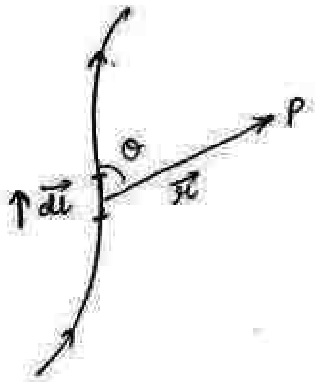
MAGNETIC EFFECT OF CURRENT

This effect was discovered by Oersted and mathematical analysis was given by Bio-Savart

Biot - Savart law (BSL)



According to BSL, magnetic field due to a current element ⇒ idl is directly proportional to that current element, sine of the angle θ and inversely proportional to the square of the distance b/w current element and the point under consideration.

equivalent to coulomb's law

$$dB \propto \frac{idl \sin\theta}{r^2}$$

** $$\boxed{dB = \left(\frac{\mu_0}{4\pi}\right)\frac{idl \sin\theta}{r^2}}$$

μ_0 ⇒ magnetic permeability of free space/vacuum

$\mu_0 = 4\pi \times 10^{-7}$ henry/m (H/m)

* $$\boxed{C = \frac{1}{\sqrt{\mu_0 \epsilon_0}}}$$

units of magnetic field/ magnetic flux density/ magnetic induction :

a) SI ⇒ tesla (T), weber/m^2 (Wb/m^2),

b) CGS ⇒ Gauss (G) maxwell/cm^2 (Mx/...

$1\ T = 10^4\ G$

Vector form of BSL :

$$\vec{dB} = \frac{\mu_0\, i dl \sin\theta}{4\pi r^2}\, \hat{n}$$

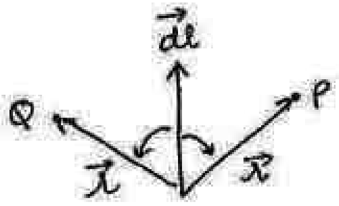
$$= \frac{\mu_0 i\,(dl\, r \sin\theta)\, \hat{n}}{4\pi r^3}$$

$$\Rightarrow \vec{dB} = \frac{\mu_0 i\,(\vec{dl} \times \vec{r})}{4\pi r^3}$$

So, the ~~dir~~ direction of magnetic field is always perpendicular to the plane containing $\vec{dl}$ and $\vec{r}$

⇒ Direction of Magnetic field :

[A]: due to current element



$\perp$ to the plane of the paper & inwards : $\otimes$

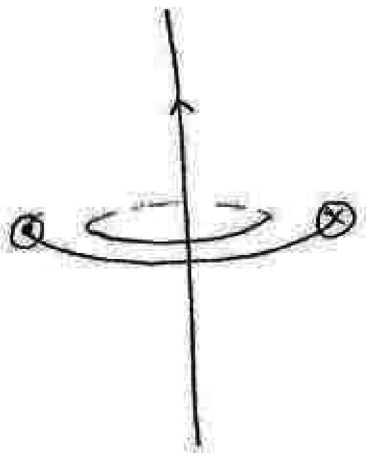
$\perp$ to the plane of the paper & outward : $\odot$

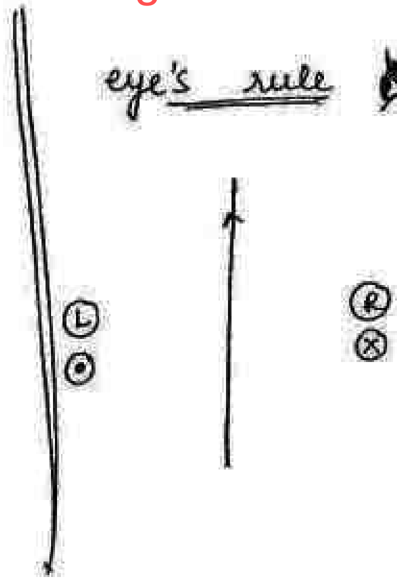
[B] due to current carrying wire :

i) if wire is in the plane of the paper :

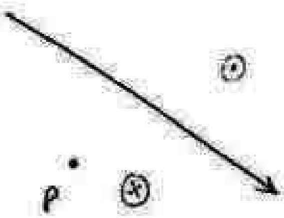
» Magnetic field line of a current carrying wire forms a closed loop / concentric circle which represents its Non-conservative nature eye's rule — Short Trick

R ⊗ L ⊙
RCLD

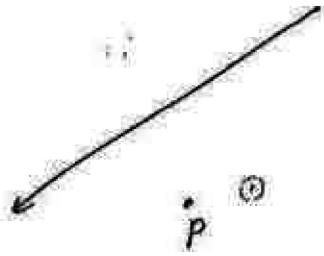




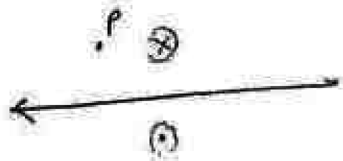
a)



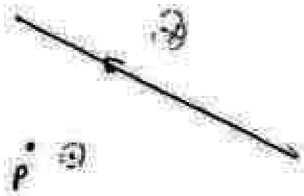
b)



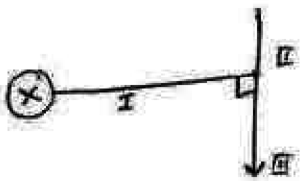
c)



d)



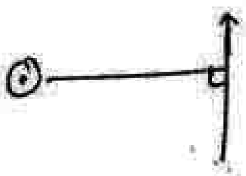
b) If wire is ⊥ to the plane of the paper



clockwise → cross ⊗

Anticlockwise → Dot ⊙

CC
AD



join
tangent
apply CCAD

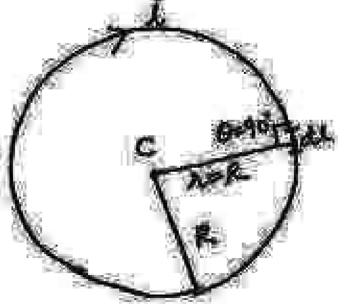
(b)

[c] due to current carrying arc/ loop :

Applications of B.S.L

1) <u>magnetic field due to current carrying circular loop:</u>

Let 'i' is the current flowing in current carrying loop of radius R, then magnetic field due to current element at the centre C in accordance with BSL is given by:



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

$r = R =$ constant

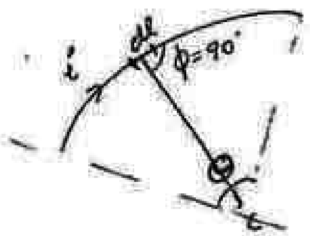
$\theta = 90° =$ constant

so, total magnetic field due to loop:

$$B = \oint \frac{\mu_0 \, i \, dl \sin 90°}{4\pi R^2} \Rightarrow \frac{\mu_0 i}{4\pi R^2} \oint dl$$

$$= \frac{\mu_0 i}{4\pi R^2} \, 2\pi R \quad \therefore \boxed{B = \frac{\mu_0 i}{2R} \otimes} \rightarrow \text{cw}$$

ii) <u>Magnetic field due to current carrying circular arc</u>



$$dB = \frac{\mu_0 i dl \sin\phi}{4\pi r^2}$$

$r = R$ = constant

$\phi = 90°$ = constant

$\therefore$ total magnetic field due to arc

$$B = \int \frac{\mu_0 i dl \sin 90°}{4\pi R^2}$$

$$= \frac{\mu_0 i}{4\pi R^2}\int dl = \frac{\mu_0 i}{4\pi R^2}\theta R \quad \left(\because \theta = \frac{l}{R}\right)$$

$$\therefore \boxed{B = \frac{\mu_0 i \theta}{4\pi R}} \quad \theta \text{ (in radian)}$$

* semicircular arc

$\theta = 180° = \pi$

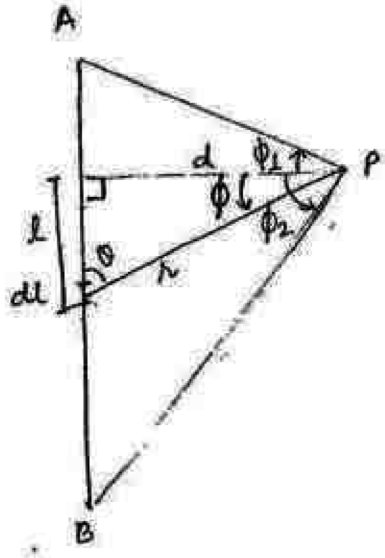
$$\therefore B = \frac{\mu_0 i}{4\pi R}\pi = \boxed{\frac{\mu_0 i}{4R}}$$

iii) <u>Magnetic field due to finite length current carrying wire.</u>

let a wire AB is carrying a current 'i' and P is a point at ⊥ distance d where magnetic field is to be obtained.

acc to BSL, magnetic field due to current element is given by.

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



$$\tan\phi = \frac{l}{d}$$

$$\therefore\ l = d\tan\phi$$

$$\frac{dl}{d\phi} = d\sec^2\phi$$

$$\therefore\ dl = d\sin^2\phi\, d\phi$$

$$\theta = 90 - \phi$$

$$\cos\phi = \frac{d}{r} \qquad \cancel{\therefore\ r = d\cos\phi}$$

$$\therefore\ r = d\sec\phi$$

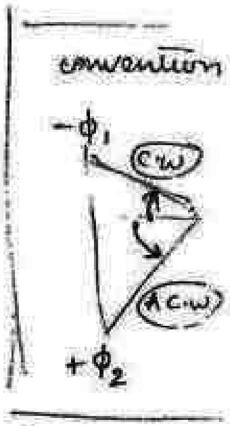
$$\therefore\ dB = \frac{\mu_0 i}{} \frac{(d\sec^2\phi\, d\phi)\sin(90-\phi)}{4\pi(d\sec\phi)^2}$$

$$\frac{\mu_0 i\cos\phi\, d\phi}{4\pi \cancel{\phi} d}$$

so, total field, $B = \dfrac{\mu_0 i}{4\pi d}\displaystyle\int_{-\phi_1}^{\phi_2}\cos\phi\, d\phi$

$$= \frac{\mu_0 i}{4\pi d}\left(\sin\phi\right)_{-\phi_1}^{\phi_2}$$

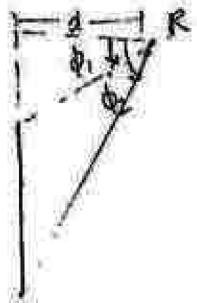
$$\frac{\mu_0 i}{4\pi d}\left[\sin\phi_2 - \sin(-\phi_1)\right]$$



*** $$\boxed{B = \frac{\mu_0 i}{4\pi d}\left[\sin\phi_1 + \sin\phi_2\right]}$$

ϕ_1 = C.W
ϕ_2 = ACW

NCA → angles
normal
centreline



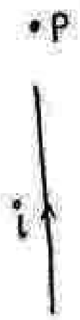
$$\phi_1 = -\phi$$

$$\phi_2 = 90^\circ$$

$$B_R = \frac{\mu_0 i}{4\pi d}(1 - \sin\phi)$$

case : If point is on the axis of the wire

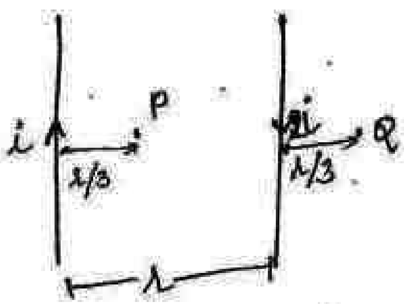
If point P is on the axis of the wire then magnetic field at this point will always be zero $(\because \theta = 0)$



$$\boxed{B_P = 0}$$

$$\boxed{B_P = 0}$$

Q. Find the magnetic field at point P in the given diagram.



$$B_P = \frac{\mu_0 i}{2\pi (r/3)} \otimes + \frac{\mu_0 2i}{2\pi (r - r/3)} \otimes$$

$$\therefore = \frac{3\mu_0 i}{2\pi r} \otimes + \frac{2\mu_0 i\, 3}{2\pi\, 2r} \otimes$$

$$\therefore = \frac{3\mu_0 i}{\pi r} \otimes$$

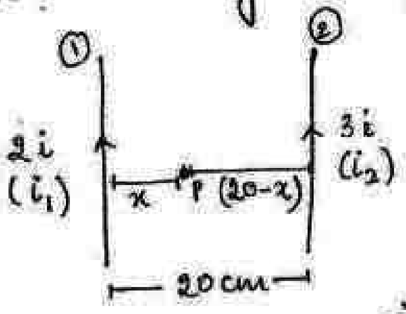
$$B_Q = \frac{\mu_0 i}{2\pi\left(r+\frac{r}{3}\right)} \otimes + \frac{\mu_0 (2i)}{2\pi\, r/3} \odot$$

$$= \frac{\mu_0 i\, 3}{2\pi\, 4r} \otimes + \frac{\mu_0\, 2i\, 3}{2\pi\, r} \odot$$

$$= \frac{\mu_0 i}{\pi r}\left(\frac{3}{8} - \frac{6}{2}\right)$$

$$= \frac{21 \mu_0 i}{8\pi r} \odot$$

Q) Find the distance of the point from wire 1 where magnetic field is zero



$B_P = 0$

$$\frac{\mu_0 i_1}{2\pi (x_1)} \otimes + \frac{\mu_0 i_2}{2\pi (x_2)} \odot = 0$$

$$\Rightarrow \frac{\mu_0 i_1}{2\pi (x_1)} - \frac{\mu_0 i_2}{2\pi (x_2)} = 0$$

$$\therefore \boxed{\frac{i_1}{i_2} = \frac{x_1}{x_2}}$$

∵ for infinite wire.

$$\frac{\mu_0 i_1}{2\pi d_1} = \frac{\mu_0 i_2}{2\pi d_2}$$

$$\therefore \frac{i_1}{d_1} = \frac{i_2}{d_2}$$

ie $\boxed{\frac{i_1}{i_2} = \frac{d_1}{d_2}}$

$$\frac{2i}{3i} = \frac{x}{20-x}$$

$$40 - 2x = 3x$$

$$\therefore 5x = 40$$

$\therefore x = 8$ cm from ①

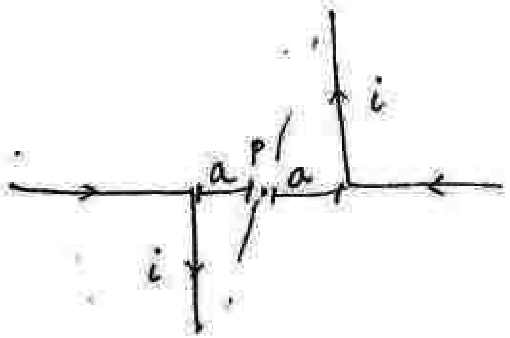
$= 12$ cm from ②

Q) Find the distance of the point in above que if dirⁿ of current is opposite in wire (1)

$$\frac{x}{20+x} = \frac{2}{3}$$

$\therefore x = 40$ cm from (1)

Q) Find the magnetic field at point P in the diagram

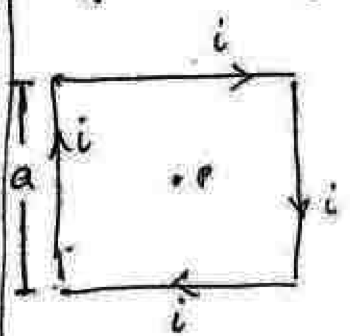


$$\frac{\mu_0 i(\sin 0 + \sin 90^\circ)}{4\pi a} \odot + \frac{\mu_0 i(\sin 0 + \sin 90)}{4\pi a} \odot$$

$$= \frac{2\mu_0 i}{4\pi a} \odot = \frac{\mu_0 i}{2\pi a} \odot$$

Q) Find the magnetic field at the centre C in the given diagram.

$\frac{\mu_0 n i}{\pi a}\sin\left(\frac{\pi}{n}\right)\tan\left(\frac{\pi}{n}\right)$



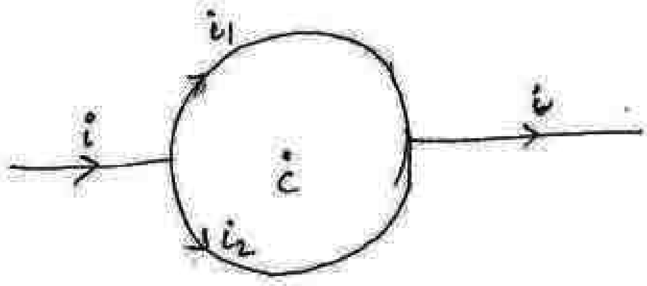
$\because$ its finite wire

$$B_p = \frac{\mu_0 i(\sin 45^\circ + \sin 45^\circ)}{4\pi\left(\frac{a}{2}\right)}$$

$$= \frac{\cancel{2}\mu_0 i\ \cancel{2}}{\cancel{4}\pi a\sqrt{2}} = \frac{\mu_0 i}{\sqrt{2}\pi a}$$ by (1) wire

$\therefore$ Total $B_p = \frac{4\mu_0 i}{}$ $\otimes$

Q) Find the magnetic field at centre C



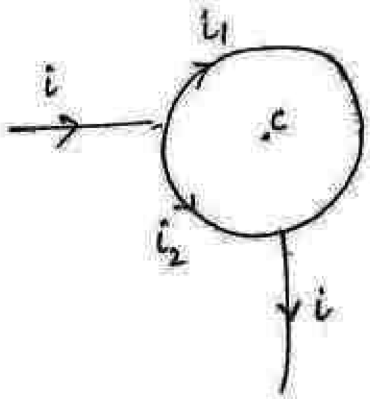
$\because$ its semicircle,

$$\therefore \quad B_c = \left(\frac{\mu_0 i_1}{2R}\right)\frac{1}{2} = \frac{1}{4}\frac{\mu_0 i_2}{R} \otimes$$

$$\therefore \text{ Total } B_c = \frac{\mu_0}{4R}\left(\frac{i}{2}\right) \otimes + \frac{\mu_0}{4R}\left(\frac{i}{2}\right) \odot$$

$$= \frac{\mu_0 i}{8R} - \frac{\mu_0 i}{8R} = 0$$

Q)



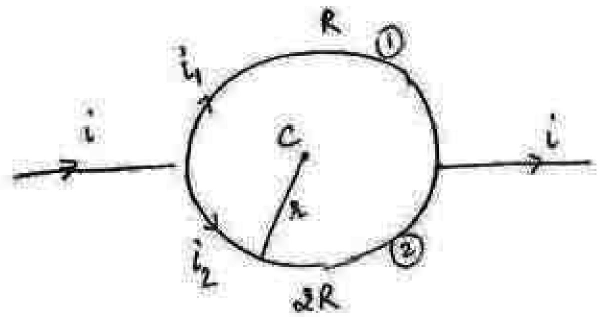
$\because \; i = \frac{V}{R} \quad \therefore \; i \propto \frac{1}{R}$

$$\frac{3}{4}\left(\frac{\mu_0 i_1}{2R}\right) \otimes + \frac{1}{4}\left(\frac{\mu_0 i_2}{2R}\right) \odot$$

$$\Rightarrow \frac{3\mu_0}{8R}\left(\frac{i}{4}\right) \otimes + \frac{\mu_0}{4}\left(\frac{3i}{4}\right)_{2R} \odot$$

$$\Rightarrow \frac{3\mu_0 i}{32R} - \frac{3\mu_0 i}{32R} = 0$$

Q)



	①		②
$R \Rightarrow$	R	:	$2R$
$i \Rightarrow$	2	:	1

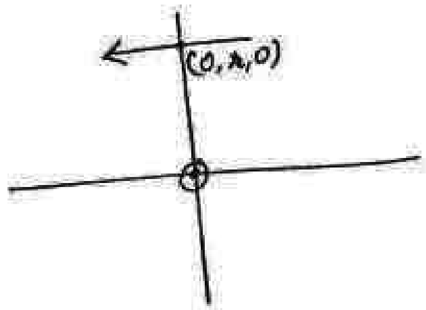
$i_1 = \frac{2}{3}i$ $\qquad$ $i_2 = \frac{i}{3}$

$B_P = B_1 + B_2$

$\frac{\mu_0 (2i/3)}{4r} \otimes + \frac{\mu_0 (i/3)}{4r} \odot$

$= \frac{\mu_0 i}{12r} \otimes$

Q) A long wire carrying a current i in positive z- dirⁿ, then find magnetic field at point $(0, r, 0) \Rightarrow y$ axis

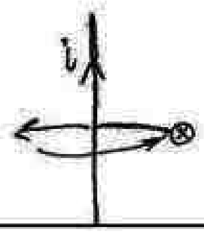


$\because$ infinite wire

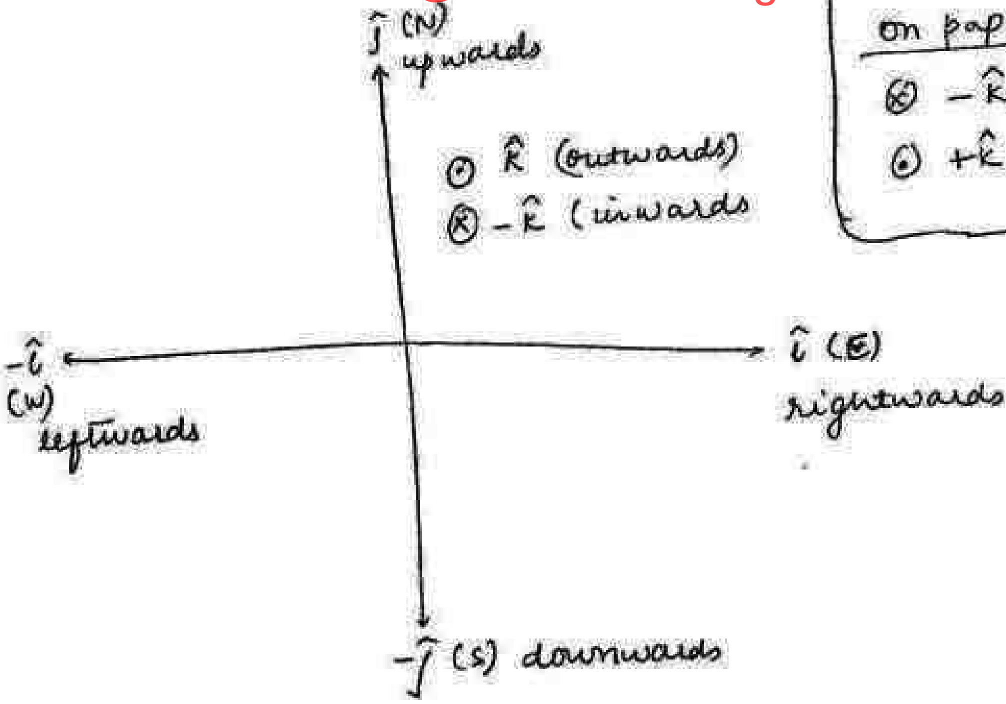
$\therefore \vec{B} = \left(\frac{\mu_0 i}{2\pi r}\right)(-\hat{i})$

Q) A long wire carrying a current from S to N. then find dirⁿ of magnetic field at a point just Below it.

Ans: (W)

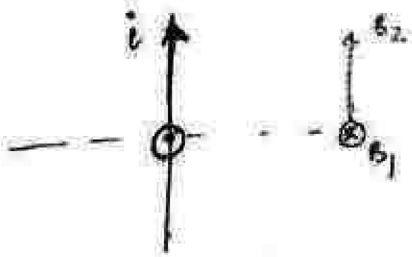


$\vec{B} = \frac{\mu_0 i}{2\pi r}(-\hat{i})$



on paper	in air
$\otimes$ $-\hat{k}$	vt downwards
$\odot$ $+\hat{k}$	vt upwards

Q) Two long wire carrying equal current 'i' in $+y$ and $+z$ dir then find magnetic field at point $(d, 0, 0) \Rightarrow x$-axis.



$$B_p = B_1(-\hat{k}) + B_2\hat{j}$$

$$B_p = \frac{\mu_0 i}{2\pi d}(-\hat{k}) + \frac{\mu_0 i}{2\pi d}(\hat{j})$$

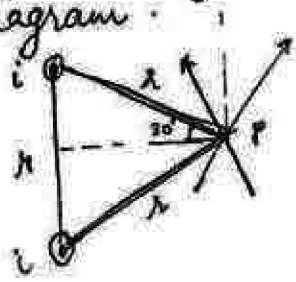
$= B_1 = B_2 = B$

and $\vec{B_1} \perp \vec{B_2}$ ∴ ⊥ dirn

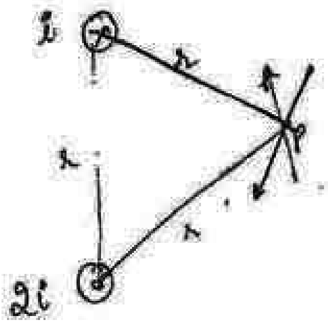
$$B_1 = B\sqrt{2} = \frac{\mu_0 i}{2\pi d}\sqrt{2}$$

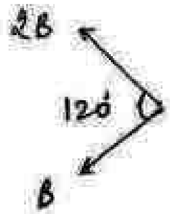
∴ infinite wire
find out seperately & combined
apply $\sqrt{\ }$ value dirn

Q) Find magnetic field at point P in the given diagram.



$$\sqrt{3}B = \frac{\mu_0 i}{2\pi r}\sqrt{3}$$





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

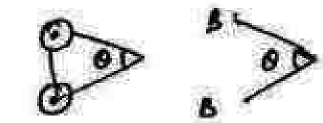
$$= \sqrt{B^2 + (2B)^2 + 2B(2B)\cos 120^\circ} \quad \cos 120^\circ \Rightarrow -\frac{1}{2}$$

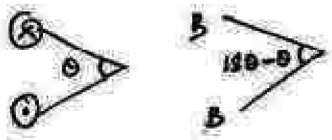
$$= \sqrt{3}\,B = \sqrt{3}\,\frac{\mu_0 i}{2\pi r} \Rightarrow \text{infinite wire}$$

* Short trick

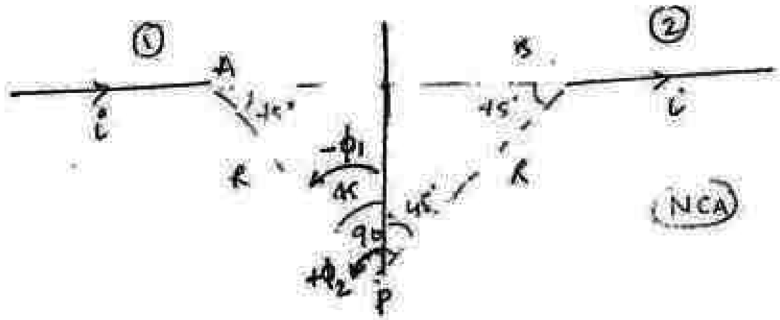
→ Same current (in dirⁿ and value) (same angle)

→ ~~same~~ diff. current (in dirⁿ and value) ($\pi - \theta$) angle





* Q1)



$$B_P = \frac{\mu_0 i}{4\pi d}\left[\sin\phi_1 + \sin\phi_2\right]$$

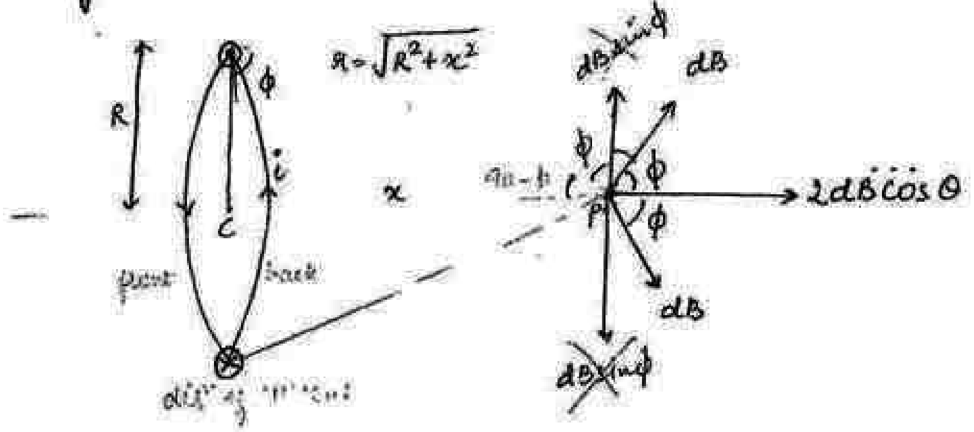
(CW) (ACW)

$\phi_1 = 45^\circ$ (∵ ACW) $\quad \phi_2 = 90^\circ$ (ACW)

$$B_P = \frac{\mu_0 i}{4\pi (R/\sqrt{2})}(1 - \sin 45^\circ) \Rightarrow \frac{\sqrt{2}\mu_0 i}{4\pi R}\left(1 - \frac{1}{\sqrt{2}}\right) = \frac{\mu_0 i(\sqrt{2}-1)}{4\pi R}$$

$B_c = 2B_1 = \mu_0 i(\sqrt{2}-1)$

Magnetic field due to current carrying coil :



considering, 2 current element diametrically opposite to each other, then their component of magnetic field $dB\sin\phi$ cancel each other and the resultant magnetic field due to these element is given by $dB_p = 2dB\cos\phi$

$$(dB)_p = 2\left(\frac{\mu_0 i \, dl \sin\theta}{4\pi r^2}\right)\cos\phi$$

$$= \frac{2\mu_0 i \, dl \sin 90^\circ}{4\pi r^2}\left(\frac{R}{r}\right) \qquad \left\{\begin{matrix} \vec{dl} \perp \vec{r} \\ \theta = 90^\circ \end{matrix}\right\}$$

$$= \frac{\mu_0 i R}{2\pi r^3} \, dl$$

so, total magnetic field at point P of the coil :

$$B_p = N\left[\frac{\mu_0 i R}{2\pi r^3}\int_0^{\pi R} dl\right]$$

$$= \frac{\mu_0 N i R}{2\pi (R^2+x^2)^{3/2}} \times \pi R \qquad \therefore \boxed{B_p = \frac{\mu_0 N i R^2}{2(x^2+R^2)^{3/2}}}$$

Important points:

i) Magnetic field at the centre of the coil

$\therefore$ at centre, $x = 0 =$ min

$$B_c = \frac{\mu_0 N i}{2R} = \text{max.}$$ (same as magnetic field of loop at centre

ii) If point P is at ~~the~~ distant, then $x >>> R$

$$B_P = \frac{\mu_0 N i R^2}{2x^3} \qquad B_P \propto \frac{1}{x^3}$$ (same as dipole

iii) If point P is very close to the centre $x <<< R$

$$= \frac{\mu_0 N i R^2}{2\left[R^2\left(1+\frac{x^2}{R^2}\right)\right]^{3/2}}$$ taking common (R^2)

$$B_P = \frac{\mu_0 N i}{2R}\left(1+\frac{x^2}{R^2}\right)^{-3/2}$$

$$\therefore B_P = B_c\left(1-\frac{3x^2}{2R^2}\right)$$ applying Binomial theorem

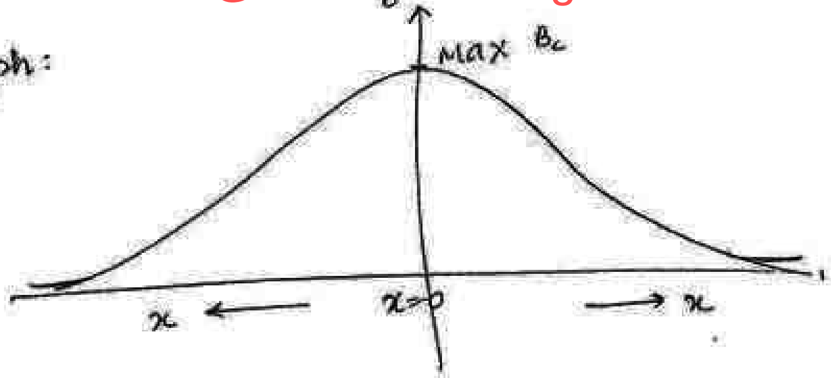
$$\therefore \frac{B_P}{B_c} - 1 = \frac{-3x^2}{2R^2}$$

$$\therefore \frac{B_P - B_c}{B_c} = \frac{-3x^2}{2R^2}$$

$$\frac{B_f - B_i}{B_i}$$

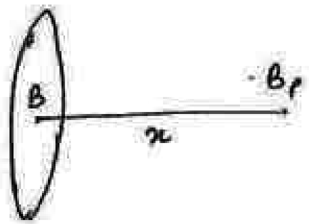
$$\boxed{\therefore \left|\text{fractional change in } B\right| = \frac{3x^2}{2R^2}}$$

iv) graph:



Q) At what distance from the centre of current carrying coil magnetic field dec to $\frac{1}{64}$ of the value at the centre

∵ it dec away from centre



$$B_p = \frac{B_c}{64}$$

$$\frac{\mu_0 N i R^2}{2(x^2+R^2)^{3/2}} = \frac{\mu_0 N i}{2R} \times \frac{1}{64}$$

$$(x^2+R^2)^{3/2} = 64R^3$$

cube root

$$(x^2+R^2)^{1/2} = 4R$$

squaring both side

$$x^2+R^2 = 16R^2$$

$$\therefore \boxed{x = \pm R\sqrt{15}}$$

Short trick: $x = \pm R\sqrt{n^{2/3}-1}$

Q) At what distance from the centre of the current carrying coil, magnetic field will be a fractional change of 2%.

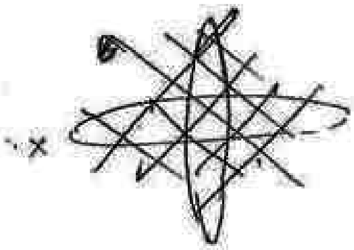
$$fc = 2\%$$

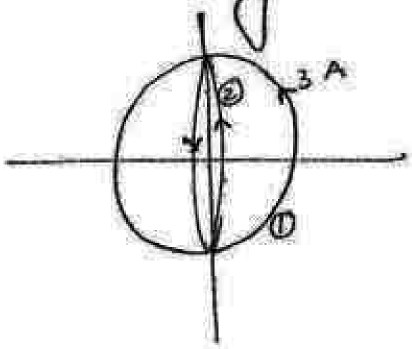
$$\frac{3x^2}{2R^2} = \frac{2}{100}$$

$$\therefore\ x^2 = \frac{2 \times 2 R^2}{100 \times 3}$$

$$\therefore\ x = \pm \frac{R}{\sqrt{75}} = \pm \frac{R}{5\sqrt{3}}$$

(Q) Two current carrying coil of equal radius 10 cm carrying current 3A and 4A. These coils are lying in X-Y and Y-Z plane respectively. then find magnetic field at their common centre. (each coil is having 100 turns)





for ①
Plane XY $\therefore\ B_1 \rightarrow Z$

for ⓘⓘ $\qquad \therefore\ \vec{B_1} \perp \vec{B_2}$

Plane Y-Z $\quad B_2 \longrightarrow X$

$$B_c = \sqrt{B_1^2 + B_2^2} = \sqrt{\left(\frac{\mu_0 N i_1}{2R}\right)^2 + \left(\frac{\mu_0 N i_2}{2R}\right)^2}$$

$$= \frac{\mu_0 N}{2R}\sqrt{i_1^2 + i_2^2} = \frac{(4\pi \times 10^{-7}) \times 100}{2 \times 10 \times 10^{-2}}\sqrt{3^2 + 4^2}$$

Q) A wire of length 'l' is bend to form a coil of n turn, ~~the~~ then field magnetic field at the centre of the coil.

$$l = (2\pi R)N$$

$$\therefore R = \frac{l}{2\pi N} \qquad \therefore \boxed{R \propto \frac{\;}{N}}$$

$$\therefore B_c = \frac{\mu_0 N i}{2R}$$

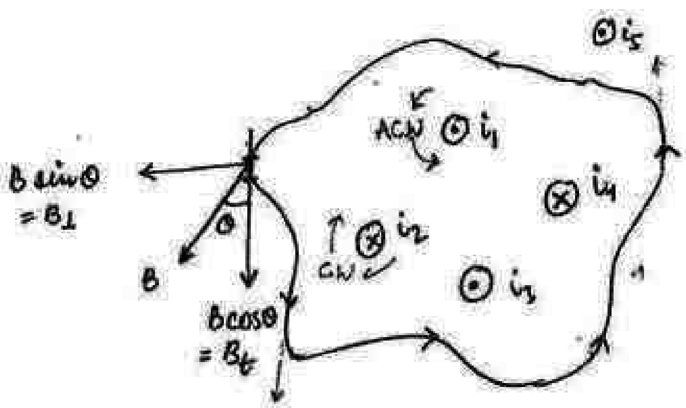
$$= \frac{\mu_0 N i\,(2\pi N)}{2\,l} \qquad \therefore \boxed{B_c = \frac{\mu_0 N^2 \pi i}{l}}$$

$$\therefore \boxed{B_c \propto N^2}$$

ACL : Ampere – Circuital Law :

According to this law, line integral of magnetic field along a closed path / loop is μ_0 time of the current enclosed by that loop / path.

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



$$\oint \vec{B}\cdot\vec{dl} = \mu_0 (i_1 - i_2 + i_3 - i_4)$$

$$\oint B\,dl\cos\theta = \mu_0 i_{en}$$

$$\boxed{\oint B_t\,dl = \mu_0 i_{en}} \quad \text{—(2)}$$

NCERT

- This law is equivalent to gauss law in electrostatics
- This law is generally applicable to the fields which have some kind of symmetricity.

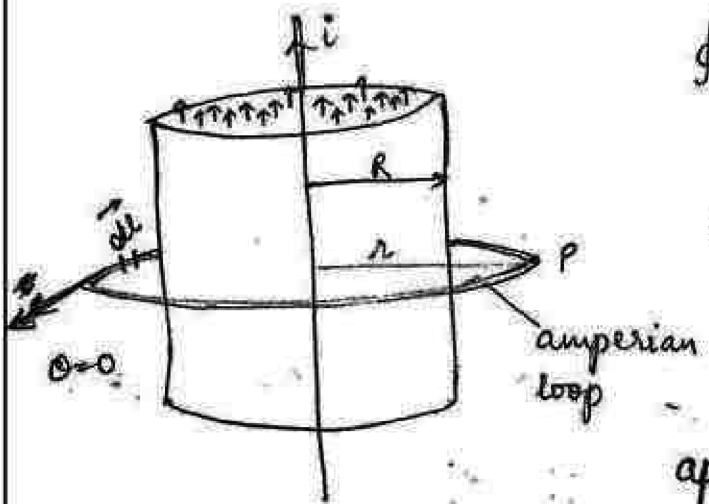
for eg: This law can be applied to find magnetic field due to long current carrying conductor which is having cylindrical symmetricity

- This law is applicable to only steady current (independent of time, continuous and same at all point)

Applications of ACL

1. Magnetic field due to long (infinite) current carrying cylindrical conductor: (behaves as infinite wire)

a) outside the conductor ($r>R$)



$\oint B\,dl\cos\theta = \mu_0 i_{en}$

considering an amperian loop of radius 'r' and passing through the point P, then applying ACL for this loop.

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 i_{en}$$

$$\oint B\,dl\cos\theta = \mu_0 i \qquad \left[\because \begin{array}{l} \vec{B} \parallel \vec{dl} \\ \theta = 0^\circ \\ i_{en} = i \end{array} \right.$$

$$B \oint dl = \mu_0 i$$

$$B(2\pi r) = \mu_0 i$$

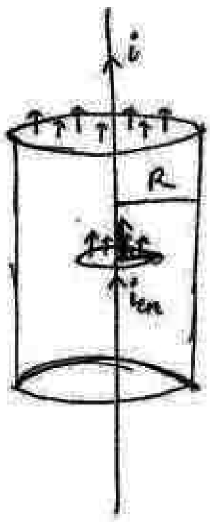
$$\boxed{B = \frac{\mu_0 i}{2\pi r}} \qquad \therefore B \propto \frac{1}{r}$$

Behaves as an infinite wire

b) on the surface $(r = R)$

$$\boxed{B = \frac{\mu_0 i}{2\pi R}} = \text{Max}$$

c) inside the conductor $(r < R)$ ∵ current flowing is reduced ∴ use the [illegible] of current density i.e. J



J = current density

$$J = \frac{i}{A} = \frac{i_{en}}{A_{en}}$$

$$i_{en} = \frac{i}{A} A_{en}$$

$$= \frac{i}{\pi R^2} \pi r^2$$

$\therefore$ from ACL

$$B \times 2\pi r = \mu_0 \left(\frac{i r^2}{R^2} \right)$$

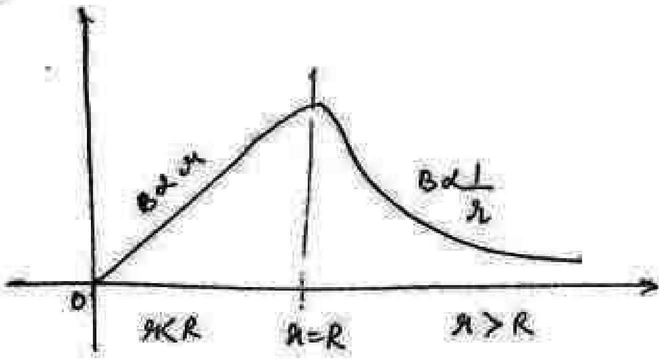
$$\therefore \boxed{B = \frac{\mu_0 i r}{2\pi R^2}} \qquad B \propto r$$

$$B = \frac{\mu_0 J r}{2} \qquad \therefore \vec{B} = \frac{\mu_0 (\vec{J} \times \vec{r})}{2} \qquad \left[\begin{array}{l} \vec{J} \perp \vec{r} \\ \theta = 90^\circ \end{array} \right]$$

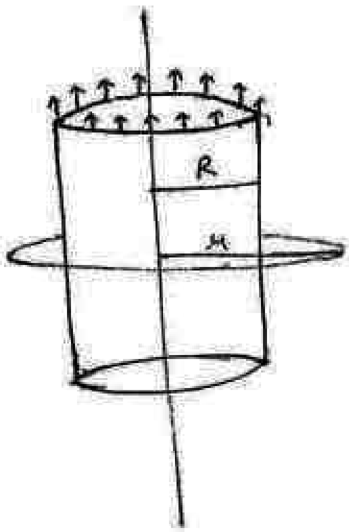
d) on the axis

$r = 0 \quad \therefore \quad \boxed{B_A = 0}$

graph:



2. **Magnetic field due to long current carrying cylindrical pipe:**



a) outside $(r>R)$

$$\underline{B \times 2\pi r} = \mu_0 i$$

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

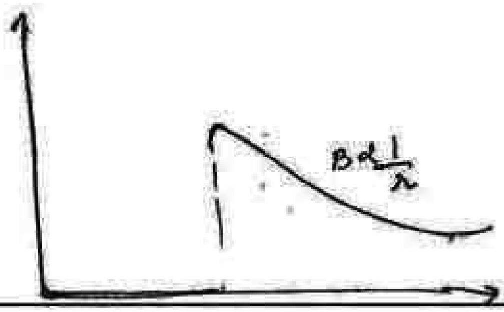
b) surface $(r=R)$

$$\boxed{B = \frac{\mu_0 i}{2\pi R}}$$

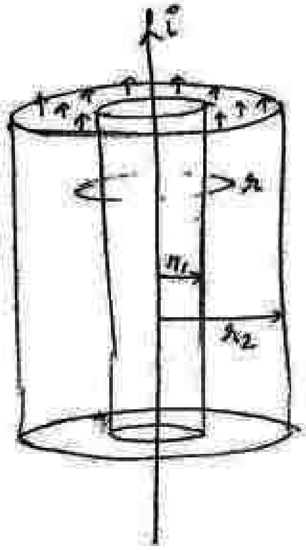
c) Inside $(r<R)$

$\therefore \; i_{en} = 0$

$$\boxed{B_{en} = 0}$$



3. Magnetic field due to long current carrying cylindrical conductor.



a) at distance r ($r_1 < r < r_2$)

$J =$ constant

∵ i is reduced [illegible] const

$$\frac{i}{A} = \frac{i_{en}}{A_{en}}$$

$$i_{en} = \frac{i}{\pi(r_2^2 - r_1^2)} \pi(r^2 - r_1^2)$$

$$= \frac{i(r^2 - r_1^2)}{r_2^2 - r_1^2}$$

from ACL,

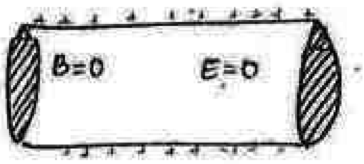
$$B \times 2\pi r = \mu_0 i_{en}$$

$$B \times 2\pi r = \mu_0 \frac{i(r^2 - r_1^2)}{r_2^2 - r_1^2}$$

$$\boxed{B = \frac{\mu_0 i (r^2 - r_1^2)}{2\pi r (r_2^2 - r_1^2)}}$$

Imp. Points **

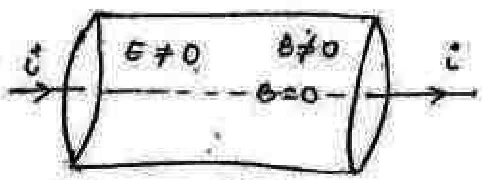
a) Charged conductor



B=0 E≠0

∵ their is no current

b) Current carrying conductor



E=0 B≠0

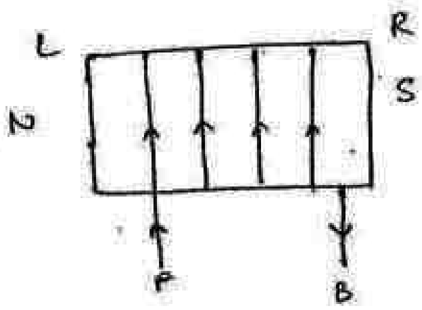
4. Solenoid

- It consists of a long copper wire which is bend to form a helix having turns along its length with equal spacing very close to each other and ~~b~~ wound over non-magnetic and non-conducting core

- ~~It~~ Solenoid is used to produce uniform magnetic field inside it along its length

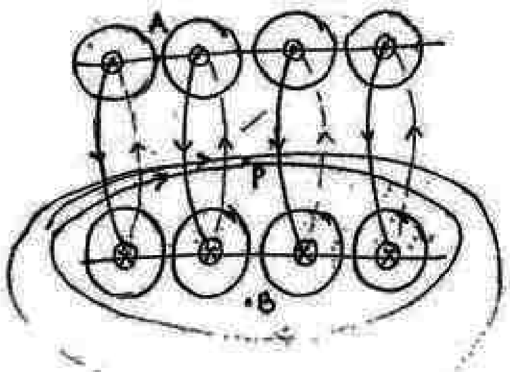
- length of a long solenoid/ infinite solenoid is very much greater than its radius

- A current carrying solenoid behaves like a bar magnet.



* LN
left north

- Magnetic field of solenoid:



» At point A, magnetic field lines are in opposite dirⁿ cancelling effect of each other

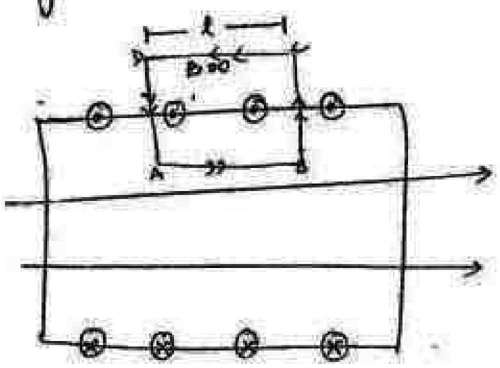
$$\therefore \quad B_A = 0$$

» At point B, magnetic field lines are distant which show weak magnetic field. For long solenoid magnetic field at this point is approx 0

$$\therefore \quad B_B \approx 0$$

» At point P, magnetic field lines are close to each other which shows strong magnetic field and for long solenoid, these field line are equidistant and unidirectional i.e. uniform magnetic field.

» Magnetic field of a long solenoid



$\oint \cancel{B\,dl\cos\theta}$

considering a rectangular amperian loop of length l passing through the point P enclosing 'N' ~~n~~ turns of solenoid, then applying ACL for this loop

$$\oint_{ABCDA} \vec{B}\cdot\vec{dl} = \mu_0 i_{en}$$

$$\int_{AB} B\,dl\cos 0 + \int_{BC} B\,dl\cos 90 + \int_{CD} \vec{B}_{out}\cdot d\vec{l} + \int_{CD} B\,dl\cos 90 = \mu_0(Ni) \{i_{en} = Ni\}$$

$$B\int dl + 0 + \underset{(\because B=0)}{0} + 0 = \mu_0 Ni \quad \{B_{out} = 0\}$$

By ACL $\cancel{B} \times l = \mu_0 Ni$

$$\therefore \boxed{B = \frac{\mu_0 Ni}{l}}$$

$\therefore \boxed{B = \mu_0 ni}$ $\quad \therefore n = \frac{N}{l}$ = turn density or no of turn per unit length

» Magnetic field due to finite length solenoid :

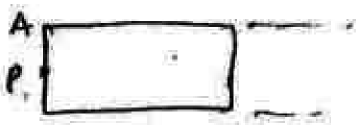
$$\boxed{B_P = \frac{\mu_0 ni}{2}(\sin\phi_1 + \sin\phi_2)}$$

for long solenoid :

$\phi_1 = \phi_2 = 90°$ $\quad \therefore \boxed{B_P = \mu_0 ni}$

If P is at one of the ends of long solenoid

$\phi_1 = 0$, $\phi_2 = 90°$

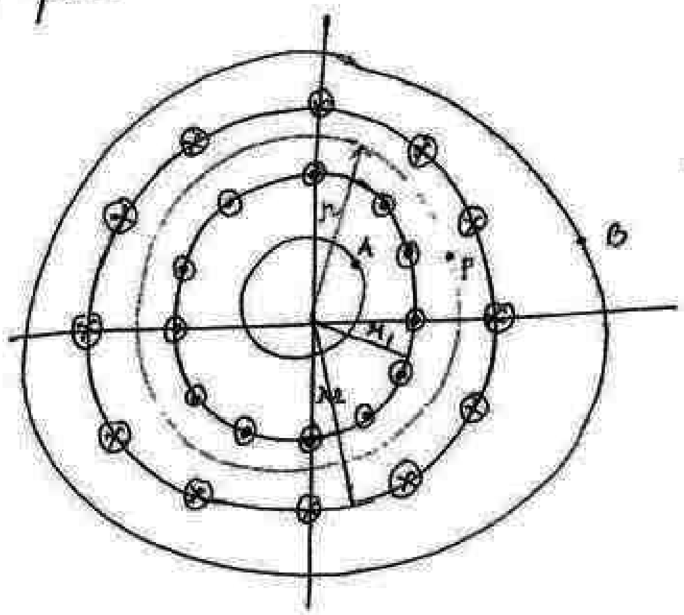


$$\boxed{B_{end} = \frac{\mu_0 ni}{2}}$$

B_{inside} $\quad$ 2

Toroid :

- It consist of a hollow ring having turns along its circumference.
- It is used to produce circular magnetic field of constant magnitude
- It is also called <u>endless solenoid</u> and doesn't have any pole.



i) at point A, $i_{en} = 0$ $\therefore$ $B_A = 0$

ii) at point B, $i_{en} = Ni - Ni = 0$ $\therefore$ $B_B = 0$

iii) at point P, $i_{en} = Ni$

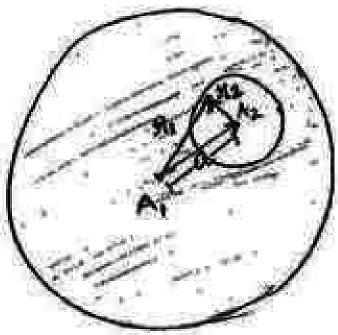
By ACL, $B \times 2\pi r = \mu_0 Ni$

$$\therefore \boxed{B = \frac{\mu_0 Ni}{2\pi r} = \frac{\mu_0 Ni}{l}}$$

$$r = \frac{r_1 + r_2}{2}$$

Mean radius

Q) A current is flowing in long cylindrical conductor of radius R. now, a cylindrical cavity is cut inside this conductor ~~to~~ having axis parallel to the axis of the conductor.
Find magnetic field inside the cavity.
The seperation b/w the ~~axis~~ axes is 'a' and current density of the conductor is 'J'



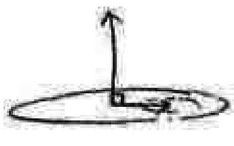
$$\boxed{\vec{B}_{remaining} = \vec{B}_{total} - \vec{B}_{cut}}$$

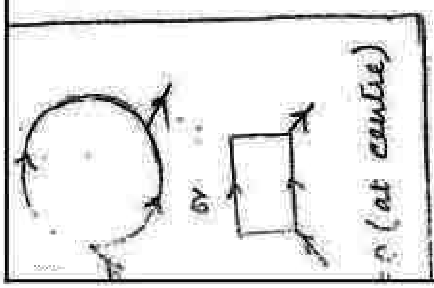
$$= \frac{\mu_0(\vec{J}\times\vec{r}_1)}{2} - \frac{\mu_0(\vec{J}\times\vec{r}_2)}{2}$$

$$= \frac{\mu_0 J \times (\vec{r}_1 - \vec{r}_2)}{2}$$

$$\therefore \boxed{B_{remain} = \frac{\mu_0(\vec{J}\times\vec{a})}{2}}$$

$$\therefore \boxed{B_{remain} = \frac{\mu_0 Ja}{2}}$$





Magnetic ~~field~~ FORCE on the moving charge

» when a charge 'q' moving with the velocity 'v' enters in a magnetic field B, at an angle θ then magnetic force is given by:

$$\boxed{\vec{F}_M = q(\vec{V} \times \vec{B})}$$ Lorent force

$\cancel{\vec{F}_M}$ $\boxed{F = qVB\sin\theta}$

» If electric and magnetic, both the fields are ⊕nt, then

$$\vec{F} = \vec{F}_E + \vec{F}_M$$

$$\therefore F = q(\vec{E} + \vec{V} \times \vec{B})$$

» Magnetic force on the particle will be zero

a) If particle is neutral (neutron, photon)

$q = 0 \quad \therefore F = 0$

b) If particle is at rest.

$\therefore V = 0 \quad \therefore F = 0$

c) If charged particle is moving along $\vec{B}$

$\theta = 0$ or π $\quad \therefore F = 0 \quad \because (\sin 0 = \sin 180° = 0)$

» Moving charge in magnetic field.

__Case-I:__ If charged particle enters in magnetic field ~~⊥ to $\vec{V}$ and $\vec{B}$~~ perpendicularly →

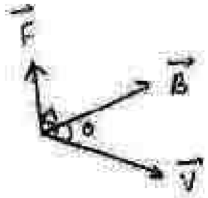
$\therefore \theta = 90^\circ$

$$\boxed{F = qVB = \text{max}}$$

a) Path of the charged particle :

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

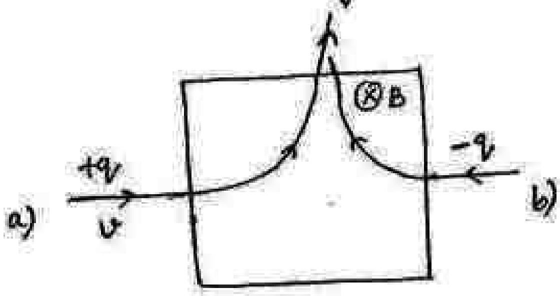
so, $\left.\begin{array}{l}\vec{F} \perp \vec{B} \\ \vec{F} \perp \vec{V}\end{array}\right]$ (always)



and path / trajectory / motion : uniform circular motion ($\because \vec{F} \perp \vec{V}$)

b) dir^n of magnetic force

It can be obtained by using Right hand thumb rule / Right hand screw rule



a) $\vec{F} = \vec{V} \times \vec{B}$

$= \hat{i} \times (-\hat{k})$

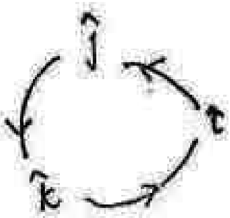
$= +\hat{j}$

b) $\vec{F} = \vec{V} \times \vec{B}$

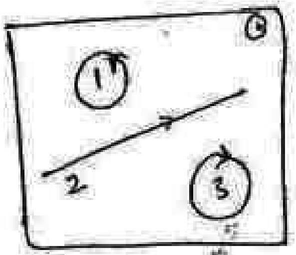
$= (-\hat{i}) \times (-\hat{k})$

$= -\hat{j}$

$\therefore$ ans $= +\hat{j}$ ($\because q$ is $-$ve)



Q)



find α, β, γ

1 $\Rightarrow$ β
2 $\Rightarrow$ γ
3 $\Rightarrow$ α

$\odot$ से $\odot$
$\otimes$ से $\otimes$
if match, then −ve

clockwise, $\vec{E}$ $\odot$ ∴ the charge is +ve 'α'

★ c) Radius of circular path:

centripetal force require for circular motion is provided by the magnetic force then,

$$F_c = F_M$$

$$\frac{mv^2}{r} = qvB \quad (\because B = \text{constant})$$

★★★★★

$$\boxed{r = \frac{mv}{qB}} \qquad r \propto \frac{m}{q} \quad (\text{if } v \text{ is same})*$$

$$\boxed{r = \frac{p}{qB}} \qquad r \propto \frac{1}{q} \quad (p = \text{same})*$$

$$\boxed{r = \frac{\sqrt{2mK}}{qB}} \qquad r \propto \frac{\sqrt{m}}{q} \quad (K = \text{same})*$$

$$\Delta K = W$$

$$K - 0 = q\Delta V$$

$$K = q\Delta V$$

$$r = \frac{\sqrt{2mq\Delta V}}{qB}$$

$$\boxed{r = \frac{1}{B}\sqrt{\frac{2m\Delta V}{q}}} \qquad r \propto \sqrt{\frac{m}{q}} \quad \left(\Delta V = \text{P.D, potential diff}\right)$$

d) Time period of the circular path

$$T = \frac{2\pi}{\omega} = \frac{2\pi r}{v} \quad \left(\because \omega = \frac{v}{r}\right)$$

$$= \frac{2\pi}{v}\left(\frac{mv}{qB}\right) \quad \therefore \boxed{T = \frac{2\pi m}{qB}}$$

$$\boxed{T \propto v^0 \propto r^0}$$

So, time period of the charged particle is independant of its velocity or radius of the circular path cz both the quantities change in same proportion.

$\therefore$ used to design cyclotrone

e) frequency / angular frequency / cyclotrony frequency

$$f = \frac{1}{T} \quad \therefore \boxed{f = \frac{qB}{2\pi m}} \quad (Hz, CPS, RPS, RPM)\ldots$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi m} qB \quad \therefore \boxed{\omega = \frac{qB}{m}} \quad (rad/s)$$

f) Kinetic energy of the charged particle:

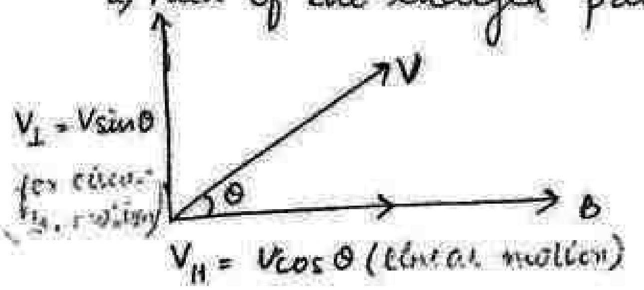
$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{qBr}{m}\right)^2 = \frac{1}{2}\frac{mq^2B^2r^2}{m^2}$$

$$\therefore \boxed{K = \frac{q^2B^2r^2}{2m}} \quad \therefore \boxed{K \propto r^2}^{*} \rightarrow K \propto \pi r^2$$

$$K = \frac{q^2B^2\pi r^2}{2\pi m} \quad \therefore K = \frac{q^2B^2A}{2\pi m} \quad \boxed{K \propto A}^{*}$$

Case II: If charged particle enters in magnetic field at an angle θ $(\theta \neq 0°, \frac{\pi}{2}$ and $\pi)$

a) Path of the charged particle



i) $V_\parallel = V\cos\theta \Rightarrow$ provides linear motion

ii) $V_\perp = V\sin\theta \Rightarrow$ provides circular motion.

$\therefore$ combined effect (combined circular linear motion) is a helix

b) Radius of the ~~circular~~ helical path:

$$F_c = F_M$$

$$\frac{mv_\perp^2}{r} = qvB\sin\theta$$

$$\frac{m(v\sin\theta)^2}{r} = qvB\sin\theta \qquad \therefore \boxed{r = \frac{mv\sin\theta}{qB}}$$

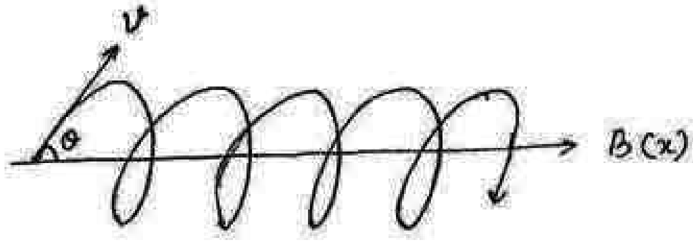
$\because V\cos\theta = 0$ $(\vec{V} \parallel \vec{B}, \sin 0° = 0)$ $\qquad \therefore \boxed{r = \frac{mV_\perp}{qB}}$

c) Time period:

$$T = \frac{2\pi r}{V_\perp} = \frac{2\pi}{V_\perp}\left(\frac{mV_\perp}{qB}\right) \qquad \therefore \boxed{T = \frac{2\pi m}{qB}}$$

$$\therefore \boxed{T_{helix} = T_{axis}}$$

d) Pitch of the helical path :



$u_x = v_{\parallel} = v\cos\theta \quad , \quad x = P \quad , \quad a_x = 0 \quad , \quad F_x = 0 \quad , \quad t = T$

$$S_x = u_x t + \frac{1}{2} a_x t^2$$

$$= v\cos\theta \times \frac{2\pi m}{qB} + 0$$

$$\boxed{P = \frac{2\pi m v \cos\theta}{qB}}$$

* Q) A charged particle q of mass 1g is moving with the velocity $\vec{v} = (3\hat{i} + 4\hat{j})$ m/s enters in a magnetic field $B = 3\hat{k}$ T then comes out of the magnetic field with the speed v' and KE K'. Then find

a) path of the charged particle [possibilities ⟵ $\overrightarrow{O}$]

b) work done by the magnetic force on the charged particle

c) KE (K')

d) speed (v')

a) Path $\quad \vec{v} \perp \vec{B} \quad \therefore$ path = circular

b) $W_M = \int \vec{F} \cdot \vec{ds} \quad$ ($\neq \frac{1}{2} m v^2$ i.e KE $\because$ KE is also unknown)

$$\vec{F}_M \perp \frac{\vec{ds}}{dt} \quad \text{(always)}$$

$$\vec{F}_M \perp \vec{ds} \quad \text{(always)} \qquad \therefore \boxed{W_M = 0}$$

∵ it is scalar, ∴ no effect on dir^n

c) $W_M = \Delta K \qquad (\Delta K = 0)$

$$K_f' - K_i = 0 \quad ; \quad \boxed{K' = K}$$

d) $\frac{1}{2} m v'^2 = \frac{1}{2} m v^2 \qquad \therefore \boxed{v' = v} \qquad \boxed{\vec{v}' \neq \vec{v}}$ ∵ dir^n changes

$$\therefore \; v = \sqrt{3^2 + 4^2} = 5 \text{ m/s}$$

Q) A proton, Deutron and α particle are moving with the same KE enters in magnetic field perpendicularly, then find ratio of radii of their circular path

	Proton ^1_1H	Deutron ^2_1H	α He^{+2}
m	m_p	$2m_p$	$4m_p$
q	$+e$	$+e$	$+2e$

$m_p = 1.67 \times 10^{-27}$

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

$$r = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB} \qquad \therefore \; r \propto \frac{\sqrt{m}}{q}$$

$$r_p : r_d : r_\alpha = \frac{\sqrt{m_p}}{q_p} : \frac{\sqrt{m_d}}{q_d} : \frac{\sqrt{m_\alpha}}{q_\alpha}$$

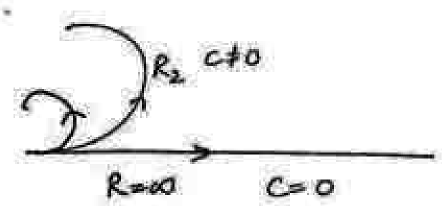
$$= \frac{\sqrt{m_p}}{e} : \frac{\sqrt{2m_p}}{e} : \frac{\sqrt{4m_p}}{2e}$$

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

Radius of curvature $(R) \propto \dfrac{1}{\text{curvature } (C)} \propto \dfrac{1}{\text{deflection}}$

$\therefore \quad R_d > (R_p = R_\alpha)$

$C_p = C_\alpha > C_d$



Q) An α particle experiences a magnetic force 10^{-15} N when enters in a magnetic field of 0.1 Wb/m^2 at an angle of 30°. Then find its speed and radius of the ~~circular path~~ helical path

$F = qvB\sin\theta$

$V = \dfrac{F}{qB\sin\theta} = \dfrac{10^{-15}}{(2\times1.6\times10^{-19})\ 0.1\times\left(\frac{1}{2}\right)}$

$q \Rightarrow 2e$

$= 6.25\times10^{4}$ m/s

$r = \dfrac{mv\sin\theta}{qB} = \dfrac{(4\times1.67\times10^{-27})\times(6.25\times10^{4})\times\left(\frac{1}{2}\right)}{(2\times1.6\times10^{-19})\ 0.1}$

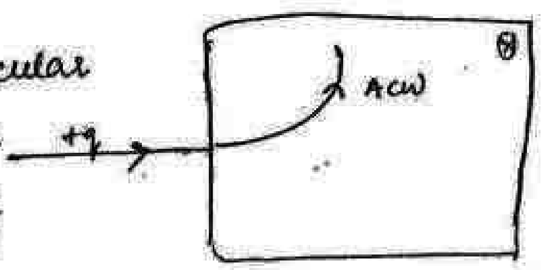
$m \Rightarrow 4m_p$

6.25×10^{-3} m

Q) A charged particle $(+q)$ moving in x dir^n rotates anti-clockwise in x-y plane, then find dir^n of magnetic field

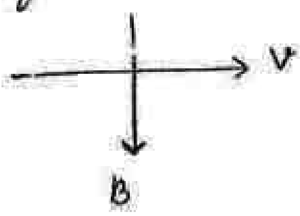
$\therefore \vec{B} = \otimes$

* Plane of the circular motion is always $\perp$ to the dir^n of magnetic field.



$\therefore$ Ans $= -\hat{k}$

Q) A charged particle $+q$ is moving in east dirⁿ enters in a magnetic field working in south dirⁿ, then find in which dirⁿ it will be deflected



$$\therefore \vec{F} = \vec{V} \times \vec{B}$$
$$\hat{i} \times -\hat{j}$$
$$= -\hat{k}$$

****

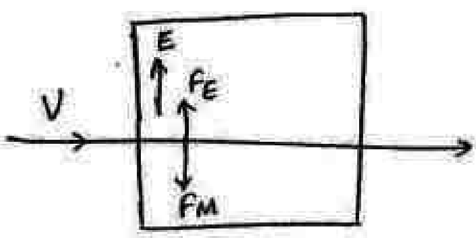
Q) A charged particle moving with the speed V in +ve x dirⁿ enters in a region of space where electric and magnetic fields are working. electric field is in +Y dirⁿ. If charged particle remains undeflected/undeviated then find

a) dirⁿ of magnetic field

b) speed of the charged particle

c) path of the charged particle when electric field is switched off.

d) path of the charged particle when magnetic field is switched off



* when charge remains undeflected in presence of any two field, then forces due to those field will balance each other.

$$\vec{F}_E = -\vec{F}_M$$

$$q\vec{E} = -q(\vec{V}\times\vec{B}) \quad \therefore \quad \boxed{\vec{E} = \vec{B}\times\vec{V}}^{*}$$

so, $\hat{j} = [\hat{k}] \times \hat{i}$

or $(\hat{k}\pm\hat{i})\times\hat{i} \Rightarrow (\hat{k}\times\hat{i}) \pm (\hat{i}\times\hat{i})$ $\hat{i}\times\hat{i}$

b) $E = BV\sin 90^\circ$ $\therefore \boxed{V = \frac{E}{B}}^{*}$

c) $E = 0$

if $\vec{V} \perp \vec{B}$, (path: circle)

if $\vec{V}$ at an angle θ to B ; (path: helix)

d) $B = 0$

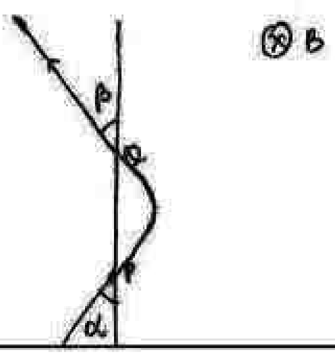
Path : Parabola

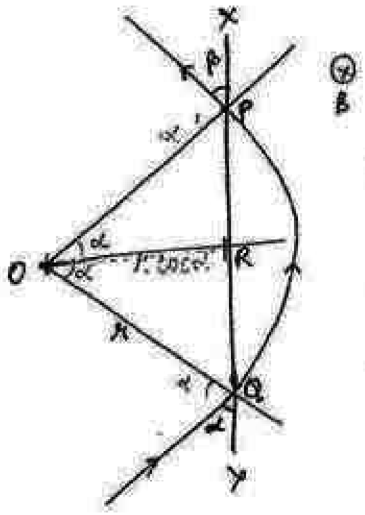
Q) In the given diagram, charged particle enters in magnetic field at an angle α and comes out of the magnetic field at an angle β. Then find

i) angle β

ii) displacement PQ

iii) Time spend by the charged particle in the magnetic field.





$\therefore \boxed{\alpha = \beta}$

a) So, in such questions where charge particle enters and exit from same line XY, then, angle of entrance α is always equal to angle of emergance.

b) $PQ = PR + RQ$

$r\sin\alpha + r\sin\alpha = 2r\sin\alpha$

c) $\theta = \omega t$

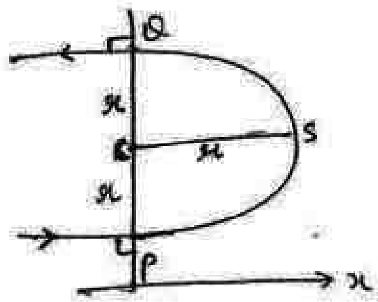
$2\alpha = \frac{qB}{m} t$

$\therefore \boxed{t = \frac{2\alpha m}{qB}}$

$\because \left\{ T = \frac{2\pi m}{qB} \quad \omega = \frac{2\pi}{T} \right\}$

* Special point:

If $\alpha = 90°$



Path: semicircle

$PQ = 2r\sin 90° = 2r$

$CS = r(1-\cos\alpha)$

$= r(1-\cos 90°) = r$

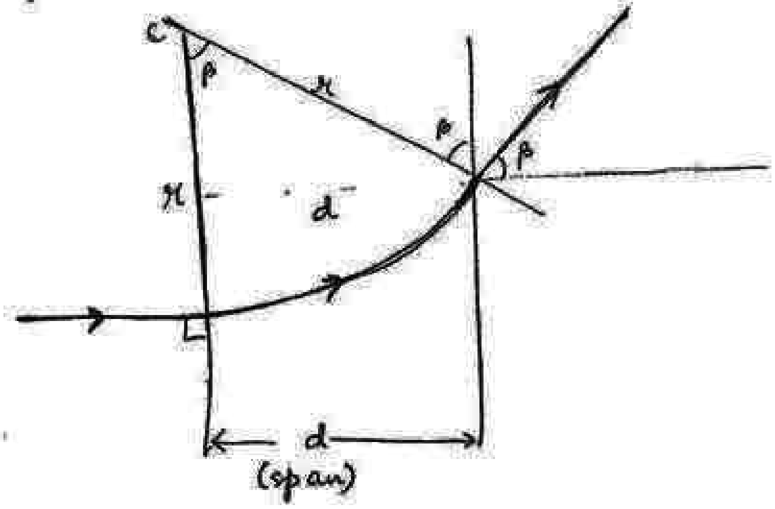
time spend:

$t = \frac{2\alpha m}{qB} = \frac{2\left(\frac{\pi}{2}\right)m}{qB} = \frac{\pi m}{qB}$

min^m span required for the ~~span~~ $\vec{B}$ in x dir^n

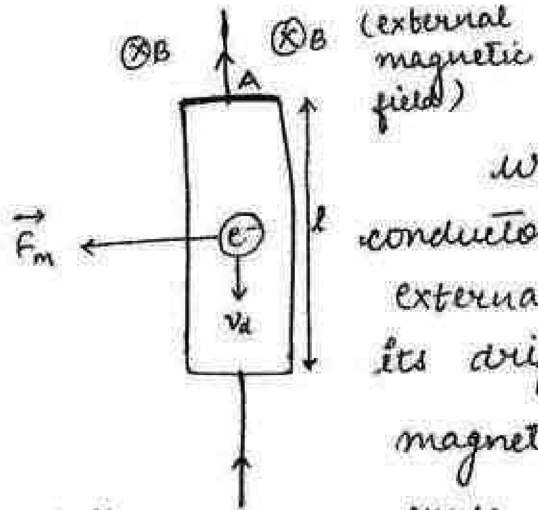
$x_{min} = r(1-\cos\alpha) = r$

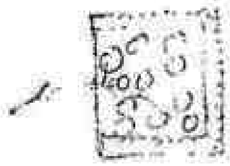
If span of $B < r_{min}$



$$\boxed{\sin\beta = \frac{d}{r}}$$

Force on current carrying conductor in external magnetic field :




mechanical analogy

When a current carrying conductor is placed in external magnetic field then its drifting e^- experiance a magnetic force as e^- can't cums out of the surface, then total force on all the e^- is combinedly experianced by the conductor.

Force on any one of the e^- , $\vec{F_e} = q\,(\vec{v} \times \vec{B})$

$\therefore \vec{F_e} = e\,(\vec{v_d} \times \vec{B})$

So, total force on the conductor :

$$\vec{F} = N[e\,(\vec{v_d} \times \vec{B})] \quad \text{—(1)}$$

If n is e^- no. density then, $n = \frac{N}{V}$ $\quad \therefore N = nV = nAl$ $\quad (\because V = Al)$(II)

from (1) and (II)

$$\vec{F} = nAle\left(\frac{\vec{l}}{\cancel{t}} \times \vec{B}\right) \qquad \because v_d = \frac{l}{t}$$

$$= neA\left(\frac{l}{t}\right)(\vec{l} \times \vec{B})$$

$$= neA\,v_d\,(\vec{l} \times \vec{B})$$

$$\vec{F} = i\,(\vec{l} \times \vec{B})$$

Special Points :

Force on current element $\vec{dF} = i(\vec{dl} \times \vec{B})$

So, total force on the wire of irregular shape

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

» If uniform magnetic field is applied,

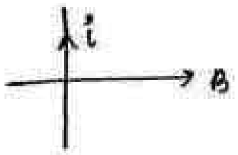
$$\vec{F} = i\left(\int \vec{dl}\right) \times \vec{B}$$

$$\vec{F} = i(\vec{l} \times \vec{B}) = \cancel{td}\ ilB\sin\theta$$

$$\boxed{\vec{F} = B(il)\sin\theta}$$

Bahar

» If conductor is $\perp$ to the magnetic field



$F = Bil\sin\theta \quad \therefore \quad F = B(il)$

» If current carrying loop is placed in uniform magnetic field

$$\vec{F} = i\left(\oint dl\right) \times \vec{B}$$

$\oint dl =$ total displacement for the loop $= 0$ (for any loop)

$$\boxed{F_{loop} = 0}$$

* So, magnetic force on current carrying loop in <u>uniform magnetic field</u> is always zero

» dir^n of magnetic force :

It can be obtained by using following two rules:

acc to this rule, if fingers : $\vec{B}$
thumb : i
dir" ⊥ to palm : $\vec{F}$

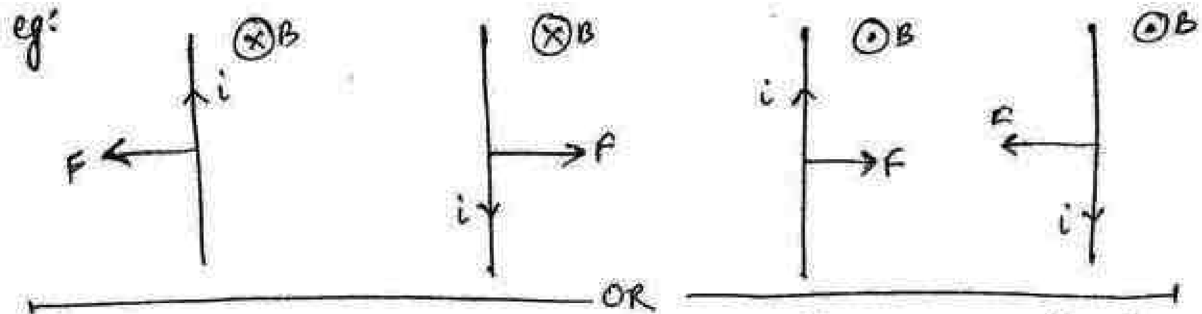
b) left hand flemming rule

if index finger ⇒ $\vec{B}$
middle ⇒ i
thumb ⇒ $\vec{F}$

c) See you late:

C	U	L
B ⊗	i(up)	F(left)

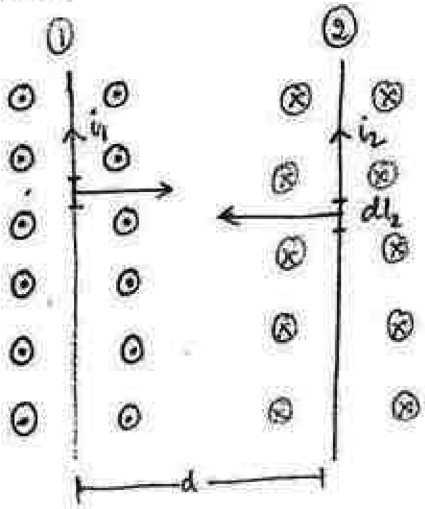
eg:



$\hat{j}\times(-\hat{k})$ $\quad$ $(-\hat{j})\times(-\hat{k})$ $\quad$ $\hat{j}\times\hat{k}$ $\quad$ $-\hat{j}\times\hat{k}$

$-\hat{i}$ $\quad$ $\hat{i}$ $\quad$ $\hat{i}$ $\quad$ $-\hat{i}$

» Magnetic force b/w 2 parallel long current carrying conductor



force on current element on wire 2

$$dF_2 = i_2(\vec{dl_2}\times\vec{B_1})$$

$$= i_2\,dl_2\,B_1\sin 90 \quad (\vec{dl_2}\perp\vec{B_1})$$

$$\frac{dF_2}{dl_2} = i_2\left(\frac{\mu_0 i_1}{2\pi d}\right)$$

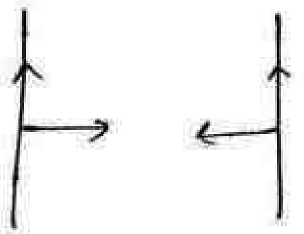
$$\boxed{\frac{df_2}{dl_2} = \frac{\mu_0 i_1 i_2}{2\pi d}}$$ force per unit length

So, force on length l

$$\boxed{F = \frac{\mu_0 i_1 i_2 l}{2\pi d}}$$

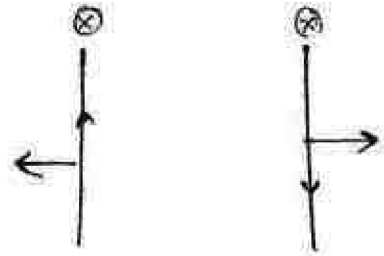
eg:

a)



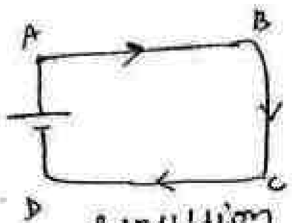
attraction

b)



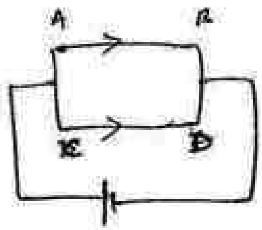
repulsion

c)



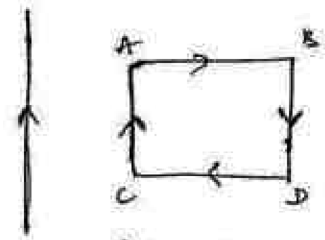
repulsion

d)



attraction

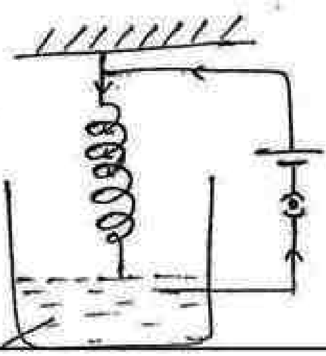
e)



loop will move towards the wire

$F_{loop} = 0$ (in uniform magnetic field) but here $\vec{B}$ for long wire is not uniform $\vec{B} = \frac{\mu_0 i}{2\pi d}$ $\left(\because B \propto \frac{1}{d}\right)$

f)

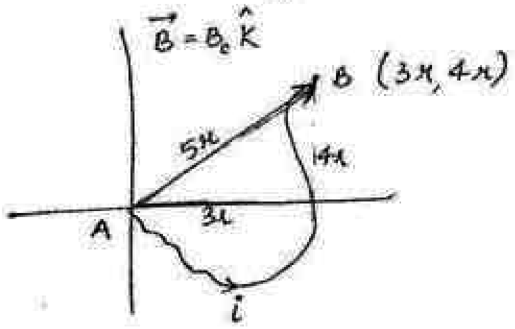


So, when DC is passed through the spring then it is compressed ($\because$ current is in same dir^n)

$\therefore$ attraction force

Q) Find the magnetic force on the conductor AB in each diagram.

i) $\vec{B} = B_0 \hat{k}$



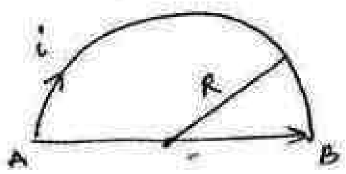
$F = Bil \sin\theta$

$l = 5x \;,\; \theta = 90 \;(\vec{l} \perp \vec{B})$

$\therefore F = B_0 i (5x) \sin 90$

$= B_0 i (5x)$

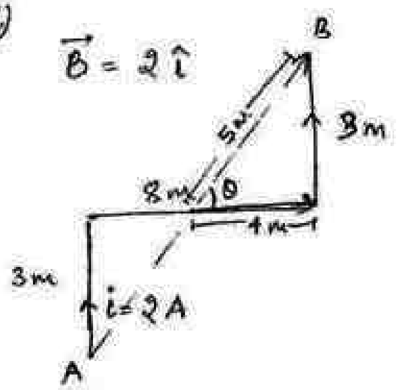
ii) $\vec{B} = B_0 \hat{i}$



$l = 2R \;,\; \theta = 0$

$F = 0$

iii) $\vec{B} = 2\hat{i}$

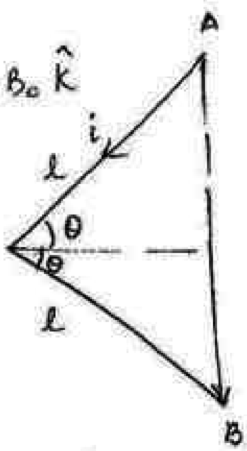


$\sin\theta = \frac{6}{10} = \frac{3}{5}$

$l = 10$

$\therefore F = 2 \times 2 \times 10 \times \frac{3}{5} = 24\text{ N}$

iv) $\vec{B} = B_0 \hat{k}$



$L = 2l \sin\theta$

$\phi = 90$

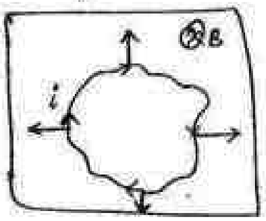
$F = B_0 i (2l \sin\theta) \sin 90$

$= B_0 i (2l \sin\theta)$

Q) A current carrying loop is placed in uniform magnetic field B as shown is diagram, then find

i) final shape of the loop.

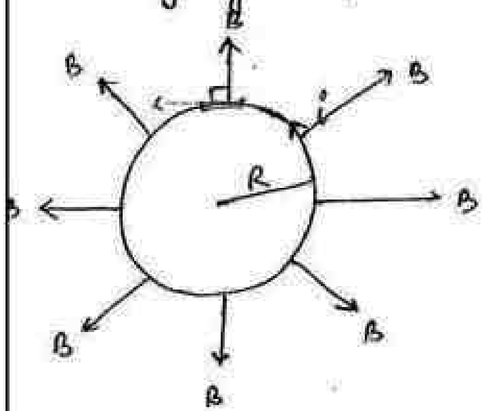
ii) force on the loop



i) ~~On each~~ magnetic force on each element is $\perp$ and outward so their will a stretching force on it and it will open into circle

ii) $F_{net} = 0$ But Tension in string $\neq 0$
($\because$ F on a part of the element $\neq 0$)

Q) Find the magnetic force on the given current carrying loop.



$$F = i \oint \vec{dl} \times \vec{B} \quad (\because B \text{ is not uniform})$$

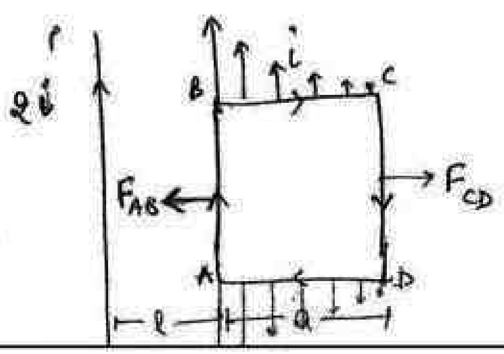
$$= i \oint dl\, B \sin 90^\circ$$

$$= iB \oint dl \quad (\because \text{same magnitude})$$

$$= iB \times 2\pi R$$

$$= 2\pi R i B$$

Q) Find the magnetic force on the given square loop ABCD due to the long wire PQ



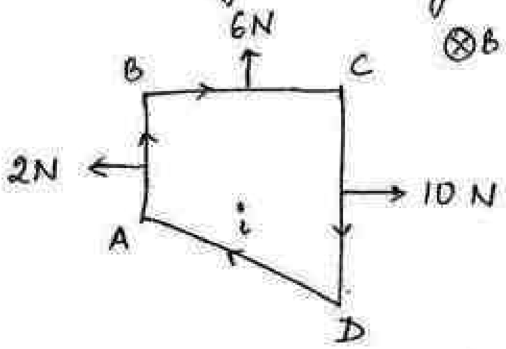
here forces working on sides BC and DA cancelling each other so net force on the loop.

$F_1 = F - F$

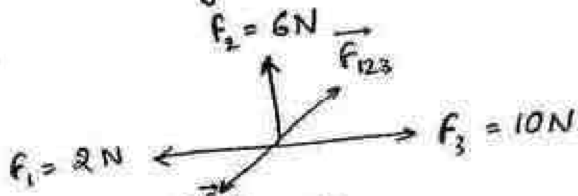
$$\frac{\mu_0 i_1 i_2 l}{2\pi d_1} - \frac{\mu_0 i_1 i_2 l}{2\pi d_2}$$

$$\frac{\mu_0 i \times 2i \times a}{2\pi}\left[\frac{1}{l} - \frac{1}{l+a}\right] = \frac{\mu_0 i^2 a^2}{\pi l(l+a)} \text{ leftward}$$

Q) Find the magnetic force on the side ~~BA~~ DA in the given diagram.



As magnetic force on current carrying loop in uniform magnetic field is always zero then,



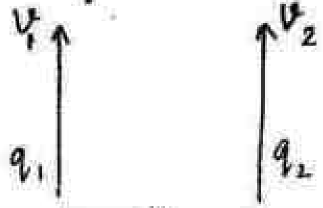
$$\vec{F}_{loop} = \vec{0}$$

$$\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \vec{F}_4 = \vec{0}$$

$$\vec{F}_{DA} = [\vec{F}_1 + \vec{F}_2 + \vec{F}_3] = \sqrt{(F_2+F_1)^2 + F_2^2}$$

$$= \sqrt{8^2 + 6^2} = \boxed{10N} \text{ (magnitude)}$$

*Q) Two charges q_1 and q_2 are moving parallel to each other with the same speed v then find, magnetic force b/w the charged particle



BSL,

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

$$\vec{dB} = \frac{\mu_0 \frac{dq}{dt} (\vec{dl} \times \vec{r})}{4\pi r^3}$$

For any charge q field produced is :

$$\vec{B} = \frac{\mu_0 q (\vec{v} \times \vec{r})}{4\pi r^3} \qquad \left\{ \frac{\vec{dl}}{dt} = \vec{v} \right\}$$

Now force on q_2 due to q_1

$$\vec{F} = q_2 (\vec{v_2} \times \vec{B_1})$$

{ F = BIl sin θ is not applied ∵ its force on moving charge ≠ current carrying conductor }

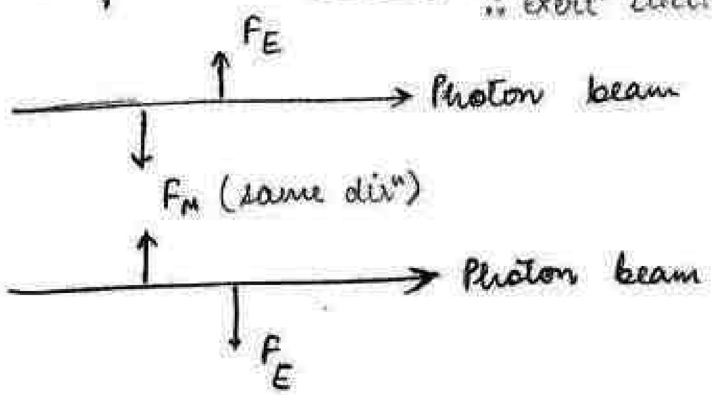
$$F = q_2 v_2 B_1 \sin 90 \qquad (\vec{v_2} \perp \vec{B_1})$$

$$q_2 v_2 \left(\frac{\mu_0 q_1 v_1 r \sin 90^\circ}{4\pi r^3} \right) \qquad (\vec{v_1} \perp \vec{r})$$

$$\boxed{\vec{F_M} = \frac{\mu_0 q_1 q_2 v_1 v_2}{4\pi r^2}}$$

- moving charge ∴ magnetic field

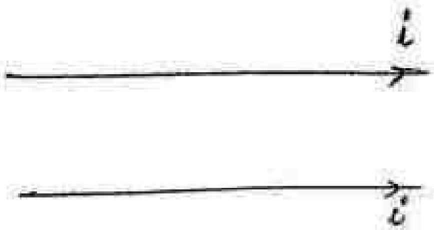
eg: a) two parallel <u>beams</u> (made up of same type of particle) ∴ exert electric field also



as $F_E >> F_M$

so beam will diverge

b) two parallel wires :

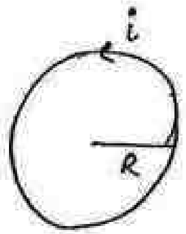


$F_E = 0$

$F_M \neq 0$ (attraction)

Magnetic moment (M)

▯ magnetic moment of a current carrying loop/ coil

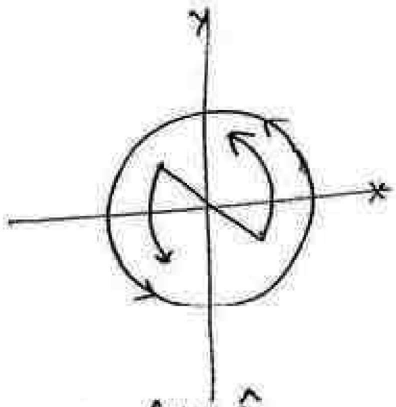


$M = iA$ if multiply all & available quantity

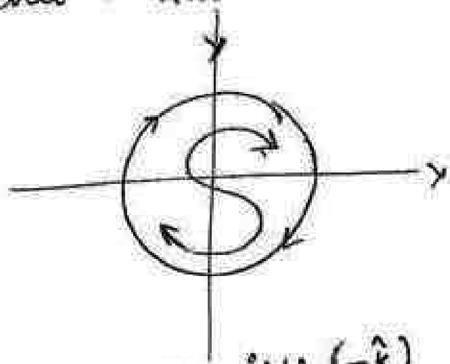
for coil, $M = N(iA)$

$$\boxed{M = iNA}$$

unit = Am^2

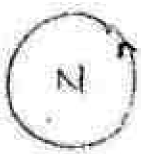


$M = iNA\,\hat{k}$



$M = iNA(-\hat{k})$

at centre,
C C
A D

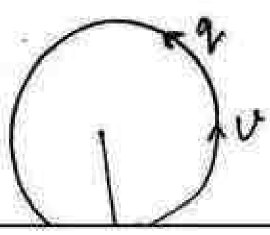


Anticlockwise

⇒ NT(W) = North

▯ Magnetic moment of revolving charge:

A revolving charge is equivalent to a current carrying loop when it completes one time period



a) current

i) $i = \frac{q}{t}$ $\boxed{i = \frac{q}{T}}$ $(t = T)$

$$\boxed{i = \frac{q\omega}{2\pi} = qf = \frac{qv}{2\pi r}}$$

b) magnetic field at the centre

$B = \frac{\mu_0 i}{2r} = \frac{\mu_0}{2r}\frac{qv}{2\pi r}$ $\boxed{B = \frac{\mu_0 q v}{4\pi r^2}}$

c) magnetic moment :

$M = iNA = \frac{qv}{2\pi r} \times 1 \times \pi r^2$ $\boxed{M = \frac{qvr}{2}}$

$M = \frac{q(mvr)}{2m}$ * $\boxed{M = \frac{qL}{2m}}$ (L = angular momentum)

$$\boxed{\frac{M}{L} = \text{gyromagnetic ratio} = \frac{q}{2m}}$$ → half of specific heat

* magnetic moment of orbiting e^- / orbital magnetic moment is given by

$$\mu_i = \frac{eL}{2m}$$

$\frac{e}{2m}\left(\frac{nh}{2\pi}\right)$ $\left[\because L = \frac{nh}{2\pi}\right]$ $\mu_l = \frac{neh}{4\pi m}$

for $n = 1$

$\mu_i = \text{min}^m = \frac{eh}{4\pi m}$ = Bohr magneton (μ_B)

$\mu_B = \frac{1.6 \times 10^{-19} \times 6.6 \times 10^{-34}}{4\pi \times 9.1 \times 10^{-31}} = \boxed{9.27 \times 10^{-24}\ J/T = \mu_B}$

Q) An e- moving along a circular path of radius 3.14 Å and with the frequency 5×10^{15} rps then find

i) current produced by the e^-

ii) magnetic field at the centre of the circle.

iii) magnetic moment produced due to its motion.

i) $i = qf$

$= 1.6 \times 10^{-19} \times 5 \times 10^{15}$

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

ii) $B = \frac{\mu_0 i}{2r}$

$$= \frac{4\pi \times 10^{-7} \times 8 \times 10^{-4}}{2 \times 3.14 \times 10^{-10}} = 1.6$$

iii) $M = iNA$

$= 8 \times 10^{-4} \times 1 \times \pi r^2$

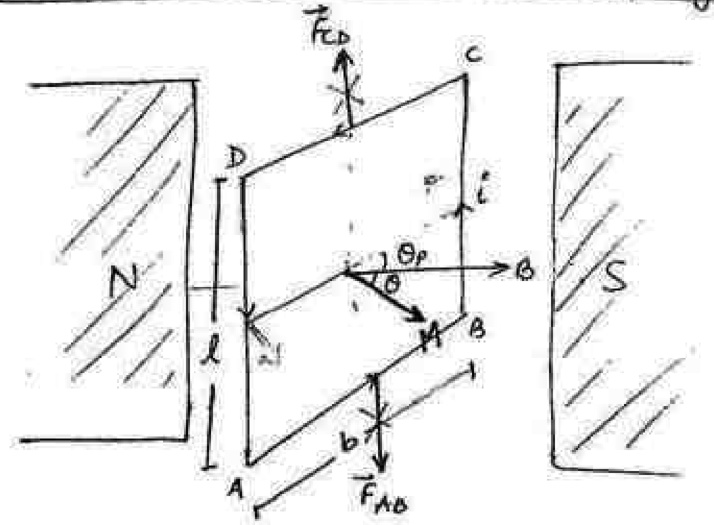
$= 8 \times 10^{-4} \times \pi \times (3.14 \times 10^{-10})^2$

$= 8 \times 10^{-4} \pi \times 10 \times 10^{-20}$

$= 8\pi \times 10^{-23}$

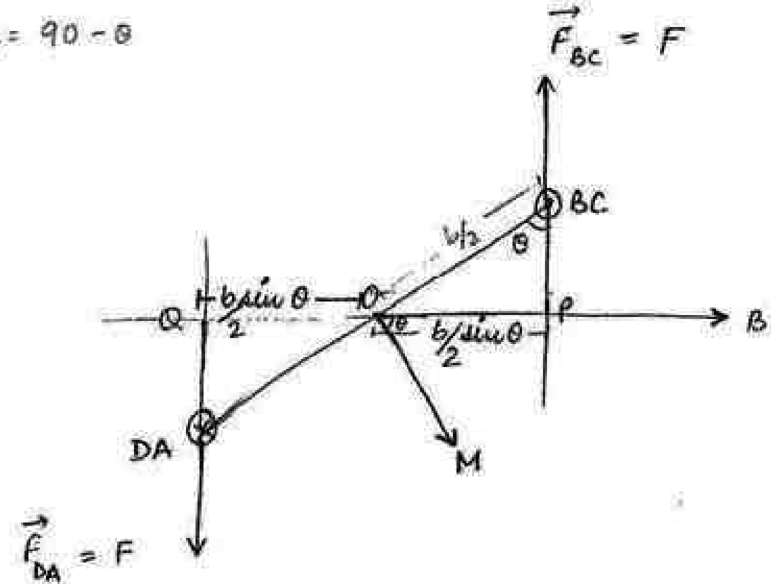
BOARD ★★★

Torque on current carrying loop / coil :



Side view

$\theta_p = 90 - \theta$



Top view

* magnetic moment tries to be in the dir^n of field

$\therefore \boxed{\tau = MB\sin\theta}$

» In above diagram, magnetic forces working on sides AB and CD are producing no torque on the coil cz their line of action of forces conciding

» The forces working on sides BC and DA are producing a couple and hence exerting a torque on the coil.

F × (⊥ distance b/w line of action of force)

$$\tau_{coil} = [\tau_{BC} + \tau_{DA}] \times N$$

$$= [F_{BC} \times OP + F_{DA} \times OQ] \times N \quad \text{coupling force}$$

$$= \left[(Bil \sin 90)\frac{b}{2}\sin\theta + (Bil \sin 90)\frac{b}{2}\sin\theta\right]N$$

$$= [Bi(lb)\sin\theta]\,N$$

$$= NBiA\sin\theta \qquad (\because A = lb)$$

$$\boxed{\tau = BiNA\sin\theta}$$

$$\boxed{\tau = MB\sin\theta} \qquad (\because M = iNA)$$

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

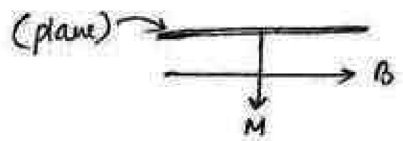
Imp points:

» If plane is ⊥, then $\vec{M} \parallel \vec{B}$ i.e. $\theta = 0$

$$\boxed{\tau = 0}$$

» If plane is ∥, then $\vec{M} \perp \vec{B}$ i.e. $\theta = 90$

$$\tau = MB = \text{max}$$



» If a current carrying coil is suspended in external magnetic field, then it experiences a torque such that its plane tries to become ⊥ and magnetic moment tries to become ∥ to the field

» $F_{net} = 0$

» work done in rotating coil, $\boxed{W = MB(\cos\theta_1 - \cos\theta_2)}$

If coil is rotated through an angle θ $= MB(\cos 0 - \cos\theta)$

$= MB\,2\sin^2(\theta/2)$ $[\because 1 - \cos\theta = 2\sin^2(\theta/2)]$ [illegible]

Q) A square coil of side 10 cm, no of turns = 10. It is carrying a current 2A, then find torque on the coil if it is placed in a magnetic field of ~~point~~ 0.1 T such that

a) plane is ⊥ to the magnetic field

b) coil is ∥ to the the magnetic field

c) coil is making an angle 60° from magnetic field

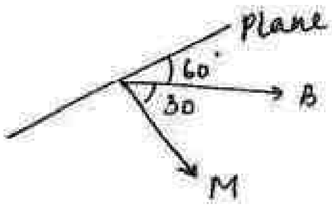
a) plane ∥ (B∥M), $\theta = 0$ $\therefore$ $\tau = 0$

~~$\theta = 90$~~

b) plane ⊥ (B⊥M), $\theta = 90$ $\therefore$ $\tau = BiNA \sin 90°$

$$= 0.1 \times 2 \times 100 \times (10 \times 10^{-2})^2 = 0.2 \text{ N-m}$$

c)

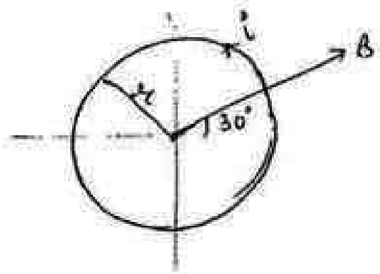


$\theta = 30°$

$\therefore \tau = BiNA \sin 30°$

$= 0.1$ Nm

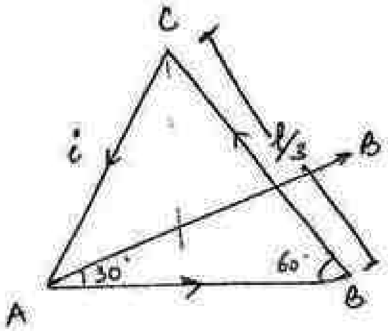
Q) Find the torque on the given current carrying ~~square~~ ~~loop~~ circular loop.



$\tau = BiNA \sin 90°$

$= Bi \times 1 \times \pi r^2$ ($\because B \perp M$)

Q) A current carrying wire of length l is bent to form an equilateral Δ ABC, Now a magnetic field B is applied in its plane making an angle 30° from side AB. Find torque on the loop if it is carrying current i.



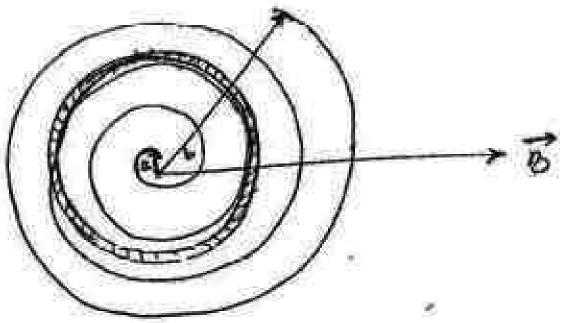
$\vec{F} = BiNA \sin 90^\circ \; (\because B \perp M)$

$\therefore \quad \tau = Bi \dfrac{1 \times l^2}{12\sqrt{3}}$

$h = \dfrac{l}{3} \sin 60^\circ = \dfrac{l}{2\sqrt{3}}$

$\therefore \; A = \dfrac{l \times l}{2 \times 3 \times 2\sqrt{3}} = \dfrac{l^2}{12\sqrt{3}}$

Q) In the given diagram, find torque on the given spiral coil.



$b - a \longrightarrow N$

$1 \longrightarrow \dfrac{N}{b-a}$

$\therefore \; dr \longrightarrow \dfrac{N}{b-a} \times dr = dN$

$$dM = i\,dN\,A$$

$$\therefore \; M = \int_a^b i\pi r^2 \left(\frac{N}{b-a}\right) dr$$

$$= \frac{i\pi N}{b-a} \left(\frac{r^3}{3}\right)_a^b$$

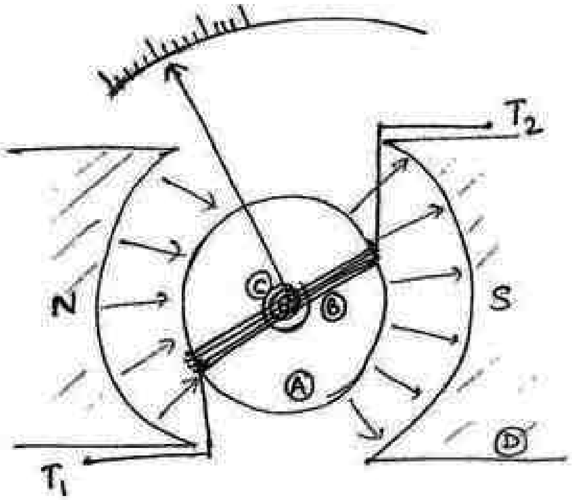
$$= \frac{\pi i N (b^3 - a^3)}{3(b-a)}$$

$\therefore \; \tau = MB \sin\theta$

Moving coil galvanometer:

It is used to detect the current that is whether the current is flowing or not or the dir^n of current is changed or not

construction:



Ⓐ iron core
Ⓑ coil
Ⓒ spiral spring
Ⓓ cylindrical cut pole magnet

- Iron core is used to ↑ the strength of magnetic field
- concave cut cylindrical pole magnet is used to produce radial magnetic field. so that plane of the coil always remains parallel to the field.

  ie $\boxed{\theta = 90^\circ}$ (always) 
- spiral spring is used to bring the coil to its initial pos^n when current is switched off.

working principle:

Its working is based on the fact that when a current carrying coil is placed in external magnetic field, then it experinces a magnetic torque working :

In equilibrium, magnetic torque is balanced by restoring torque in the spring then $\tau_{string} = \tau_M$

$\because F = Ka$

$\therefore \tau = K\phi$

$$K\phi = BiNA \sin 90^\circ \quad \left[\begin{array}{l} K = \text{Torsional constant} \\ \phi = \text{angle of twist} \end{array}\right.$$

$$\boxed{\phi = \left(\frac{BNA}{K}\right) i} \qquad \phi \; BNA \; K \; i$$

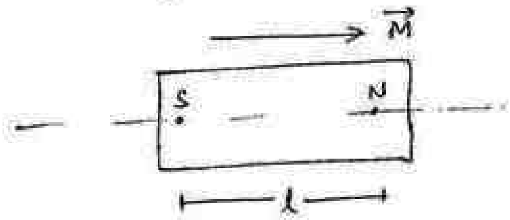
$$\boxed{\phi \propto i} \quad [B, N, A, K \text{ constant for a galvanometer}]$$

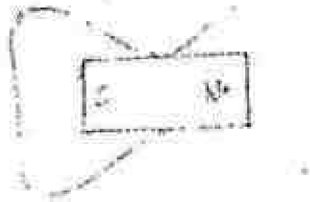
current sensitivity(i_s) of galvanometer :

It is defined as deflection produced by unit current in galvanometer

$$i_s = \frac{\phi}{i} \quad \therefore \boxed{i_s = \frac{BNA}{K}} \quad \left(\because \phi = \frac{BNA}{K} i\right)$$

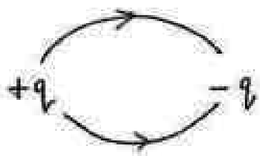
Bar Magnet

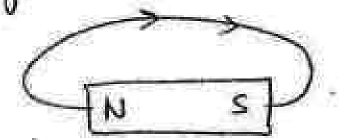




i) Poles: These are locations in the bar magnet where its attraction power is max.

ii) Pole strength (m): It represents attraction power of a pole of a magnet



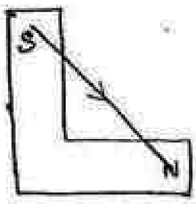


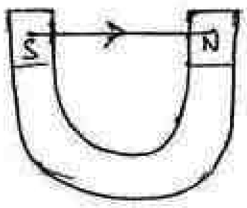
$S = -m$

$N = +m$

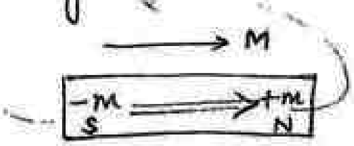
$\therefore \boxed{m \propto A}$

iii) Effective length of bar magnet: It represents displacement b/w the poles of the magnet.





iv) magnetic moment:

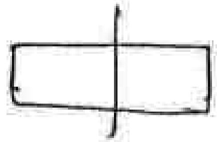


$\therefore \boxed{\vec{M} = ml\,\hat{n}}$ $\quad \hat{n} =$ S to N

Q) A bar magnet of magnetic moment M is cut into two equal parts parallel to its length. Find new magnetic moment

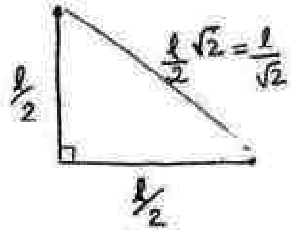
$\because M \propto A \quad \therefore m \propto A$

$\therefore M' = \frac{m}{2} \times l = \frac{M}{2}$



$M' = \frac{m}{2} \times l = \frac{M}{2}$ $\qquad\qquad$ $M' = m \times \frac{l}{2} = \frac{M}{2}$

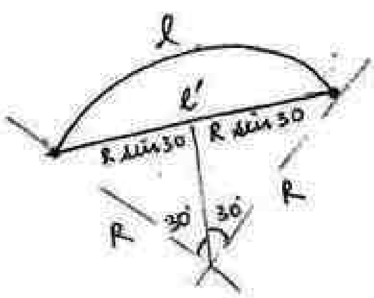
Q) A wire of magnetic moment M is bent from midpoint to form a right angle find its new magnetic moment



$M' = m\frac{l}{\sqrt{2}} = \frac{M}{\sqrt{2}}$

Q) A wire of magnetic moment M is bent to form a circular arc which substend an angle 60° at the centre then find its new magnetic moment

l
$(M = ml)$



$\frac{\pi}{3} = \frac{l}{R}$ $\left(\theta = \frac{l}{R}\right)$ $\qquad\qquad$ $2R \sin 30° = l'$

$R = l'$

$\therefore R = \frac{3l}{\pi}$. $\qquad$ $l' = \frac{3l}{\pi}$ $\qquad$ $M' = m\frac{3l}{\pi}$

$60° = \frac{60 \times \pi}{180} \cdot \frac{\pi}{3}$ $\qquad\qquad$ $= \frac{3M}{\pi}$

» Coulomb's law of magnetism:

$m_1 \xrightarrow{\quad r \quad} m_2$ $\therefore$ $\boxed{F = \frac{K m_1 m_2}{r^2}}$ $K = \frac{\mu_0}{4\pi} = 10^{-7}$

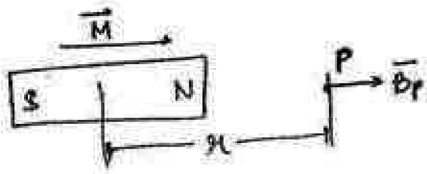
» Gauss law in magnetism:

$$\oint \vec{B} \cdot \vec{ds} = \mu_0 m_{en} = \mu_0 (m - m) = 0$$ [$\because$ poles always exist in pair

$$\boxed{\phi_M = 0}$$

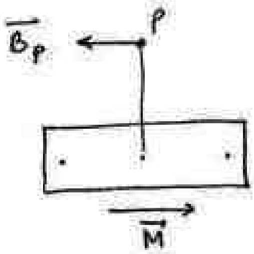
» Magnetic field of a bar magnet:

a) Axial pos^n (end-on)



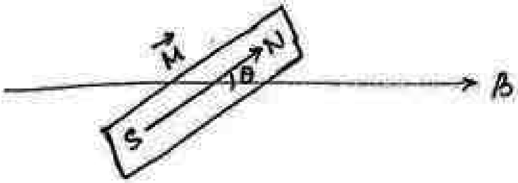
$$\boxed{B_P = \frac{2KM}{r^3}}$$

b) Terminal pos^n (Broad on)



$$\boxed{B_P = \frac{KM}{r^3}}$$

» Magnetic dipole / bar magnet in external magnetic field



a) $F_{net} = MB - MB = 0$

b) $\boxed{\vec{\tau} = \vec{M} \times \vec{B}} = MB \sin\theta$

c) $\boxed{q = MB(\cos\theta_1 - \cos\theta_2)}$

If θ_1 is not mentioned then $\theta_1 = 0°$ is considered

d) $\boxed{U = \vec{M} \cdot \vec{B}}$

e) ★★★ $\boxed{T = 2\pi\sqrt{\frac{I}{MB}}}$ $I = \frac{mL^2}{12}$ mass

$$T = 2\pi\sqrt{\frac{I}{MB}}$$

above concept of SHM is used in vibration magnetometer

Q) Time period for a bar magnet in vibration magnetometer is T now it is cut into 2 equal part ∥ to its length, then find time period for one of the part.

$M = ml$

$I = \frac{ml^2}{12}$

$T = 2\pi\sqrt{\frac{I}{MB}}$

$M = \frac{ml}{2} = \frac{M}{2}$

$I = \frac{m}{2}\frac{l^2}{12} = \frac{I}{2}$

$\therefore T' = 2\pi\sqrt{\frac{I/2}{M/2\ B}} = T$

$\therefore \boxed{T' = T}$

Short trick:

$T \propto \sqrt{\frac{ml^2}{MB}}$

$T \propto \sqrt{\frac{1/2 \times 1^2}{1/2 \times 1}} = 1 \Rightarrow T$

case b) if magnet is cut ~~h~~ ⊥ to its length

$T \propto \sqrt{\frac{\frac{1}{2} \times (\frac{1}{2})^2}{1/2 \times 1}} = \frac{T}{2}$

Q) A bar magnet oscillates with the frequency 30 oscillations / min in vibration magnetometer. If magnetic moment is ↑ed by 3 times then what will be the new time taken

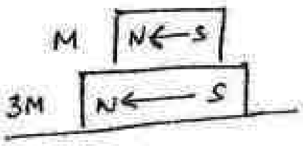
$f_1 = 30$ osc/min

$T_1 = \frac{1}{30} \times 60 = 2$ sec $\qquad M_2 = M + 3M = 4M$

$T \propto \frac{1}{\sqrt{M}} \qquad \frac{T_2}{T_1} = \sqrt{\frac{M}{4M}} = \frac{2}{2} = 1$ sec

Q) Two bar magnet of 3M and M are arranged in vibration magnetometer first in sum position and then in difference position then find the ratio of Time period in two cases

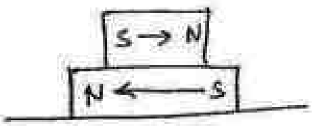
sum posⁿ :



$M_s = 3M + M = 4M$

$I_s = I_1 + I_2$

difference posⁿ :



$M_d = 3M - M = 2M$

$I_d = I_1 + I_2 = I_s$

$T \propto \frac{1}{\sqrt{M}} = \frac{T_s}{T_d} = \sqrt{\frac{M_d}{M_s}} = \sqrt{\frac{2}{4}} = \frac{1}{\sqrt{2}}$

magnetic field & ... differentiated only on the basis of units

Magnetic Materials:

i) magnetic field / magnetic flux density / magnetic induction: $(\vec{B})$

It is defined as force experienced by the conductor of unit length carrying unit current when placed ⊥ to the magnetic field

$$B = \frac{F}{il\sin\theta}$$

Unit : $\frac{N}{Am}$

dimension : $M^1L^0T^{-2}A^{-1}$

ii) Magnetic permeability (μ):

It represents the degree of extent to which a substance permits magnetic field lines to pass through it.

μ : magnetic permeability of medium

μ_0 : magnetic permeability of vaccum / free space

$= 4\pi \times 10^{-7}$ H/m

μ_r : magnetic permeability of substance w.r.t. vaccum

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

iii) Magnetic intensity / Magnetising intensity / magnetising field / Magnetic field / magnetising force / magnetic force (H)

In toroid / solenoid, magnetic field is given by

$B_0 = \mu_0(ni) = \mu_0 H$ $\quad\therefore H = ni$ $\quad$ Unit - A/m (SI)

- N ; cgs - oersted

iv) Intensity of Magnetisation (I)

It represent the degree of extent to which a substance is magnetised in ⊕nce of external magnetic field.

It is defined as <u>magnetic moment acquired by the substance per unit vol^m</u>

$$I = \frac{M}{V} = \frac{ml}{Al} \quad (\because V = Al) \qquad \therefore \boxed{I = \frac{m}{A}}$$

for a given magnet, I = constant

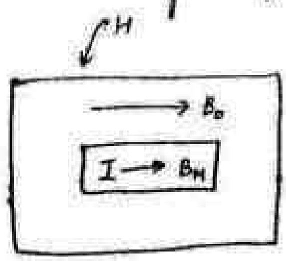
$$\boxed{m \propto A} \qquad \text{unit} = \frac{Am^2}{m^3} = A/m$$

v) Magnetic Susceptibility (χ) → chi

It represents how easily a substance can be magnetised and given by the ratio of I and H

$$\boxed{\chi = \frac{I}{H}}$$

Relationship b/w $B, \mu, H,$ & χ



$$B = B_0 + B_M$$

$$= \mu_0 H + \mu_0 I$$

$$\therefore B = \mu_0 (H + I)$$

$$\mu H = \mu_0 H \left(1 + \frac{I}{H}\right)$$

$$\mu = \mu_0 (1 + \chi)$$

$$\frac{\mu}{\mu_0} = 1 + \chi$$

$$\mu_R = 1 + \chi$$

Types of magnetic material :

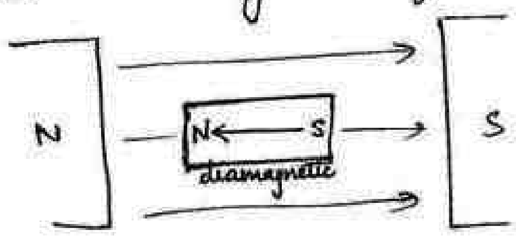
i) Diamagnetic substance

> Atoms / molecules / ions of these substances do not have their own magnetic dipole moment generally due to paired e^-

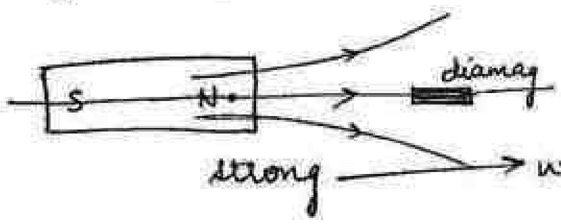
eg: सब भाई कू जन्नतमे हीरा सोना चाँदी पानी मिलने का क्या

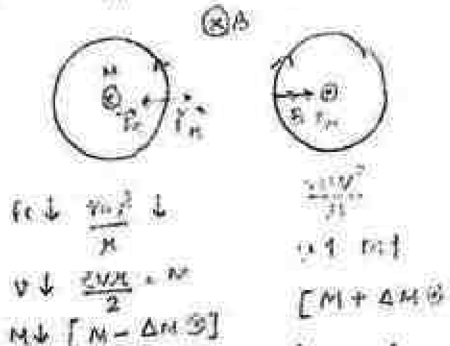
Sb Bi Cu Zn C Au Ag H_2O Inert gases

> These substances are magnetised in the opposite dir^n to applied magnetic field .

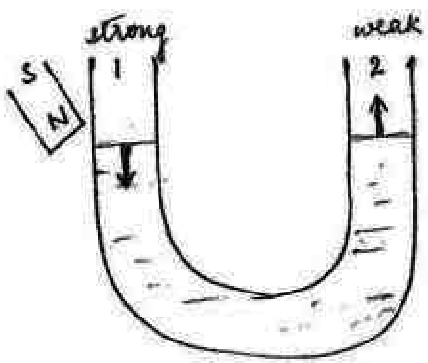


. These substances move from strong magnetic field to weak magnetic field .

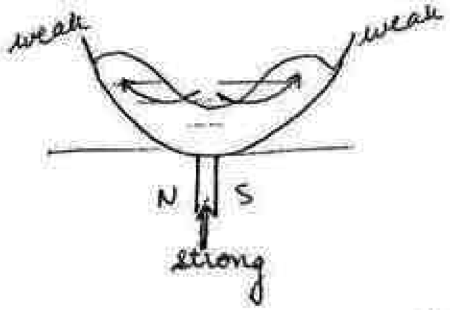




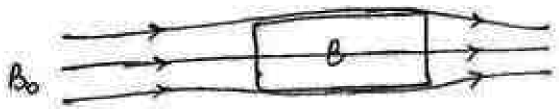
> In U Tube, these substances move as shown in diagram



> Behaviour in watch glass



* These substances slightly repel magnetic field lines



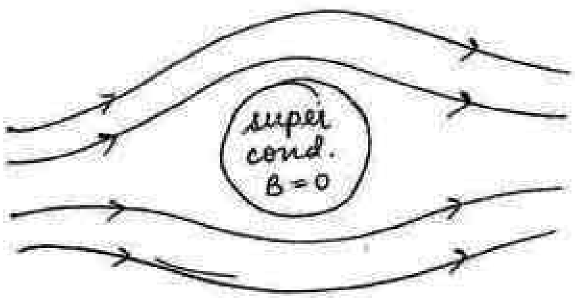
a) $B < B_0$

b) $\mu H < \mu_0 H$ $\quad \boxed{\mu < \mu_0}$

c) $\dfrac{\mu}{\mu_0} < 1$ $\quad \boxed{\mu_r < 1}$

d) $\mu_r = 1 + \chi$ $\quad \therefore \chi = \mu_r - 1$ $\quad$ [small and −ve]

* superconductors exibit perfect diamagnetism :



Meissener effect

$\boxed{B = 0}$

$\mu_0 (H + I) = 0$

$\boxed{I = -H}$

$\dfrac{I}{H} = -1$ $\quad \therefore \boxed{\chi = -1}$

$\mu_r = 1 + \chi$ $\quad \therefore \boxed{\mu_r = 0}$

> magnetism of these substances is explained by orbital motion of the e^-

> Magnetism of these substances doesn't depends on the change in Temp.

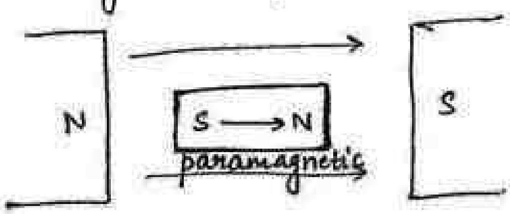
(ii) Paramagnetic substance

> Atoms / molecules / ions of these substances have their small magnetic moment

eg: हमार अलाहाबाद पटना का सर्कसमा टन मेनिकवा दिखावत है भैया

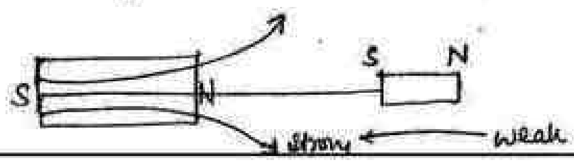
Al Pt Ca Cu Mn W Mg

> These substances are magnetised in the dirⁿ of external magnetic field



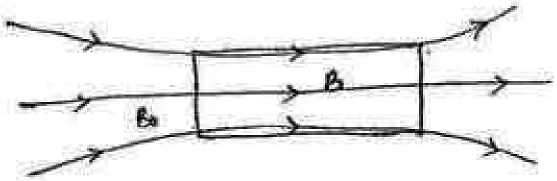
> Initially all atomic magnets are arranged randomly so there is no net magnetic moment for the substance, when external magnetic field is applied then these atomic magnet sligutly rotates in the dirⁿ of external field and due to their this alingment, the substance is magnetised in the dirⁿ of field

> These substances move from weak magnetic field to strong magnetic field.



> Behaviour of these substances is just opposite to diamagnetic substances.

> These substances slightly attract magnetic field lines



a) $B > B_0$

b) $\mu > \mu_0$

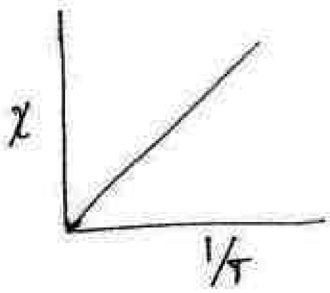
c) $\mu_r > 1$

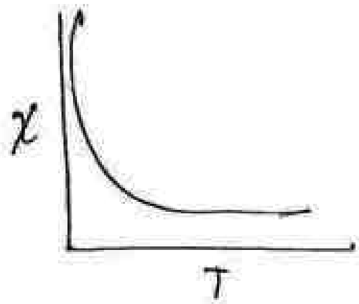
d) χ (+ve and small

> Magnetism of these substances depends on temp in accordance with curie's law

$$\chi \propto \frac{1}{T} \quad \text{(curie's law)}$$

$$\chi = \frac{C}{T} \quad \text{(C = curie's constant)}$$



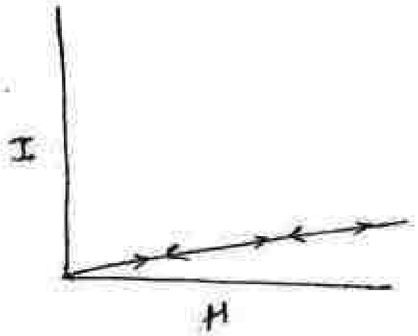


> when Temp is increased, then due to thermal disturbance, randomness of atomic magnet ↑es which results in ↓es in magnetism of the sub.

$T \uparrow \; M \downarrow \; \frac{M}{V} \downarrow \; I \downarrow \; \frac{I}{H} \downarrow \; \chi \downarrow$

Magnetism of these substances is explained by <u>spin motion</u> of the e^-.

> I-H curve



iii) Ferro-magnetic substance [1|1|1]

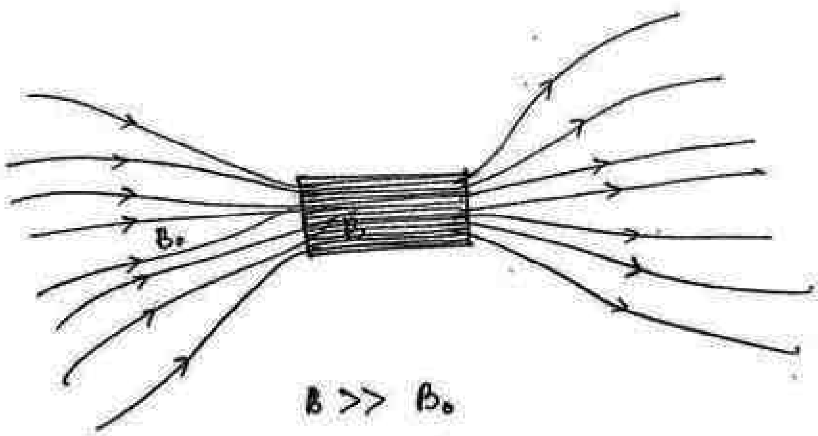
> Atoms /molecules / ions of these substances have their own strong magnetic moment.

$\mu_f \neq 0$ $(\mu_f >>> \mu_p)$ (atomic magnetic moment)

> These substances are strongly magnetised in the direction of external field.

> Behaviour of these substances is same as paramagnetic but with the stronger effect.

> These substances strongly attract magnetic field lines



$B >> B_0$

$\mu >> \mu_0$

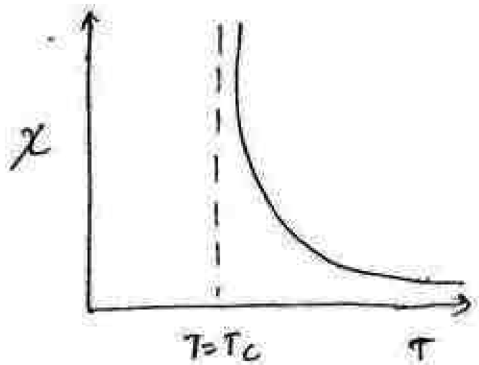
$\mu_r >> 1$ $(\mu_r \approx 10^3)$

χ (+ve and large)

> Magnetism of these substances depends on temp in accordance with curie - weiss law

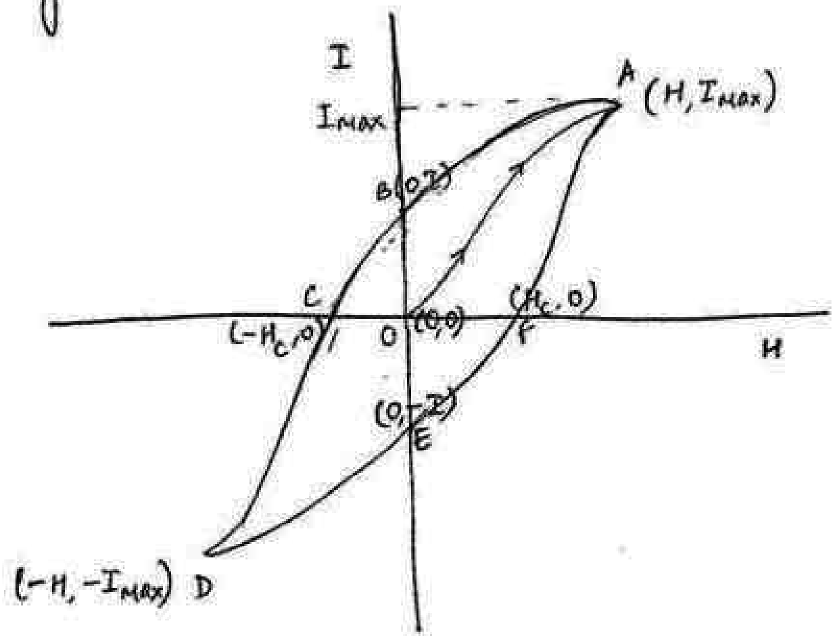
$$\chi \propto \frac{1}{T - T_c}$$ [curie weiss law $(T > T_c)$ only]

$$\chi = \frac{C}{T - T_c}$$ T_c = curie temp.



> T_c is the Temp above which ferromagnetic substances behaves like paramagnetic substances

> Hystersis curve :



Point A : It represents magnetic saturation ie max possible magnetisation of the substance.

OB : it represents residual magnetism i.e. magnetism retained by the substance even after the removal of magnetising field H. This property of substance is called retentivity

OC : It represents coercive field i.e. the magnetising field H applied in opposite dir^n to completely demagnetise the substance. This property of substance is called coercivity

* Coercivity is the measure of magnetic hardness.

area under ~~da~~ hysteresis curve:

$$A = \oint y\,dx$$

$$= \oint B\,dH \quad \circ \quad \frac{N}{A\cdot m} \times \frac{A}{m} \Rightarrow \frac{N\text{-}m}{m^3}$$

$$\boxed{A = \frac{\text{Energy loss}}{\text{volume}}}$$

Energy loss, E

$E = AV$ (one cycle)

$E_{1sec} = fAV$ (1 sec)

$E_t = FAVt$

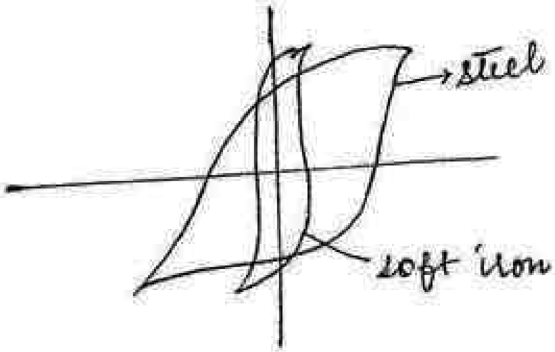
Selection of material

a) Permanent magnet : high coercivity, high retentivity

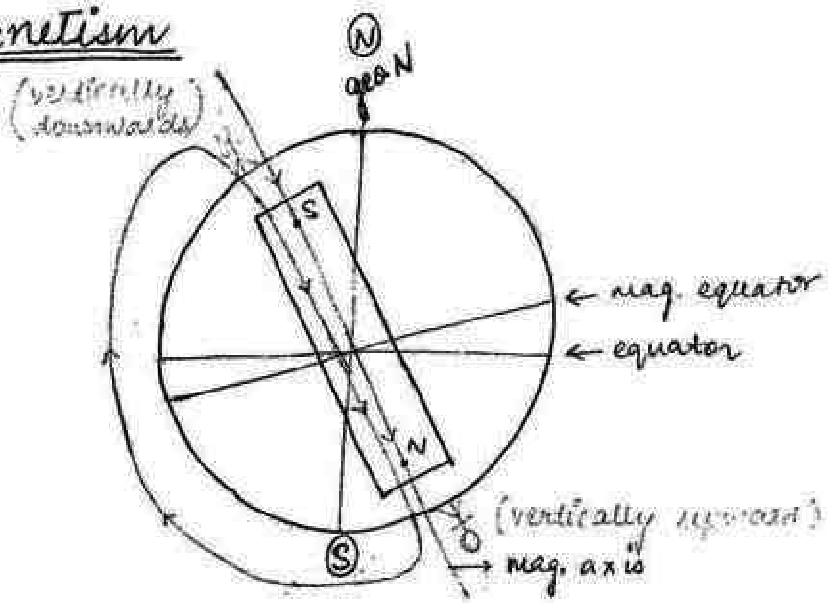
steel, AlNiCo, TiCONAl

b) Temporary ~~magnet~~ / Electromagnet :
low coercivity
low retentivity
SI (soft iron)

c) Transformer core
lesser area under hysteresis curve
SI (soft iron)



Geomagnetism



Geographic ~~medi~~ meridian

~~Geo~~ It is the plane passing through geometric axis of the earth

magnetic meridian

It is a plane passing through magnetic axis of the earth

Angle of declination (θ)

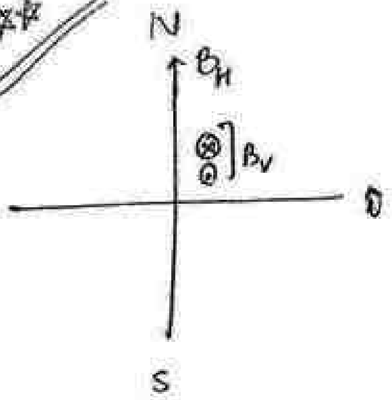
It is the angle b/w geographic meridian and magnetic meridian

Angle of dip (δ):

It is the angle b/w Horizontal and the dir^n of magnetic field of the earth.

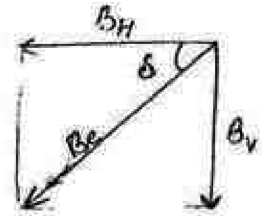
components of magnetic field of the earth:

There are two components of magnetic field of the earth H or B_H, always from South to North (approx) and the other component is V or B_V which may change its dir^n vertically upwards or vertically downwards



$B_H \Rightarrow \hat{j}$ (always)

$B_V \Rightarrow \pm \hat{k}$



$$B_H = B_e \cos ;$$

$$B_V = B_e \sin \delta$$

$$\tan \delta = \frac{B_V}{B_H}$$

$$B_e = \sqrt{B_H^2 + B_V^2}$$

Important Points:

i) At Poles

Needle: vertically up or down

$\delta = 90^\circ$

$B_H = B_e \cos 90^\circ = 0$

$B_V = B_e \sin 90^\circ = 1$

ii) At equator

Needle: horizontal (S to N)

$\delta = 0$

$B_H = B_e$

$B_V = 0$

iii) Compass is used to find dirⁿ in which needle is free to rotate in horizontal plane about vertical axis due to the torque produced by horizontal component e

iv) If compass needle is taken to poles then it may orient itself in any dirⁿ due to ~~the~~ absence of B_H

Q) At certain place, angle of dip is 60° and magnetic field of the earth is 0.5 G. If magnetic field at the centre of circular loop is balanced by horizontal component of the earth then find current in the loop, if its radius is π cm.

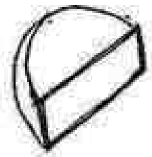
$$B_c = B_H$$

$$\frac{\mu_0 i}{2r} = B_e \cos\delta \qquad (\delta = 60)$$

$$\therefore\ i = \frac{0.5\times10^{-4}\times\frac{1}{2}\times 2\times\pi\times10^{-2}}{4\pi\times10^{-7}} = 1.25\ \text{Å}$$

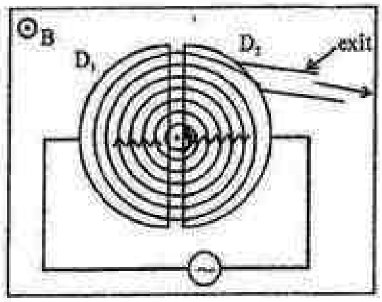
$\because\ 1\ T = 10^4\ G$

Cyclotron



It is used to accelerate charged particles/ions to a very high energy.

Construction :-



It consist of two Dee's which are hollow metal boxes arranged in same plane close to each other. An oscillator is connected to these Dee's and a magnetic field is applied perpendicular to the plane of the Dee's.

Working Principle :-

Its working is based on the fact that electric field supplies kinetic energy to the charge particle and magnetic field force the charge particle to follow the circular path.

Working :-

Initially a charge particle +q is released from rest which moves towards D_2 assuming D_1 and D_2 are having ⊕ve and ⊖ve polarity respectively. It enters in D_2 with some speed and moves under the action of only magnetic field because electric field inside meta boxes is zero. When charge particle completes semi-circular path at that instant polarities of Dee's are reversed. Now charge particle is forced to move towards Dee 1 due to electric force. Particle enters in Dee 1 and the above process repeats itself but with greater radius of circular path but the time taken remains same because time period is independent of radius or speed of the charge particle. After sometime particle is projected from exit pole with a very high KE.

Cyclotron frequency :-

It is the frequency of the oscillation which is equal to frequency of circular path of the charged particle.

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

Radius of the Dee's :-

It is decided by the required kinetic energy of the charged particle.

Let r is the max radius of the circular path then:

R = Radius of the Dee

$$\boxed{R = \frac{\sqrt{2mK}}{qB}} \qquad \because r = \frac{mv}{qB} = \frac{p}{qB} = \frac{\sqrt{2mK}}{qB}$$

$\boxed{A \propto K}$ $[A = \pi R^2]$

Limitation of Cyclotron :-

Cyclotron is used to accelerate heavy charge particles or ions. It is not used to accelerate higher charge particles like e^- because, due to very lesser mass e^- acquires very high speed in short interval. Which increase its mass and results in change in time period and frequency of its circular path.