When there is a short circuit current.

From the graph, we find

$I_{max} = 0.265$ Amp

$\therefore$ 1.1 volt $= r \cdot (0.265$ Amp.$)$

$\Rightarrow r = \dfrac{1.1}{0.265} = 4.15\ \Omega$

— o —

Magnetic effect of electric current

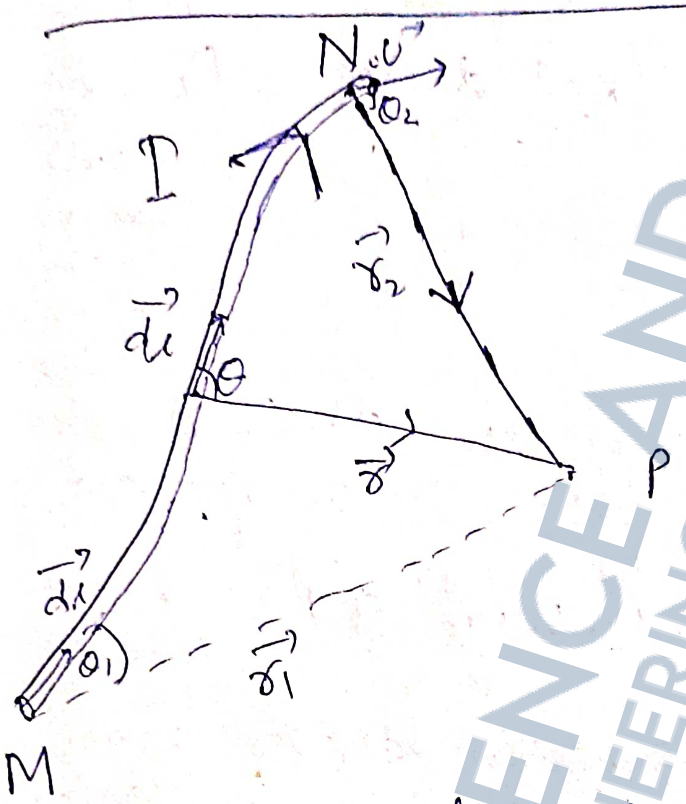
Oersted was the first scientist to show that a current carrying conductor produces a magnetic field around it. Laplace gave a formula for the magnetic induction developed around the conductor.

He didnot give the direction of magnetic field intensity. Thus, Laplace's formula is only quantitative.

Biot and Savart gave an expression for the magnetic induction in vector form. Thus, magnitude and direction

Of $\vec{B}$ are ~~...~~ contained in Biot and Savart's law.

Biot and Savart's law (Or Ampere's theorem).



Due to flow of current of a current I amp through a small straight element $\vec{dl}$ (which is a small straight portion chosen on the conductor along the direction of current), there is a magnetic induction $\vec{dB}$ developed at the point P having a position vector $\vec{r}$ with respect to $\vec{dl}$ is given by the expression,

$$\boxed{\vec{dB} = \frac{\mu_0}{4\pi} I \left(\frac{\vec{dl} \times \vec{r}}{r^3} \right)}$$

Magnitude of the magnetic induction is given by:

$$dB = \frac{\mu_0 I}{4\pi}\left(\frac{dl\, r \sin\theta}{r^3}\right)$$

$$= K\, I\, \frac{dl \sin\theta}{r^2}$$

(where $K = \frac{\mu_0}{4\pi}$ = constant having the value 10^{-7} in M.K.S units)

Thus $dB \propto I$, where dl, θ, r are kept constants.

$dB \propto dl$, where θ, I, r are kept constant

$dB \propto \sin\theta$, where dl, I, r kept constant

$dB \propto \frac{1}{r^2}$, where dl, I, θ are kept constant.

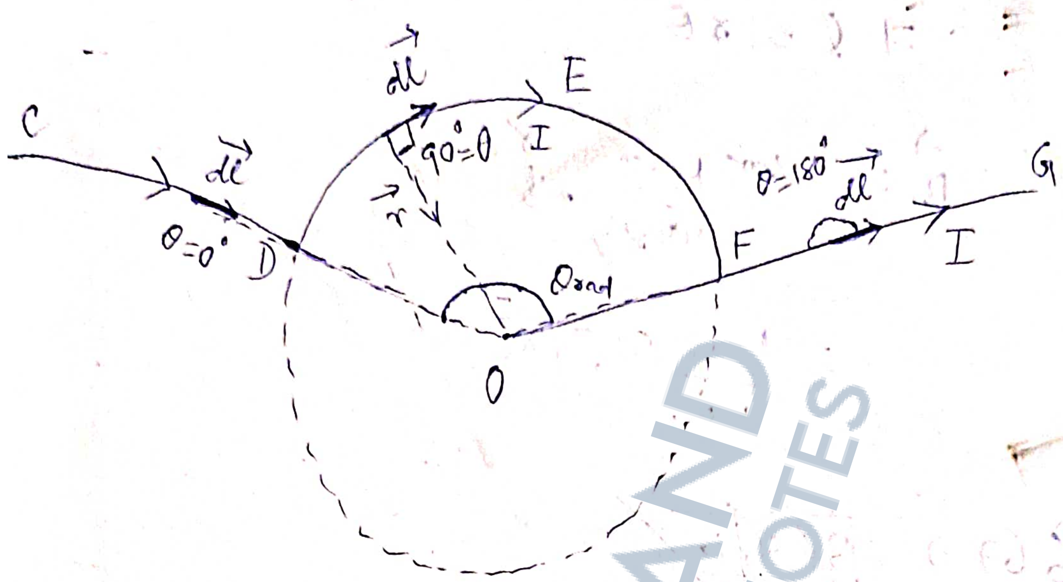
These 4 laws together are sometimes called Laplace's laws.

The direction of $\vec{dB}$ is contained in the cross product $\vec{dl} \times \vec{r}$ which is onto the plane of the paper that contains $\vec{dl}$ and $\vec{r}$.

Symbolically it is represented by

$\otimes$

1. To find $\vec{B}$ at O



From Biot and Savart's law the magnetic induction at the point O can be obtained by integrating the expression for $\vec{dB}$.

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int_{CDEFG} \frac{\vec{dl} \times \vec{r}}{r^3}$$

$$= \frac{\mu_0 I}{4\pi} \left[\int_{CD} \frac{\vec{dl} \times \vec{r}}{r^3} + \int_{DEF} \frac{\vec{dl} \times \vec{r}}{r^3} + \int_{FG} \frac{\vec{dl} \times \vec{r}}{r^3} \right]$$

$$= \frac{\mu_0 I}{4\pi} \left[\int_{CD} \frac{dl\, r \sin 0}{r^3} + \int_{DEF} \frac{dl\, r \sin 90°}{r^3}, \otimes + \int_{FG} \frac{dl\, r \sin 180}{r^3} \right]$$

$$= \frac{\mu_0 I}{4\pi} \left[0 + \frac{1}{r^2} \int_{DEF} dl, \otimes + 0 \right]$$

$$= \frac{\mu_0 I}{4\pi r^2} \cdot l, \otimes$$ where l = length of the arc DEF

But $\theta = \frac{l}{r}$

$\Rightarrow l = r\theta$

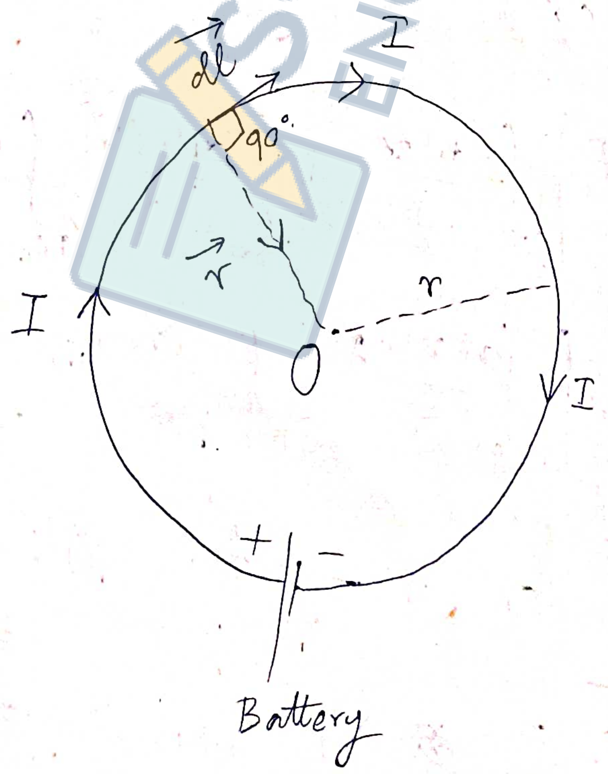
$\therefore \vec{B} = \frac{\mu_0 I}{4\pi r^2} \cdot r\theta$ ⊗

$= \frac{\mu_0 I \theta}{4\pi r}$, ⊗

667 → $\boxed{3, 4, 10}$

Applications

(2)) To find $\vec{B}$ at the Centre of a Circular Coil Carrying Current.



Let there be a circular coil of radius 'r' having 'N' no of turns. The current be flowing in the clockwise manner. One such circular turn be considered,

From Biot and Savart's law, the magnetic induction at the point O due to a current element $\vec{dl}$ is given by

$$\vec{dB} = \frac{\mu_0 I}{4\pi} \frac{\vec{dl} \times \vec{r}}{r^3}$$

Integrating both the sides, we can get the total magnetic induction developed at the point O due to all such current elements.

$$\therefore \vec{B_0} = \frac{\mu_0 I}{4\pi} \oint \frac{\vec{dl} \times \vec{r}}{r^3}$$

Where $\oint$ represents the integration around a closed path.

$$\therefore \vec{B_0} = \frac{\mu_0 I}{4\pi} \oint \frac{dl\, r \sin 90^\circ}{r^3}, \otimes$$

Where $\otimes$ shows the direction of $\vec{B_0}$ which is into the plane of the paper, where the turn lies.

$$\vec{B_0} = \frac{\mu_0 I}{4\pi r^2} \oint dl \, , \otimes$$

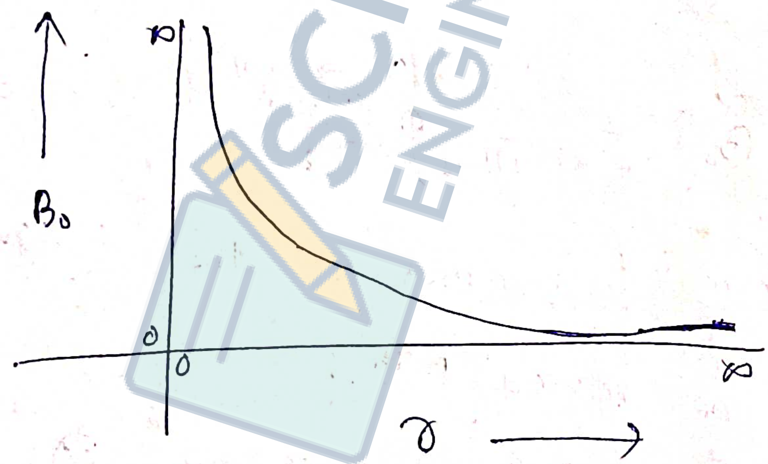
$$= \frac{\mu_0 I}{4\pi r^2} \cdot l, \otimes = \frac{\mu_0 I}{4\pi r^2} \cdot 2\pi r, \otimes$$

$$= \frac{\mu_0 I}{2r}, \otimes$$

Since there are N number of turns in the coil, the magnetic induction is increased N times.

$$\therefore \boxed{\vec{B_0} = \frac{\mu_0 N I}{2r}, \otimes}$$

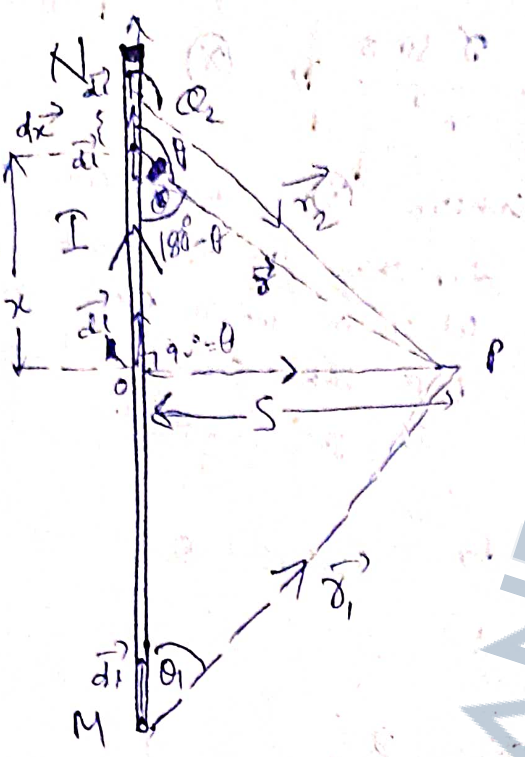
Thus $B_0 \propto \frac{1}{r}$



~~2nd~~ 3rd application :-

To find $\vec{B}$ at a point near a long, ~~Steel~~ straight current carrying conductor.

MN is a straight conductor in which



$r = \sqrt{x^2+s^2}$

A current I units is flowing. P is some external point where magnetic induction is required.

Let's divide the wire into large number of current elements and we see that the position vectors and θ values vary from point to point. One such current element $\vec{dl} = \vec{dx}$ be considered at a point which is x units away from the foot of the $\perp$ dropped from the point P on the wire.

From Biot and Savart's law, the magnetic induction at the point P due to current flowing through the wire is given by

$$\vec{dB} = \frac{\mu_0 I}{4\pi}\left[\frac{\vec{dx}\times\vec{r}}{r^3}\right]$$

$$\vec{dB} = \frac{\mu_0 I}{4\pi} \frac{dx\ r \sin\theta}{r^3} \ , \ \otimes$$

where $\otimes$ represents the direction of $\vec{dB}$ at P or the which is into the plane paper that contains the straight conductor.

$$dB = \frac{\mu_0 I}{4\pi} \frac{dx}{r^2} \sin(180^\circ - \theta)$$

$$= \frac{\mu_0 I}{4\pi} \frac{dx}{r^2} \cdot \frac{S}{r}$$

$$= \frac{\mu_0 I S}{4\pi} \cdot \frac{dx}{(r^2)^{\frac{3}{2}}}$$

$$= \frac{\mu_0 I S}{4\pi} \cdot \frac{dx}{(x^2+S^2)^{\frac{3}{2}}}$$

Integrating both the sides with proper limits, ~~we~~ one can get the value of $\vec{B}$ at P.

$$\therefore \int_0^B dB = \frac{\mu_0 I S}{4\pi} \int_{\theta_1}^{\theta_2} \frac{dx}{(x^2+S^2)^{\frac{3}{2}}}$$

Since $\cot(180^\circ - \theta) = \frac{x}{S}$, we have

$$-\cot\theta = \frac{x}{S}$$

$$\Rightarrow x = -S\cot\theta$$

$\Rightarrow dx = -S.(-\operatorname{cosec}^2\theta\, d\theta)$

$= S \operatorname{cosec}^2\theta\, d\theta$

$$\therefore B = \frac{\mu_0 I S}{4\pi}\int_{\theta_1}^{\theta_2} \frac{S \operatorname{cosec}^2\theta\, d\theta}{(S^2\cot^2\theta + S^2)^{\frac{3}{2}}}$$

$$= \frac{\mu_0 I S^2}{4\pi}\int_{\theta_1}^{\theta_2} \frac{\operatorname{cosec}^2\theta\, d\theta}{S^3 \operatorname{cosec}^3\theta}$$

$$= \frac{\mu_0 I}{4\pi S}\int_{\theta_1}^{\theta_2} \sin\theta\, d\theta$$

$$= \frac{\mu_0 I}{4\pi S}\Big[(-\cos\theta)\Big]_{\theta_1}^{\theta_2}$$

$$= \frac{\mu_0 I}{4\pi S}\left(-\cos\theta_2 + \cos\theta_1\right)$$

$$= (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{4\pi S}$$

If the conductor will be very long, then $\theta_1 \to 0$ and $\theta_2 \to 180^\circ$

$$\therefore B = \frac{\mu_0 I}{4\pi S}(\cos 0 - \cos 180^\circ)$$

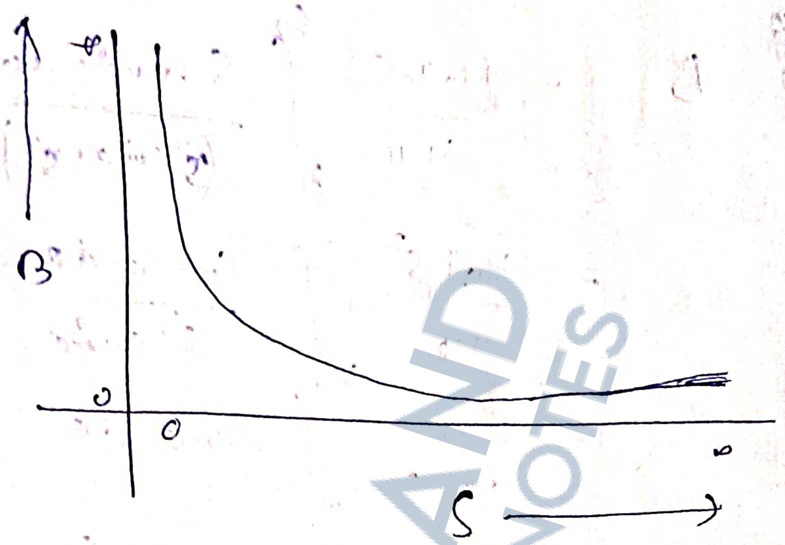
$$= \frac{\mu_0 I}{4\pi S}\cdot(1+1)$$

$$= \frac{\mu_0 I}{2\pi S}$$

$$\therefore \boxed{\vec{B} = \frac{\mu_0 I}{2\pi S}, \otimes}$$

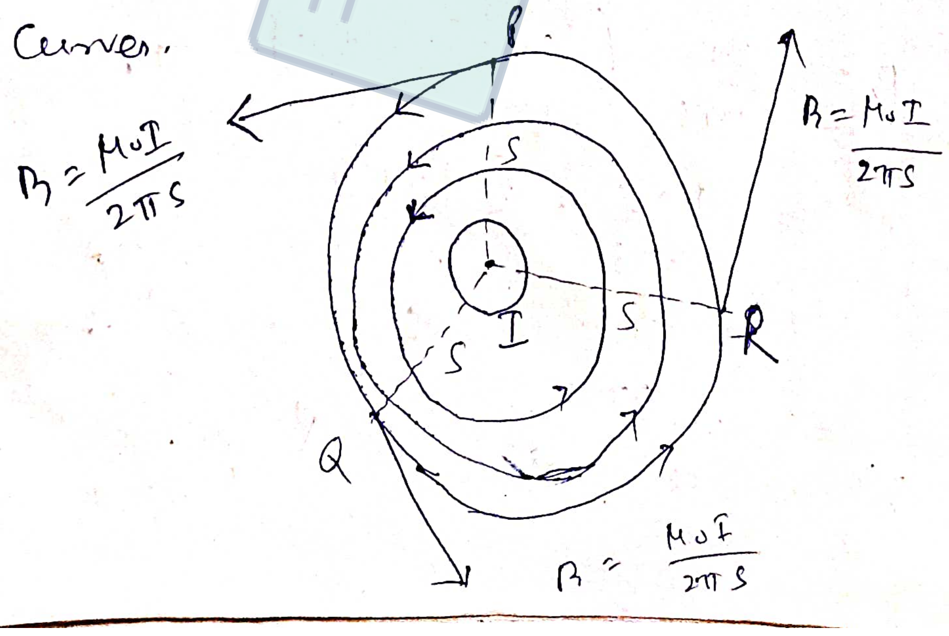
$\mu_0 = 4\pi\times10^{-7}\, wb.A^{-1}.m^{-1}$

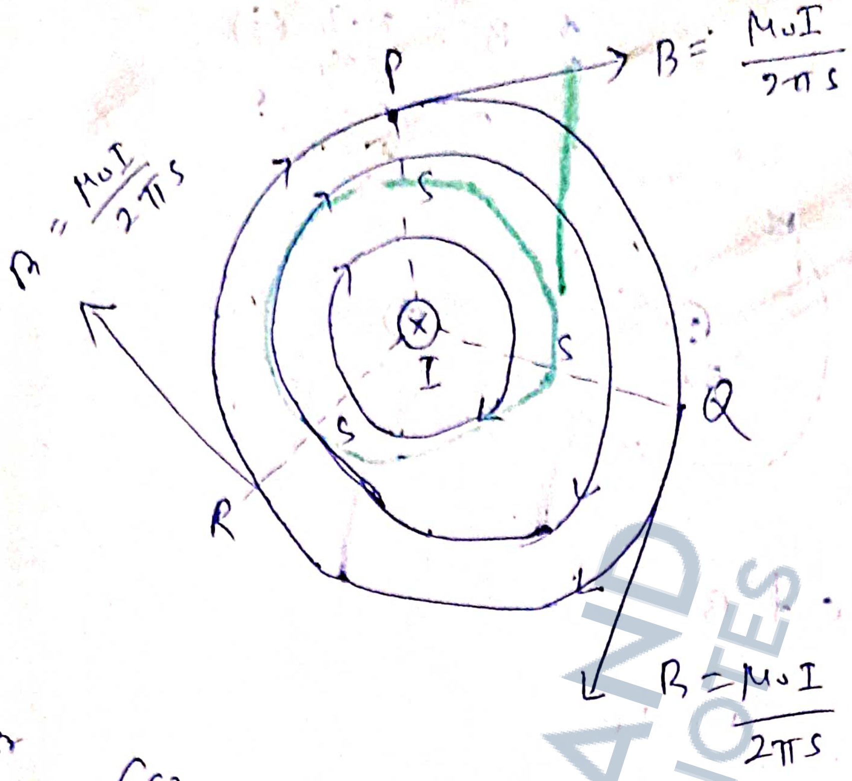
Variation of B with s is shown in the following graph



If the straight conductor will be ⊥ to the plane of the paper, then magnetic lines of force can be drawn which are concentric circles, having the conductor as there centre.

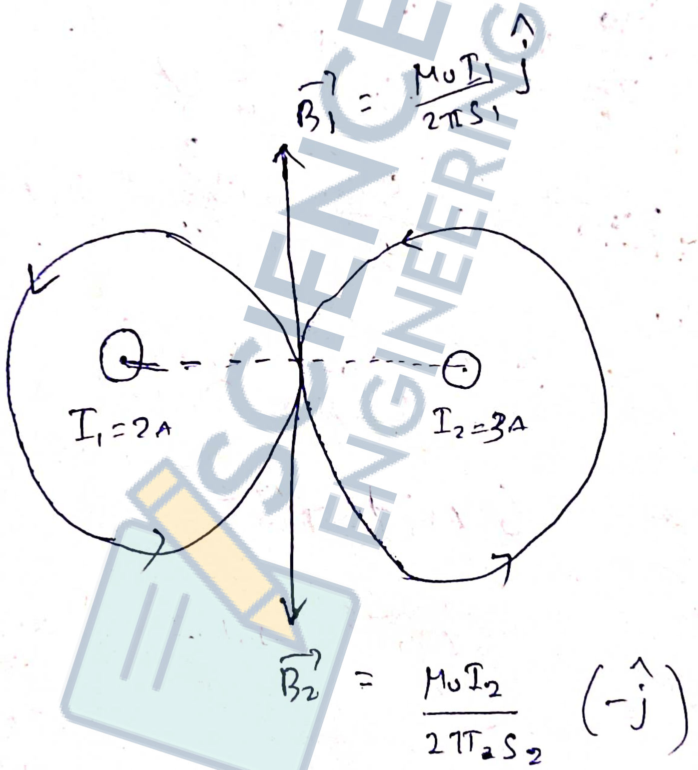
The direction of $\vec{B}$ are the tangents drawn at any point on the curves.





667

6.



$$\text{Net } B = |\vec{B_2}| - |\vec{B_1}|$$

$$= \frac{\mu_0 I_2}{2\pi s_2} - \frac{\mu_0 I_1}{2\pi s_1}$$

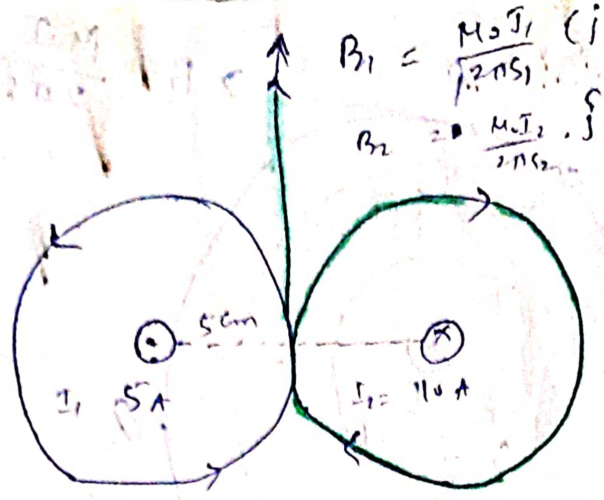
$$= \frac{2\times10^{-7}}{\cancel{2}} \cdot \frac{3}{5}\times 100 - \frac{2\times10^{-7}\times 2}{2\times 5}\times 100$$

$$= 10^{-7}(120 - 80) = 4\times10^{-6} \text{ wb/m}^2$$

8.

$B_1 = \frac{\mu_0 I_1}{2\pi S_1} (\hat{j})$

$B_2 = \frac{\mu_0 I_2}{2\pi S_2} \hat{j}$



Net B

$= B_1 + B_2$

$= \frac{\mu_0}{2\pi}\left(\frac{I_1}{S_1} + \frac{I_2}{S_2}\right)$

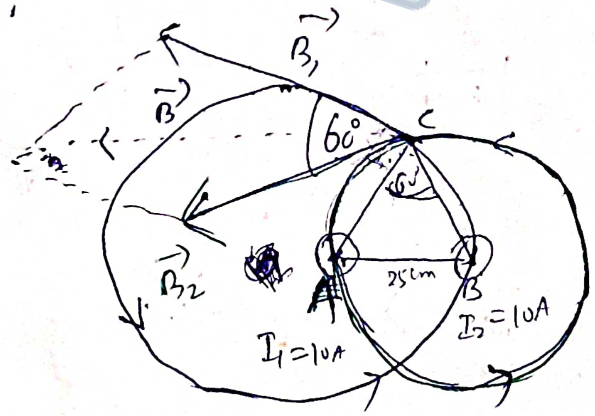
$= 2\times10^{-7}\left(\frac{5\times100}{5} + \frac{10\times100}{5}\right)$

$= 2\times10^{-7}(100 + 200)$

$= 6\times10^{-7}\times10^{2}$

$= 6\times10^{-5}$ wb/m², along the +ve Y direction.

15.



$$B_1 = \frac{\cancel{2\pi}\,\mu_0\, 10\times 100}{2\pi \cdot 25}, \quad B_2 = \frac{\mu\, 10\times 100}{2\pi \cdot 25}$$

$$\therefore B_1 = B_2$$

$$B = \sqrt{B_1^2 + B_2^2 + 2B_1 \cdot B_2 \cdot \cos 60}$$

$$= \sqrt{2B_1^2 + \cancel{2} \cdot B_1 \cdot B_1 \cdot \frac{1}{\cancel{2}}}$$

$$= \sqrt{3B_1^2}$$

$$= \sqrt{3}\, B_1$$

$$\therefore B = \sqrt{3} \times \frac{\mu}{2\pi} \times 40$$

$$= \sqrt{3} \times 2\times 10^{-7} \times 40$$

$$= \cancel{\ldots}$$

$$= 8\sqrt{3} \times 10^{-6}$$

$$= 8(1.732)\times 10^{-6}$$

$= 13.856 \times 10^{-6}$ Wb/m², along the direction which makes 30° with both $\vec{B_1}$ and $\vec{B_2}$.

~~Prob~~

Problem →

1. A square loop of wire of edge 'a' carries a current I. Show that the value of $\vec{B}$ at the centre is given by $B = \frac{2\sqrt{2}\,\mu_0 I}{\pi a}$

2. A straight wire segment of length l carries a current I. Show that $\vec{B}$ at a distance R from the segment along a perpendicular bisector is given by

$$B = \frac{\mu_0 I}{2\pi R} \times \frac{l}{(l^2+4R^2)^{\frac{1}{2}}}$$

Does this expression reduce to the expected result as $l \to \infty$? (Yes)

3. Prove that B at a centre of a rectangle of length l and width 'd' carrying a current I is given by $B = \frac{2\mu_0 I}{\pi} \cdot \frac{(l^2+d^2)^{\frac{1}{2}}}{ld}$ for $l \gg d$ what will be the result?

4. (13) page 668

↳ Ans 2.98×10^{-5} wb/m²

at 37° W of N,

1.8×10^{-6} wb/m²

along North.

5. 10 $k\Omega$ 2 only substracted.

3. $I = ?$, $B = 1 \times 10^{-7}$ wb/m2

$r = 4.5$ cm $= .045$ metre

$l = 12$ cm $= .12$ m

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

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

$$\Rightarrow I = \frac{B \times 4 \times \pi \times r^2}{\mu_0 \, l}$$

$$= \frac{\cancel{10^{-7}} \times \cancel{4 \times \pi} \times (.045)^2}{\cancel{4\pi \times 10^{-7}} \times 0.12}$$

$$= \frac{.045 \times .045}{.12}$$

$$= \frac{\frac{45}{1000} \times \frac{45}{1000}}{\frac{12}{100}} = \frac{\overset{3.75}{\cancel{45}} \times 45}{\underset{10^4}{\cancel{10^6}}} \times \frac{\cancel{10^2}}{\cancel{12}}$$

$$= \frac{168.75}{10000}$$

$= 0.016875$ Amp.

Direction is along the plane of paper.

4. $I = 18$ Amp, $B = 4.48 \times 10^{-4}$ wb/m2

$\theta = 3$ rad, $r = ?$

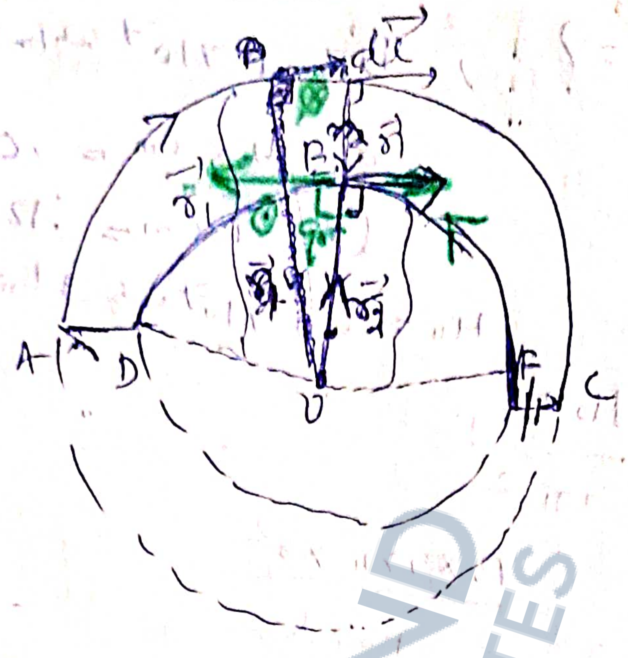
$$B = \frac{\mu_0 I \theta}{4\pi r}$$

$$\Rightarrow r = \frac{\mu_0 I \theta}{4\pi B} = \frac{\cancel{4\pi} \times \cancel{10^{-7}} \times 18 \times 3}{\cancel{4\pi} \times 4.48 \times \cancel{10^{-4}} \, 10^{3}}$$

$$= \frac{54}{4480} = .012 \text{ metre}$$

$= 1.2$ cm

10.



From Biot and Savart's law, the magnetic induction at a point O can be obtained by integrating the expression for $d\vec{B}$

For the curve at a distance r_1

$$\vec{B}_1 = \frac{\mu_0 I}{4\pi} \int \frac{\vec{dl} \times \vec{r}_1}{r_1^3}$$

$$= \frac{\mu_0 I}{4\pi} \int_{ABC} \frac{dl\, \cancel{r_1} \sin 90^\circ}{\cancel{r_1^3}\, r_1^2}$$

$$= \frac{\mu_0 I}{4\pi r_1^2} \int dl$$

$$= \frac{\mu_0 I\, l}{4\pi r_1^2} = \frac{\mu_0 I \times \pi r_1}{4\pi r_1^2} \quad \left(\because \text{curve} = \frac{2\pi r_1}{2} = \pi r_1 \right)$$

$$= \frac{\mu_0 I}{4 r_1}$$

$\vec{B}$ for the curve at a distance r_2

$$\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{\vec{dl} \times \vec{r}_2}{r_2^3}$$

$$\Rightarrow \vec{B_2} = \frac{\mu_0 I}{4\pi} \int \frac{dl\, r_2 \sin\alpha}{r_2 \cdot r_2^2}$$

$$= \frac{\mu_0 I}{4\pi r_2^2} l = \frac{\mu_0 I}{4\pi r_2^2} \cdot \frac{\pi r_2}{r_2}$$

$$= \frac{\mu_0 I}{4 r_2}$$

$\therefore$ Net Magnetic induction at P

$$= \vec{B_1} - \vec{B_2}$$

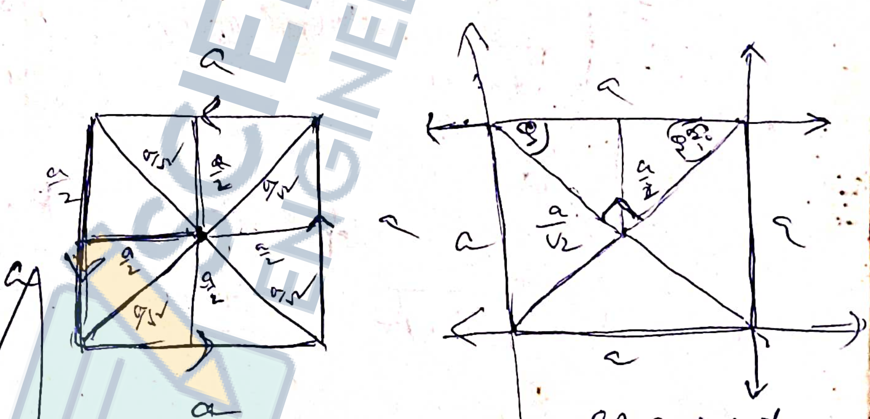
$$= \frac{\mu_0 I}{4 r_1} - \frac{\mu_0 I}{4 r_2}$$

$$= \frac{\mu_0 I}{4}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$ —— (Proved)

Direction out of the paper.

Problem

1.



$\vec{B}$ at a point near a straight current carrying current $= \frac{\mu_0 I}{2\pi S}$

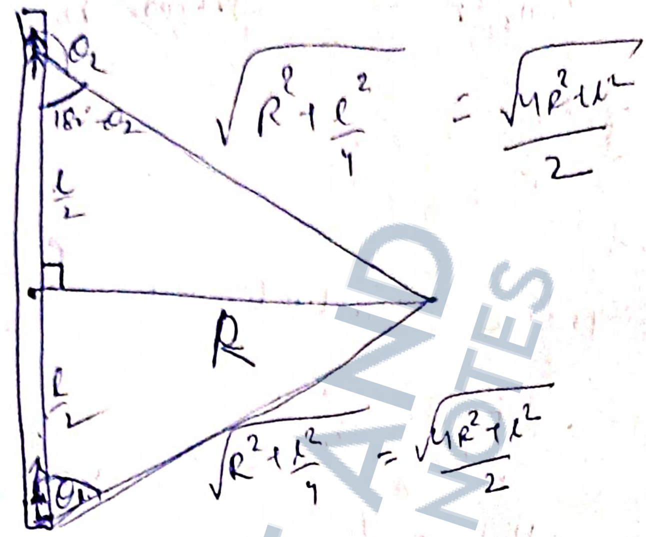
Consider the square to be consist of 4 conductors.

$$\vec{B} = \frac{4 \times \mu_0}{2\pi S}$$

At the centre distance $= \frac{a}{\sqrt{2}}$ from each conductor

$$\therefore B = \frac{2\mu_0 I}{\pi \cdot \frac{a}{\sqrt{2}}} = \frac{2\sqrt{2}\,\mu_0 I}{\pi a}$$

2.



$$B = (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{4\pi R}$$

$$= \left(\frac{\frac{l}{2}}{\frac{\sqrt{4R^2+l^2}}{2}} + \cos(180° - \theta_2)\right)\frac{\mu_0 I}{4\pi R}$$

$$= \left(\frac{l}{\sqrt{4R^2+l^2}} + \frac{\frac{l}{\cancel{2}}}{\frac{\sqrt{4R^2+l^2}}{\cancel{2}}}\right)\frac{\mu_0 I}{4\pi R}$$

$$= \frac{\cancel{2} \cdot l}{\sqrt{4R^2+l^2}} \times \frac{\mu_0 I}{\cancel{4}_{2}\pi R}$$

$$= \frac{\mu_0 I}{2\pi R} \cdot \frac{l}{\sqrt{l^2+4R^2}}, \quad (X)$$

If $l \to \infty$, $\theta_1 \to 0$, $\theta_2 \to 180°$

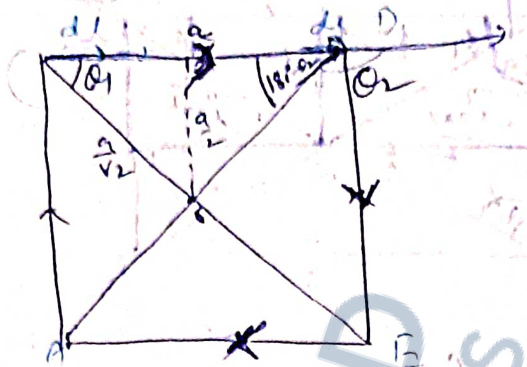
$\cos\theta_1 = 1$, $\cos 180° = -1$

$$B = \frac{2\mu_0 I}{2 \cdot 4\pi R} = \frac{\mu_0 I}{2\pi R} \quad \text{(Yes)}$$

It will be the expected result when

$l \to \infty$

1.



B for one side of square

$$= (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{4\pi\left(\frac{a}{2}\right)}$$

$$= (\cos 45^\circ - \cos 135^\circ)\frac{\mu_0 I}{\cancel{4}^{2}\pi \frac{a}{\cancel{2}}}$$

$$= \left(\frac{1}{\sqrt{2}} - \left(-\frac{1}{\sqrt{2}}\right)\right)\frac{\mu_0 I}{2\pi a} \quad \left(\because \theta_1 = 45^\circ,\ \theta_2 = 135^\circ\right)$$

$$= \left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right)\frac{\mu_0 I}{2\pi a}$$

$$= \frac{\cancel{2}}{\sqrt{2}} \times \frac{\mu_0 I}{\cancel{2}\pi a}$$

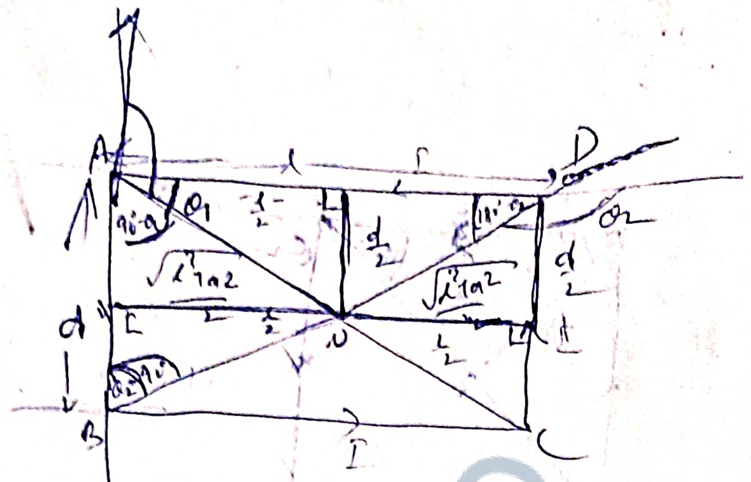
$$= \frac{\mu_0 I}{\sqrt{2} a \pi} \quad ; \quad \otimes$$

At the point O, for 4 conductors,

$$B = \cancel{4}^{2\sqrt{2}} \times \frac{\mu_0 I}{\cancel{\sqrt{2}} a \pi}$$

$$= \frac{2\sqrt{2}\,\mu_0 I}{\pi a}$$

3.



B for one side (lengthwise)

$$= (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{\cancel{4}^{2}\pi \frac{d}{\cancel{2}}}$$

$$= (\cos\theta_1 + \cos(180-\theta_2)) \cdot \frac{\mu_0 I}{2\pi d}$$

$$= \left(\frac{\frac{l}{\cancel{2}}}{\frac{\sqrt{l^2+d^2}}{\cancel{2}}} + \frac{\frac{l}{\cancel{2}}}{\frac{\sqrt{l^2+d^2}}{\cancel{2}}}\right)\frac{\mu_0 I}{2\pi d}$$

$$= \left(\frac{\cancel{2}\, l}{\sqrt{l^2+d^2}} \times \frac{\mu_0 I}{\cancel{2}\pi d}\right)$$

B for another side (breadth wise)

$$\angle BAO = 90° - \theta_1$$

To find $\angle ABD$

$$1\cancel{8}0° - \theta_2 + 90° + \angle ABD = 18\cancel{0}0$$

$$\Rightarrow \angle ABD = \theta_2 - 90°$$

$$B = (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= \left\{\cos(\theta_2 - 90^\circ) - \cos(90^\circ + \theta_1)\right\}\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= \left(\cos\{-(90^\circ - \theta_2)\} + \sin\theta_1\right\}\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= (\sin\theta_2 + \sin\theta_1)\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= (\sin(180^\circ - \theta_2) + \sin\theta_1)\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= \left(\frac{\frac{d}{\cancel{2}}}{\frac{\sqrt{l^2+d^2}}{\cancel{2}}} + \frac{\frac{d}{\cancel{2}}}{\frac{\sqrt{l^2+d^2}}{\cancel{2}}}\right)\frac{\mu_0 I}{2\pi l}$$

$$= \frac{\cancel{2} d}{\sqrt{l^2+d^2}} \times \frac{\mu_0 I}{\cancel{2}\pi l}$$

$$= \frac{\mu_0 I d}{\pi l \sqrt{l^2+d^2}}$$

$$\text{Net } B = 2\times\left\{\frac{\mu_0 I l}{\sqrt{l^2+d^2}\,\pi d} + \frac{\mu_0 I d}{\pi l\sqrt{l^2+d^2}}\right\}$$

$$= 2\left\{\frac{\mu_0 I l^2 + \mu_0 I d^2}{l\sqrt{l^2+d^2}\,\pi d}\right\}$$

$$= \frac{2\mu_0 I}{l\pi d}\left(\frac{l^2+d^2}{\sqrt{l^2+d^2}}\right) = \frac{2\mu_0 I}{l\pi d}\times\left(\sqrt{l^2+d^2}\right)$$

sp.

When $l >> d$

$\therefore$ d^2 can be neglected w.r.t. l^2.

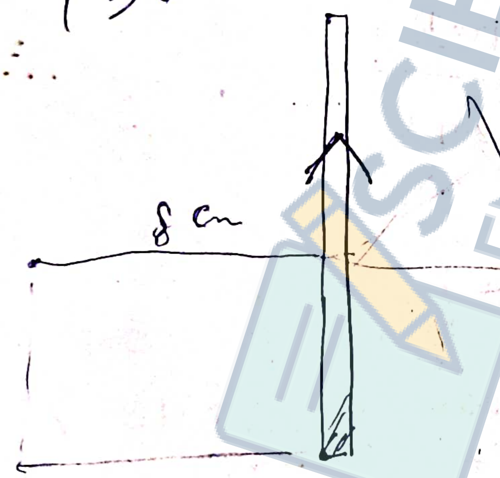
$\therefore$ The expression will be

$$\frac{2\mu_0 I \cancel{l}}{\pi \cancel{l} d}$$

$$= \frac{2\mu_0 I}{\pi d}$$

07. 66 space

13.



After 2 page

$$B_{wire} = \frac{\mu_0 I}{2\pi S} = \frac{\cancel{4\pi}\,2 \times 10^{-7} \times 7.2}{\cancel{2} \times \cancel{\pi} \times .08}$$

$$= \frac{2 \times 10^{-7} \times \cancel{7.2}\,.9 \times 100}{\cancel{8}}$$

$$= 1.8 \times 10^{-5} \text{ Wb/m}^2$$

$$\left.\begin{aligned} B_1 &= 1.8\times10^{-5} \\ B_2 &= 2.38\times10^{-5} \end{aligned}\right\} wb/m^2$$

$$B = \sqrt{B_1^2 + B_2^2 + 2B_1B_2.\cos\theta}$$

$$= \sqrt{\frac{(1.8)^2}{10^{10}} + \frac{(2.38)^2}{10^{10}} + 2.\underline{(1.8).(2.38)}\cos 90^\circ}$$

$$= \frac{\sqrt{3.24 + 5.6644}}{10^5} = \frac{\sqrt{8.9044}}{10^5} = 2.98\times10^{-5}$$

$$\phi = \tan^{-1}\left(\frac{B\sin\alpha}{A+B\cos\alpha}\right)$$

$$= \tan^{-1}\left(\frac{2.38\times\cancel{10^{-5}}\times1}{1.8\times\cancel{10^{-5}}}\right)$$

$$= \tan^{-1}\left(\frac{238}{180}\right)$$

$$= \tan^{-1}(1.322)$$

$$= 52^\circ\ 9'$$

or $$\tan^{-1}\left(\frac{1.8\times10^{-5}}{2.38}\right)$$

$$= \tan^{-1}\left(\frac{180}{238}\right)$$

$$= \tan^{-1}(.75)$$

$$= 37^\circ$$

3. For Side AB 

$$\vec{B} = (\cos\theta_1 - \cos\theta_2)\frac{\mu_0 I}{4\pi \frac{d}{2}} \qquad \theta_2 = \left(\cos\theta - \cos(180^\circ - \theta_1)\right)\frac{\mu_0 I}{4\pi \frac{l}{2}}$$

$$= \left(\frac{\frac{d}{2}}{\frac{\sqrt{l^2+d^2}}{2}} + \frac{\frac{d}{2}}{\frac{\sqrt{l^2+d^2}}{2}}\right)\frac{\mu_0 I}{2\cdot 4\pi \frac{l}{2}}$$

$$= 2\,\frac{d}{\sqrt{l^2+d^2}}\cdot\frac{\mu_0 I}{2\pi l} = \frac{\mu_0 I d}{\pi l\sqrt{l^2+d^2}}$$

For side AE

$$\vec{B'} = \left\{\cos\theta_1' - \cos(180^\circ - \theta_1')\right\}\frac{\mu_0 I}{2\cdot 4\pi \frac{d}{2}}$$

$$= \left(\frac{\frac{l}{2}}{\frac{\sqrt{l^2+d^2}}{2}} + \frac{\frac{l}{2}}{\frac{\sqrt{l^2+d^2}}{2}}\right)\frac{\mu_0 I}{2\pi d}$$

$$= 2\,\frac{l}{\sqrt{l^2+d^2}}\cdot\frac{\mu_0 I}{2\pi d}$$

Net $\vec{B} = 2\left\{\frac{\mu_0 I d}{\pi l\sqrt{l^2+d^2}} + \frac{\mu_0 I l}{\pi d\sqrt{l^2+d^2}}\right\}$

$$= 2\left\{\frac{\mu_0 I d^2 + \mu_0 I l^2}{\pi l d\sqrt{l^2+d^2}}\right\}$$

$$= \frac{2\mu_0 I\sqrt{l^2+d^2}}{\pi l d}$$

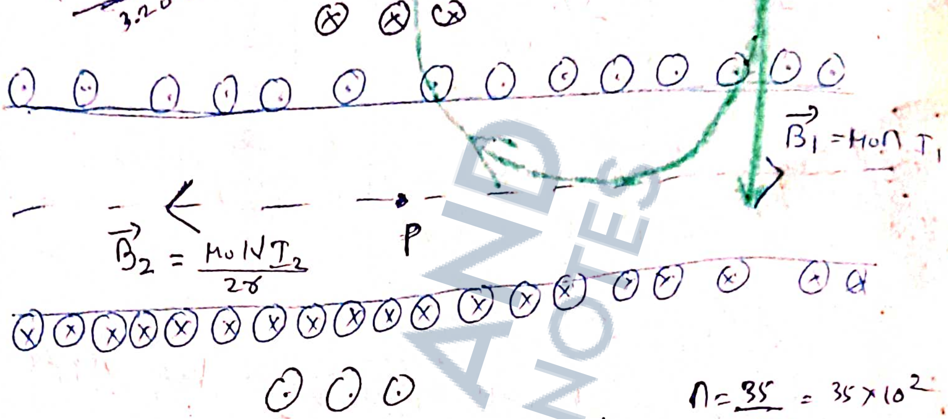
Application - 3

To find magnetic induction at the point P

P. 668

(16)

1020
314
4080
1020
3060
3.20280 × 10^5



$n = \frac{35}{.01\,m} = 35\times10^2$

$I_1 = 8A$

$N = 25,\ r = .06\,m = 6\times10^{-2}\,m$

$I_2 = 12A$

$$B_P = B_1 - B_2$$

$$= \mu_0 n I_1 - \frac{\mu_0 N I_2}{2r}$$

$$= \mu_0 \left(n I_1 - \frac{N I_2}{2r}\right) = \mu_0 \left(35\times10^2 .8 - \frac{25\times12}{2\times6\times10^{-2}}\right)$$

$$= \mu_0 \left(280\times10^2 - 25\times10^2\right)$$

$$= \mu_0 10^2 (255)$$

$$= 4\times3.14\times10^{-7}\times10^2 (255)$$

$$= 4\times314\times255\times10^{-7}$$

$$= 3.2028\times10^5\times10^{-7}$$

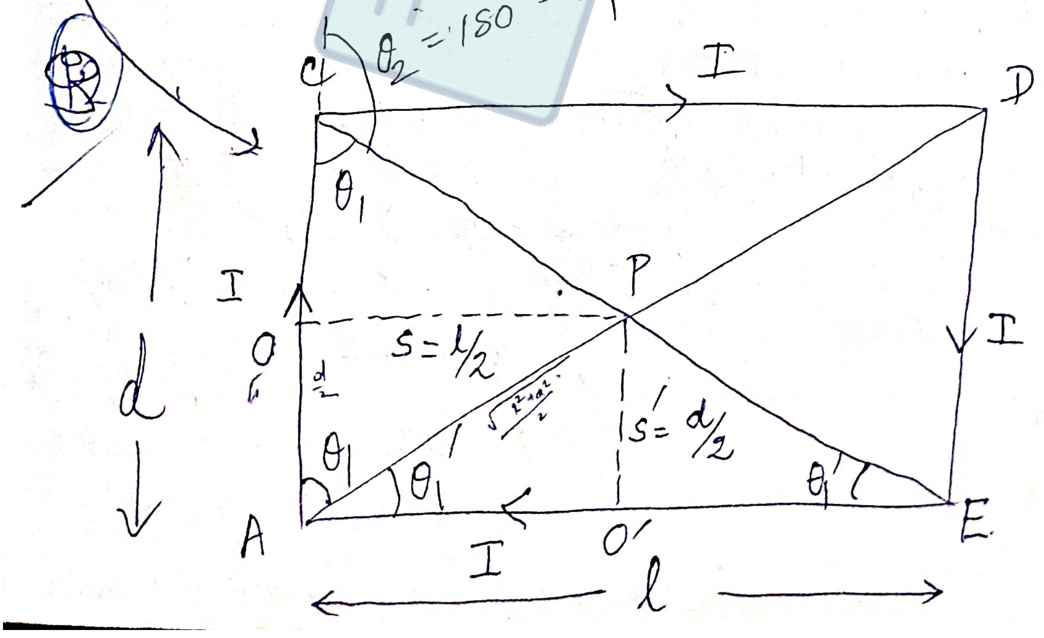
$$= 3.2028\times10^{-2}\ Wb/m^2$$

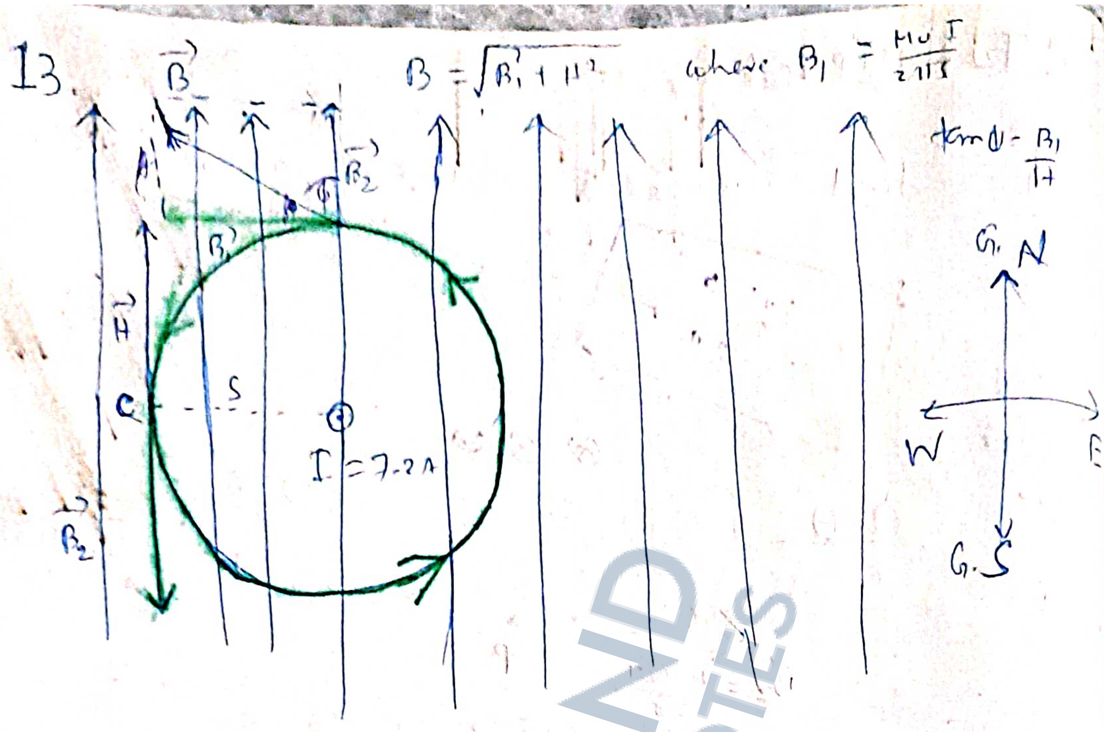
(Ans)

$\theta_2' = 180^\circ - \theta_1'$

$\theta_2 = 180^\circ - \theta_1$

(17)



13. 

$B_C = B_2 - H$, along the bigger vector.

<u>Ans</u>: $|\vec{B_1}| = |\vec{B_2}| = \frac{\mu_0 I}{2\pi s}$

$= \frac{2\times10^{-7}\times7.2}{\frac{8}{100}}$ Wb/m2

$= 2\times10^{-7}\times0.9\times10^{2}$

$= 1.8\times10^{-5}$ Wb/m2

(a) At the point A,

Using the law of parallelogram of vectors,

$B = \sqrt{B_1^2 + H^2}$

$= \sqrt{(1.8\times10^{-5})^2 + (2.38\times10^{-5})^2}$

$= 10^{-5}\sqrt{3.24 + 5.6644}$

$= 10^{-5}\times2.984$ Wb/m2

∴ Magnetic induction at a point, 8 cm from the wire north of the wire is 2.98×10^{-5} Wb/m2

(b) $\tan\phi = \frac{B_1}{H}$

$$= \frac{1.8\times10^{-5}}{2.38\times10^{-5}}$$

$$= 0.757 = 37^\circ \text{ W of N}$$

At point B,

$$B_C = H - B_2$$

$$= 2.38\times10^{-5} - 1.8\times10^{-5}$$

$$= 10^{-5}\times0.58$$

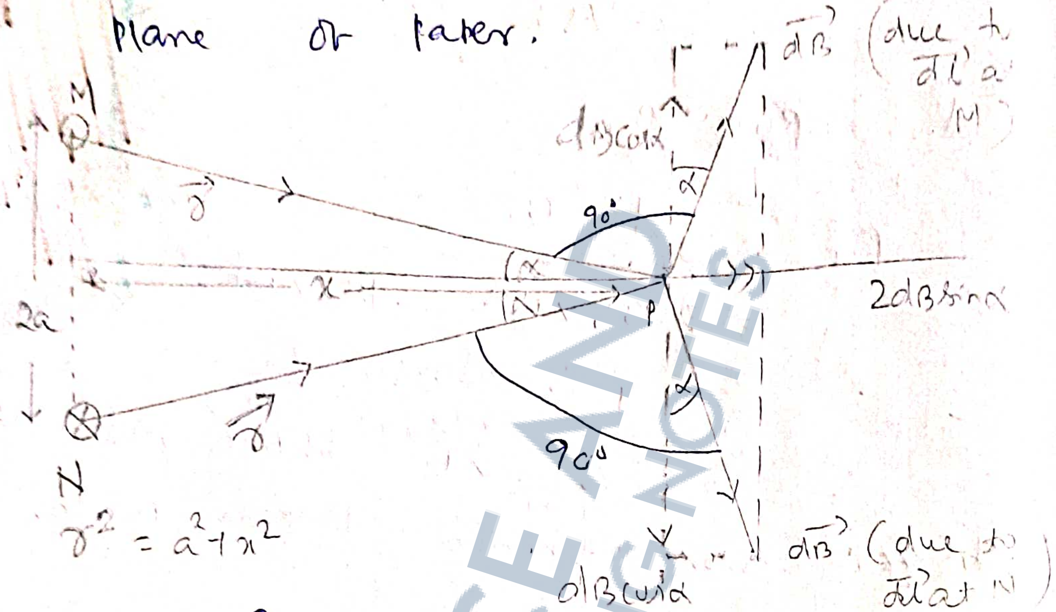
$$= 5.8\times10^{-6}\ \text{Wb/m}^2$$, along the bigger vector and hence towards north.

4. Application

To find $\vec{B}$ at any point on the axis of a circular coil carrying current

Let there are be 'N' number of turns on the circular coil of radius 'a'. One such turn be considered where current is flowing in the anticlockwise manner to an observer at P. To derive an expression

For $\vec{B}$ at P, let us represent the circular current carrying conductor MN, so that the axis of it can be represented on the plane of paper.



$r^2 = a^2 + x^2$

Choosing a small current element $\vec{dl}$ at M, we can apply Biot and Savart's law to find magnetic induction at P.

$$\therefore \quad d\vec{B_P} = \frac{\mu_0 I}{4\pi}\left(\frac{\vec{dl} \times \vec{r}}{r^3}\right)$$

$$= \frac{\mu_0 I}{4\pi} \frac{dl\, r \sin 90^\circ}{r^3}$$, direction being shown in the figure

$$dB_P = \frac{\mu_0 I}{4\pi} \cdot \frac{dl}{r^2}$$

One can resolve $d\vec{B_P}$ into two rectangular components, one being along the axis and the other being perpendicular to the axis. Choosing another current element

$\vec{dl}$ at the point N which is dimetrically opposite to M, we can write

$\vec{dB_P} = \frac{\mu_0 I}{4\pi} \frac{dl}{r^2}$, along a direction that makes α with the vertical & $(90^\circ - \alpha)$ with the axis as shown in the figure.

Resolving this vector into two rectangular components, we see that the component $dB\cos\alpha$ cancels out leaving behind $2\,dB\sin\alpha$.

Choosing always such pairs of current elements at diametrically opposite points it is seen that all the $dB\cos\alpha$ components cancel out. leaving behind $dB\sin\alpha$ components. Net magnetic induction at P due to all the current elements present in the circular ~~to~~ turn

$$= \sum dB \sin\alpha$$

$$= \sum \frac{\mu_0 I}{4\pi} \frac{dl}{r^2} \cdot \frac{a}{r}$$

$$= \frac{\mu_0 I a}{4\pi r^3} \sum dl$$

$$= \frac{\mu_0 I a}{4\pi r^3} \cdot 2\pi a$$

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

If $x = 0$, then the point P will be at the centre of the circular coil

$$\therefore B = \frac{\mu_0 I a^2}{2(a^2)^{\frac{3}{2}}} = \frac{\mu_0 I a^2}{2a^3} = \frac{\mu_0 I}{2a}$$

Since there are N numbers of turns in the coil, the magnetic induction is increased N times.

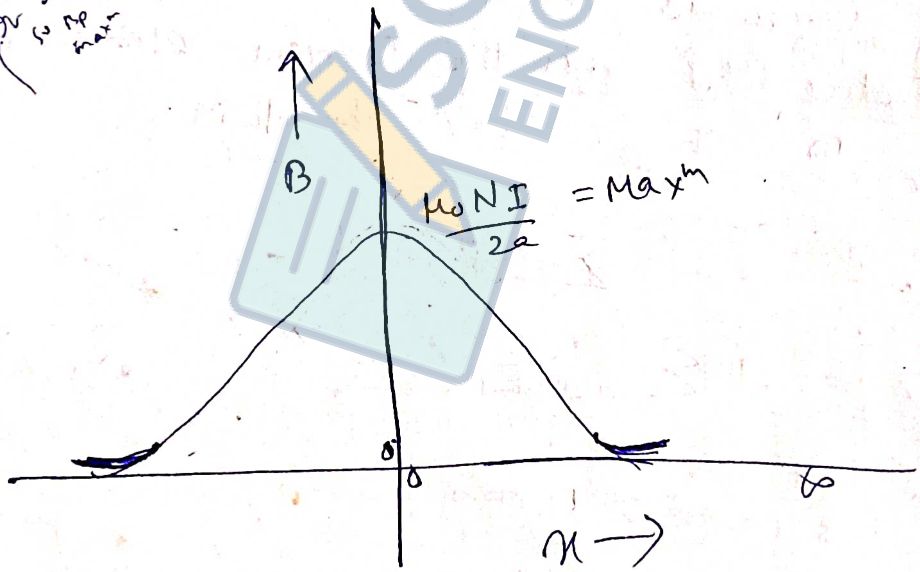
$$\boxed{\therefore \vec{B_P} = \frac{\mu_0 N I a^2}{2(a^2+x^2)^{\frac{3}{2}}}, \text{ directed away from the coil along the axis.}}$$

If $x \to \infty$, $B_P \to 0$

$x \to -x$, B_P remains unchanged.

$x \to 0$, B_P = Max^m $= \dfrac{\mu_0 N I}{2a}$.

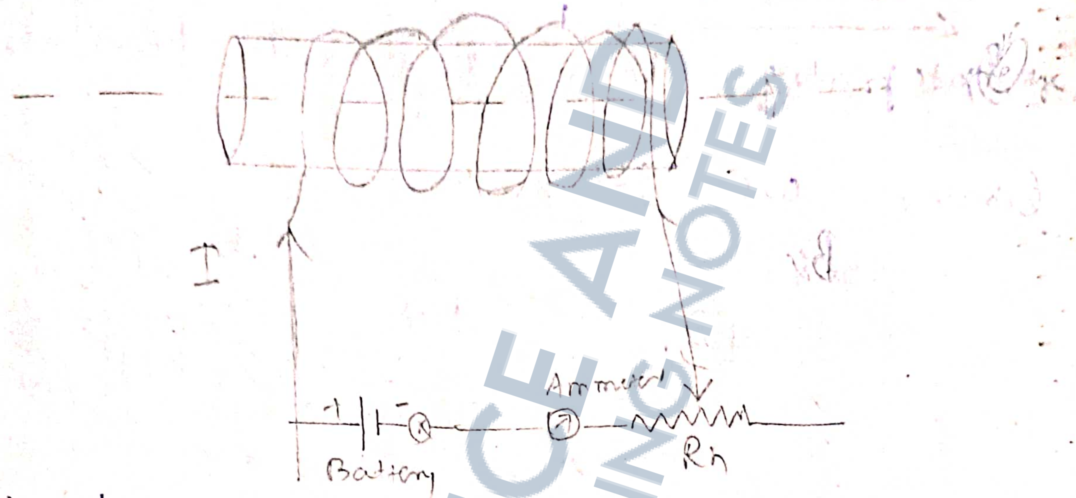
Minimum is : x^2 min value 0, dr min, so B_P is max



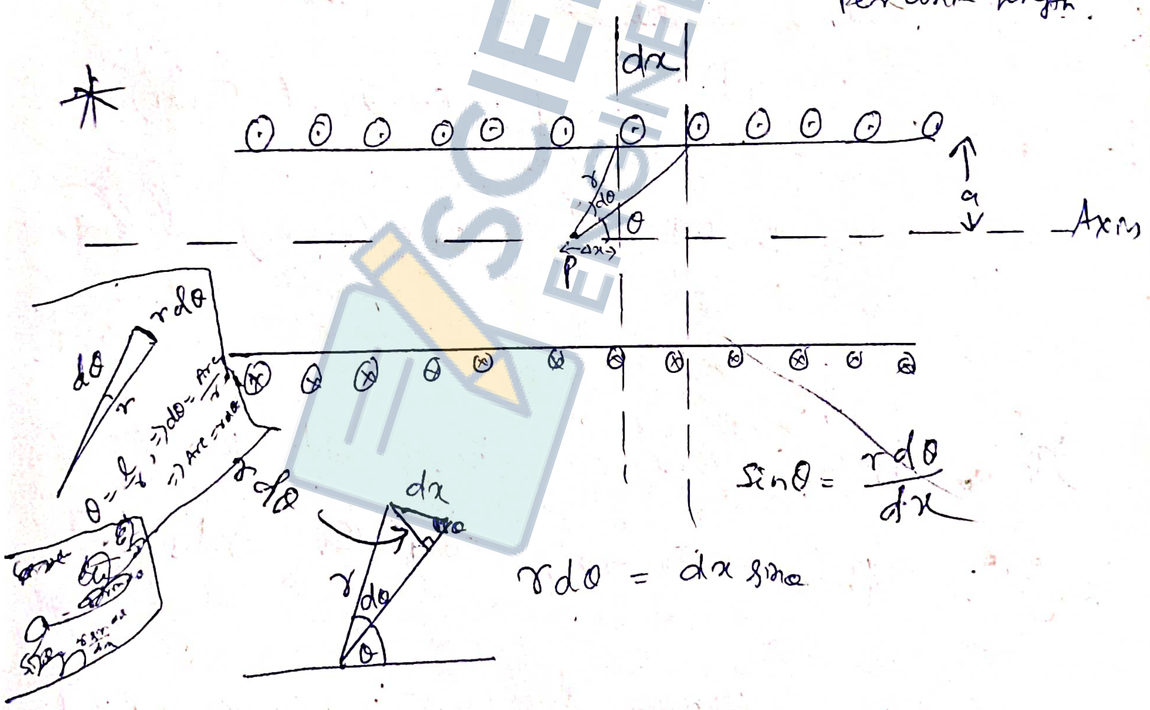
5. $\vec{B}$ at any point on the axis of a solenoid

Let's imagine the solenoid to be made

out of large number of circular coil each of width 'dx'. The magnetic induction at the point P due to one such coil be found out. Total number of turns in this coil width $dx = n\,dx$



$$|\vec{B}| = \mu_0 n I \text{, where } n = \frac{N}{L} = \text{number of turns per unit length.}$$



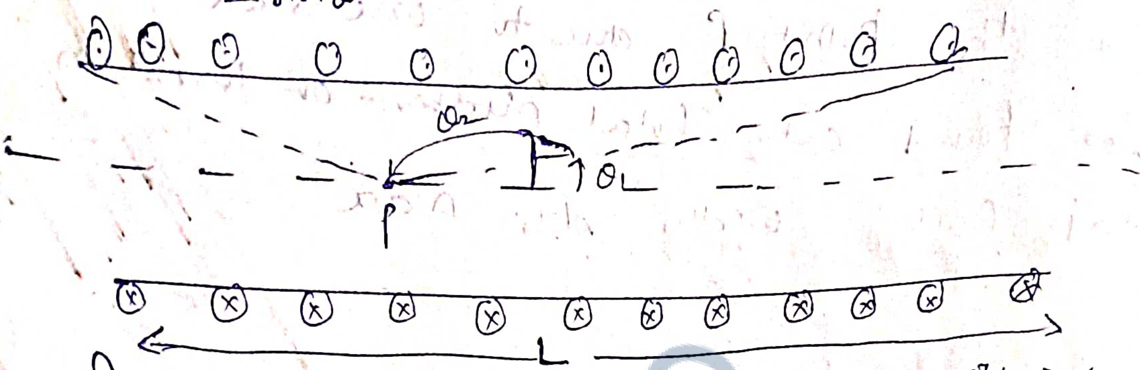
$$\sin\theta = \frac{r\,d\theta}{dx}$$

$$r\,d\theta = dx\sin\theta$$

$$dB_P = \frac{\mu_0 N I a^2}{2(a^2+x^2)^{\frac{3}{2}}} = \frac{\mu_0 n\,dx\,I a^2}{2r^3}$$

$$= \frac{\mu_0 \cdot n \cdot \frac{r\,d\theta}{\sin\theta} \cdot I a^2}{2r^3} = \frac{\mu_0 n\,d\theta \cdot I a^2}{2\sin\theta \cdot r^2}$$

$$\Rightarrow \frac{\mu_0 n' I \, d\theta \sin^2\theta}{2\sin\theta} \quad \left(\because \sin\theta = \frac{a}{r},\ \frac{a^2}{r^2} = \sin^2\theta\right) \Rightarrow \frac{\mu_0 n I \, d\theta \sin\theta}{2}$$



Integrating both the sides with proper limits, we get

$$\int_0^{B_P} dB_P = \frac{\mu_0 n I}{2} \int_{\theta_1}^{\theta_2} \sin\theta \, d\theta$$

$$\Rightarrow B_P = \frac{\mu_0 n I}{2} \Big[-\cos\theta\Big]_{\theta_1}^{\theta_2}$$

$$= \frac{\mu_0 n I}{2} \Big[-\cos\theta_2 - (-\cos\theta_1)\Big]$$

$$= \frac{\mu_0 n I}{2} (\cos\theta_1 - \cos\theta_2)$$ for a finite solenoid

If the solenoid be of infinite length then $\theta_1 \to 0$, and $\theta_2 \to 180^\circ$

$\therefore B$ (At any point on its axis) $= \frac{\mu_0 n I}{2} (\cos 0^\circ - \cos 180^\circ)$

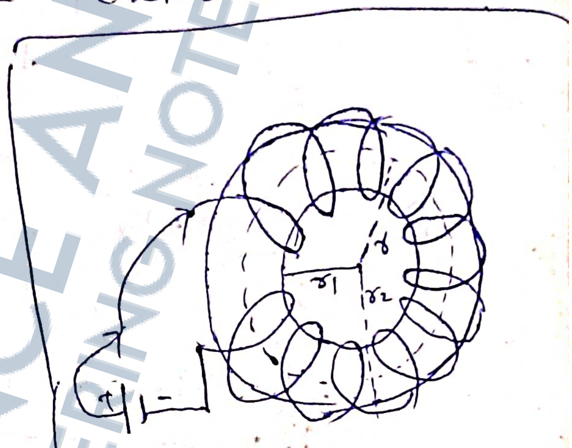
$$= \frac{\mu_0 n I}{2} (1 - (-1))$$

$$\therefore \boxed{B = \mu_0 n I}$$

The direction is decided by the right hand screw ~~B~~ rule.

6. $\vec{B}$ at any point on the axis of a ~~tor~~ toroid

It can be regarded as ~~a~~ an infinite solenoid so that the expression for $\vec{B}$ at any point on its axis will be the same as that of solenoid.



$B = \cancel{\ }\ \mu_0 n I$

where $n = \frac{N}{2\pi r}$ = Number of turns per unit length.

$r = \frac{r_1 + r_2}{2}$ = Average radius of the toroid.

Problems

Q.

$\cancel{B = \mu_0 n I}$

$= \cancel{4\pi \times 10^{-7} \times 30}$

30 turns per inch

30 turns per 2.54 cm

30 turns per .0254 meter.

$B = \mu_0 n I$

$B = 4\pi \times 10^{-7} \times \frac{\cancel{\ }}{\cancel{\ }} \times \frac{525}{100} = \frac{4 \times 3.14 \times \cancel{\ } \times 525}{10^6 \times 10^7}$

$B = \mu_0 n I$

30 turns per 1 inch

30 " " 2.54 cm

30 " " .0254 m

$$n = \frac{N}{L} = \frac{30}{.0254} = \frac{30}{\frac{254}{10000}} = \frac{30 \times 10000}{254}$$

$$= \frac{3 \times 10^5}{254}$$

$$B = 4\pi \times 10^{-7} \times \frac{3 \times 10^5}{254} \times 5.25$$

$$= \frac{(4 \times 3.14 \times 3 \times 5.25)}{254} \times 10^{-2}$$

$$= \frac{12 \times 16.485}{254} \times 10^{-2}$$

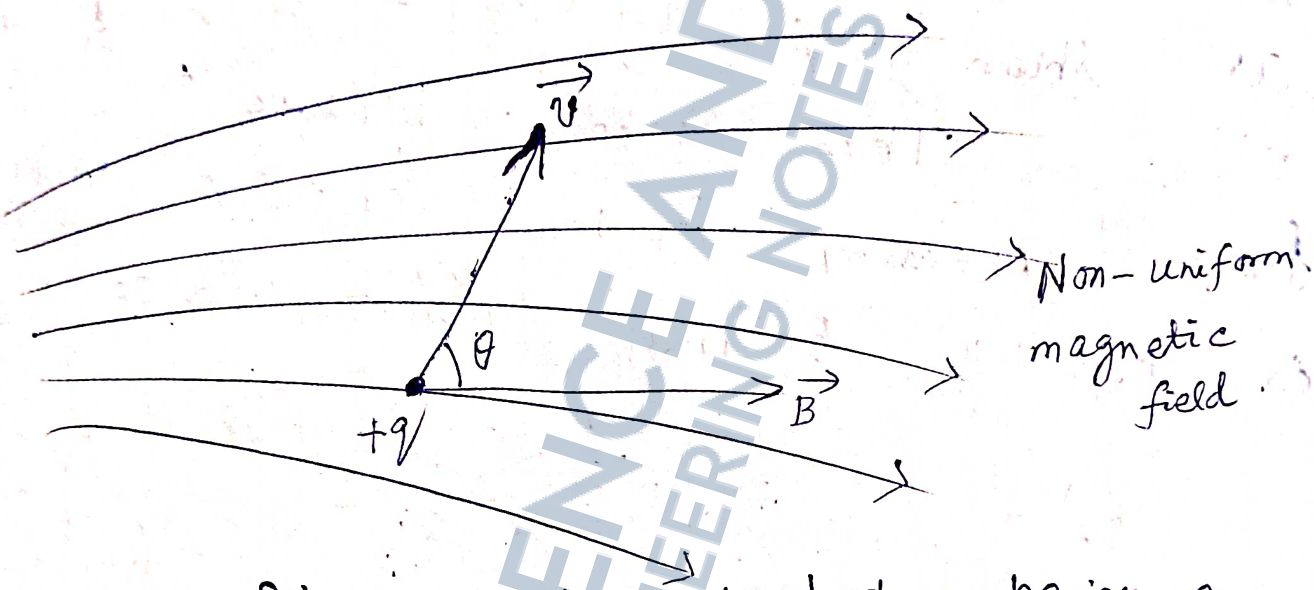
$$= \frac{197.820}{254} \times 10^{-2}$$

$$= \frac{1978.20}{254} \times 10^{-3}$$

$$= 7.788 \times 10^{-3}$$

18.08.2K

Lorentz force (Force on a charged particle moving in a magnetic field)



If a charged body having a charge $+q$ be moving with a velocity $\vec{v}$ in a magnetic field of strength $\vec{B}$, Lorentz has shown experimentally that the force experienced by the charge is given by

$$\boxed{\vec{F} = q(\vec{v} \times \vec{B})}$$

Magnitude of the force
$F = q \cdot VB \sin\theta$ and direction is into the plane of the paper

that contains $\vec{v}$ and $\vec{B}$.

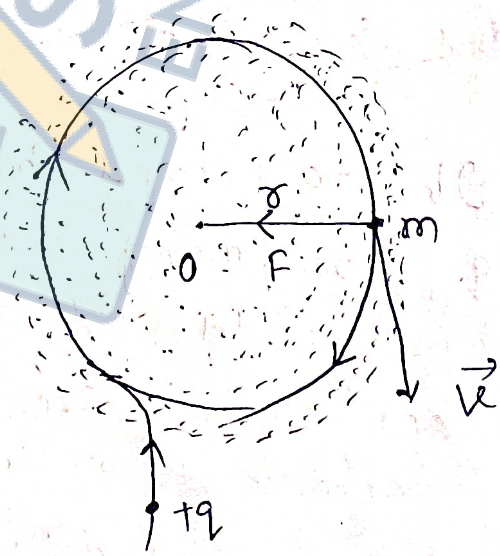
If $\theta = 90^\circ$, then the force becomes max^m and

$$F = qvB$$

Motion of a charged particle entering a uniform magnetic field at right angles

A +vely charged particle of mass 'm' is found to rotate in a circular path when it enters at right angles to a uniform upward magnetic field as shown in the figure.

This happens because the centripetal force necessary for the circular motion is provided by the Lorentz force.



$$\therefore \frac{mv^2}{r} = qvB\sin 90^\circ$$

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

$$\Rightarrow \frac{v}{r} = \frac{qB}{m}$$

T = Time period of revolution

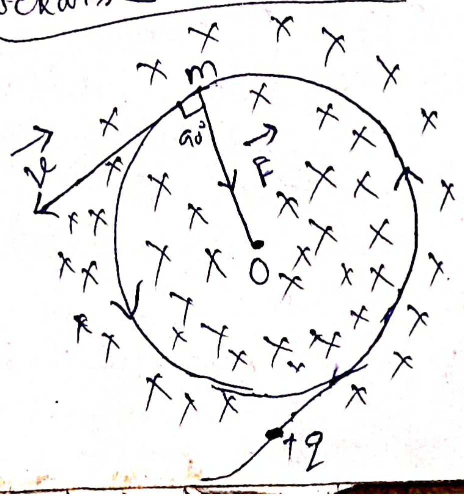
$$= \frac{2\pi r}{v}$$

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

= constant

If a -vely charged particle be introduced into such a magnetic field then that represented by dots, particle is found to rotate in a circular path, but in an anticlockwise manner.

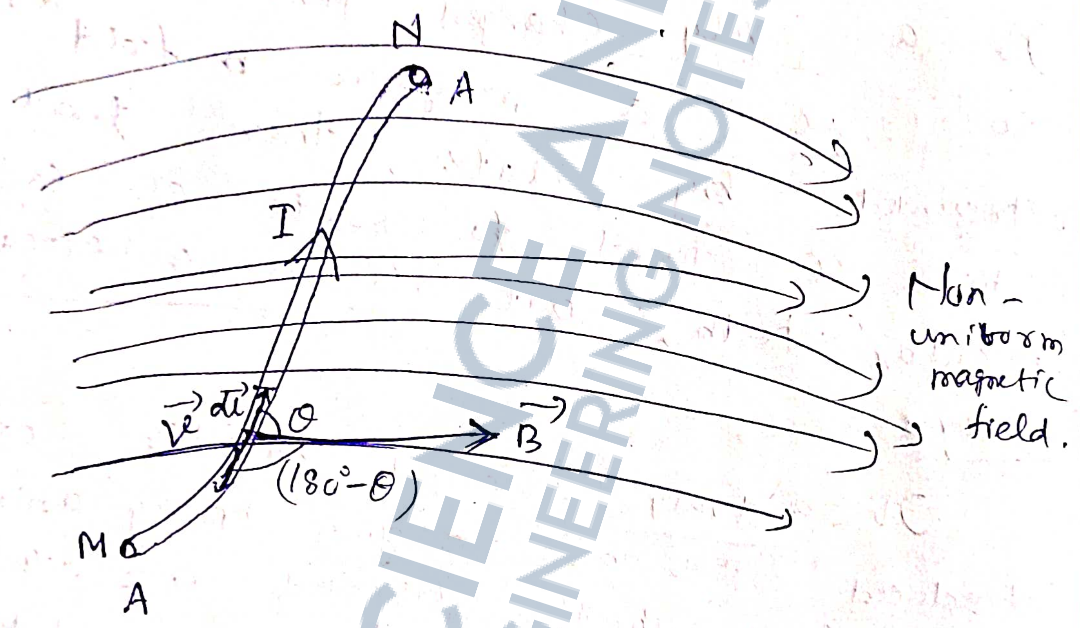
If a +vely charged particle be introduced into a region having uniform magnetic field but directed into the plane of the paper, then it rotates in a circular path but in the anticlockwise manner. A -vely charge particle entering into such a uniform field (represented by crosses) is found to rotate in the clockwise manner



Force on a current carrying Conductor Placed in a magnetic field

The conductor MN can be imagined to be made out of large number of small current elements $\vec{dl}$ chousen along the direction of the current.

If the direction of current is from M to N, then the electrons



must be moving in the opposite direction with a drift velocity $\vec{v_e}$.

Each electron experiences Lorentz force and the total force experienced by all the electrons present in the current element will be equal to the current force ~~expr~~ experienced by the current element.

Volume of the current element

$= A.dl$ (where A = Area of crossection of the conductor)

If n = Number of electrons per unit volume, then total number of electrons present in the current element

$= n.A.dl$

Force on each electron

$= q(\vec{v} \times \vec{B})$

$= (-e)\, vB \sin(180° - \theta)$, $\odot$

$= -evB\sin\theta$, $\odot$

$= evB\sin\theta$, $\otimes$

Force on all the electrons present on the current element

$d\vec{F} = nAdl \cdot evB\sin\theta$, $\otimes$

$= (nAve)\, dl\, B\sin\theta$, $\otimes$

$= I\, dl\, B\sin\theta$, $\otimes$

$= I(\vec{dl} \times \vec{B})$

Integrating both the sides, one can get the total force experienced by the entire current carrying conductor MN.

$$\int_0^F \vec{dF} = I \int_{MN} \vec{dl} \times \vec{B}$$

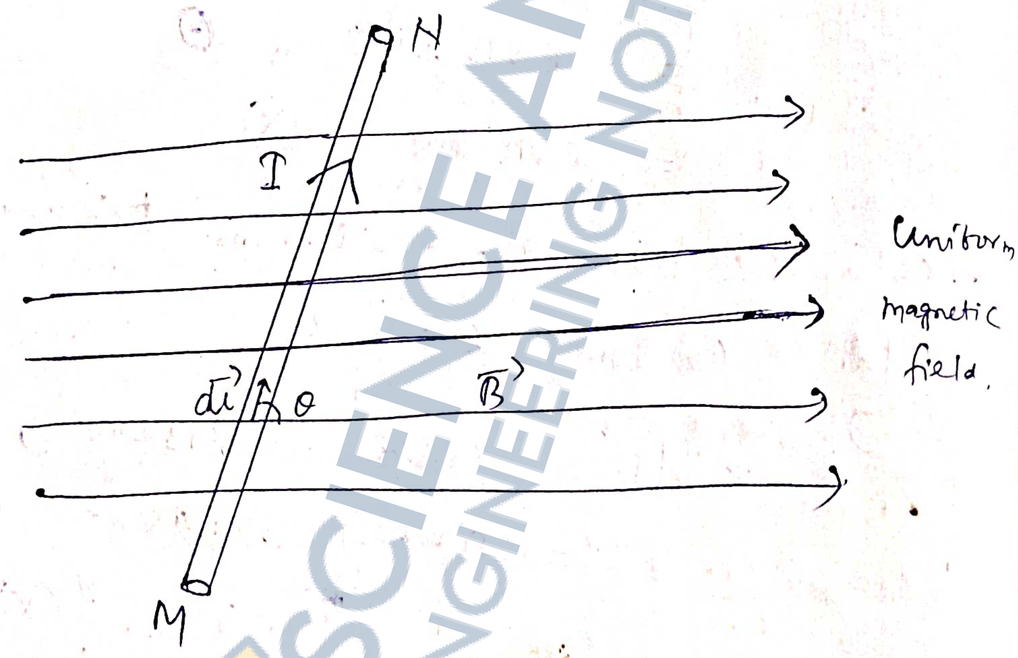
$$\Rightarrow \boxed{\vec{F} = I \int_{MN} \vec{dl} \times \vec{B}}$$

Special case

1. Straight conductor placed in a uniform magnetic field

Here θ and B are constants for all current elements choosen on MN.

$$\therefore \vec{F} = I \int_{MN} dl\, B \sin\theta , \quad (X)$$



$$\therefore \vec{F} = I B \sin\theta \int_{MN} dl , \quad (X)$$

$$= I B L \sin\theta , \quad (X)$$

If the conductor will be at right angles to the uniform field, then $\theta = 90°$.

and $\vec{F} = I B L , \quad (X)$

$= Max^m$

If the conductor will lie

along the field direction, then

$$\theta = 0^\circ$$

and $\vec{F} = 0$

i.e the conductor will not experience any force.

Task → page 668 → 14, 18
684 → 4, 9, 12

Defⁿ and units of magnetic induction

Method:1 (From Lorentz force)

We have seen that the expression for the force experienced by a charged particle moving with a velocity $\vec{v}$ in a magnetic field is given by the expression

$$\vec{F} = q(\vec{v} \times \vec{B})$$

$$\Rightarrow F = qvB\sin\theta$$

$$\Rightarrow B = \frac{F}{qv\sin\theta}$$

When $q = 1$ unit, $v = 1$ unit, $\theta = 90^\circ$

then $B = F$

Thus, magnetic induction at a point in a magnetic field can be defined as numerically equal to the force experienced by a unit +ve charge moving with unit

unit velocity at right angle to the magnetic field at that point.

C.G.S unit of B $= \frac{\text{Dyne}}{\text{Stat Colomb} \cdot \text{Cm/sec}}$

$= \frac{\text{Dyne sec}}{\text{Stat Colomb}\cdot\text{Cm}}$.

M.K.S unit of B $= \frac{\text{Newton sec}}{\text{Colomb - meter}}$

Relation :

$$\frac{1 \text{ Newton} \times 1 \text{ sec}}{1 \text{ colomb} \times 1 \text{ meter}}$$

$$= \frac{10^5 \text{ dyne} \times 1 \text{ sec}}{3\times10^9 \text{ Stat C} \times 100 \text{ Cm}}$$

$$= \frac{1}{3} \times 10^{-6} \cdot \frac{\text{dyne sec}}{\text{Stat C}\cdot\text{Cm}}$$

Method : 2

(B) (easier to write) From magnetic flux

Magnetic flux is a scalar quantity defined as

$$\phi_m = \int_S \vec{B} \cdot \hat{n} \, ds$$

Which reduces to the simple form

$\phi_m = BA$ when the area is plane and kept at right angles to the uniform magnetic field

$$\therefore B = \frac{\phi_m}{A} = \text{Flux density}$$

If $A = 1$ square unit,

then $B = \phi_m$

Thus magnetic induction can be defined as numerically equal to the magnetic flux over unit area kept at right angles to the uniform magnetic field.

$$\text{C.G.S unit of } B = \frac{\text{Maxwell}}{\text{cm}^2} = \text{Gauss}$$

$$\text{M.K.S unit of } B = \frac{\text{weber}}{\text{m}^2} = \text{Tesla.}$$

Relation between Tesla and Gauss

$$1 \text{ Tesla} = \frac{1 \text{ Weber}}{1 \text{m}^2} = \frac{10^8 \text{ maxwell}}{(100 \text{ cm})^2}$$

$$= 10^4 \frac{\text{Maxwell}}{\text{cm}^2} = 10^4 \text{ Gauss.}$$

Method- 3

From the expression for the force experienced by a current carrying conductor placed in a magnetic field

The force experienced by a current carrying conductor is found to be

$$\vec{F} = I \int \vec{dl} \times \vec{B}$$

If the conductor will be straight

and the field be uniform, then

$$F = IBl\sin\theta$$

$$\Rightarrow B = \frac{F}{Il\sin\theta}$$

When $I = 1$ unit, $l = 1$ unit, $\theta = 90°$,

then $B = F$

Thus, magnetic induction can be defined as numerically equal to the force experienced by a straight conductor of unit length kept at right angles to a uniform magnetic field in which a unit current is flowing.

<u>C.G.S. unit of B</u> $\dfrac{\text{Dyne}}{\text{ab ampere . Cm}}$ = Gauss

where 1 ab ampere = 10 Amp

M.K.S unit of B $\dfrac{\text{Newton}}{\text{Amp. meter}}$ = Tesla

<u>Relation between Tesla and Gauss</u>

$$1 \text{ Tesla} = \frac{1 \text{ Newton}}{1 \text{ Amp. } 1 \text{ meter}} = \frac{10^5 \text{ dyne}}{\frac{1}{10} \text{ ab ampere} . 10^2 \text{ Cm}}$$

$$= \frac{10^7 \text{ dyne}}{\text{ab ampere . Cm}} = 10^4 \text{ Gauss.}$$

Problem 668 page

14. $\frac{V}{r} = \frac{qB}{m}$

$\Rightarrow V = \frac{rqB}{m}$

$= \frac{.04\,m \times 1.6 \times 10^{-19}\,c \times 5 \times 10^{-3}}{9.1 \times 10^{-31}}$

$= \frac{.32}{9.1} \times 10^{-22} \times 10^{31}$

$= \frac{32}{9.1} \times 10^{-24} \times 10^{31}$

$= 3.5 \times 10^{7}$ m/sec.

18. $T = 2\pi \cdot \frac{m}{qB}$

$= \frac{\cancel{2} \times 3.14 \times 9.1 \times 10^{-31}\,kg}{.8\,\cancel{1.6} \times 10^{-16}\,c \times (0.6) \times 10^{-4}}$

$= \frac{3.14 \times 9.1}{0.8 \times 0.6} \times 10^{-31} \times 10^{16} \times 10^{4}$

$= \frac{\cancel{3.14}^{1.57} \times 9.1}{\cancel{0.8}_{.4} \times 0.6} \times 10^{-11}$

$= \frac{1.57 \times 9.1 \times 10^{2}}{24} \times 10^{-11}$

$= \frac{1428.7}{24} \times 10^{-11}$

$= 58.6 \times 10^{-11}$

$= .586 \times 10^{-9}$.

19.08.2

Q. No. 4. Force between two long, straight, parallel current carrying conductor

Experimental it is found that two conductors having current in the same direction attract each other whereas they repell each other if the directions of current are opposite in the two wires.

Case 1 → Like currents

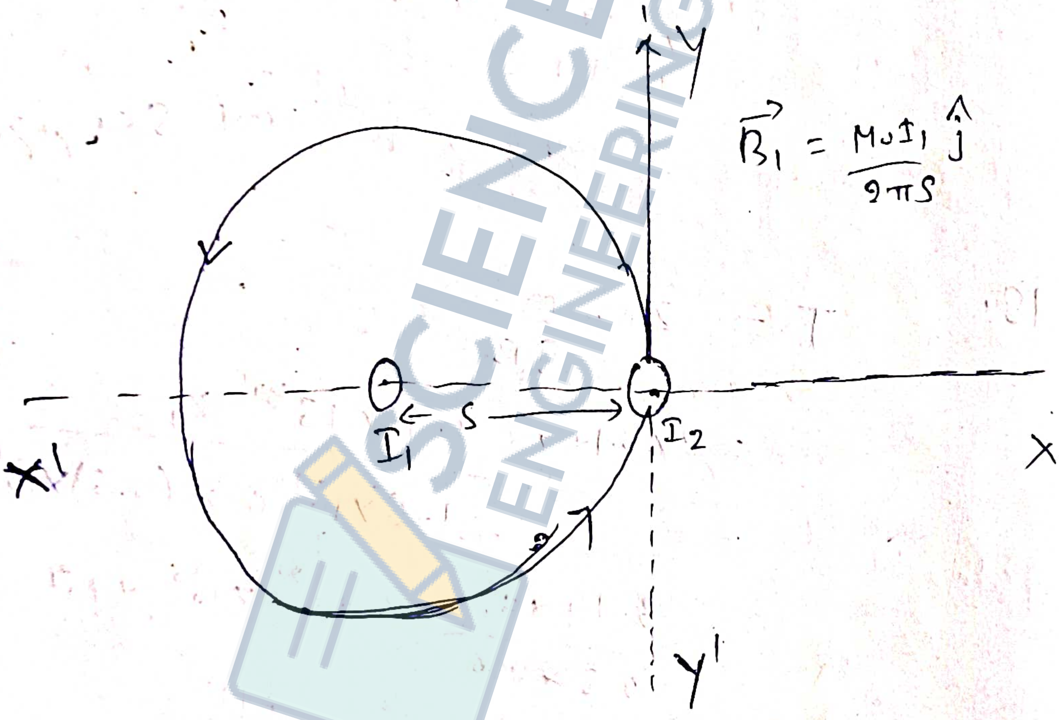
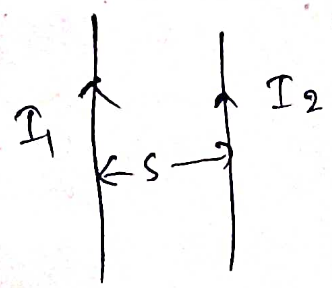


Fig (i)



Lets represent the straight conductors as 2 dots on the plane of the paper as shown in the figure (i). Choosing a small current element $\vec{dl}$ on the second conductor we see that the force experienced by it is given by $\vec{dF_2} = I_2(\vec{dl} \times \vec{B_1})$

$$= I_2 \left(dl\,\hat{k} \times \frac{\mu_0 I_1}{2\pi s} \hat{j} \right)$$

$$= I_2 \cdot dl \frac{\mu_0 I_1}{2\pi s} (\hat{k} \times \hat{j})$$

$$= \frac{\mu_0 I_1 I_2 dl}{2\pi s} (-\hat{i})$$

Integrating both the sides, we can get the expression for force on a straight conductor of length 'l'.

$$\int_0^{F_2} d\vec{F_2} = \frac{\mu_0 I_1 I_2 (-\hat{i})}{2\pi s} \int_0^{l} dl$$

$$\Rightarrow \boxed{\vec{F_2} = \frac{\mu_0 I_1 I_2 (-\hat{i})}{2\pi s} \cdot l}$$

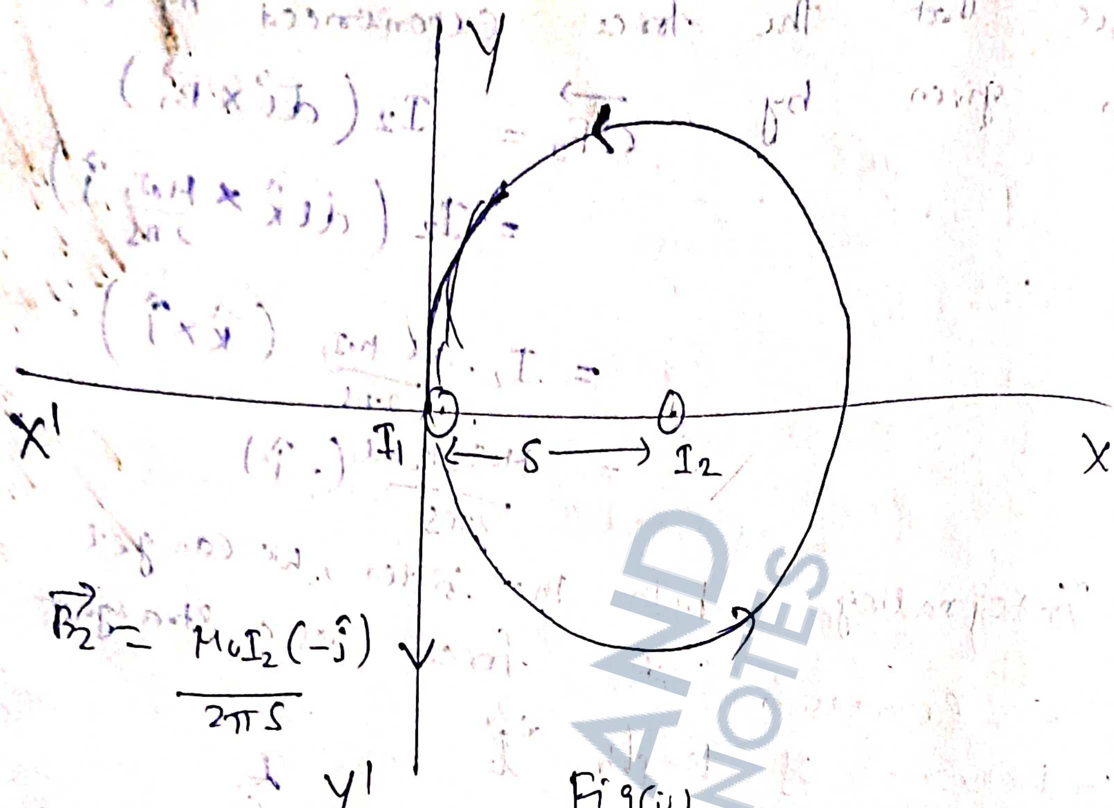
The presence of the $-\hat{i}$ in the expression for the $\vec{F_2}$ clearly shows that the 2nd conductor is attracted towards the first conductor with a force $\frac{\mu_0 I_1 I_2 l}{2\pi s}$.

Choosing a small current element $\vec{dl}$ on the first conductor we see that the force experienced by it is given by

$$\vec{dF_1} = I_1 (\vec{dl} \times \vec{B_2})$$

$$= I_1 \left(dl\,\hat{k} \times \frac{\mu_0 I_2}{2\pi s} (-\hat{j}) \right)$$

$$= \frac{I_1 I_2 \mu_0 dl}{2\pi s} (\hat{k} \times (-\hat{j}))$$



$$\vec{B_2} = \frac{\mu_0 I_2 (-\hat{j})}{2\pi S}$$

Fig (ii)

$$\therefore \; \vec{dF_1} = \frac{I_1 I_2 \mu_0 \, dl}{2\pi S} \hat{i}$$

Integrating both the sides, we can the expression for the force on a straight line conductor of length l

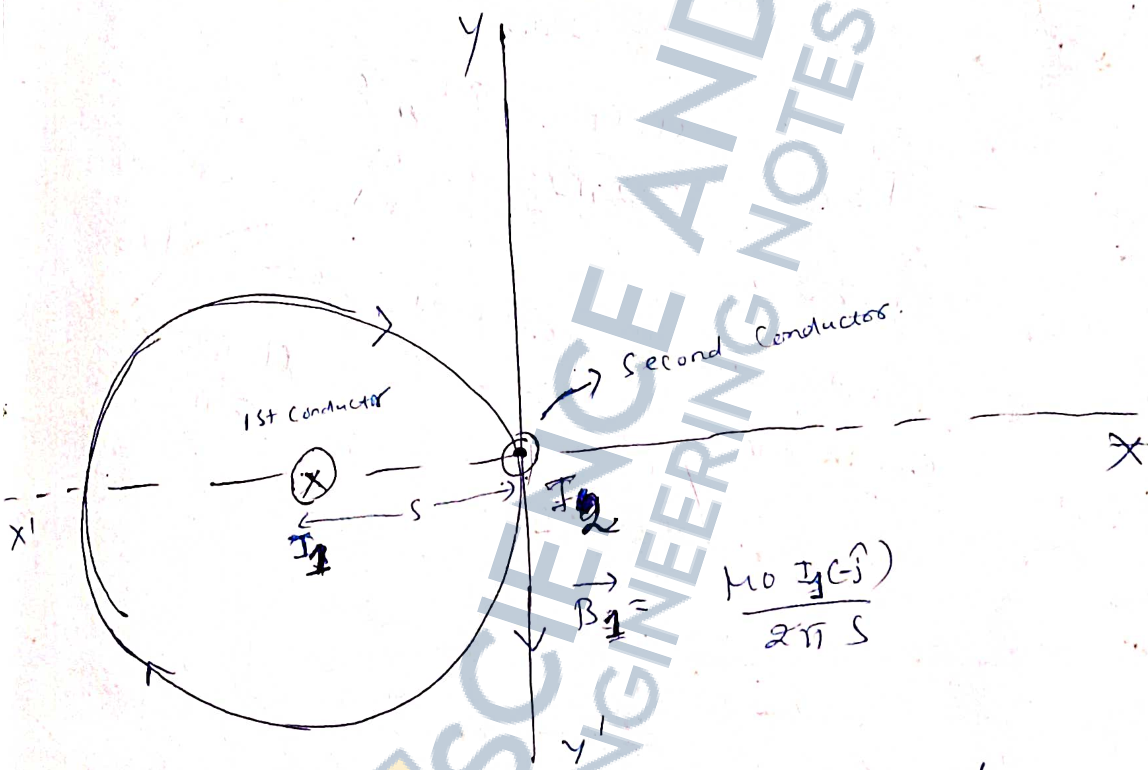
$$\int_0^{F_1} \vec{dF_1} = \frac{\mu_0 I_1 I_2 \hat{i}}{2\pi S} \int_0^l dl$$

$$\Rightarrow \boxed{\vec{F_1} = \frac{\mu_0 I_1 I_2 \hat{i} \, l}{2\pi S}}$$

The presence of $\hat{i}$ in the expression ~~clearly shows~~ that for the $\vec{F_1}$ clearly shows that the 1st conductor is attracted towards 2nd conductor with a force $\frac{\mu_0 I_1 I_2 \, l}{2\pi S}$.

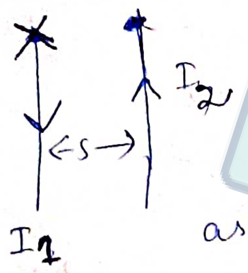
Thus the two conductors attract with same force of magnitude $\frac{\mu_0 I_1 I_2 l}{2\pi s}$

(ii) 2nd ~~Conductor~~ Case → Unlike currents



$$\vec{B}_1 = \frac{\mu_0 I_1(-\hat{j})}{2\pi s}$$

(iii)



Lets represent one of the straight conductors as cross and another as dot in the plane of the paper as shown in the figure (iii). Choosing a small current element $\vec{dl}$ on the 2nd conductor we see that force experienced by it is given by

$$\vec{dF_2} = I_2(\vec{dl} \times \vec{B_1})$$

$$= I_2\left(dl\hat{k} \times \frac{\mu_0 I_1(-\hat{j})}{2\pi s}\right)$$

$$= \frac{I_1 I_2 \mu_0 dl}{2\pi s}\left(\hat{k} \times (-\hat{j})\right)$$

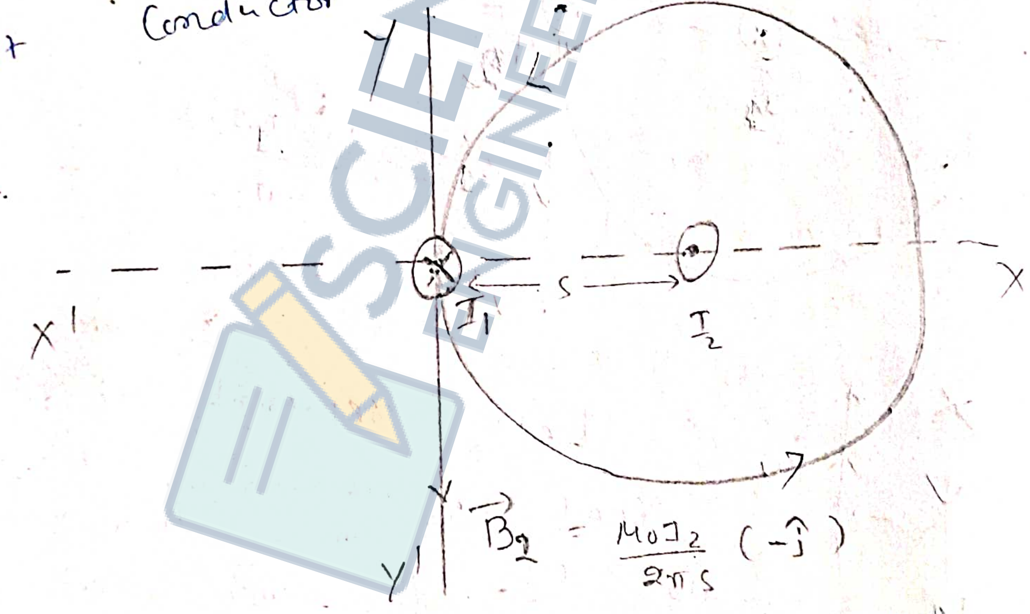
$$\therefore \vec{dF_2} = \frac{\mu_0 I_1 I_2}{2\pi s} dl (\hat{i})$$

Integrating both the sides, we can get the expression for the force on the 2nd straight conductor of length l

$$\int_0^{F_2} \vec{dF_2} = \frac{\mu_0 I_1 I_2 \hat{i}}{2\pi s} \int_0^l dl$$

$$\Rightarrow \vec{F_2} = \frac{\mu_0 I_1 I_2}{2\pi s} (\hat{i}) l$$

The presence of $\hat{i}$ in the expression shows that the second conductor is repelled by the 1st conductor with a force $\frac{\mu_0 I_1 I_2 l}{2\pi s}$.



Choosing a small current element $\vec{dl}$ on the first conductor we see that the force experienced by it, is given by

$$\vec{dF_1} = I_1 (\vec{dl} \times \vec{B_2})$$

$$\vec{dF_1} = I_1 \left(dl(-\hat{k}) \times \frac{\mu_0 I_2}{2\pi s}(-\hat{j}) \right)$$

$$= \frac{\mu_0 I_1 I_2}{2\pi s} dl \left((-\hat{k}) \times (-\hat{j}) \right)$$

$$= \frac{\mu_0 I_1 I_2}{2\pi s} dl (-\hat{i})$$

Integrating both the sides, the expression we can get the for the force on the 1st straight conductor of length 'l'

$$\therefore \int_0^{F_1} \vec{dF_1} = \frac{\mu_0 I_1 I_2}{2\pi s}(-\hat{i}) \int_0^l dl$$

$$\Rightarrow \vec{F_1} = \frac{\mu_0 I_1 I_2}{2\pi s} l (-\hat{i})$$

The presence of $(-\hat{i})$ on the expression of $\vec{F_1}$ clearly shows that the first conductor is repelled by the 2nd conductor with a force

$$\frac{\mu_0 I_1 I_2 l}{2\pi s}.$$

Thus the conductors repell each other with same force of magnitude $\frac{\mu_0 I_1 I_2 l}{2\pi s}$.

Defn Of Ampere (Amp)

The force Of attraction between two long, straight, parallel current carrying conductors having current in the same direction and placed at a separation 'S' in air is given by $F = \frac{\mu_0 I_1 I_2 l}{2\pi S}$

If $I_1 = I_2 = 1$ unit (Amp), $l = 1$ meter, $S = 1$ meter.

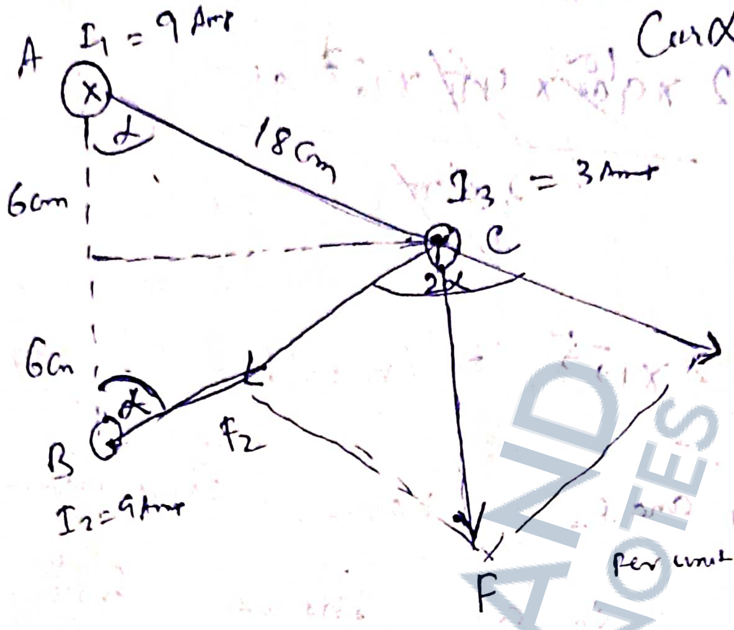
Then $F = \frac{\mu_0}{2\pi}$ Newton

$= 2\times10^{-7}$ Newton

Thus 1 Amp is that amount of current which when flows through two long, parallel, straight conductors having the same current in the same direction placed at a separation 1 meter in air attract each other with a force of 2×10^{-7} Newton per meter length of the wire.

Page-) 683 → (2)

$\cos\alpha = \frac{6}{18} = \frac{1}{3}$



Per unit length $l = 1$ metre

$$F_1 = \frac{I_1 I_2 \mu_0 l}{2\pi s} = \frac{9 \times 3 \times \mu_0 \times 1}{2\cdot\pi\cdot\left(\frac{18}{100}\right)}$$

$$= \frac{9 \times 3 \times 100 \times \mu_0}{36\pi}$$

$$= \frac{2700\,\mu_0}{36\,\pi}$$

$$F_2 = \frac{I_1 I_2 \mu_0 l}{2\pi s} = \frac{9 \times 3 \times \mu_0 \times 1}{2\pi\left(\frac{18}{100}\right)}$$

$$= \frac{2700 \times \mu_0}{36\pi}$$

Resultant Force $= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos 2\alpha}$

$$= \sqrt{2F_1^2 + \cancel{2}F_1^2 \cdot \frac{1}{3}}$$

$$= \frac{\sqrt{8}F_1}{\sqrt{3}}$$

2

$$= \sqrt{F_1^2 + F_1^2 + 2F_1F_1\cos 2\alpha}$$

$$= \sqrt{2F_1^2\,(1 + \cos 2\alpha)}$$

$$= \sqrt{2}F_1 \cdot \sqrt{2}\cos\alpha = 2F_1\cos\alpha$$

$= 2 \times \frac{\cancel{2700}^{900} \times \mu_0}{36\pi} \times \frac{1}{\cancel{3}}$

$= \frac{2 \times \cancel{900}^{100} \times 4\cancel{\pi} \times 10^{-7} \times 1}{\cancel{36\pi}_{9}}$

$= 2 \times 10^{-5}$ H / meter.

Since F_1 and F_2 have same magnitude, $CF_1F_3F_2$ is a rhombus. So $\vec{F}$ bisect 2α. So each angle is α.

So Alternative/corresponding angles are same.

So direction is parall to AB.

$\boxed{\text{Task} \rightarrow 8\ \text{पृष्ठ} = 681}$

Q → An electron of mass m and charge (e) falls through a potential difference V and then enters at right angles to B, a region of uniform magnetic induction. Show that the radius (r) of the electron path in the magnetic field is $r = \sqrt{\frac{2Vm}{eB^2}}$

Ans: The electron gains Kinetic energy when it moves through a potential difference of V units.

$$\therefore \Delta W = \Delta E_K$$

$$\Rightarrow q \cdot \Delta V = \frac{1}{2} m v^2 - \frac{1}{2} m \cdot 0^2$$

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

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

$$\Rightarrow v = \sqrt{\frac{2eV}{m}} \text{ ——— (i)}$$

When it enters in the region of uniform magnetic field, it will rotate in a circular path because centripetal force is provided by the ~~Lorentz~~ Lorentz force.

force,

$$\frac{m v^2}{r} = e v B \sin 90^\circ \text{ ——— (ii)}$$

$$\Rightarrow \frac{m v}{r} = eB$$

$$\Rightarrow v = \frac{eBr}{m}$$

Equating (i) and (ii)

$$\frac{\cancel{e}Br}{\sqrt{m}} = \frac{\sqrt{2} \cdot \sqrt{\cancel{e}} \cdot \sqrt{V}}{\sqrt{m}}$$

$$\Rightarrow r = \frac{\sqrt{m} \cdot \sqrt{2} \cdot \sqrt{V}}{\sqrt{e} \cdot B}$$

$$= \sqrt{\frac{2Vm}{eB^2}} \text{ (Proved)}$$

$$\cancel{\frac{m v^2}{r} = e v \cdot B \sin 90^\circ}$$

$$= eB$$

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

$$= \cancel{\sqrt{m \cdot}}$$

$$\Rightarrow r^2 = \frac{mv}{eB} = \cancel{\frac{m \cdot \sqrt{\frac{2eV}{m}}}{eVB}}$$

$$\Rightarrow r^2 = \frac{\sqrt{m} \cdot \sqrt{2} \cdot \sqrt{e} \cdot \sqrt{V}}{\sqrt{m} \cdot eB}$$

$$= \cancel{\frac{m \cdot 2 e V}{m \cdot eB}}$$

Long question

Moving Coil Galvanometer (Dead-beat type)

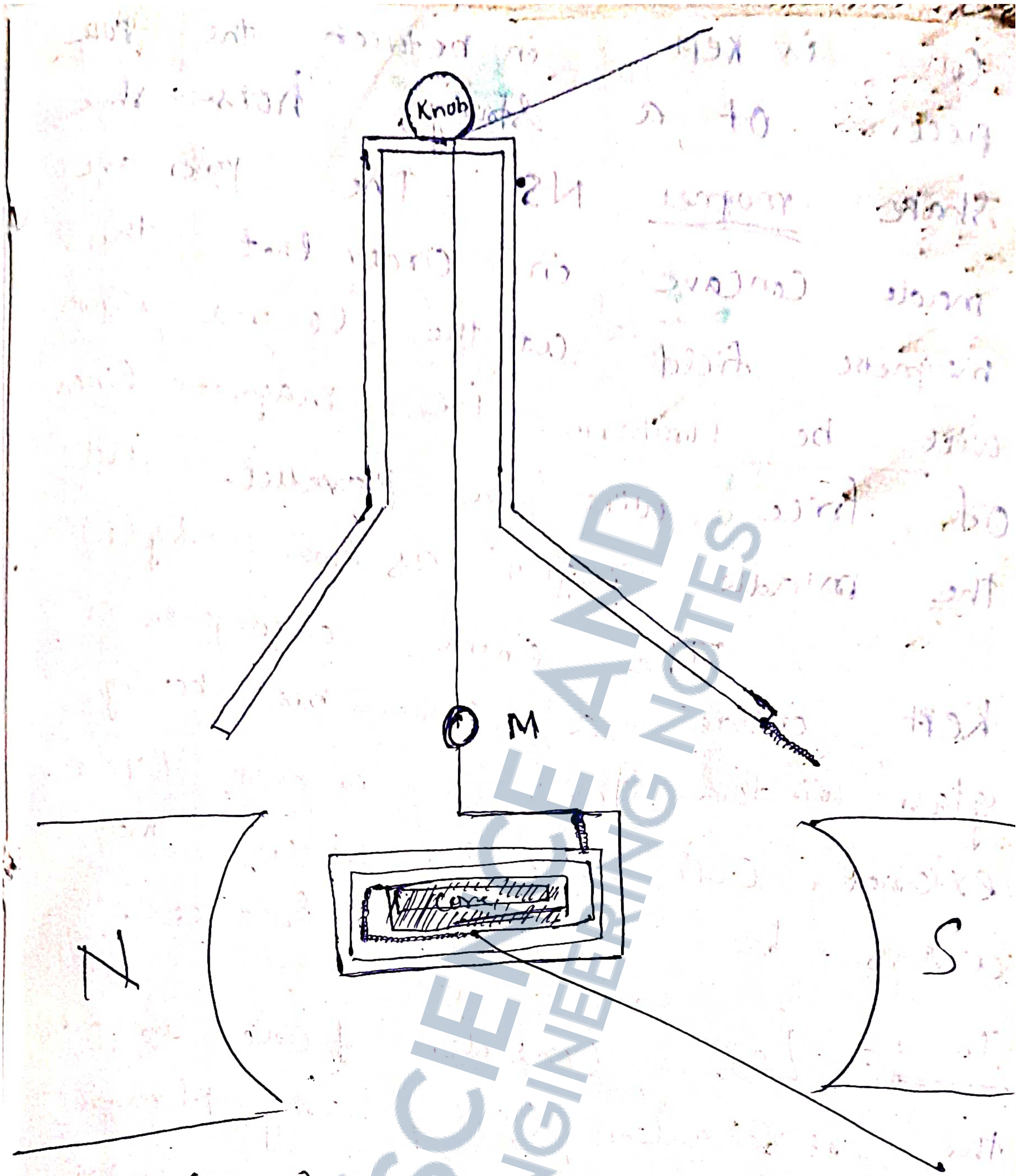
Introduction :-

It is an instrument by which presence of small current in a closed circuit can be known. It can be converted into an ammeter by using a low resistance in parallel with it (called shunt). By changing the resistance of the shunt, higher currents can also be measured. It can be converted into a voltmeter by using a high resistance in series with the galvanometer.

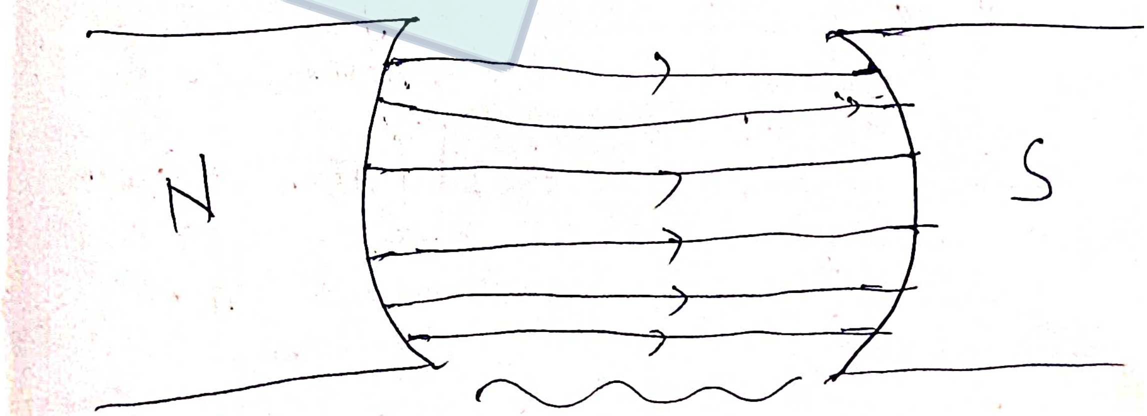
Description :-

It consists of a long, uniform metallic wire which hangs from a heavy mass called Knob. The other end of the wire is wound several times on a rectangular piece of soft iron called core. The wire is made up of quartz or phosphor-Bronze.

A small plane mirror or concave mirror of circular apparature is attached to this wire by which any deflection produced in the wire can be measured. This rectangular



(Fig 1)



Uniform magnetic field

Fig (2)

Coil is kept in between the pole pieces of a strong, horse-shoe shape magnet NS. The poles are made concave in order that the magnetic field at the central region will be uniform. i.e magnetic lines of force will be parallel at the middle region as show in fig (ii)

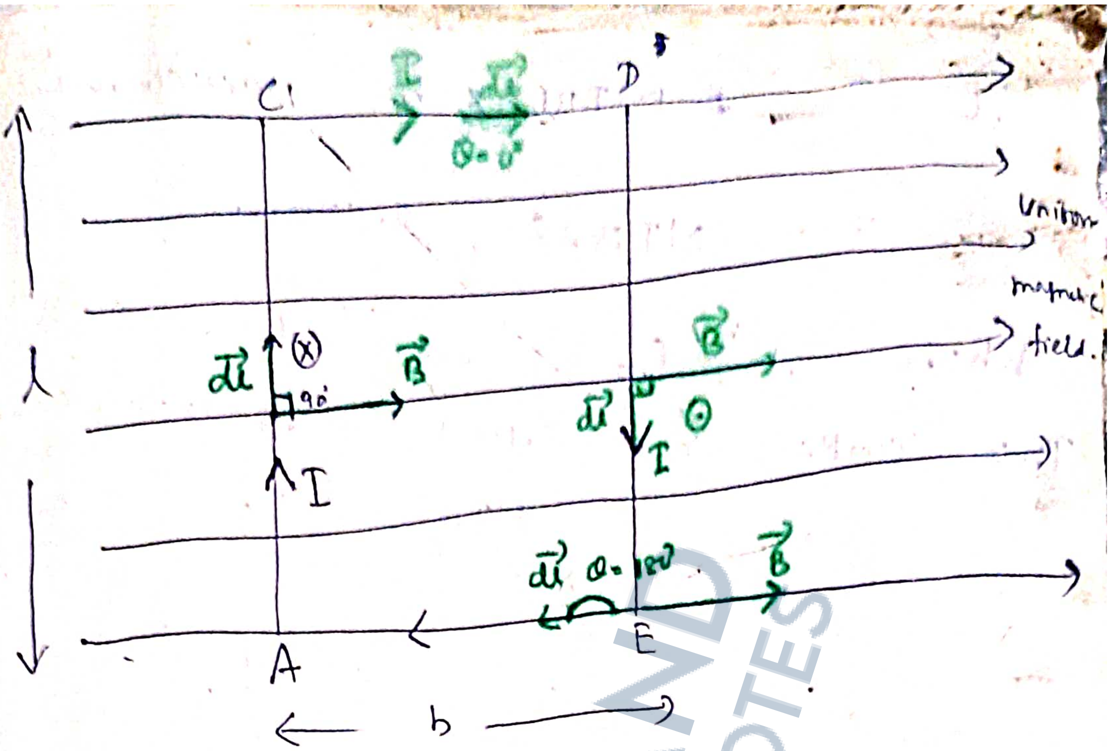
The entire arrangement is kept inside a wooden box having glass windows. This is necessary to prevent external air current which may disturb the deflection produced.

Theory :- Lets consider ~~of~~ one turn of the rectangular coil having N number of turns. Force on a current carrying conductor placed in a magnetic field is given by,

$$\vec{F} = I \int_{ACDEA} \vec{dl} \times \vec{B}$$

$$= I \left[\int_{AC} \vec{dl} \times \vec{B} + \int_{CD} \vec{dl} \times \vec{B} + \int_{DE} \vec{dl} \times \vec{B} + \int_{EA} \vec{dl} \times \vec{B} \right]$$

$$= I \left[\int_{AC} dl\, B \sin 90^\circ, \; \otimes \; + \int_{CD} dl B \sin 0^\circ \right.$$



$$+ \int_{DE} dlB\sin 90^\circ, \odot + \int_{EA} dlB\sin 180^\circ \Big]$$

$$\cancel{= IB\Big[\int_{AC} dl, \otimes + \ldots \odot +}$$

$$= IB \int_{AC} dl, \otimes + 0 + IB\int_{DE} dl, \odot + 0$$

$$= IBl, \otimes + IBl, \odot$$

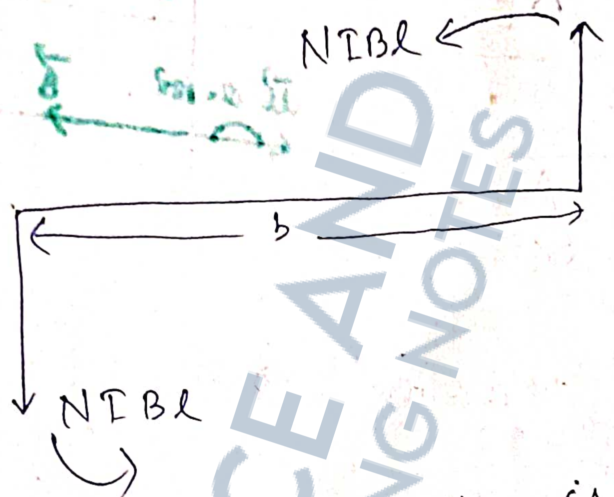
Since there are N number of turns in the rectangular coil the coil will experience two forces NIBL each acting in opposite directions. Hence the coil will experience a couple. Torque due to the couple is the product of magnitude of one of the forces and perpendicular distance between two forces.

$\vec{\tau} = NIBl \times b$, anticlockwise

$= NIBA$, anticlockwise

Where $A = lb$ = Area of the coil.

This couple is called ~~deflecting~~ deflecting couple.



But a restoring couple is developed in the wire due to which the wire rotates by an angle θ and then comes to rest.

If 'c' be the couple per unit twist (1 radian) in the suspension wire, then the restoring couple $= c\theta$ where θ is the angle of deflection in radian produced.

$$\left[C = \frac{\eta \pi r^4}{2l} \right.$$, where η = rigidity modulus of the material of the wire
r = radius of the wire
l = length of the wire

For equilibrium, the torque due to the restoring ~~coup~~ couple must balance the torque due to the deflecting couple.

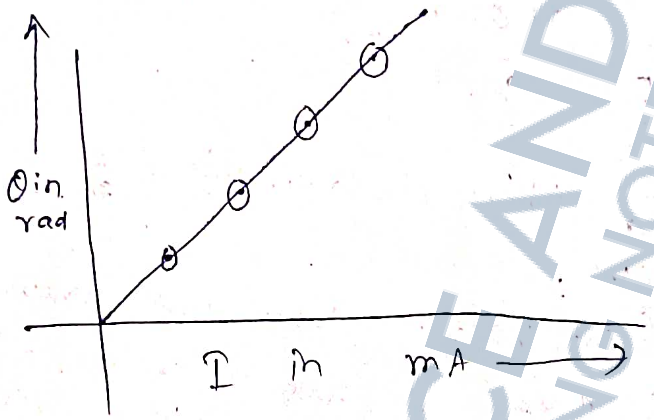
$\therefore NIBA = C\theta$

$$\Rightarrow I = \frac{C}{NBA} \cdot \theta$$

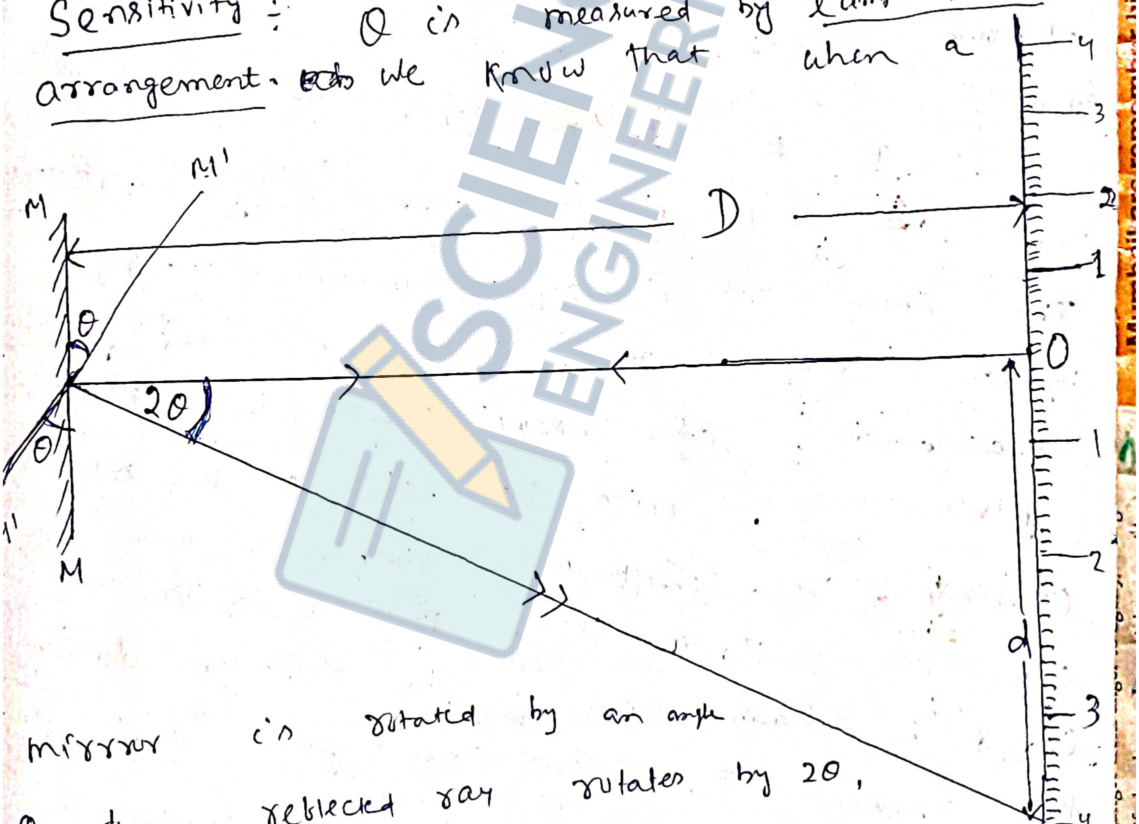
$$\Rightarrow \boxed{I = K\theta}$$

where $K = \frac{C}{NBA}$ = a constant, called galvanometer constant.

$\therefore I \propto \theta$.



Sensitivity: θ is measured by lamp and scale arrangement. ~~ec~~ we know that when a



mirror is rotated by an angle θ the reflected ray rotates by 2θ.

Before passing current through the galvanometer the spot of light should coincide the centre of the zero position of the plastic scale, when with the current is passed the mirror is rotated and the spot of light gets displaced by an amount 'd' units.

Plastic Scale

on the scale. If the distance between the scale and the mirror be D, then

$$\tan 2\theta = \frac{d}{D}$$

For some angle of ~~deflection~~ deflection which is produced when there is a small current passing through the galvanometer, we can write

$$\tan 2\theta \simeq 2\theta = \frac{d}{D}$$

$$\Rightarrow \theta = \frac{d}{2D}$$

$$\therefore I = K\theta = \frac{K \cdot d}{2D}$$

$$\Rightarrow \boxed{I = K' \frac{d}{D}}$$ where $K' =$ a constant $= \frac{K}{2} =$ A measure of sensitivity.

Defn of sensitivity :-

A galvanometer is said to possess unit sensitivity when a current of 1 μA passing through it produces a deflection of 1 m.m on a plastic scale kept at a distance of 1 meter away from the mirror of the galvanometer.

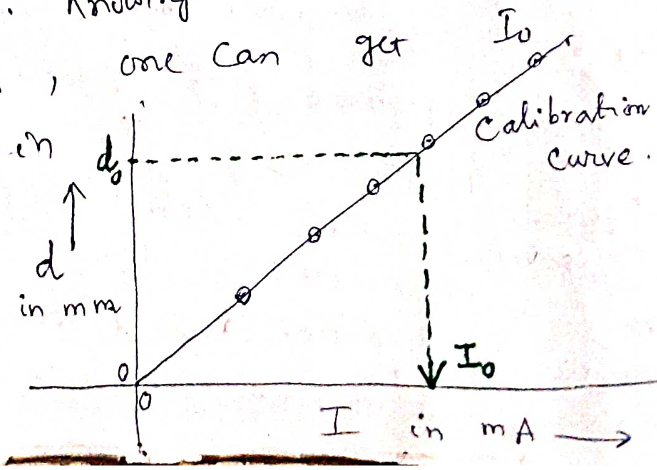
$\therefore I = 1\mu A,\ d = 1\,m.m,\ D = 1\,meter$

$\therefore 1\mu A = K' \cdot \frac{1\,m.m}{1\,meter} \Rightarrow K' = \frac{1\mu A \times 1\,meter}{1\,m.m} = 1\,\frac{\mu A \times meter}{m.m}$

This shows that K' can be regarded as a quantity by which sensitivity of a galvanometer can be measured.

Measurement of unknown current by the dead beat galvanometer :

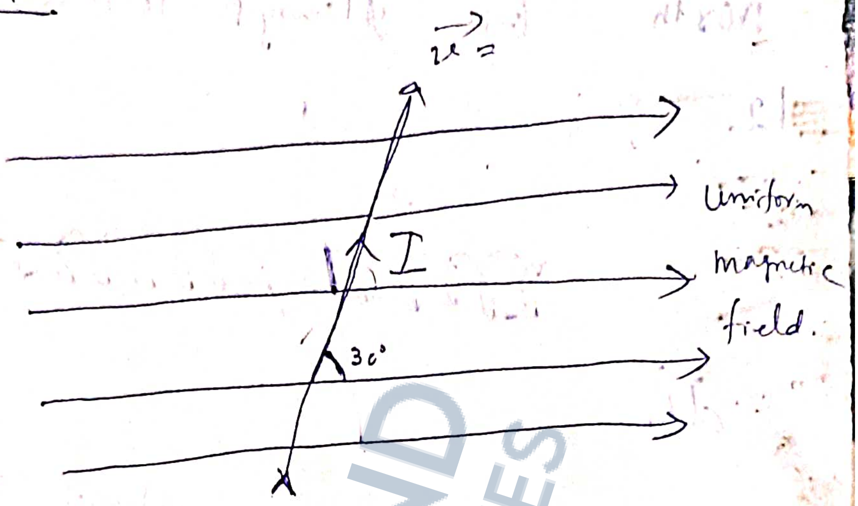
With the help of some known currents, the corresponding deflections are to be found out on the plastic scale and a calibration curve be drawn. Knowing the deflection d_0 for the unknown I_0, one can get I_0 as shown in the graph.



Problems :

681 → 4, 9, 12

4.



$l = 125\ \text{cm}$
$= 1.25$ metre

$I = 30\ A$

$\theta = 30^\circ$

$\vec{B} = 4\times10^{-4}$

$$\vec{F} = IBL\sin\theta, \otimes$$

$$= 30 \times 4\times10^{-4} \times 1.25 \sin 30^\circ, \otimes$$

$$= 30\times4\times10^{-4}\times\frac{1}{2}\times1.25$$

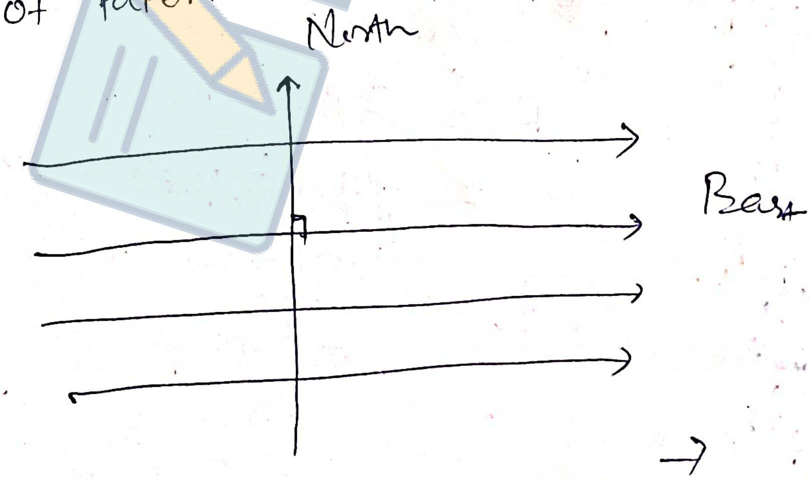
$$= 60\times1.25\times10^{-4}$$

$$= 7500\times10^{-7}$$

$$= 7.5\times10^{-3}\ \text{Newton.}$$

The direction of the force is into the plane of paper.

9.

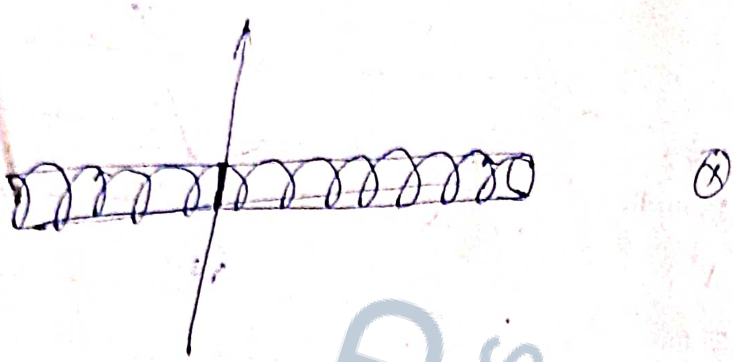


$l = .8$ meter, $I = 20A$, $\theta = 90^\circ$, $\vec{B} = 5\times10^{-4}\ wb/m^2$

$$F = IBL\sin 90^\circ = 20\times5\times10^{-4}\times .8 \times 1$$
$$= 80\times10^{-4} = 8\times10^{-3}\ \text{Newton.}$$

The direction of force is along the North by fleming's left hand rule.

12.



$\vec{dl}$,

$dl = 2.3 cm$, $n = \frac{\text{Number of turns}}{\text{Length}}$

$= \frac{1200}{.35} = \frac{1200 \times 10^2}{35}$

$= \frac{12 \times 10^4}{35} =$

$\vec{B} = \mu_0 nI$

$= 4\pi \times 10^{-7} \times \frac{12 \times 10^4}{35} \times 1.5$

$= 4 \times 3.14 \times 10^{-7} \times \frac{120}{35} \times 10^3 \times 1.5$

$= 6 \times 3.14 \times 3.43 \quad \times 10^{-7}$

$=$

$35) 120 (3.428$
105
150
140
100
70
300
280
20

3.14
9
28.26
3.43
8478
11304
8478
96.9318

$F = IBl \sin 90^\circ$

$= 1.5 \times 6 \times 3.14 \times 3.43 \times 10^{-4} \times 1 \times$

$= 9 \times 3.14 \times 3.43 \times 10^{-7}$

$= 96.9318 \times 10^{-7}$

$= 9.69318 \times 10^{-3}$

Again $dl = 2.3 cm = .023$ meter.

$n = \frac{1200}{.35} = \frac{1200 \times 10^2}{35}$

$= \frac{12}{35} \times 10^4$

$B = \mu_0 n I$

$= 4\pi \times 10^{-7} \times \frac{12}{35} \times 10^{4} \times 1.5$

$F = I(\vec{dl} \times \vec{B})$

$= I \; dl \; B \sin 90$

$= 18A \times \left(\frac{23}{1000}\right) \times \frac{4\pi \times 10^{-7} \times \frac{12}{35} \times 10^{4} \times 1.5}{} \times 1$

$= \frac{72\pi \times 18 \times 23 \times 10^{-6}}{35}$

$= 72\pi \times \frac{414}{35} \times 10^{-6}$

$= 72 \times 6.11 \times 3.14 \times 10^{-6}$

$= \cancel{1351.34 \times 10^{-6}}$

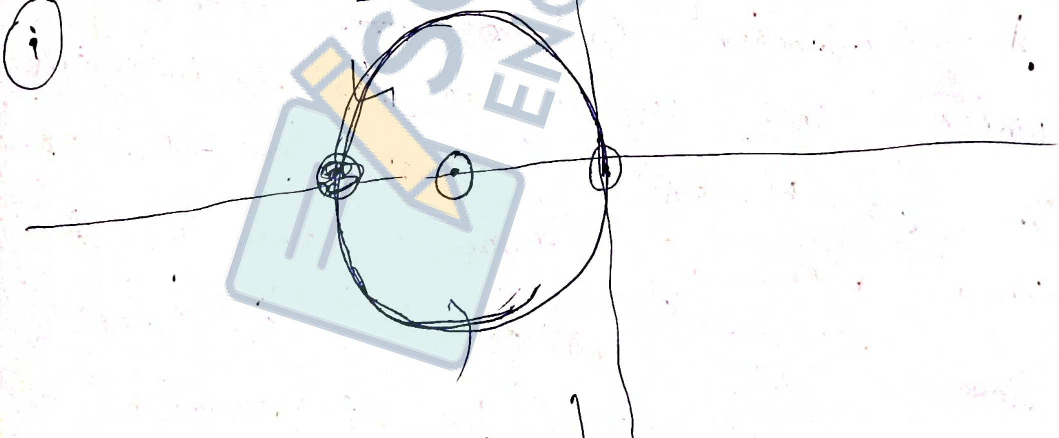
$= \cancel{1.35134 \times 10^{-3}}$

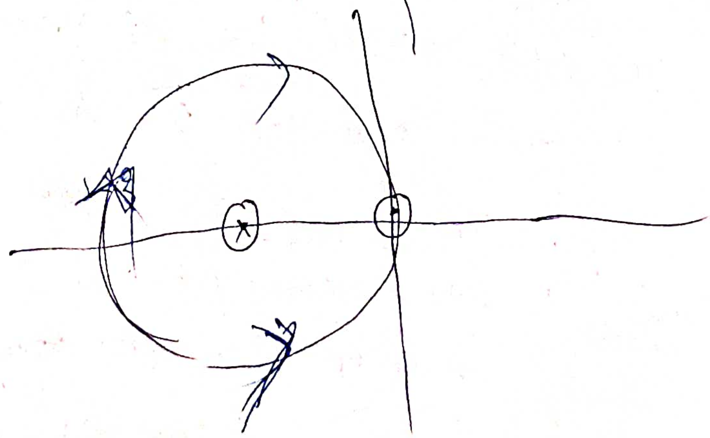
$= 2674.203 \times 10^{-6}$ $= 2.674203 \times 10^{-3}$

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

8.

i





When the currents ~~is~~ are flowing in the same direction then the force is attractive and $= \frac{\mu_0 I_1 I_2 l}{2\pi r}$

$$= \frac{\cancel{4\pi} \times 10^{-7} \times 10 \times 5 \times 1\ metre}{\cancel{2\pi} \times \cancel{\cdot 2}}$$

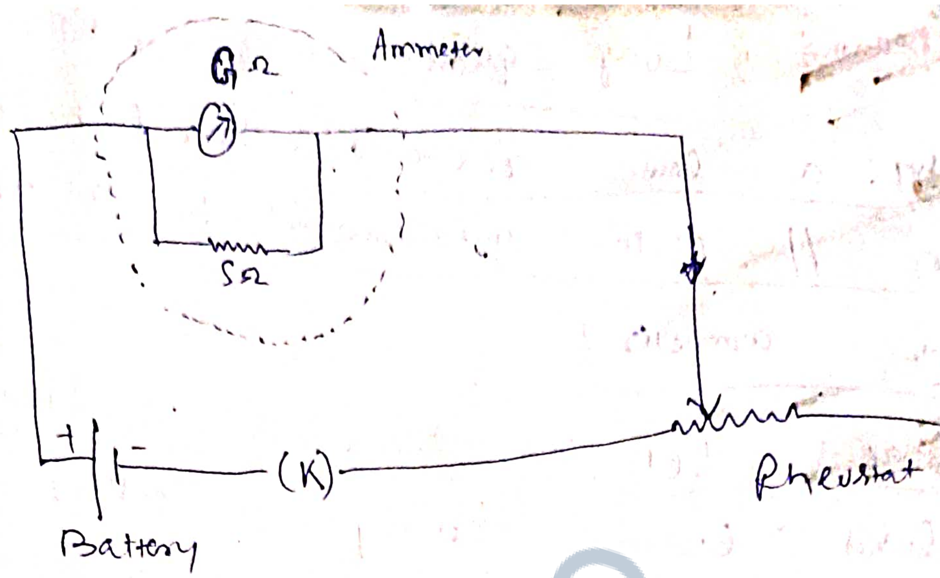
$= 5 \times 10^{-5}$ Newton.

When the current ~~is~~ are flowing in the opposite direction, then force is repulsive ~~and~~ of magni 5×10^{-5} Newton

Conversion of moving coil galvanometer in to an ammeter

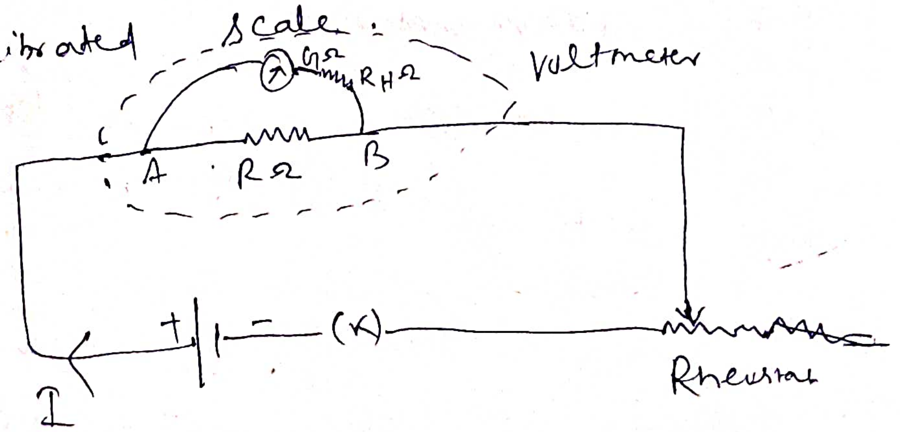
An ammeter is an ~~instr~~ instrument by which the current is measured in a circuit. It is placed in series with the circuit whose current is to be measured. A shunt (low resistance) is connect in parallel with the galvanometer to make an ammeter of suitable range.

There is an 'Al' pointer attached to the core of the galvanometer by which readings can be taken as the pointer moves on a calibrated scale.



Conversion of a moving coil galvanometer into a voltmeter

A Voltmeter is a instrument by which potential difference between two points of a closed circuit can be measured. It is placed in parallel with the two points whose P.D is to be measured. It is prepared out of a moving coil galvanometer by using a high resistance in series with the galvanometer. There is an Aluminium pointer by which readings can be taken on the calibrated scale.

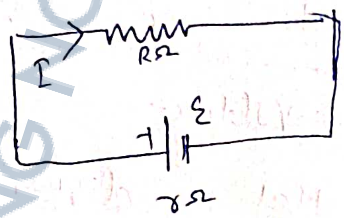


Reason ÷ (*) Long question

Why a low resistance has to be used in // with galvanometer to prepare the ammeter ?

Step-I Let us think of a simple Closed circuit having a battery of emf $\mathcal{E}$ and internal resistance $r\Omega$. along with an external resistance $R\Omega$.

$$I = \frac{\mathcal{E}}{R+r}$$

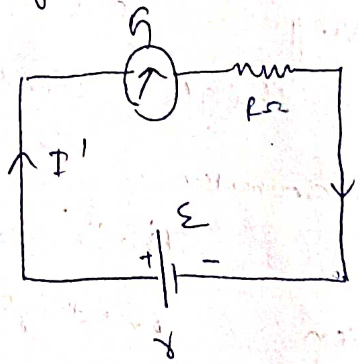


= to be measured.

Step-II

Let us place a galvanometer in series with the circuit to measure the current. The current gets changed

to $I' = \dfrac{\mathcal{E}}{R+G+r}$



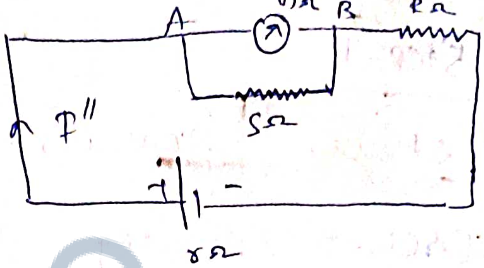
Naturally, $I' < I$.

Thus the galvanometer measures a current which is less than the actual current.

Step-III

Let us try to decrease the resistance of the galvanometer by using a low resistance ~~[illegible]~~ ~~[illegible]~~ in parallel with ckt of resistance $S\,\Omega$. (say)

Equivalent resistance between A and B is R_P.



$$\frac{1}{R_P} = \frac{1}{G} + \frac{1}{S}$$

Hence $R_P < G$ and $R_P < S$

$$\text{Current} = I'' = \frac{\mathcal{E}}{R_P + R + r}$$

Thus, $I'' > I'$, yet $I'' < I$

In the limiting situation, $S \to 0$

$$\therefore \frac{1}{R_P} \to \frac{1}{G} + \frac{1}{0}$$

$$\Rightarrow \frac{1}{R_P} \to \frac{1}{G} + \infty$$

$$\Rightarrow \frac{1}{R_P} = \infty \Rightarrow R_P \to \frac{1}{\infty}$$

$$\Rightarrow R_P \to 0$$

$$\therefore I'' \to \frac{\mathcal{E}}{R + r} \to I$$

Hence current measurement of current is possible by galvanometer when a very low resistance is placed parallel with ckt.

However, this combination (Galvanometer and the low resistance) are together called ammeter and kept in series with the circuit.

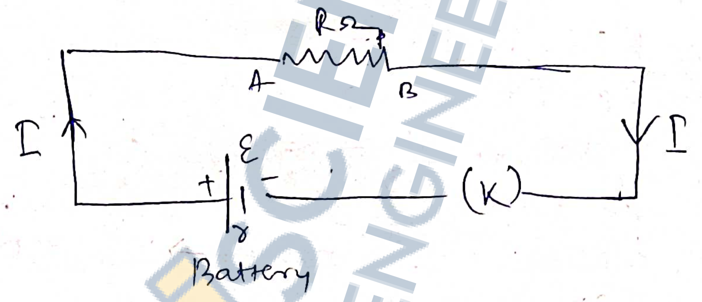
Q-> Why a high resistance will be placed in series with the galvanometer to prepare a voltmeter?

Step-I

Let us consider a simple closed circuit having a battery of emf $\mathcal{E}$ and internal resistance 'r' along with an external resistance $R\,\Omega$.

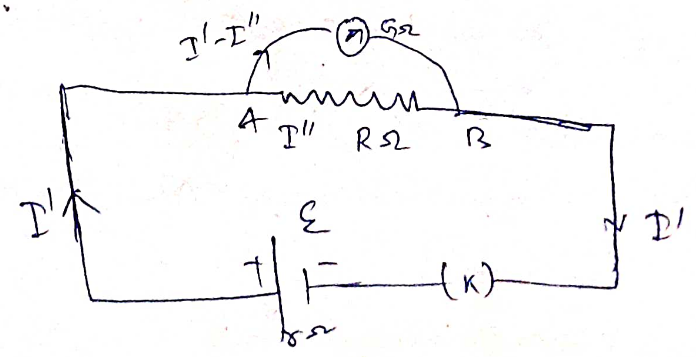
$$V_A - V_B = R\,I = \text{to be measured}$$

where $I = \frac{\mathcal{E}}{R+r}$



Step-II

Let us connect a galvanometer or resistance $G\,\Omega$ in between the two points A and B so that it becomes parallel to the resistance wire AB.



If I'' be the current flowing through the resistance wire AB when the galvanometer has been connected in parallel with AB.

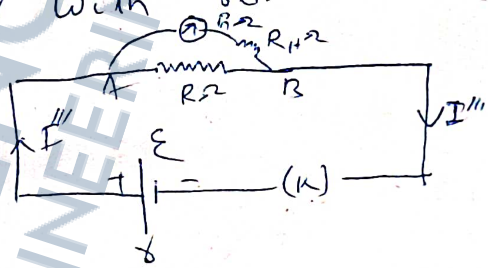
$V_A - V_B = I''R$ which is less than $I'R$

where $I' = \dfrac{\mathcal{E}}{R_P + r}$

where $\dfrac{1}{R_P} = \dfrac{1}{R} + \dfrac{1}{G}$

Step-III

Let us try to increase the resistance of the galvanometer by using a high resistance in series with it, the Combination being connected in // with resistance wire



$I''' = \dfrac{\mathcal{E}}{R_P'' + r}$

where $\dfrac{1}{R_P''} = \dfrac{1}{G + R_H} + \dfrac{1}{R}$

$\Rightarrow V_A - V_B = I''' R_P''$

In the limiliting situation when $R_H \to \infty$

$\Rightarrow G + R_H \to \infty$ or $\dfrac{1}{G + R_H} \to 0$

$\therefore \dfrac{1}{R_P''} = 0 + \dfrac{1}{R} \Rightarrow R_P'' = R$

$I''' = \dfrac{\mathcal{E}}{R + r} = I$

$V_A - V_B = I \cdot R$ will be correctly measured since almost no current passes through the galvanometer. Thus, a voltmeter is prepared out of a galvanometer by using a high resistance in series with the instrument.

84

6. Given $d = 20\ cm = 200\ mm$

Open part

$D = 250\ cm = 2.5\ meter$

$I = 3.00 \times 10^{-5} A$

$= 3.00 \times 10^{-5} \times 10^{6}\ \mu A$

$= 30\ \mu A$

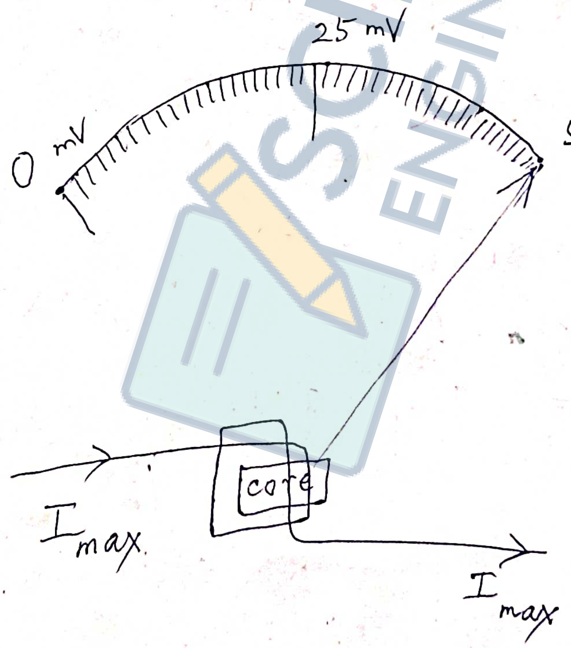
We know that $I = K' \dfrac{d}{D}$

$\Rightarrow 30 = K' \cdot \dfrac{200}{2.5}$

$\Rightarrow K' = \dfrac{30 \times 2.5}{200}$

$= .375\ \dfrac{\mu A \cdot meter}{m.m}$

12.



$I_{max} = \dfrac{V_{max}}{R}$ (From ohm's law)

$= \dfrac{50\ mV}{.400\ \Omega} = \dfrac{50 \times 10^{-3}}{4} \times 10 = 12.5 \times 10^{-2}$

$= 0.125$ Amp

(a) Let the resistance of shunt be $S\,\Omega$

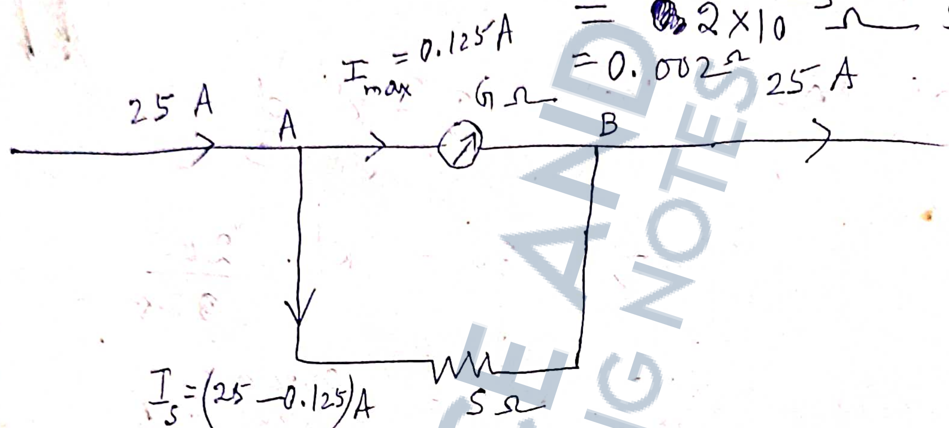
$V_A - V_B = I_{max} \times G = I_S \cdot S$

$= 0.125 \times 0.4 = (25 - .125) \times S$

$$\begin{array}{r} 25.000 \\ -\ .125 \\ \hline 24.875 \end{array}$$

$\Rightarrow S = \dfrac{.050}{24.875} = \dfrac{50}{24875} \simeq \dfrac{\cancel{5}\,1}{\cancel{25}000_{\,5}}$

$= 2 \times 10^{-3}\,\Omega$



$0.05 = 25 \times S$

$S = \dfrac{.05}{25} = \dfrac{\cancel{5}\ 1}{\cancel{25}00_{\,5}} = \dfrac{0.2}{100}$

$= 0.002\,\Omega$

(b) $I_{max} = 0.125$

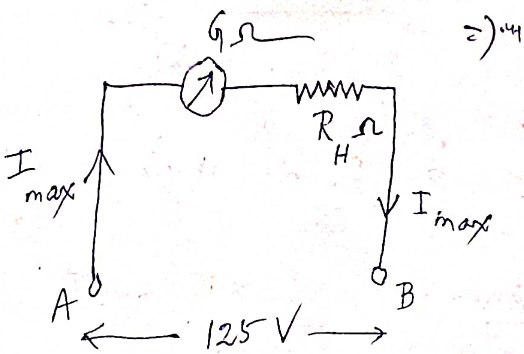
$R_H = ?$

$V_A - V_B = I_{max}(G + R_H)$

$\Rightarrow 125 = 0.125(.4 + R_H)$

$\Rightarrow .4 R_H = \dfrac{125}{.125} = \dfrac{125000}{125} = 1000$

$\Rightarrow R_H = 1000 - .4 = 999.6\,\Omega$



$V_A - V_B = 125\,V = I_{max} \cdot (G + R_H)$

Try → even numbers

Write the answers of the following questions

1. Dibberence between voltmeter and Ammeter.
2. Why the galvanometer is called dead beat type. → one side coincide not return back, but when off it return.
3. Why Concave shaped magnets are used in moving coil galvanometer?
4. Why X- rays are not deblected in a magnetic field. → ~~less~~ [illegible]
5. Dibberence between ammeter and ~~voltmeter~~ Galvanometer? [illegible]
6. How can ~~coil~~ an ~~be~~ a ammeter be converted to voltmeter? [illegible]
7. Flemings left hand rule →
8. What do you mean by ~~detail~~ radial field.
9. A magnetic field as well as an electric field can deflect a charged particle. What is the difference between the deflections produced by the two fields?

Answers

Q. (1)

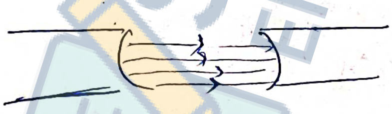
Ammeter

1. An ammeter is an electronic device which is use for the measurement of current in a circuit.
2. It is prepared by joining a low resistance parallel with the galvanometer coil.
3. While measuring a current in the circuit ammeter is connected ~~~~ in series.

Voltmeter

1. A voltmeter is an electronic device which is use for ~~the measurement~~ measuring the p.d between two points.
2. It is prepared by joining a high resistance in series with the galvanometer coil.
3. While measuring p.d between ~~~~ two points ~~~~ voltmeter is connected in parallel with them.

(3) In a moving coil galvanometer magnetic poles are made concave in order that the magnetic field at the central region will be ~~~~ uniform. i.e radial field and it provides a strong magnetic lines of forces are parallel.



(5)

Ammeter

1. It is an electronic device which is used for measuring large currents in the circuit.
2. It is not very sensitive.
3. Ammeter can be prepared by connecting a low resistance in parallel with the galvanometer coil.

Galvanometer

1. It is an electronic device which is used for measuring small currents.
2. It is very sensitive.

7. Direction of force ~~on~~ on a conductor carrying current placed on a magnetic field can be obtained by applying Fleming's left hand rule which can be stated as follows.

Stretch first finger, central finger and thumb of your left hand in mutually perpendicular directions. If the first finger points towards magnetic field, central finger points towards electric current then the thumb gives the direction of force acting on the conductor.

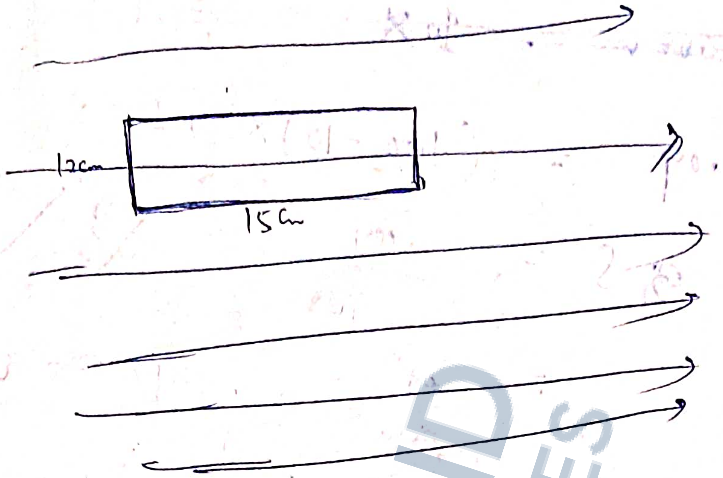
(8) Radial field

Since the pole pieces are of cylindrical ~~the~~ form, the lines of force will be along the radius. Therefore as the coil rotates, its plane will always be parallel to the direction of lines of force, in ~~all~~ all its positions. Such a field is known as radial field.

(9) An electric field will deflect the charged particle along the direction of field. But magnetic field deflects the charged particle perpendicular to the direction of magnetic field as well as to that of direction of the instantaneous velocity of charged particle.

Problems

10.



$\vec{B} = 4\times10^{-3}$ wb/m², $I = 400$ mA

$b = 12$ cm $= .12$ meter

$l = 15$cm $= .15$ meter

Torque $= NIBl \times b = 25 \times 400\times10^{-3} \times 4\times10^{-3} \times \frac{15}{100} \times \frac{12}{100}$

$= 400\times10^{-2} \times 12\times15 \times 10^{-6} \times 10^{-4}$

$= 720\times10^{-2} \times 10^{-6} \times 10^{-4}$

$= 72\times10^{-5}$

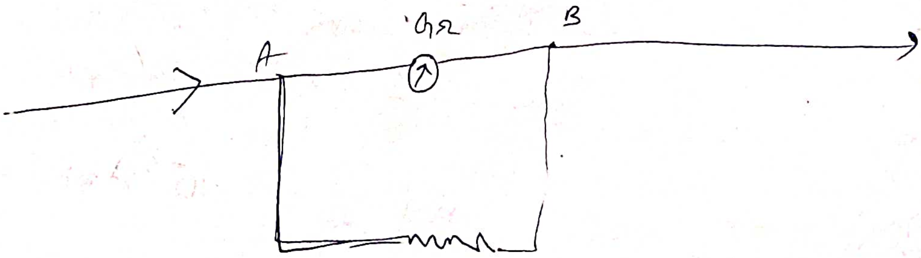
$= 7.2\times10^{-4}$ Newton. meter.

14.

16. Ammeter has resistance 0.09Ω.

$I = 10$ Amp

$S = ?$



Ammeter has resistance 0.009, $I_{max} = 10A$.

$V = 10A \times .009 =$ .09 volt

~~$V_{max} = \frac{10}{.09} = \frac{10\times100}{9} = \frac{1000}{9}$ volt~~

$V_A - V_B = \cancel{I_{max} \times R_{sh}} = I_S \times S$

$\cancel{(10)}$

$\cancel{10 \times 9}$

$\Rightarrow \cancel{100\,V = 10 \times}$

$\Rightarrow .09 = (100 - 10) \times S$

$\Rightarrow S = \frac{.09}{90} = \cancel{\frac{9}{100}} = \cancel{\frac{1}{100}} = .01$

$= \frac{.09}{9000} = .001\,\Omega$

18. Let the current flowing be I.

$V = \underline{I \times .6} = .6I$.

$V = I_S \times S$

$\Rightarrow .6I = (I_S) \times .2$

$\Rightarrow I_S = \frac{.6I}{.2} = 3I$

If total ~~total~~ current flowing $= 100\%$.

~~[illegible]~~ Current flowing in the instrument $= I$.

$\therefore$ ~~Through~~ Through Shunt $= 3I$

Total $= 4I = 100\%$

$\Rightarrow I = 25\%$.

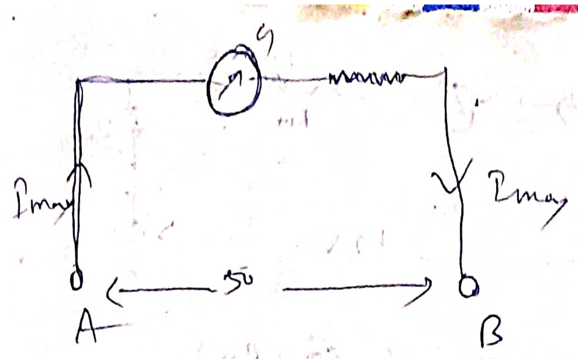
$\therefore$ 25% ~~[illegible]~~ Current is flowing.

20. $I_{max} = 1.00\,mA = 10^{-3}$ Amp.

$G = 7.0\,\Omega$,

Before using resistance it could measure

$V = IR = 10^{-3} \times 7 = .007$ Volt



$V_A - V_B = I_{max}(G + R_H)$

$\Rightarrow 50 = 10^{-3}(7 + R_H)$

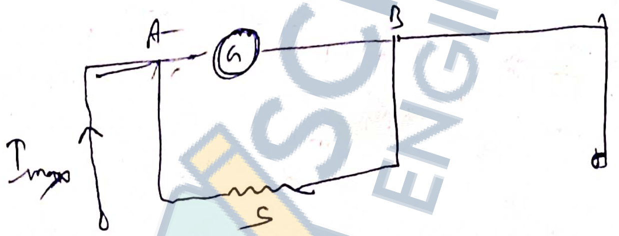
$\Rightarrow 7 + R_H = \frac{50}{10^{-3}} = 5 \times 10^{4} = 50000$

$\Rightarrow R_H = 50{,}000 - 7 = 49{,}993\ \Omega$.

24. $R = .8\ \Omega$, $V_{max} = 24\ mV$.

$I_{max} = \frac{24 \times 10^{-3}}{.8} = \frac{24 \times 10^{-3} \times 10}{8}$

$= 3 \times 10^{-2}$ Amp.



$V_A - V_B = I_{max} \times G = I_S \times S$

$= 3 \times 10^{-2} \times .8 = (30 - .03) \times S$

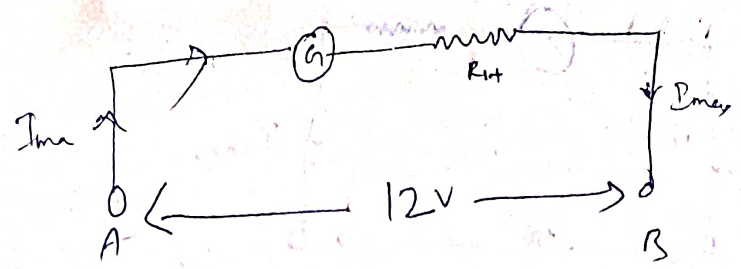
$\Rightarrow S = \frac{3 \times 10^{-2} \times 8}{10 \times 29.97}$

$= \frac{30}{29.97} \times 8 \times 10^{-4}$

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

$= 800 \times 10^{-6}$

$= 800\ \mu\Omega$



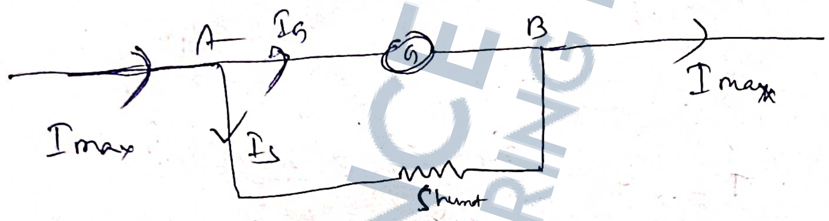
$V_A - V_B = I_{max}(G + R_H)$

$\Rightarrow 12 = .03 \times (.8 + R_h)$

$\Rightarrow .8 + R_h = \frac{12}{.03} = 4 \times 10^2$

$\Rightarrow R_h = 400 - .8 = 399.2\,\Omega$

26.



$G = 5.00\Omega$, $I_{max} = 10\,mA = 10^{-2} = .01$

$V_{max} = I \times G = 10 \times 10^{-3} \times 5 = 10^{-2} \times 5$

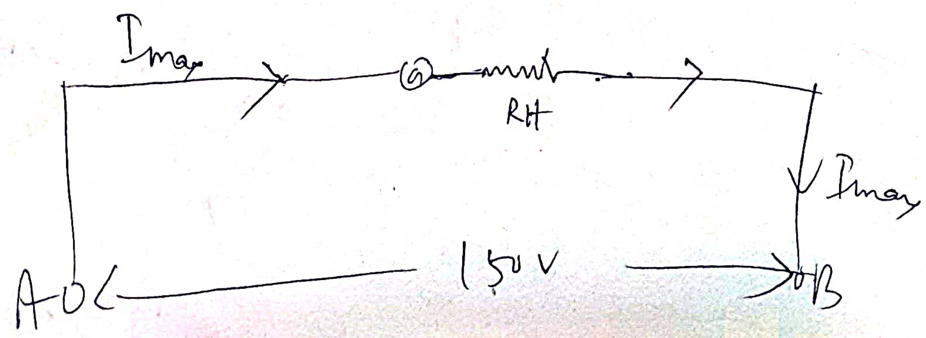
$V_A - V_B = I_G \times G = I_S \times S$

$\Rightarrow 10^{-2} \times 5 = (10A - .01) \times S$

$\Rightarrow S = \frac{10^{-2} \times 5}{(10 - .01)}$

$= 10^{-3} \times 5$

$= .005\,\Omega$



$$V_A - V_B = I_{max}(G + R_h)$$

$$\Rightarrow 150 = .01 \times (5 + R_h)$$

$$\Rightarrow 5 + R_h = \frac{150}{.01} = 15000$$

$$\Rightarrow R_h = \frac{15000 - 5}{14995} = 14,995\ \Omega$$

or $15,000\ \Omega$

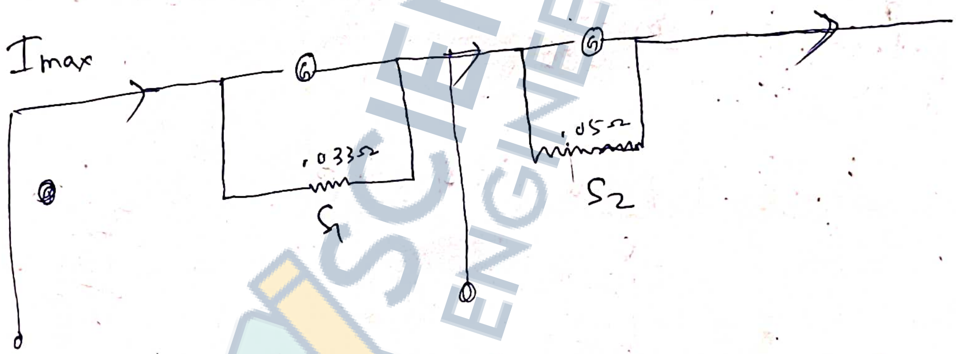
(15,000)

Q8. $I_{max} = 1.50\,A$

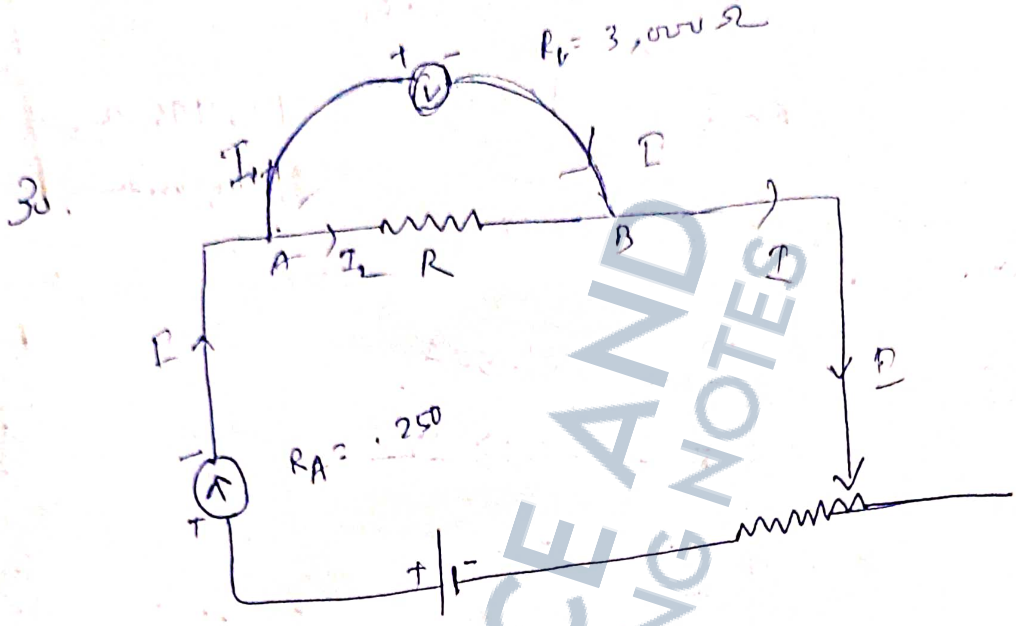
$S_1\ R = .033\ \Omega$

$I_{max} = 1.00\,A$

$S_2 = .050\ \Omega$



3.



$R = \frac{V}{I} = \frac{8.50}{.035} = \frac{8500}{35} = 242.8\,\Omega$

35) 8500 (242.8
70
150
140
100
70
300

But this is error reading.

$I = \frac{V}{R_P} = \frac{8.5\,(3000+R)}{(3000R)} = .035$

$\left(\because R_P = \frac{3000 \times R}{3000+R}\right)$

$\Rightarrow 25.500 + 8.5R = 105R$

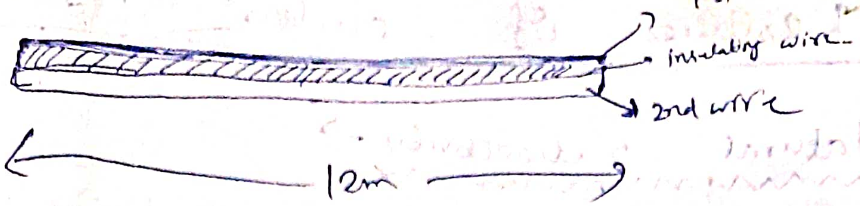
$\Rightarrow 25,500 = 96.5R$

$\Rightarrow R = \frac{25,500}{96.5} = 264.248$

35 × 3 = 105

105.0 − 8.5 = 96.5

32:



$I = 25A$, $l = 12m$, $b = 3.6$ mm

$= .36$ cm

$= \frac{.36}{100}$ metre

$= \frac{36}{10^4}$

$\vec{B} = \frac{\mu_0 I_1 I_2}{2\pi s} l$

$F = \frac{\mu_0 I_1 I_2}{2\pi s} l$

$= \frac{4\pi \times 10^{-7} \times 25 \times 25 \times 100 \times 12}{2\pi \times 8 (36)}$

$= \frac{3750}{36} \times 10^{-3}$

$= \frac{4\pi \times 10^{-7} \times 25 \times 25 \times 12 \times 10^{4}}{2\pi .36 \; 8}$

$= 416 \times 10^{-3}$

$= 4.16 \times 10^{-1}$

(i), (c), (d), (A)