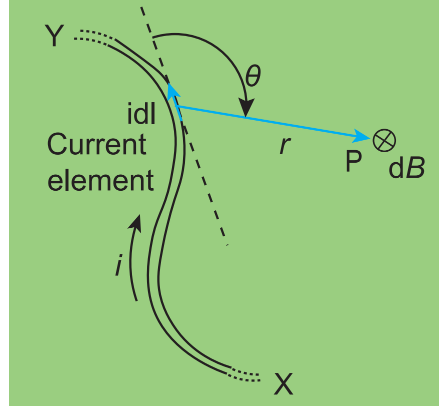
MOVING CHARGES AND MAGNETISM

BIOT – SAVART'S LAW

The Biot – Savart law gives the relationship of magnetic field at any point with current carrying element. $dB = \frac{\mu_o}{4\pi}\int \frac{\vec{d\ell} \times \vec{r}}{|\vec{r}|^3}$

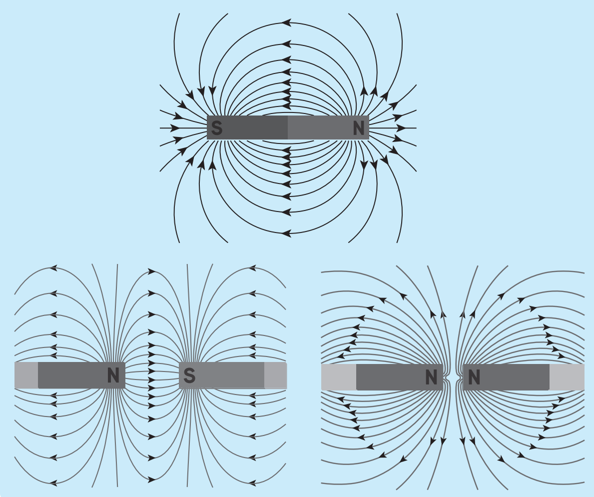


In vector form : $\vec{B} = \frac{\mu_0 i}{4\pi}\int \frac{\vec{dl} \times \vec{r}}{|\vec{r}|^3}$

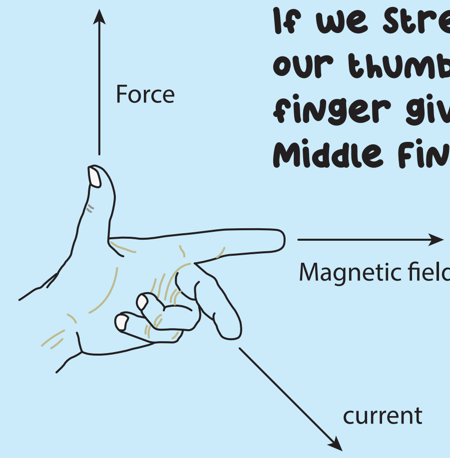
MAGNETIC FIELD

The region around a magnet in which its magnetic influence can be experienced is called magnetic field. $(\vec{B})$

- S.I unit Tesla (T).
- Denote coming out.
- Denote going into the paper.

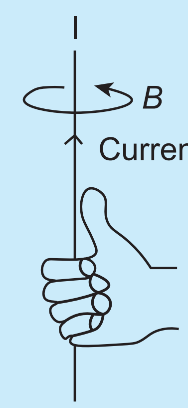


FLEMING'S LEFT-HAND RULE



If we stretch our finger's like image, then our thumb gives direction force, index finger gives direction of magnetic field & middle finger gives current.

RIGHT-HAND RULE

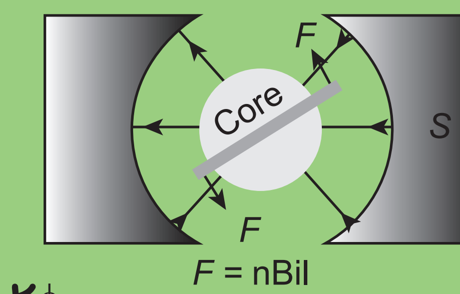


Holding a currant carrying conductor in right hand in such a way that thumb points in the direction of current and curling finger's gives direction of magnetic field.

MOVING COIL GALVANOMETER

It works on the principle that a current carrying coil in uniform magnetic field, experience a torque.

- Torque – $\tau = nBiA$
  n = Number of coils
  A = Area
- Restoring Torque = $\tau = K\phi$
  ϕ = Deflection
- In equillibrium = $\tau = nBiA = K\phi$
  $\rightarrow i = \frac{K}{nBA}\phi$



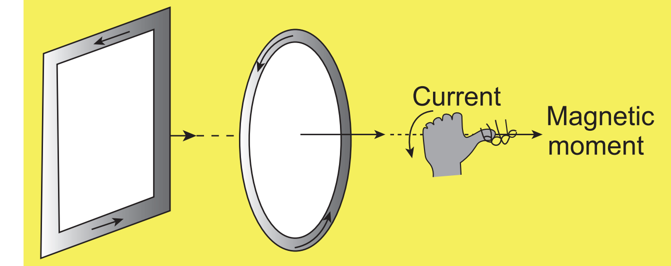
Current sensitivity : $S_i = \frac{\phi}{i} = \frac{nBA}{K}$

Voltage sensitivity : $S_V = \frac{\phi}{i} = \frac{Si}{R} = \frac{nBA}{KR}$

CURRENT CARRYING LOOP AS MAGNETIC DIPOLE

The current carrying coil behaves as a bar magnet and magnetic moment of such coil can be expressed as $M = niA$.

n = Number of coils
A = Area

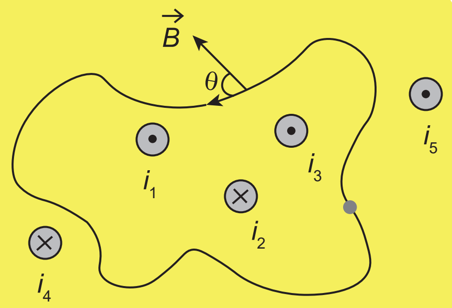


Direction of current in coil show's polarity

AMPERE'S CIRCUITAL LAW

This law states that the line integral of magnetic field $\vec{B}$ around a closed loop is equal to μ_0 times the net current enclosed by the loop.

$\oint \vec{B}.\vec{dl} = \mu_o \sum i_{enclosed}$



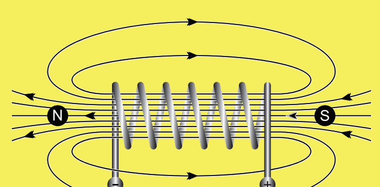
MAGNETIC FIELD OF TOROID :

$B = \mu_0 ni$: Here, $n = \frac{N}{2\pi r}$

r = average radius

N = Total number of turns in toroid.

MAGNETIC FIELD OF LONG SOLENOID :

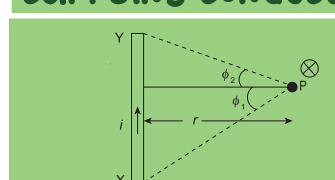
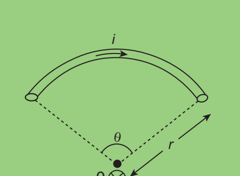
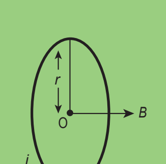
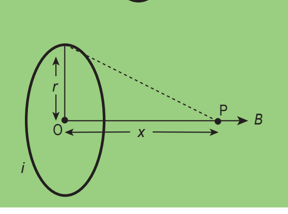


$B = \mu_0 ni$

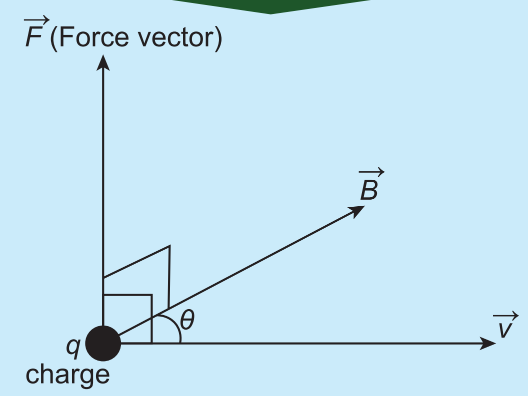
N = Number of turn's per unit length.

i = Current flowing

MAGNETIC FIELD OF SOME SPECIAL CURRENT CARRYING CONDUCTORS

Shape of current carrying conductor	Formula	Special case
	$B = \frac{\mu_o i}{4\pi r}(\sin\phi_1 + \sin\phi_2)\hat{\eta}$	For infinitely long conductor.
	$\vec{B} = \frac{\mu_o i}{2\pi r}\left(\frac{\theta}{360_o}\right)\hat{\eta}$	For semicircular arc.
	$\vec{B} = \frac{\mu_o i}{2\pi r}\hat{\eta}$	r = radius of coil.
	$\vec{B} = \frac{\mu_o ir^2}{2(x^2 + r^2)^{3/2}}$	X = distance from the center of coil.

MAGNETIC FORCE ON A MOVING CHARGED PARTICLE



$\vec{F} = q(\vec{V} \times \vec{B})$, $|\vec{F}| = qVB\sin\theta$

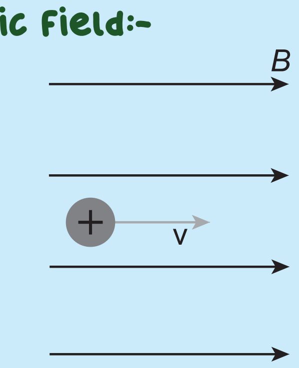
θ = Angle between direction of motion of charge and magnetic field.

- Power delivered by magnetic force to charged particle is always zero.

$P = \vec{F}.\vec{V} = \upsilon[\because(\vec{F} \perp \vec{V})]$

Path of charged particle in external magnetic field:-

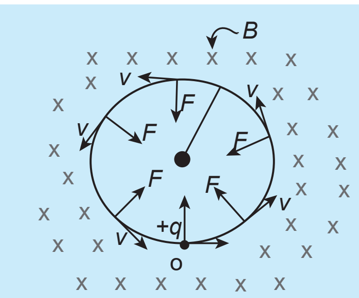
Case 1:



When charged particle is moving parallel or antiparallel to magnetic field: Magnetic force $F = qvB\sin\theta = 0$

Charge particle move un – deviated Radius of path is $r = \infty$

Case 2:



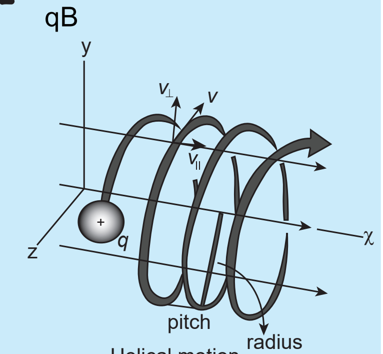
When charge particle moving perpendicular to magnetic field:- Magnetic force – $F = qvB\sin 90° = qvB$

$\therefore \frac{mv^2}{r} = qvB \Rightarrow r = \frac{mV}{qB}$

$\therefore$ Radius of circular- path $r = \frac{mV}{qB}$

Time period – $T = \frac{2\pi m}{qB}$

Case 3:



When charge particle is moving in any orbitary direction with respect to magnetic field:- Magnetic force $F = q(\vec{V} \times \vec{B}) = qvB\sin\theta$

Charge particle follow helical path.

Radius of helix – $r = \frac{mV\sin\theta}{qB} = \frac{mV_\perp}{qB}$

Time period – $T = \frac{2\pi}{qB}$

Bohr Magneton

The magnetic moment associated with an electron which is revolving in first orbit of an atom.

It is represented as:-

$\mu_B = \frac{eh}{4\pi m} = 0.923 \times 10^{-23}\ Am^2$

e = electronic charge
m = mass of electron
h = Planck & constant

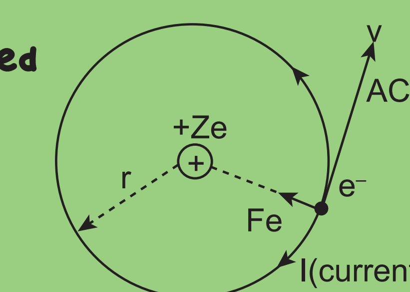
ATOMIC MAGNETISM

When an electron revolves, due to its movement it behaves as a current carrying loop and produce magnetic field. This is known as atomic magnetism.

Orbital Current

The orbital current generated by electron revolving around nucleus $I = \frac{e\omega}{2\pi}$

ω is angular velocity of electron.



Magnetic induction at nucleus position

$B = \frac{\mu_o I}{2r} = \frac{\mu_o ew}{4\pi r}$

r = orbital radius, I = orbital current

Magnetic moment circular orbit

$M = IA = \frac{ewr^2}{2} = \frac{evr}{2}$ A = Area of orbit.

Relation between magnetic moment and angular momentum of charge particle

$M = \frac{qL}{2m} \Rightarrow \frac{M}{L} = \frac{q}{2m}$

where, M = Magnetic moment
L = mvr – Angular momentum
m = mass of particle.

Torque acting on current carrying coil:	Work done in rotating a coil placed in magnetic field:	Potential energy of a coil placed in magnetic field:
$\tau = nBiA\sin\theta$ N = Number of turns A = Area I = current Magnetic moment – $\vec{M} = i\vec{A}$ $\therefore \vec{\tau} = \vec{M} \times \vec{B}$	$W = MB(1 - \cos\theta)$ Here, M = Magnetic moment of coil.	$U = -MB\cos\theta$ $= -\vec{M}.\vec{B}$

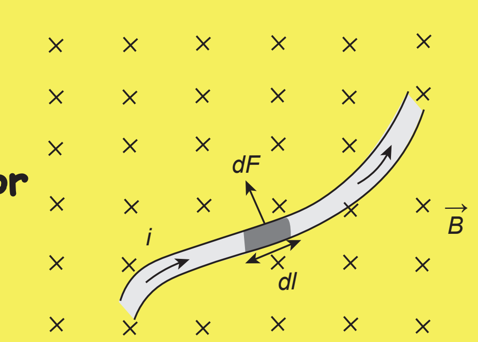
MAGNETIC EFFECT OF CURRENT

Force on current carrying conductor in magnetic field

In uniform magnetic field the total force acting on conductor of length L is expressed as.

$\vec{F} = i(\vec{L} \times \vec{B}) = iLB\sin\theta$

θ = Angle made by current direction with magnetic field.



Force between two parallel current carrying conductor' s

$F_1 = F_2 = F = \frac{\mu_o i_1 i_2}{2\pi a} \times L$

a = distance between two wires.

L = Length of wires.