Moving Charges & Magnetism

Oersted law

In April, 1820, Hans Christian Oersted discovered that flow of current in a wire could deflect a nearby magnetic compass needle.

Magnetic field ($\vec{B}$)

- It is a region around a magnet or current carrying conductor or a moving charge in which its magnetic effect can be felt.
- SI unit is Tesla (T) = weber/m^2
- 1 Gauss = 10^{-4} Tesla

Magnetic force on moving charge

$\vec{F} = q\vec{v}\times\vec{B}$

$= qvB\sin\theta$

- For $\theta = 0$, $\vec{F} = 0$ along the magnetic field
- For $\theta = 90°$, i.e., if charge's velocity is perpendicular to field direction, force is perpendicular to both field and velocity.
- $F = qvB = \dfrac{mv^2}{r}$

  $r = \dfrac{mv}{qB}$ = Radius of the circle in which charge rotates
- Time period (T) = $\dfrac{2\pi m}{qB}$
- ν (frequency) = $\dfrac{1}{T} = \dfrac{qB}{2\pi m}$

Cyclotron

$T = \dfrac{2\pi m}{qB} = \dfrac{1}{\nu_c}$

$U = qBR/M$

$KE = \dfrac{1}{2}mu^2 = \dfrac{(qBR)^2}{2m}$

Here, R in the radius of D's

Ampere's law

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

where, i = total current crossing the area bounded by closed curve.

Solenoid

- Magnetic field at a point inside due to a long solenoid, $B = \mu_0 ni$
- And at point on one end, $B = \dfrac{\mu_0 ni}{2}$

where n = number of turns per unit length along the length of solenoid.

Magnetic field due to toroid

$B = \dfrac{\mu_0 Ni}{2\pi r}$, N = Total number of turns, i = Current in toroid

Force on a current carrying conductor

$d\vec{F} = i\,d\vec{l} \times \vec{B}$, $F = ilB\sin\theta$

Force between parallel current carrying wires

$F = \dfrac{\mu_0 i_1 i_2}{2\pi d}L$

Torque experienced by a loop in uniform magnetic field

$\vec{\tau} = mB\sin\theta\,\hat{n} = \vec{m}\times\vec{B}$

Definition of Ampere

If two parallel wires kept 1 m apart, and experienced force $F = 2\times10^{-7}$N, then current = 1A in each.

Sensitivity

Current: $\dfrac{\phi}{I} = NBA/K$

Voltage: $\dfrac{\phi}{V} = \left(\dfrac{NBA}{K}\right)\dfrac{1}{R}$

Conversion of galvanometer

into voltmeter: $R = \dfrac{V}{I_g} - G$

into ammeter: $S = \dfrac{I_g}{I - I_g}G$

Biot-Savart law

Mathematical

$d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{id\vec{l}\times\vec{r}}{r^3}$

$dB = \dfrac{\mu_0}{4\pi}\dfrac{idl\sin\theta}{r^2}$

where $\mu_0 = \dfrac{1}{\varepsilon_0 c^2}$

$= 4\pi \times 10^{-7}$ TmA^{-1}

θ = Angle between $d\vec{l}$ and $\vec{r}$

Direction of field will be perpendicular to plane containing current element and the point of observation.

Here, $c = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

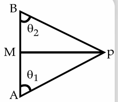
Symbolic field

Outside ⊙ In side ⊗

Magnetic field due to straight wire current

- $B = \dfrac{\mu_0 i}{4\pi r}(\sin\theta_1 - \sin\theta_2)$

  Where, θ_1 and θ_2 are the angles corresponding to the lower and upper ends respectively.



- Field due to a long straight wire current i.e., $\theta_1 = 0$, $\theta_2 = \pi/2$

  $B = \dfrac{\mu_0 I}{4\pi r}$

Field due to a circular current

Field at the centre: $B = \dfrac{\mu_0 i}{2a}$

Field at an axial point: $B = \dfrac{\mu_0 i a^2}{2(a^2 + d^2)^{3/2}}$

Field at a point far away from the centre: i.e. for d>>>a

$B = \dfrac{\mu_0 i a^2}{2d^3}$

Trace the Mind Map

- First Level
- Second Level
- Third Level