by the relation,

$$B = \frac{\mu_0 N I}{l}$$

$$= \frac{4\pi \times 10^{-7} \times 2000 \times 8}{0.8}$$

$$= 8\pi \times 10^{-3}$$

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

Hence, the magnitude of the magnetic field inside the solenoid near its centre is 2.512×10^{-2} T.

4.9) Length of a side of the square coil, $l = 10$ cm $= 0.1$ m.

Current flowing in the coil, $I = 12$ A

Number of turns on the coil, $n = 20$

Angle made by the plane of the coil with magnetic field, $\theta = 30^\circ$.

Strength of the magnetic field, $B = 0.8$ T

Magnitude of the magnetic torque experienced by the coil in the magnetic field is given by the relation,

$$\tau = nBIA\sin\theta$$

$$\Rightarrow l \times l = 0.1 \times 0.1 = 0.01 \, m^2$$

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

$$= 0.96 \, Nm.$$

Hence, the magnitude of the torque experienced by the coil is 0.96 Nm.

4.10) For moving coil meter M_1,
Resistance, $R_1 = 10$
No. of turns, $N_1 = 30$
Area of cross-section, $A_1 = 3.6 \times 10^{-3}\ m^2$
Magnetic field strength, $B_1 = 0.25\ T$.
Spring constant, $k_1 = k$
For moving coil meter M_2,
Resistance, $R_2 = 14\ \Omega$
No. of turns, $N_2 = 42$
Area of cross-section, $A_2 = 1.8 \times 10^{-3}\ m^2$
Magnetic field strength, $B_2 = 0.50\ T$.
Spring constant, $k_2 = k$

a) Current sensitivity of M_1 is given as,

$$I_1 = \frac{N_1 B_1 A_1}{k_1}$$

and current sensitivity of M_2 is given as,

$$I_2 = \frac{N_2 B_2 A_2}{k_2}$$

$$\therefore \text{Ratio} = \frac{I_2}{I_1} = \frac{N_2 B_2 A_2 k_1}{k_2 N_1 B_1 A_1}$$

$$= \frac{42 \times 0.5 \times 1.8 \times 10^{-3} \times 10 \times k}{k \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$= 1.4.$$

Hence, the ratio of current sensitivity of M_2 and M_1 is 1.4.

b) Voltage sensitivity for M_2 is given as,

$$V_2 = \frac{N_2 B_2 A_2}{K_2 R_2}$$

and voltage sensitivity for M_1 is given as,

$$V_1 = \frac{N_1 B_1 A_1}{K_1 R_1}$$

$\therefore$ Ratio $= \frac{V_2}{V_1} = \frac{N_2 B_2 A_2 K_1 R_1}{K_2 R_2 N_1 B_1 A_1}$

$$= \frac{42 \times 1.8 \times 10^{-3} \times 10 \times k}{k \times 14 \times 30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$= 1.$$

Hence, the ratio of voltage sensitivity of M_2 to M_1 is $\underline{1}$.

4.11) Magnetic field strength, $B = 6.5\ G$
$= 6.5 \times 10^{-4}\ T$.
Speed of the electron, $v = 4.8 \times 10^{6}\ m/s$.
Charge on the electron, $e = 1.6 \times 10^{-19}\ C$.
Mass of the electron, $m_e = 9.1 \times 10^{-31}\ kg$.
Angle between the shot electron and magnetic field is given as
$F = evB\sin\theta$

This force provides centripetal force to the moving electron. Hence, the electron starts moving in a circular path of radius r.
Hence, centripetal force exerted on the electron,

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

In equilibrium, the centripetal force exerted on the electron is equal to the magnetic ~~for~~ force. i.e,

$F_e = F$.

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

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

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

$$= 4.2\ cm.$$

Hence, the radius of the circular orbit of the electron is 4.2 cm.

4.12) Magnetic field strength, $B = 6.5 \times 10^{-4}\ T$.
Charge of the electron, $e = 1.6 \times 10^{-19}\ C$.
Mass of the electron, $m_e = 9.1 \times 10^{-31}\ kg$
Velocity of the electron, $v = 4.8 \times 10^{6}\ m/s$
~~Real~~ Radius of the orbit, $r = 4.2\ cm$
$= 0.042\ m$.

Frequency of revolution of the electron $= v$.
Angular ~~fre~~ frequency of the electron, $\omega = 2\pi\theta$.
Velocity of the electron is related to the angular ~~freq~~ frequency as:

$$v = r\omega$$

In circular orbit, the magnetic force on the electron provides the centripetal force. Hence,

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

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

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

This expression for frequency is independent of the speed of the electron.
On substituting the known values in this expression, we get the frequency as,

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

$$= 18.2 \times 10^{6} \text{ Hz}$$

$$= 18 \text{ MHz}.$$

Hence, the frequency of the electrons is around 18 MHz and is independent of the speed of the electron.

4.13) a) Number of turns on the circular coil, $n = 30$
~~Rest~~ Radius of the coil, $r = 8$ cm
$= 0.08$ m.

Area of the coil $= \pi r^2 = \pi (0.08)^2 = 0.0201 \text{ m}^2$.
Current flowing in the coil, $I = 6$ A
Magnetic field strength, $B = 1$ T

Angle between the field lines and normal with the coil surface, $\theta = 60°$.
The coil experience a torque in the magnetic field. Hence, it turns the counter torque applied to prevent the coil from turning is given by the relation,

$$\tau = nIBA \sin\theta \quad \text{—— (1)}$$

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

$$= 3.133 \text{ Nm}.$$

b) It can be inferred from relation (1) 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 plane coil of some irregular shape that encloses the same area

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