Mind Map-4

⊗ **Cross,** if magnetic field is directed perpendicular and into the plane of the paper
• **Dot**, if magnetic field is directed perpendicular and out of the plane of the paper.

Galvanometer to ammeter conversion : Low resistance or shunt connected in parallel

$$S = \left(\frac{I_g}{I - I_g}\right)G$$

Reading of ammeter is always less than actual current in the circuit.

Galvanometer to voltmeter conversion : High resistance

in series $R = \dfrac{V}{I_g} - G$

Greater the resistance of voltmeter, more accurate its reading.

Magnetic field due to a straight current carrying conductor of

infinite lenght $B = \dfrac{\mu_0 I}{2\pi R}$

Biot-Savart's law
Magnetic field due to current carrying element, $dB = \dfrac{\mu_0}{4\pi}\dfrac{Idl\sin\theta_n}{r^2}$
It is an inverse-square law and is the magnetic analogue of coulomb's law

Magnetic field due to a current carrying circular loop

On the axis of circular loop
$$B = \dfrac{\mu_0 NIa^2}{2(r^2 + a^2)^{3/2}}$$
If a >> r, B = ℓ
$$\dfrac{\mu_0}{4\pi}\cdot\dfrac{2NiA}{a^3}$$

At the centre of circular loop $B = \dfrac{\mu NI}{2R}$
Magnetic field due to circular current carrying are $B = \dfrac{\mu_0 I}{2r}$

Direction of magnetic field- Depends upon the direction of current. **Right hand thumb rule-** Thumb points in the direction of current, curling of fingers represents direction of magnetic field.

Magnetic field space in the surrounding of a magnet or any current carrying conductor in which its magnetic influence can be experienced

Moving Charges And Magnetism

Magnetic field due to a current carrying wire at a point which lies at a perpendicular distance

r from the wire $B = \dfrac{\mu_0}{4\pi}\cdot\dfrac{1}{r}(\sin\phi_1 + \sin\phi_2)$

or, $B = \dfrac{\mu_0}{4\pi}\cdot\dfrac{1}{r}(\cos\alpha - \cos\beta)$

For a wire of finite length Magnetic field at a point which lies on perpendicular bisector of finite length wire $B = \dfrac{\mu_0}{4\pi}\cdot\dfrac{1}{r}(2\sin\phi)$

For a wire of infinite length When the linear conductor is of infinite length and the point lies near the centre of the conductor.
$B = \dfrac{\mu_0}{4\pi}\dfrac{i}{r}(\sin 90° + \sin 90°) = \dfrac{\mu_0}{4\pi}\dfrac{2i}{r}$

For a wire of semi-infinite length When the linear conductor is of infinite length and the point lies near the end
$B = \dfrac{\mu_0}{4\pi}\cdot\dfrac{i}{r}(\sin 90° + \sin 0°) = \dfrac{\mu_0 i}{4\pi r}$

For axial position of wire When point lies on axial position of current carrying conductor then magnetic field $\vec{B} = 0$

Magnetic field due to a **solenoid**.
Inside a long solenoid $B = \mu_0 nI$
At a point on one end $B = \dfrac{\mu_0 nI}{2}$
n – number of turns per unit length

Ampere's circuital law
$\oint Bdl = \mu_0 \Sigma i$ Absolute permeability of air or vacuum,
$\mu_0 = 4\pi\times 10^{-7}\dfrac{Wb}{Amp-metre}$

Magnetic field due to a **toroid**
$B = \mu_0 nI$; $n = \dfrac{N}{2\pi r}$

Magnetic field due to a cylindrical wire.
Outside the cylinder Magnetic field $B_{out} = \dfrac{\mu_0 I}{2\pi r}$ and $B_{surface} = \dfrac{\mu_0 I}{2\pi r}$

Inside the hollow cylinder
Magnetic field inside the hollow cylinder is zero.

Magnetic field within the solenoid is uniform and parallel to the axis of solenoid.

Ampere law is analogous to Gauss's law $\oint \vec{E}\cdot d\vec{s} = \dfrac{q}{\epsilon_0}$
This law is valid for symmetrical current distributions and is based on the principle of electromagnetism

Toroid is like an endless cylindrical solenoid. Number of turns per unit length $n = \dfrac{N}{2\pi r}$

Inside the solid cylinder
Magnetic field $B = \dfrac{\mu_0}{2\pi}\cdot\dfrac{ir}{R^2}$
Inside the thick portion of hollow cylinder:
$B = \dfrac{\mu_0 i}{2\pi r}\cdot\dfrac{(r^2 - R_1^2)}{2\pi r(R_2^2 - R_1^2)}$

Motion of a charged particle in a uniform magnetic field follows a circular path, radius

$$r = \dfrac{MV\sin\theta}{Bq}$$

Force on a conductor carrying current in a uniform magnetic field,
$F = I B l \sin\theta$
$F = I (B \times l)$

Force between two parallel current carrying conductors
$$F = \dfrac{\mu_0}{4\pi}\cdot\dfrac{2I_1 I_2}{r}\times l$$

If two charges q_1, q_2 are moving with velocities v_1 and v_2 and at any instant distance between then is 'r'
$$F_{magnetic} = \dfrac{\mu_0}{4\pi}\dfrac{q_1 q_2 v_1 v_2}{r^2}$$
For charges moving with same velocity
$F_{magnetic} < F_{electrostatic}$

Force acting on a charged particle moving in a uniform magnetic field $F = qVB$
$\sin\theta = q(V \times B)$

Lorentz force
$F = q[\vec{E} + \vec{V}\times\vec{B}]$
Electric force,
$\vec{F}_e = q\vec{E}$
Magnetic force,
$\vec{F}_m = q(\vec{v}\times\vec{B})$

Zero force i.e., F = 0 on a charged particle, if field $\vec{B} = 0$
charge q = 0
charge is at rest, v = 0
when $\theta = 0°$ or 180°

• When $\vec{V}$, $\vec{E}$ and $\vec{B}$ are all collinear $F_{magnetic} = 0$
$\vec{F}_e = q\vec{E} \Rightarrow \vec{a} = \dfrac{\vec{F}}{m} = \dfrac{q\vec{E}}{m}$
• When $\vec{V}$, $\vec{E}$ and $\vec{B}$ are mutually perpendicular
$\vec{F} = \vec{F}_e \Rightarrow \vec{F}_m = 0$
$\Rightarrow a = \dfrac{\vec{F}}{m} = 0$

Direction of force If two conductors carry current in same direction, force between them is attractive and if carry currents in opposite direction force between them is repnisive

Torque experienced by a current carrying loop in a uniform magnetic field $\vec{T} = MB\sin\theta\hat{n}$
$= M \times B$

• **Torque** experienced is zero when $\theta = 0$ i.e. plane of the coil is perpendicular to the field.
• **Torque** is maximum when $\theta = 90°$ i.e., plane of the coil is parallel to the field, $T_{max} = NBiA$
• **Work** done, $W = MB(1 - \cos\theta)$
W_{max}, if $\theta = 180°$
$W_{max} = 2MB$
• Potential energy,
$U = -MB\cos\theta \Rightarrow U = -\vec{M}.\vec{B}$

Trajectory of a particle is a straight, line, if the direction of a particle moving with velocity $\vec{v}$ parallel or anti-parallel to $\vec{B}$
i.e., $\theta = 0$ or $\theta = 180°$

Trajectory of a particle is a circle if particle velocity $\vec{v}$ perpendicular to $\vec{B}$ i.e., $\theta = 90°$ and radius of path,
$$r = \dfrac{mV}{qB} = \dfrac{1}{B}\sqrt{\dfrac{2mV}{q}}$$

Trajectory of a particle is helical if a charged particle is moving at an angle to the field other than 0°, 90°, 180° and radius of path r = $\dfrac{m(V\sin\theta)}{qB}$

Cyclotron.
A device used to accelerate positively charged particles like α-particles, deuterons, etc. to acquire sufficient energy to carry out nuclear disintegration.
• Cyclorton frequency $v = \dfrac{qB}{2\pi m}$
Cyclotron frequency also known as magnetic resonance frequency
• Time period, $T = \dfrac{2\pi m}{qB}$
• Maximum energy gained by charged particle
$$E_{max} = \left(\dfrac{q^2 B^2}{2m}\right)r^2$$