13. Magnetism

Bar Magnet

- It consists of a magnetic dipole.
- The two poles of a magnet point to the North and South Poles of the Earth when the magnet is suspended freely.
- Properties of magnetic poles:
  - Like poles repel each other and unlike poles attract each other.
  - They can never be separated.
- Magnetic length is the distance between the two poles of a magnet.
- Magnetic dipole moment is the product of either pole strength and magnetic length of a magnet.
- Magnetic dipole moment is a vector quantity. Its SI unit is joule/tesla or ampere-metre^2.
- A current-carrying coil behaves like a magnetic dipole whose one face represents the North Pole and the other face represents the South Pole.
- The magnetic moment of a current-carrying coil is given by $M = nIA$.
- The magnetic moment of a bar magnet is equal to the magnetic moment of an equivalent solenoid that produces the same magnetic field.
- The magnetic field of a small bar magnet along the axial line is given by B=μ4π2Mr3.
- The magnetic field of a small bar magnet along the equatorial line is given by
  B equals fraction numerator mu over denominator 4 pi end fraction M over r cubed.

Magnetic Field Lines

- A magnetic field line is an imaginary curve the tangent to which at any point gives the direction of magnetic field B with rightwards arrow on top at that point.
- Magnetic field lines move from the South Pole to the North Pole within the magnet's material and from the North Pole to the South Pole outside it.
- Magnetic field lines do not intersect each other.

Magnetic dipole in a uniform magnetic field

- Equal and opposite forces act on the poles, which constitute a couple on the bar magnet.
- The net torque(τ) acting on the magnetic dipole,
  - tau with rightwards arrow on top equals M with rightwards arrow on top cross times B with rightwards arrow on top
    Here, M is the magnetic moment of the dipole and B is the magnitude of the magnetic field.

Electrostatic Analogue

- The equations for magnetic field $\vec{B}$ due to a magnetic dipole can be obtained from the equation of an electric field $\vec{E}$ due to an electric dipole, by making the following changes:

$\vec{E} \rightarrow \vec{B}$

$\vec{p} \rightarrow \vec{M}$

$\frac{1}{4\pi\varepsilon_0} \rightarrow \frac{\mu_0}{4\pi}$

- Magnetic induction due to a bar magnet at any point on the axis,

B = μ04π2Mrr2-l22
Here, M = magnetic moment of the bar magnet
r = distance of the points where the magnetic field is to be calculated along the axis of the dipole.

- Magnetic induction due to a bar magnet at any point on the equator,

B = μ04πMr2-l232
Here, M = magnetic moment of the bar magnet
r = distance of the points where the magnetic field is to be calculated along the equatorial line of the dipole

Earth's Magnetism

Dynamo effect −According to this the earth's magnetic field is due to electrical currents produced by convective motion of metallic fluids in the outer core of the earth.

Magnetic elements

Magnetic declination(θ) − It is the angle between the geographic meridian and magnetic meridian.
Magnetic inclination or dip(δ**)** − It is defined as the angle made by the direction of the earth's total magnetic field with the horizontal direction.
Horizontal component of earth's magnetic field − It is the component of earth's magnetic field along the horizontal direction. It is denoted by B_H.

BsinδBcosδ=BVBHtanδ=BVBH

Permanent magnets

- Those substances which remain ferromagnetic at room temperature for a long period of time are called permanent magnets.
- Methods of making permanent magnets:
  - Holding a steel rod and striking it with a permanent magnet.
  - Placing a ferromagnetic substance in a solenoid and passing current through it.
- The material used to make a permanent magnet should have high rententivity and high coercivity.

Electromagnets

- The soft iron core in the solenoid acts as an electromagnet.
- The core of an electromagnet should have high permeability and low retentivity.

- The most suitable material for making an electromagnet is soft iron.

- Electromagnets are used in various devices such as electric bells, loud speakers and telephone diaphragms.
- An electromagnet must have:
  - high value of saturation magnetisation
  - low retentivity and coercivity
  - low hysteresis loss