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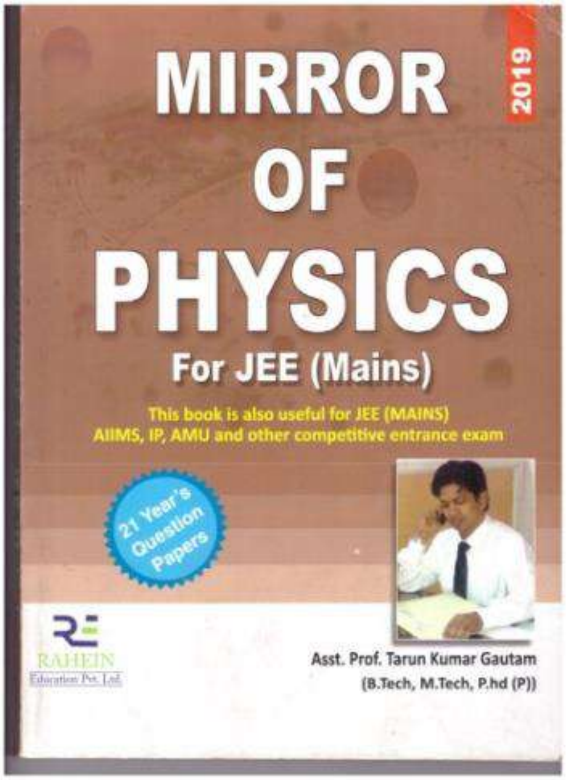
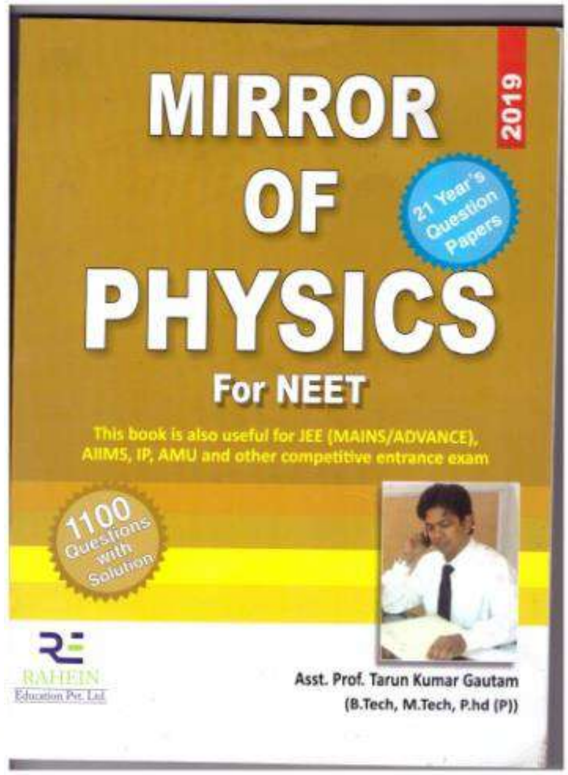
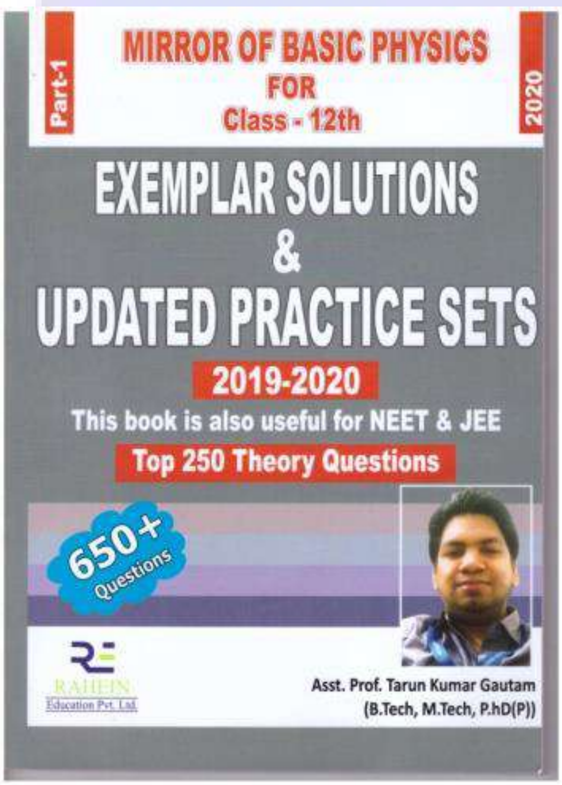
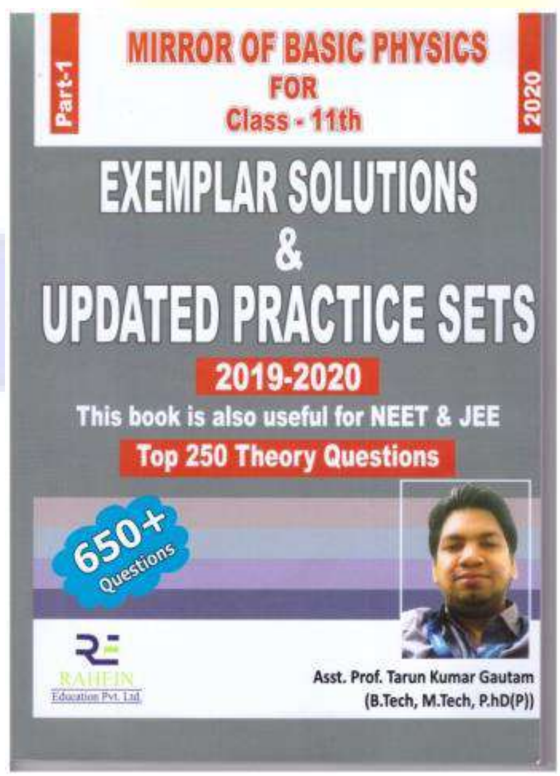
PHYSICS







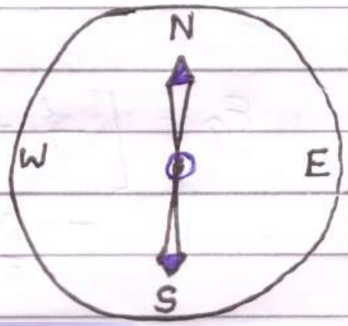


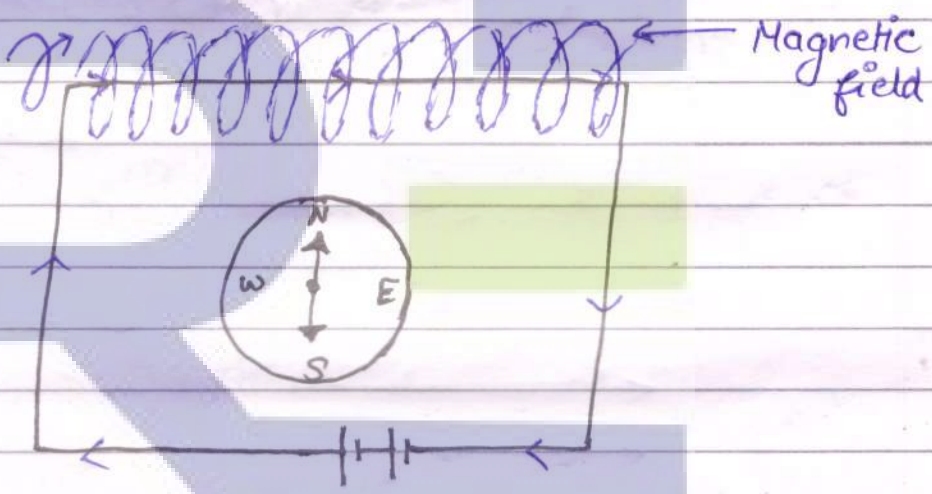
Chapter-4
(Magnetic effect of Current)

Oersted Experiment

Magnetic needle

Needle always show the direcⁿ.

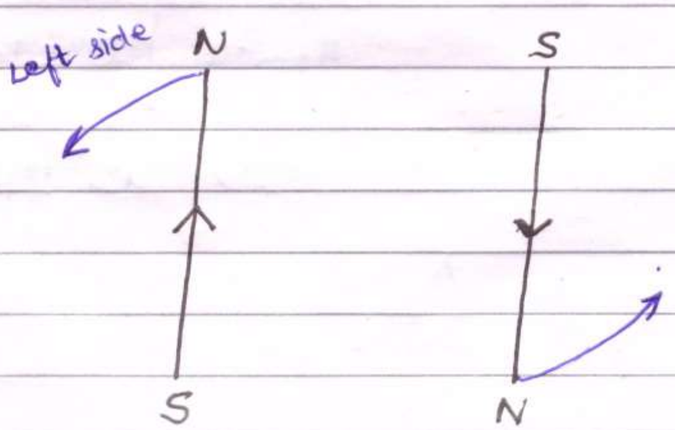




SNOW (South North Over West)

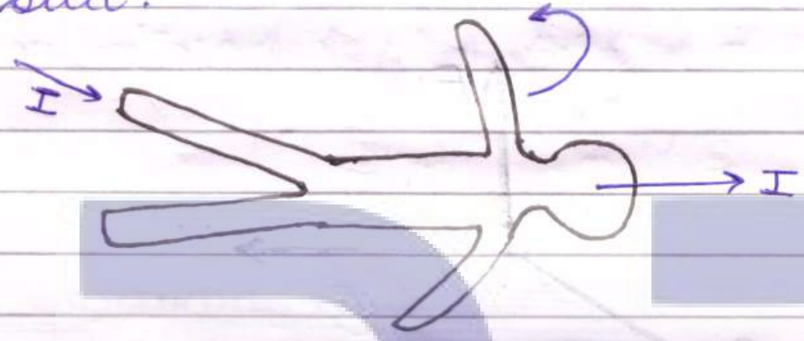
when Current move from South to North then needle deflect over the west.

Ex–



Amper Swimming Rule

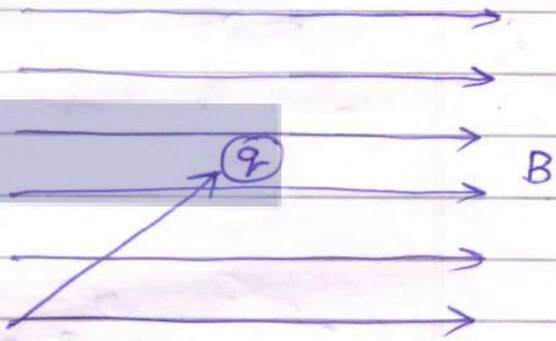
Assume that a current enter in a leg and out from head then needle will be deflect left side (Needle) will deflect towards left side.

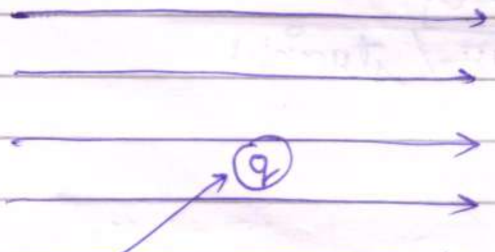


Magnetic Field (B)

A charge particle enter into Magnetic field, it will experience a force.

$$\boxed{f = qVB\sin\theta}$$





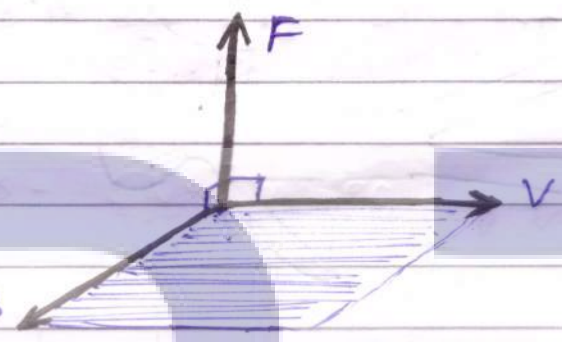
A charge moving with velocity (v) with making angle 'theta' (θ) with magnetic field (B).

Unit → Tesla (T)

$\longrightarrow \quad f = qvB\sin\theta$

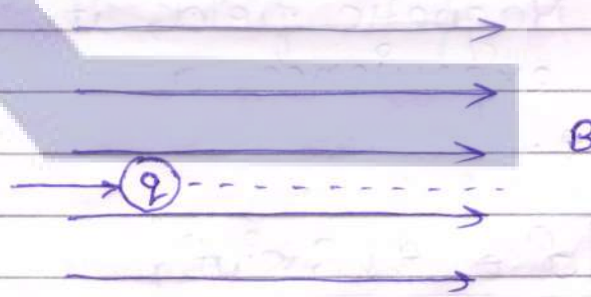
$\longrightarrow \quad \boxed{f = q(\vec{v} \times \vec{B})}$

It mean, force is perpendicular to plane which contain (v) and (B)



Note -

1. If $\theta = 0^\circ$

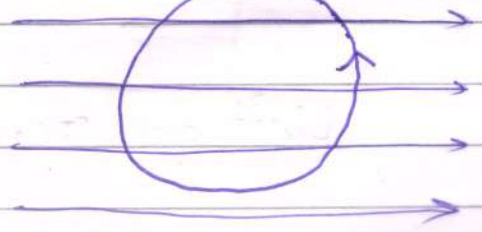


$f = qvB\sin\theta$
$= qvB\sin(0)$
$= 0$, $\boxed{f = 0}$

Path will be linear / straight

2. If $\theta = 90^\circ$

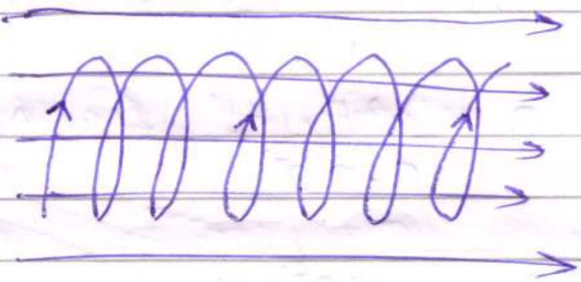
$f = qvB\sin\theta$
$= qvB\sin 90^\circ$
$\boxed{f = qvB}$



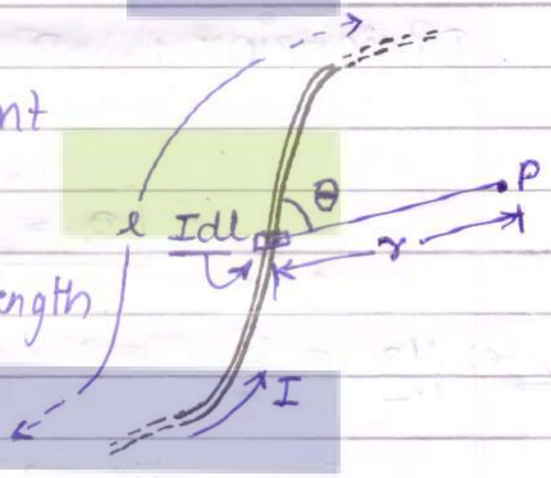
$\longrightarrow$ $\boxed{f = qvB}$

The path will be circular.

(5) If θ = any angle



Biot - Savart Law



Let 'l' be length of current carrying conductor

Let 'dl' is small distance/length

Let 'r' is distance from 'P' point to dl.

It will experience magnetic field (dB)

$$dB \propto dl \quad \text{------} \quad (1)$$

$$dB \propto I \quad \text{------} \quad (2)$$

$$dB \propto \sin\theta \quad \text{------} \quad (3)$$

$$dB \propto \frac{1}{r^2} \quad \text{------} \quad (4)$$

$$dB \propto \frac{I\,dl\,\sin\theta}{r^2} \Rightarrow \boxed{dB = \frac{K I\,dl\,\sin\theta}{r^2}}$$

$$\boxed{K = \frac{\mu_0}{4\pi} = 10^{-7}}$$

$I = \frac{q}{t}$

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Unit and Dimension of Magnetic Field

(1) $\boxed{f = qvB}$

$B = \frac{f}{qv} \Rightarrow \boxed{B = \frac{f}{qv}}$

Unit: $B = \frac{N}{C \cdot ms^{-1}} = NC^{-1}m^{-1}sec$

$$\boxed{B = NC^{-1}m^{-1}sec}$$

Dimension: $B = \frac{[MLT^{-2}]}{[AT][LT^{-1}]}$

$$\boxed{B = [MA^{-1}T^{-2}]}$$

Note: $\frac{\mu_0}{4\pi} = K$

$\mu_0 \rightarrow$ Magnetic Permitivity of free space
$\mu \rightarrow$ Magnetic Permitivity of medium
$\mu_r \rightarrow$ Relative permitivity

$$\boxed{\mu = \mu_0 \times \mu_r}$$

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

$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2} \Rightarrow \boxed{dB \propto \mu_0}$

So, $\boxed{B_2 = \mu_r \times B_1}$

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Dimension of (μ_0)

$$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2}$$

$$\mu_0 = \frac{dB \times 4\pi \times r^2}{I dl \sin\theta}$$

$$\mu_0 = \frac{[MA^{-1}T^{-2}][L^2]}{[A][L]}$$ [$\because$ 4π & $\sin\theta$ have no dimensions]

$$\boxed{\mu_0 = [MA^{-2}T^{-2}L]}$$

Vector form of Magnetic Field

① $$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta}{r^2}$$

Multiply by 'r' on both num. & den.

$$dB = \frac{\mu_0}{4\pi} \frac{I dl \sin\theta \times r}{r^2 \times r}$$

$$= \frac{\mu_0}{4\pi} \frac{I dl\, r \sin\theta}{r^3}$$

$$\boxed{\vec{dB} = \frac{\mu_0}{4\pi} \frac{I(\vec{dl} \times \vec{r})}{r^3}}$$ [$\because$ $\vec{A} \times \vec{B} = AB\sin\theta$]

Note :- Current Density → $J = \frac{I}{A}$

$$\boxed{I = JA}$$

Note : Velocity of light → $\boxed{C = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}}}$

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**

Que What is Dimension of $\frac{1}{\sqrt{\mu_0 \times \varepsilon_0}} = ?$

Ans As we know $\frac{1}{\sqrt{\mu_0 \times \varepsilon_0}} = c$

$$= \frac{1}{\mu_0 \times \varepsilon_0} = c^2$$

As c is velocity of light.

Dimension - $c = [LT^{-1}]$ Ans

$$c^2 = [LT^{-1}]^2$$
$$= [L^2T^{-2}]$$ Ans

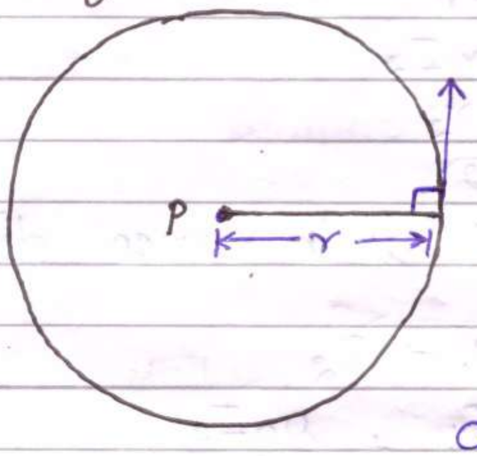
Note: $c = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}}$, $c^2 = \frac{1}{\mu_0 \times \varepsilon_0}$

$v/c \rightarrow$ velocity of Light
$\nu \rightarrow$ Frequency
$\lambda \rightarrow$ Wavelength

$\boxed{c = \nu \times \lambda}$ or $\boxed{V = \lambda\nu}$

$$\Rightarrow \boxed{c = \frac{1}{\sqrt{\mu_0 \times \varepsilon_0}} = \nu\lambda = \frac{1}{T} \times \lambda}$$

Magnetic Field due to Circular Carrying Current



Let, dB is small magnetic field due to dl

By Using Biot Savart Law

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl \sin\theta}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl \sin 90^\circ}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

Then, Integrade both side

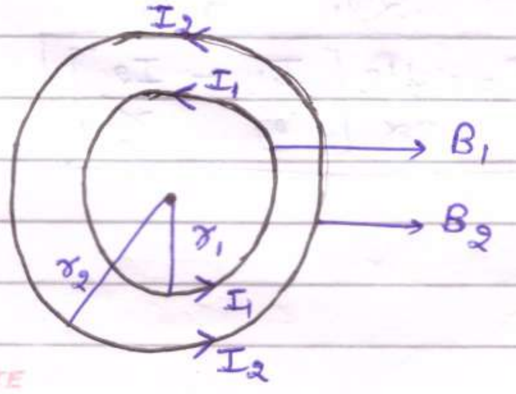
$$\int dB = \int \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}$$

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

$$B = \frac{\mu_0}{{}_2\cancel{4\pi}}\frac{I}{r^{\cancel{2}}} \times \cancel{2\pi r}$$

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

C-1 :



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$$B_1 = \frac{\mu_0 \times I_1}{2r_1} \quad \text{------} \quad (1)$$

$$B_2 = \frac{\mu_0 \times I_2}{2r_2} \quad \text{------} \quad (2)$$

Add both eq^n (1) & (2)

$\therefore$ As current is in same direction

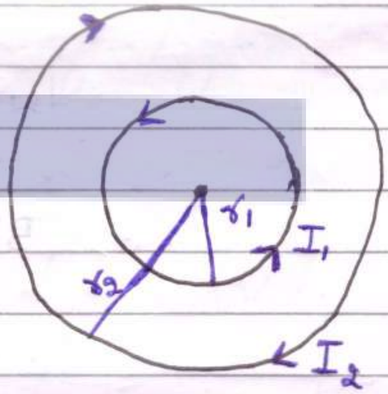
$$B = B_1 + B_2$$

$$B = \frac{\mu_0 I_1}{2r_1} + \frac{\mu_0 I_2}{2r_2}$$

$$\boxed{B = \frac{\mu_0}{2}\left[\frac{I_1}{r_1} + \frac{I_2}{r_2}\right]} \quad A$$

C-2

when current flow in opposite direction.



$$B_1 = \frac{\mu_0 I_1}{2r_1} \quad \text{------} \quad (1)$$

$$B_2 = \frac{\mu_0 I_2}{2r_2} \quad \text{------} \quad (2)$$

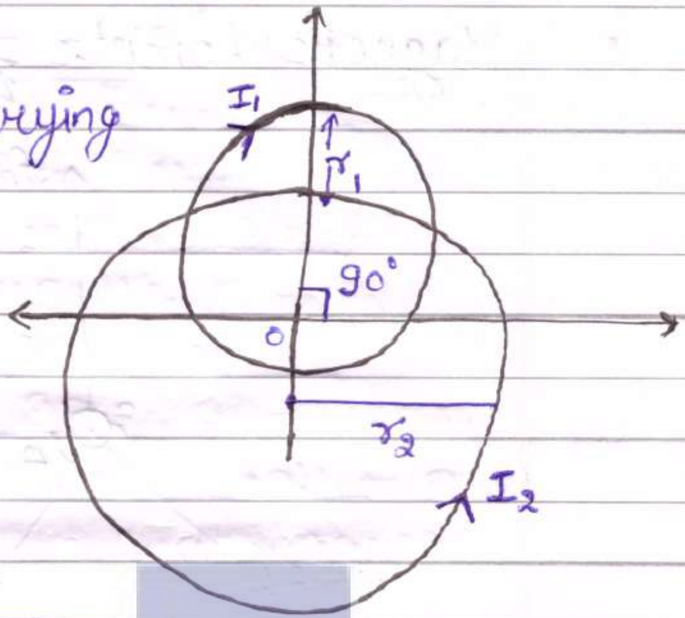
$$B = B_1 - B_2$$

$$B = \frac{\mu_0 I_1}{2r_1} - \frac{\mu_0 I_2}{2r_2}$$

$$\boxed{B = \frac{\mu_0}{2}\left[\frac{I_1}{r_1} - \frac{I_2}{r_2}\right]} \quad A$$

C-3

When two current carrying coil at perpendicular to each other.



$$B_1 = \frac{\mu_0 I_1}{2r_1} \quad \text{------} \quad (1)$$

$$B_2 = \frac{\mu_0 I_2}{2r_2} \quad \text{----} \quad (2)$$

$$B_N = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos\theta} \quad [\because \theta = 90°]$$

$$= \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos 90°}$$

$$= \sqrt{B_1^2 + B_2^2 + 2B_1B_2 \times 0}$$

$$= \sqrt{B_1^2 + B_2^2}$$

If $I_1 = I_2 = I$

$r_1 = r_2 = r$

then,

$$B_1 = B_2 = B$$

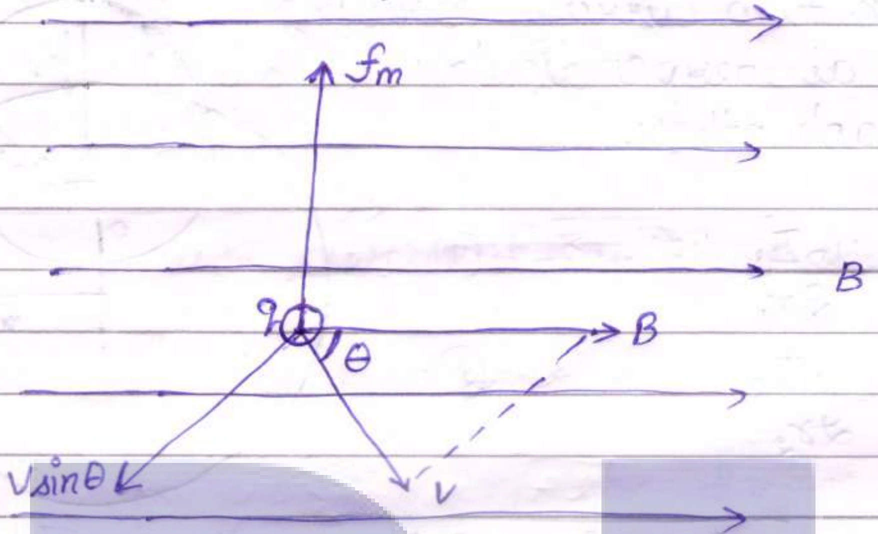
So,

$$B_N = \sqrt{B^2 + B^2}$$

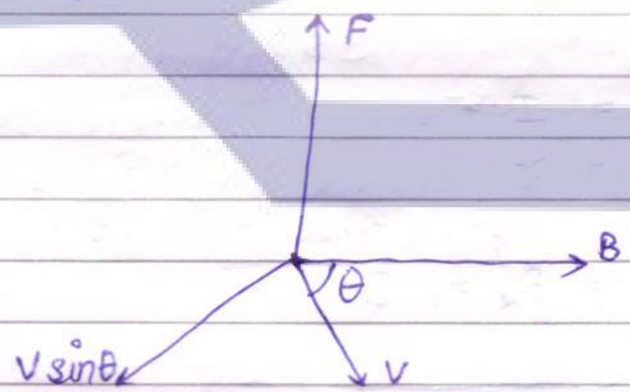
$$= \sqrt{2B^2} \Rightarrow \sqrt{2}B$$

$$\boxed{B_N = \sqrt{2} \times \frac{\mu_0 I}{2r}}$$

Magnetic Lorentz force



A charge (q) move in magnetic field with velocity (v) and making an angle (θ) with magnetic field



$$F = BqV\sin\theta$$

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

$\longrightarrow$ $F = qvB\sin\theta$

$$\frac{f}{qv} = B$$

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$$\Rightarrow \frac{N}{C\,m\,s^{-1}} = T$$

$$\Rightarrow T = \frac{N}{\left[\frac{C}{sec}\right]m}$$

$$\left[\frac{C}{sec} = A\right] = \left[I = \frac{q}{t}\right]$$

$$\Rightarrow T = \frac{N}{A \cdot m}$$

$$\boxed{T = NA^{-1}m^{-1}} \qquad \boxed{T = NA^{-1}m^{-1}}$$

<u>Note:</u>

① $\boxed{1T = NA^{-1}m^{-1} = \frac{N}{Am}}$

② $\boxed{1T = 10^4 G}$ T → Tesla , G → Gauss

③ $\boxed{1T = \frac{wb}{m^2}}$ → weber

[∵ weber is unit of Magnetic Flux]

$$\boxed{\phi = B \times A}$$

ϕ → Magnetic Flux, B → Magnetic Field, A → Area

<u>Ques</u> Copper has 8×10^{28} electron per cubic metre. A copper wire of length 1m & cross sectional area $8\times10^{-6}\,m^2$. carrying a current & lying at right angle to a magnetic field of strength $5\times10^{-3}T$ experience a force of $8\times10^{-2}N$. Calculate the drift velocity of free electron of wire?

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Ans $f = 8\times10^{-2}\,N$, $B = 5\times10^{-3}\,T$

$f = qvB\sin\theta$, $[\because \theta = 90^\circ]$

$\boxed{f = qvB}$

$v = \frac{f}{qB}$ — — — (1)

$q = Ne$, ~~Ne~~

As we know, $n = \frac{N}{Al}$

So, $N = nAl$

$\boxed{N = 8\times10^{28}\times 8\times10^{-6}\times 1}$

By eqn (1)

$v = \frac{f}{NeB}$

$= \frac{8\times10^{-2}}{8\times10^{28}\times 8\times10^{-6}\times 1.6\times10^{-19}\times 5\times10^{-3}}$

$= \frac{\cancel{8}\times10^{-2}}{\cancel{8}\times 8\times 1.6\times 5\times 10^{0}}$

$= \frac{1}{100\times 8\times 1.6\times 5} = \frac{1}{6400} = \underline{0.000156}$ m/s

Ques A proton moves with speed of 8×10^{6} m/sec. along X-axis. It enter a region where then is magnetic field 2.5T directed at angle 60° to axis lying in XY plane. cause magnetic force and accelaration?

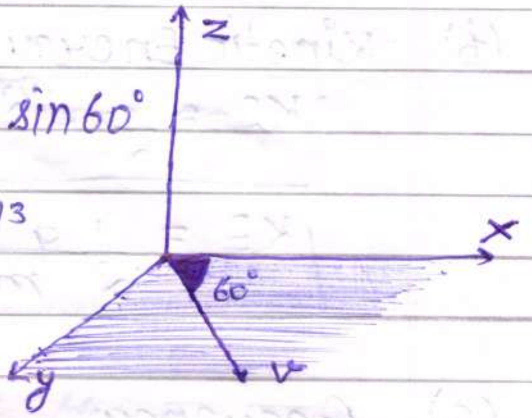
Ans $q = e = 1.6\times10^{-19}$
$v = 8\times10^{6}$ m/sec
$B = 2.5\,T$, $\theta = 60^\circ$

GOOD WRITE

$f = qBv \sin\theta$

$f = 1.6\times10^{-19} \times 8\times10^{6} \times 2.5 \times \sin 60^\circ$

$f = \cancel{32}^{16} \times 10^{-13} \times \frac{\sqrt{3}}{\cancel{2}} \Rightarrow \underline{16\sqrt{3}\times10^{-13}}$



$f = m\times a \;,\; a = \frac{f}{m}$

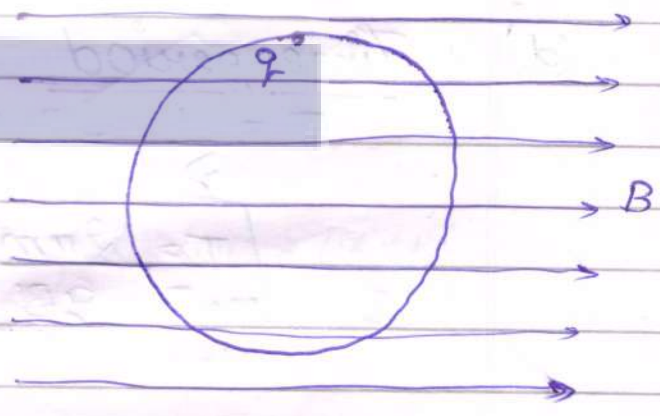
$a = \frac{16\sqrt{3}\times10^{-13}}{1.67\times10^{-27}} = \frac{27.68\times10^{14}}{1.67} = \underline{16.57\times10^{14}\, m/s^2}$

Ques A proton is moving in a circular orbit of radius 14cm in 0.3T magnetic field perpendicular to velocity of proton. Find the orbital speed of proton?

Ans velocity

(a) $r = 14cm \;,\; B = 0.3T$

$\angle 90^\circ$



$f = qvB$ ---- (1)

$f = \frac{mv^2}{r}$ ---- (2)

$q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$

$qB = \frac{mv}{r} \Rightarrow \boxed{r = \frac{mv}{qB}} \Rightarrow \boxed{v = \frac{qBr}{m}}$

$v = \frac{1.6\times10^{-19}\times0.3\times14\times10^{-2}}{1.67\times10^{-27}}$

$\boxed{v = \frac{qBr}{m}}$

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(b) Kinetic Energy of Proton (K.E)

$KE = \frac{1}{2}mv^2 \Rightarrow \frac{1}{2}m\left[\frac{qBr}{m}\right]^2$

$$\boxed{KE = \frac{1}{2}\frac{q^2B^2r^2}{m}}$$

(c) Frequency

$v = \omega r \Rightarrow \omega = \frac{v}{r}$ | $\omega = \frac{2\pi}{T} = 2\pi\nu$

$\omega = \frac{qB\cancel{r}}{m \times \cancel{r}}$

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

$$\boxed{\nu = \frac{1}{2\pi}\frac{qB}{m}}$$

$$\boxed{\omega = \frac{qB}{m}}$$

(d) Time period

$T = \frac{1}{\nu} = \frac{2\pi m}{qB}$

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

Note : → Rotation in 1 min/sec

Ques A Body/charge move in 50 rpm (rotate per mintute). Calculate it frequency.

$\nu = \frac{50}{60}$ rotate per minute

$= 0.833\ hz$

→ Concept of Potential (V)

$$\left[\begin{array}{l} w = \underset{\text{Potential}}{V} \times q = f \times d \quad \text{------} \quad (1) \\ w = V \times q = \frac{1}{2} m \underset{\text{velocity}}{v^2} \quad \text{------} \quad (2) \end{array}\right]$$

Ques An electron accelarated through a potential difference of 100 volt enter a uniform magnetic field of 0.004 T perpendicular to its direction of Motion. Calculate the radius of path described by electron?

Ans $w = V \times q = \frac{1}{2} m v^2$

$w = \underset{\text{Potential}}{V} \times e = \frac{1}{2} m \underset{\text{velocity}}{v^2}$

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

velocity

$$\boxed{v = \sqrt{\frac{2Ve}{m}}} = \sqrt{\frac{2 \times 100 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}}$$

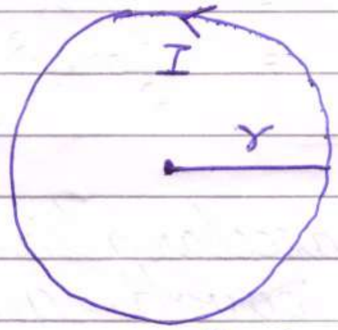
Radius

$$\boxed{r = \frac{mv}{qB}} = \frac{1.67 \times 10^{-27} \times v}{1.6 \times 10^{-19} \times 0.004}$$

$$r = \frac{1.67 \times 10^{-27}}{1.6 \times 10^{-19} \times 0.004} \times \sqrt{\frac{2 \times 100 \times 1.6 \times 10^{-19}}{1.67 \times 10^{-27}}}$$

Note

Magnetic field due to current carrying coil

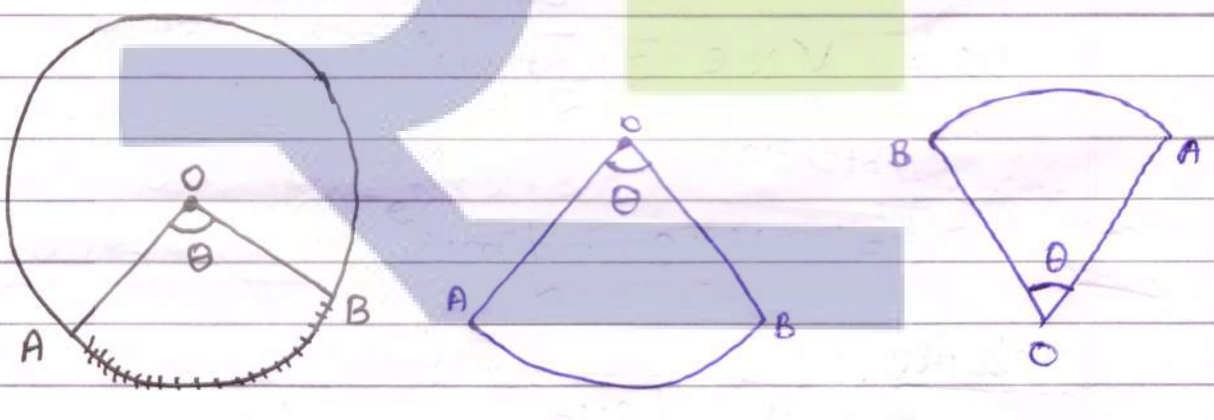


$$\boxed{\sin\theta = 1}$$

$$\rightarrow \int dB = \frac{\mu_0 I}{4\pi r^2}\int dl$$

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

Ques



$$B = \frac{\mu_0 I}{4\pi r^2}\int dl = \frac{\mu_0 I}{4\pi r^2}\int l_{AB}$$

$$\boxed{\because \theta = \frac{l}{r}}$$

$$B = \frac{\mu_0 I}{4\pi r^{\cancel{2}}} \times \theta \times \cancel{r}$$

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

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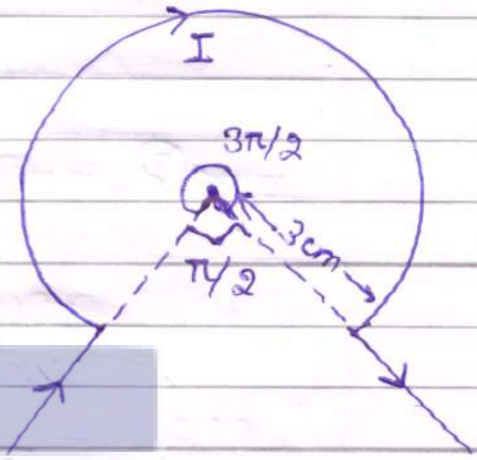
Ques The wire carrying a current of 10A. Determine the magnitude of magnetic field at the centre O. given radius of bent coil 3 cm.

Ans

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

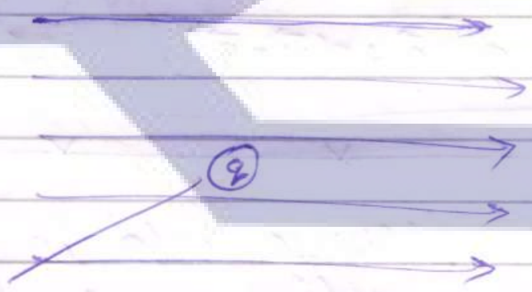


$$B = \frac{10^{-7} \times \cancel{10}^{5} \times \cancel{3\pi}}{\cancel{4\pi} \times \cancel{3} \times 10^{-2} \times \cancel{2}}$$

$$B = \frac{1}{4} = 0.25\ T$$

$$\boxed{B = 0.25\ \text{Tesla}}$$

1) Magnetic Lorentz force



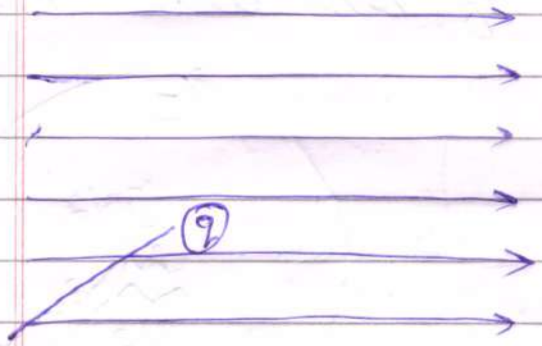
$$\boxed{F = qvB\sin\theta} \quad \text{---} (1)$$

force on charge particle in Magnetic field

q - charge
v - velocity
B - Magnetic field

$$\boxed{F = q(\vec{v} \times \vec{B})} \quad \text{----} (2)$$

Electric Lorentz force



$$\boxed{f_e = qE}$$

Lorentz force

$$\boxed{\vec{f} = \vec{f_e} \times \vec{f_B}}$$

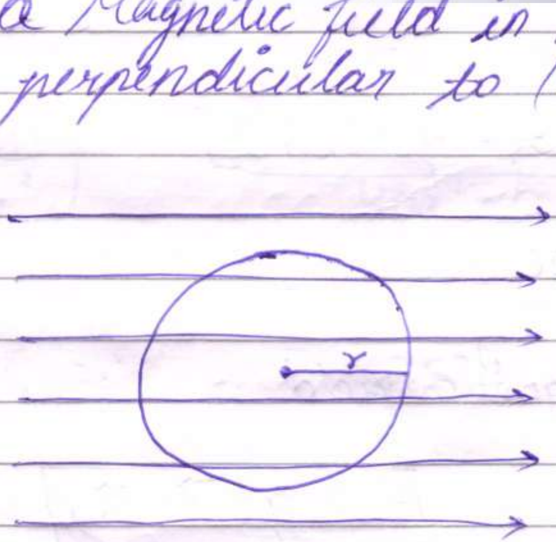
$$\vec{f} = q\vec{E} + q(\vec{v} \times \vec{B})$$

$$\longrightarrow \boxed{\vec{f} = q[\vec{E} + (\vec{v} \times \vec{B})]} \quad A$$

$\Rightarrow$ Consider a Magnetic field in which particle is have perpendicular to (B) and (v)

path- circular

$\boxed{\theta = 90}$



$\angle 90^\circ$

$$\boxed{f = \frac{mv^2}{r}}$$

$$f = qvB \sin 90$$

$$\boxed{f = qvB}$$

$\rightarrow$ $\frac{mv^{\cancel{2}}}{r} = q\cancel{v}B$

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

$$\boxed{v = \frac{qBr}{m}}$$

* radius (r) = $\boxed{r = \frac{vm}{qB}}$

$W = Ve = \frac{1}{2}mv^2$

$$\boxed{v = \sqrt{\frac{2Ve}{m}}}$$

$r = \sqrt{\frac{2Ve}{m}} \times \frac{m}{qB} = \sqrt{\frac{2Ve\,m^{\cancel{2}}}{\cancel{m}q^2B^2}}$

<u>Note</u>

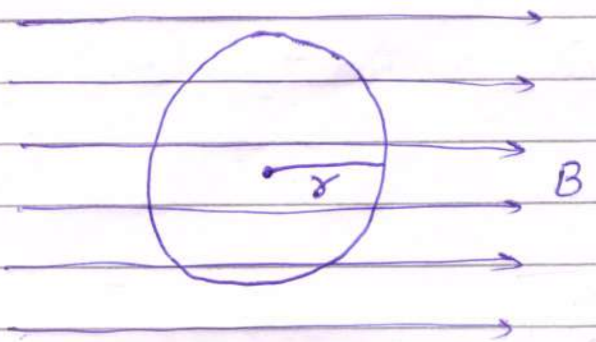
$$\boxed{\begin{aligned} W &= f \cdot d \\ W &= Vq \\ W &= \frac{1}{2}mv^2 \\ W &= Ve \end{aligned}}$$

$r = \sqrt{\frac{2V\cancel{e}}{e^{\cancel{2}} \times B^2}}$ $[q = e]$

$$\boxed{r = \sqrt{\frac{2V}{e \times B^2}}}$$ Ans

<u>Ques</u> An electron travels in circular path of radius 20 cm in Magnetic field 2×10^{-3} T ?
(a) Calculate the speed of electron
(b) What is the difference potential difference through which electron must be accelarated acquire this speed?

Ans



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

$B = 2 \times 10^{-3} T$

$$\rightarrow \quad q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$$

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

Speed

$$\boxed{\frac{qBr}{m} = v}$$

$$W = Ve$$

$$\boxed{\frac{1}{2}mv^2 = eV_p}$$

Ques An electron been payes through a magnetic field 2×10^{-3} wb m^{-2} & electric field of 3.4×10^{4} Vm^{-1}. Both acting simultaneous. If the path of electron remain undeviated cause the speed of electron. If the electric field is removed, what will be radius of circular path & mass of electron is 9.1×10^{-31} kg ?

Ans

$$\boxed{B = 2 \times 10^{-3} \ wb \ m^{-2}}$$

$$\boxed{E = 3.4 \times 10^{4} \ Vm^{-1}}$$

If path is undeviated

$$f_c = f_B \qquad R =$$

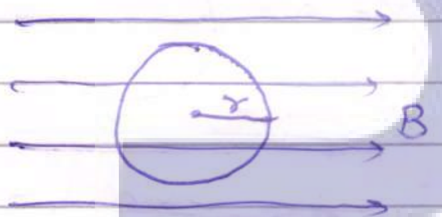
$$\cancel{q}E = \cancel{q}vB$$

$$\boxed{E = vB}$$

$$\boxed{v = \frac{E}{B}}$$ velocity of charge

(a) $v = \frac{E}{B} \Rightarrow \frac{3.4 \times 10^4}{2 \times 10^{-3}} = 1.7 \times 10^7 \, m s^{-1}$

(b)



$\longrightarrow \boxed{f = \frac{mv^2}{r}}$ ---- (1)

$\longrightarrow f = qvB \sin 90°$

$\boxed{f = qvB}$ ---- (2)

from eq^n (1) & (2)

$$q\cancel{v}B = \frac{m v^{\cancel{2}}}{r}$$

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

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

Note

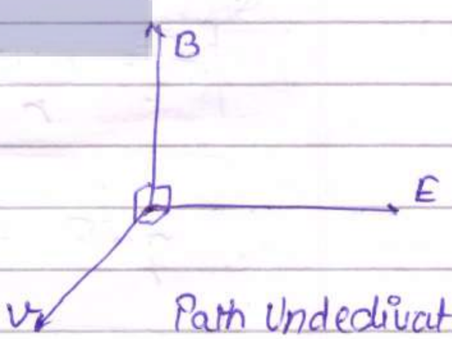
$\longrightarrow \phi = \vec{E} \cdot \vec{S}$ (Electric Field)

$\longrightarrow \phi = \vec{B} \cdot \vec{S}$ (Magnetic Field)

$wb = \vec{B} \times m^2$

$\boxed{\vec{B} = wb \, m^{-2}}$

(1)



Path Undediviated

(2) $f_c = f_B$

$\cancel{q}E = \cancel{q}vB$

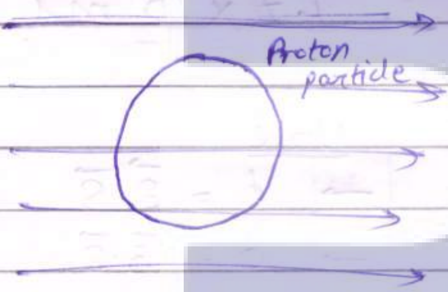
$\boxed{v = \frac{E}{B}}$

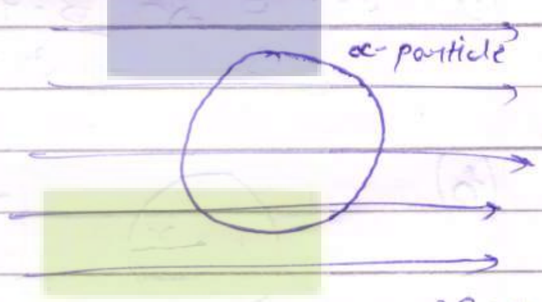
(3)

$\boxed{f_B = \frac{mv^2}{r} = qvB}$

Ques A proton & alpha particle enter at right angles into a uniform magnetic field of intensity (B). Calculate ratio of radii of their paths, when they enter the field?

	Mass	charge
Proton particle	$m_p = m$	$q_p = q$
Deutron particle	$m_d = 2m_p$	$q_d = q_p$
Alpha particle	$m_\alpha = 2m_p$	$q_\alpha = 2q_p$





if, $V_p = V_\alpha = V$

$f = qvB \sin 90°$

$\boxed{f = qvB}$ --- (1)

$\boxed{f = \frac{mv^2}{r}}$ --- (2)

$q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$

$\boxed{\frac{qBr}{m} = v}$

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

Proton

$r_p = \frac{m_p v_p}{q_p \times B}$

α particle

$r_\alpha = \frac{m_\alpha v_\alpha}{q_\alpha \times B}$

$\frac{r_p}{r_\alpha} = \frac{m_p \times \cancel{V}}{q_p \times \cancel{B}} \times \frac{q_\alpha \times \cancel{B}}{m_\alpha \cancel{V}}$

$\frac{r_p}{r_\alpha} = \frac{m_p \times q_\alpha}{q_p\, m_\alpha}$

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$$\frac{r_p}{r_\alpha} = \frac{m_p}{m_\alpha} \times \frac{q_\alpha}{q_p}$$

$$= \frac{\cancel{m} \times 2\cancel{q}}{4 \times \cancel{m} \times \cancel{q}} = \frac{1}{2} \Rightarrow \boxed{\frac{r_p}{r_\alpha} = \frac{1}{2}}$$

Ques A proton, a deutron and alpha particle having same K.E are allowed to pass through uniform Magnetic field perpendicular to the direction of motion. Compare the radii of circular path.

Ans

$$\frac{mv^{\cancel{2}}}{r} = q\cancel{v}B \qquad KE = \frac{1}{2}mv^2$$

$$\frac{mv}{r} = qB \qquad \sqrt{\frac{2KE}{m}} = v$$

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

$$r = \frac{m}{qB}\sqrt{\frac{2KE}{m}} = \frac{1}{qB}\sqrt{\frac{2KEm^{\cancel{2}}}{\cancel{m}}} = \frac{\sqrt{2mK.E}}{qB}$$

$$\boxed{r = \frac{\sqrt{2mK.E}}{qB}} \Rightarrow r = \frac{\sqrt{K.m}}{qB}$$

$$r_p : r_d : r_\alpha$$

$$\frac{1}{q_pB}\sqrt{Km_p} : \frac{1}{q_dB}\sqrt{Km_d} : \frac{\sqrt{Km_\alpha}}{q_\alpha B}$$

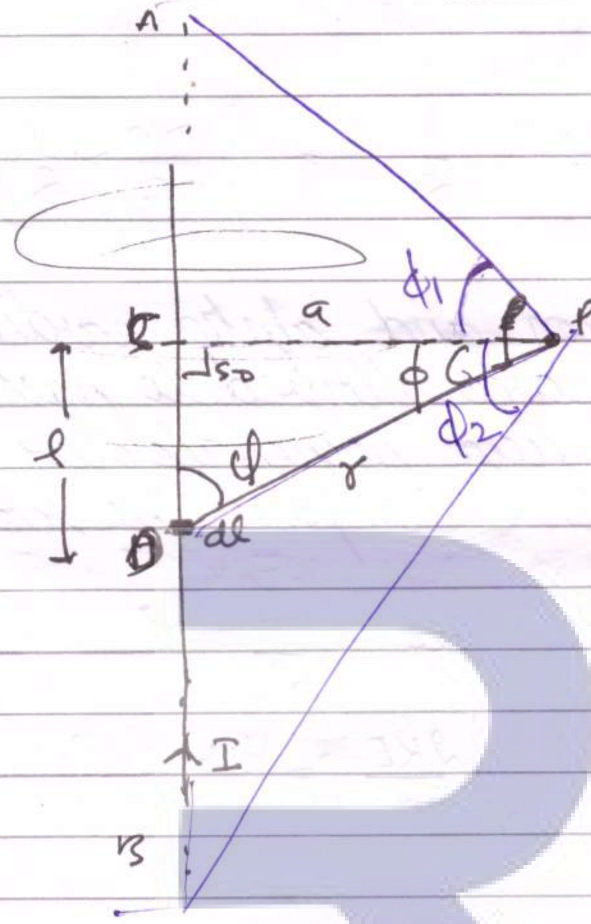
$$\frac{\sqrt{m_p}}{q_p} : \frac{\sqrt{m_d}}{q_d} : \frac{\sqrt{m_\alpha}}{q_\alpha}$$

$$\frac{\sqrt{m}}{q} : \frac{\sqrt{2m}}{q} : \frac{\sqrt{4m}}{2q}$$

$$1 : \sqrt{2} : 1$$

L-

Magnetic field due to Infinite current carrying conductor



→ $L = (AB)$ → It is length of infinite conductor

→ Let CD is small distance (l)

→ $\boxed{\theta + \phi = 90^\circ}$ → $\boxed{\theta = 90 - \phi}$

→ (dl) is small length
(dB) is small Magnetic field

→ $\boxed{dB = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{r^2}}$ [Biot Savart Law]

→ μ_0 = Magnetic Permitivity of free space → $\left[\frac{\mu_0}{4\pi} = 10^{-7}\right]$

→ $\tan\phi = \frac{l}{a}$

→ $\boxed{l = a\tan\phi}$

Differentiate Both side

$\rightarrow l = a\tan\phi$

$\rightarrow \boxed{dl = a\sec^2\phi \cdot d\phi}$

$\boxed{\cos\phi = \frac{a}{r}} \rightarrow \boxed{r = \frac{a}{\cos\phi}}$

$$\rightarrow dB = \frac{\mu_0 I}{4\pi} \frac{a\sec^2\phi \times \sin(90-\phi)}{\left(\frac{a}{\cos\phi}\right)^2}$$

$$\rightarrow dB = \frac{\mu_0 I}{4\pi} \frac{a\cancel{\sec^2\phi}}{a^2 \times \cancel{\sec^2\phi}} \cdot \cos\phi \, d\phi$$

$$\rightarrow \boxed{dB = \frac{\mu_0 I \cos\phi}{4\pi a} \cdot d\phi}$$

$$\rightarrow dB = \frac{\mu_0 I \cos\phi}{4\pi a}$$

Integrate Both side

$$\rightarrow \int dB = \int_{-\phi_2}^{\phi_1} \frac{\mu_0 I \cos\phi \cdot d\phi}{4\pi a}$$

$$\rightarrow B = \frac{\mu_0 I}{4\pi a} \int_{-\phi_2}^{\phi_1} \cos\phi \cdot d\phi$$

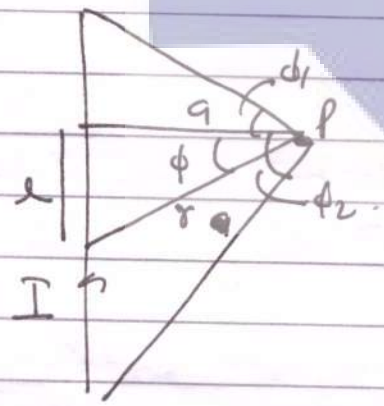
$$B = \frac{\mu_0 I}{4\pi a}\int_{-\phi_2}^{\phi_1} \cos\phi \cdot d\phi$$

$$\vec{B} = \frac{\mu_0 I}{4\pi a}\left[\sin\phi\right]_{-\phi_2}^{\phi_1}$$

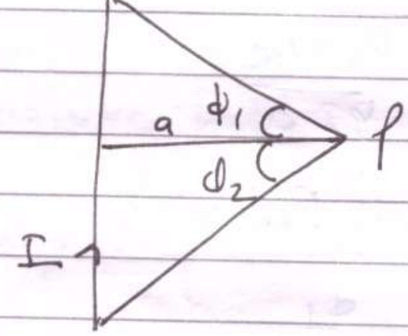
$$B = \frac{\mu_0 I}{4\pi a}\left[\sin\phi_1 - (-\sin\phi_2)\right]$$

$$\rightarrow \boxed{B = \frac{\mu_0 I}{4\pi a}\left[\sin\phi_1 + \sin\phi_2\right]}$$

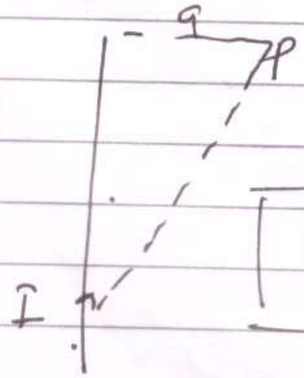
Note



$$\boxed{B = \frac{\mu_0 I}{4\pi a}\left[\sin\phi_1 + \sin\phi_2\right]}$$



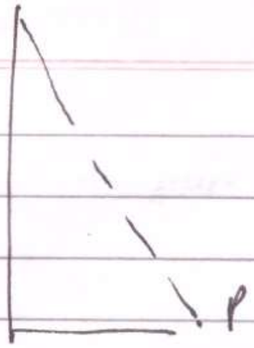
C-1



$\boxed{\phi_1 = 0}$, $\boxed{\phi_2 = \phi}$

$$\boxed{B = \frac{\mu_0 I}{4\pi a}\sin[\phi]}$$

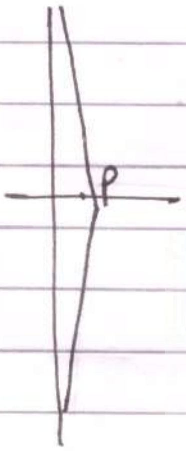
C-2



$\phi_1 = 0, \phi_2 = \phi$

$$\boxed{B = \frac{\mu_0 I}{4\pi a} \sin\phi}$$

C-3



$$\boxed{\phi_1 = \phi_2 = 90}$$

$$B = \frac{\mu_0 I}{4\pi a}\left[\sin 90 + \sin 90\right]$$

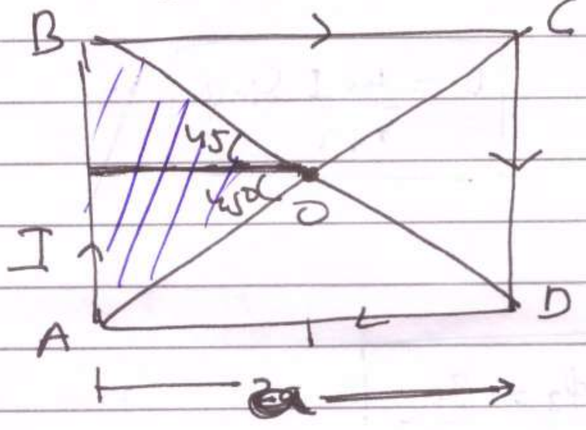
$$B = \frac{\mu_0 I}{\cancel{4}\pi a} \times \cancel{2}$$

$$\boxed{B = \frac{\mu_0 I}{2a\pi}}$$

* Magnetic filed due to straight current carrying conductor is 'B'

If angle not given $\boxed{B = \frac{\mu_0 I}{2\pi a}}$

Q: find the magnetic field at 'O'



A: Magnetic field due to AB

$$B_{AB} = \frac{\mu_0 I}{2\pi (a/2)} = \frac{\mu_0 I}{2\pi a}\times 2$$

$$\boxed{B = \frac{\mu_0 I}{\pi a}}$$

for whole square: $\boxed{B_N = 4\times B = 4\times\frac{\mu_0 I}{\pi a}}$

or

$$B_1 = \frac{\mu_0 I}{\cancel{4}\pi \frac{a}{\cancel{2}}}\left[\sin 45 + \sin 45\right] = \frac{\mu_0 I}{\pi a}\times\left[\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right]$$

$$B_1 = \frac{\mu_0 I}{4\pi}\times\frac{2}{\sqrt{2}} = \frac{\mu_0}{4\pi}\,\frac{\cancel{2}\times\sqrt{2}}{\sqrt{2}\,\cancel{\sqrt{2}}} = \frac{\mu_0}{4\pi}\times\sqrt{2}$$

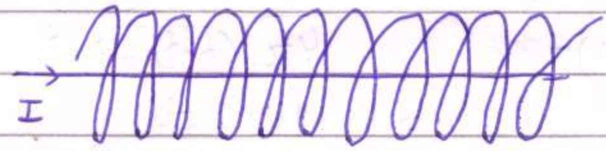
$$\rightarrow B_T = 4\times B_1 = 4\times\frac{\mu_0}{4\pi}\times\sqrt{2}$$

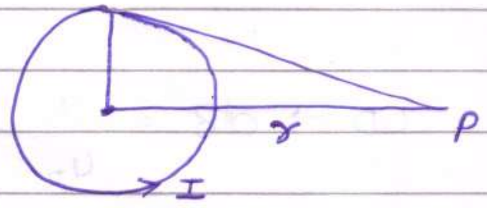
$$\boxed{B_T = \frac{\mu_0}{4\pi}\times 4\sqrt{2}}$$ Ans.

(Continue...) Chapter-4

Note

①



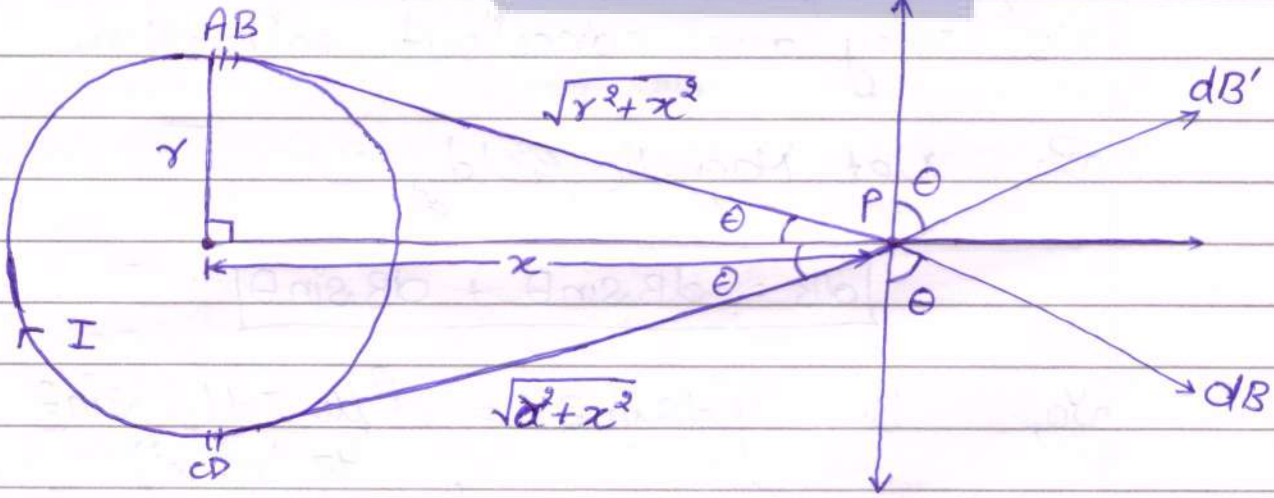


② Biot-Savart Law → $\boxed{dB = \frac{K I dl \sin\theta}{r^2}}$

dl → small distance / length
B → Magnetic field
E → Electric field
ε_0 → electrical Permitivity
μ_0 → Magnetic Permitivity

$\boxed{K = \frac{\mu_0}{4\pi}} = 10^{-7}$

* Magnetic field due to current Carrying coil at axial point



Let 'P' is point where we went find magnetic field

Let dB & dB' is magnetic field due to AB & CD

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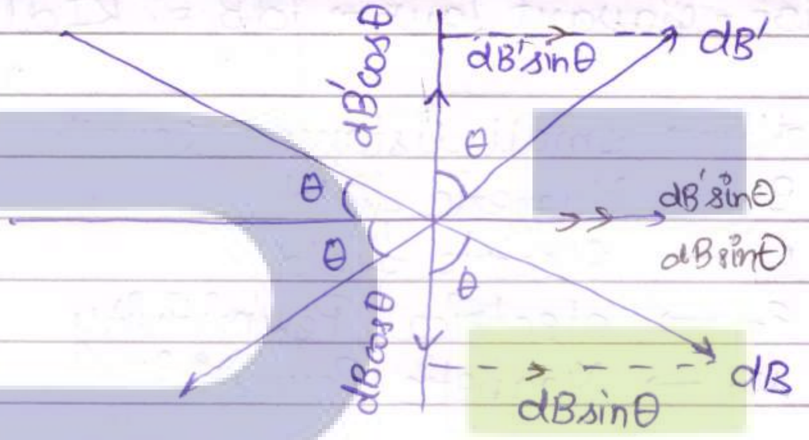
$AB \rightarrow \quad dB = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{(BP)^2} = \frac{\mu_0 I\,dl}{4\pi (\sqrt{r^2+x^2})^2} = \frac{\mu_0 I\,dl}{4\pi(r^2+x^2)}$

$CD \rightarrow dB' = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{(DP)^2} = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{(\sqrt{r^2+x^2})^2}$

$= \frac{\mu_0 I\,dl}{4\pi (r^2+x^2)}$



$\longrightarrow$ dB & dB' are equal.
So, $dB'\cos\theta$ & $dB\cos\theta$ are equal & opposite direcⁿ
So, They are cancel out each other.

So, Net Magnetic field

$$\boxed{dB = dB'\sin\theta + dB\sin\theta}$$

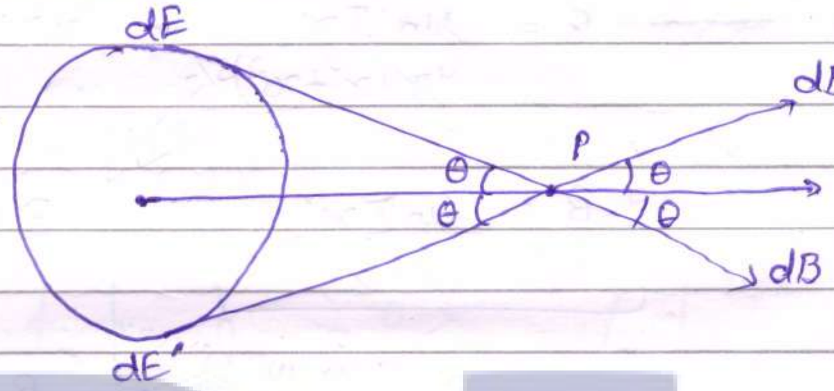
So, $\quad B = \int dB\sin\theta = \int \frac{\mu_0 I\,dl}{4\pi(r^2+x^2)} \sin\theta$

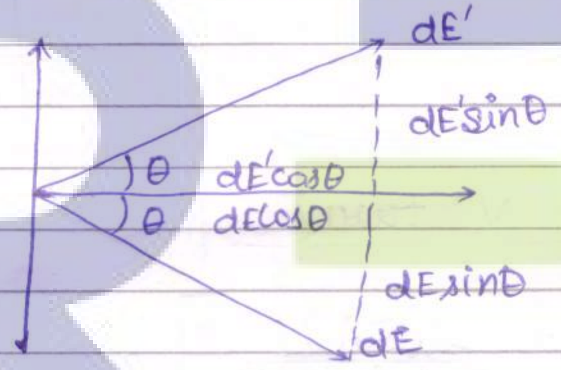
$$\left[\because \sin\theta = \frac{r}{\sqrt{r^2+x^2}}\right]$$

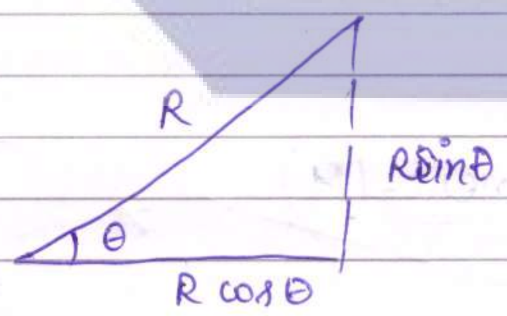
GOOD WRITE

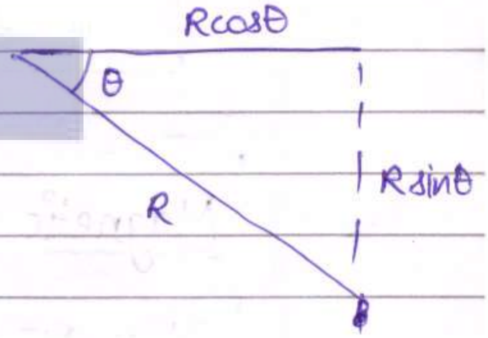
$$B = \int \frac{\mu_0 I dl}{4\pi(r^2+x^2)} \times \frac{r}{\sqrt{r^2+x^2}} = \frac{\mu_0 I r}{4\pi(r^2+x^2)^{3/2}} \int dl$$

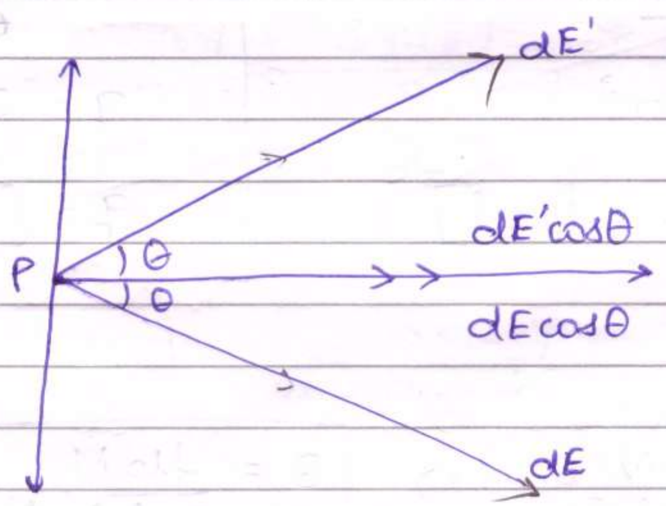
Electric Field











$$\boxed{E = dE\cos\theta + dE'\cos\theta}$$

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$$B = \frac{\mu_0 I r}{4\pi(r^2+x^2)^{3/2}} \int dl$$

$$B = \frac{\mu_0 I r}{\cancel{4\pi}_{2}(r^2+x^2)^{3/2}} \times \cancel{2\pi} r$$

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

Circumference

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

$$\boxed{B = \frac{\mu_0 I A}{2\pi(r^2+x^2)^{3/2}}} \quad [A = \pi r^2]$$

Area

For 'N' turns

$$\boxed{B = \frac{\mu_0 I A N}{2\pi(r^2+x^2)^{3/2}}}$$

Magnetic Moment (M)

$$\boxed{M = NIA}$$

Unit – Am^2

Dimension – $[AL^2]$

Note

$$I = \frac{q}{t}$$

$$q = It$$

$$q = [AT]$$

Note

$$B = \frac{\mu_0 IAN}{2\pi(r^2+x^2)^{3/2}} \Rightarrow \boxed{B = \frac{\mu_0 M}{2\pi(r^2+x^2)^{3/2}}}$$

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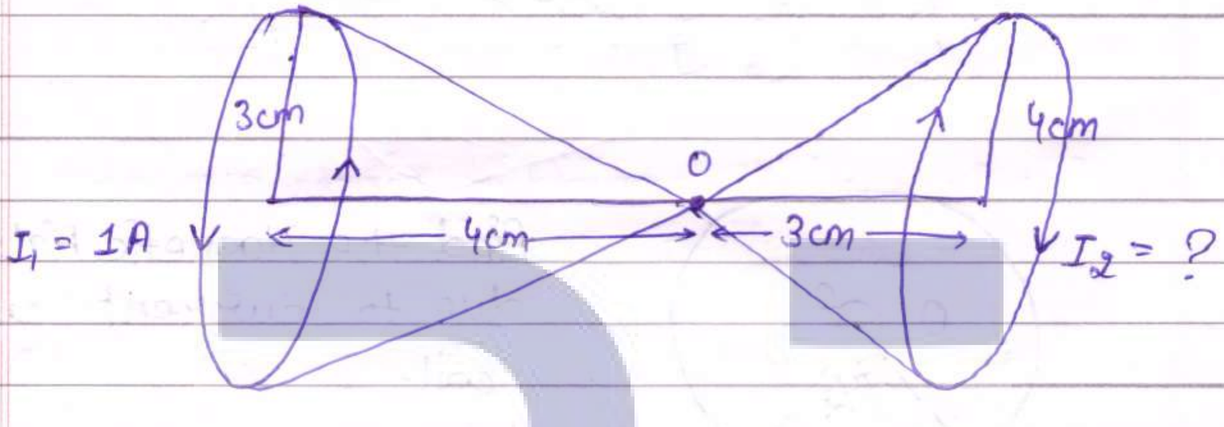
Ques Two coaxial circular Loops (L_1) & (L_2) of radii 3cm & 4cm are placed in fig. What should be magnitude & direction of current in Loop (L_2) so that Net Magnitude field at point O be zero?



$$B_1 = \frac{\mu_0 I r^2}{2(r^2+x^2)^{3/2}} \quad \Bigg| \quad B_2 = \frac{\mu_0}{2(r^2+x^2)^{3/2}}$$

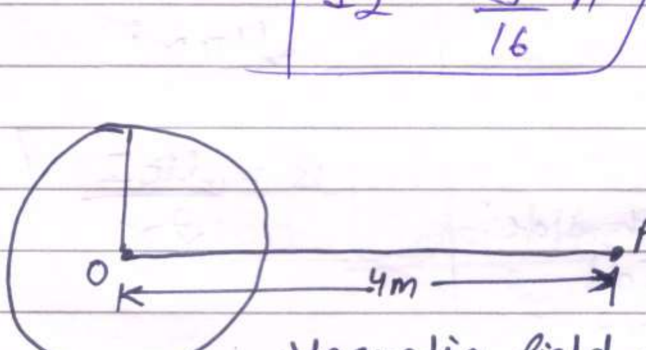
$$\frac{\cancel{\mu_0} I_1 r_1^2}{\cancel{2}(r_1^2+x_1^2)^{3/2}} = \frac{\cancel{\mu_0} I_2 r_2^2}{\cancel{2}(r_2^2+x_2^2)^{3/2}}$$

$$\frac{1\times(3)^2}{\cancel{(9+16)^{3/2}}} = \frac{I_2 \times 16}{\cancel{(16+9)^{3/2}}}$$

$$9 = I_2(16)$$

$$\boxed{I_2 = \frac{9}{16}\,A}$$

Ques



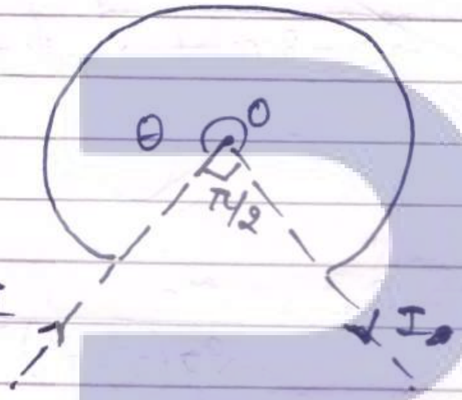
Magnetic field at P is 1/9 times at 'O' find the radius of circle if current flows is 2A?

$$\boxed{B_P = \frac{1}{9} B_0}$$

$$\frac{\cancel{\mu_0 I} r^2}{\cancel{2}(r^2+x^2)^{3/2}} = \frac{1}{9}\frac{\cancel{\mu_0 I}}{\cancel{2} r}$$

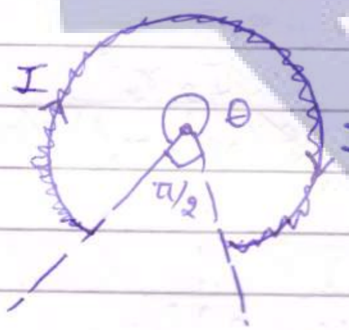
$$\boxed{r^3 = \frac{1}{9}(r^2+x^2)^{3/2}}$$ Ans

Ques



Find the Magnetic Field at O due to current carrying coil.

Ans



$$dB = \frac{\mu_0 I dl \sin\theta}{4\pi r^2}$$

$\boxed{\theta = 90}$

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

Integrate both side

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

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

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

If full circle

$$B = \frac{\mu_0 I \cancel{2\pi r}}{{}_2\cancel{4\pi r^2}}$$

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

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For arc

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

$$\theta = \frac{\text{arc}}{\text{radius}}$$

$$\boxed{\text{arc} = \theta \times \text{radius}}$$

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

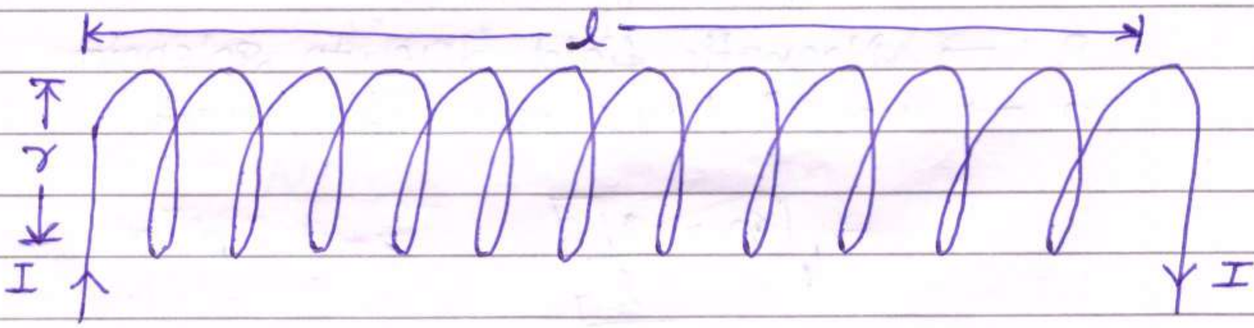
$$\boxed{B = \frac{\mu_0 I \theta}{4\pi r}}$$

Note

$$B = \frac{10^{-7} \times I \times}{r} \frac{3\pi}{2}$$

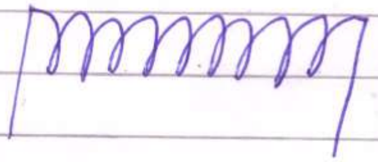
$$\boxed{B = 10^{-7} \times \frac{3\pi}{2} \times \frac{I}{r}}$$

* Solenoid



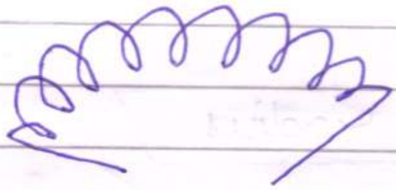
If a coil have length more than radius, coil is called Solenoid.

I



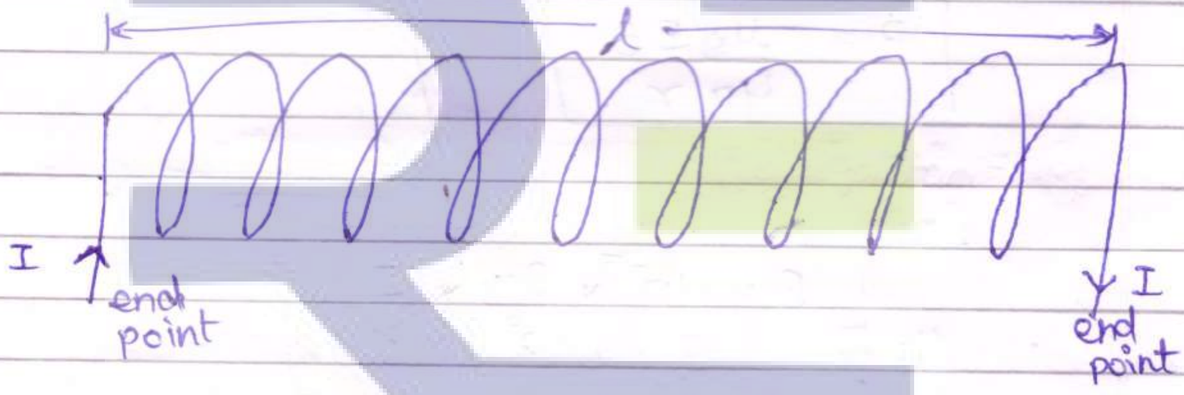
→ Solenoid
→ Inductor

II



→ $\boxed{\text{Toiroid}}$

Bending of solenoid in circular path is called Toiroid.



l → length of solenoid
N → Number of turns
B → Magnetic field due to solenoid
n → no. of turns per unit length

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

$B = \mu_0 \times n \times I$

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

end point

$$\boxed{B_e = \frac{B}{2} = \frac{\mu_0 N I}{2l}}$$

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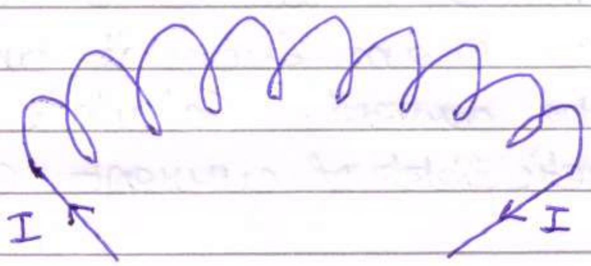
Toroid



$B = \mu_0 n I$

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

at end point $\boxed{B_e = \frac{\mu_0 n I}{2l}}$

Note

① $B_r = \frac{\mu_0 I r^2 \times 2\pi \times N}{4\pi (r^2+x^2)^{3/2}}$

② $B_0 = \frac{\mu_0 I \cancel{2\pi r}}{\cancel{4\pi} r^{\cancel{2}}} \Rightarrow \frac{\mu_0 I}{2r}$

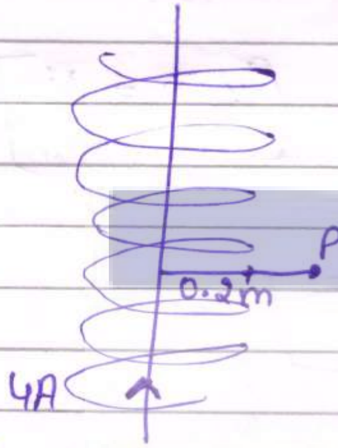
③ $M = NIA$

④ $B_s = B_T = \mu_0 n I$

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

Ques A long straight wire AB carries current of 4A. A proton travels at 4×10^6 m/sec parallel to the wire, 0.2m from it and in direction opposite to the current. Calculate the force which magnetic field of current exert on the proton.

Ans



$V = 4 \times 10^6$ m/sec

(a) $[q = \text{proton} = 1.6 \times 10^{-19} C]$

$$f = qVB \sin\theta$$

$$\boxed{f = 1.6 \times 10^{-19} \times 4 \times 10^6 \times B} \qquad [\because \theta = 90^\circ]$$

(b) Magnetic field due to straight current carrying conductor

$$\boxed{B = \frac{\mu_0 I}{2\pi r}} \qquad \frac{\mu_0}{4\pi} = 10^{-7}$$

$$\boxed{\mu_0 = 10^{-7} \times 4\pi}$$

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

$$\boxed{B = 10 \times 4 \times 10^{-7} \text{ T}}$$

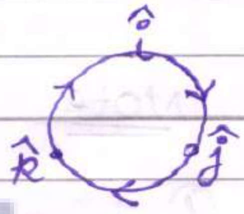
Ques A positive charged of 1.5 µC is moving with speed of $2\times10^6\ ms^{-1}$ along positive X-axis. A magnetic field $\vec{B} = (0.2\hat{j} + 0.4\hat{k})T$ acts as in space. Find Magnetic force on charge.

Ans

$q = 15\mu C = 1.5\times10^{-6}\ C$

$v = 2\times10^6\ ms^{-1}$

$\vec{B} = (0.2\hat{j} + 0.4\hat{k})T$



$f = qvB\sin\theta$

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

$\vec{f} = 1.5\times10^{-6}\left[2\times10^6\,\hat{i}\times(0.2\hat{j}+0.4\hat{k})\right]$

$\vec{f} = 1.5\times10^{-6}\left[2\times10^{-6}\times0.2\,(\hat{i}\times\hat{j}) + 2\times10^6\times0.4\,(\hat{i}\times\hat{k})\right]$

$\vec{f} = 1.5\times10^{-6}\left[2\times10^{-6}\times0.2\times\hat{k} + 0.8\times10^6\,(-\hat{j})\right]$

$\vec{f} =$ ______

Ques An electron in moving at $10^6\ ms^{-1}$ in a direction parallel to current of 5A. flowing through an infinitely long straight wire, separated by perpendicular distance of 10cm air. Calculate the Magnetic force experienced by electron?

Ans

$V = 10^6\ ms^{-1}$

$q = -1.6\times10^{-19}\ C$

$I = 5A$

$r = 0.10m$

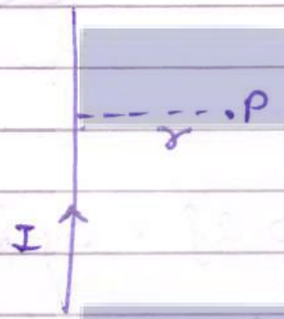
$$f = qvB\sin\theta \quad , \quad \theta = 90^\circ$$

$$\boxed{f = qvB}$$

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

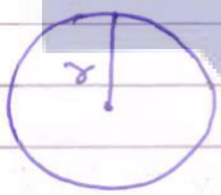
Note

(1)



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

(2)

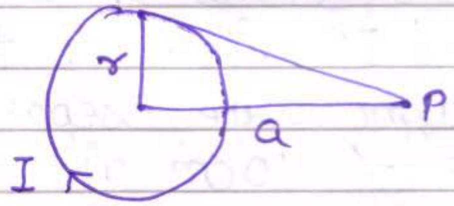


$$\boxed{B = \frac{\mu_0 I}{2\pi r}}$$

(3) Biot Savart Law

$$\boxed{dB = \frac{\mu_0 I\, dl \sin\theta}{4\pi \; r^2}}$$

(4)



$$\boxed{B = \frac{\mu_0 I a^2 \times 2\pi}{4\pi (r^2 + a^2)^{3/2}}}$$

(5) Magnetic Moment

$$\boxed{M = NAI}$$

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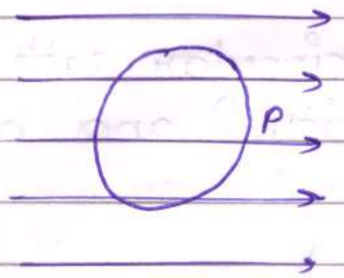
(6)



$$\boxed{\theta = 90^\circ}$$

$$\boxed{f = \frac{mv^2}{r}} \quad \text{--- (1)} \qquad \boxed{f = qvB} \quad \text{--- (2)}$$

$$\frac{mv^{\cancel{2}}}{r} = q\cancel{v}B$$

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

(i) velocity $\Rightarrow$ $\boxed{v = \frac{qBr}{m}}$

(ii) radius $\Rightarrow$ $\boxed{r = \frac{mv}{qB}}$

(iii) angular velocity

$$\boxed{v = r\omega}$$

$$\omega = \frac{v}{r} \qquad \omega = \frac{qB\cancel{r}}{m} \times \frac{1}{\cancel{r}}$$

$$\boxed{\omega = \frac{qB}{m}}$$

(iv) $\omega = 2\pi\nu \longrightarrow$ frequency

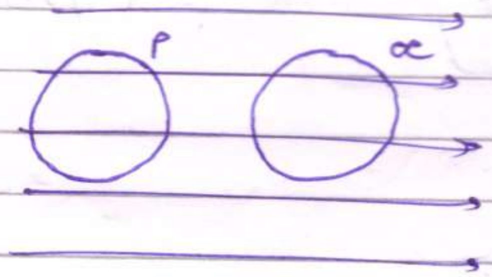
$$\boxed{\nu = \frac{\omega}{2\pi} = \frac{qB}{2\pi m}}$$

(v) Time Period (T)

$$T = \frac{1}{\nu} \Rightarrow \boxed{T = \frac{2\pi m}{qB}}$$

Ques A proton & alpha move in circular path in magnetic field their velocity ? and both same radius.

Ans



$$V_p = \frac{qBr}{m} = \frac{q_p B r}{m_p} \quad , \quad V_\alpha = \frac{q_\alpha \times B \times r}{m_\alpha}$$

$$\frac{V_p}{V_\alpha} = \frac{\frac{q_p \times \cancel{B \times r}}{m_p}}{\frac{q_\alpha \times \cancel{B \times r}}{m_\alpha}} = \frac{q_p}{m_p} \times \frac{m_\alpha}{q_\alpha}$$

$$\frac{V_p}{V_\alpha} = \frac{q_p m_\alpha}{m_p q_\alpha} \Rightarrow \frac{\cancel{q_p} \times 4\cancel{m_p}}{\cancel{m_p} \times 2\cancel{q_p}} = 2$$

$$\boxed{V_p = 2V_\alpha}$$

Ques A charge get potential (v) It will move

$$\boxed{E = eV_0}$$

electron → Potential

$$\boxed{E = \frac{1}{2}mv^2}$$

$$\boxed{eV_0 = \frac{1}{2}mv^2} \Rightarrow \boxed{v = \sqrt{\frac{2eV_0}{m}}}$$

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Que An electron after having being accelarated through a potential difference of 10^4V enter uniformly magnetic field at 0.04T perpendicular to its direction of motion. Calculate the radius of curvature of its path?

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

Potential difference $= V_0 = 10^4$ volt

$B = 0.04T$
$\theta = 90°$
$r = ?$

$m \rightarrow$ mass of $e^- = 9.1 \times 10^{-31}$ kg

(i) $\boxed{r = \frac{mv}{qB}}$ velocity

$$r = \frac{9.1 \times 10^{-31} \times v}{1.6 \times 10^{-19} \times 0.04}$$

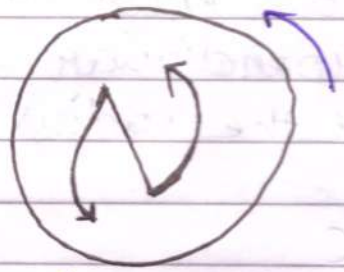
$\Rightarrow E = eV_0 = \frac{1}{2}mv^2$

$$v = \sqrt{\frac{2eV_0}{m}}$$

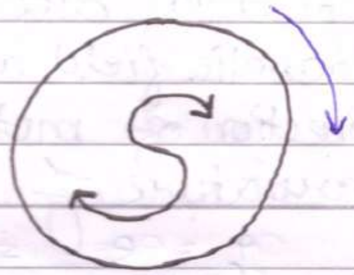
$$\boxed{v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 10^4}{9.1 \times 10^{-31}}}}$$

$r =$ ___

Note

① 

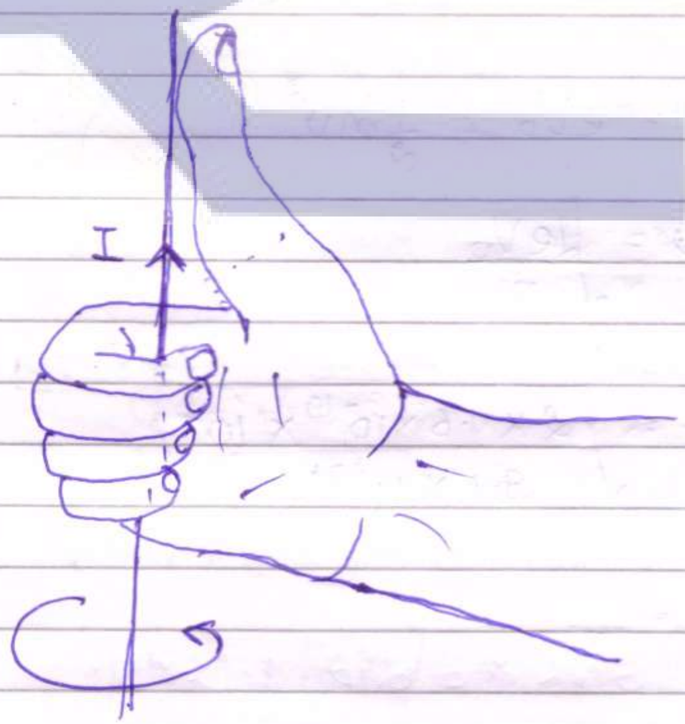
Anticlockwise current



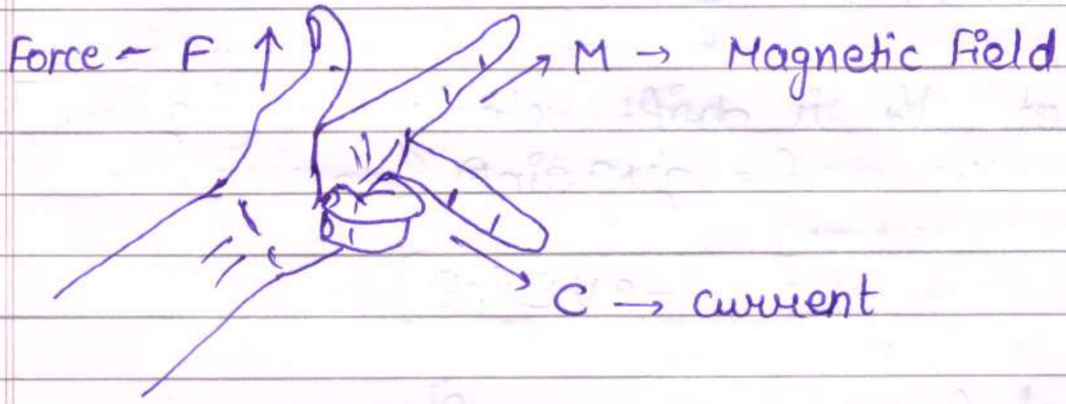
Clockwise Current

② Right Hand Thumb Rule

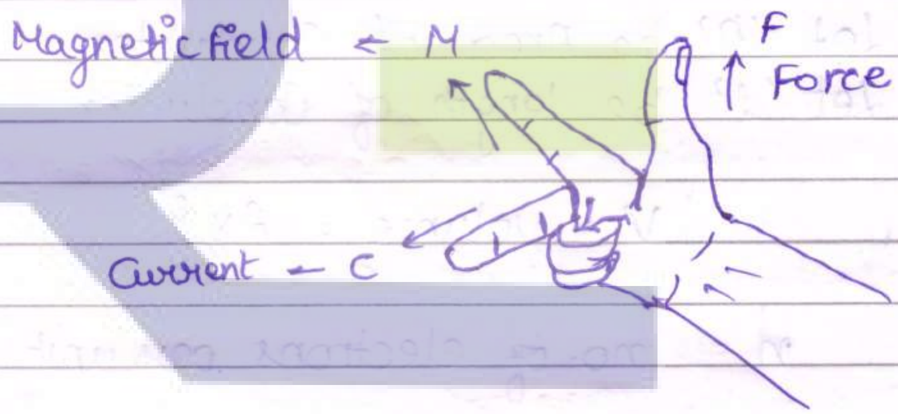
If we hold a current carring conductor pointing thumb towards current then the folds of finger will show the direction of magnetic field.



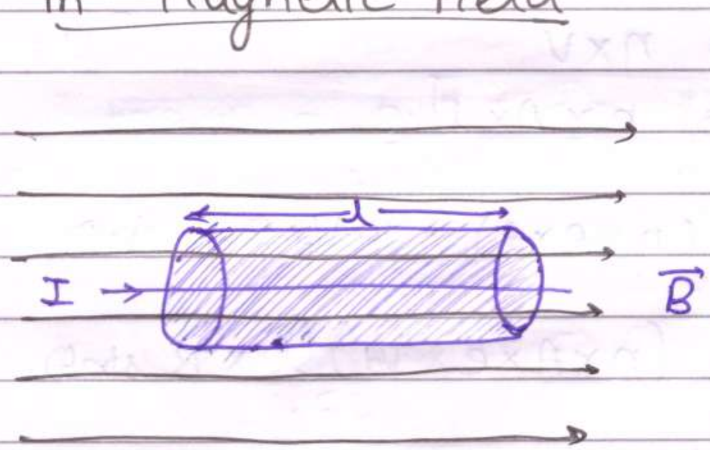
3) Fleming Left Hand Rule



4) Fleming Right Hand Rule



Force on a Current carrying conductor in Magnetic field



Let (e) is electron in Conductor, It will experienced a force.

Let V_d is drift velocity [$q = -e$]

$$f = qVB\sin\theta$$

$$\boxed{f = -eVB\sin\theta}$$

Total force $\rightarrow$ $\boxed{F = N \times f}$

N = Total no. of electron in conductor

Let 'A' be Area of Conductor
Let 'l' be length of Conductor

$$\boxed{V = \text{volume} = A \times l}$$

n = no. of electrons per unit volume (V)

$$\boxed{n = \frac{N}{V}}$$

$N = n \times V$ [$V = A \times l$]

$$\boxed{N = n \times A \times l}$$

$$F = [(n \times A \times l) \times eV_d B \times \sin\theta$$

$$F = (n \times A \times e \times V_d)\, l \times B \sin\theta$$

$$F = IlB\sin\theta$$

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$$\boxed{F = BIl\sin\theta}$$

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

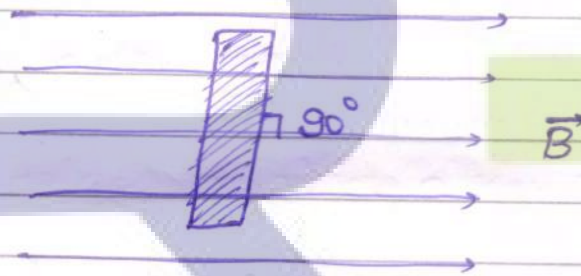
Note

$n = \frac{N}{V}$, $V = A\times l$

$f = qvB\sin\theta$, $\boxed{V_d = \frac{eE\tau}{m} = neV_dA}$

Special Case

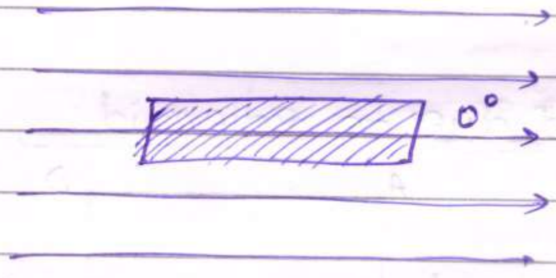
(1)



$f = BIl\sin\theta$ $[\theta = 90^\circ]$

$\boxed{f = BIl}$ maximum force

(2)



$f = BIl\sin\theta$

$\boxed{f = 0}$ minimum force

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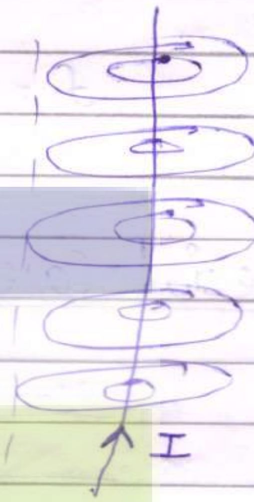
Ampere's Circuital Law

It states that line integral of magnetic field ($\vec{B}$) around any closed circuit is equal to μ_0 times the total current (I) passing through closed circuit.

$$\boxed{\oint \vec{B} \cdot \vec{dl} = \mu_0 I}$$



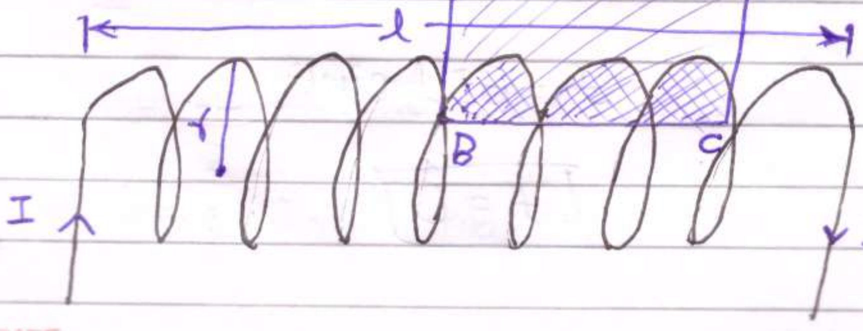
Application

① Magnetic field of Solenoid → $\boxed{B = \mu_0 \times nI}$

② Magnetic field of Toroid → $\boxed{B = \mu_0 nI}$

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

Magnetic field due to Solenoid



Let ABCD is small part conside
Let 'l' is length of Solenoid
Let 'N' is no. of Turns
Let 'n' is no of Turn per unit length

$\boxed{n = \frac{N}{l}}$, Let length of BC is l

By using Ampere circuital Law

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = \oint_{A}^{B} \vec{B}\cdot\vec{dl} + \oint_{B}^{C} \vec{B}\cdot\vec{dl} + \oint_{C}^{D} \vec{B}\cdot\vec{dl} + \oint_{D}^{A} \vec{B}\cdot\vec{dl}$$

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = \oint_{A}^{B} Bdl\cos\theta + \oint_{B}^{C} Bdl\cos\theta + \int_{C}^{D} Bdl\cos\theta + \int_{D}^{A} Bdl\cos\theta$$

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = \oint_{A}^{B} Bdl\cos 90^\circ + \oint_{B}^{C} Bdl\cos(0)^\circ + \oint_{C}^{D} Bdl\cos 90^\circ + \underbrace{\oint_{D}^{A} Bdl\cos\theta}_{0}$$

'AD' length is outside no. Magnetic Field

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = 0 + \int_{B}^{C} Bdl + 0 + 0$$

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = \int_{B}^{C} Bdl$$

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = B \times l_{BC} \quad \text{---} (1) \quad [l_{BC} = l]$$

$$\oint_{ABCD} \vec{B}\cdot\vec{dl} = \mu_0 I \quad \text{---} (2)$$

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From eq^n (1) & (2)

$$B \times l = \mu_0 I$$

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

For 'N' turns

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

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

Que A solenoid have 100 turns of 20m length and have 4A current pairing through it. Find the Magnetic Field due to solenoid?

Ans

$l = 20m$, $I = 4A$, $N = 100$, $B = \mu_0 I \times n$

$$B = \mu_0 I n$$

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

$$= 4\pi \times 10^{-7} \times \cancel{4}^{2} \times \frac{1\cancel{00}}{\cancel{20}}$$

$$\boxed{B = 8\pi \times 10^{-6}\, T}$$

(b) Magnetic Field at end point

$$\boxed{B_{end} = \frac{B}{2} = \frac{\mu_0 n I}{2}}$$

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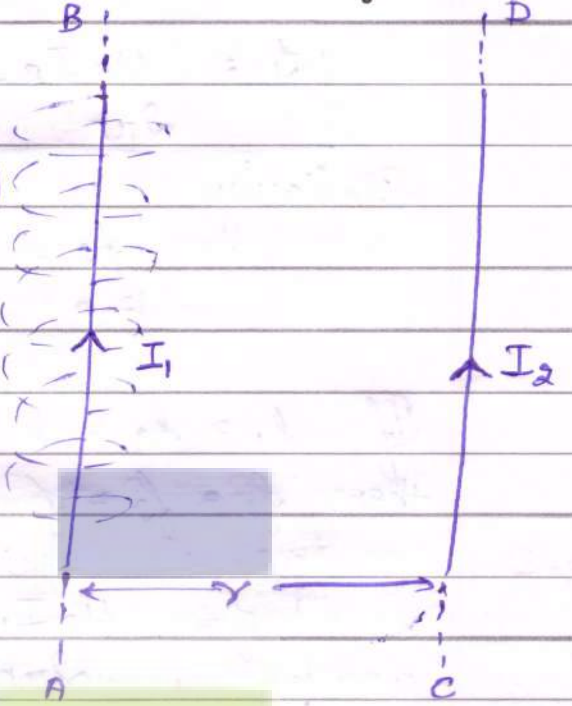
Force Between two parallel wires carrying Currents



Let Two parallel wires AB and CD having current (I_1) and (I_2) & They separated by distance (r).
Let have l_1 & l_2 are length of AB & CD wire.

Let F_1 & F_2 are two forces AB & CD

$[\theta = 90^\circ]$

$F_1 = BIl\sin\theta$

$F_1 = BIl\sin 90^\circ$

$\boxed{F_1 = B_2 I_1 l_1}$ ------ (1)

Let $F_2 = BIl\sin 90^\circ$

$\boxed{F_2 = B_1 I_2 l_2}$ ------ (2)

B_1 & B_2 are magnetic field due to AB & CD

$\longrightarrow \quad B_1 = \dfrac{\mu_0 I_1}{2\pi r}$

$\longrightarrow \quad B_2 = \dfrac{\mu_0 I_2}{2\pi r}$

Putting values (B_1) & (B_2) in eqn (1) & (2)

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$$f_1 = B_2 I_1 l_1$$

$$\boxed{f_1 = \frac{\mu_0 I_2 I_1 l_1}{2\pi r}}$$

Similarly,

$$\boxed{f_2 = \frac{\mu_0 I_1 I_2 l_2}{2\pi r}}$$

If $l_1 = l_2 = l$

then, $f_1 = f_2 = f$

$$\boxed{f = \frac{\mu_0 I_1 I_2 \times l}{2\pi r}}$$

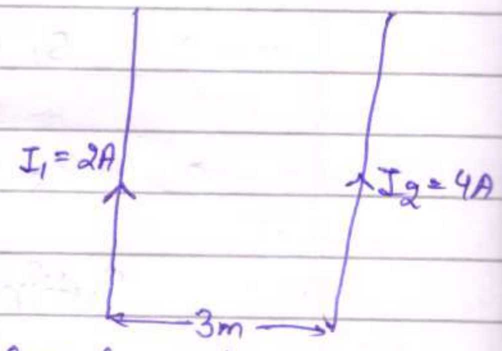
Force per unit length

$$F = \frac{f}{l}$$

$$F = \frac{\mu_0 I_1 I_2 \times \cancel{l}}{2\pi r \times \cancel{l}}$$

$$\boxed{F = \frac{\mu_0 I_1 I_2}{2\pi r}}$$

Ques



$l_1 = l_2 = 1m$

find force?

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

$$f = \frac{4\pi \times 10^{-7} \times 2 \times 4 \times l}{2\pi \times 3}$$

$$\boxed{f = \frac{16 \times 10^{-7}}{3} N}$$

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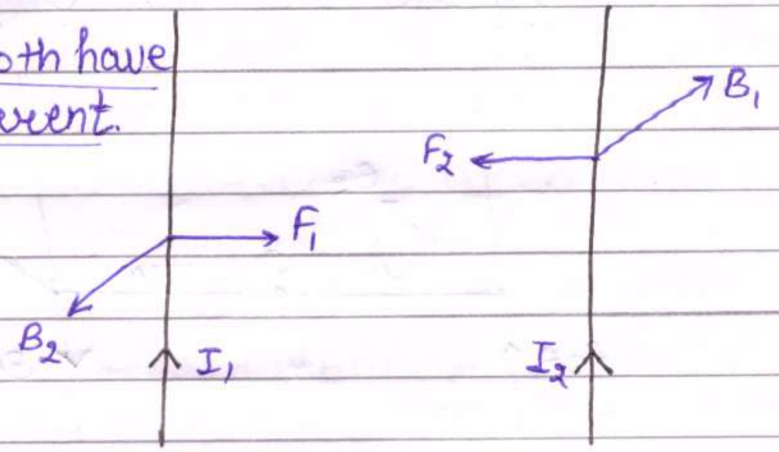
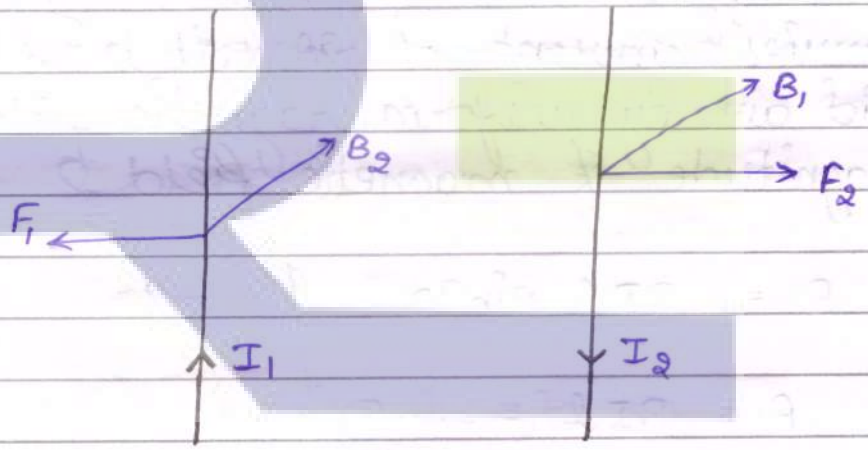
Note

① when Both have same current.



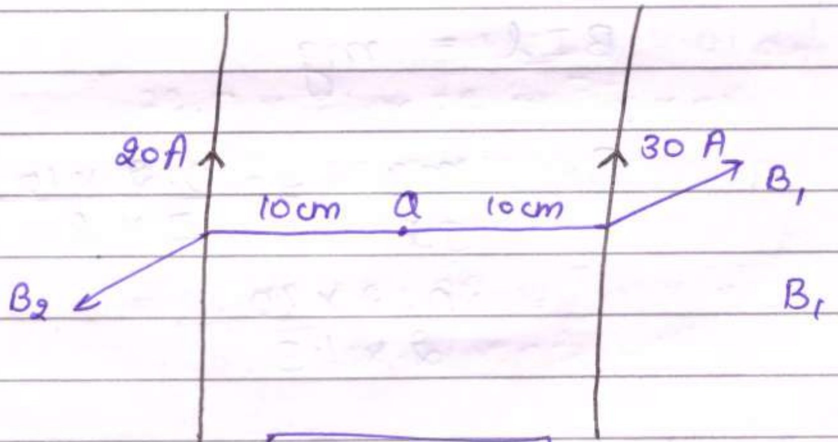
Attraction between them.

② when Both have opposite current



Ques Find the Magnetic field at O ?

Ans



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

$$\boxed{B = B_1 - B_2}$$

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

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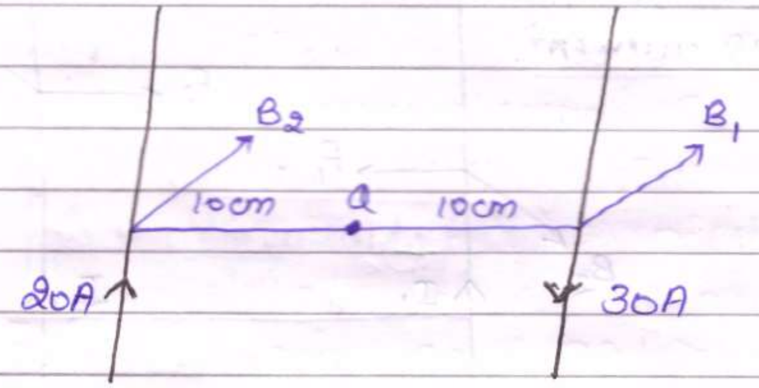
Ques Find the Magnetic Field at Θ ?



$$B_1 = \frac{\mu_0 I_1}{2\pi r_1}, \quad B_2 = \frac{\mu_0 I_2}{2\pi r_2}$$

$$\boxed{B = B_1 + B_2}$$

Ques A Straight wires of mass 200g & length 1.5m carries current of 2A. It is suspended in mid air by uniform Magnetic field $\vec{B}$. What magnitude of magnetic field ?

Ans

$F = BI\ell \sin 90$

$F = BI\ell$ ----(1)

$F = mg$ -----(2)

then

$$BI\ell = mg$$

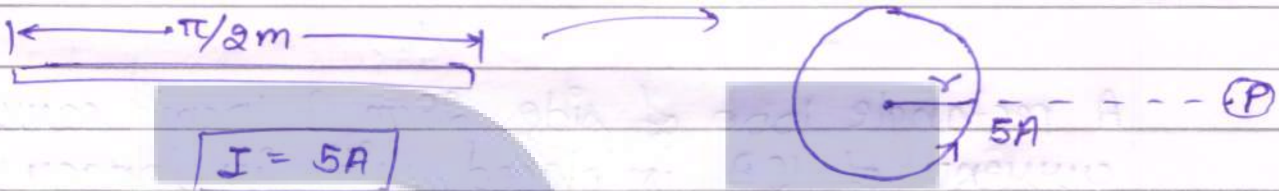
$$B = \frac{mg}{I\ell} = \frac{0.2 \times 10}{I \times \ell}$$

$$= \frac{0.2 \times 10}{2 \times 1.5}$$

$$\boxed{B = 0.6T}$$

Ques A Straight wire of length $(\pi/2)$ m is bent into a circular shape. If the wire were to carry a current in it of 5A. Calculate the magnetic field due to it before at a point distant 0.01 times the radius of circular formed from it. Also calculate the magnetic field at centre of circular loop?

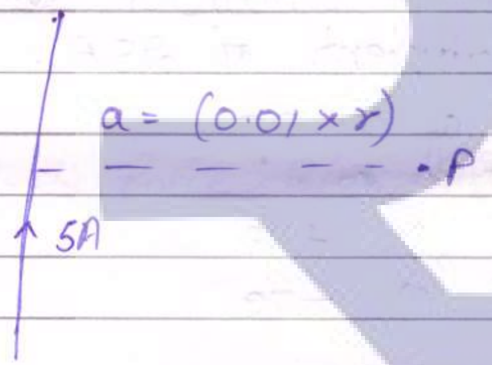
Ans



$\boxed{I = 5A}$

$2\pi r = l$

$2\pi r = \frac{\pi}{2} \Rightarrow \boxed{r = \frac{1}{4}}$



(i) Magnetic Field due to Current carrying straight conductor

$B = \frac{\mu_0 I}{2\pi a} \Rightarrow \quad a = 0.01 \times r$

$= 0.01 \times \frac{1}{4}$

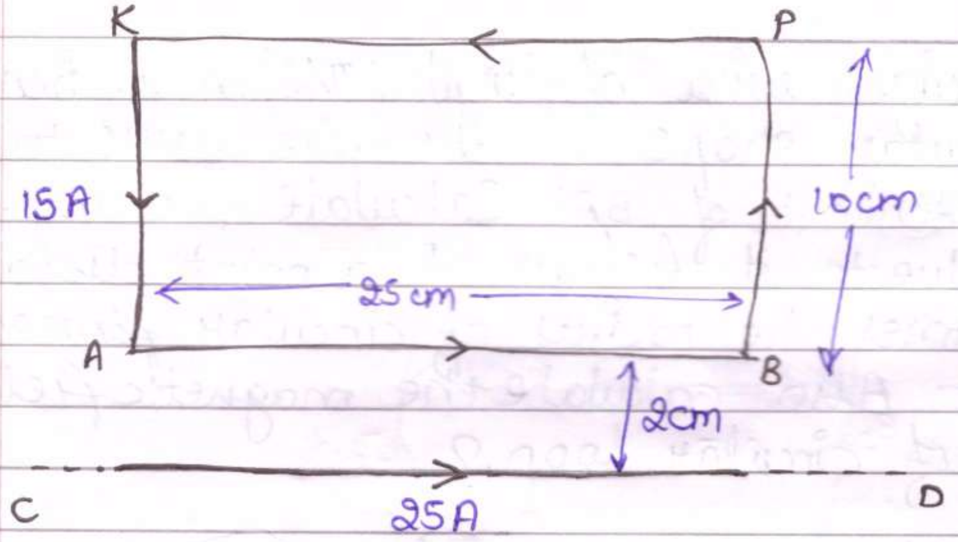
$$\boxed{B = \frac{4\pi \times 10^{-7} \times 5 \times 4}{2 \times \pi \times 0.01} \text{ T}}$$

(ii) Magnetic Field in circle

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

$$\boxed{B = \frac{4\pi \times 10^{-7} \times 5 \times 4}{2} \text{ T}}$$

Ques



A rectangle loop of side 25cm & 10cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying & current of 25A.
find the net force of loop.

Ans

f_1 = B/w CD & AB ⇒ +ve
f_2 = B/w CD & KP ⇒ −ve

$$\boxed{f = f_1 - f_2}$$

$$\boxed{f = \frac{\mu_0 I_1 I_2 \times l}{2\pi r}}$$

$$f_1 = \left[\frac{4\pi \times 10^{-7} \times 25 \times 15 \times 0.25}{2 \times \pi \times 0.02}\right] \text{ - - - - } (1)$$

$$f_2 = \left[\frac{4\pi \times 10^{-7} \times 25 \times 15 \times 0.25}{2\pi \times 0.12}\right] \text{ - - - - } (2)$$

$$\boxed{f_N = f_1 - f_2}$$

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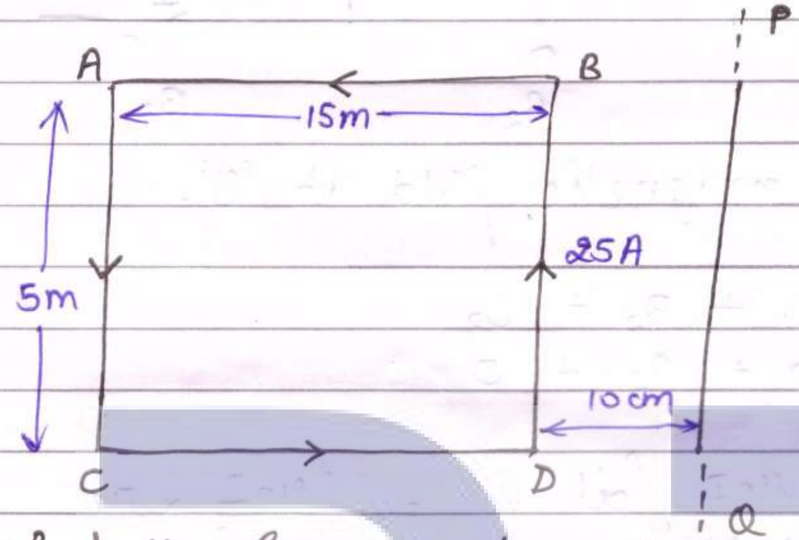
$$\boxed{f_N = \frac{4\pi \times 10^{-7} \times 25 \times 15 \times 0.25}{2\pi}\left[\frac{1}{0.02} - \frac{1}{0.12}\right] N}$$

Ques



Find the force on loop?

Ans

f_1 is force B/w PQ & AC.
f_2 is force B/w PQ & BD.

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

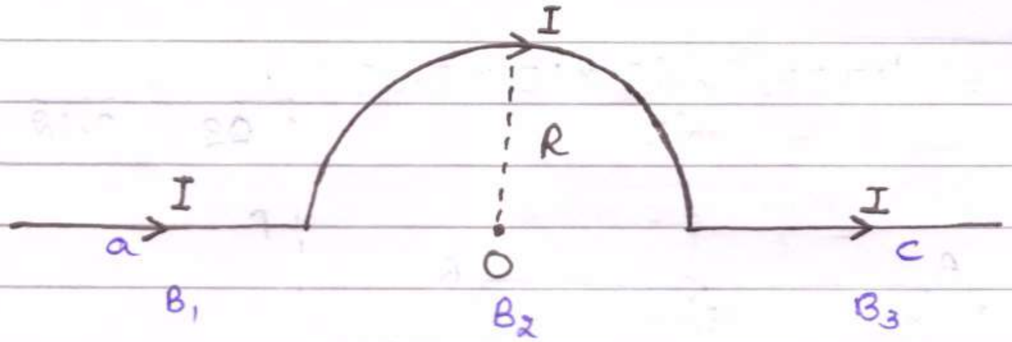
$$f_1 = \frac{4\pi \times 10^{-7} \times 10 \times 25 \times 5}{2\pi \times 25} \quad \text{---- (1)} \quad \left[\begin{matrix}\text{Same} \\ \text{direc}^n\end{matrix}\right]$$

$$f_2 = \frac{4\pi \times 10^{-7} \times 10 \times 25 \times 5}{2\pi \times 10} \quad \text{--- (2)} \quad \left[\begin{matrix}\text{opposite} \\ \text{direc}^n\end{matrix}\right]$$

$$f = f_1 - f_2$$

GOOD WRITE

Ques



Find the magnetic field at 'O'.

Ans

$$B = B_1 + B_2 + B_3$$
$$= 0 + B_2 + 0$$

$$B_2 = \frac{\mu_0 I}{4\pi r^2}\int dl = \frac{\mu_0 I}{4\pi r^2} \times \pi r$$

$$B_2 = \frac{\mu_0 I}{4r}$$

$$B = 0 + \frac{\mu_0 I}{4r} + 0$$

$$\boxed{B = \frac{\mu_0 I}{4r}}$$

Note

$$dB = \frac{\mu_0 I}{4\pi r^2}\sin\theta \cdot dl \qquad [\theta = 90^\circ]$$

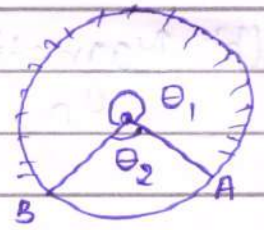
$$\int dB = \int \frac{\mu_0 I\, dl}{4\pi r^2}$$

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

① $B = \dfrac{\mu_0 I}{4\pi r^2} \times 2\pi r$ [full circle]

② $B = \dfrac{\mu_0 I}{4\pi r^2} \times \pi r$ [half circle]

(3) $B = \frac{\mu_0 I}{4\pi r^2} \times \int AB$



$B = \frac{\mu_0 I}{4\pi \cancel{r^2}} \theta_2 \times \cancel{r}$

$$\boxed{B = \frac{\mu_0 I \theta_2}{4\pi r}}$$

$\theta_1 = \frac{AB}{r}$

$\boxed{AB = \theta_1 \times r}$

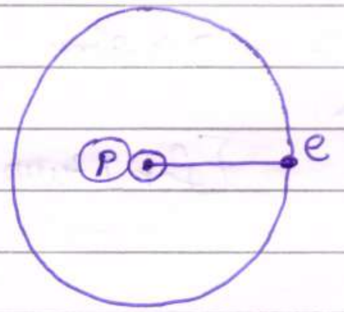
$\theta_2 = \frac{(AB)'}{r}$

$\boxed{AB' = \theta_2 \times r}$

Ques The electron in hydrogen atom circles around the proton with speed of 2.18×10^6 m/sec in a orbit of radius 5.3×10^{-11} m.

(a) what is equivalent dipole moment ?
(b) what magnetic field does it produces at proton?

Ans



$v = 2.18 \times 10^6$ m/sec
$r = 5.3 \times 10^{-11}$ m

(a) $M = NIA$

$M = 1 \times \frac{ev}{2\pi r} [\pi r^2]$

$I = \frac{q}{t} = \frac{e}{t}$

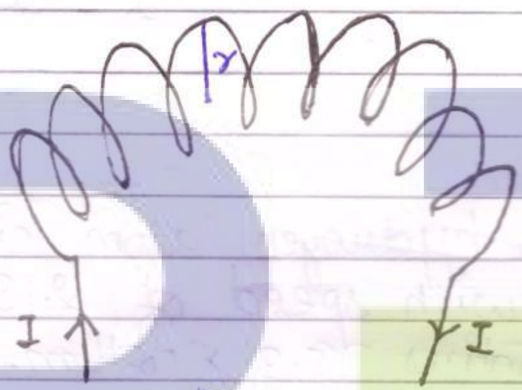
$\boxed{I = \frac{e}{2\pi r / v} = \frac{ev}{2\pi r}}$

$$\boxed{M = 1 \times 1.6 \times 10^{-19} \times 3.18 \times 10^6 \times 5.3 \times 10^{-11} \ Am^2}$$

(b) Magnetic Field

$$B = \frac{\mu_0 I}{2\pi r} = \left[\frac{4\pi \times 10^{-7} \times I}{2\pi \times 5.3 \times 10^{-11}}\right] T$$

Magnetic Field due to Toroid



By Ampere Circuital Law

$$\longrightarrow \oint \vec{B} \cdot \vec{dl} = \mu_0 I$$

LHS = $\oint B \cdot dl = B \oint dl = B \times 2\pi r$

$$\boxed{B_1 = \frac{\mu_0 I}{2\pi r}} \quad [\text{for 1 turn}]$$

for 'N' turns

$$B = N \times B_1 = \left[N \times \frac{\mu_0 I}{2\pi r}\right]$$

$$n = \frac{N}{2\pi r}, \quad B = N \times \frac{\mu_0 I}{2\pi r}$$

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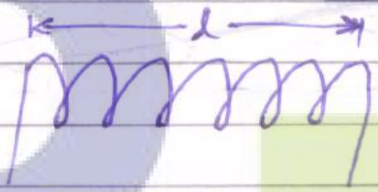
$$B = \frac{n \times \cancel{2\pi r} \times \mu_0 I}{\cancel{2\pi r}}$$

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

at end $\boxed{B_{end} = \frac{B}{2} = \frac{\mu_0 n I}{2}}$

Note

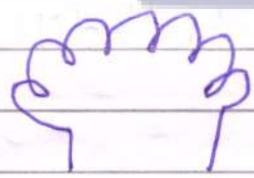
① Solenoid



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

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

② Toroid



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

$\boxed{n = \frac{N}{2\pi r} = \frac{N}{l}}$

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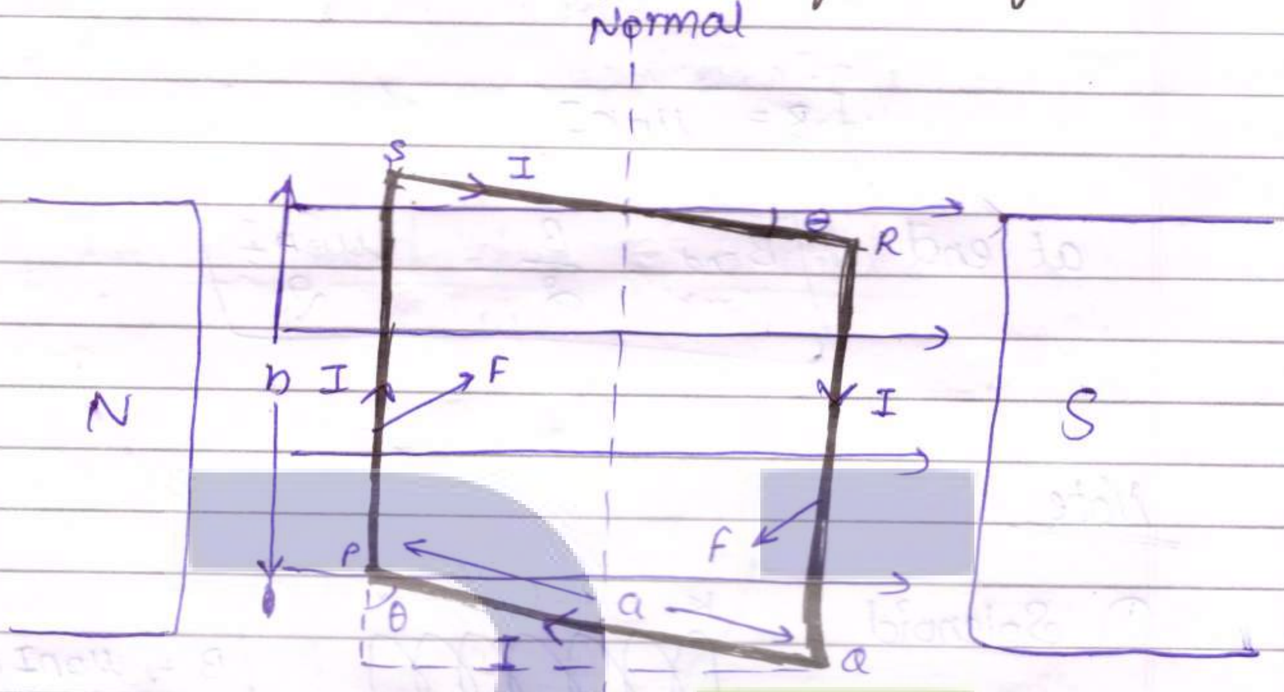
Torque on Current Loop in Uniform Magnetic Field



Let PQRS is rectangular coil B/w two strong magnetic fields
It is perpendicular to field
Let,
'a' & 'b' length & breadth of rectangular coil
Let, 'A' be Area

$\boxed{A = a \times b}$

Let, 'θ' is angle b/w Magnetic field (B) & Normal to plane of coil.

Let, It 'τ' be Torque

when coil placed b/w magnetic field, It will explained Torque.

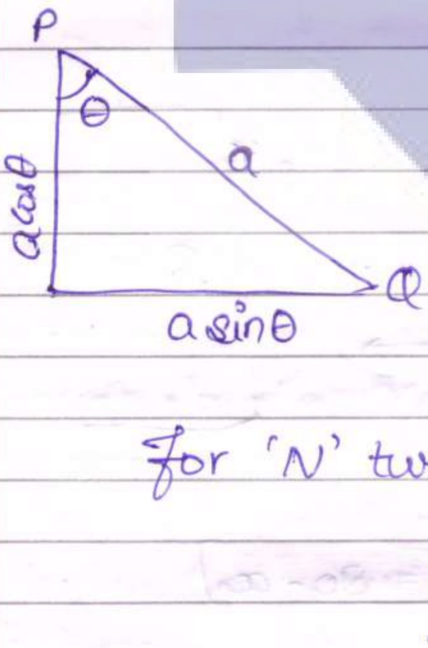
→ let 'f' is force on coil sides
→ force on PQ & RS are equal so resultant force is zero

→ due to this it will experience a Torque

$$\tau = \text{couple of force}$$
$$\tau = \text{force} \times \text{perpendicular distance}$$
$$\tau = f \times d$$

'f' is force on side, $f = BIb \sin 90°$ $(\theta = 90)$

$$f = BIb \quad [\text{length} = b, \sin 90 = 1]$$



$$\tau = BIb \times a \sin\theta$$
$$\tau = BI(ab)\sin\theta$$
$$\tau = BIA \sin\theta \quad [A = \text{Area}]$$

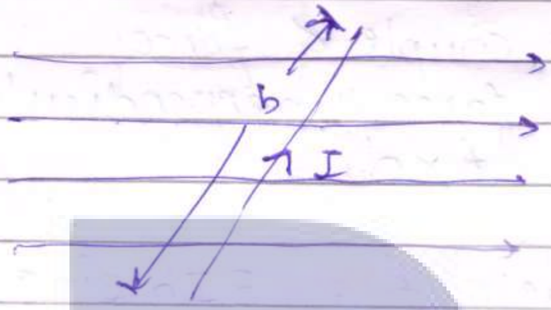
for 'N' turns

$$\tau = NBIA \sin\theta$$
$$\tau = MB\sin\theta \quad [M = NIA]$$

$$\boxed{\vec{\tau} = \vec{M} \times \vec{B}}$$

Note

(1) $\tau = f \times$ displacement
$\tau =$ force on side of coil, which where current (I)
Perpendicular distance $= a \sin\theta$

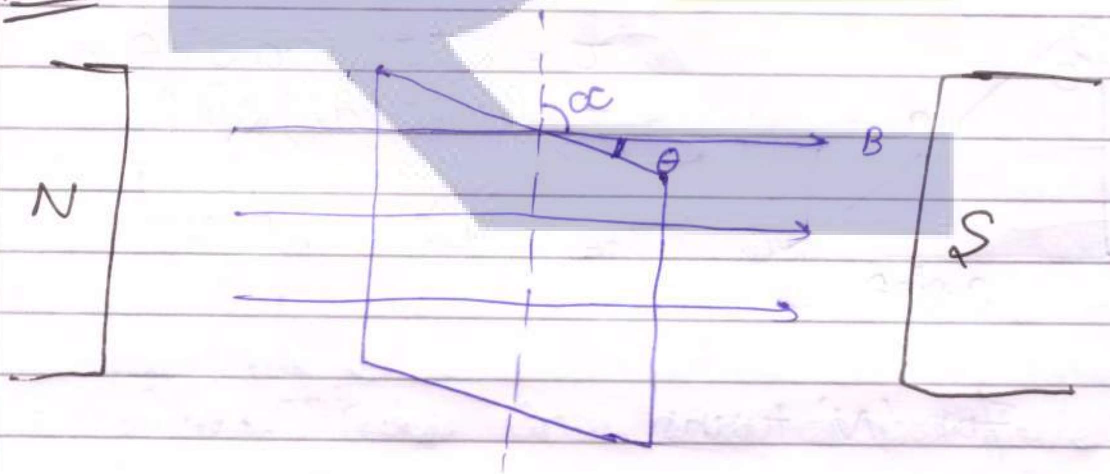


$f = BIb \sin\theta$ $[\theta = 90]$

$\boxed{F = BIb}$

$\theta = 90^\circ$

Note



$\boxed{\alpha + \theta = 90^\circ}$ $[\theta = 90 - \alpha]$

$\tau = MB\sin\theta$
$\tau = NIAB \sin\theta$
$\tau = NIAB \sin(90 - \alpha)$
$\tau = NIAB \cos\alpha$
$\tau = MB \cos\alpha$ $\Rightarrow$ $\boxed{\vec{\tau} = \vec{M} \cdot \vec{B}}$

Note

$$\theta \Rightarrow \quad \tau = NIBA \sin\theta$$
$$= MB \sin\theta \Rightarrow \boxed{\vec{\tau} = \vec{M} \times \vec{B}}$$

$$\alpha \Rightarrow \quad \tau = NIBA \cos\alpha$$
$$= MB \cos\alpha \Rightarrow \boxed{\vec{\tau} = \vec{M} \cdot \vec{B}}$$

Ques A rectangular coil of sides 8cm & 6cm having 200 turns and carrying a current 200mA is placed in a uniform magnetic field of 0.2T directed along +ve axis?

(a) What is max Torque the coil can experience? In which orientation does it experience the max torque?

Ans

$l = 8cm = 8 \times 10^{-2}\, m$

$b = 6\, cm = 6 \times 10^{-2}\, m$

$A = [8 \times 6 \times 10^{-4}]$

$N = 200$

$B = 0.2$

$I = 200mA = 200 \times 10^{-3}$

$\tau = (BIl) \times M \sin\theta \times A$

$\boxed{\tau_{max} = (BIl)\, A \times M}$

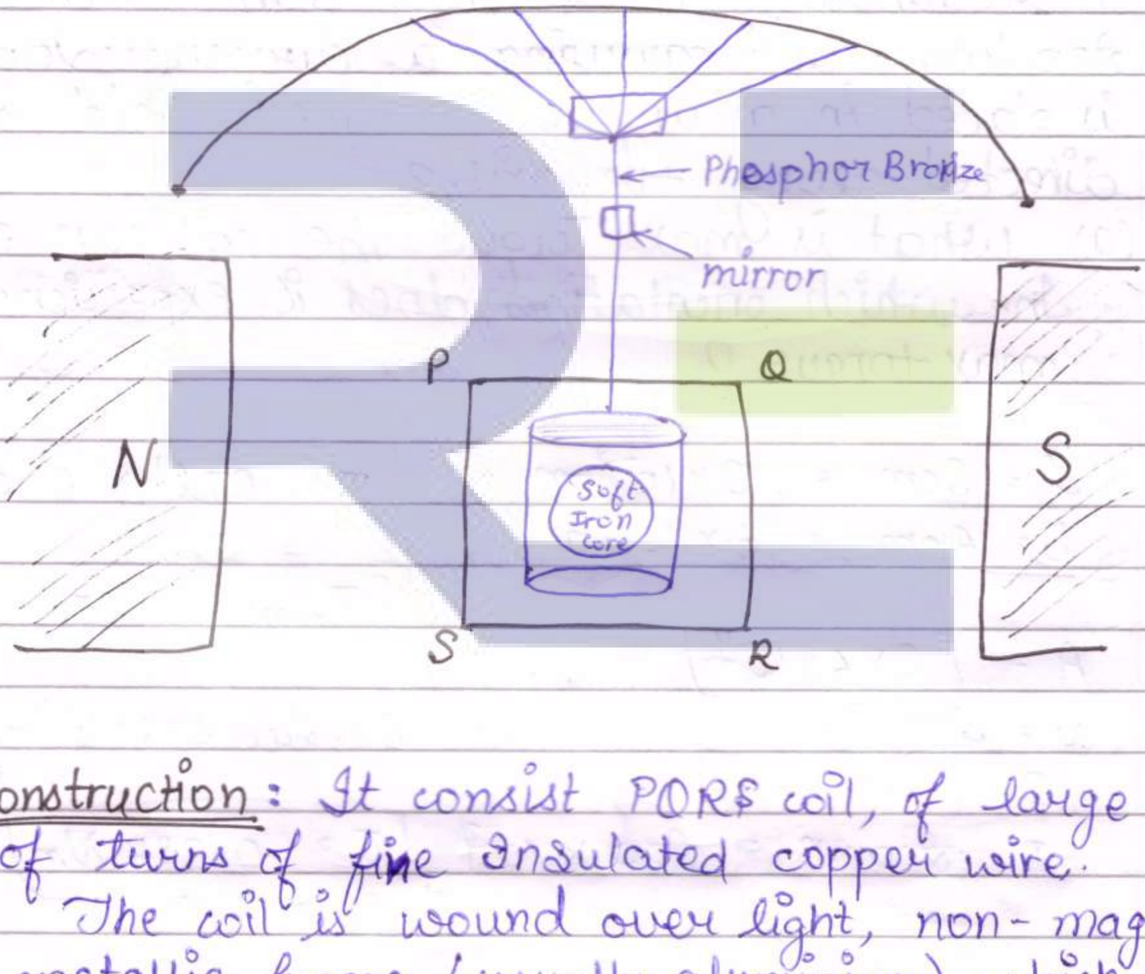
$\tau = 200 \times 8 \times 6 \times 10^{-4} \times 0.2 \times 200 \times 10^{-3}$

$\boxed{\tau = 0.384\, Nm}$

Moving Coil Galvanometer

It is device to detect current in a circuit.

Principle - A current carrying coil placed in magnetic field exprience a Torque, the magnitude of which depends on strength of current.



Construction: It consist PQRS coil, of large no. of turns of fine Insulated copper wire.
The coil is wound over light, non-magnetic, metallic frame (usually aluminium) which may be circular or rectangle. It is suspended from a movable torsion head (T) by fine phosphor-bronze strip
It is placed b/w string magnetic field b/w (N) & (S) pole.

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Let 'C' is soft Iron Core. It rote inside the frame without touching.
Let 'u' be mirror strip attached to phosphor-Bronze strip. It help to measuring deflection of coil.

le

Radial Magnetic Field – when plane of coil in all its position must remain parallel to magnetic field. This magnetic field called "radial magnetic field" & It that time max. Torque applied.

Theory Let 'N' be total no. of turns
'A' is Area of coil
B is magnetic field
I is current.
If 'T' is Torque acting on the coil.

$$\tau = NIBA\sin\theta$$

'θ' is angle B/w magnetic field & Normal to plane of coil

[θ = 90°]

$$[\tau = NIBA] \quad \text{(max Torque)}$$

When coil is deflected, the suspension fibre (phosphor Bronze strip) is twisted. Due to property of elasticity. The fibre tends to untwist itself

This tendency give rise to couple called "~~Restoring~~ Restoring force"

If 'θ' is twist in fibre
'K' is moment of Restoring couple per unit angular twist

Moment of restoring Couple, $\boxed{\tau = K \times \theta}$ - (1)

In equilibrium position

$$NIBA = K\theta$$

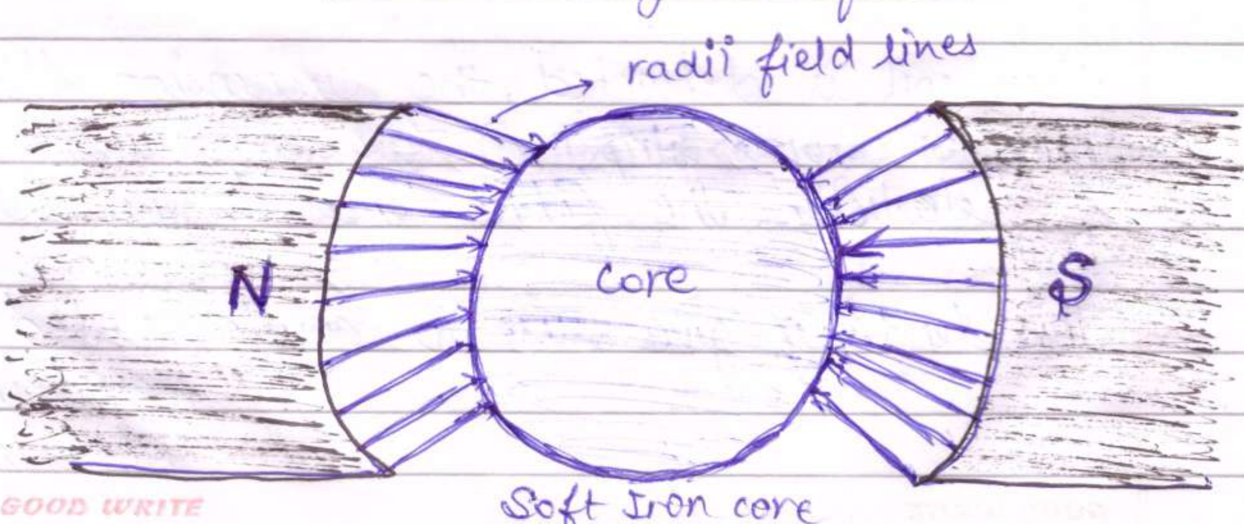
$$\boxed{I = \frac{K\theta}{NBA}}$$

$$\left[\because G = \frac{K}{NBA}\right]$$

Also, $\boxed{I = G \times \theta}$

$$\left[G = \text{Galvanometer const.} = \frac{K}{NBA}\right]$$

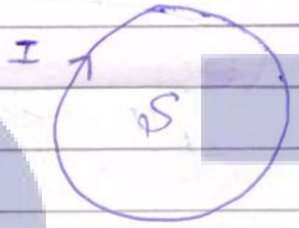
Note - Magnetic field lines tends to concentrate into soft Iron Core, almost coincide with radii of pole pieces. This magnetic field called "Radial Magnetic field"



Magnetic field due to Circular Coil
or
Circular Current carring coil show as Magnet

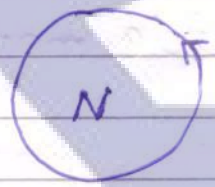
Let 'I' be current in circular coil of radius(r)
There are two faces of circular coil.

Upperface show south pole, due to clock wise current



clock wise current

But Lower face show North pole due to anticlock wise current.



Anticlockwise current.

So, It behaves as magnet.

North & South Because.