Date: 23/07/21

Chapter-4

# Moving Charges & Magnetism:

## Exercise

1. Given;

Number of turns of coil = 100.

Radius of each turn of coil = 8.0 cm.

$= 8 \times 10^{-2}$ m.

Current in the coil of wire = 0.40 A

Hence,

The magnitude of magnetic filed at centre of the coil is.

$$B = \frac{\mu_0 I N}{2a}$$

$$= \frac{4\pi \times 10^{-7} \times 0.4 \times 100}{2 \times 8 \times 10^{-2}}$$

$$= 3.14 \times 0.1 \times \frac{10^{-7}}{10^{-2}} \times 100$$

$$= 0.314 \times 10^{-5} \times 100$$

$$\cancel{= 3.14 \times 10^{-6} T}$$

$$= 0.314 \times 10^{-3}$$

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

2. Given;

Current in a long straight wire = 35 A

Distance between the wire and point where field is created = 20 cm.

$= 20 \times 10^{-2}$ m.

Hence,

The magnitude of the magnetic field is.

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

$$\cancel{= 4\pi \times 10^{-7}}$$

$$= \frac{4\pi \times 10^{-7} \times 35}{2\pi \times 20 \times 10^{-2}}$$

$$= \frac{2 \times 35 \times 10^{-7}}{20 \times 10^{-2}}$$

$$= \frac{70 \times 10^{-7}}{20 \times 10^{-2}}$$

$$= \frac{7}{2} \times 10^{-5}$$

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

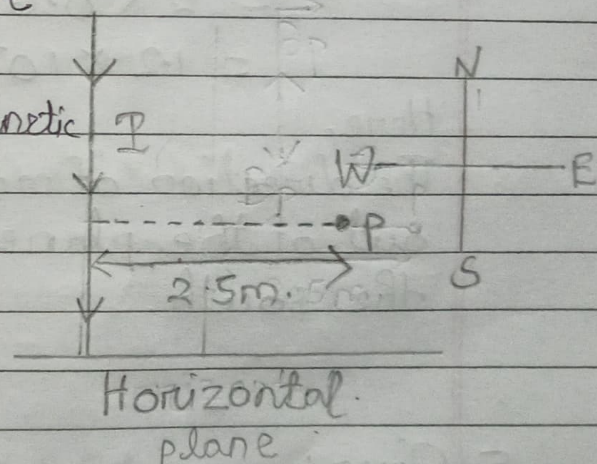
3. Given;

Current in a long straigh wire = 50A

Distance between the point and the wire is = 2.5 m east of wire

Hence,

The magnitude of the magnetic field at point P:




$$\vec{B}_P = \frac{\mu_0 I}{2\pi r}$$

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

$$= \frac{2 \times 500 \times 10^{-7}}{25}$$

$$= 2 \times 20 \times 10^{-7}$$

$$= 40 \times 10^{-7}$$

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

Here,

The direction of the magnetic field is moving is out of the plane of the paper.

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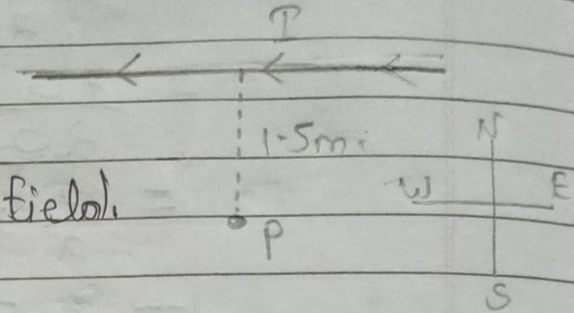
4. Given;
Current in the overhead power line = 90 A.
Distance between the power line and magnetic field produce = 1.5m.




Hence,
The magnitude of magnetic field at point P.

$$B_P = \frac{\mu_0 I}{2\pi r}$$
$$= \frac{4\pi \times 10^{-7} \times 90}{2\pi \times 1.5}$$
$$= \frac{2 \times 90}{1.5} \times 10^{-7}$$
$$= 2 \times 0.6 \times 10^{-7}$$
$$= 1.2 \times 10^{-7}$$

Here,
The direction of magnetic field is ~~no~~ normally, out of the plane of the paper. towards the south.

5. Given;
Current in a wire = 8 A
Angle between the magnetic field and the current = 30°
Magnitude of magnetic field = 0.15 T.
Hence,
~~The magnitude of the magnetic field.~~
~~B = F~~

The magnitude of the magnetic force per unit length is.

$$F_m = IBl \sin\theta$$

$$\Rightarrow \frac{F_m}{l} = IB \sin 30^\circ$$

$$= 8 \times 0.15 \times \frac{1}{2}$$

$$= 4 \times 0.15$$

$$= 0.60 \text{ N/m}$$

6. Given;
length of the wire = 3.0 cm
$= 3 \times 10^{-2}$ m.
Current in the wire = 10A
Magnetic field inside the solenoid = 0.27 T
Hence,
The magnetic force on the wire is.

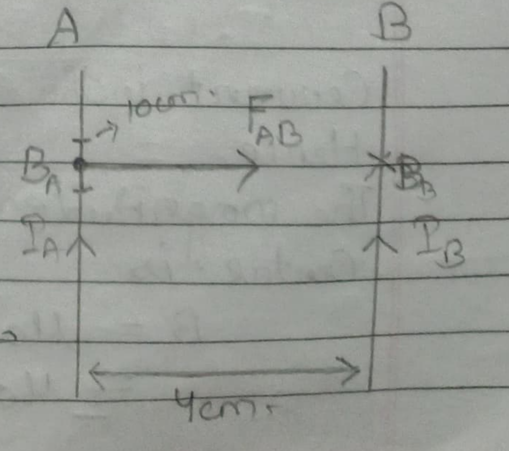
$$F_m = IBl \sin\theta$$

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

$$= 2.7 \times 3 \times 10^{-2}$$

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

7. Given;
Current in the wire A = 8.0 A
Current in the wire B = 5.0 A
Separation distance between the two wires.
A and B is = 4.0 cm
$= 4 \times 10^{-2}$ m.




Here,
As the both currents are in the same direction, there will be an attractive force between the two wires.

Current element of wire A = 10 cm
= $10 \times 10^{-2}$ m.

Hence,
The magnetic force on 10 cm section of wire is.

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

$$= \frac{4\pi \times 10^{-7} \times 8 \times 5 \times 10 \times 10^{-2}}{2\pi \times 4.0 \times 10^{-2}}$$

$$= \frac{2 \times 400 \times 10^{-9}}{4 \times 10^{-2}}$$

$$= 200 \times 10^{-7}$$

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

Here,
The direction of force on wire A is towards the wire B. It is attractive in nature.

8. Given,
Length of solenoid = 80 cm.
Total no. of turns in solenoid.

$$N = 400 \times 5$$
$$= 2000$$

Diameter of the solenoid = 1.8 cm.
Radius of the solenoid = $\frac{1.8}{2}$

$$= 0.9 \text{ cm} = 9 \times 10^{-3} \text{ m}.$$

Current in the solenoid = 8.0 A.
Hence,
The magnitude of B inside the solenoid near its centre is

$$B = \mu_0 n I$$

$$= \mu_0 \frac{N}{l} I \qquad \left[n = \frac{N}{l}\right]$$

$$= 4\pi \times 10^{-7} \times \frac{2000}{80 \times 10^{-2}} \times 8$$

$$= 4\pi \times 10^{-7} \times \frac{2000}{10^{-1}}$$

$$= 4\pi \times 10^{-7} \times 20000$$

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

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

$$\approx 8 \times 3.14 \times 10^{-3}\ T$$

$$\approx 2.5 \times 10^{-3}\ T$$

9. Given;
Length of side of square coil = 10 cm.
Number turns with 10 cm of length = 20.
Current in the solenoid = 12 A
Magnitude of uniform magnetic field = 0.80 T
The angle between the normal to the palane of the coil and magnetic field = 30°
Hence,
The magnitude of the torque experienced by the coil is.

$$\tau = NIAB \sin\phi$$

$$= NIAB \sin 30^\circ$$

$$= 20 \times 12 \times 0.80 \times \frac{1}{2} \times 10^{-2}$$

$$= 20 \times 12 \times 0.4 \times 10^{-2}$$

$$= 240 \times 0.4 \times 10^{-2}$$

$$\cancel{= 96 \times 10^{-2}}$$

$$= 96 \times 10^{-2}\ Nm$$

$$= 0.96\ Nm$$

10. Given;

Resistance of $M_1$ coil $(R_1) = 10\,\Omega$.

Resistance of $M_2$ coil $(R_2) = 14\,\Omega$.

Area of $M_1$ coil $(A_1) = 3.6 \times 10^{-3}\,m^2$.

Area of $M_2$ coil $(A_2) = 1.8 \times 10^{-3}\,m^2$.

Magnetic field of $M_1$ coil $(B_1) = 0.25\,T$.

Magnetic field of $M_2$ coil $(B_2) = 0.50\,T$.

~~Now,~~

a) ~~Current Sensitivity~~ of $M_1$ Coil.

$$\cancel{I_1 = \frac{NBA}{K}}$$

$$\cancel{= \frac{N_1 B_1 A_1}{K_1}} =$$

Number of turns in $M_1$ coil $(N_1) = 30$

Number of turns in $M_2$ coil $(N_2) = 42$.

Spring constant is identical for both.

i.e., $K_1 = K_2 = K$

Now,

a) Current Sensitivity of $M_1$ coil is.

$$I_1 = \frac{N_1 B_1 A_1}{K_1}$$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{K}$$

Current Sensitivity of $M_2$ Coil is.

$$I_2 = \frac{N_2 B_2 A_2}{K_2}$$

$$= \frac{42 \times 0.50 \times 1.8 \times 10^{-3}}{K}.$$

Hence,

The ratio of the current sensitivity of $M_2$ & $M_1$ is.

$$\frac{I_2}{I_1} = \frac{\dfrac{42 \times 0.50 \times 1.8 \times 10^{-3}}{K}}{\dfrac{30 \times 0.25 \times 3.6 \times 10^{-3}}{K}}$$

$$= \frac{42 \times 0.50 \times 1.8 \times 10^{-3}}{30 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$= \frac{7 \times 0.50}{10 \times 0.25}$$

$$= \frac{7}{5} = 1.4.$$

Now,

b) Voltage sensitivity of $M_1$ coil.

$$V_{S1} = \frac{N_1 B_1 A_1}{K_1 R_1}$$

$$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{K \times 10}$$

$$= \frac{3 \times 0.25 \times 3.6 \times 10^{-3}}{K}.$$

Voltage sensitivity of $M_2$ Coil.

$$V_{S2} = \frac{N_2 B_2 A_2}{K_2 R_2}$$

$$= \frac{42 \times 0.50 \times 1.8 \times 10^{-3}}{K \times 14.}$$

$$= \frac{3 \times 0.50 \times 1.8 \times 10^{-3}}{K}.$$

Hence,

The ratio of Voltage Sensitivity of $M_2$ & $M_1$ is.

$$\frac{V_{S2}}{V_{S1}} = \frac{\dfrac{3 \times 0.50 \times 1.8 \times 10^{-3}}{K}}{\dfrac{3 \times 0.25 \times 3.6 \times 10^{-3}}{K}}$$

$= \cancel{3 \times 0.5}$

$$= \frac{3 \times 0.50 \times 1.8 \times 10^{-3}}{3 \times 0.25 \times 3.6 \times 10^{-3}}$$

$$= \frac{0.50 \times 1.8}{0.25 \times 3.6}$$

$$= 1$$

11. Given,

Magnitude of magnetic field = 6.5 G
= $6.5 \times 10^{-4}$ T

Velocity of electron = $4.8 \times 10^{6}$ m/s

The angle between the magnetic field direction and direction of motion electron = 90°.

Here,

The direction of motion of electron is perpendicular to the magnetic field. So, the magnetic force acting on the electron will be perpendicular to both ~~them~~ of them i.e., $\vec{v}$ & $\vec{B}$. So, there will be no change in energy of the electron but the force will tend to turn the electron in a circular trajectory and produces the centripetal force on it.

Hence, the path of the electron is circular.

Now,

Charge of electron = $1.5 \times 10^{-19}$ C.

Mass of electron = $9.1 \times 10^{-31}$ Kg.

Here,

The Magnetic force experienced by the ~~field~~ electron will provide the centripetal force which describes the circular trajectory of electron.

i.e., Centripetal Force = Magnetic Force.

$$F_c = F_m$$

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

$$\Rightarrow \frac{mv}{r} = Bq \sin 90^\circ$$

$$\Rightarrow \frac{mv}{r} = Be$$

$$\Rightarrow r = \frac{mv}{Be}$$

$$= \frac{9.1 \times 10^{-31} \times 4.8 \times 10^{6}}{6.5 \times 10^{-4} \times 1.5 \times 10^{-19}}$$

$$= \frac{9.1 \times 4.8 \times 10^{-25}}{9.75 \times 10^{-23}}$$

$$\cancel{= 4.85 \times 10^{-2} m}$$

$$\cancel{= 4.85\ cm}$$

$$\doteq 4.48 \times 10^{-2} m.$$

$$= 4.48\ cm.$$

12. From Q.11,

The time period of revolution of electron in a circular orbit.

$$T = \frac{2\pi r}{v}$$

Now, $\cancel{= 2 \times 3.14 \times}$

The frequency of revolution of electron in a circular orbit.

$$f = \frac{1}{T} = \frac{v}{2\pi r}$$

$$= \frac{4.8 \times 10^{6}}{2 \times 3.14 \times 4.48 \times 10^{-2}}$$

$$\cancel{= 1.07 \times 10^{8}}$$

$$= \frac{2.4 \times 10^6}{3.14 \times 4.48 \times 10^{-2}}$$

$$= \frac{2.4}{14.07} \times \frac{10^6}{10^{-2}}$$

$$= 0.17 \times 10^8$$

$$= 17 \times 10^6 \text{ Hz.}$$

$$= 17 \text{ MHz}$$

Here,
The frequency of revolution of electron does not depend on the speed of electron. As it is directly proportional to it. It depends upon the radius of the circular path followed by the electron.

13-a) Given;
No. of turns of circular coil = 30
Radius of the circular coil = 8.0 cm.
$= 8 \times 10^{-2}$ m.
Current in the coil = 6.0 A.
Magnitude of magnetic field = 1.0 T
The angle between the magnetic field and the normal of the coil = 60°
Hence,
The counter torque that should be applied in order to prevent coil from turning, is

$$\tau = NIAB \sin\phi$$

$$= 30 \times 6 \times \pi r^2 \times 1.0 \times \sin 60^\circ$$

$$= 180 \times 3.14 \times (8 \times 10^{-2})^2 \times 1 \times \frac{\sqrt{3}}{2}$$

$$= 90 \times 3.14 \times 64 \times 10^{-4} \times \sqrt{3}$$

$$= 282.6 \times 64 \times \sqrt{3} \times 10^{-4}$$

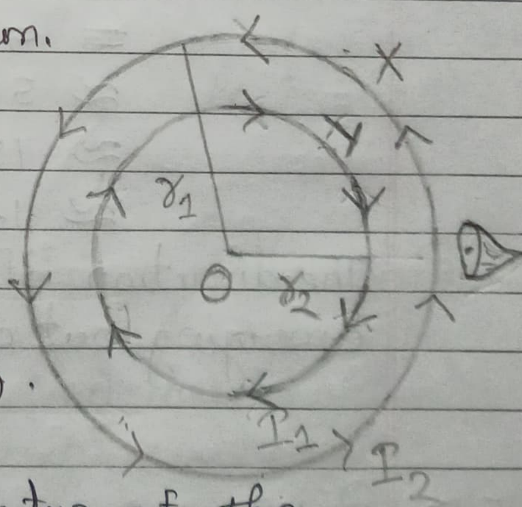
$= 18{,}086.4 \times \sqrt{3} \times 10^{-4}$
$= 31{,}325.64 \times 10^{-4}$
$= 3.13 \ N/m$

b) No, the answer remains unchanged even if the circular coil is replaced by a planar coil of some irregular shape.
In the formula.

$$\tau = NIAB \sin\phi$$

The torque does not depend upon the shape of the coil as long as it enclosed the same area. And in this case, as the planar coil encloses the same area, the answer remains same.

14. Given;
Radius of coil X $(r_2) = 16$ cm.
Radius of coil Y $(r_1) = 10$ cm.
No. of turns in coil X $(N_2)$
$= 20$.
No. of turns in coil Y $(N_1)$
$= 25$
Current in the coil X = 16 A
Current in the coil Y = 18 A.




Now,
The magnetic field at the centre of the coil X is

$$B_X = \frac{\mu_0 I_2 N_2}{2r_2} = \frac{4\pi \times 10^{-7} \times 16 \times 20}{2 \times 16 \times 10^{-2}}$$
$$= 2\pi \times 10^{-5} \times 20$$
$$= 4\pi \times 10^{-4} \, T$$

Now,

The magnetic field at the centre of the coil Y is.

$$B_Y = \frac{\mu_0 I_1 N_1}{2r_1}$$

$$= \frac{4\pi \times 10^{-7} \times 25 \times 18}{2 \times 10 \times 10^{-2}}$$

$$= 2\pi \times 25 \times 18 \times \frac{10^{-7}}{10^{-1}}$$

$$= 2\pi \times 450 \times 10^{-6}$$

$$= 90\pi \times 10^{-5}$$

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

Hence,

As here, the direction of current is opposite for the coil X and Y.

The net Magnetic field due to the coils at centre is

$$B_{net} = B_Y - B_X$$

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

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

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

$$\approx 5 \times 3.14 \times 10^{-4}$$

$$\approx 15.7 \times 10^{-4}\ T$$

$$\approx 1.57 \times 10^{-3}\ T$$

The direction of magnetic field is toward west emerging out of the two concentric coils.

15. Given;

Magnitude of magnetic field $= 100G$

$= 100 \times 10^{-4}\ T$

Length of the region $= 10$ cm.

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

Area of crossection of the region $= 10^{-3} m^2$

Current capacity of a coil of wire $= 15$ A.

Number of turns per unit length = 1000 turns $m^{-1}$
Now,
From the relation of magnetic field

$$B = \mu_0 n I$$

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

$$= \frac{100 \times 10^{-4}}{4\pi \times 10^{-7}}$$

$$= \frac{25}{3.14} \times 10^{3}$$

$$= 7.9617 \times 10^{3}$$

$$\approx 8 \times 10^{3}\ Am^{-1}$$

$$\approx 8000\ Am^{-1}$$

$$\Rightarrow nI = 8000\ Am^{-1}$$

$$= (800 \times 10)\ Am^{-1}$$

Here,
As the maximum current capacity of the coil is 15A., so we will consider the ~~deg~~ design to be 10A, and Number of turns per unit length to be 800 $m^{-1}$
Hence,
If the length is taken about 50cm, radius will be about 4cm, total number of turns is about 400 cm. and current about 10A. These particular are not unique. Some adjustment with limits is possible.

16. Given;
Expression for magnetic field in a circular coil at a distance x from centre. $B_1 = \frac{\mu_0 I R^2 N}{2(x^2+R^2)^{3/2}}$

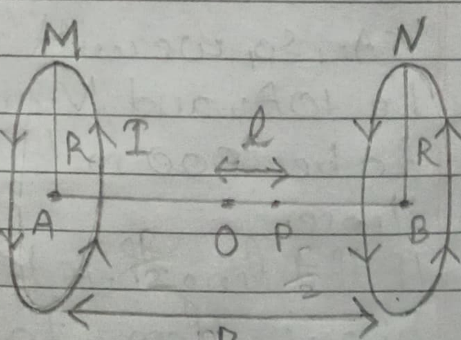
a) At the centre of the circular coil, $x = 0$,
So, the magnetic field at the centre of the circular coil is expressed as:

$$B_2 = \frac{\mu_0 I R^2 N}{2R^3}$$

$$= \frac{\mu_0 I N}{2R}.$$

Here,
In the case of $B_1$, the value in the denominator is greater than that of magnetic field $B_2$,
Hence,
It proves that ~~this reduces~~ the value of $B_1$ reduces to the familiar result for field at the centre of coil, i.e., the value of $B_2$
So, Magnitude of $B_1$ < Magnitude of $B_2$.

b) Given;
Radius of coil M and N
= R.
Number of turns in both the coil = N
Current in both the coil
= I




Separation distance between the two coils = R.
The distance, $OA = OB = \frac{R}{2}$.

Lets consider, the small distance around midpoint between the coils i.e., OP be $l$.
Now,
The magnetic field at point P due to the coil M is.

$$B_M = \frac{\mu_0 I a^2 N}{2(a^2 + x^2)^{3/2}}.$$

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

$$= \frac{\mu_0 I R^2 N}{2\left(R^2 + \frac{R^2}{4}\right)^{3/2}} \qquad [l <<<< R]$$

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

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

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

The magnetic field at point P due to the coil N is.

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

$$= \frac{\mu_0 I R^2 N}{2\left(R^2 + \left(\frac{R}{2} - l\right)^2\right)^{3/2}}.$$

$$= \frac{\mu_0 I R^2 N}{2\left(R^2 + \frac{R^2}{4}\right)^{3/2}} \qquad [l <<< R]$$

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

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

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

Hence,
The net magnetic field at point P is.

$$B_{net} = B_M + B_N$$

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

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

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

$$= 0.72 \cdot \frac{\mu_0 I N}{R} \text{ (approx)}$$

Hence,
This proves that the magnetic field is uniform, around the midpoint at point P as $B_M = B_N$
And,
The expression for magnetic field is also given by the following above.

~~17. Inner radius o.~~

17. Given;
Inner radius of torroid $= 25 cm$
$= 25 \times 10^{-2} m$
Outer radius of torroid $= 26 cm$
$= 26 \times 10^{-2} m.$
No. of turns of wire in torroid $= 3500$
Current in the wire $= 11 A$
Now,
a) The magnetic field outside the toroid is zero
$B = 0.$

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because, magnetic field only exists in the tubular. ~~sect~~ section of the toroid.

Now,

~~b) The magnetic field.~~

b) The length of the toroid is given by.

$$l = 2\pi r$$
$$= 2\pi\left(\frac{r_1 + r_2}{2}\right)$$
$$= 2\pi\left(\frac{25 + 26}{2}\right)$$
$$= 2\pi \times \frac{51}{2}$$
$$= 3.14 \times 51 = 160.14 \text{ cm}$$
$$= 160.14 \times 10^{-2} \text{ m.}$$

Hence,

The magnitude of the field inside the core of the toroid,

$$B = \mu_0 n I$$
$$= \frac{\mu_0 N I}{l}$$
$$= \frac{4\pi \times 10^{-7} \times 3500 \times 11}{51\pi \times 10^{-2}}$$
$$= \frac{44 \times 3500 \times 10^{-7}}{51 \times 10^{-2}}$$
$$= \frac{1{,}54{,}000}{51} \times 10^{-5}$$
$$= 3{,}019.6 \times 10^{-5}$$
$$= 3 \times 10^{-2} \text{ T}$$

Now,

c) The magnetic field in the empty space surrounded by the toroid is also zero, same as outside the toroid.

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18 a) As in this case,
The charged particle enters and travels undeflected along a straight line in the chamber with constant speed, the initial velocity of the particle must be either, parallel or anti-parallel to the magnetic field.
So, that the magnitude of magnetic force experienced by the particle ~~is~~ will be zero.

i.e., $F_m = Bvq \sin\theta$
$= Bvq \sin 0° = 0$ (parallel)
$F_m = Bvq \sin\theta$
$= Bvq \sin 180° = 0$ (antiparallel)

~~b) Yes, its final speed will be equal to its~~
b) Yes, The final speed of the charged particle will be equal to its initial speed, if it suffered no collision with the environment because, the magnetic force can change the direction of velocity of the particle but ~~not~~ it cannot change its magnitude.

c) In order to prevent the electron from deflecting from its straight line path.
The magnetic force and electrostatic force should have equal magnitude and should be opposite in direction.
So in order to make it, the uniform magnetic field should vertically downwards in the direction and magnetic force acts toward South, and this cancels out both the forces.

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19. Given;
Potential difference of electron $(V) = 2.0\ kV$
$= 2 \times 10^3\ V$
Magnitude of magnetic field $= 0.15\ T$.
Charge on electron $(e) = 1.6 \times 10^{-19}\ C$
Mass of the electron $(m) = 9.1 \times 10^{-31}\ Kg$.
Now,
Work done = Change in Kinetic energy.
$\Rightarrow qV = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ $[W = qV]$

$\Rightarrow eV = \frac{1}{2}mv^2$ $[u = 0]$

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

$\Rightarrow v = \sqrt{\frac{2eV}{m}}$

where →
v → Velocity of the electron.
V → potential diffence of the electron.
Now,
a) Magnetic field is transverse to the initial velocity of the electron.
This means that, the velocity vector has no component and the magnetic force is perpendicular to the velocity of electron.
So,
Magnetic force on electron provide the centripetal force on it.
i.e, ~~Forc~~
Magnetic force = Centripetal Force.
$F_m = F_c$
$\Rightarrow Bev \sin 90° = \frac{mv^2}{r}$

$$\Rightarrow BeV = \frac{mv^2}{r'}$$

$$\Rightarrow Be = \frac{mv}{r'}$$

$$\Rightarrow r = \frac{mv}{Be}$$

$$\Rightarrow r_1 = \frac{m}{Be}\sqrt{\frac{2eV}{m}}$$

$$= \frac{1}{B}\sqrt{\frac{2eVm^2}{e^2m}}$$

$$= \frac{1}{B}\sqrt{\frac{2Vm}{e}}$$

$$= \frac{1}{0.15}\sqrt{\frac{2\times2\times10^{3}\times9.1\times10^{-31}}{1.6\times10^{-19}}}$$

$$= \frac{1}{0.15}\sqrt{\frac{4\times9.1\times10^{-28}}{1.6\times10^{-19}}}$$

$$= \frac{1}{0.15}\sqrt{\frac{36.4\times10^{-9}}{1.6}}$$

$$= \frac{1}{0.15}\sqrt{22.75\times10^{-9}}$$

$$\cancel{= 4.77\times10}$$

$$= \frac{1}{0.15}\sqrt{2.275\times10^{-8}}$$

$$= \frac{1.50\times10^{-4}}{0.15}$$

$$= 10\times10^{-4}$$

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

Hence,
The electron will have a circular trajectory of radius 1 mm in the region of magnetic field in uniform,

Now,

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b) Magnetic field makes an angle of 30° with the initial velocity.
The intial velocity will now have two components.,
But only the perpendicular component will, have the effect of magnetic force.
because, the horizontal component will be in, the direction of magnetic field.
Hence,
The vetical component is. $V_\perp = V \sin\theta$
Now,
The radius of the path followed by the electron.

$$r_2 = \frac{mV_\perp}{Be}$$
$$= \frac{mV\sin\theta}{Be}$$
$$= \frac{m}{Be}\sqrt{\frac{2eV}{m}} \sin\theta$$
$$= \frac{1}{B}\sqrt{\frac{2mV}{e}} \cdot \sin 30°$$
$$= \frac{1}{0.15}\sqrt{\frac{2\times2\times10^{3}\times9.1\times10^{-31}}{1.6\times10^{-19}}} \cdot \frac{1}{2}$$
$$= \frac{1.5\times10^{-4}}{0.15} \times \frac{1}{2}$$
$$= 10^{-3} \times \frac{1}{2}$$
$$= 0.5\times10^{-3}\ m = 0.5\ mm.$$

Hence,
The electron will have a helical trajectory of radius 0.5 mm. in the region of uniform magnetic field.

20. Given;

Magnitude of magnetic field = 0.75 T

Potential difference of charged particles.

$= 15 KV$

$= 15 \times 10^3 V$

Magnitude of electrostatic field $= 9.0 \times 10^{-5} Vm^{-1}$

Lets Consider,

the charged particles to be electron,

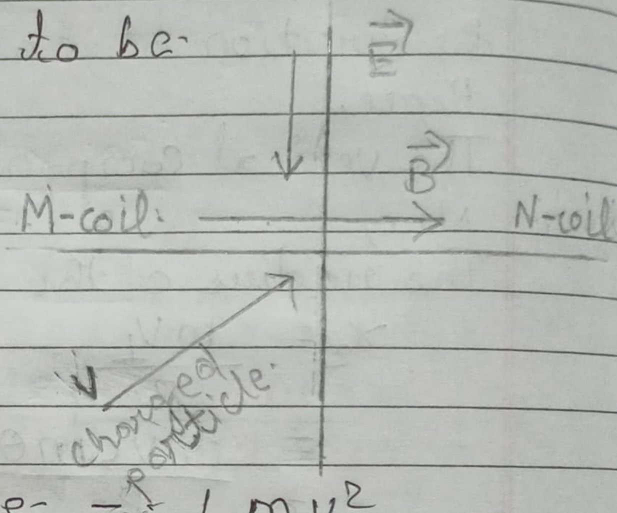
Mass of electron;

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

Charge of electron.

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

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




Now,

Kinetic energy of the electron $= \frac{1}{2} mv^2$

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

$\Rightarrow \frac{e}{m} = \frac{v^2}{2V}$

Now,

As the electron remains undeflected even though the magnetic & electrostatic field both exists in the region.

Magnetic force = Electro static force

$F_m = F_E$

$\Rightarrow Bvq \sin 90° = qE$

$\Rightarrow Bve = eE$

$\Rightarrow Bv = E$

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

Now,
The value of charge to mass ratio of the electron is:

$$\frac{e}{m} = \frac{v^2}{2V}$$

$$= \frac{\left(\frac{E}{B}\right)^2}{2V}$$

$$= \left(\frac{9.0 \times 10^{-5}}{0.75}\right)^2 \times \frac{1}{2 \times 15 \times 10^3}$$

$$= \frac{81 \times 10^{-10}}{5625 \times 10^{-4}} \times \frac{1}{30 \times 10^3}$$

$$= \frac{27 \times 10^{-10}}{5625 \times 10^{-4} \times 10^4}$$

$$= 0.0048 \times 10^{-10}$$

$$= 4.8 \times 10^{-13}$$

Hence,
The value of charge to mass ratio is same as that of the deuteron or deuterium ions.
This is not unique answer.
Other possible answer are $He^{++}$, $Li^{+++}$, etc.

21. Given;
Length of conducting rod = 0.45 m
Mass suspended = 60 g = $60 \times 10^{-3}$ Kg
Current in the rod through wires = 5.0 A
Now,
a) Angle between the direction of current and the magnetic field = 90°
Condition is:
The tension in the wires should be zero.

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So, here,
The magnetic force on the conductor
= Force acting downward due to the weight

$\Rightarrow F_m = F_g$
$\Rightarrow IBl \sin 90° = mg$
$\Rightarrow IBl = mg$
$\Rightarrow B = \frac{mg}{Il}$ [$g = 9.8 m/s^2$]

$= \frac{60 \times 9.8 \times 10^{-3}}{5 \times 0.45}$

$= \frac{12 \times 9.8 \times 10^{-3}}{0.45}$

$= \cancel{\frac{117.6 \times 10}{0.45}}$

$= \frac{117.6 \times 10^{-3}}{0.45}$

$= 261.3 \times 10^{-3} = 0.26 T$

Hence,
A horizontal magnetic field of magnitude 0.26T is to be set up inorder to make the tension in the wires zero.

~~Also~~,

b) If the direction of the current is reversed keeping the magnetic field same as before.
The total tension in the wires.
$= F_m + F_g$
$= IBl \sin 90° + mg$
$= (5 \times 0.26 \times 0.45) + (60 \times 10^{-3} \times 9.8)$
$= 0.585 + 588 \times 10^{-3}$
$= 0.585 + 0.588$
$= 1.173 N$

22. Given;
Current in the wire = 300A
length of the wire = 70cm
$= 70 \times 10^{-2} m.$
distance between the wires = 1.5cm
$= 1.5 \times 10^{-2}.$

Hence,
The Force per unit length between wires.

$$F_m = \frac{\mu_0 I_1 I_2 l}{2\pi r}$$

$$\Rightarrow F_m = \frac{\mu_0 I^2 l}{2\pi r} \quad [I_1 = I_2 = I]$$

$$\Rightarrow \frac{F_m}{l} = \frac{\mu_0 I^2}{2\pi r}$$

$$= \frac{4\pi \times 10^{-7} \times (300)^2}{3\pi \times 1.5 \times 10^{-2}}$$

$$= \frac{2 \times 10^{-7} \times 9 \times 10^{4}}{1.5 \times 10^{-2}}$$

$$= \frac{18 \times 10^{-3}}{1.5 \times 10^{-2}}$$

$$= 12 \times 10^{-1}.$$

$$= 1.2\ N/m.$$

Hence,
As the direction of current is opposite, the force will be repulsive in nature.

23. Given;
The magnitude of magnetic field = 1.5T
Radius of Cylindrical region = 10.0 cm
$= 10 \times 10^{-2} m.$
Current in the wire = 7.0 A.

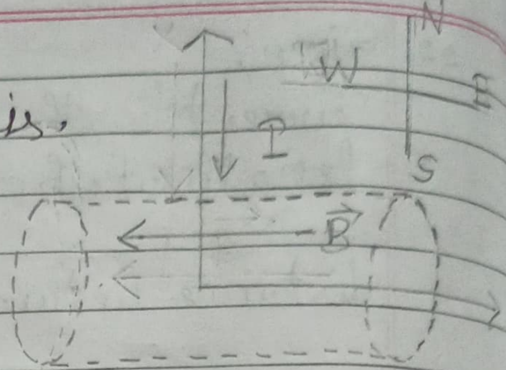
Now,

a) If the wire intersects the axis.

Then,

~~Magnitude~~

The length of the wire on which the force is being experienced will be equal to the ~~di~~ diameter of the cylindrical region.




So, $l = 2r$.

Hence,

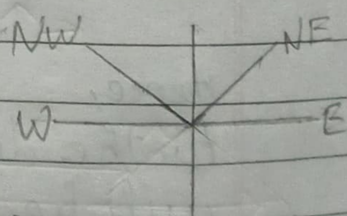
Magnitude of the magnetic ~~field is~~ force on the wire is.

$$F_{m_1} = IBl\sin\theta$$
$$= IB \times 2r \times \sin 90^\circ$$
$$= 7 \times 1.5 \times 2 \times 10 \times 10^{-2} \times 1$$
$$= 7 \times 3 \times 10^{-1}$$
$$= 21 \times 10^{-1}$$
$$= 2.1\,N$$

Here, the force will act vertically downwards

Now,

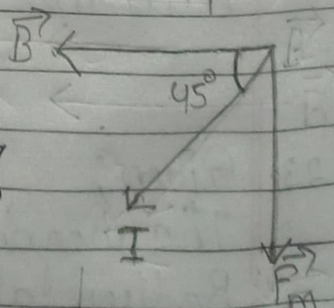
b) If the wire is turned from N-S to north east - north west direction.




Then.

The length of the wire on which the force is being experenced due to magnetic field is.

$$l_1 = \frac{l}{\sin\theta} \quad [l \rightarrow \text{intial length}]$$




$$\Rightarrow l = l_1 \sin\theta$$

Hence,

Magnitude of the magnetic ~~field~~ force on the wire is.

$$F_{m_2} = IBl_1 \sin\theta$$
$$= IBl$$
$$= 7 \times 1.5 \times 2 \times 10 \times 10^{-2}$$
$$= 7 \times 3 \times 10^{-1}$$
$$= 21 \times 10^{-1}$$
$$= 2.1\ N$$

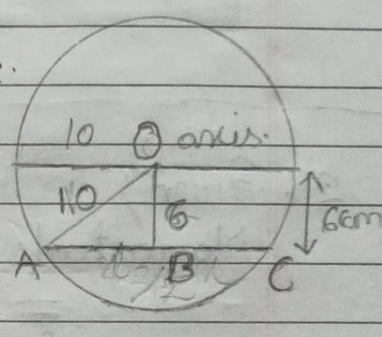
Here, the force will act vertically downwards.

Now,

e) If the wire in the N-S direction is lowered from the axis by a distance of 6.0 cm.

Then,

Let the length of the wire in the cylindrical region of magnetic field be $l_2$.




So, According to pythagoras theorem,

In $\triangle AOB$,

$AC = l_2$

$AB = \frac{l_2}{2}$

$$(AO)^2 = (AB)^2 + (BO)^2$$
$$\Rightarrow (AB)^2 = (AO)^2 - (BO)^2$$
$$\Rightarrow AB = \sqrt{(AO)^2 - (BO)^2}$$
$$\Rightarrow \frac{l_2}{2} = \sqrt{10^2 - 6^2}$$
$$\Rightarrow l_2 = 2\sqrt{100 - 36}$$
$$= 2\sqrt{64}$$
$$= 2 \times 8 = 16\text{ cm}.$$

Hence,

~~The magnetic field ha~~

The magnitude of the magnetic force on the wire is.

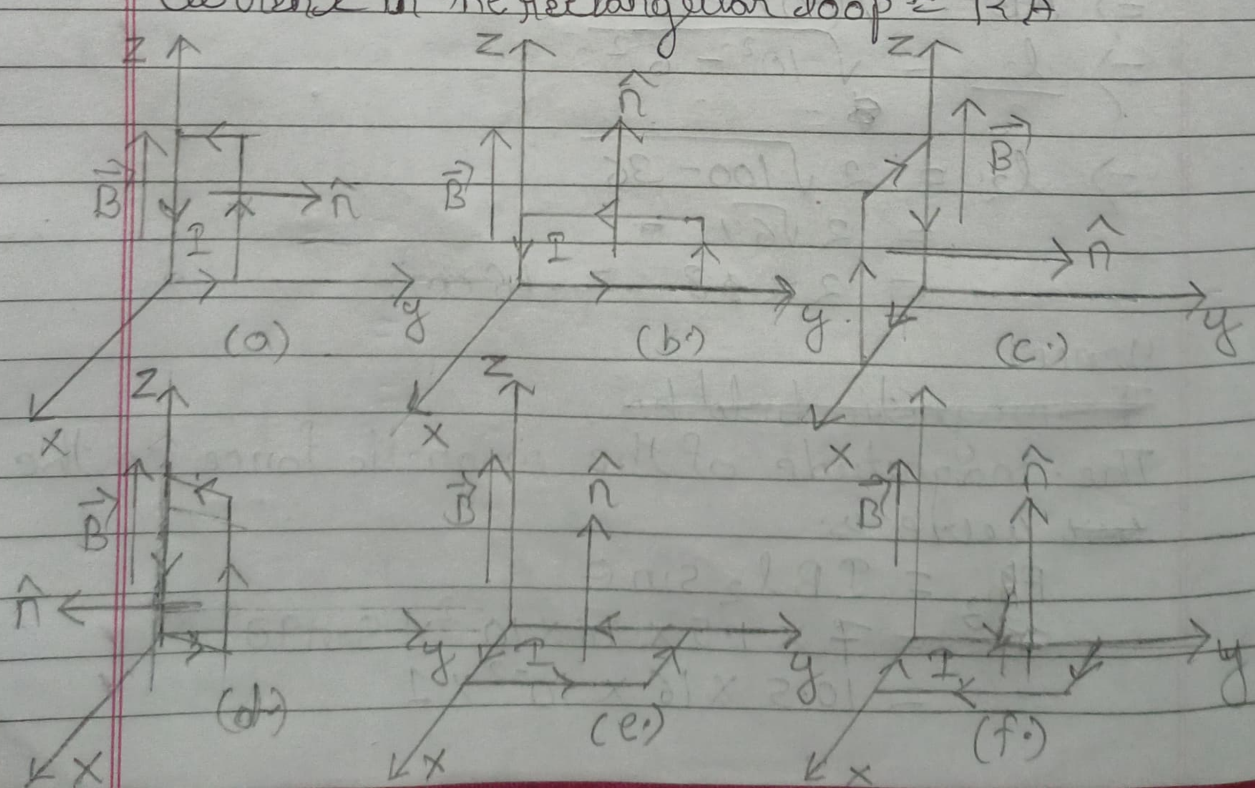
$$F_{m_3} = IBl_2 \sin\theta$$
$$= 7 \times 1.5 \times 16 \times 10^{-2} \times \sin 90^\circ$$
$$= 10.5 \times 16 \times 10^{-2} \times 1$$

$= 10.5 \times 16 \times 10^{-2}$
$= 168 \times 10^{-2}$
$= 1.68\ N$

~~The~~ Here,
The force on the wire will act towards vertically downwards.

~~24. Given;~~
~~Magnitude of the magnetic field = 3000 G~~
~~$= 3000 \times 10^{-4}$~~
~~$= 0.3\ T$~~

24. Given;
Magnitude of the magnetic field is.
$= 3000\ G$
$= 3000 \times 10^{-4} = 0.3\ T$
Sides of the rectangular loop are
$l = 10\ cm$ ; $b = 5\ cm$.
Current in the rectangular loop = 12 A



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Here,
Area of the rectangular loop in each case is.

$A = l \times b$
$= (10 \times 5) cm^2 = 50 cm^2$
$= 50 \times 10^{-4} m^2$

Now,
a) The torque on the rectangular loop is.

$\vec{\tau} = I(\vec{A} \times \vec{B})$
$= 12[(50 \times 10^{-4} \hat{i}) \times (0.3 \hat{k})]$
$= 12 \times 15 \times 10^{-4} (-\hat{j})$
$= 180 \times 10^{-4} (-\hat{j})$
$= 1.8 \times 10^{-2} (-\hat{j})$ Nm.

Hence,
The magnitude of torque is $1.8 \times 10^{-2}$ Nm. and its direction is along -ve y-axis.
Now,
b) The torque on the rectangular loop is.

$\vec{\tau} = I(\vec{A} \times \vec{B})$
$= 12 \times [(50 \times 10^{-4} \hat{i}) \times (0.3 \hat{k})]$
$= 1.8 \times 10^{-2} (-\hat{j})$ Nm.

Hence,
The magnitude of torque is $1.8 \times 10^{-2}$ Nm and its direction is along Negative y-axis.
Now,
c) The torque on the rectangular loop is.

$\vec{\tau} = I(\vec{A} \times \vec{B})$
$= 12[(50 \times 10^{-4} (-\hat{j})) \times (0.3 \hat{k})]$
$= 12 \times 15 \times 10^{-4} (-\hat{j} \times \hat{k})$
$= 180 \times 10^{-4} (-\hat{i})$
$= 1.8 \times 10^{-2} (-\hat{i})$ Nm.

Hence,
The magnitude of torque is $1.8 \times 10^{-2}$ Nm and

its direction is along -ve $x$-axis.
Now,
d) The magnitude of the torque on the rectangular loop is:
$$|\tau| = IAB \sin 90^\circ$$
$$= 12 \times 50 \times 10^{-2} \times 0.3 \times 1$$
$$= 12 \times 15 \times 10^{-2}$$
$$= 180 \times 10^{-2}$$
$$= 1.8 \times 10^{-2} \text{ Nm.}$$
Here,
~~The area of the loop $\vec{A}$ is m~~
The rectangular loop is making an angle of $30^\circ$ with +ve $y$-axis.
So, as $\vec{A}$ is normal to the loop, it will make an angle of $30^\circ$ with +ve $x$-axis. In the -ve $y$-direction, so, $\vec{A}$ and $\vec{B}$ will be perpendicular to each other.
Hence,
The direction of the torque is:
$$360^\circ - (90^\circ + 30^\circ) = 360^\circ - 120^\circ = 240^\circ$$
from the positive $x$-axis.
Now,
e) The torque on the rectangular loop is.
$$\vec{\tau} = I(\vec{A} \times \vec{B})$$
$$= 12 \times [(50 \times 10^{-2}\hat{k}) \times (0.3\hat{k})]$$
$$= 12 \times 15 \times 10^{-2}(\hat{k} \times \hat{k})$$
$$= 180 \times 10^{-2} \times 0$$
$$= 0$$
Hence,
No torque is acting on this rectangular loop as magnitude is zero.
Now,

(f) The torque on the rectangular loop is.

$$\vec{\tau} = I(\vec{A} \times \vec{B})$$
$$= 12 \times [(50 \times 10^{-2}(-\hat{k})) \times (0.3\hat{k})]$$
$$= 12 \times 15 \times 10^{-2}(-\hat{k} \times \hat{k})$$
$$= 180 \times 10^{-2} \times 0$$
$$= 0$$

Hence,
In this case also, No. torque is acting on the rectangular loop.

25. Given;
Number turns of circular coil = 20
radius of the circular coil = 10 cm
$= 10 \times 10^{-2}$ m
Magnitude of magnetic field = 0.10 T
Angle between the plane of the coil and the magnetic field = $0°$
Current in the coil = 5.0 A
Area of the circular coil is.

$$A = \pi r^2$$
$$= 3.14 \times (10 \times 10^{-2})^2$$
$$= 3.14 \times 10^{-2}\ m^2$$

~~Hen~~ Now,
a) total torque on the coil is.

$$\tau = NIAB \sin\phi$$
$$= 5 \times 20 \times 3.14 \times 10^{-2} \times 0.10 \times \sin 0°$$
$$= 0$$

Now,
b) Total force on the torque is zero.
Because, ~~equal~~ forces of equal magnitude and opposite direction are acting on the circular

coil and hence, they cancel out each other's effect and the force experienced by the coil is zero.

Now,

(c) Given;

Area of crossection of the coil $= 10^{-5} m^2$

Number density of free electrons in copper $= 10^{29} m^{-3}$

charge on 1 electron $= 1.6 \times 10^{-19} C$

Hence,

The Average force acting on each electron in the coil due to magnetic field is.

$$F_m = B v_d q \sin\theta$$
$$= B v_d e \sin 90^\circ$$
$$= 0.1 \times \frac{I}{neA} \cdot e \times 1$$
$$= 0.1 \times \frac{5}{10^{-5} \times 10^{29}}$$
$$= \frac{5 \times 10^{-1}}{10^{24}}$$
$$= 5 \times 10^{-25} N$$

26. Given;

length of the solenoid $= 60 cm$
$= 60 \times 10^{-2} m$

Radius of the solenoid $= 4 cm$
$= 4 \times 10^{-2} m$

Total No. of turns in the solenoid

$N = 300 \times 3$
$= 900$

Length of the wire $= 2 cm = 2 \times 10^{-2} m$

Mass of the wire = 2.5 g
= $2.5 \times 10^{-3}$ Kg
Current supplied in the wire = 6 A
Acceleration due to gravity
i.e., $g = 9.8\ m/s^2$
Let the current in the windings of the solenoid be $I_s$
Now,
The Magnetic field inside the solenoid

$$B = \mu_0 n I_s$$
$$= \frac{\mu_0 N I_s}{l}$$
$$= 4\pi \times 10^{-7} \times \frac{900}{60 \times 10^{-2}} \times I_s$$
$$= 4\pi \times 15 \times \frac{10^{-7}}{10^{-2}} \times I_s$$
$$= 60\pi \times 10^{-5} \times I_s$$
$$= 60\pi I_s \times 10^{-5}$$

Now,
The Magnetic ~~field~~ force on the wire due to the magnetic field

$$F_m = IBl \sin\theta$$
$$= 6 \times 60\pi I_s \times 10^{-5} \times 2 \times 10^{-2} \times \sin 90^\circ$$
$$= 360\pi I_s \times 2 \times 10^{-7} \times 1$$
$$= 720\pi I_s \times 10^{-7}$$

Now,
In order to balance the weight of the wire within the ~~coil has~~ Solenoid.
~~the~~ Magnetic force on wire should be equal to the Force on the wire due to its weight.
i.e., $F_m = F_g$
$\Rightarrow 720\pi I_s \times 10^{-7} = mg$

$$\Rightarrow 720\pi I_s \times 10^{-7} = 2.5\times10^{-3}\times 9.8$$
$$\Rightarrow 720\pi I_s = \frac{2.5\times9.8\times10^{-3}}{10^{-7}}$$
$$\Rightarrow I_s = \frac{2.5\times9.8\times10^{-3}}{720\pi\times10^{-7}}$$
$$= \frac{24.5\times10^{-3}}{720\times3.14\times10^{-7}}$$
$$= \frac{24.5}{2260.8}\times10^{4}$$
$$= 0.01083\times10^{4}$$
$$= 108.3\ A.$$

Hence,
The Required current in the windings of the solenoid inorder to support the weight of the wire is 108 A.

27. Given;
Resistance of a galvanometer coil = 12 Ω.
Current passed through the coil = 3 mA
$= 3\times10^{-3}$ A.
Potential range to be measured = 18 V.
Now,
Magnitude of series resistance to be connected is
$$V = I_g(G+R)$$
$$\Rightarrow R = \frac{V}{I_g} - G$$
$$= \frac{18}{3\times10^{-3}} - 12.$$
$$= 6\times10^{3} - 12.$$
$$= 6000 - 12.$$
$$= 5988\ \Omega$$

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Hence,
To convert the galvanometer into voltmeter of range 0 to 18V, we have to connect a series resistor of resistance 5988 $\Omega$ in Series with the galvanometer coil.

28. Given;
Resistance of galvanometer coil = 15 $\Omega$.
Current passed through the coil = 4mA
$= 4 \times 10^{-3}$ A.
Range of the current to be achieved
= 6A or 0 to 6 A.
Now,
Let S be the shunting resistance that is to be connected in the circuit in order to ~~covert~~ achieve conversion.
As the galvanometer is connected in parallel combination to measure current.
The potential difference within that parallel circuit is zero.
So,
The resistance of the series resistor is.

$$(I - I_g)S = I_g G$$

$$\Rightarrow S = \frac{I_g G}{I - I_g}$$

$$= \frac{4 \times 10^{-3} \times 15}{6 - 4 \times 10^{-3}}$$

$$= \frac{60 \times 10^{-3}}{6 - 0.004}$$

$$= \frac{60 \times 10^{-3}}{5.996}$$

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$$= \frac{60}{5.996} \times 10^{-3}$$

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

$$= 10\ m\Omega.$$

Hence,
To Convert the galvanometer into the ammeter of range 0 to 6A, we have to connect a shunting resistance of $10 m\Omega$ in parallel combination with the galvanometer coil.

24. Force on each case given on the rectangular loop is zero because, the rectangular loops are in the uniform magnetic field.
The rectangular loop in case (e.) Corresponds to the stable equilibrium.