Mind Map–4

@anjit

MOVING CHARGES AND MAGNETISM

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

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 due to a straight current carrying conductor of infinite length $B = \frac{\mu_0 I}{2\pi R}$

⊗ **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 $R = \frac{V}{I_g} - G$

Greater the resistance of volt-meter, more accurate is reading.

Biot-Savart's law
Magnetic field due to current carrying element, $dB = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta_n}{r^2}$
It is an imverse-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 $B = \frac{\mu_0 NIa^2}{2(r^2 + a^2)^{3/2}}$
If $a \gg r, B = \ell$
$\frac{\mu_0}{4\pi} \cdot \frac{2NiA}{a^3}$

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

Magnetic fields die to a current carrying wire at a point which lies at a perpendicular distance r from the wire $B = \frac{\mu_0}{4\pi} \cdot \frac{1}{r} (\sin\phi_1 + \sin\phi_2)$

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

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

For a wire of infinite length When the linear conductor is of infinite length and the point lies near the centre of the conductor.

$B = \frac{\mu_0}{4\pi} \frac{i}{r} (\sin 90^\circ + \sin 90^\circ) = \frac{\mu_0 2i}{4\pi r}$

For a wire of semi-infinite length When the linear conductor is of infinite length and the point lies near the end

$B = \frac{\mu_0}{4\pi} \cdot \frac{i}{r} (\sin 90^\circ + \sin 0^\circ) = \frac{\mu_0 i}{4\pi r}$

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

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

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

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

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

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

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

Magnetic field due to a cylindrical wire.
Outside the cylinder Magnetic field $B_{out} = \frac{\mu_0 i}{2\pi r}$ and $B_{surface} = \frac{\mu_0 i}{2\pi r}$
Inside the hollow cylinder
Magnetic field inside the hollow cylinder is zero.

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

Motion of a charged particle in a uniform magnetic field follows a circular path, radius
$r = \frac{MV \sin\theta}{Bq}$

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

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 θ = 0° or 180°

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., θ = 0 or θ = 180°

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

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

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

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

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

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 repulsive

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

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'
$F_{magnetic} = \frac{\mu_0}{4\pi} \frac{q_1 q_2 v_1 v_2}{r^2}$
For charges moving with same velocity
$F_{magnetic} < F_{electrostatic}$

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

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