Chapter 4

MOVING CHARGES AND MAGNETISM

Introduction

In 1820 Hans Christian Oersted noticed that a current carrying conducting wire create a magnetic field around the wire.

His experimental observations are,

1. Alignment of the magnetic compass needle tangent to an imaginary circle around the current carrying wire at its centre.
2. By reversing the direction of current the orientation of the needle also reverses.
3. Deflection of the needle depends upon the strength of the current through the wire. (Increases with increasing current)

Conclusion

Moving charges or Current produces a magnetic field in its surrounding space.

Note

1. Charges at rest produces electrifield only.
2. Charges in motion produces both magnetic field as well as electric field.

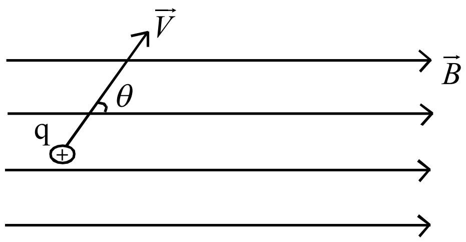
- What is the Lorentz Force?

A point charge ‘q’ moving with a velocity $\vec{V}$ in a magnetic field $\vec{B}$ experiences a force on it.

It is given by, $\vec{F} = q(\vec{V} X \vec{B})$

$ie, \vec{F} = qVBSin\theta\hat{n}$

Where 'θ' is the angle between velocity vector and the magnetic field vector.



The direction of the force experienced is obtained by right hand screw rule. -

Curl the figures of the right hand from $\vec{v}$ to $\vec{B}$, the direction of extended thumb gives the directory of Lorenz force.

Note

1. If the charge is negative, the force experienced is opposite to that of the +ve charge.
2. The force experienced by the charge q is ‘Zero’ when,
   a) $\vec{V}$ and $\vec{B}$ are parallel or antiparallel
   ie, $\theta = 0^0$ or $\theta = 180^0$ (Sin0=0, Sin 180=0)
   b) $|\vec{V}| - 0$
   c) The particle is neutral

3. Force on the charge is maximum for the given $|\vec{V}|$ and $|\vec{B}|$

When,

a) $\vec{V}$ is perpendicular to $\vec{B}$. ie, when $\theta = 90^0$ (Sin 90^0=1)

State Direction of Lorenz Force

The direction of the lorenz force is perpendicular to both $\vec{V}$ and $\vec{B}$ and is obtained by right hand screw rule or right hand rule.

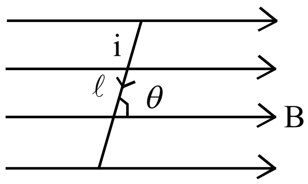
Features of Magnetic Lorenz Force

- Magnetic lorenz force does no work on the charged particle, because it is prependicular to $\vec{V}$ and $\vec{B}$.
- Magnetic lorenz force does not change the kinetic energy of the charged particle.
- Magnetic lorenz force changes the momentum of the charge particle.

Magnetic Force On a Current Carrying Conductor in a magnetic field

Find the equation for magnetic force on current carrying conductor.

A straight conductor of length 'l' area of cross section 'A' carrying a current 'i' ampere is placed in a magnetic field $\vec{B}$.



Let 'e' be the charge of an electron (current carrier)

Let No.of. electrons/unit volume = n

Volume of the conductor = Aℓ

$\therefore$ No.of electrons in the conductor = nAℓ

Amount of charge conducting per unit time

q = neAℓ

This charge is drifting with a velocity $\vec{V}$.

Then the force on the conductor. (by using Lorenz force)

* $\vec{F} = qVB\ Sin\theta\ \hat{n}$

$|\vec{F}| = qVB$ Sinθ

Substituting q=neAl

$|\vec{F}| = neAlVBSin\theta$

neAV = i $\left[V = l/t \therefore \frac{neAl}{t}\ which is\ q/t, i = q/t\right]$ (Charge per unit time)

$|\vec{F}| = iBlSin\theta$

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

Magnitude of Force on the current carrying condctor.

F = Bil Sinθ

Force is maximum when θ=90^0

F=Bil Sin 90^0

$\boxed{F = Bil}$

The direction of force is given by Fleming's left hand rule - strech mid finger, forefinger and thumb of the left hand in three mutually perpendicular directions. Mid finger indicates direction of current, Forefinger indicates direction of magnetic field then thumb will indicate the direction of force.

Question

- A current carrying straight wire is aligned in N.S direction. What is the force on the conductor.

  a) Zero b) Bil sin θ c) Bil

- A current straight wire is aligned in E-W direction. What is the force on the conductor.

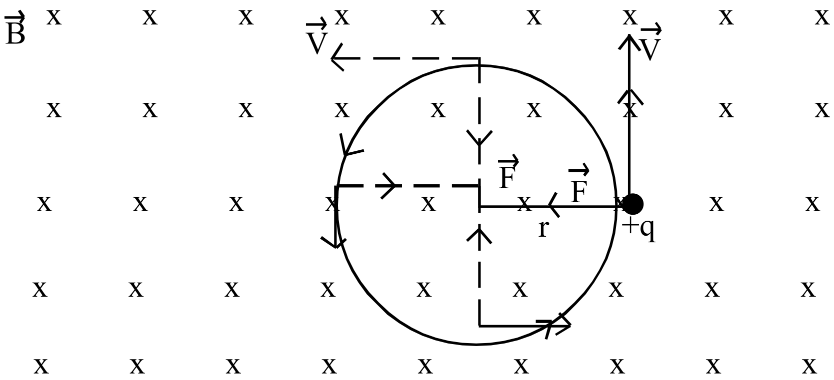
  a) Zero b) Bil sin θ c) Bil

Explain Motion of a charged particle in a magnetic field

- A charged particle is travelling with velocity $\vec{V}$ parallel to the filed $\vec{B}$, the trajectory is a straight line because the magnetic lorenz force is zero.

  Same is the result when the particle is antiparallel to $\vec{B}$.

- If $\vec{V}$ is perpenditure to $\vec{B}$, the magnetic lorenz force is perpendicular to both $\vec{V}$ and $\vec{B}$. It provides necessary centrepetal force and the trajectory is a circle.



$$\text{Centrepetal force} = \frac{mV^2}{R}$$

Lorenz force = qVB

Both are the same since the lorenz force is acting as the centrepetal force.

$$\frac{mV^2}{R} = qVB$$

$$\boxed{\therefore V = \frac{qBR}{m}}$$

From the equation; We obtain

$\therefore$ $V \alpha R$, for constant 'B' and 'q/m'

V=Rw Where w - angular velocity.

$$\therefore Rw = \frac{qBR}{m}$$

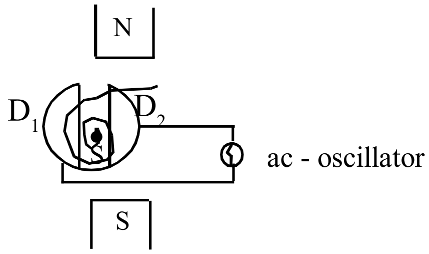
$$\therefore w = \frac{qB}{m}, \quad w=2\pi\upsilon$$

υ is the freequency.

$$\therefore 2\pi\upsilon = \frac{qB}{m} \qquad \therefore \upsilon = \frac{qB}{2\pi m}$$

This frequency called cyclotron freequency.

Cyclotron



What is cyclotron

Cyclotron is a particle accelarator - used to accelerate charged particle to a very high speed (KE)

Who invented cyclotron

E.O. Lawrence and M.S. Livinyston in 1934.

Explain the Principle of cyclotron

In a cyclotron, charged partide is made to move in a circular path using magnestic field and is accelarated using electric field.

(Motion of the charged parctide is a crossed electric and magnetic field)

Construction and working of cyclotron

Cyclotron consist of two semicircular hollow metallic cylinders called dees $_2$. D_1, D these Dees are arranged such that their surface is perpenditure to the magnetic field. The dees are connected to an ac oscillator that provides a constant alternating electric field which is perpendicular to the magnetic field.

Working

The charged particle (s) that is to be accelarated is placed in the gap between the dees.

As the particle moves from one dee towards the other, the polarity of the dees should be changed. This can be done by ac oscillator.

At the gap between the dees, the particle is accelarated by means of suitable electric field.

The frequency of the ac oscillator is adjusted with the cyclotron frequency of the particle. (precaution of cyclotron)

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

KE of the particle ejected from the cyclotron in a cyclotrus, (Speed α radius of the path $V \alpha R$)

For maximum speed of the particle.

V(max) α R, where 'R' is the radius of the dees.

$$V_{(max)} = \frac{qBR}{m}$$

$$KE_{(max)} = \frac{1}{2}m\left(V_{max}\right)^2 = \frac{q^2B^2R^2}{2m} \qquad \text{OR} \qquad KE_{(max)} = 2\pi^2\upsilon^2 mR^2$$

But $qB = 2\pi\upsilon m$

Question

- Is it possible to accelearate a particle like electron using cyclotron? Why?

  No, Due to relativistic effect, the mass of the particle increases with speed. The electron has got negligibly small mass and so the relativistic effect on an electron is more and there is frequent change in the cyclotron frequency which is dependent on mass of the particle to be accelarated.

Limitation of cyclotron

Due to the relativistic effect, the mass of the particle being accelarated increases with speed. There fore cyclotron frequency constantly changes and hence it is difficult to synchronise with the frequency of the ac oscillator.

Questions

- Explain the construction of a cyclotron
- Explain the working principle of cyclotron
- What is cyclotron frequency

Note : Cyclotron frequency

The Frequency at which a charged particle undergoes circular motion in a perpendicular $(\perp r)$ magnetic field $\vec{B}$.

$\upsilon \; \alpha \; (q/m)$ (Charge to mass ratio of the particle)

υ is independent of the particle speed V.

Question

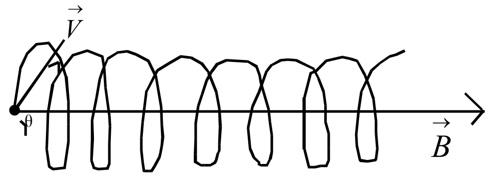
A proton, deutron and α - particle are entering in a uniform $\vec{B}$ with same speed transverse to $\vec{B}$ direction. Which particle circulate in the field with more frequency and more radius.

i) $R \, \alpha \, 1 / \left(q/m\right)$,

α - particle of least (q/m), hence it traces with circular path more radius.

ii. $\upsilon \left(q/m\right)$ electrons has more $\left(q/m\right)$ and have more frequency.

Note: If the charge enetered with velocity $\vec{V}$ in a uniform magnetic field $\vec{B}$ making an angle θ, the path of the charged particle is helical.



Total lorentz force

The electric force on a charged particle of charge 'q' in a uniform $\vec{E}$ is given by $\vec{Fe} = q\vec{E}$

Magnetic force on the charge in a uniform magnetic field is given by

$$\vec{Fm} = q\left(\vec{V} X \vec{B}\right)$$

The total force on the charge in a perpendicular $\vec{E}$ and $\vec{B}$ is given by

$$\vec{F} = q\vec{E} + q\left(\vec{V} X \vec{B}\right)$$

This is called total lorentz force.

Note

A charged particle of charge 'q' undergoes an undeflected path in a perpendicular electric and magnetic field, then $\vec{F} = O$

$$qE = qVB$$
$$V = E/B$$

Where V is the speed.
This conditon can be used to select charged particles of particular velocity out from a beam containing charges moving with different velocities.
This condition is used in velocity selector.

Note :

i. This method is used by JJ Thomson to determine the charge to mass ratio of electron (e/m).
ii. This principle is also used in mass speotrometer used to separate charged particles according to their $\frac{e}{m}$ ratio.

Biot - Savart Law

What in current element?

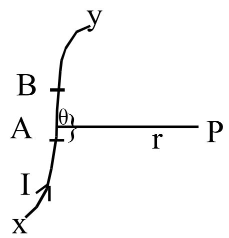
An infinetessimally small current carrying segment is called current element.

State Biot - savart law

Consider a current carrying conductor xy carrying current 'i' ampere. AB is a small current element of length dl, The Magnetic field at a point 'p' due to this current element is given by $\vec{dB}$.

Biot - savart law states that; the magnetic field.

i) dB is proportional to the strength of the current.
ii) dB is proportional to the length of the current element.
iii) dB is proportional to $\sin\theta$
iv) dB is inversely proportional to the square of the distance of that point from the current element



$$\Rightarrow dB\alpha \frac{idlRSin\theta}{r^2}$$

$$dB = \frac{kidl\sin\theta}{r^2} \text{ where } k = \frac{\mu_0}{4\pi}$$

$= 4\pi x10^{-7}\dfrac{NS^2}{C^2}$ μ_0 is called as the permeability of free space.

Note :

Biot savart law when expressed in vector form.

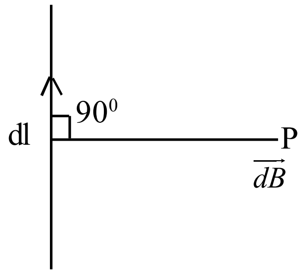
$$\vec{dB} = \frac{\mu_o}{4\pi}\frac{id\vec{\ell}x\hat{r}}{r^2}$$

$$\vec{dB} = \frac{\mu_o}{4\pi}\frac{id\vec{\ell}\times\hat{r}}{r^3}$$

Questions

A point P is at a distance 'r' perpendicular to current element

a. Write the expression for magnetic field at P



$$\vec{dB} = \frac{\mu o}{4\pi}\frac{id\vec{\ell}\sin 90^0}{r^2}$$

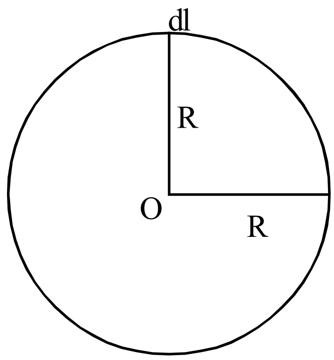
$$\Rightarrow \vec{dB} = \frac{\mu o}{4\pi}\frac{id\ell}{r^2}$$

b. How to find the direction of $\vec{dB}$

Right hand screw rule. Rotate a right hand screw from $\vec{idl}$ to $\vec{r}$ the tip of the screw advances gives direction of $\vec{dB}$

Application of Biot - savart law

Magnetic field at the centre of the circular coil carrying current i.



Consider a circular coil of radius R carrying a current i

$$dB = \frac{\mu_o}{4\pi}\frac{idl\sin\theta}{r^2} \qquad \theta = 90^0,\ \sin 90^0 = 1$$

$$dB = \frac{\mu_o}{4\pi}\frac{idl\sin\theta}{R^2} \qquad r = R$$

$$dB = \frac{\mu_o}{4\pi}\frac{idl}{R^2} \text{ ....(1)}$$

Total magnetic field at the centre can be found by integrating the expression (1).

$$\Rightarrow B = \frac{\mu_0 i}{4\pi R^2}\int dl \qquad \int dl = 2\pi R(circumference)$$

$$B = \frac{\mu_0 i 2\pi R}{4\pi R^2}$$

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

Direction of the magnetic field at the centre.

By right hand thumb rule.

Curl the palm of the right hand such that the curled fingers are in the direction of the current through the coil, then the extended thumb gives the direction of $\vec{B}$

I in anticlockwise direction **in clockwise direction**

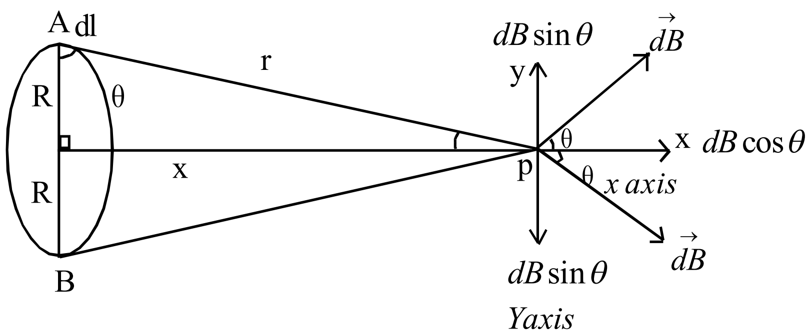
$\vec{B}$ outwards $\vec{B}$ Inwards

Question

Is the field uniform inside the coil.

No, It is maximum at the centre and decreases towards the periphery of the coil.

Magnetic field at any point along the axis of circular coil carrying current.



Consider a coild of radius R carrying current i ampere in the anticlockwise direction

A and B are two current elements of length dl at the diametrically opposite edges of the coil.

Magnetic field at P due to A

$$dB = \frac{\mu_o i dl}{4\pi r^2}$$

Resolving dB at P into 2 components

dBcos θ and dB sin θ along x and y axis respectively.

dB sin θ components; being equal in magnitude and in opposite direction cancel out.

Mangetic field at P is $dB^1 = dB \cos\theta$

i.e $\overrightarrow{dB}^1 = \frac{\mu_0 idl}{4\pi r^2}\cos\theta$

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

$\cos\theta = R/r \Rightarrow \cos\theta = \frac{R}{\sqrt{x^2 + R^2}}$

$r = \sqrt{x^2 + R^2}$ or $(x^2 + R^2)^{1/2}$

$$\Rightarrow dB^1 = \frac{\mu idl}{4\pi(x^2 + R^2)} x \frac{R}{(x^2 + R^2)^{1/2}}$$

$$\Rightarrow dB^1 = \frac{\mu_0 idlR}{4\pi(x^2 + R^2)^{3/2}}$$

Total magnetic field B^1 at P is $\int dB^1$

$$\Rightarrow B^1 = \frac{\mu_0 iR}{4\pi(x^2 + R^2)^{3/2}}\int dl$$

$$\Rightarrow B^1 = \frac{\mu_0 i \times 2\pi R}{4\pi(x^2 + R^2)^{3/2}} \quad \left(\int dl = 2\pi R, (circumference)\right)$$

$$\Rightarrow B^1 = \frac{\mu_0 iR^2}{2(x^2 + R^2)^{3/2}}$$

If the coil has N turns

$B^1 = NB^1$

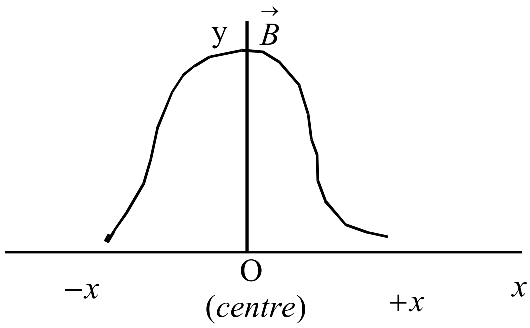
$$\Rightarrow B = \frac{\mu_0 NiR^2}{2(x^2 + R^2)^{3/2}}$$

At the centre, x=0

$$\Rightarrow B^1 = \frac{\mu_0 iR^2}{2(R^2)^{3/2}}$$

$$\Rightarrow B^1 = \frac{\mu_0 i}{2R} \qquad B = NB^1 = \frac{\mu_0 Ni}{2R}$$

Draw the graph showing the relation between B and x



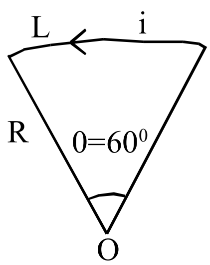
Question

A coil of length l make an angle 60^0 with its vertex. If it carries a current i ampere.

a. Find the equation for magnetic field at the centre.

b. If i = 2A in anticlockwise direction find the magnitude and direction of the field at the centre.

We have ;



$$\theta = \frac{Arc}{Radius}$$

$$\theta = \frac{L}{R}$$

We also have L = Rθ . ...(1)

$$dB = \frac{\mu_o idl}{4\pi R^2}$$

$$\int dl = L$$

$$B = \frac{\mu_o i}{4\pi R^2}\int dl$$

$$\Rightarrow \int dl = R\theta \text{ Fromk (1)}$$

$$\Rightarrow B = \frac{\mu_o i\theta}{4\pi R}$$

$$B = \frac{\mu oi\theta}{4\pi R}$$

$$\theta = 60^0 \text{ or } \pi/3$$

$$\Rightarrow B = \frac{\mu_0 i}{4\pi R}\times \pi/3$$

$$\Rightarrow B = \frac{\mu_0 i}{12R}$$

2. i = 2A

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

$$B = \frac{4\pi \times 2\times 10^{-7}}{12R}$$

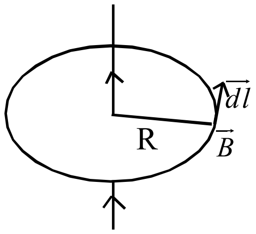
$$B = \frac{4\pi \times 10^{-7}}{6R}$$

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

Ampere's circuital law

The line intergral of the magnetic field along any closed path is equal to μ_0 times the current enclosed by the path.

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

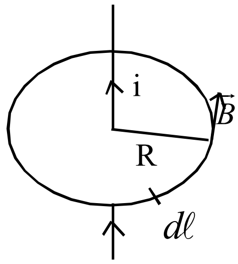


Application of Ampere circuital law

1. Magnetic field at a point due to a long straight wire. - Consider a long straight wire carrying a current i. P is point at a distance 'R' from the wire. - B - magnetic field at P.

From ampere circuited law we have

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



Draw amperian loopat P - Here it in a circle of radius R.

Since B in constant at any point on the loop; $B\oint d\ell = \mu_0 i$

$$\Rightarrow B \times 2\pi R = \mu_0 i$$

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

The direction of the magnetic field is found by right hand thumb rule.

Curl the fingers of the right hand with thumb extended and hold the wire such that the thumb is along the direction of the current, then the curled fingers give the direction of the megnetic field at any point.

Magnetic field due to a solenoid

A conductor wounded in the form of a helical spring A short solinoid behaves as a short magnet with North pole on one side and south pole on the other side.

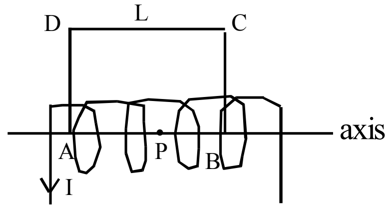
Polarity depends upon the current through it.

Consider an ideal solenoid (Magnetic field at a point inside the solenoid is strong and uniform, but outside is zero)

n - Number of turns/unit length, I - Current through the solenoid. p - magnetic field point.

By ampere's circulated law $\oint Bd\ell = \mu_0$ I endosed ....(1) B - magnetic field at P.

Draw Amperian loopat P-here it is a rectangle of length ℓ number of turns of wire over the length = n ℓ. $\therefore$ I exndosed =n ℓ I



Eq.(1) $\Rightarrow \oint_{ABCD} Bd\ell = \mu_0 n\ell I$ ....(2)

$$\oint_{ABCD} Bd\ell = \int_{AB} Bd\ell + \int_{BC} Bd\ell + \int_{CD} Bd\ell + \int_{DA} Bd\ell$$

$$\int_{AB} Bd\ell = B\ell \quad (\theta = 0, \quad \ell \|^{d} \ to\ B)$$

$$\int Bd\ell = B\ell\ Cos\theta$$

$$\int_{BC} Bd\ell = \int_{DA} Bd\ell = 0 \quad (\theta = 90, \ \ell \perp r\ to\ B)$$

$\int_{CD} Bd\ell = 0$ (For ideal solenoid, outside the solenoid B=0)

$$\oint_{ABCD} Bd\ell = B\ell \text{..........(3)}$$

using (2) and (3),

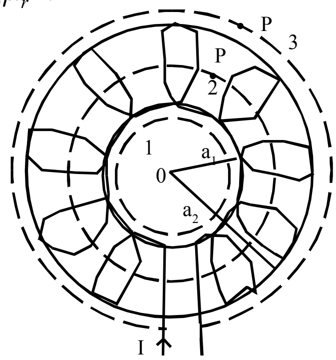
$$B\ell = \mu_0 n\ell I$$

$$B = \mu_0 nI \ \ (core\ is\ air)$$

If the core is a material of relative permiability $\mu r | \mu r = \dfrac{\mu}{\mu_0}$ B= $\mu_0 \mu_r\ nl$

3. Magnetic field due to a Toroid

Toroid - Endless current carrying solenoid.



a) Field point inside the toroid

By ampere's circuital law $\oint_1 Bd\ell = \mu_0 I$ enclosed

But I endosed by the amperian loop is zero. $\therefore B = 0$

b) Field point P on the circular axis of the toroid.

By Ampere's circuital law $\oint_2 Bd\ell = \mu 0\ \ I\ enclosed$ (1)

$\oint_2 Bd\ell = B2\pi a$...........(2) where $a = \dfrac{a_1 + a_2}{2}$

I enclosed = $n2\pi a.I$..............(3)

From Eg. (1), (2), (3) - $B\ 2\pi a = \mu_0 n\ 2\pi a\ I\ = \ B = \mu_0 nI$

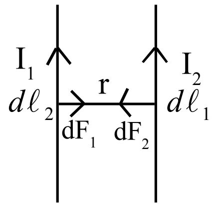
c) Field point P is outside toroid.

By ampere's circuital law $\oint_3 Bd\ell = \mu_0 \ I \ enclosed$

I enclosed = 0 Since current entering the plane of the paper is cancelled by the current leaving from the plane of the paper. $\therefore$ B=0

- A Toroid has no free N - pole and southe pole (its is endless)

<u>Force between two parallel short conductors carrying currents.</u>



By Biot-Savaret's Law

Magnetic field produced by the current element

$$I_1 d\ell_1 \ at \ d\ell_2, \ dB_1 = \frac{\mu_0}{4\pi}\frac{I_1 d\ell_1}{r^2} \quad (\theta = 90)$$

$\therefore$ For experienced by the current element $I_2 d\ell_2$ in this magnetic field is $dF_2 = I_2 \ d\ell_2 \ dB_1$

$$= \frac{\mu_0}{4\pi}\frac{I_1 \ I_2 \ d\ell_1 \ d\ell_2}{r_2} \qquad (\theta = 90)$$

ie, $dF_1 = \frac{-\mu_0}{4\pi}\frac{I_1 \ I_2 \ d\ell_1 \ d\ell_2}{r^2}$ (-ve sign shows direction opposite)

$\therefore dF_1 =^- dF_2, \ attractive$

Force between parallel conductors carrying currents in the same direction (parallel currents) is attractive, it is repulsive in nature. If the currents are in the opposite directions (Anti Parallel Currents).

Qn. An over head cable carries a current of 90 A in the N-S direction. What is the magnitude of magnetic field at a distance 2cm below the wire. What is the direction which principle is used.

$B = \frac{\mu_0}{2\pi}\frac{I}{r} = \frac{2x10^{-7}x90}{2x10^{-2}} = 9x10^{-4}A$, towards East using right hand grip rule.

* When a charged particle moves perpendicular to a magnetic field its momentum changes but its KE and speed remain constant. Because motion of a charged particle in a perpendicular magnetic field is circle.

* Torque acting on a dipole in a magnetic field is $\tau = NIABSin\theta$ (N-Number of truns, A-area, θ angle between m and B. m= NIA, Magnetic moment, Hence $\tau = mBSin\theta$

Moving Coil Galvanometer (MCG) - Used for the measurement of electric current 8 voltage.

Devised by Kelvin Principle - A current loop(Dipole) in a magnetic field experiences torque.

Ns - field magnet - produces radial magnetic field (B)

A-Copper coil of N turns and area A

Sp - Spring - Produces restoring torque.

C - Softiron core to increase the magnetic field B. When electric current I flows through the coil deflecing torque experienced by the coil $\tau def = NIAB$. Restoring torque act by the pring τ rest

= Kθ (Since B parallel to the plane of the coil)

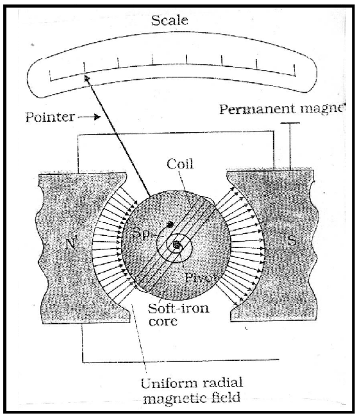
Where θ is the angle though which the coil rotates.

K - Torsional constant of the spring. At equillibrium $\tau_{def} = \tau \ rest$. The coil does not rotate.

NIAB = θ

$$I = \left(\frac{K}{NAB}\right)\theta$$

$I \alpha \theta$, working principle of MCG.



* Pole pieces are cylinderical in shape -
  To produce radial magnetic field.
* Current sensitiveness of MCG -
  The deflection in a galvanometer per unit current, $\theta/I = \dfrac{NAB}{K}$
* How can increase the sensitiveness of MCG : Increase N, B, A and decrease K.
* Voltage sensitiveness of MCG - The deflection in a Galvanometer per unit voltage

$$\theta/V = \frac{\theta}{IRg} = \frac{NAB}{KRg}$$

  where Rg - Resistance of Galvanometer coil.
* Increase in current sensitivity by doubling number of truns may not increase voltage sensitivity - Justify.

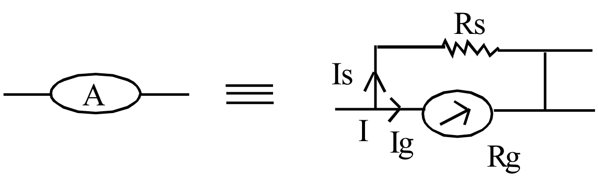
$$\frac{Q}{I} = \frac{NAB}{K}$$

$$If\ N \Rightarrow 2N, \quad (\theta/I)^1 = 2.\frac{\theta}{I}$$

$$But\ Rg \Rightarrow 2Rg \quad (Since\ R\alpha\ell)$$

$$\theta/v = 2\frac{\theta}{I.2Rg} \Rightarrow \frac{\theta}{IRg}$$

* Resistance of Milli Ammeter is greater than resistance of Ammeter - To measure small current greater is the sensitivity of MCG. To increase the sensitivity increase the number of turns (N). This will increase the resistance of Milli Ammeter Since $R\alpha\ell$.
* Figure of merit - Minimum current required to produce a deflection of Idiv on a galvanometer.
  $I\alpha\theta,\ then\ \ I = K\theta,\ \ \ K = \dfrac{I}{\theta}$, Figure of merit.
* Smaller the figure of merit greater is the sensitivity.
* AGalvanometer cannot as such is used as an ammeter to measure the current.
  (i) Due to small resistance and high sensitivity
  (ii) When it is connected to a circuit this will change the value of current because it has a resistance.
* Convert ion of Galvanometer into Ammeter.
  A Low resistance (or shunt resistance) connected in parallel to Galvanometer.



Rs - Shunt resistance
Rg - Galvanometer resistance
Ig - Current for full scale deflection in Galvanometer.

* Resistance of Ammeter (R) Since Rs and Rg are in parallel

$$\frac{1}{\mathrm{R}_{eff}} = \frac{1}{Rs} + \frac{1}{Rg}$$

$$\mathrm{R}_{eff} = \frac{Rs\ Rg}{Rs + Rg} \ll Rg\ of\ Rs < Rg$$

* Ammeter has very low resistance. So it is connected in series with an electrical circuit to measure the current in the circuit.
* Expression for shunt resistance used

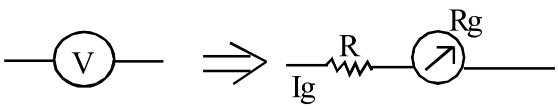
$$P.d(Rs) = Pd(Rg)$$

$$Is\ Rs = Ig\ Rg$$

$$Rs = \frac{Ig\ Rg}{Is} \qquad \mathrm{I=Is+Ig}$$

$$Rs = \frac{Ig\ Rg}{(I - Is)}$$

* Conversion of Galvanometer into voltmeter.
  A high resistance is connected in series with Galvanometer.



* Resistance of voltmeter: Since R and Rg are in series.

  Resistance of voltmeter Ref - R+Rg
* Voltmeter has very high resistance so it is connected in parallel to a circuit to measure voltage.