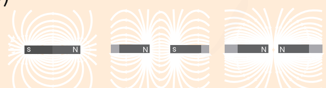
MOVING CHARGES AND MAGNETISM

MAGNETIC FIELD

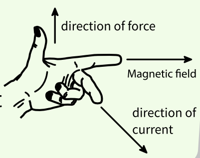
The Region around a magnet in which its magnetic influence can be experienced is called magnetic field. (B)



- ✦ S.I unit Tesla (T).
- ✦ Denote magnetic field Coming out ⊙.
- ✦ Denote magnetic field going into the paper ⊗ .

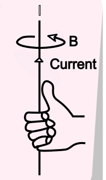
FLEMING'S LEFT-HAND RULE

If we stretch our left hand finger's like image, then thumb gives direction Force, Index finger gives direction of Magnetic Field & Middle Finger gives direction current and thumb indicates the direction of force



AMPERE'S RIGHT-HAND RULE

Holding a current 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.



Lorentz force

Force experienced when a charged particle of charge (q) moves with velocity (v) in presence of electric field $\vec{E}$ and Magnetic Field $\vec{B}$.

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

BIOT – SAVART'S LAW

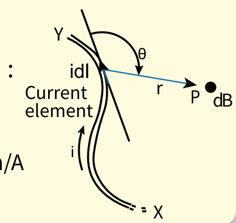
The Biot–Savart law gives the relationship of magnetic field at any point with current carrying element.

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

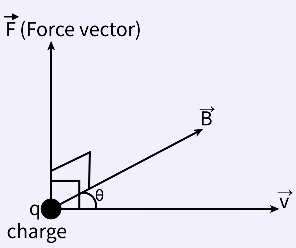
In vector form :

$$\vec{B} = \frac{\mu_0 i}{4\pi}\int \frac{d\vec{l} \times \vec{r}}{|r|^3}$$

$\mu_0 = 4\pi \times 10^{-7}$ T.m/A



MAGNETIC FORCE ON A MOVING CHARGED PARTICLE



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

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

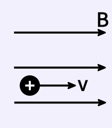
Power delivered by Magnetic Force to charged Particle is always zero.

$P = \vec{F}.\vec{V} = 0$ [∴$(\vec{F} \perp \vec{V})$]

Path of charged particle in External Magnetic Field:-

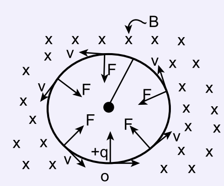
Case1: When charged particle is moving parallel or antiparallel to magnetic field: magnetic force

$F = qvB\sin\theta = 0$



Charge Particle move un – deviated

Radius of Path is $r = \infty$



Case2: When charged Particle moving perpendicular to magnetic Field:- Magnetic Force

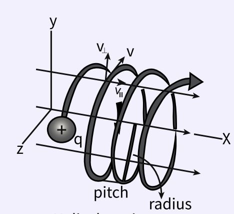
$F = qvB\,\text{Sin}90^\circ = qvB$

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

∴ Radius of circular- Path

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

Time period - $T = \frac{2\pi m}{B}$



Helical motion

Case3: When charged particle is moving in any orbitary direction with respect to Magnetic Field:- Magnetic Force

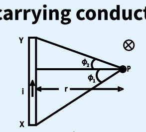
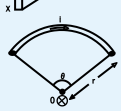
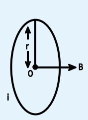
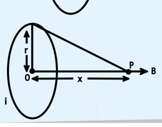
$\vec{F} = q(\vec{V} \times \vec{B})$; $F = qVB\sin\theta$

Charged particle follow Helical path.

Radius of Helix $-r = \frac{mV\sin\theta}{qB} = \frac{mV_\perp}{qB}$

Time period $-T = \frac{2\pi r}{qB}$

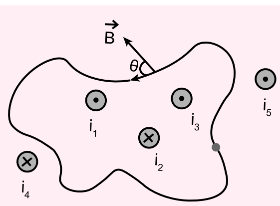
Magnetic Field of Some Special Current Carrying Conductors

Shape of current carrying conductor	Formula	Special case
	$\vec{B} = \frac{\mu_o i}{4\pi r}(\text{Sin}\phi_1 + \text{Sin}\phi_2)\hat{n}$	For infinitely long conductor. $\vec{B} = \frac{\mu_0 i\,\hat{n}}{2\pi r}$
	$\vec{B} = \frac{\mu_o i}{2r}(\frac{\theta}{360^\circ})\hat{n}$	For Semicircular arc. $\vec{B} = \frac{\mu_0 i\,\hat{n}}{4r}$
	$\vec{B} = \frac{\mu_o i}{2r}\hat{n}$	r = radius of Coil.
	$\vec{B} = \frac{\mu_o i r^2}{2(x^2 + r^2)^{3/2}}$	X = distance from the center of coil.

AMPERE'S CIRCUITAL LAW

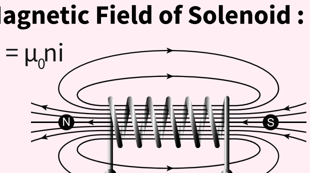
This Law states that the line integral of magnetic field around a closed loop is equal to μ_0 times the net current enclosed by the loop.

$$\oint \vec{B}.d\vec{l} = \mu_0 \Sigma i_{enclosed}$$



Magnetic Field of Solenoid :

$B = \mu_0 ni$

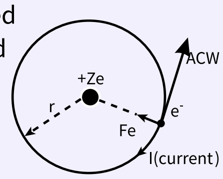


n = Number of turn's per unit length.
i = Current flowing

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

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

r = orbital Radius, I = orbital current

Magnetic Moment circular orbit

$$M = IA = \frac{e\omega r^2}{2} = \frac{evr}{2}$$, A= Area of orbit.

Bohr Magneton

The magnetic moment associatedwith an electron which is revolving in First orbit of an atom. It is represented as:-

$$\mu_B = \frac{eh}{4\pi m} = 0.927 \times 10^{-23}\ Am^2$$

where, e = electronic charge, m = mass of electron, h = Planck's Constant

MOVING COIL GALVANOMETER

It works on the principle that a current carrying Coil in uniform magnetic Field, experience a Torque.

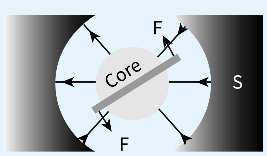
Torque - $\tau = NBiA$

N = Number of turns in the coil

A = Area

Restoring Torque $= \tau = K\phi$

ϕ = Deflection



F =nBil

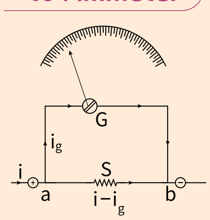
In Equilibrium $= \tau = NBiA = K\phi$

$\rightarrow i = \frac{K\phi}{NBA}$

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

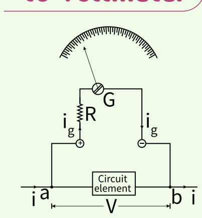
Voltage sensitivity : $S_V = \frac{\phi}{V} = \frac{S_i}{R} = \frac{NBA}{KR}$

Galvanometer to Ammeter



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

Galvanometer to Voltmeter

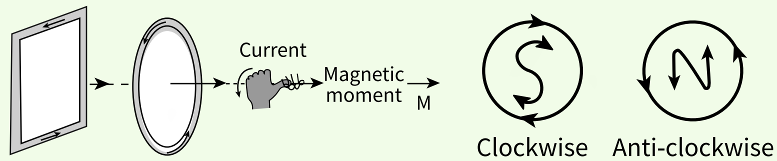


$$R = \frac{V}{i_g} - G$$

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 turns in the coil   A = Area



Clockwise   Anti-clockwise

Direction of current in Coil show's Polarity

ATOMIC MAGNETISM

When an electron revolves in a bounded orbit around nucleus, due to its movement it behaves as a current carrying loop and produce magnetic field. This is known as Atomic Magnetism.

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.

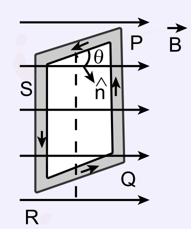
Torque Acting on current Carrying Coil:

$\tau = NBiA\ Sin\theta$

N = Number of turns, A = Area , I = current

Magnetic moment – $\vec{M} = i\vec{A}$

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



Work done in Rotating a coil placed in magnetic Field:

W = MB (1 - Cosθ)

Here, M = Magnetic Moment of coil.

Potential Energy of a Coil Placed in Magnetic Field:

$$U = -MB\cos\theta = -\vec{M}.\vec{B}$$

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,

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

θ = Angle made by current direction with magnetic Field.

Force between two Parallel Current Carrying Conductors

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

a = distance between two wires
L = Length of the wire.