Magnetism And Matter

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 .

Magnetic Field Lines

- A magnetic field line is an imaginary curve the tangent to which at any point gives the

  direction of magnetic field 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,

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 = μ04π2Mr(r2−l2)2B = 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 = μ04πM(r2−l2)32B = 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

Gauss' law for magnetism

- This law suggests that the number of magnetic field lines leaving any closed surface is always equal to the number of magnetic field lines entering it.
- According to Gauss' law for magnetism, the net magnetic flux (f*B*) through any closed surface is always zero.

ΦB=∮B→.ds→ =0ΦB=∮B→.ds→ =0

- No magnetic monopole(isolated magnetic poles) can exist.

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

- **Magnetic Intensity:** It is given by
  H=B0μ0H=B0μ0
- **Intensity of magnetisation** – It is defined as the magnetic moment developed per unit volume when a magnetic specimen is subjected to magnetising field. It is denoted by *I*.
  I=MVI=MV
- **Magnetic Induction** – It is defined as the number of magnetic lines of induction crossing per unit area through the magnetic substance. It is denoted by *B*.

  $B = \mu_0 (H + I)$
- **Magnetic susceptibility** – The magnetic susceptibility of a magnetic substance is defined as the ratio of the intensity of magnetisation to the magnetic intensity. It is denoted by χ_m.

  χm=IHχm=IH
- **Magnetic permeability** – The magnetic permeability of a magnetic substance is defined as the ratio of the magnetic induction to the magnetic intensity. It is denoted by μ.
  BH=μ0(1+χm)BH=μ0(1+χm)
  or,
  μ=μ0(1+χm)μ=μ0(1+χm)

Relation between magnetic intensity (*H*) and magnetic field (*B*):

$$\boldsymbol{B = \mu_0 (1 + \chi) H}$$

Where, χχ is the magnetic susceptibility

Classification of magnetic materials:

- **Diamagnetic substances:** When such substances are placed in an external magnetic field, they get feebly magnetised in the direction opposite to the field.

- **Paramagnetic substances:** When such substances are placed in an external magnetic field, they get feebly magnetised in the direction of the field.

- **Ferromagnetic substances:** When such substances are placed in an external magnetic field, they get strongly magnetised in the direction of the field.

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