H.W for (1-8-21).

MOVING CHARGES and MAGNETISM

27/7/21 NCERT EXERCISES.

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1) No. of turns on circular coil, $n = 100$
Radius of each turn on the circular coil, $n = 100$
Radius of each turn, $r = 8.0cm = 0.08m$.

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

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

where,
μ_0 = Permeability of free space
$= 4\pi \times 10^{-7} m A^{-1}$

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

$= 3.14 \times 10^{-4} T$ [magnitude of magnetic field]

2) Current in wire, $I = 35A$.
Distance from a point from the wire, $r = 20cm = 0.2m$
Magnitude of magnetic field at this point is given as.

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

where, μ_0 = Permeability of free space $= 4\pi \times 10^{-7} m/A$

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

$\therefore$ magnitude of magnetic field at a point 20cm from the wire is $3.5 \times 10^{-5} T$.

6) ~~Answer~~ length of the wire, $l = 3cm = 0.03m$
Current flowing in the wire, $I = 10A$
Magnetic field, $B = 0.27T$.
Angle between the current & magnetic field
$\theta = 90°$
Magnetic force exerted on the wire is given as
$F = BIl \sin\theta$
$= 0.27 \times 10 \times 0.03 \sin 90°$
$= 8.1 \times 10^{-2} N$
Hence, the magnetic force on the wire is $8.1 \times 10^{-2} N$. The direction of the force can be obtained from Fleming's left hand rule.

7) Current flowing in wire A, $I_A = 8.0A$
Current flowing in wire B, $I_B = 5.0A$
Distance between the two wires, $r = 4.0cm$
$= 0.04m$

length of a section of wire A, $l = 10cm = 0.1m$
Force exerted on length l due to the magnetic field is given as

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

where,
μ_0 = Permeability of free space $= 4\pi \times 10^{-7} T m/A$

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

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

The magnitude of force is $2 \times 10^{-5} N$. This is an attractive force normal to A towards B because the direction of the currents in the wire is the same.

8) length of solenoid, $l = 80 cm = 0.8 m$
five layers of windings of 400 turns each on the solenoid.
$\therefore$ Total number of turns on the solenoid
$N = 5 \times 400 = 2000$
Diameter of solenoid, $D = 1.8 cm = 0.018 m.$
current carried by solenoid, $I = 8.0 A$
magnitude of magnetic field inside the solenoid near its centre is given by

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

μ_0 = Permeability of the free space $= 4\pi \times 10^{-7} Tm/A$

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

$= 8\pi \times 10^{-3} = 2.512 \times 10^{-2} T$

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

11) (a) Magnetic field strength $= B = 6.5 G = 6.5 \times 10^{-4} T$.
Speed of electron, ~~4.8×10^{6}~~
$v = 4.8 \times 10^{6} m/s$
charge on electron $= 1.6 \times 10^{-19} C.$
Mass of electron $= 9.1 \times 10^{-31} kg.$

Angle between short electron & magnetic field $\Rightarrow \theta = 90°$

Magnetic force exerted on the electron in magnetic field $\Rightarrow F = evB \sin\theta$

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

$= 4.2 \times 10^{-2}\, m = 4.2\, cm$ [radius]

12) $B = 6.5 \times 10^{-4}\, T$. $v = 4.8 \times 10^{6}\, m/s$.

$e = 1.6 \times 10^{-19}\, C$. $r = 4.2\, cm = 0.042\, m$.

$m_e = 9.1 \times 10^{-31}\, kg$ revolution of electron ν.

Ang. freq. of $e^- \Rightarrow \omega = 2\pi\nu$

$v = r\omega$.

In circular orbit, the magnetic force on the electron is balanced by centripetal force.

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

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

$\nu = \frac{Be}{2\pi m}$, on substituting the known values in this expression, we get

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

$\therefore$ frequency of electron is around 18 MHz, & independent of speed of electron

(13)

a) No. of turns on circular coil, $n = 30$.
Radius of coil, $r = 8.0\,cm = 0.08\,m$.

$= \pi r^2 = \pi(0.08)^2 = 0.0201\,m^2$

Current flowing in coil $= I = 6.0\,A$.
magnetic field strength, $B = 1T$.

Angle between the field lines & normal with the coil surface, $\theta = 60^\circ$.

The coil experiences a torque in the magnetic field ∴ it turns, the counter torque applied to prevent the coil from turning is given by the relation.

$T = n I B A \sin\theta$ ..... (1)

$= 30 \times 6 \times 1 \times 0.0201 \times \sin 60^\circ = 3.133\,Nm$

b) It can be inferred from relation (1) that the magnitude of applied torque is not dependent on shape of coil. It depends on area of coil.

∴ the answer wouldn't change if the circular in the above case is replaced by a planar coil of some irregular shape that encloses the same area.

(14) Magnetic field due to coil X at their centre

$$B_1 = \frac{\mu_0 n_1 I_1}{2r_1}$$

where,
μ_0 = permeability of free space = $4\pi \times 10^{-7}$ Tm/A

$$\therefore B_1 = \frac{4\pi \times 10^{-7} \times 20 \times 16}{2 \times 0.16}$$

$$= 4\pi \times 10^{-4}\,T \text{ (towards east)}$$

Magnetic field due to coil Y at centre

$$B_2 = \frac{\mu_0 n_2 I_2}{2r_2}$$

$$= \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 0.10} = 9\pi \times 10^{-4}\,T \text{ (west)}$$

$\therefore$ magnetic field $\Rightarrow$ $B = B_2 - B_1$

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

$$= 5\pi \times 10^{-4}\,T$$

$$= 1.57 \times 10^{-3}\,T \text{ (towards west)}$$

15) Magnetic field strength, $B = 100\,G = 100 \times 10^{-4}\,T$.
No. of turns / unit length, $n = 1000$ turns m^{-1}
Current flowing in the coil, $I = 15A$.

Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}\,TmA^{-1}$
Magnetic field is given by the relation.

$B = \mu_0 nI$

$\therefore nI = \frac{B}{\mu_0}$

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

17) Inner radius of toroid, $r_1 = 25\,cm = 0.25\,m$
Outer radius of toroid, $r_2 = 26\,cm = 0.26\,m$

Number of turns on coil $\Rightarrow N = 3500$
Current in coil, $I = 11\,A$.

a) Magnetic field outside a toroid is 0. It is non-zero only inside the core of a toroid.

b) Magnetic field inside the core of a toroid is given by,

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

μ_0 = Permeability of free space $= 4\pi \times 10^{-7}\,TmA^{-1}$
l = length of toroid.

$\Rightarrow 2\pi \left[\frac{r_1 + r_2}{2}\right]$ $B = 4A$

$= \pi(0.25 + 0.26) = 0.51\pi$

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

c) Magnetic field in the empty space surrounded by topic is 0.

18a) 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 ~~changed~~ 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 ~~def~~ undeflected if the electric force acting on it is equal and opposite of magnetic field. Magnetic force is directed towards the South. According to Fleming's left hand rule, magnetic field should be applied in a vertically downward direction.

Magnetic field strength, $B = 0.15\,T$.
Charge of the electron, $e = 1.6 \times 10^{-19}\,C$.

Mass of electron, $m = 9.1 \times 10^{-31}\,kg$
Potential difference, $V = 2.0\,kV = 2 \times 10^{3}\,V$

Thus, kinetic energy of the electron $= eV$.

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

$v = \sqrt{\frac{2eV}{m}}$ ... (1),
v = velocity of electron

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

Magnetic force on the electron is given by the relation,

$B e v$.
Centripetal force $= \frac{mv^2}{r}$

$\therefore Bev = \frac{mv^2}{r}$, $r = \frac{mv}{Be}$ — (2)

From (1) & (II), we get

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

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

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

Hence, the electron has a circular trajectory of radius 1.0mm normal to the magnetic field.

b) When the field makes an angle θ of 30° with initial velocity, the initial velocity will be,

$$v_1 = v \sin\theta.$$

From eq (1), we can write the expression for new radius

$$r_1 = \frac{mv_1}{Be}$$

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

$$= \frac{9.1 \times 10^{-31}}{0.15 \times 1.6 \times 10^{-19}} \times \left[\frac{2 \times 1.6 \times 10^{-19} \times 2 \times 10^{3}}{9 \times 10^{-31}}\right] \times \sin 30^\circ$$

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

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

8a) $B = 0.75T$ (magnetic field)

Accelerating voltage, $V = 15kV = 15 \times 10^3 V$.

Electrostatic field, $\mathcal{E} = 9 \times 10^5 V/m$.

Mass of electron $= m$
charge of electron $= e$
velocity of the electron $= v$
Kinetic energy of the electron $= eV$

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

$$\therefore \frac{e}{m} = \frac{v^2}{2V} \quad \text{....} \; (1)$$

Since the particle remains undeflected by electric and magnetic fields, we can infer that the electric field is balancing the magnetic field.

$$\therefore e\mathcal{E} = evB$$

$$v = \frac{\mathcal{E}}{B} \quad \text{....} \; (2)$$

Putting equation (2) is eq^n (1), we get.

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

$$= \frac{(9.0 \times 10^5)^2}{2 \times 15000 \times (0.75)^2} = 4.8 \times 10^7 \; C/kg.$$

The value of specific charge e/m is equal to the value of deuteron or deuterium ions. This is not a unique answer. Other possible answers are He^{++}, Li^{++}, etc.