Chapter - 4 Moving charges & Magnetism

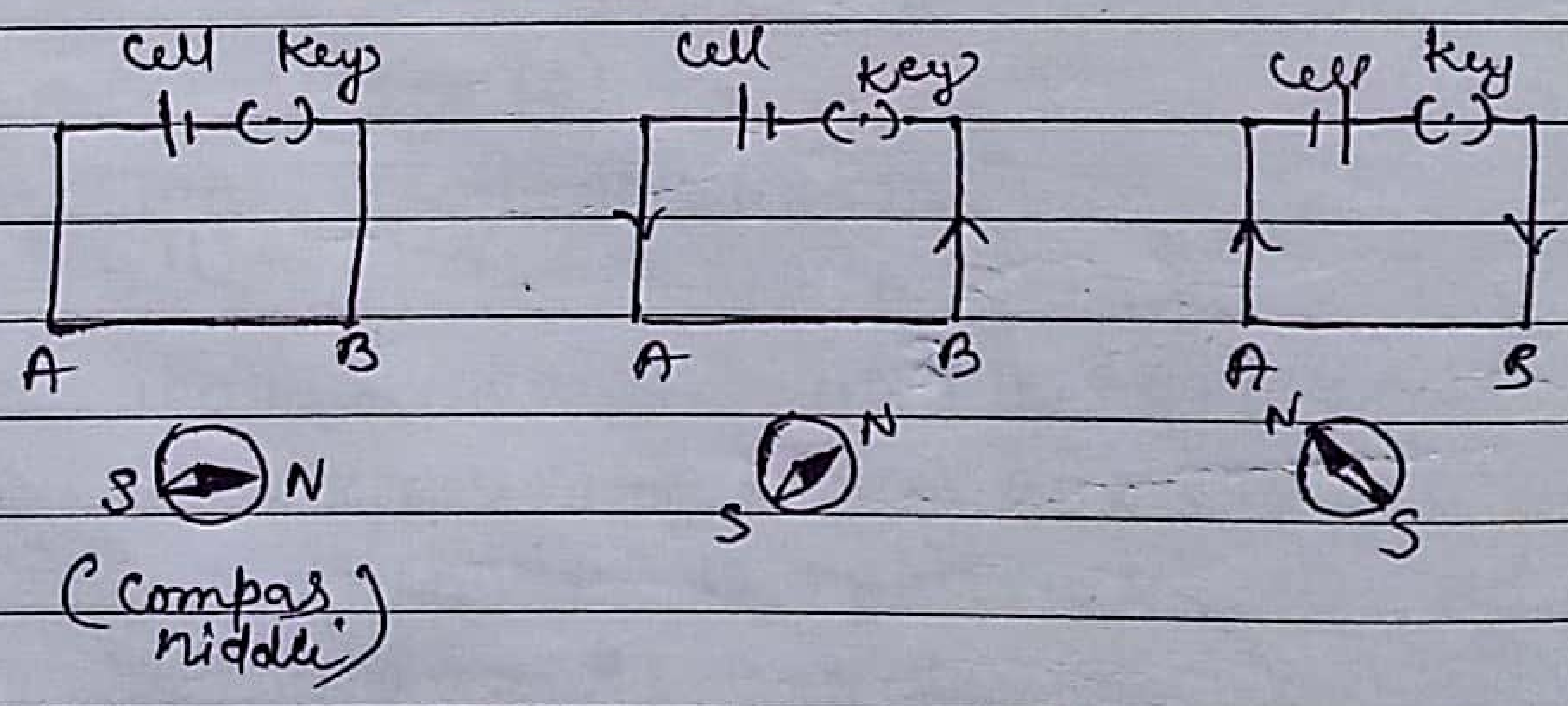
Magnetic field - The space in the surroundings of a magnet or current carrying conductor in which its magnetic influence can be experience is called magnetic field.

SI unit of magnetic field is - Tesla, or weber/m^2 or N/(amp-m).

In C.G.S system the unit of magnetic field is gauss.

1 Tesla = 10^4 Gauss

Oested's Experiment



Oested by his experiment concluded that a current carrying conductor deflected magnetic compass niddle placed near it.

Therefore -

"A moving charge or current flowing through a conductor produces a magnetic field".

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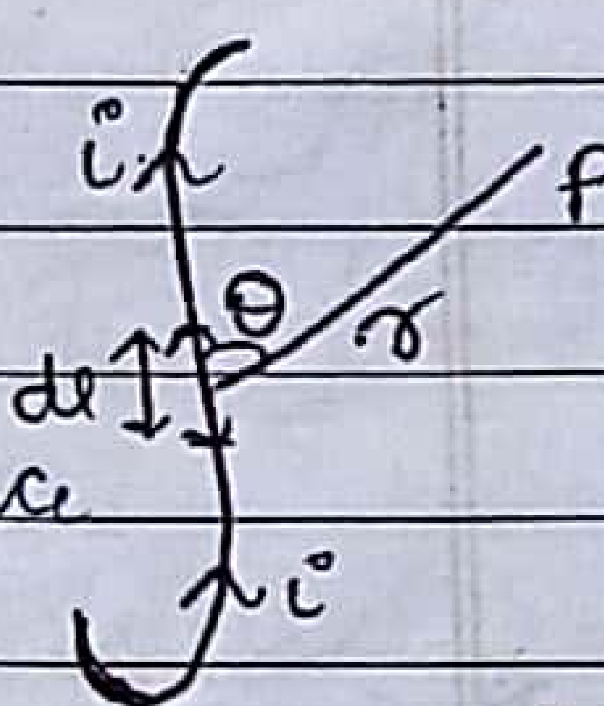
Magnetic field due to a current Element.

(Biot Savart's Law)

Let there is a current carrying conductor in which i current is flow dl is a small element of the conductor there is a point P at distance r from the element.



According Biot Savarts Law the magnetic field dB due to a current element at P depends upon following factor

1. It is directly proportional to current i

   i.e. $dB \propto i$

2. It is directly proportional to the length of element

   i.e. $dB \propto dl$.

3. It is directly proportional to the sign of angle b/w element and the line joining the element to the point

   i.e. $dB \propto \sin\theta$.

4. It is inversely proportional to the square of ~~eleme~~ distance b/w element & the point P.

   i.e. $dB \propto \frac{1}{r^2}$

Therefore —

$$dB \propto \frac{i\,dl \sin\theta}{r^2}$$

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

where μ_0 is a constant
it is called Permeability of space

$$\left[\mu_0 = 4\pi \times 10^{-7}\ \text{w/amp-m} \right]$$

★ The magnetic field at point P due to entire current carrying conductor

$$\left[B = \int dB = \int \frac{\mu_0}{4\pi} \frac{i\,dl \sin\theta}{r^2} \right]$$

★ The Vector representation of Biot Sarwarts Law is

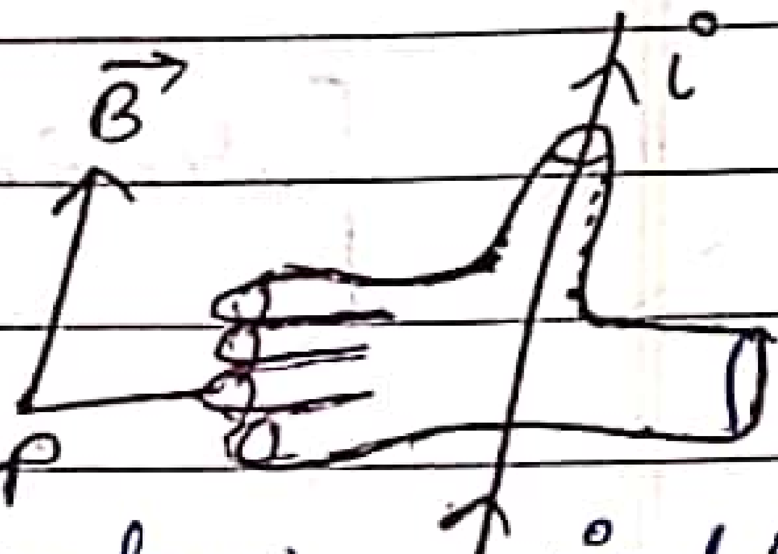
$$\left[\vec{dB} = \frac{\mu_0}{4\pi} \frac{i\,(\vec{dl} \times \vec{r})}{r^3} \right]$$

Direction of magnetic field

The direction of magnetic field due to a straight current carrying conductor can be find either of the following rules —

(1) <u>Right hand thumb rule</u> → If we hold the straight conductor in the grip of our right hand in such a way that the extended thumb points in the direction of the current then the direction of curve of figer fingers will give the direction of magnetic field.

(2) <u>Right hand palm rule</u> →



If we expand our right hand palm such that in the directionp of current and fingers ~~tow~~ incates indicates towards that point at which the direction of magnetic field has been form.

The direction of magnetic field will be $\perp$ in the direction of pussing of the palm at outward.

(3) <u>Maxwell screw Law</u> →

If the right handed screw will rotated along the wire so that it advances in the direction of current, the direction in which the thumb rotates gives the direction of magnetic field.

<u>Relation b/w ϵ_0 & μ_0</u>

$$\frac{1}{4\pi\epsilon_0} = 9\times10^9 \ N\text{-}m^2/C^2$$

$$\epsilon_0 = \frac{1}{4\pi\times9\times10^9}$$

$\mu_0 = 4\pi \times 10^{-7}\ Tm/amp.$

$$\mu_0 \epsilon_0 = \frac{1}{\cancel{4\pi} \times 9 \times 10^9} \times \cancel{4\pi} \times 10^{-7}$$

$$\mu_0 \epsilon_0 = \frac{1}{9 \times 10^{16}} = \frac{1}{(3 \times 10^8 m/sec)^2}$$

$$\left[\mu_0 \epsilon_0 = \frac{1}{C^2}\right]$$

where c is the velocity of light in Vacuum.

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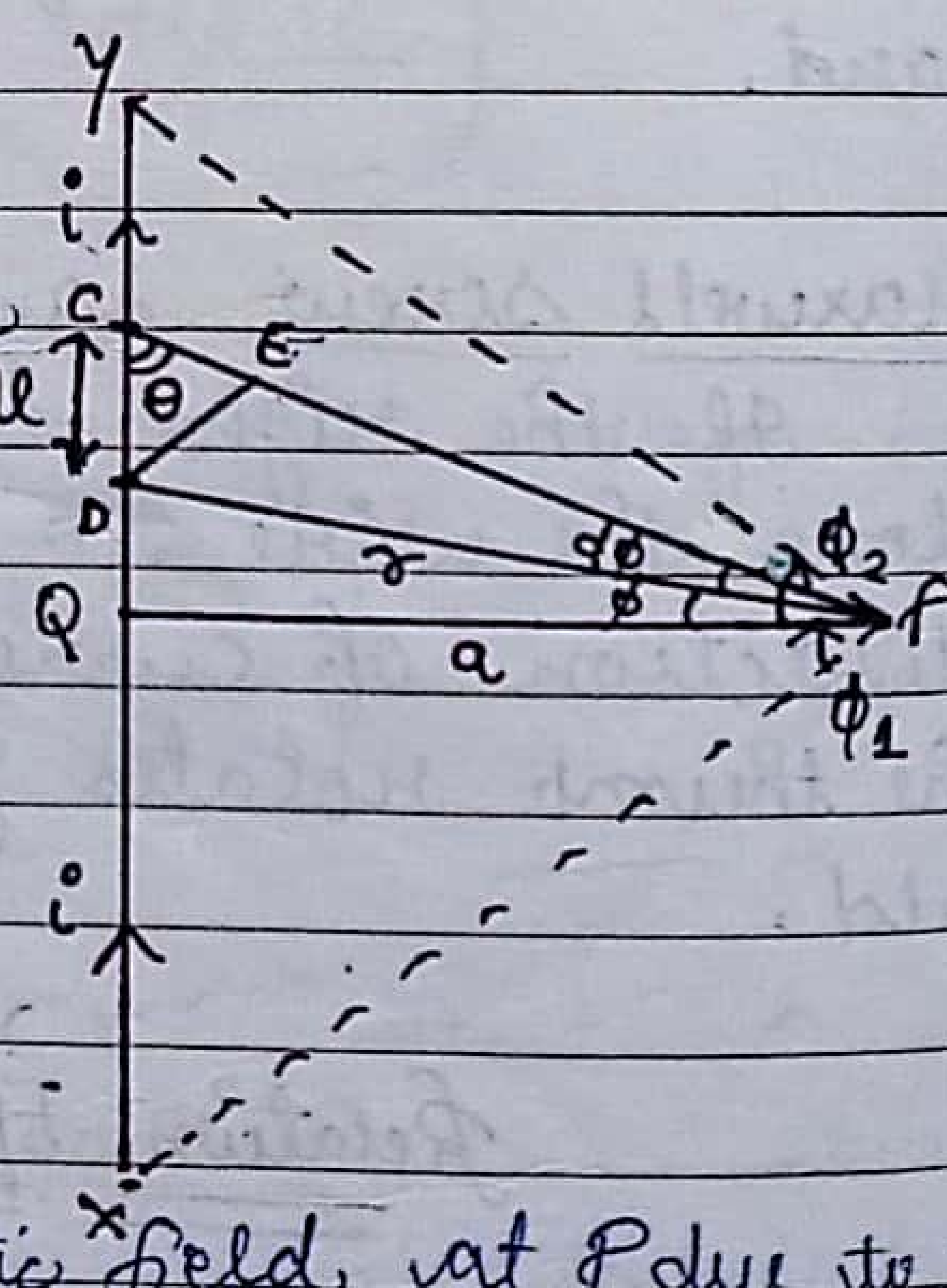
Magnetic field due to a long straight current carrying Conductor



Let us consider a straight current carrying conductor XY, in which i current is flowing there is a point P at distance a where we have to find magnetic field due to current carrying conductor.

Consider a small element dl the magnetic field at P due to this this element by Biot Savart's law –

$$dB = \frac{\mu_0}{4\pi} \frac{i\,dl \sin\theta}{r^2} \quad —①$$

In ΔCDE

$$\sin\theta = \frac{DE}{CD} = \frac{DE}{dl}$$

$$DE = dl\sin\theta \quad -②$$

$$\therefore d\phi = \frac{DE}{r}$$

$$DE = r\,d\phi \quad -③$$

from eq ② & ③

$$r\,d\phi = dl\sin\phi$$

from eq ①

$$dB = \frac{\mu_0}{4\pi} \times \frac{i \times \cancel{r}\,d\phi}{r^{\cancel{2}}}$$

$$dB = \frac{\mu_0}{4\pi} \times \frac{i\,d\phi}{r} \quad -④$$

In ΔPQD

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

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

from eqn ④

$$dB = \frac{\mu_0}{4\pi} \times \frac{i \times d\phi}{a/\cos\phi}$$

$$dB = \frac{\mu_0}{4\pi}\,\frac{i\cos\phi\,d\phi}{a}$$

Therefore the magnetic field at P due to whole current carrying conductor.

$$B = \int_{-\phi_1}^{+\phi_2} dB = \int_{-\phi_1}^{+\phi_2} \frac{\mu_0}{4\pi}\,\frac{i\cos\phi\,d\phi}{a}$$

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

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

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

If the current carrying conductor is (∞ long) Infinitely long then —

$$\phi_1 = \phi_2 = 90^\circ$$

Therefore magnetic field due to this current carrying conductor at P —

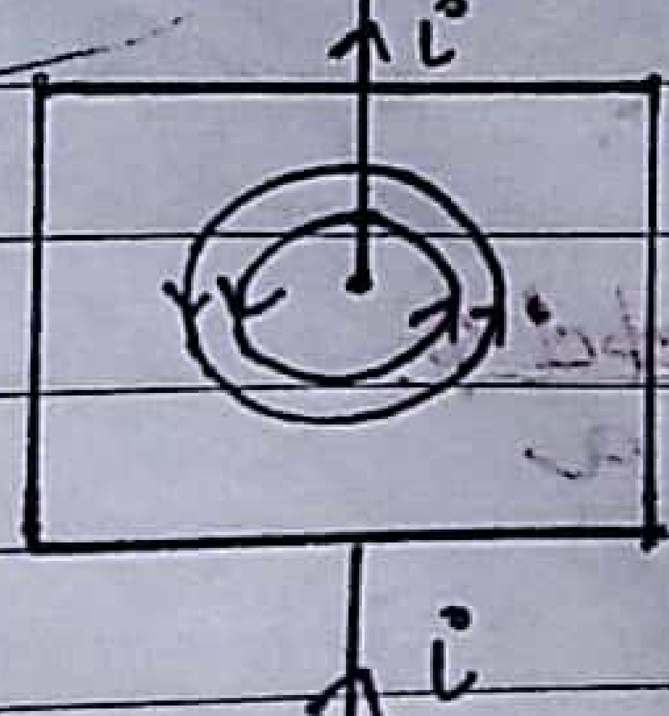
$$\phi_1 = \phi_2 = 90^\circ$$

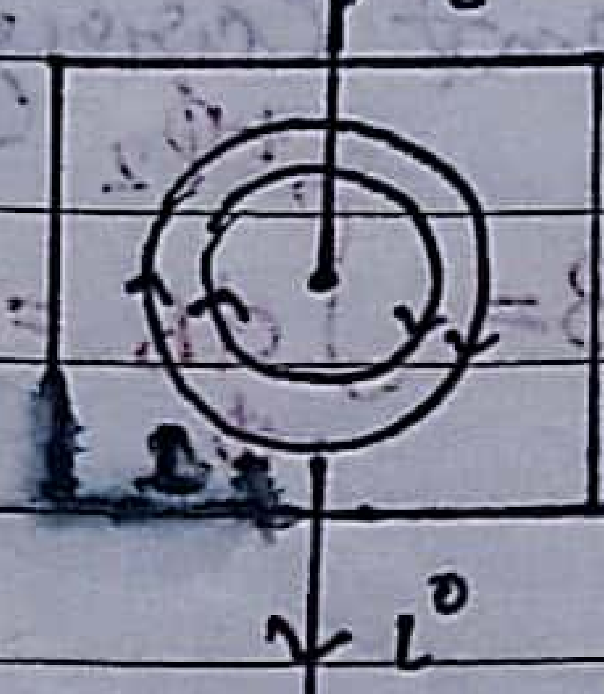
$$B = \frac{\mu_0}{4\pi}\frac{i}{a}\left[\sin 90^\circ + \sin 90^\circ\right]$$

$$B = \frac{\mu_0}{\cancel{4}_2\pi}\frac{i}{a}\times\cancel{2}$$

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

Direction of Magnetic field





The magnetic force line of a straight current carrying conductor are cocentric circle with the wire at the centre and in a plane $\perp$ to the wire.

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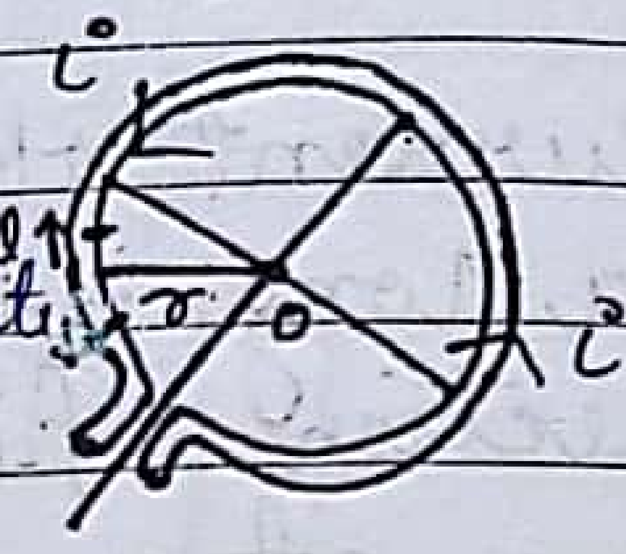
Magnetic field at the centre of Current Carrying Loop.

Let us consider a circular loop of radius r carrying current i we wish to calculate its magnetic field at the centre O. The entire loop can be divided into a large no. of ~~cu~~ small current element. Let us consider an element dl



According to Biot savart law the magnetic field at O due to this element dl

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

$$\because \sin 90^\circ = 1$$

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

The magnetic field due to whole circular current loop at the centre O —

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

$$= \frac{\mu_0}{4\pi} \times \frac{i}{r^2} \int dl \qquad \because \int dl = 2\pi r$$

$$= \frac{\mu_0}{4\pi} \frac{i}{r^2} \times 2\pi r$$

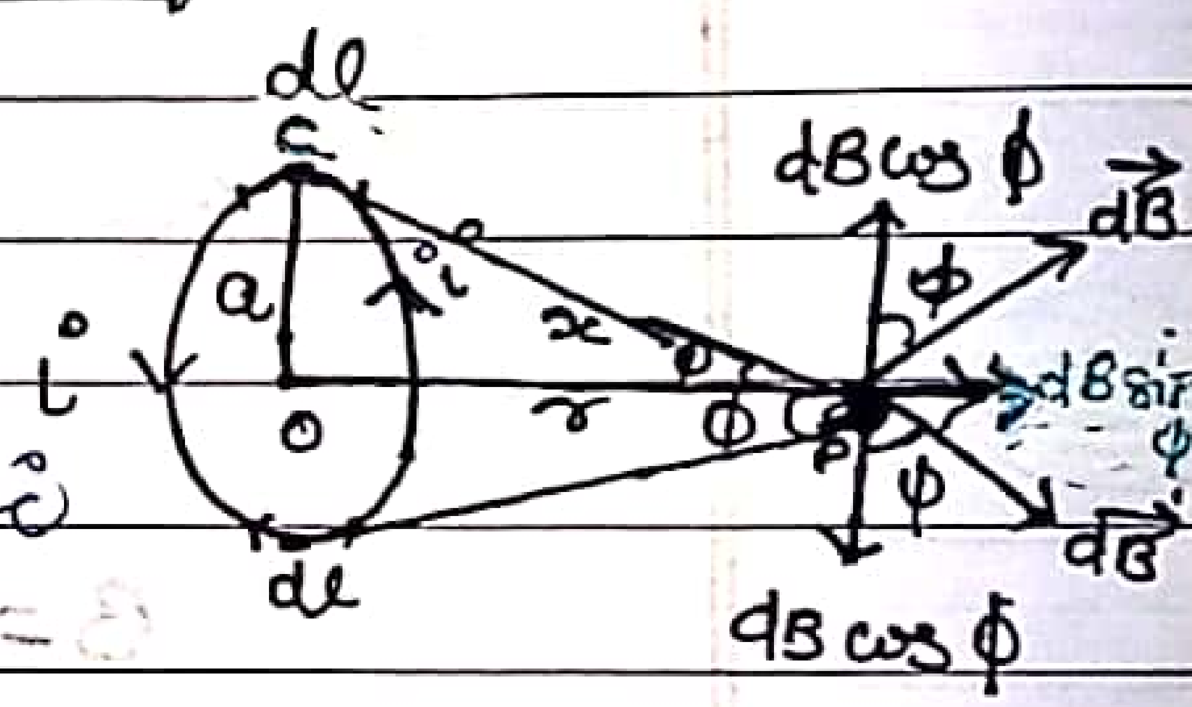
$$\boxed{B = \frac{\mu_0 i}{2r}}$$

If there are N turns then

$$\left[B = \frac{\mu_0 N i}{2r}\right]$$

If the current is flowing anticlockwise in the loop then the direction of magnetic field will be $\perp$ outward and if current is flowing clockwise then the direction of magnetic field will be $\perp$ inward.

Magnetic field along the axis of a current carrying loop



Let us consider a circular loop of wire of radius a & carrying current i we have to find magnetic field at an axial point P at distance r from the centre O.

Consider a current element dl at the top of the loop and also at the bottom of the loop the magnetic field at P due to the current element dl according to Bio Savarts Law–

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

$$dB = \frac{\mu_0}{4\pi} \frac{i\,dl}{x^2}$$

Let $\angle$ b/w OP & CP is ϕ then $\vec{dB}$ can be resolve in two component

① $dB \sin\phi$ in direction of axis

② $dB \cos\phi$ $\perp$ to the axis.

The Component $dB \cos\phi$ neutralise each other therefore, total magnetic field will be due to Component $dB \sin\phi$

Therefore the magnetic field at P.

$$B = \int dB \sin\phi$$

$$B = \int \frac{\mu_0}{4\pi} \frac{i\,dl}{x^2} \sin\phi$$

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

$$\sin\phi = \frac{a}{x} = \frac{a}{(a^2+r^2)^{1/2}}$$

$$B = \int \frac{\mu_0}{4\pi} i \times \frac{a}{(a^2+r^2)^{1/2}} \times \frac{1}{(a^2+r^2)} dl$$

$$B = \frac{\mu_0}{4\pi} \frac{ia}{(a^2+r^2)^{3/2}} \int dl \quad \because \int dl = 2\pi a$$

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

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

at Centre

$r = 0$

$$B = \frac{\mu_0 i \cancel{a^2}}{2\, \cancel{a^3}}$$

$$\boxed{B = \frac{\mu_0 i}{2a}}$$

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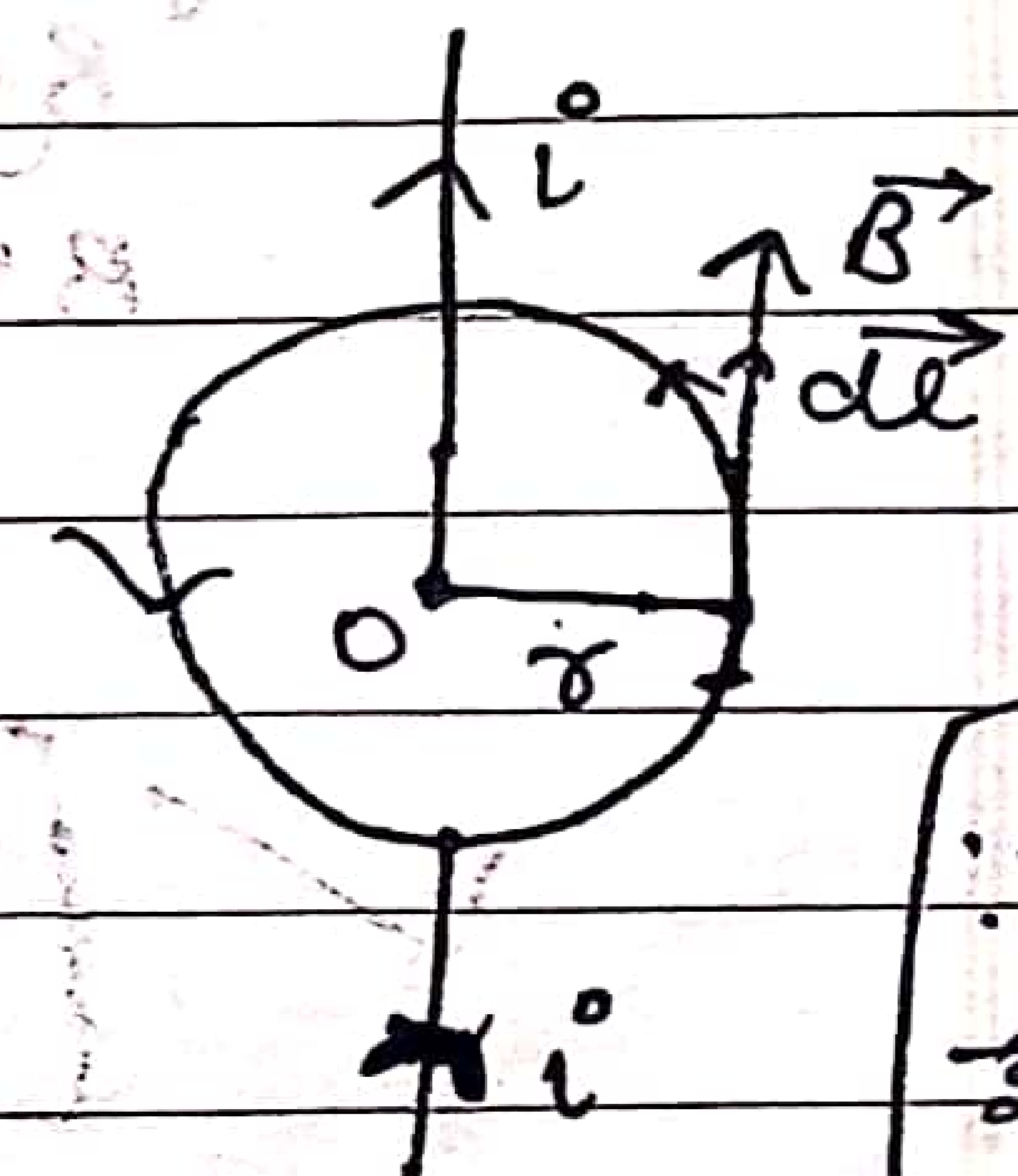
Ampere's Circuital law -

According to this law the line integral of magnetic field $\vec{B}$ around any close path in vacuum is μ_0 times the net current i enclosed by the curve.

$$\left[\oint \vec{B}\cdot\vec{dl} = \mu_0 i\right]$$



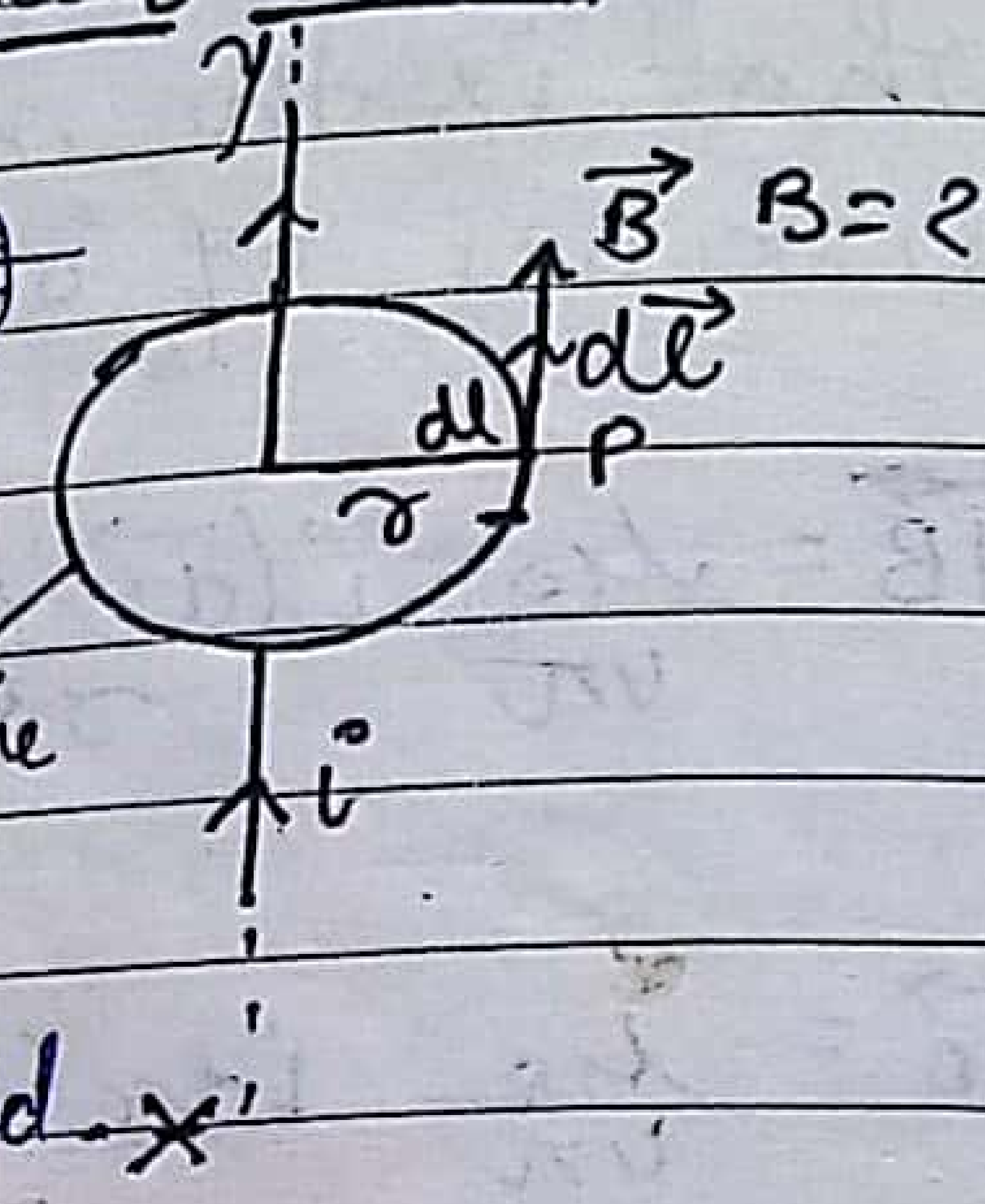
Proof -

$$\oint \vec{B}\cdot\vec{ds}$$
$$= \oint B\,dl\cos 0^\circ$$
$$= \oint B\,dl$$
$$= B\oint dl = \frac{\mu_0}{\cancel{2\pi}}\frac{i}{\cancel{r}} \times \cancel{2\pi r}$$

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

So, $\left[\oint \vec{B}\cdot\vec{dl} = \mu_0 i\right]$ Ampere's Circuital Law

Magnetic field of a Straight Current Carrying Conductor wire



Let there is a straight current carrying wire in which i current is flowing, there is a point P at distance r at which we have to find magnitude of magnetic field.

Let us consider a circle of radius r which is taken as closed path for ampere loop.

Angle b/w $\vec{B}$ & $\vec{dl}$ is 0.

From Amperes Circutal Law –

According to ampere Circutal Law.

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i$$

$$\oint B\,dl \cos 0 = \mu_0 i$$

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

$$\because \oint dl = 2\pi r$$

$\cancel{\oint B dl}$.

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

$$B \times 2\pi r = \mu_0 i$$

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

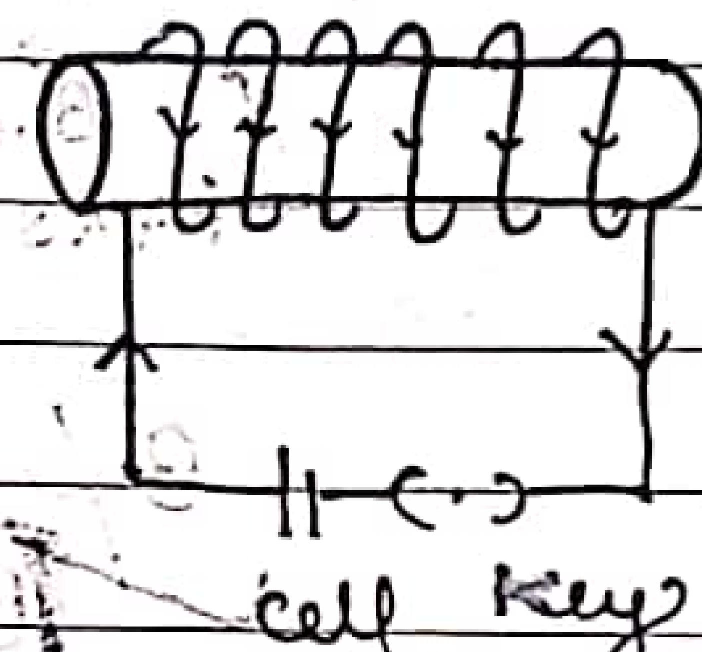
$$\boxed{B = \frac{\mu_0}{2\pi}\frac{i}{r}}$$

(1) The magnetic field at every point will be concentric circle whose centre will be same.

(2) The direction of magnetic field at any point will be tangential on this circle. This circular lines are called <u>magnetic field lines</u>.

Solenoid

A solenoid is an insulated long wire closely bound in the form of helix.

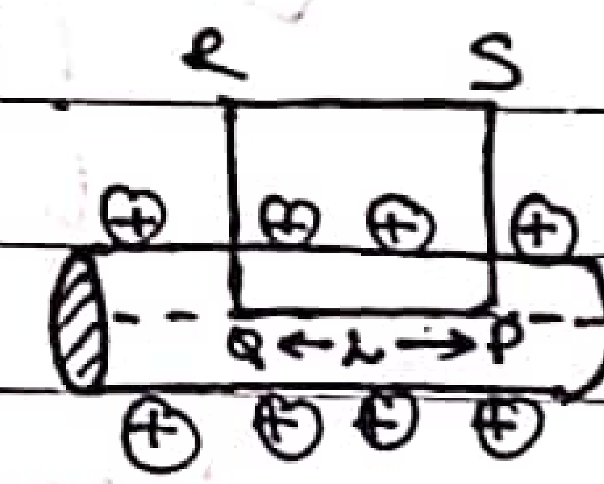


Its length is very long as compare to its diameter.

We make use of solenoid to generate magnetic field.

Magnetic field of a Solenoid

Let us consider a solenoid in which i current is flowing in every turn let there is a small n turns in per unit length.



Let us consider a rectangular ampere ~~pat~~ closed path PQRS where $PQ = l$

According to Ampere's circuital Law

$$\oint_{PQRS} \vec{B}\cdot\vec{ds} = \int_P^Q \vec{B}\cdot\vec{dl} + \int_Q^R \vec{B}\cdot\vec{dl} + \int_R^S \vec{B}\cdot\vec{dl} + \int_S^P \vec{B}\cdot\vec{dl}$$

$$\because \int_Q^R \vec{B}\cdot\vec{dl} = \int_S^P \vec{B}\cdot\vec{dl} = 0 \because \theta = 90^\circ$$

and $\int_R^S \vec{B}\cdot\vec{dl} = 0 \because B=0$

Therefore

$$\int_{PQRS} \vec{B}\cdot\vec{dl} = \oint_P^Q \vec{B}\cdot\vec{dl} = \oint_P^Q B\,dl\cos 0 = B\oint_P^Q dl = BL \quad -(i)$$

The no. of turns on $PQ = nL$

Net current in $PQ = nLi \quad -(ii)$

By Ampere's circuital law

$$\oint_{PQRS} \vec{B}\cdot\vec{dl} = \mu_0 i_{net}$$

$$B\cancel{L} = \mu_0 \times n\cancel{L}i$$

$$\boxed{B = \mu_0 ni}$$

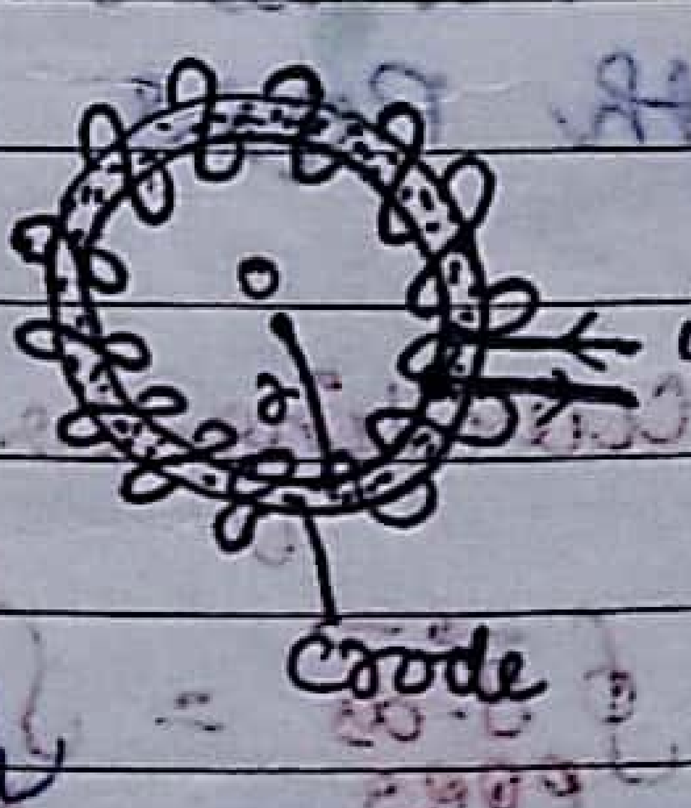
The magnetic field near any end of solenoid

$$\boxed{B = \frac{1}{2}\mu_0 ni}$$

Magnetic field of a Toroid

An endless solenoid in the form of ring is called toroid.

Let small r is the ~~main~~ mean radius of toroid, n is the number of turns per unit length and i is the current.



Therefore,

by Ampere circutal law.

$\oint \vec{B}.\vec{dl}$ = μ_0 x total current bounded by closed path.

The net current bounded in closed path

$i_{net} = 2\pi r \times n \times i$

$\because$ $\vec{B}$ and $\vec{dl}$ are in the direction

$\therefore \theta = 0$

So,

$$\oint \vec{B}.\vec{dl} = \mu_0 i_{net}$$

$$\oint B dl \cos\theta = \mu_0 \times 2\pi r \times ni$$

$$B \oint dl = \mu_0 \times 2\pi r \times ni \quad \because \oint dl = 2\pi r$$

$$B \times \cancel{2\pi r} = \mu_0 \times \cancel{2\pi r} \times ni$$

$$\boxed{B = \mu_0 ni}$$

NOTE → There will be no magnetic field outside the toroid and also in the empty space surrounded by the toroid.

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Force on a moving charge in a uniform magnetic field

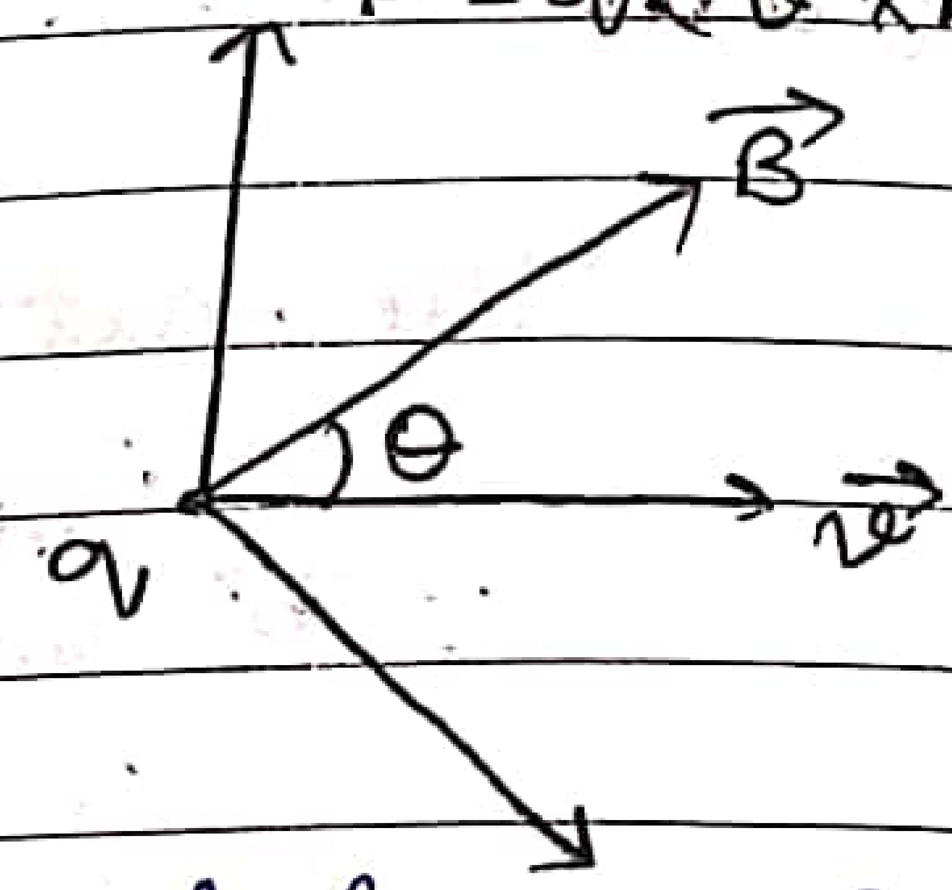
When a charge particle q moves with velocity $\vec{v}$ inside the uniform magnetic fied $\vec{B}$ then the force acting on it will be

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

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

The direction of force will be perpendicular to velocity $\vec{v}$ and magnetic field $\vec{B}$

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



(1) If the charge is in rest in magnetic field i.e. $v = 0$

$$[F = 0]$$

Therefore if any charge is at rest in a uniform magnetic field there will be no magnetic force on the charge.

(2) If charge is moving perpendicular to the direction of magnetic field i.e. $\theta = 90^\circ$

then the force on the charge will be maximum

$$\theta = 90^\circ$$

$$[F = qvB]$$

(3) If the charge is moving in the direction of magnetic field i.e. $\theta = 0$

then $\rightarrow [F = 0]$

it means if any charge is moving in direction of magnetic field there will be no force acting on the charge.

Force on a Moving charge in a uniform magnetic & electric field (Lorentz Force)

Suppose a point charge q is moving with velocity $\vec{v}$ in presence of electric field $\vec{E}$ and magnetic field $\vec{B}$ both then the total force appling on charge —

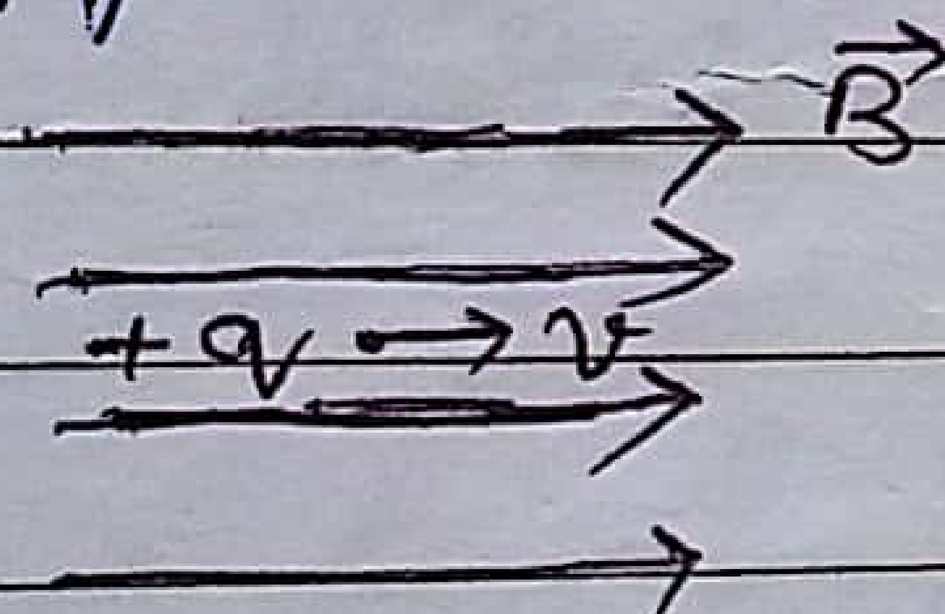
$$\vec{F}_{net} = \vec{F}_{electric} + \vec{F}_{magnetic}$$

$$\vec{F}_{net} = q\vec{E} + q(\vec{v} \times \vec{B})$$

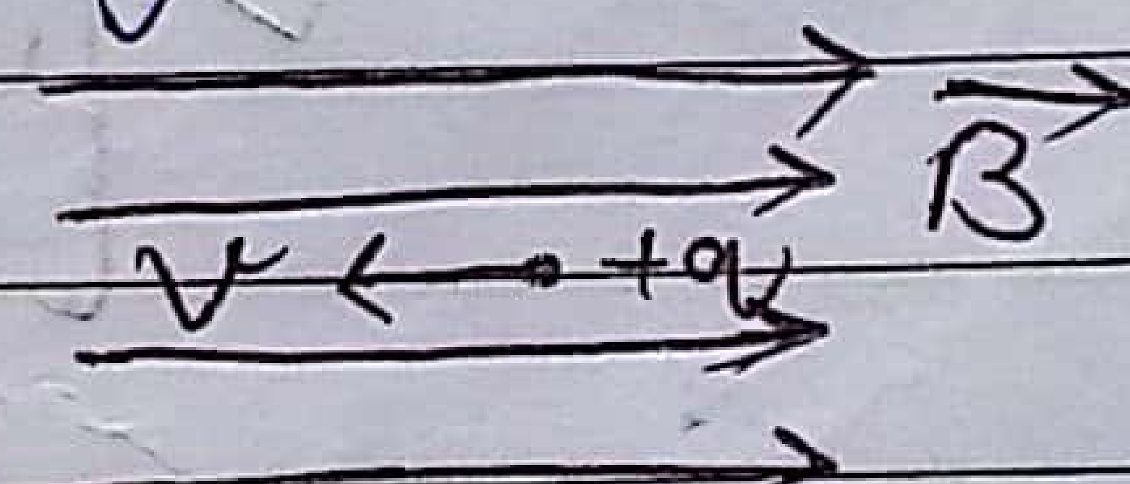
This net force is called Lorentz Force

Moving Path of a charge particles moving in uniform magnetic field.

1) If the charge particles move in direction of magnetic or in opposite direction of magnetic field.



or



$\theta = 0$

$F = qvB\sin\theta$

$= qvB\sin 0$

$F = 0$

$\theta = 180^\circ$

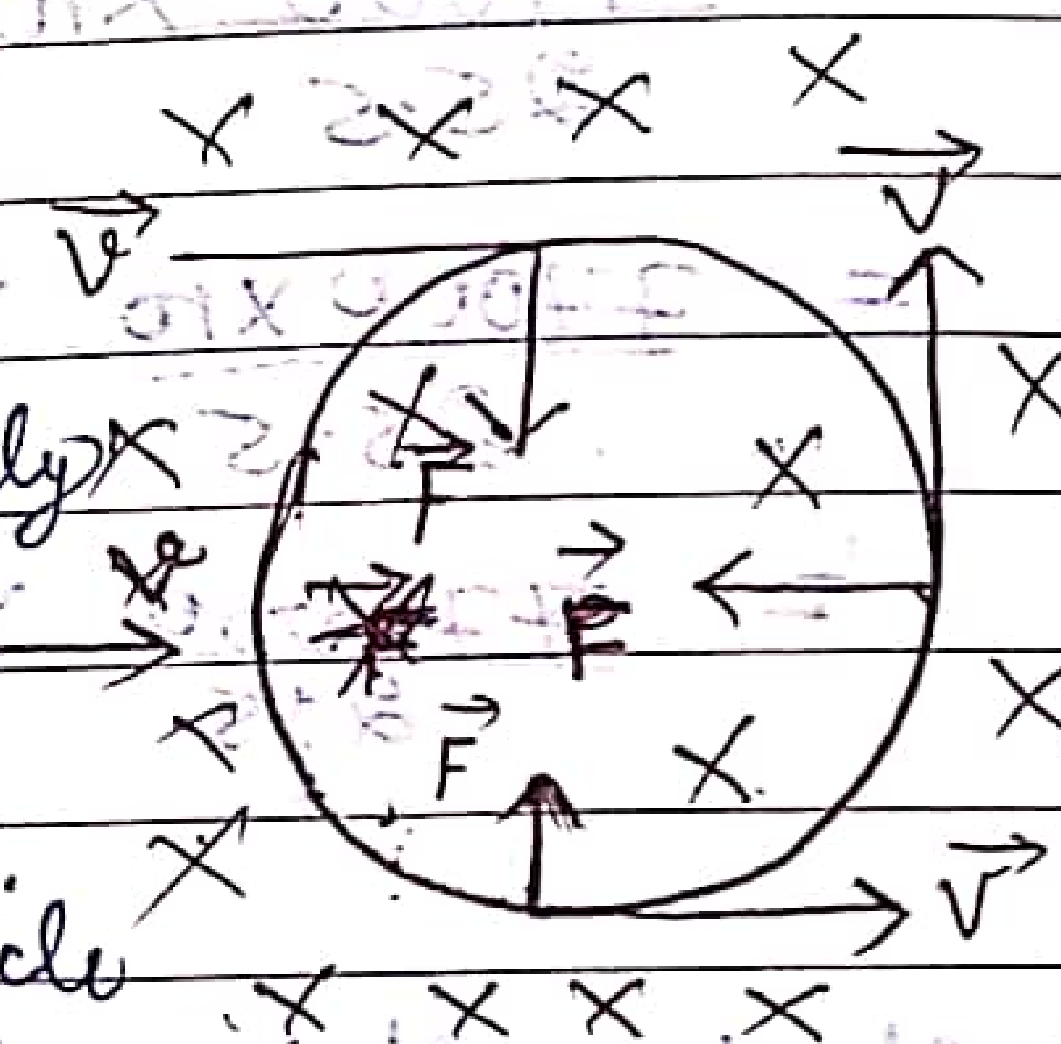
$F = qvB\sin 180^\circ$

$F = 0$

In both case there will act no force on moving charge particle therefore its moving path will be same as its original path.

(2) When charge particles entered perpendicular in uniform magnetic field

If a charge particle entered in a uniform magnetic field perpendicularly its moving path will be circular.



Let a ~~charg~~ charge particle of mass (m) and having charge (q) enter in uniform magnetic field B perpendicularly with velocity (v) let the radius of circular path is (r) then

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

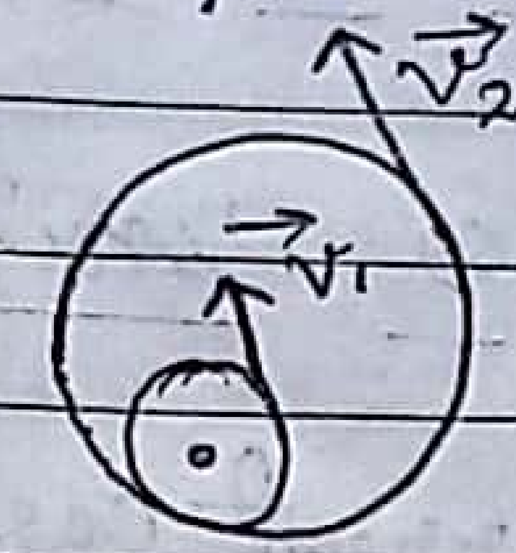
$$qB = \frac{mv}{r}$$

$$\left[r = \frac{mv}{qB}\right]$$

The time period.

$$T = \frac{2\pi r}{v} \Rightarrow \frac{2\pi \times m\cancel{v}}{\cancel{v} \times qB} = \frac{2\pi m}{qB}$$

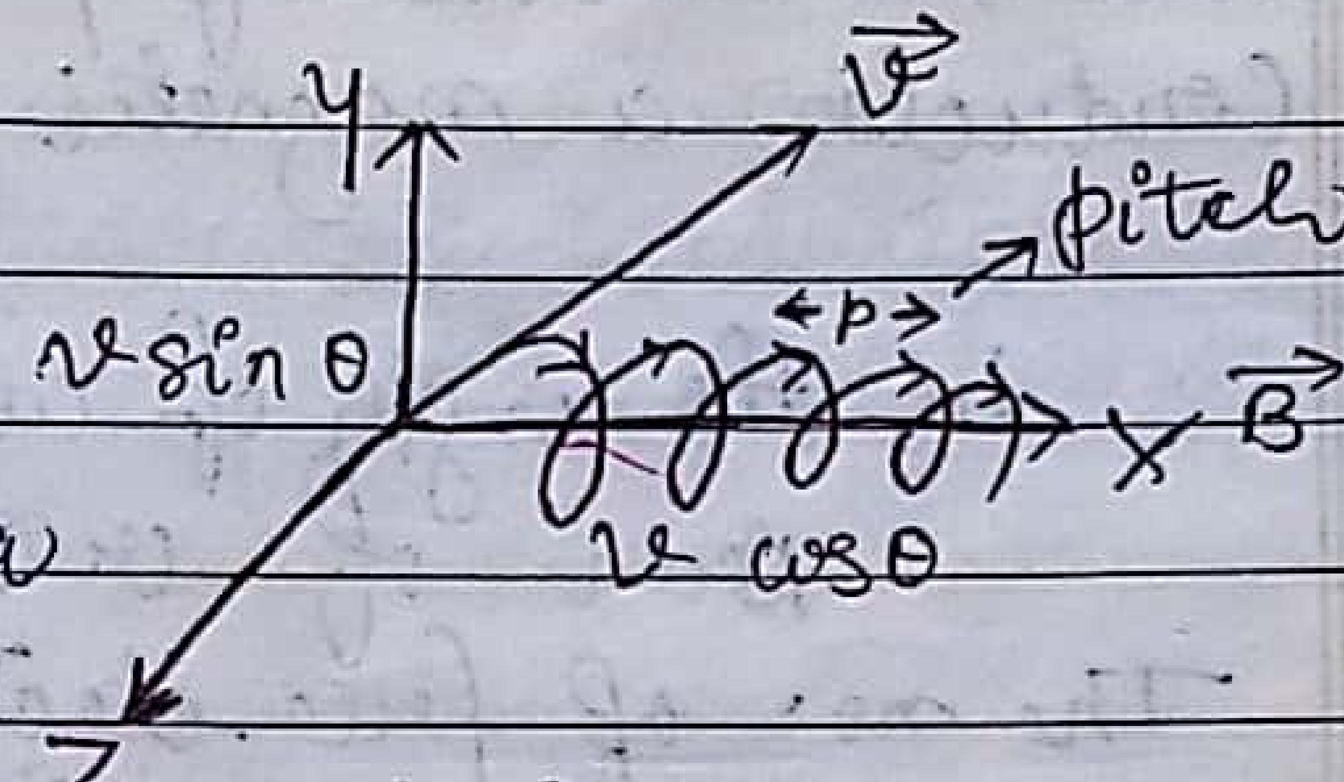
The time period doesnot depend on the velocity of particles.



$\vec{v}_2 > \vec{v}_1$

(3) If the charge particle entered in magnetic field at direction θ.

In this condition the moving path of charge particle will be like a helix.



Let the radius of helix is (r)

$$\frac{m v_{\perp}^{2}}{r} = q v_{\perp} B$$

$$\frac{mv\sin\theta}{r} = qB \rightarrow \left[r = \frac{mv\sin\theta}{qB} \right]$$

for helical path the distance moved along the magnetic field in one rotation is called pitch of helix path.

Pitch of the path

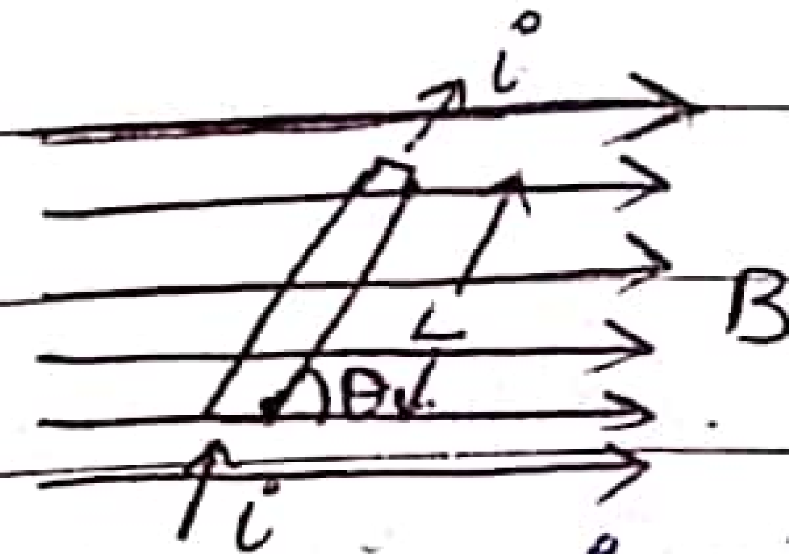
$$p = v_{\parallel} \times T$$

$$p = v_{\parallel} \times \frac{2\pi m}{qB}$$

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

Force on a current carrying conductor in a uniform magnetic field

when a current carrying conductor is placed in a uniform magnetic field then due to motion of free electrons inside the conductor a magnetic forces acts on it.



Let the length of current carrying conductor is (L)
Area of cross section $= (A)$
The no. of free electrons in per unit Volume $= (n)$
Let the drift velocity of free electrons $= (v_d)$

The force on one free electron.

$$F' = e v_d B \sin\theta$$

Total no. of free e^- in current carrying conductor.

$$N = nAL$$

The net force on current carrying conductor.

$$F = N \times F'$$

$$F = nALev_d B \sin\theta$$

$$F = (neAv_d) BL \sin\theta \quad \because i = neAv_d$$

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

i. If $\theta = 0$

$F = 0$

It means if a current carrying conductor is placed parallel to the direction of M.F. experiences no force

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

$$\boxed{F_{max} = iBL}$$

It means a current carrying conductor is placed $\perp$ to the direction of magnetic field experienances maximum force.

Direction of Force

The direction of force acting on a current carrying conductor in a magnetic field can be find by any of the following two rules.

1. Fleming left hand Rule

If the forefinger, middle finger & thumb of left hand are ~~stress~~ stretch mutually $\perp$ to one another such that the forefinger points in the direction of magnetic field & the middle finger in the direction of current then thumb will point in the direction of force (F)

2. Right hand palm Rule

If we stretch our right hand palm Such that the thumb point in the direction of current & stretched fingers in the direction of magnetic field then force on the conductor will be $\perp$ to the palm. in the direction of pushing by the palm.

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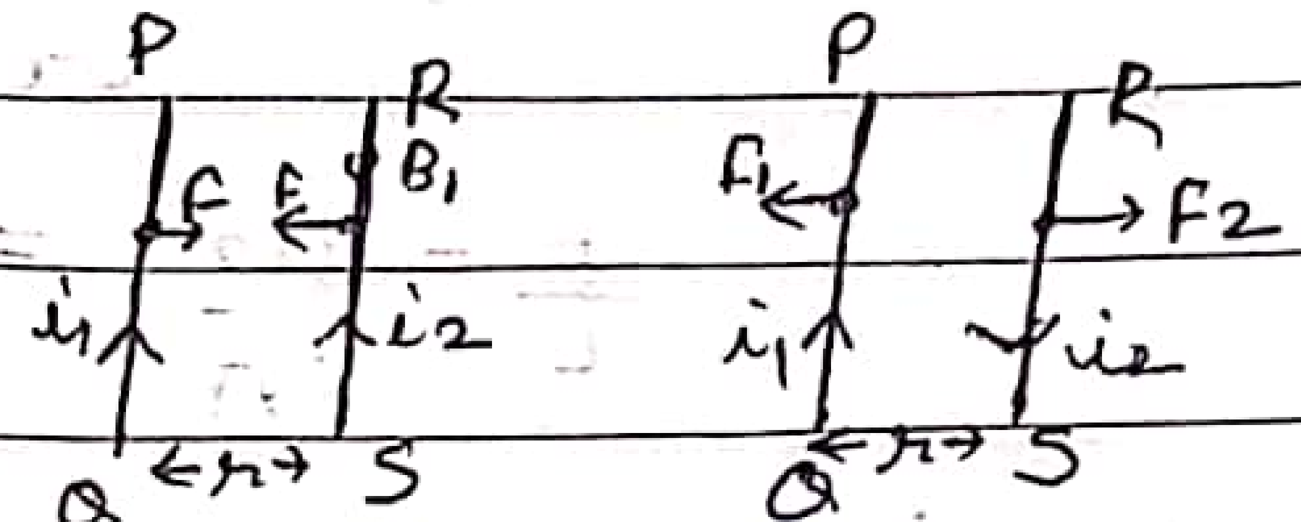
* Force between two parallel current carrying conductor



If two parallel current carrying conductors are placed a short distance then one conductor applied magnetic force on one another. If the current are in same direction then there will be attractive force and if carrying current in opposite direction there will be repulsion.

Let P, Q & RS are two infinite long current carrying conductor i_1 & i_2 are the currents flowing through them and these are placed at distance (r)

The magnetic field on conductor RS due to current carrying conductor PQ

$$B_1 = \frac{\mu_0}{2\pi}\frac{i_1}{r}$$

The magnetic force of current carrying conductor RS on length L:

$$F = i_2 B_1 L \sin 90^\circ$$

$$F = i_2 B_1 L$$

$$F = i_2 \times \frac{\mu_0}{2\pi} \times \frac{i_1}{r} \times L$$

$$\boxed{\frac{F}{L} = \frac{\mu_0}{2\pi}\frac{i_1 i_2}{r}}$$

Definition of ampere :-

if $i_1 = i_2 = 1\,amp$

$r = 1\,m$

$$\frac{F}{L} = \frac{\mu_0}{2\pi} = 2 \times 10^{-7}\ N/m.$$

1 ampere is the current which flows through each of the two parallel uniform long linear conductors which are placed unit distance in space and which applied 2×10^{-7} N/m magnetic force on each other.

Cyclotron –

It is a type of machine that provides energetic charge particle.

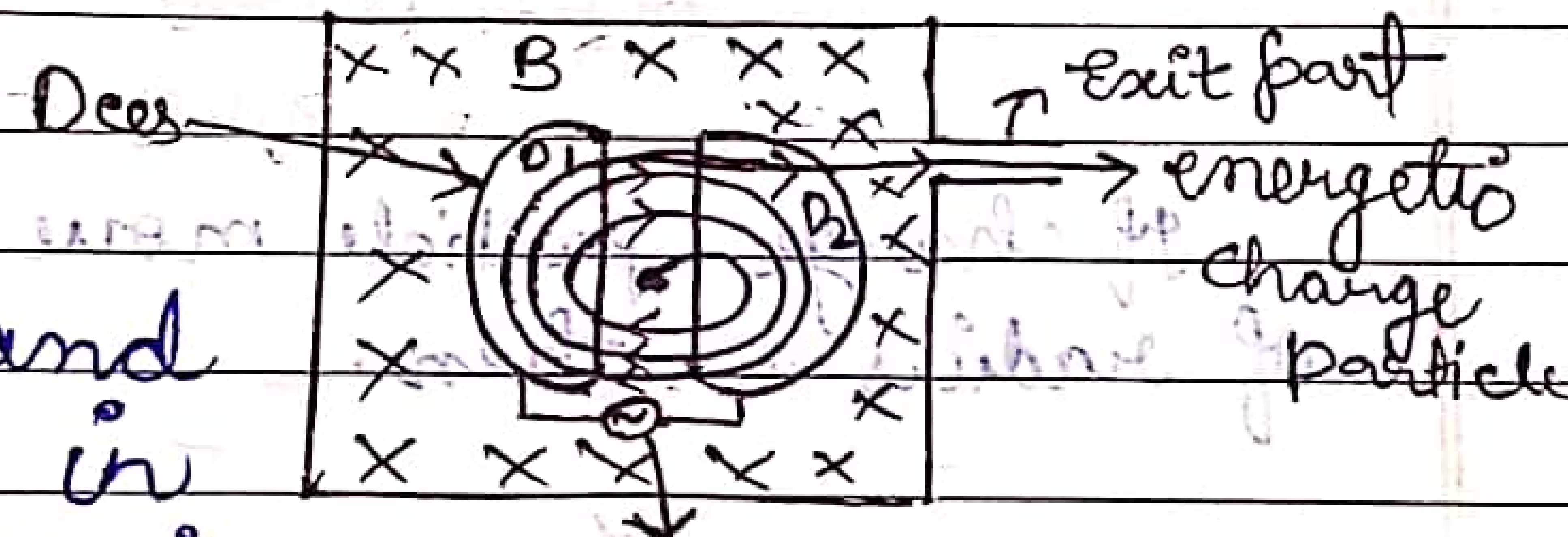
It is used to study the structure of nucleus and atom.

Principle –

when a charge particle ready to pass through a small electric field again and again with the help of strong magnetic field then it accquire high energy.

Structure –

The cyclotron is uses both electric field and magnetic field in combination to increase the energy of charge particle.



The charge particle move most of time inside two semi circular dees like metal container D_1 and D_2 ~~Dees~~ which are called dees.

Inside the metal boxes the particle is shielded and is not acted on by the electric field. the magnetic field however acts on the particle and makes it ~~whole~~ go round in a circular inside the dees everytime the particle moves from one dees to another it is acted upon by the electric field this insure that the particle is always accelerated by electric field.

Each time the acceleration increases the energy of the particle. Therefore, we get an energetic charge particle.

Formula– If any charge q moving with velocity v in any magnetic field $\vec{B}$ then magnetic force on the charge particle.

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

$$\Rightarrow \vec{F_m} = qvB\sin\theta$$

if $\theta = 90°$

$$\Rightarrow \vec{F_m} = qvB \quad \text{--- (1)}$$

If charge particle move in circular path of radius R then.

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

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

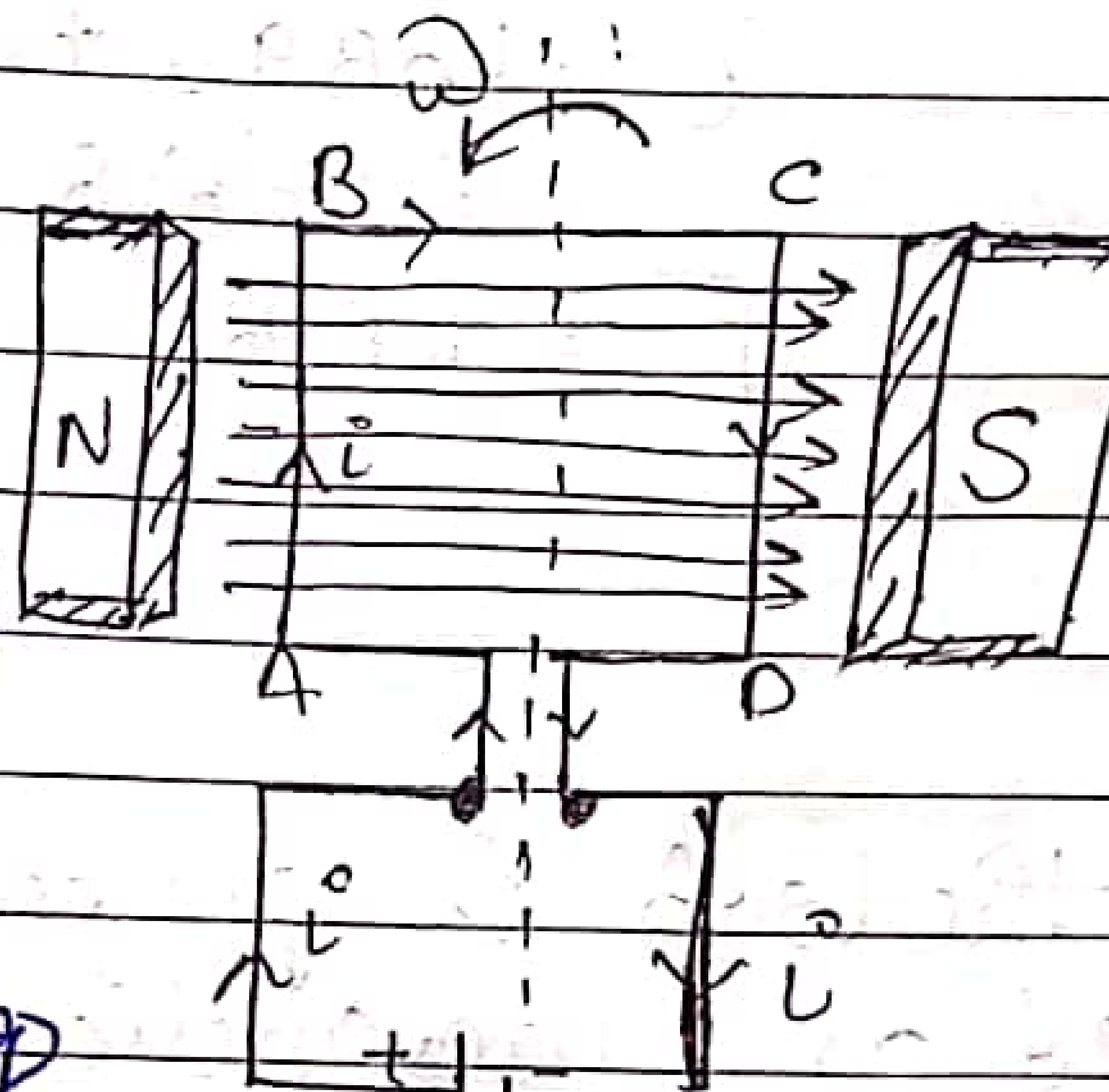
The energy of charge particle:

$$\frac{1}{2}mv^2 = \frac{1}{2}\cancel{m} \times \frac{q^2B^2R^2}{m^{\cancel{2}}}$$

$$\boxed{\frac{1}{2}mv^2 = \frac{q^2B^2R^2}{2m}}$$

Torque on Current Loop : Magnetic Dipole

when a rectangular current carrying loop is placed in a uniform B (magnetic field) it experiences a torque.



★ Let a current carrying loop ABCD is placed such that the magnetic field is in the plane of loop.

The field exerts no force on arms AD and BC of the loop because for this θ is zero

$$F = iBL\sin 0^\circ$$

$$\boxed{F = 0}$$

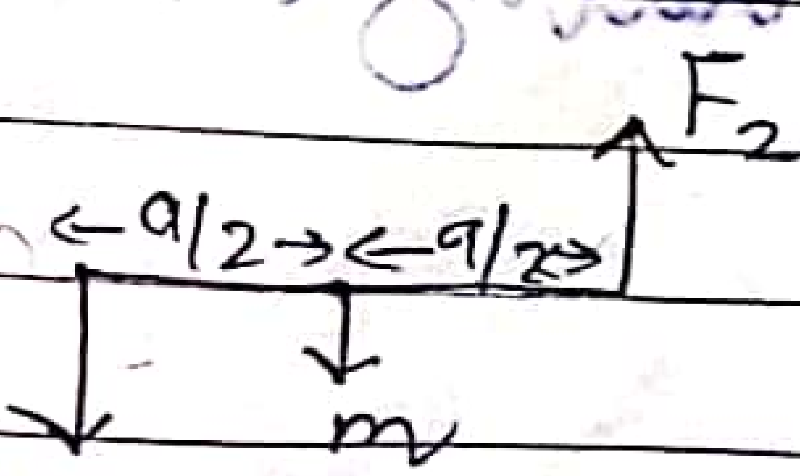
The magnetic forces on arms AB and CD F_1 & F_2

$$F_1 = F_2 = ibB\sin 90^\circ$$

$$[= ibB]$$

★ Therefore the net force on the loop is zero. there is torque on the loop due to the force F_1 & F_2

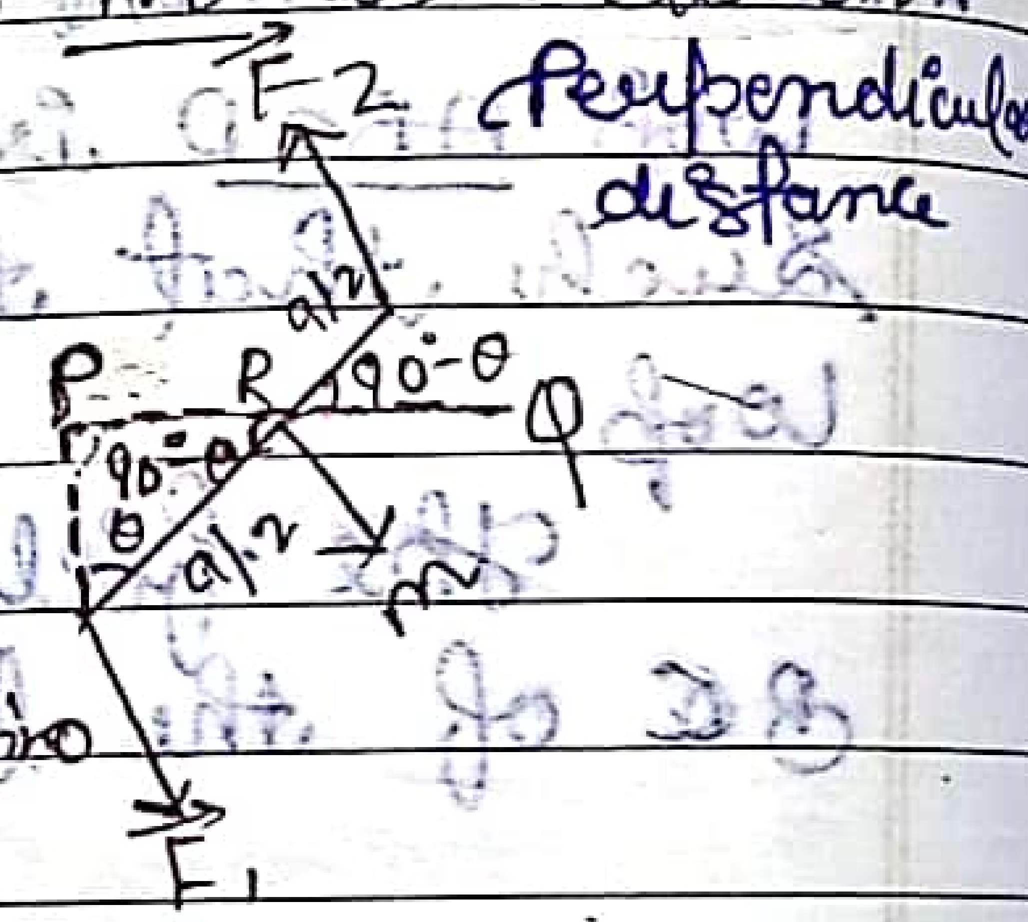
The resultant torque on the loop.



Let BC = a
AB = b

$$\tau = \tau_1 + \tau_2$$
$$\tau = F_1 \times a/2 + F_2 \times a/2$$
$$\tau = ibB\,a/2 + ibB\,a/2$$
$$\tau = i(ab)B$$
$$\boxed{\tau = iAB}$$

(2) If the loop is placed such that the magnetic field and magnetic moment $\vec{m}$ is acts on $\angle\theta$.



$$PR = RQ = \frac{a}{2}\sin\theta$$
$$\tau = \tau_1 + \tau_2$$
$$\tau = F_1 \times \frac{a}{2}\sin\theta + F_2 \times \frac{a}{2}\sin\theta$$
$$\tau = ibBa\sin\theta$$
$$\tau = i(ab)B\sin\theta$$
$$\boxed{\tau = iAB\sin\theta}$$

$m = iA$
m = magnetic dipole moment

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

If there are N number of turns in the rectangular coil then magnetic moment will be–

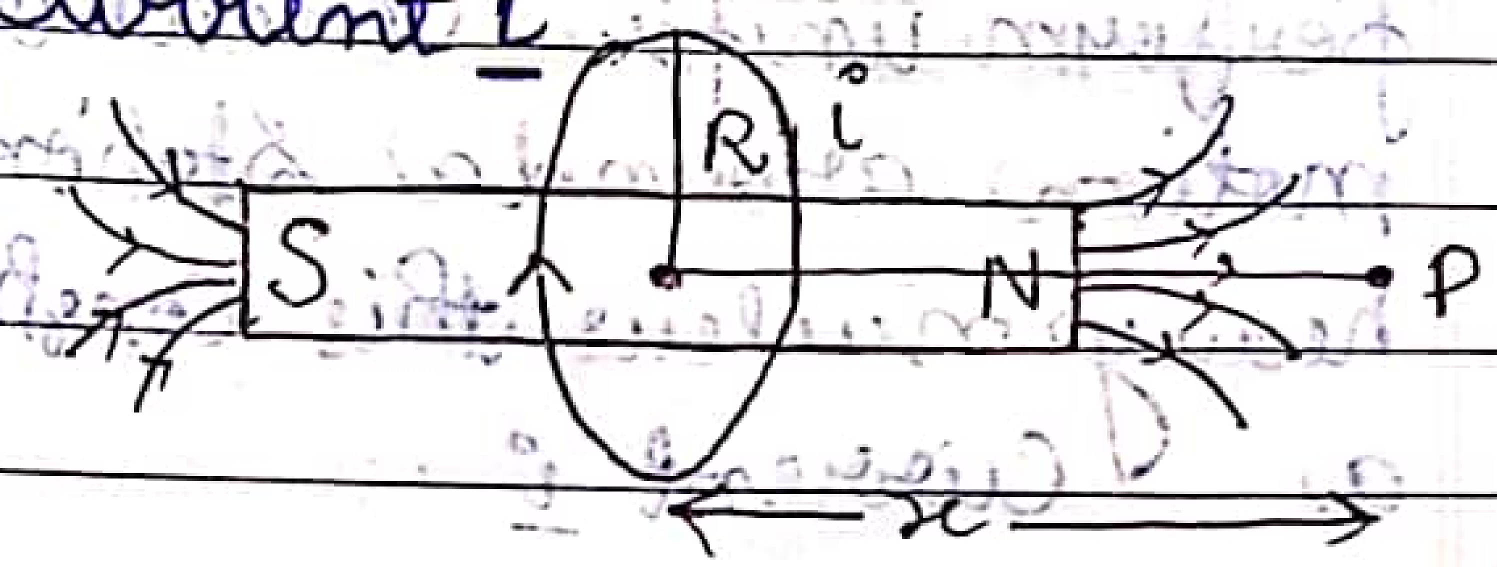
$$\boxed{m = NiA}$$

The S.I unit of magnetic moment is amp-m^2

Date: 01/7/19

Circular Current Loop as a Magnetic ~~too~~ dipole

Let us Consider a Circular loop of radius R Carrying a Steady Current i the magnetic field at distance x on the axis of loop from its centre —



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

$\because$ $x >> R$

$\therefore$ R^2 Negligible (in denominator)

$$B = \frac{\mu_0 i R^2}{2 \times x^3}$$

Multiplying ~~divide~~ by π in numerator & denominator

$$B = \frac{\mu_0 i \pi R^2}{2\pi x^3} \quad \because \pi R^2 = A$$

$$B = \frac{\mu_0 i A}{2\pi x^3} \quad \because iA = m$$

$$B = \frac{\mu_0 m}{2\pi x^3}$$

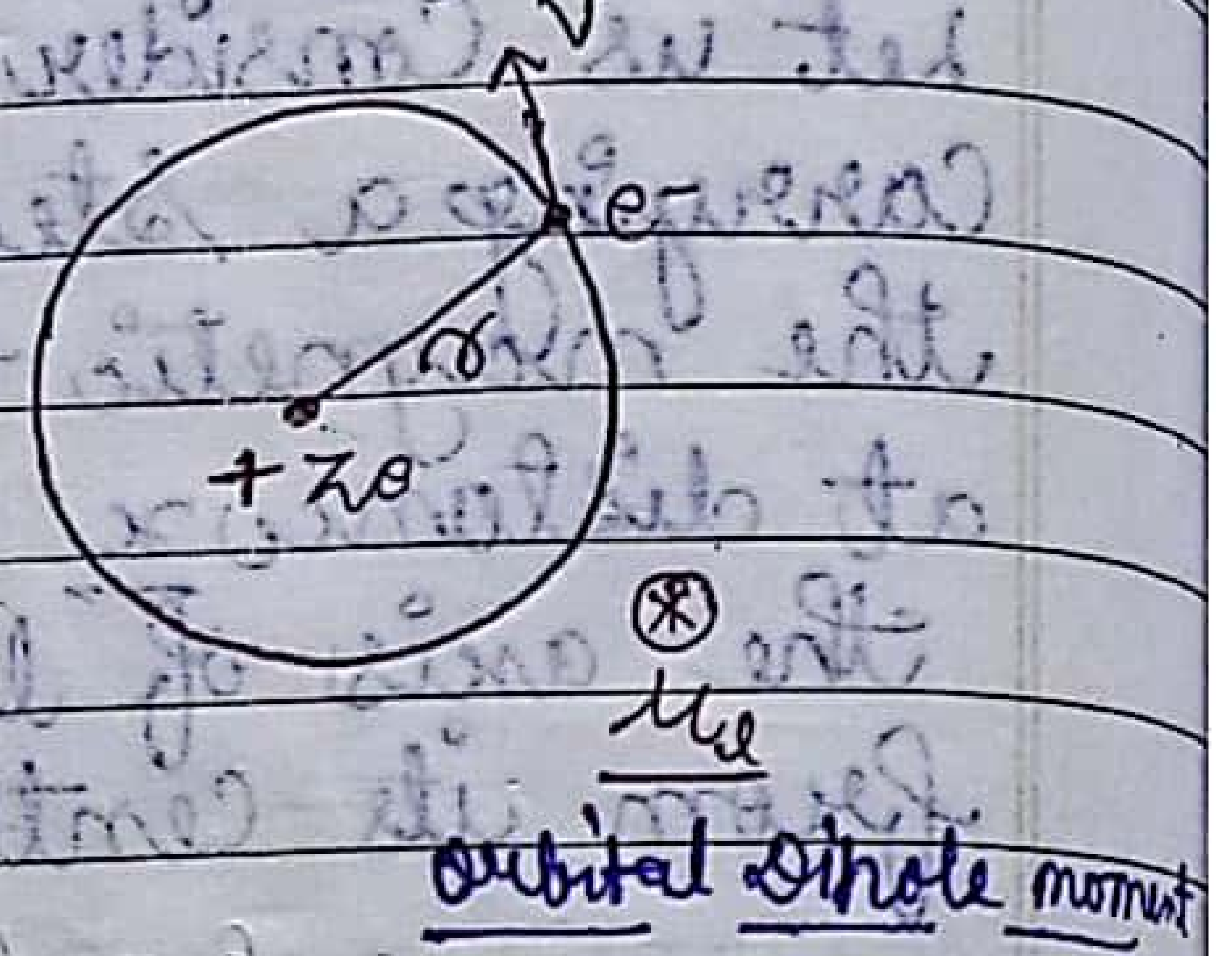
multiplying by 2 in numerator & denominator

$$\boxed{B = \frac{\mu_0}{4\pi} \frac{2m}{x^3}}$$

Result → The result obtained above can be shown to apply any planer rule. A planer current loop is equivalent to a magnetic dipole having magnetic dipole moment m.

The Magnetic dipole moment of a revolving electron

The electron of charge e perform uniform circular motion around a stationary heavy nucleus this constitute a current i



$$i = \frac{e}{T}$$

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

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

$$i = \frac{ev}{2\pi r}$$

orbital magnetic dipole moment $\underline{\mu_l} = \underline{iA}$

$$\mu_l = \frac{ev}{2\cancel{\pi} \cancel{r}} \times \cancel{\pi} r^{\cancel{2}}$$

$$\mu_l = \frac{evr}{2}$$

multiply by m in numerator & denominator

$$\mu_l = \frac{e(mvr)}{2m}$$

$$\left[\mu_l = \frac{el}{2m}\right]$$ where l is angular momentum

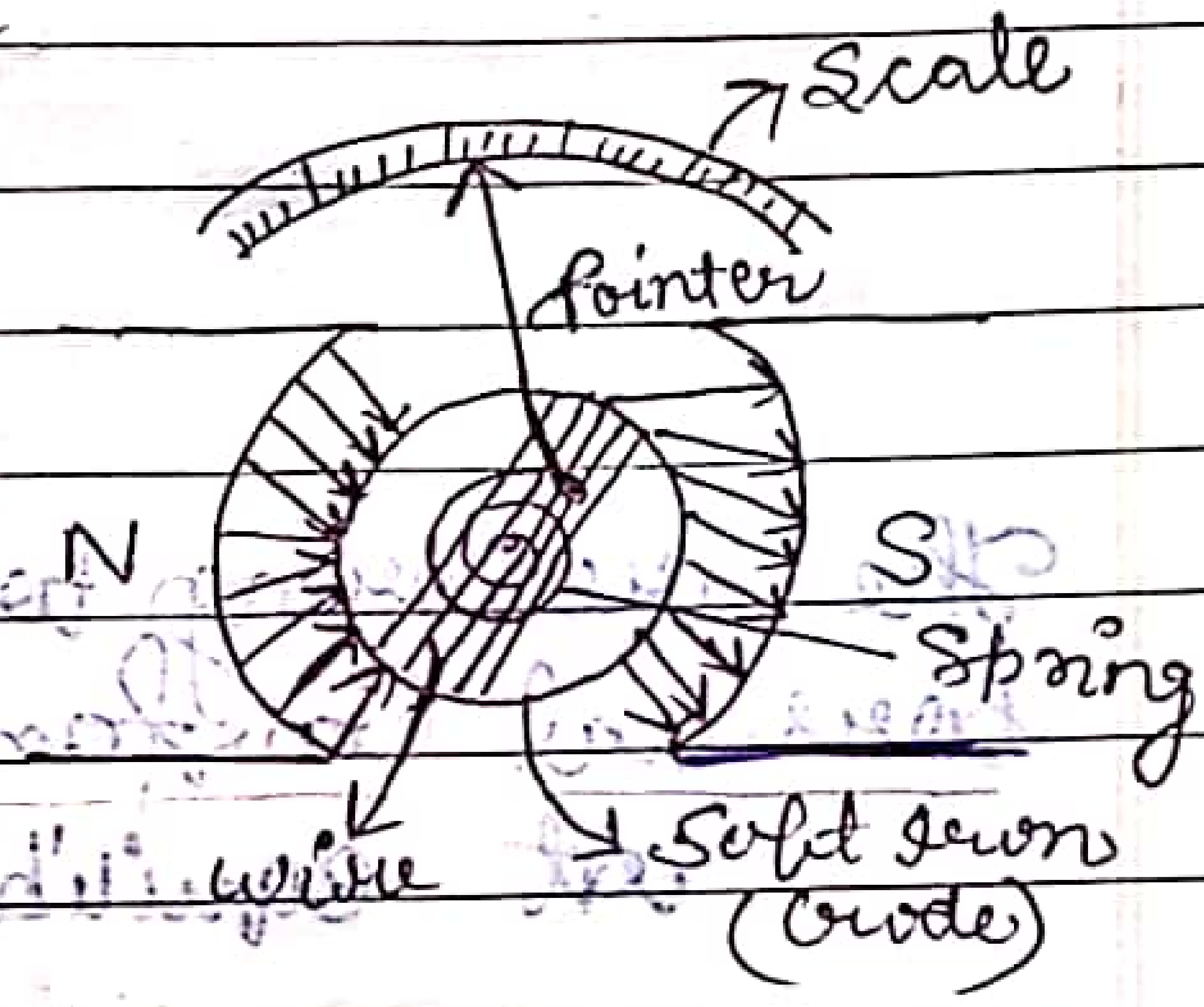
$$\left[\frac{\mu_l}{l} = \frac{e}{2m}\right]$$

$\frac{\mu_e}{L}$ is called Gyromagnetic Ratio

★ $\left[\frac{\mu_e}{L} = \frac{1.6 \times 10^{-19}}{2 \times 9.1 \times 10^{-31}} = 8.8 \times 10^{10} \ C/Kg \right]$

Moving Coil Galvanometer

The instrument which measure the current in a circuit or for the Voltage drop across a resistor is called moving coil Galvanometer



Construction

The Galvanometer Consist of a Coil with many turns free to rotate about the fix axis in a uniform radial magnetic field there is a Cylindrical Soft iron (core) which makes the field radial and also increases the strength of magnetic field.

Principle

when a current flows through the ~~wire~~ coil a torque xe on it

$$\tau = NiAB \sin\theta$$

$$\text{But } \theta = 90^\circ$$

$$\therefore \tau = NiAB \quad \text{--- (1)}$$

The magnetic torque tends to rotate the coil then Spring provide a counter torque which is directly proportional the deflection angle ϕ this deflection ϕ is indicated on the Scale by a pointer attach to the Spring.

$$\tau \propto \phi$$

$$\tau = K\phi \quad \text{--- (2)}$$

↳ where K is constant which is torsinal constant of spring.

★ The restoring torque per unit twist is called torsinal Constant

At equilibrium from eqn (1) & (2)

$$NiAB = K\phi$$

$$\boxed{\frac{\phi}{i} = \frac{NAB}{K}}$$

↳ current Sensitivity $\left(\frac{\phi}{i}\right)$

If we increase number of turns then Current Sensitivity increase.

$$\because \quad i = \frac{V}{R}$$

$$\frac{\phi}{V/R} = \frac{NAB}{K}$$

$$\boxed{\frac{\phi}{V} = \left(\frac{NAB}{K}\right)\frac{1}{R}}$$

$\frac{\phi}{V}$ is called voltage Sensitivity

If we change number of turns of coil voltage Sensitivity remain Constant.

Conversion of Galvanometer into Ammeter

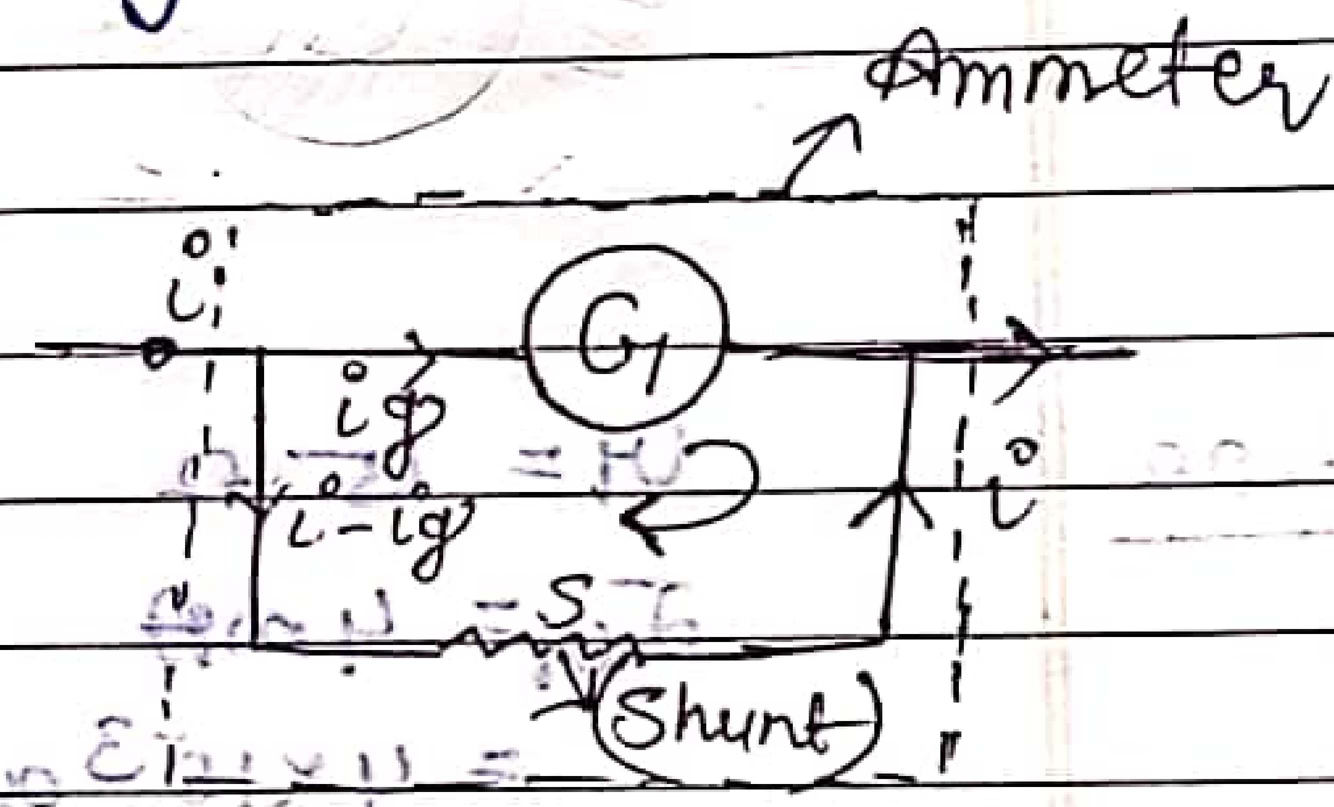
To Convert a Galvanometer into ammeter its resistance needs to be lower so that the maximum current can pass through it & it can give ~~exactly~~ exact reading.

$$i_g G - (i - i_g)S = 0$$

$$i_g G = (i - i_g)S$$

$$S = \frac{i_g G}{i - i_g}$$

$$\boxed{S = \left(\frac{i_g}{i - i_g}\right)G}$$



Conversion of Galvanometer into Voltmeter

To Convert a Galvanometer into Voltmeter its resistance needs to be increase so that there is no potential drop across it because with high resistance no current is passes through it.

$$V = iG + iR$$

$$iR = V - iG$$

$$\left[R = \frac{V}{i} - G \right]$$