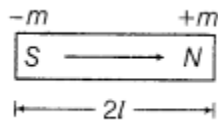


Magnetism And Matter

1. **The magnetic dipole** moment of a magnetic dipole is given by

$$M = m \times 2l$$

where, m is pole strength and $2l$ is dipole length directed from S to N.

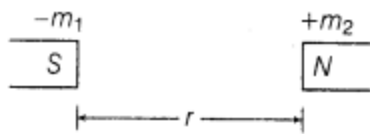


The SI unit of magnetic dipole moment is A-m² or J/T.

It is a vector quantity and its direction is from South pole to North pole.

2. Coulomb's Law in Magnetism

Magnitude of force acting between two magnetic poles is given by



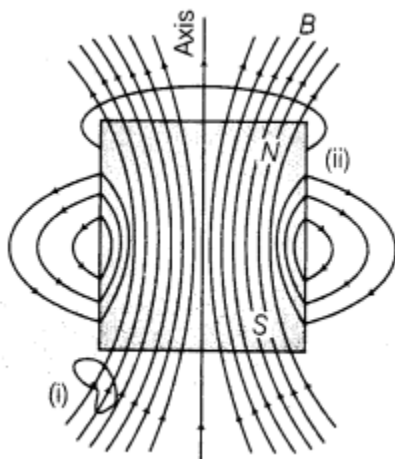
$$F = k \frac{\mu_0}{4\pi} \cdot \frac{m_1 m_2}{r^2}$$

where, m_1 and m_2 are magnetic strength of poles and k is magnetic force constant. Its SI unit is A-m.

3. **Magnetic Field Lines** These are imaginary lines which give pictorial representation for the magnetic field inside and around the magnet.

Their properties are given as below:

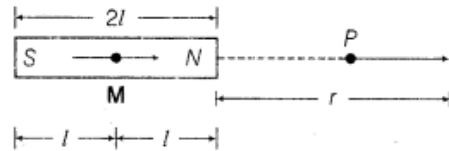
- (i) These lines form continuous closed loops.
- (ii) The tangent to the field line gives direction of the field at that point.
- (iii) Larger the density of the lines, stronger will be the magnetic field.
- (iv) These lines do not intersect one another.



4. Magnetic field due to a bar magnet at
(i) an axial point (end-on-position)

$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{2\mathbf{M}}{r^3}$$

($\because r \gg l$)

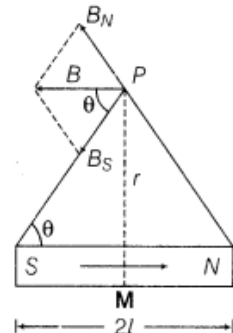


The direction of magnetic field is along the direction of magnetic dipole moment (M).

- (ii) on equatorial point (broadside-on-position)

$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{\mathbf{M}}{r^3}$$

The direction of magnetic field is parallel to the magnetic dipole and opposite to the direction of dipole moment.



NOTE: The direction of magnetic field between the poles of the dipole is in the direction opposite to the magnetic moment (South to North) while inside the current loop it is in the same direction to that of magnetic moment.

5. **Torque** on a bar magnet in a uniform magnetic field is

$$\tau = MB \sin \theta = \mathbf{M} \times \mathbf{B}$$

where, θ is the angle between M and B . Its SI unit is joule per tesla (JT^{-1}).

6. **Potential energy** of a magnetic dipole in a magnetic field is given by

$U = -MB \cos \theta = -\mathbf{M} \cdot \mathbf{B}$ where, θ is the angle between M and B .

7. **Work done** in rotating the dipole in a uniform magnetic field from θ_1 to θ_2 is given by

$$W = MB (\cos \theta_1 - \cos \theta_2)$$

8. **Current loop** behaves like a magnetic dipole whose dipole moment is given by $M=IA$

The direction of dipole moment can be obtained by right hand thumb rule. Its. SI unit is $\text{A}\cdot\text{m}^2$.

9. **Magnetic dipole** moment of a revolving electron is given by

$$M = \frac{evr}{2} \text{ or } M = \frac{e}{2m} L$$

where, v is speed of electron on a circular path of radius r .

L is angular momentum and given as $L = mvr$.

10. **Interaction** between two magnetic dipoles is

$$F = \frac{\mu_0}{4\pi} \cdot \frac{6m_1m_2}{r^4}$$

11. **Oscillation of a Freely Suspended Magnet** The oscillations of a freely suspended magnet (magnetic dipole) in a uniform magnetic field are SHM.

The time period of oscillation, $T = 2\pi \sqrt{\frac{I}{MB}}$

where, I = moment of inertia of the magnet, M = magnetic moment and B = magnetic field intensity.

12. **Bar Magnet as an Equivalent Solenoid** The expression of magnetic field at distance r from centre is given by

$$\mathbf{B} = \frac{\mu_0}{4\pi} \cdot \frac{2\mathbf{M}}{r^3}$$

This expression is equivalent to that of bar magnet.

13. The Electrostatic Analog

The table given below summarises the analogy between electric and magnetic dipoles

	Electrostatics ($1/\epsilon_0$)	Magnetism (μ_0)
Dipole moment	\mathbf{p}	\mathbf{M}
Equatorial field for a short dipole	$-\mathbf{p}/4\pi\epsilon_0 r^3$	$-\mu_0 \mathbf{M}/4\pi r^3$
Axial field for a short dipole	$2\mathbf{p}/4\pi\epsilon_0 r^3$	$\mu_0 2\mathbf{M}/4\pi r^3$
External field : Torque	$\mathbf{p} \times \mathbf{E}$	$\mathbf{M} \times \mathbf{B}$
External field : Energy	$-\mathbf{p} \cdot \mathbf{E}$	$-\mathbf{M} \cdot \mathbf{B}$

14. Magnetism and Gauss' Law

The net magnetic flux (Φ_B) through any closed surface is always zero.

$$\Phi_B = \Sigma \mathbf{B} \cdot \Delta \mathbf{S} = 0$$

