13. Magnetic Effects of Electriuc Current

Ampere's circuital law

- The line integral of magnetic field induction B→ around a closed path in vacuum is equal to m_0 times the total current *I* threading it.

  ∫B→.dl→=μ0nI

Applications of Ampere's circuital law

- Magnetic field (*B*) due to a long straight conductor carrying current is given by **B = μ04π2Ir.**

  Here, *r* = radius and *I* = current

Solenoid

- It consists of an insulating long wire closely wound in the form of a helix.
- The magnetic field induction at a point as well as inside a solenoid is given by $B = \mu_0 nI$. Here, *n* is the number of turns of the solenoid and *I* is the current flowing in the solenoid.

Toroid

It is a hollow circular ring on which a large number of turns of wire are closely wound.

The magnetic field (*B*) due to a toroid is given by B= μ0nI2πr.

Here, *r* = radius, *I* = current and *N* = no. of turns of the toroidal coil

Moving Coil Galvanometer

- Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque that deflects the coil connected with the pointer.
- The suspension wire provides the restoring or control torque.
- The relation between deflection θ and current (I) is given by I=kNBAθ.
  - kNBA=G is the galvanometer constant.
  - Current sensitivity =NABk
  - Voltage sensitivity = NABk1R
- **Conversion of a Galvanometer into an Ammeter**
  - It can be converted into an ammeter by introducing a shunt resistance (r_s) of small value in parallel with it.
- **Conversion of a Galvanometer into a Voltmeter**

- It can be converted into a voltmeter by introducing a series resistance of large value in series with it.
- **Advantages of a Moving Coil Galvanometer**
  - It is not affected by the Earth's magnetic field.
  - It has a high value of torque-weight ratio.
  - It is highly accurate and reliable.
  - Its scales are uniform.

- Sensitivity of moving coil galvanometer is given by S = NBAC.

  Here,
  N = number of turns in the coil
  B = magnetic field
  A = area of the rectangular coil
  C = twist constant of the suspension wire

- Fractional error in a galvanometer is given by dII=dθθ.

Motion of a charged particle in a uniform magnetic field

- In a uniform magnetic field B, a charge q executes a circular orbit in a plane normal to B.
- The magnetic force acts as the centripetal force.
- q(v⟶× B⟶)=mv2r

If v⟶and B⟶ are at right angles, then radius of the circular orbit, r=mvBq

- Time period (T), T=2πmqB
- Frequency of rotation, ω=Bqm

Motion of a charged particle in combined electric and magnetic field

- Generally, a charged particle moves in a spiral path when the magnetic and electric field are combined.
- **Velocity selector**
  - The magnetic and the electric field are perpendicular to each other.
  - At a certain velocity at which the the net force due to the magnetic and the electric field is zero, we have:

    qvB=qEor v=EB

Cyclotron

- It works on the principle that the frequency of revolution of a charged particle is not dependent on the energy.
- The electric and the magnetic field are used in combination to increase the energy.
- **Cyclotron frequency:**

v=Bqm

Limitations of Cyclotron

- It cannot accelerate uncharged particles like neutrons.
- There is a limit of speed beyond which a charged particle cannot be accelerated by a cyclotron.
- It cannot produce highly energetic particles with energy of the order of 500 MeV.