Moving Charges and Magnetism

- **Biot – Savart law:** The magnitude of Magnetic Field $d\vec{B}$ is proportional to the steady current I due to an element $d\vec{l}$ at a point P and inversely proportional to the distance r from the current element is, $d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{l} \times \vec{r}}{r^3}$
- **Magnetic field due to long straight current carrying conductor:** $B = \frac{\mu_o I}{4\pi a}[\sin\phi_1 + \sin\phi_2]$
- If conductor is infinitely long, $B = \frac{\mu_o I}{2\pi a}$
- Right-hand rule is used to find the direction of magnetic field due to straight current carrying conductor.
- **Force on a Straight Conductor:** Force F on a straight conductor of length l and carrying a steady current I placed in a uniform external magnetic field B, $\vec{F} = I(\vec{l} \times \vec{B})$
- **Lorentz Force:** Force on a charge q moving with velocity v in the presence of magnetic and electric fields B and E. $\vec{F} = q(\vec{v} \times \vec{B} + \vec{E})$
- **Magnetic Force:** The magnetic force $\vec{F_B} = q(\vec{v} \times \vec{B})$ is normal to $\vec{V}$ and work done by it, is zero.
- **Cyclotron:** A charge q executes a circular orbit in a plane normal with frequency called the cyclotron frequency given by $\nu_c = \frac{qB}{2\pi m}$
  This cyclotron frequency is independent of the particle's speed and radius.
- **Magnetic Field due to Circular current carrying Coil:** Magnetic field due to circular coil of radius 'a' carrying a current I at an axial distance r from the centre- $B = \frac{\mu_0 I a^2}{2(r^2 + a^2)^{3/2}}$
  At the centre of the coil, $B = \frac{\mu_0 I}{2a}$
- **Ampere's Circuital Law:** For an open surface S bounded by a loop C, then the Ampere's law states that $\oint_C \vec{B}.d\vec{l} = \mu_0 I$ where I refers to the current passing

through S.

- If B is directed along the tangent to every point on the perimeter, then $BL = \mu_0 I_e$ Where Ie is the net current enclosed by the closed circuit.
- **Magnetic Field:** Magnetic field at a distance R from a long, straight wire carrying a current I is given by, $B = \frac{\mu_0 I}{2R}$
  The field lines are circles concentric with the wire.
- **Magnetic field B inside a long Solenoid carrying a current I:** $B = \mu_0 nI$ Where n is the number of turns per unit length.
- For a toroid, $B = \frac{\mu_0 NI}{2\Pi r}$ Where N is the total numbers of turns and r is the average radius.
- **Magnetic Moment of a Planar Loop:** Magnetic moment m of a planar loop carrying a current I, having N closely wound turns, and an area A, is $\overrightarrow{m} = NI\overrightarrow{A}$
- **Direction of $\overrightarrow{m}$ is given by the Right – Hand Thumb Rule:** Curl and palm of your right hand along the loop with the fingers pointing in the direction of the current, the thumb sticking out gives the direction of $\vec{m}$
- **Loop placed in a Uniform Magnetic Field:**

1. When this loop is placed in a uniform magnetic field B, Then, the force F on it is, F = 0

   And the torque on it is $\overrightarrow{\tau} = \overrightarrow{m} X \overrightarrow{B}$

   In a moving coil galvanometer, this torque is balanced by a counter torque due to a spring, yielding.

   $k\phi = NI$ AB Where ϕ is the equilibrium deflection and k is the torsion constant of the spring.

- **Magnetic Moment in an Electron:** An electron moving around the central nucleus has a magnetic moment μ_l, given by
  $\mu_l = \frac{e}{2m} l$ Where l is the magnitude of the angular momentum of circulating electron about the central nucleus.
- **Bohr Magneton:** The smallest value of μ_l is called the Bohr magneton μBOr