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 B equals fraction numerator mu over denominator 4 pi end fraction M over r cubed
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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:

$$\vec{E} \to \vec{B}$$

$$\vec{p} \to \vec{M}$$

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

- 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

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.

` $\Phi B=\oint B\rightarrow.ds\rightarrow =0$

- 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}.

$B\sin\delta B\cos\delta=BVBH\tan\delta=BVBH$

Magnetic Intensity: It is given by

$H=B0\mu0$

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*.

$I=MV$

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.

$$\chi m=IH$$

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.

$$BH=\mu 0(1+\chi m)$$

or,

$$\mu=\mu 0(1+\chi m)$$

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

$$B = \mu_0 (1+\chi) H$$

Where, χ 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