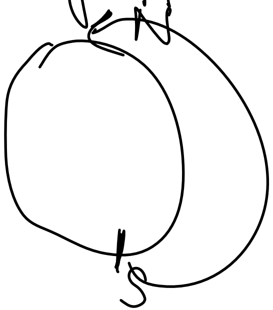
# Magnetism and Matter:

- Magnetic phenomena are universal in nature.
- 'magnesia', Greece, for the first time, magnetic ores were discovered.

Some of the commonly known ideas regarding magnetism:

a) The earth behaves as a magnet with magnetic field pointing approximately from the geographic south to the north.

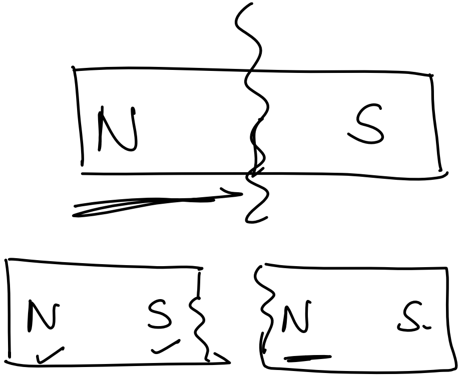


b) When a bar magnet is freely suspended. It points in the North - South direction. Apex points to the geographic north is called north pole and the other end which points to the geographic south ~~p~~ is called south pole of the magnet.

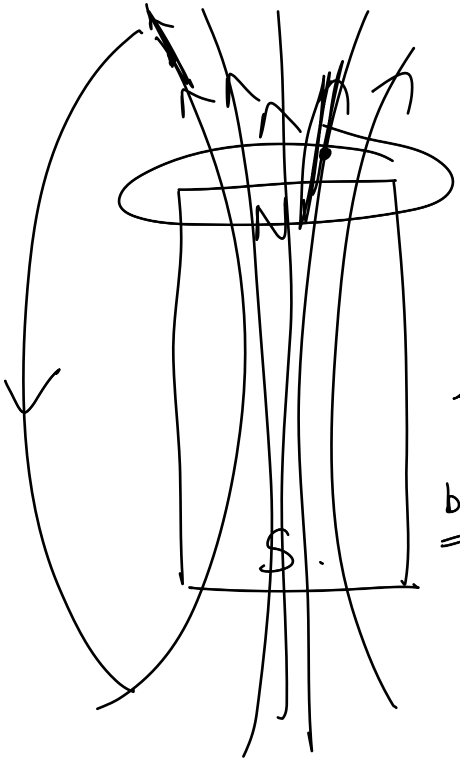
c) There is a repulsive force when north pole of two magnets are brought closer. while in the The north pole and south pole, there is an attractive force

d) We cannot isolate the north | south pole of a magnet. If a bar magnet is broken into two halves, we get two similar bar magnets with weaker properties. Unlike, electric charge, isolated poles does not exist.

c)



Iron / Alloys -



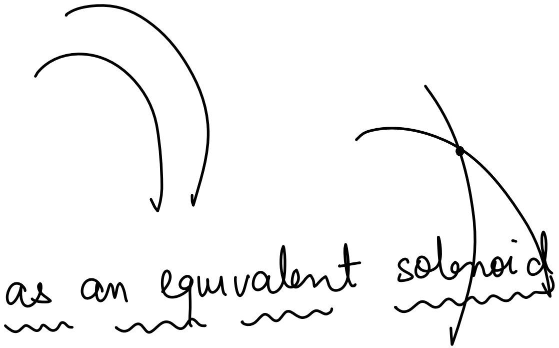
# Properties of magnetic field lines:

a) The magnetic field lines of a magnet for continuous closed loops.

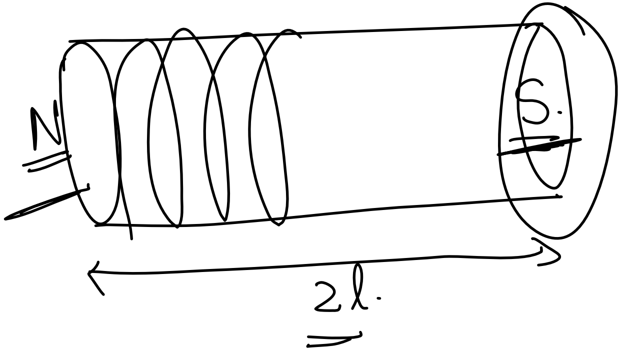
b) The tangent to the field at any point represents the direction of the net magnetic field.

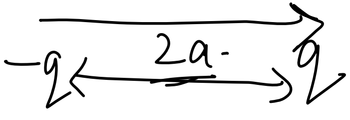
c) The larger the number of magnetic field lines crossing per unit area, the stronger is the magnitude of magnetic field.

d) The magnetic field lines do not intersect.



## Bar magnet as an equivalent solenoid:





$p = q(2a)$

N → No. of turns in the loop.

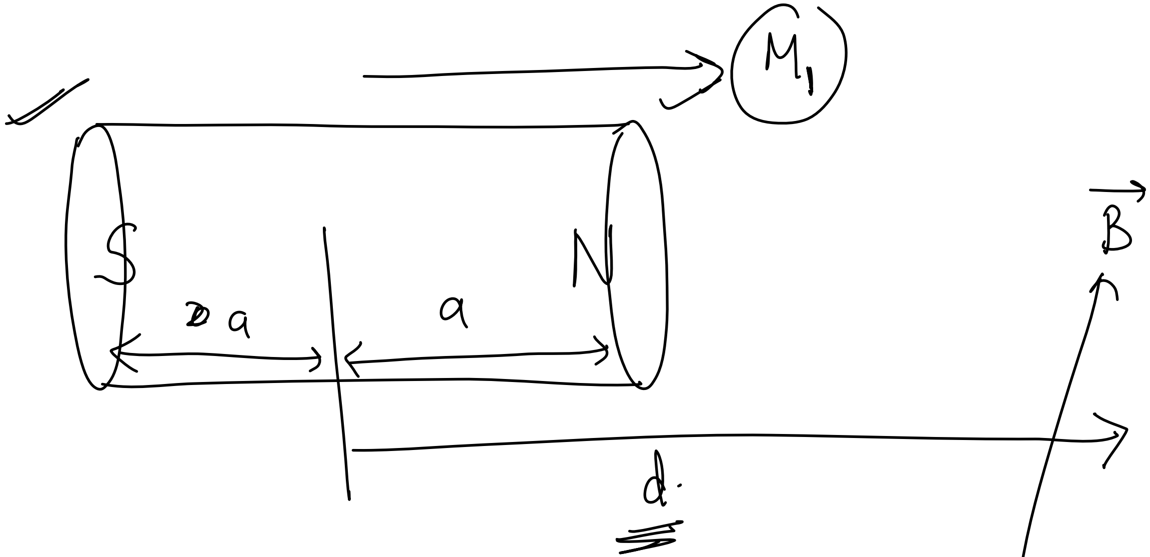
I → current.

A → Area vector.

$q \times (2a)$

$m$ (magnetic dipole moment) $= \underline{NI. \times A}$

$$\frac{2\boxed{K}\vec{P}}{r^3}$$

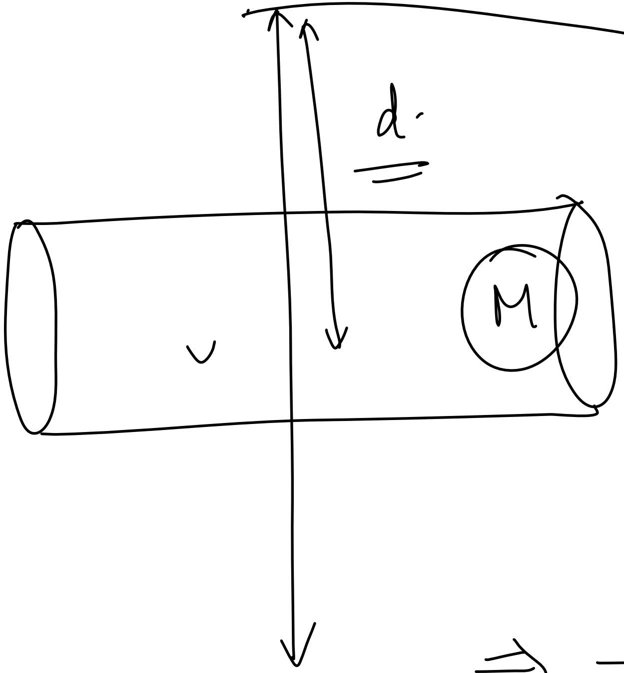


$$\vec{B} = \frac{\mu_0}{4\pi}\left(\frac{2M_1}{d^3}\right)$$

$$m\,M = Nia.$$

$$\frac{\mu_0(m)}{4\pi\, r^2}.$$

Magnetic field at 'd' distance from the magnet.



$$\frac{\mu_0 \boxed{M}}{4\pi (d^3)}$$

$$\Rightarrow -\frac{K\vec{P}}{r^3}$$

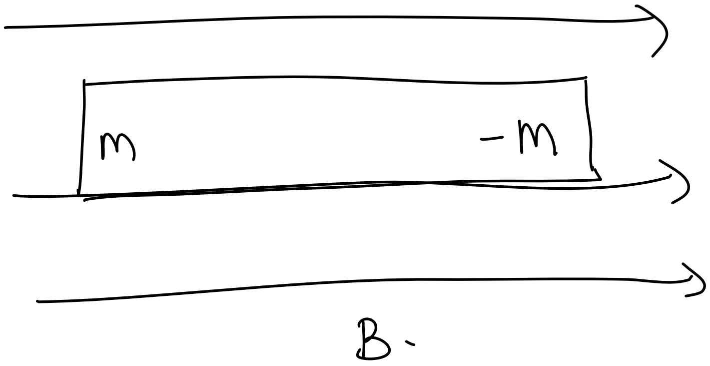
'n' → no. of turns / unit length

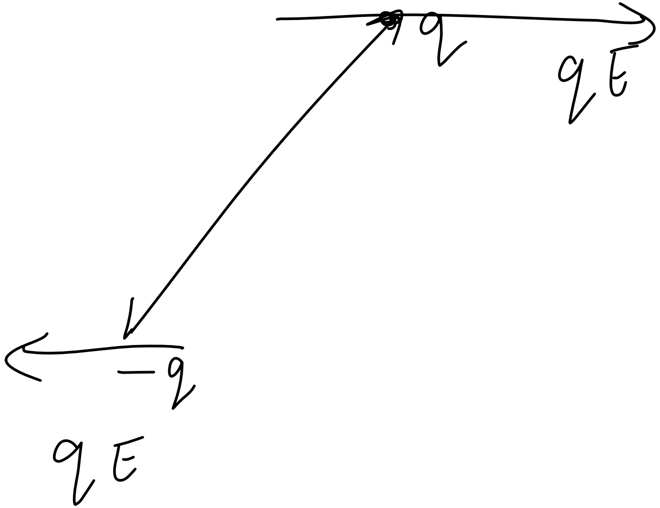
→ magnetic dipole moment / Pole strength

$$\boxed{m = \underbrace{n(2l)}_{\text{Total no. of turns}}(I)\underbrace{(\pi a^2)}_{A}}$$

$$\Rightarrow -\frac{\mu_0 M}{4\pi d^3}.$$

# Dipole kept in a uniform magnetic field:





$$\tau = \underrightarrow{m \times B}.$$

$\tau = mB\sin\theta$ [ $\theta$ is the angle between $\underrightarrow{m}$ & $\underrightarrow{B}$)

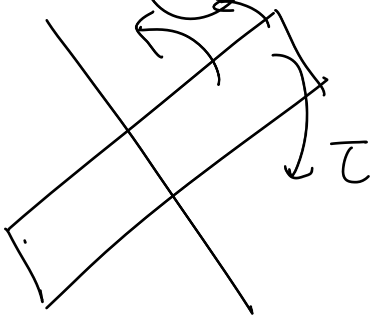
↳ I.

$$\tau = I\alpha \rightarrow$$

$$I\frac{d^2\theta}{dt^2} = -mB\sin\theta$$

'θ' is very small

$$\theta$$



$$\tau = p \times E \sin\theta$$

$$I\frac{d^2\theta}{dt^2} = mB\theta \; , \quad \frac{d^2\theta}{dt^2} = \frac{mB\theta}{I}$$

ω

$$T = 2\pi\sqrt{\frac{I}{mB}}$$

$$T = \frac{2\pi}{\omega}$$

$$\frac{d^2x}{dt} = \frac{Kx}{m}$$

Magnetic potential energy, $= \int \tau(\theta)\, d\theta$

$$= \int mB \sin\theta \, d\theta$$

$$= mB \int \sin\theta \, d\theta$$

$$\Rightarrow \underline{mB}\,[-\underline{\cos\theta}]. \qquad [\vec{A}\cdot\vec{B} = |A||B|\cos\theta)$$

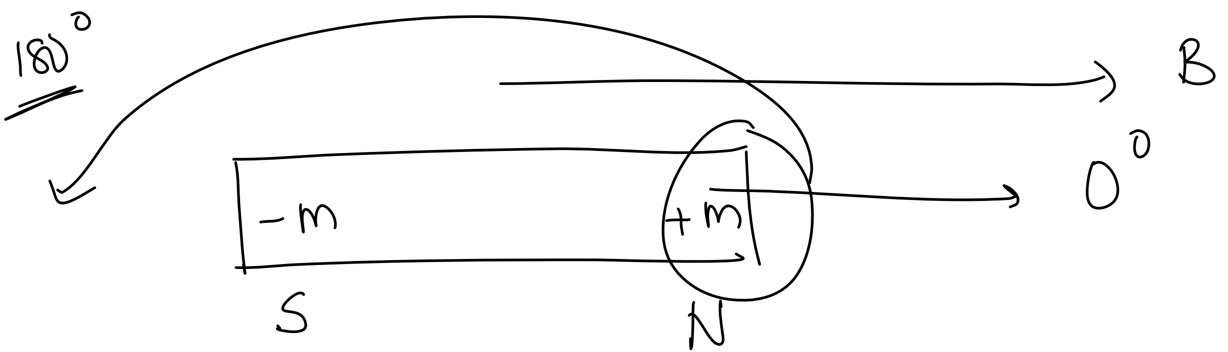
$$= -\underline{m\cdot B}$$

$\uparrow$

$\underline{m}$ & $\underline{B}$.

$\theta = 0^\circ$ to $\underline{\theta = 180^\circ}$.

Work done



Work done by external force $= \Delta U$

$$\Rightarrow U_f - U_i$$

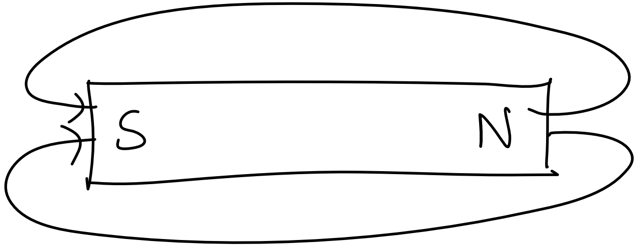
$$\Rightarrow -m \cdot B \underset{(-1)}{\cos\theta_f} - (-mB\cos\theta_i)$$

$$\Rightarrow \underline{-mB}\ \underline{\cos 180^\circ} + mB\cos 0^\circ$$

$$\Rightarrow mB + mB = \boxed{2mB}$$

$$P = \underline{n}(i)(A)$$

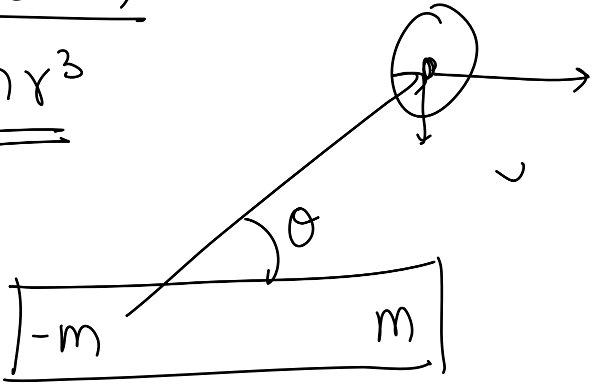
$$\underline{m} = p \times (2l)$$



$$\vec{B}_E = -\frac{\mu_0 m}{4\pi r^3}$$

Axial

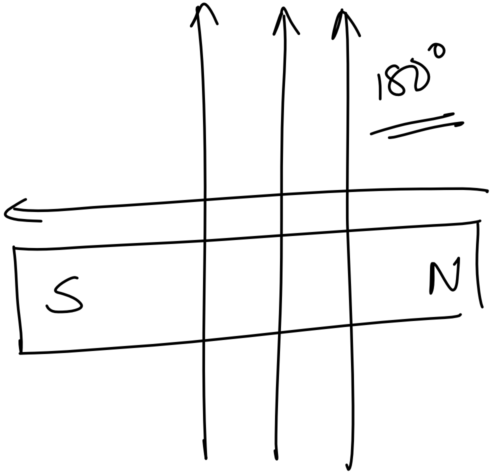
$$\vec{B} = \frac{\mu_0 (2m)}{4\pi r^3}$$



$$\vec{B}_{net} = \frac{\mu_0}{4\pi r^3}\sqrt{1+3\cos^2\theta} \quad , \quad \tan\phi = \frac{\tan\theta}{2}$$

$\tau = m \times B$.

$\tau)_{maximum}$ : $\vec{m}$ & $\vec{B}$ , $\theta = 90^\circ$



$\theta = 0^\circ$ [Stable Equilibrium]

$\theta = 180^\circ$ [Unstable Equilibrium]

$\tau)_{minimum}$ : $\theta = 0^\circ$ / $180^\circ$