28.7.21

MOVING CHARGES & MAGNETISM

NCERT EXERCISE

1) $n = 100$ $r = 8cm$ $I = 0.40 A$

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

$$= \frac{10^{-7} \times 2 \times 3.14 \times 0.4 \times 100}{8 \times 10^{-2}}$$

$$= 3.1 \times 10^{-4} T$$

The direcn of magnetic field depends on the direcn of current. If the directn of current is anti-clockwise.
According to Maxwell's right hand rule, the direcn of magnetic field at the centre of coil will be perpendicular outwards to the plane of paper.

2) $I = 35A$ $r = 20cm = 20 \times 10^{-2} m$

Let the point be P

The wire is long & it is considered as an infinite length wire.

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

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

The direc^n of B is given by Maxwell's right hand rule. If current is upward, magnetic field at P is perpendicular inward to the plane of paper.

6) ~~Agle be~~

6) Angle bet^n B & I is 90°

$l = 3 cm$ $I = 10A$ $B = 0.2 T$

$$|F| = ILB \sin 90^\circ = 10 \times 3 \times 10^{-2} \times 0.27 \times \sin 90$$

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

According to right hand palm rule, direc^n of magnetic force is perpendicular to the plane of paper inward.

7) $I_1 = 8A$ $I_2 = 5A$ $r = 4cm$

$$F = \frac{\mu_0}{4\pi} \cdot \frac{2I_1 \times I_2}{r} = \frac{10^{-7} \times 2 \times 8 \times 5}{0.04}$$

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

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Force on A of length 10cm, $F' = F \times 0.1$

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

Using Maxwell's right hand rule, the direcⁿ of magnetic field due to B on A is ⊥ outward to the plane of paper.

According to Fleming's left hand rule, the ~~direcⁿ~~ direcⁿ of force is towards B & the nature of force is attractive.

8) $l = 80cm$ ~~$n = 5$~~

No. of layers $= 5$

No. of turns per layer $= 400$

Diameter of solenoid $= 1.8cm$

$I = 8A$

∴ Total no. of turns, $N = 400 \times 5 = 2000$

& no. of turns/length, $n = \frac{2000}{0.8} = 2500$

$|B| = \mu_0 n I$

$= 4 \times 3.14 \times 10^{-7} \times 2500 \times 8$

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

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11) $B = \cancel{6.5G}\ 6.5G$

$e = -1.6 \times 10^{-19} C$
$V = 4.8 \times 10^{6} m/s$
$m_e = 9.1 \times 10^{-31} Kg$

Angle betn B & electron $\theta = 90^\circ$

$F = q(V \times B) = e(V \times h)$

According to the right hand palm rule, the direction of force is $\perp$ to both velocity & B.

So, the force will only change the direcn of motion without changing the magnitude of velocity. So, the electron attains a circular path & the necessary centripetal force is provided by the magnetic force.

$$e(V \times B) = \frac{mv^2}{r}$$

$$eVB\sin 90 = \frac{mv^2}{r}$$

$$r = \frac{mv}{eB}$$

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

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

$$= 4.2 cm$$

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(2) $B = 6.5G$ $\quad V = 4.8 \times 10^6 \, m/s$

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

$m_e = 9.1 \times 10^{-31} Kg$

We Know that when an electron moves on a circular path in uniform magnetic field then the required centripetal force provided by the magnetic force on it.

$$\frac{mv^2}{r} = qVB \Rightarrow \frac{mv}{r} = qB$$

angular velocity $= \omega$

$$V = r\omega$$

$$\frac{m(r\omega)}{r} = qB$$

$$\omega = \frac{qB}{m}$$ (If frequency's revolution $= n$ $\omega = 2\pi n$)

$$2\pi n = \frac{qB}{m}$$

$$n = \frac{qB}{2\pi m}$$

Frequency of revolution of electron in orbit.

$$V = \frac{Bq}{2\pi m}$$

$$= \frac{Be}{2\pi m_e} = \frac{6.5\times10^{-4}\times1.6\times10^{-19}}{2\times3.14\times9.1\times10^{-31}}$$

$$= 18.18\times10^{6}\ Hz$$

Here, we observe that the frequency of electron is independent to the velocity.

13) a) $n = 30$ $\quad r = 8cm$

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

$I = 6A$ $\quad B = 1T$

$\theta = 60^\circ$

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

$\tau = nIBA\sin\theta$ — (1)

$= 30\times6\times1\times0.0201\times\sin60$

$= 3.133N$

b) It can be inferred from relation (1) that the magnitude of the applied torque is not dependent on the shape of coil. It depends on the area of the coil. Hence, the answer wouldn't 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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14] For coil x :) $r_x = 16cm$ $n_x = 20$ $I_x = 16A$

For coil y :) $r_y = 10cm$ $n_y = 25$ $I_y = 18A$

$B_x = \frac{\mu_0}{4\pi} \cdot \frac{2 I_x \pi n_x}{r_x}$ $= \frac{10^{-7} \times 2 \times 16 \times 3.14 \times 20}{0.16}$

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

The direction of B_x due to coil x at centre O is towards i.e west, according to Maxwell's left hand rule.

Hence, the magnitude of B_y is greater than B_x. So, the resultant magnetic field will be in the direc^n of B_y i.e left (west).

$B_y = \frac{\mu_0}{4\pi} \cdot \frac{2 I_y \pi n_y}{r_y}$ $= 9\pi \times 10^{-4}$ T

$B_{net} = B_y - B_x$

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

$= 5\pi \times 10^{-4} T$ ($\because B_y$ & B_x are opp to each other)

$= 1.6 \times 10^{-3} T$ (towards west)

15] $B = 100 G = 100 \times 10^{-4} T = 10^{-2} T$

$I_{min} = 15A$ $n = 1000/m$

To design the solenoid, let we find the product of I & n.

$B = \mu_0 n I$

$nI = \frac{B}{\mu_0} = \frac{10^{-2}}{4 \times 3.14 \times 10^{-7}}$.

$nI = 7961 \approx 8000$

Here the product of nI is 8000 so,

$I = 8A$ & $n = 1000$

The other design is $I = 10A$ & $n = 800/m$.
This is the most appropriate design as the requirement.

16) a) Magnetic field at dist^n x,

$$B = \frac{\mu_0 N I R^2}{2(x^2+R^2)^{3/2}}$$

To get magnetic field at centre of coil, we put $x = 0$.

~~B~~ Magnetic field at centre,

$$B = \frac{\mu_0 I R^2 N}{2R^3}$$

$$\Rightarrow B = \frac{\mu_0 I N}{2R}$$

The result is same as the magnetic field due to current loop at the centre.

b) Radius of 2 parallel co-axial coil = R no. of turns = N.

Let the midpoint of betn the coil is at O & P be the point around O.

Suppose the distn betn OP = d (which is very less than R, $d << R$)

For the coil A, $O_AP = \frac{R}{2} + d$

The magnetic field at Point P due to coil A.

$$B_A = \frac{\mu_0}{4\pi} \cdot \frac{2\pi n I R^2}{(O_AP^2 + R^2)^{3/2}}$$

$$= \frac{\mu_0}{2} \cdot \frac{NIR^2}{\left\{\left(\frac{R}{2}+d\right)^2 + R^2\right\}^{3/2}}$$

$$= \frac{\mu_0 NIR^2}{2\left[\frac{R^2}{4} + d^2 + Rd + R^2\right]}$$

$$= \frac{\mu_0 NIR^2}{2\left[\frac{5R^2}{4} + Rd\right]}$$ {As, $d << R$, we can neglect d^2}

$$= \frac{\mu_0 NIR^2}{2\left[\frac{5R^2}{4}\right]^{3/2}\left[1 + \frac{R\times d\times 4}{8R^2}\right]^{3/2}}$$

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$$\frac{\mu_0 N I R^2 \left(1+\frac{4d}{5R}\right)^{-3/2}}{2\left(\frac{5R^2}{4}\right)^{3/2}}$$

The direcⁿ of B_A is along PO_B according to Maxwell's ~~8~~ right hand rule..

For the coil B, $O_BP = \left(\frac{R}{2}-d\right)$.

$$B_B = \frac{\mu_0}{4\pi}\frac{2\pi N I R^2}{(O_BP^2+R^2)^{3/2}}$$

$$= \frac{\mu_0}{2}\cdot\frac{2NIR^2}{\left[\left(\frac{R}{2}-R\right)^2+R^2\right]^{3/2}}$$

$$= \frac{\mu_0 N I R^2}{2\left[\frac{R^2}{4}+d^2-Rd+R^2\right]^{3/2}}$$

$$= \frac{\mu_0 N I R^2 \left(1-\frac{4d}{5d}\right)^{-3/2}}{2\left[\frac{5R^2}{4}\right]^{3/2}}$$

Direcⁿ of B_B is towards PO_B.

So, $B_{net} = B_A + B_B$ -

$$\frac{\mu_0 N I R^2}{2\left(\frac{5R^2}{4}\right)^{3/2}}\left[\left(1+\frac{4d}{5R}\right)^{-3/2}+\left(1-\frac{4d}{5R}\right)^{-3/2}\right]$$

Now by using binomial theorem,

$$B=\frac{\mu_0 N I R^2}{2\left(\frac{5R^2}{4}\right)^{3/2}}\cdot\left[1-\frac{3}{2}\times\frac{4d}{5R}+1+\frac{3}{2}\times\frac{4d}{5R}\right]$$

$$=\frac{\mu_0 N I R^3 4^{3/2}}{2\times R^3\times 5^{3/2}}\times 2$$

$$=\frac{\mu_0 N I}{2R}\left(\frac{4}{5}\right)^{3/2}\times 2$$

$$=\left(\frac{4}{5}\right)^{3/2}\frac{\mu_0 N I 2}{2R}$$

$$=\frac{\mu_0 N I}{(5)^{3/2} 2R}\left(\frac{4}{2}\right)^{3/2} = 0.72.\frac{\mu_0 N I}{R}$$

17) a) For outside the turnoid, B is 0 bcoz the B due to toroid is only inside it & along the length of toroid.

b) $r = 25cm = 0.25m$ $\quad R = 26cm$

$N = 3500$ $\quad I = 11A$

Mean radius $r' = \frac{R+r}{2} = \frac{2}{5}(0.25+0.26) = 0.51$

Magnetic field Strength due to Toroid, $B = \mu_0 n I$

Where n is no. of turns per unit length

$n = \frac{N}{l}$

$B = 4\pi \times 10^{-7} \times \frac{3500}{\pi \times 0.51} \times 11 = 3.02 \times 10^{-2} T$

c) The magnetic field in empty space surrounded by the toroid is only along its length.

18) a) The magnetic field is in constant direcⁿ from east to west. Acc to ques, a charged particle travels undeflected along a straight path with constant speed. It is only possible if the magnetic force experienced by the charged particle is 0.

The magnitude of magnetic force on a moving charged particle in a magnetic field is,
$F = qVB\sin\theta$

$F = 0$, if & only if $\sin\theta = 0$ (as $V \neq 0, q \neq 0, B \neq 0$)
So, $\theta = 0$ & 180.

Thus charged particle moves parallel or anti-parallel to the magnetic field B.

b) Yes, the final speed be equals to its initial speed as the F acting on it only changes the direcⁿ of vel of charged particle but can't change the magnitude of vel of charged particle

c) As $\vec{E}$ is north to South that means the plate in north is +ve & in south is -ve. Thus the electrons attract towards the +ve plate i.e north.

If we want that there is no deflection in the path of electron the F should be in south direcn.

By $F = -e(v \times B)$ the direcn of vel is west to east. The direcn of force is towards south by using the Fleming's left hand rule, the direcn of B is ⊥ inwards to the plane of paper.

19) $V = 2KV$ $e = 1.6 \times 10^{-19} C$ $m_e = 9.1 \times 10^{-31}$

Let v = velocity of electron

$eV = \frac{1}{2} m_e v^2$

$v^2 = \frac{1.6 \times 10^{-19} \times 1000 \times 2}{9.1 \times 10^{-31}}$

$v = \frac{8 \times 10^7}{3}$ m/s $= 2.7 \times 10^7$ m/s

a) $B = 0.15T$ direction is transverse to the initial vel of electron

$F = Bev$ direcn is ⊥ to B

electron moves on a circular path. F provides the centripetal force to electron :

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

$$r = \frac{mv}{Be} = \frac{9.1 \times 10^{-31} \times 8 \times 10^7}{3 \times 0.15 \times 1.6 \times 10^{-19}}$$

$$= 10^{-3} m = 1 mm$$

b) As the electron enters in the B at angle 30° to the B.

Vertical component of vel is V_1 & Horizontal component of vel is V_2

$$V_1 = V \sin 30 = \frac{8 \times 10^7 \times 1}{3 \times 2} = \frac{4 \times 10^7}{3} m/s$$

$$V_2 = V \cos 30 = \frac{8 \times 10^7 \times \sqrt{3}}{3 \times 2} = \frac{4\sqrt{3} \times 10^7}{3} m/s$$

$$F_{Horizontal} = q(V_2 \times B) = 0 \quad (\text{as } V \parallel B)$$

$$F_{vertical} = e(V_1 \times B) = eV_1 B \sin 90$$

This force gives centripetal force to the electron

$$eV_1 B = \frac{mV_1^2}{r'} \Rightarrow \frac{mV_1}{eB} = \frac{9.1 \times 10^{-31} \times 4 \times 10^7}{3 \times 1.6 \times 10^{-19} \times 0.15}$$

$$\Rightarrow r' = 0.5 \times 10^{-3} m = 0.5 mm$$

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20) $B = 0.75\,T$ $\qquad V = 15\,kV$ $\qquad \vec{E} = 9\times10^{-5}\ V/m.$

q = charge $\qquad m$ = mass $\qquad v$ = vel of particle

The energy due to potential diff gives the kinetic energy to the partile.

$qV = \frac{1}{2}mv^2$ — (1)

As, q is not deflected as B & E apply that means F due to magnetic force is balanced by Force due to E.

$$qE = q(v \times B)$$

$$qE = qvB$$

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

Putting this value in (1) :-

$$\frac{1}{2}m\left[\frac{E}{B}\right)^2 = eV$$

$$\frac{e}{m} = \frac{E^2}{2VB^2} = \frac{(9\times10^5)^2}{2\times15000\times(0.75)^2} = 4.8\times10^7\ c/kg.$$

24) $B = 0.3\hat{k}\,T$ $\qquad A = 50\times10^{-4}\,m^2$

$I = 12A$ $\qquad$ ~~$\tau = 180\times10^{-2}\hat{j}\ N\text{-}m$~~

$\tau = I\,A \times B.$

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a) $A = 50 \times 10^{-4} \hat{i}\, m^2$

$\tau = I(A \times B) = 12 \times 50 \times 10^{-4} \hat{i} \times 0.3 \hat{k}$

$= -1.80 \times 10^{-2} \hat{j}$ N-m. (in -ve Y-axis)

b) $A = 50 \times 10^{-4} \hat{i}\, m^2$

$\tau = -1.80 \times 10^{-2} \hat{j}$ N-m.

c) $A = 50 \times 10^{-4} (-\hat{j})\, m^2$

$\tau = 12(-50 \times 10^{-4}) \hat{j} \times 0.3 \hat{k}$

$= -1.80 \times 10^{-2} \hat{i}$ N-m (-ve x-axis)

d) $A = 50 \times 10^{-4}\, m^2$ (in XY plane)

$\tau = 12 \times 50 \times 10^{-4} \times 0.3$

$= 1.80 \times 10^{-2}$ N-m

The direc^n of τ is $(90° + 30°)$ from -ve x-axis & $(360° - 120° = 240°)$ from +ve x-axis

e) $A = 50 \times 10^{-4} \hat{k}\, m^2$

$\tau = 12(50 \times 10^{-4}) \hat{k} \times 0.3 \hat{k} = 0$

f) $A = -50 \times 10^{-4} \hat{k}\, m^2$

$\tau = 12(-50 \times 10^{-4} \hat{k}) \times 0.3 \hat{k} = 0$

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27) Resistance of Galvanometer, $G = 12\Omega$

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

We can convert galvanometer to Voltmeter by using a large resistance (R) in series.

$$R = \frac{V}{I_g} - G$$

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

So, we can use $R = 5988\Omega$ in series to convert galvanometer into voltmeter., so that no current passes through it & it gives exact value of potential diff.

28) $G = 15\Omega$ $I_g = 4 \times 10^{-3} A$ $I = 6A$

By connecting a small resistance S called shunt in parallel to the galvanometer, it is converted into Ammeter.

$$S = \frac{I_g \cdot G}{I - I_g} = \frac{4 \times 10^{-3} \times 15}{6 - 4 \times 10^{-3}} = 0.01\Omega$$

So, we can use $S = 0.01\Omega$ in parallel to convert galvanometer into ameter, so that most of current passes through it & it gives exact value of current.