LAKSHYA BATCH

Magnetism and Matter
Magnetic field due to bar Magnet, Torque, work and Questions

LECTURE - 2

GOALS OF THE DAY

- Magnetic field at axial and equatorial points Not in CBSE
- Torque on dipole (Not in CBSE)
- Work done in rotation of dipole (Not in CBSE)
-

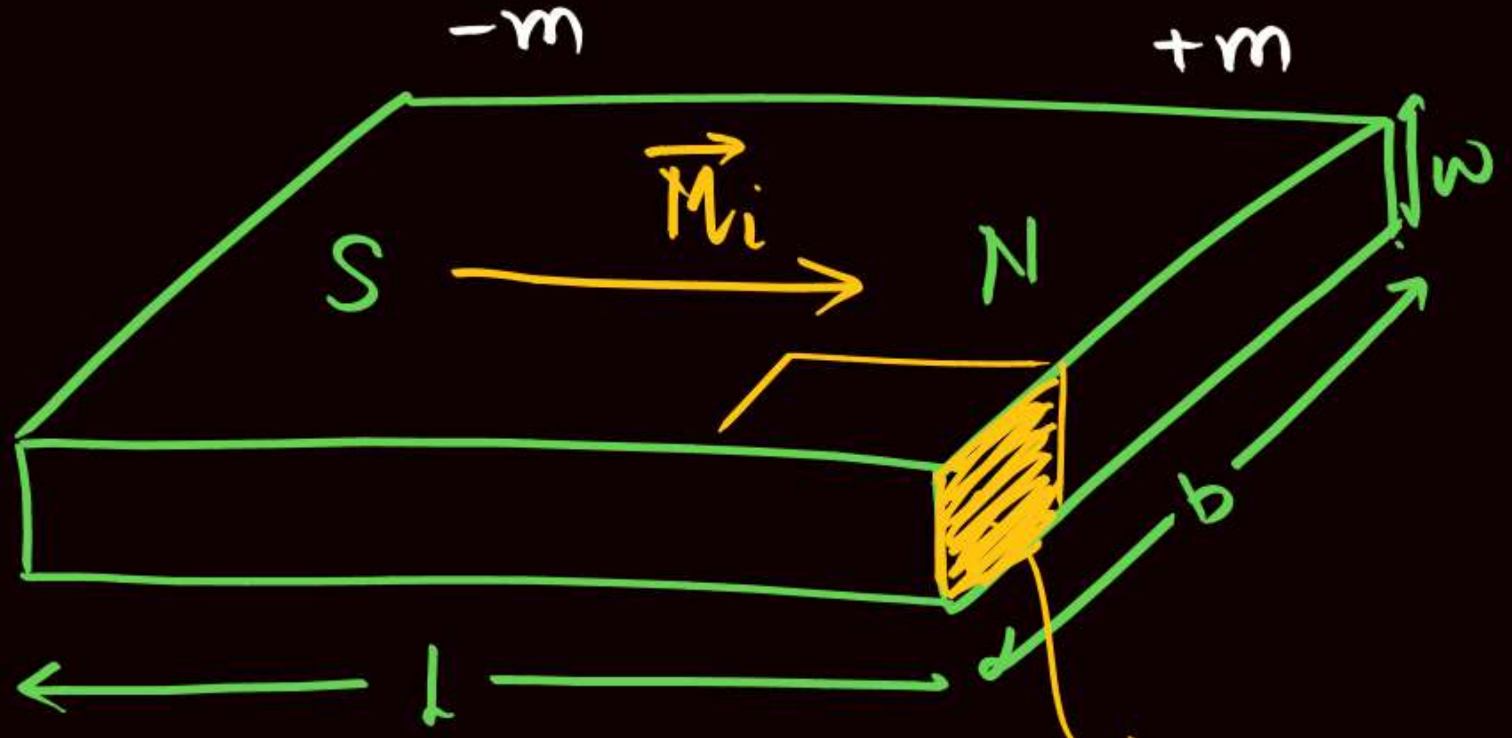
but in Mains, Not in Advance

The pain you feel today, will be strength you feel tomorrow. Lets Get to work!

Successful people will always question whether they're Still doing enough, while unsuccessful people are Satisfied with what they are doing.

we are born weak & die weak. But what you are in between is only upto you. →

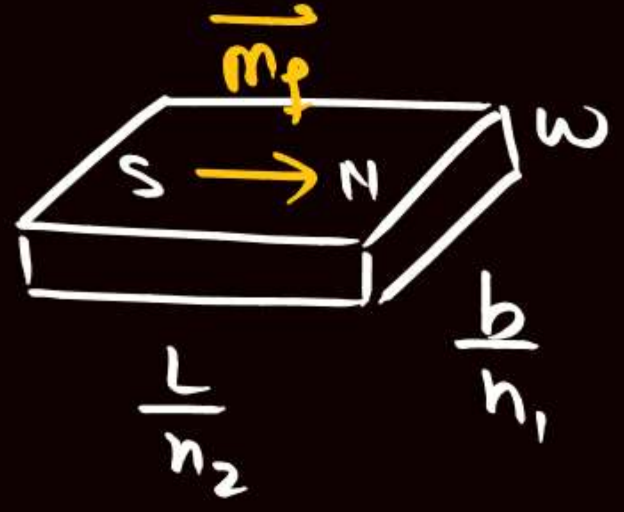
$A_i = bw$



$\vec{M}_i = mL$

$A = \frac{b}{n_1} w$

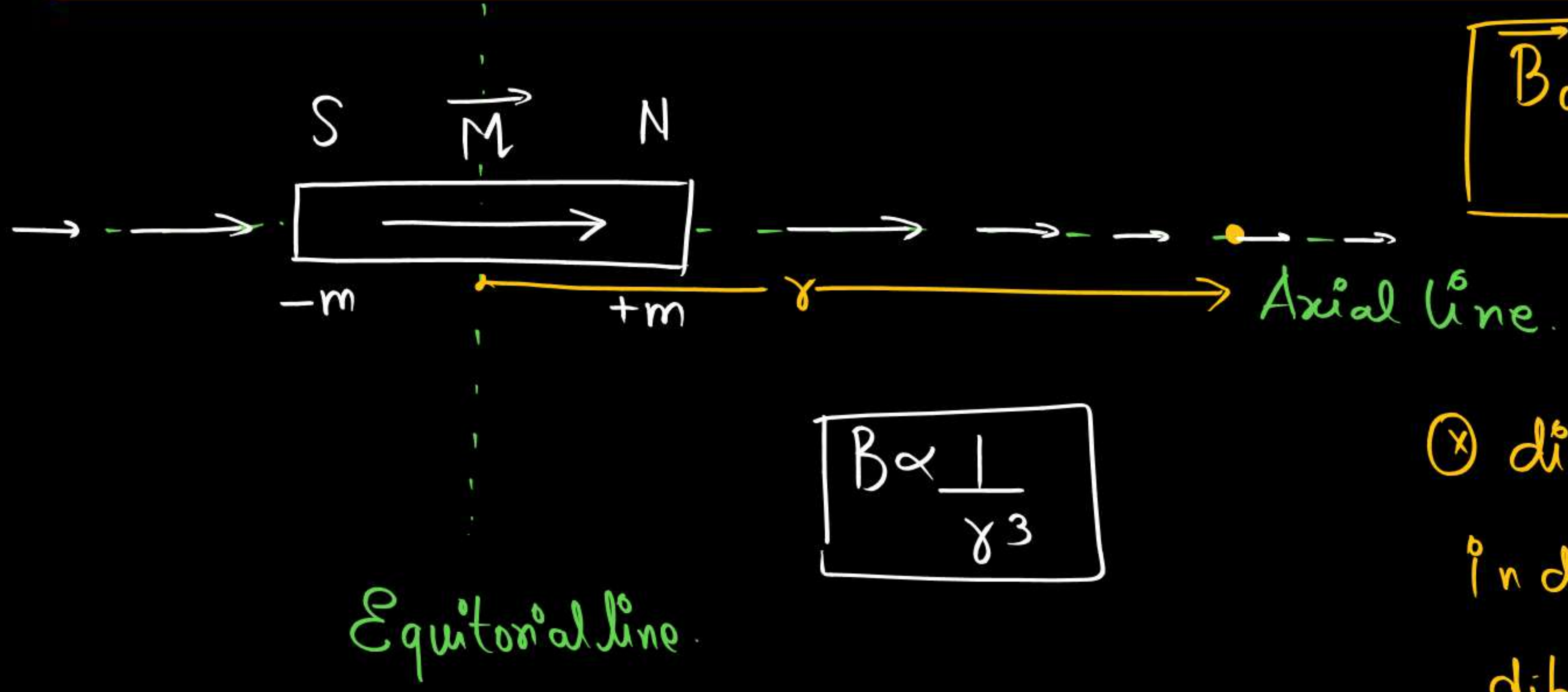
$A_f = \frac{A_i}{n_1}$



Pole strength new $= \frac{m}{n_i}$

$$\vec{M}_f = \frac{m}{n_i} \frac{L}{n_2} = \frac{mL}{n_1 n_2} = \frac{\vec{M}_i}{n_1 n_2}$$

Magnetic field Due to Bar magnets



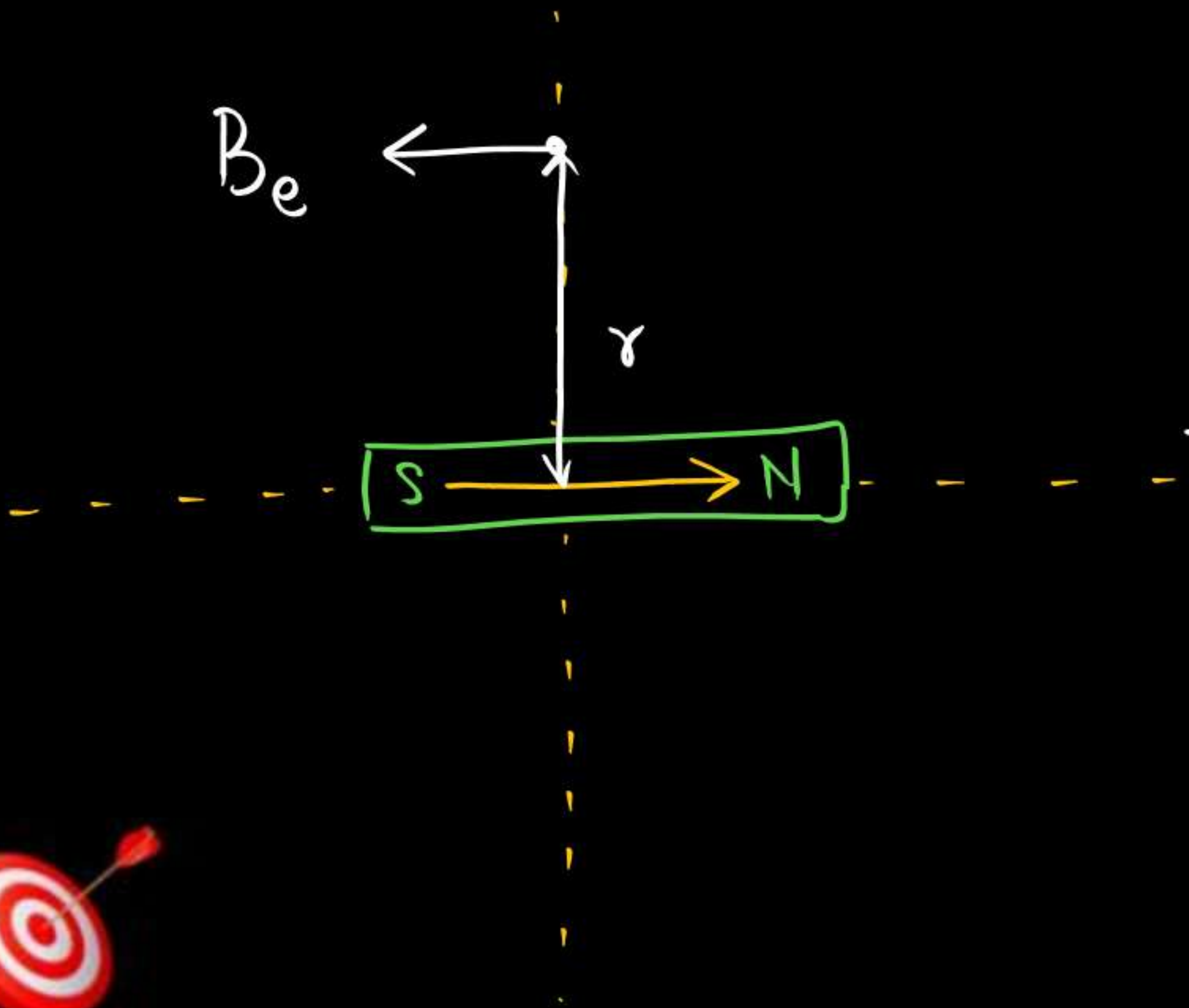
$$\boxed{\vec{B}_{\substack{\text{axial}\\\text{Point}}} = \frac{\mu_0}{4\pi}\frac{2M}{r^3}}$$

$$\boxed{B \propto \frac{1}{r^3}}$$

(x) direction of MF is in direction of Magnetic dipole Moment.

Magnetic field Due to Bar magnets

Case. Equitorial points.



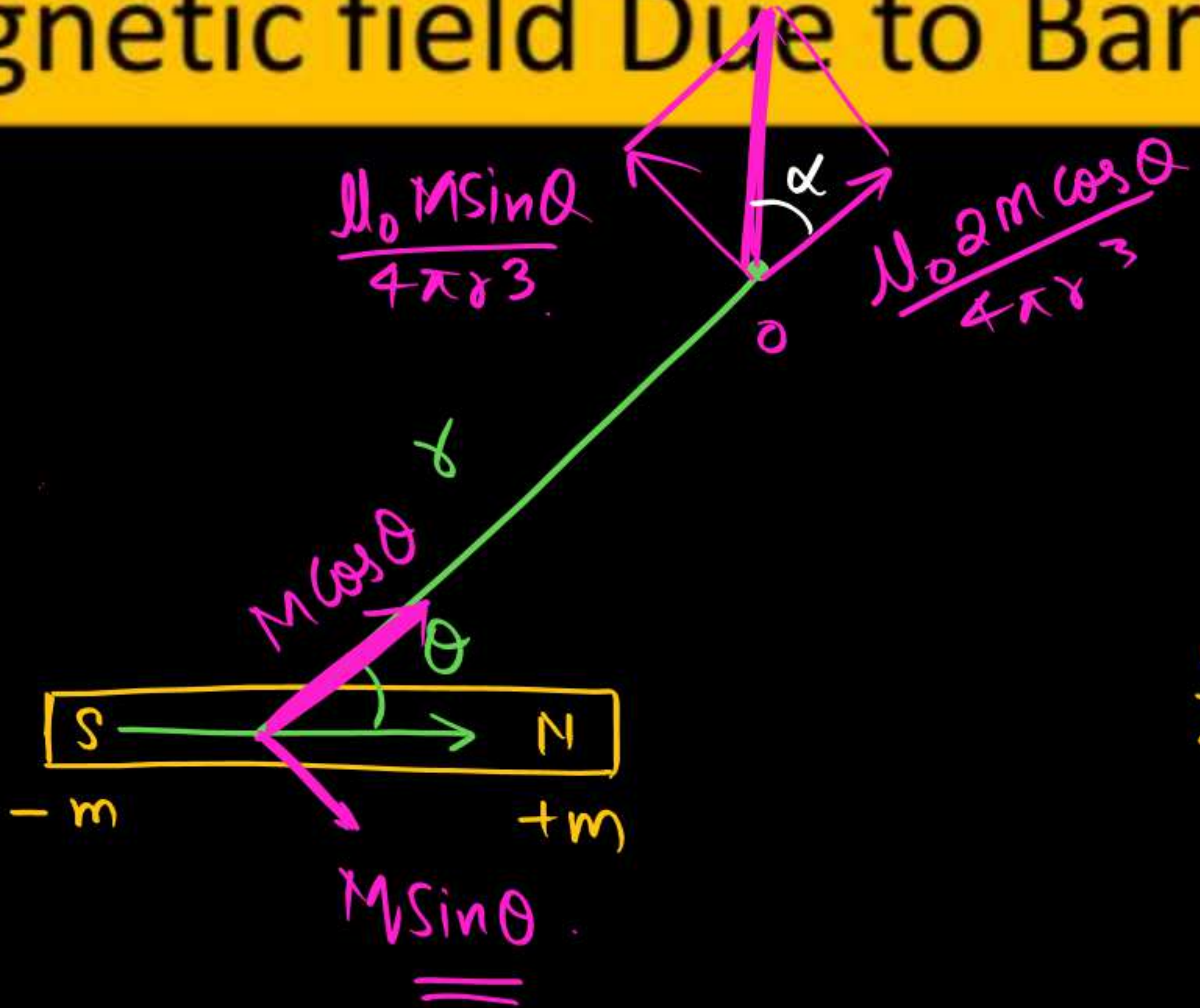
$$|B_e| = \frac{\mu_0 M}{4\pi r^3}$$

$$\boxed{B \propto \frac{1}{r^3}}$$

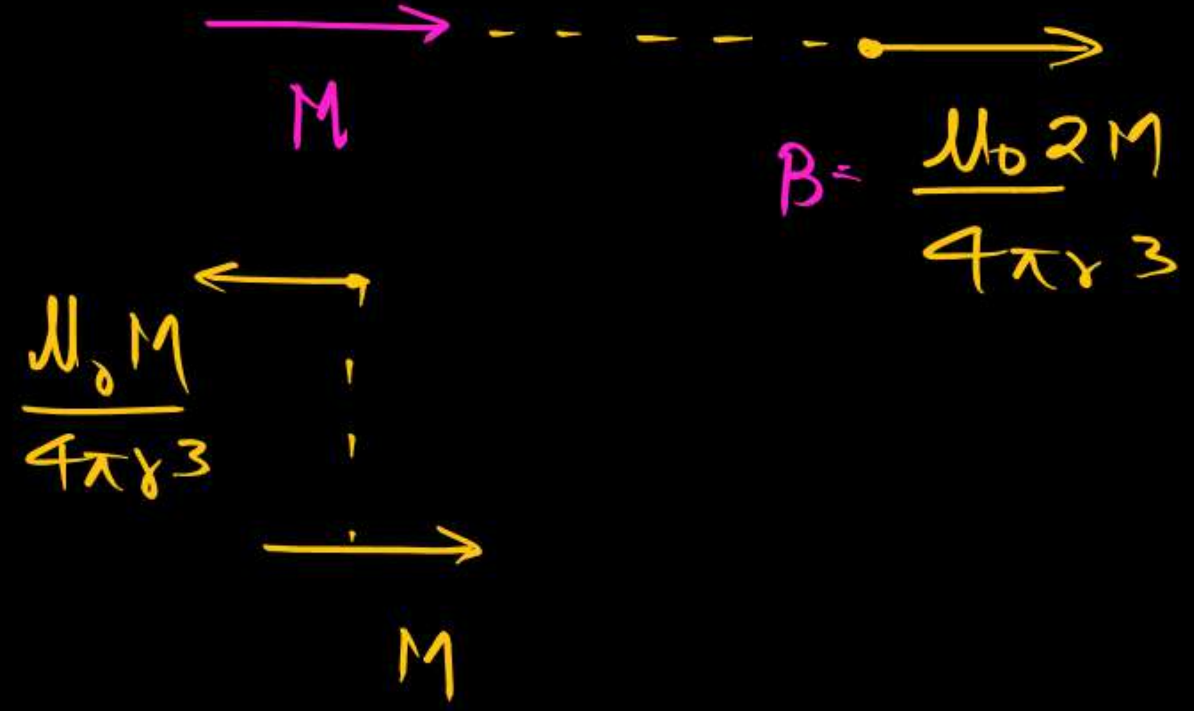
direction of MF at Equitorial point is anti parallel to $\vec{M}$.

Magnetic field Due to Bar magnets

$B_r = \frac{\mu_0 M}{4\pi r^3}\sqrt{3\cos^2\theta + 1}$



$$\boxed{\tan\alpha = \frac{P}{B} = \frac{1}{2}\tan\theta}$$

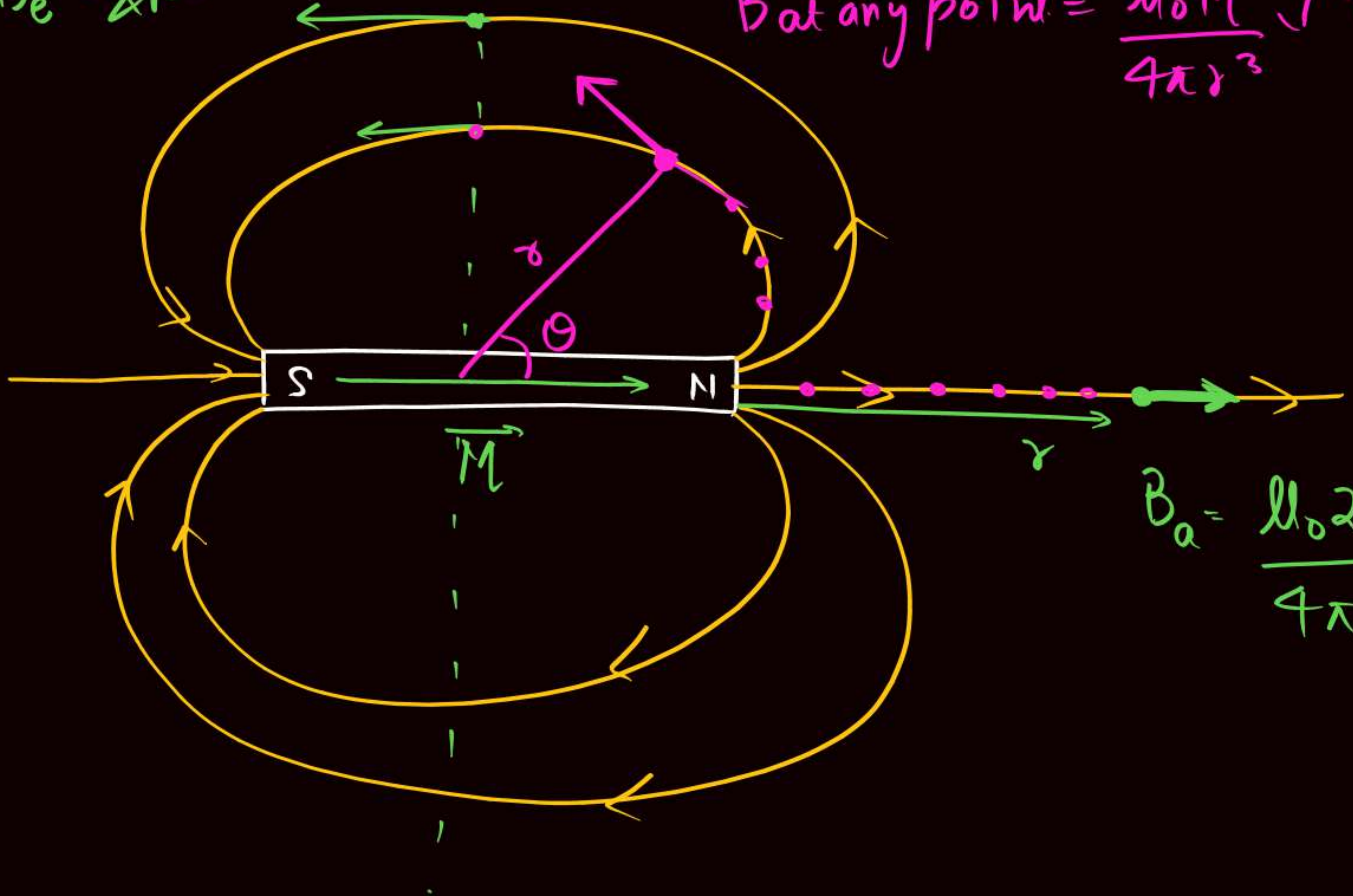


Equitorial Points

$B_e = \frac{\mu_0 M}{4\pi r^3}$

B at any point $= \frac{\mu_0 M}{4\pi r^3}\sqrt{3\cos^2\theta+1}$

↳ $\theta = 0^\circ$ $B_a = \frac{\mu_0 2M}{4\pi r^3}$



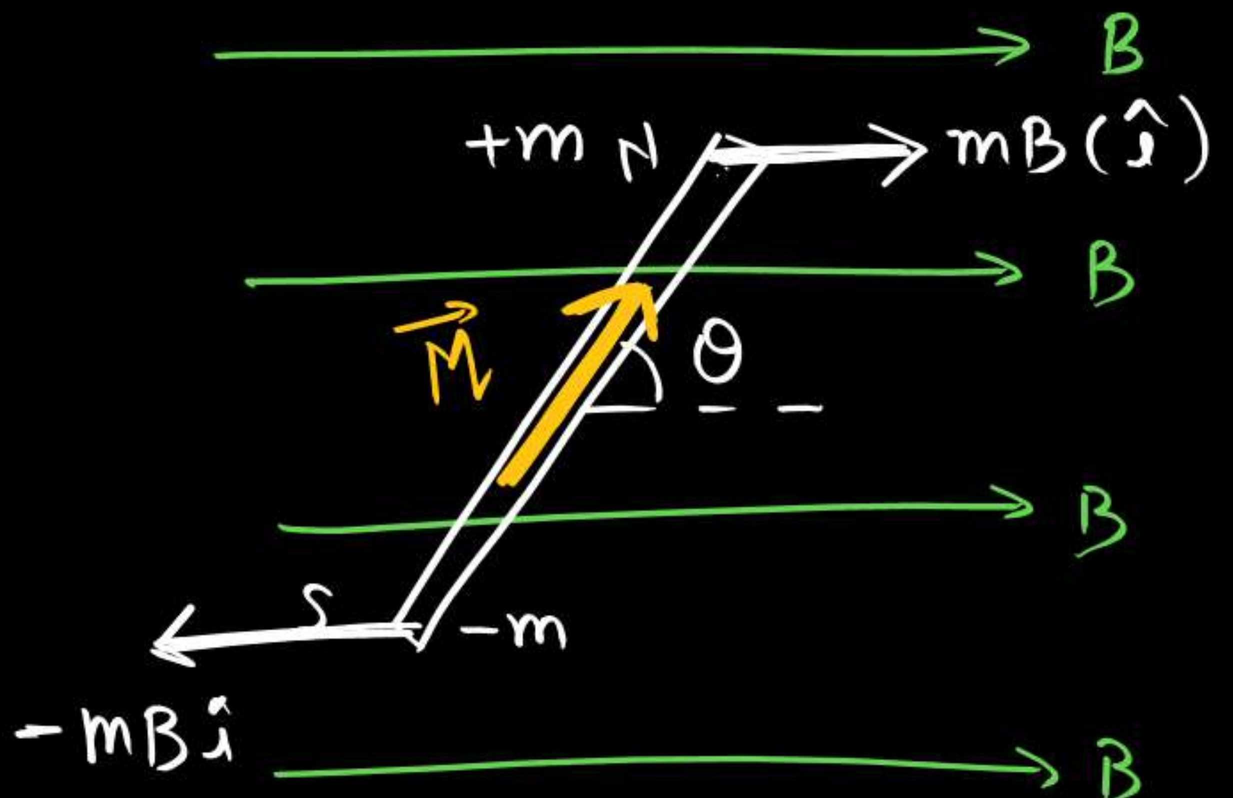
$B_e = \frac{\mu_0 M}{4\pi r^3}$

$B_a = \frac{\mu_0 2M}{4\pi r^3}$

$$\boxed{\frac{B_a}{B_e} = \frac{2}{1}}$$

(Not in Boards)

Torque on Magnetic dipole



Torque $= \vec{M} \times \vec{B}$.

$$\boxed{|\tau| = MB\sin\theta}$$

τ_{max}

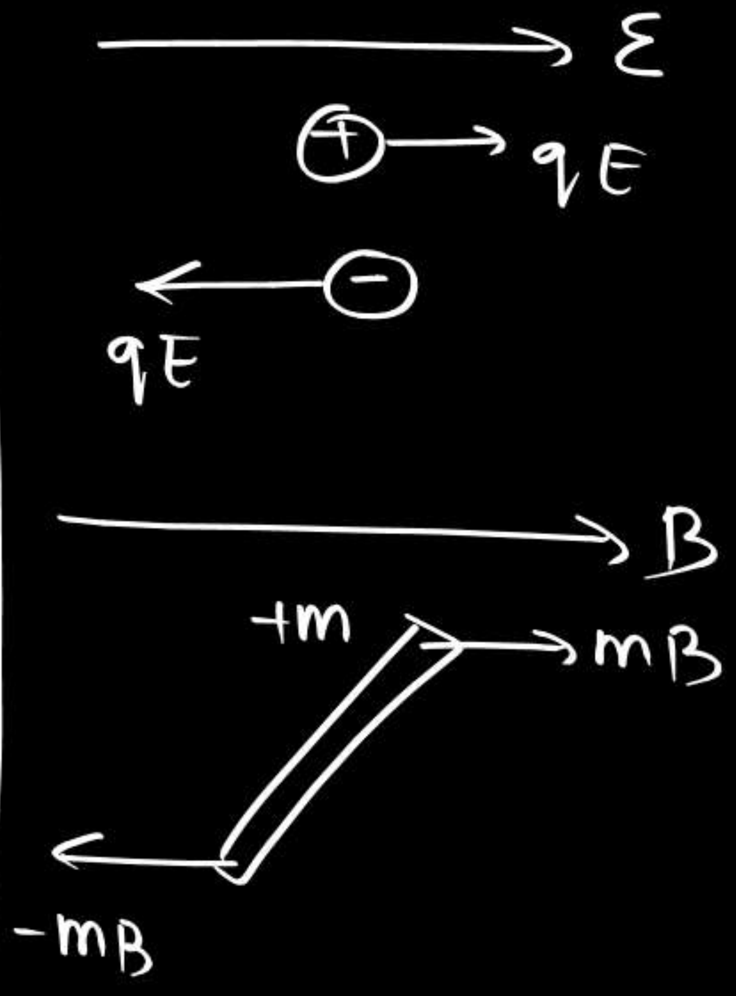
$\theta = 90°$

$\tau_{max} = MB$

τ_{min} $\theta = 0, 180°$

$$\boxed{\tau = 0}$$

In Electro

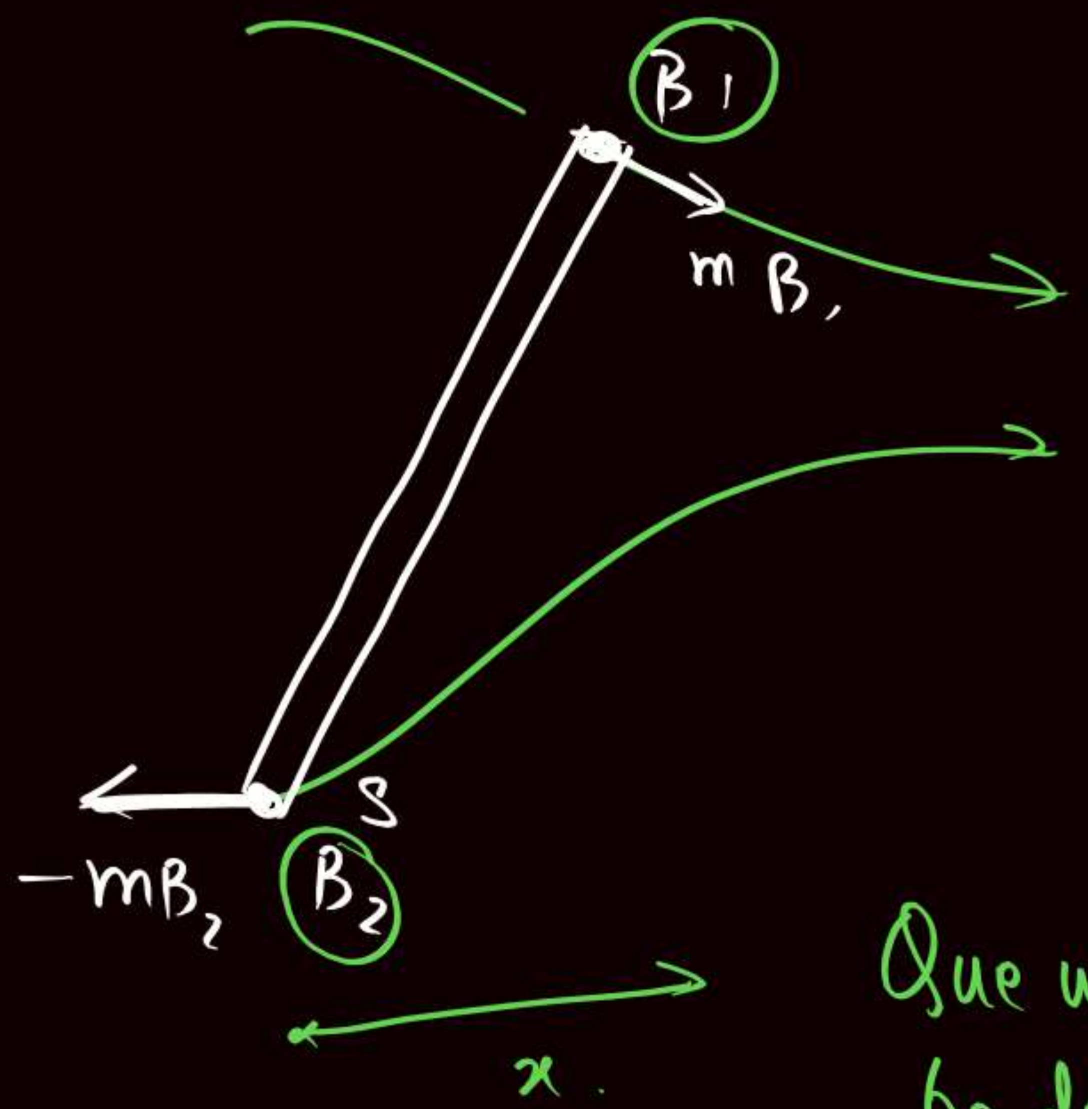


$\boxed{F_{net} = 0}$ in uniform $\vec{B}$.

Torque may or may not be Zero.

Mains.

If MF is Non uniform



F_{Total} = will not be Zero.

τ not Zero.

for Mains***.

Force on dipole in non uniform Field

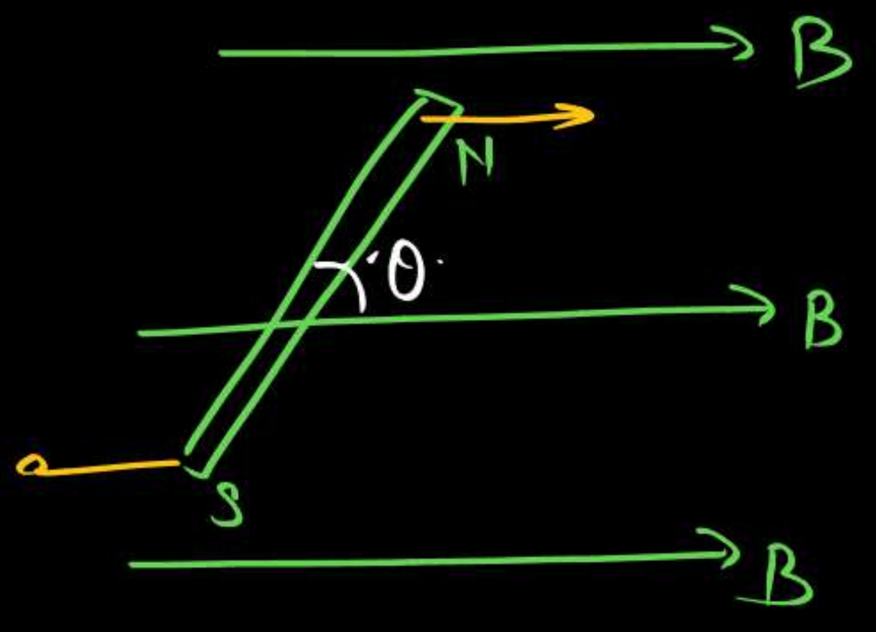
$$\boxed{F = M\frac{dB}{dx}}$$

$\frac{dB}{dx} \Rightarrow$ Rate of change of B wrt x.

Que will be done in Practice.

Work done and Potential energy

When we Rotate a dipole work has to be done.



$dW = \tau\, d\theta$

$dW = MB\sin\theta\, d\theta$

$W_T = -MB\cos\theta$

$\boxed{W = -\vec{M}\cdot\vec{B}}$

$\boxed{PE = -M\cdot B}$

If it is Rotated from θ_1 to θ_2

$W = MB[\cos\theta_1 - \cos\theta_2]$

In Electro

$\tau = \bar{P}\times\bar{E}$

$PE = W = -\vec{P}\cdot\vec{E}$

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

$\boxed{\begin{matrix} P \to M \\ E \to B \end{matrix}}$

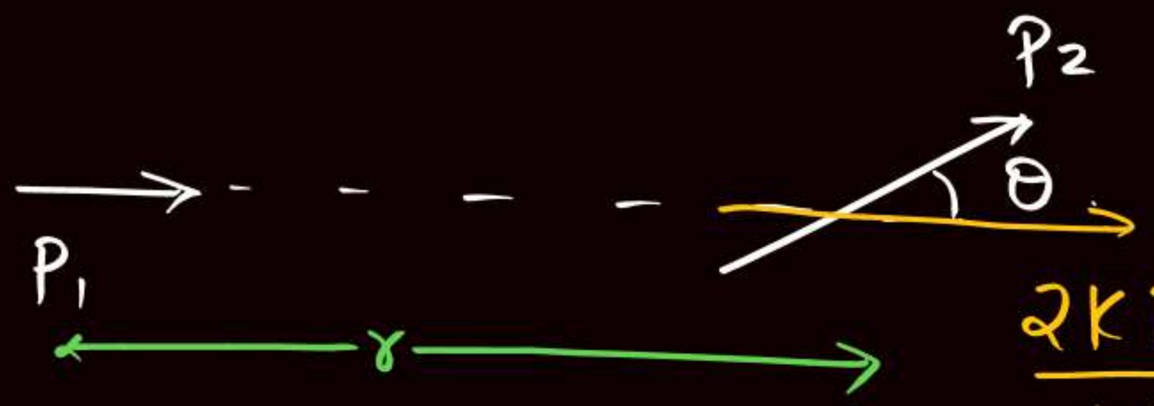
LAKSHYA KO HAR HAAL ME PAANA HAI

Only Mains. Find the force of interaction between two dipoles.

Class 11

$$\boxed{\vec{F} = -\frac{\partial U}{\partial r}}$$

Case 1



$$\frac{2KP_1}{r^3} = E_1$$

$$PE = -\vec{P}_2 \cdot \vec{E}_1$$

$$U = -\frac{P_2 2KP_1}{r^3} \cos\theta$$

$$f = -\frac{\partial}{\partial r}\left[\frac{-2KP_1P_2\cos\theta}{r^3}\right]$$

$$f = +2KP_1P_2\cos\theta \frac{\partial}{\partial r} r^{-3}$$

$$= -6KP_1P_2\cos\theta \frac{1}{r^4}$$

$$= -\frac{6KP_1P_2\cos\theta}{r^4}$$

Case 1

Attract

$$f = -\frac{6KP_1P_2}{r^4}$$

$$f = \frac{6KP_1P_2}{r^4}$$

Repel

If we have to find force

1. write PE

vector ← → Scalar

2. $f = -\frac{\partial U}{\partial r}$

gradient

$$F = -\frac{\partial U}{\partial r}$$

$$= -\frac{\partial}{\partial r}\left(-\frac{Gm_1m_2}{r}\right)$$

$$= Gm_1m_2 \frac{\partial}{\partial r} r^{-1}$$

$$\boxed{F = -\frac{Gm_1m_2}{r^2}}$$

"attractive".

Class-XI

(+) (+) → +ve Rep.

(−) (−)

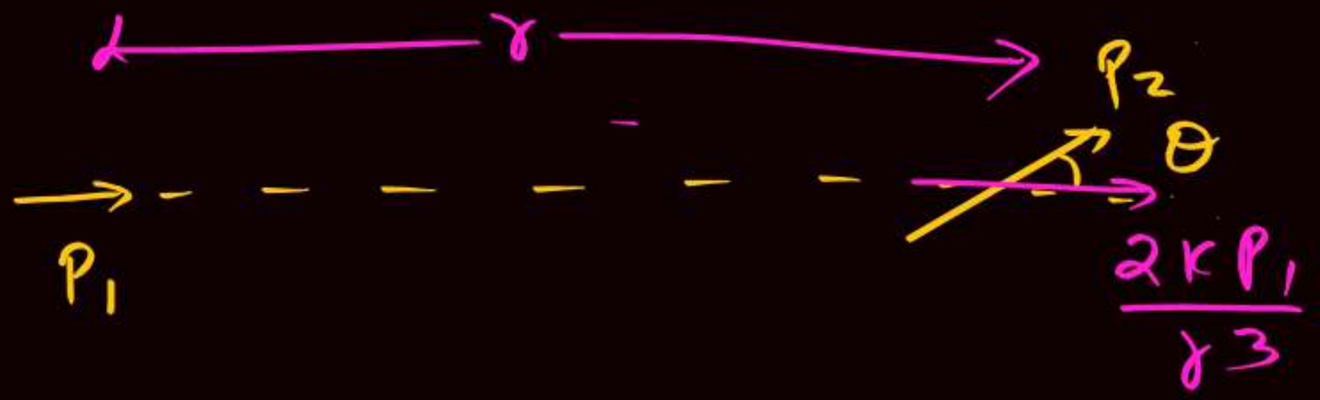
(+) (−) −ve

$$f = \frac{Gm_1m_2}{r^2}$$

f = +ve Repulsion

#

$$PE = U = -\frac{Gm_1m_2}{r}$$



attract

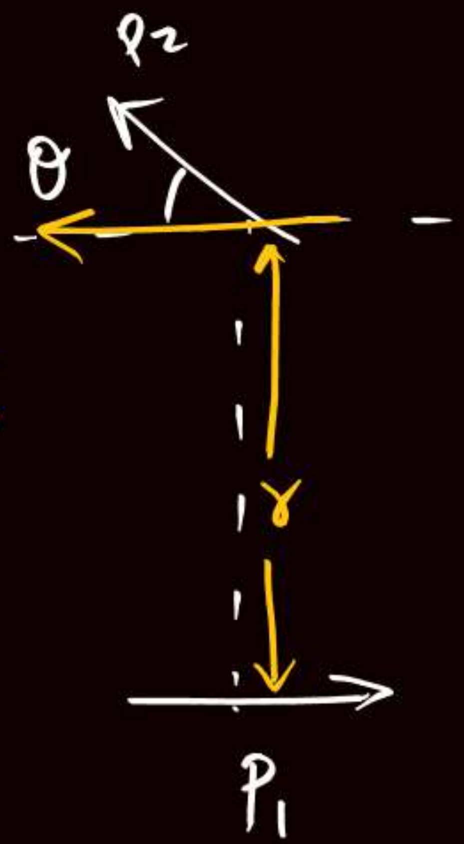
S $\xrightarrow{\;p_1\;}$ N   S $\xrightarrow{\;p_2\;}$ $f = -\frac{6kp_1p_2}{r^4}$ $PE = -p_2\frac{2kp_1}{r^3}\cos\theta$

$\xrightarrow{\;p_1\;}$ N   N $\xleftarrow{\;p_2\;}$ $f = \frac{6kp_1p_2}{r^4}$ $U = -\frac{2kp_1p_2\cos\theta}{r^3}$

repel

$$F = -\frac{\partial U}{\partial r} = -\frac{\partial}{\partial r}\left(-\frac{2kp_1p_2\cos\theta}{r^3}\right) = -\frac{6kp_1p_2\cos\theta}{r^4}$$

force is position & orientation dependent.



$$\mathcal{E} = \frac{KP_1}{r^3}$$

force between dipoles?

$$PE = -\vec{P}\cdot\vec{\mathcal{E}} = -P\mathcal{E}\cos\theta$$

$$P\cdot\mathcal{E} = -P_2\frac{KP_1}{r^3}\cos\theta$$

$$f = -\frac{\partial U}{\partial r}$$

$$= -\left(-KP_1P_2\cos\theta\right)\frac{\partial}{\partial r}r^{-3}$$

$$\boxed{F = -\frac{3KP_1P_2\cos\theta}{r^4}}$$

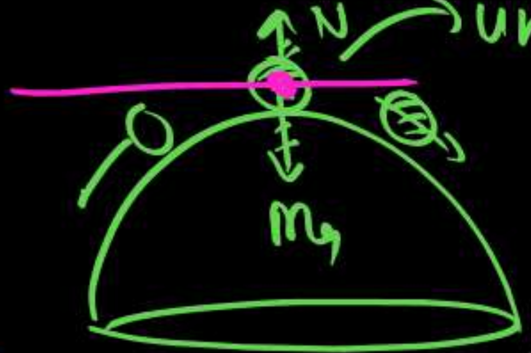
Equilibrium positions and Oscillation

* $\boxed{F_{net} = 0}$

Stable | Unstable | Neutral

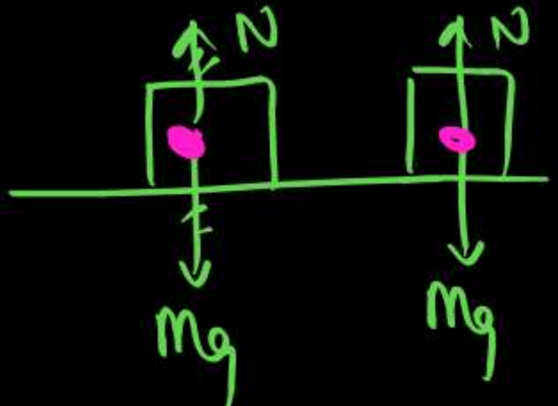
PE min

This point is Stable Equil



unstable Equili

PE max

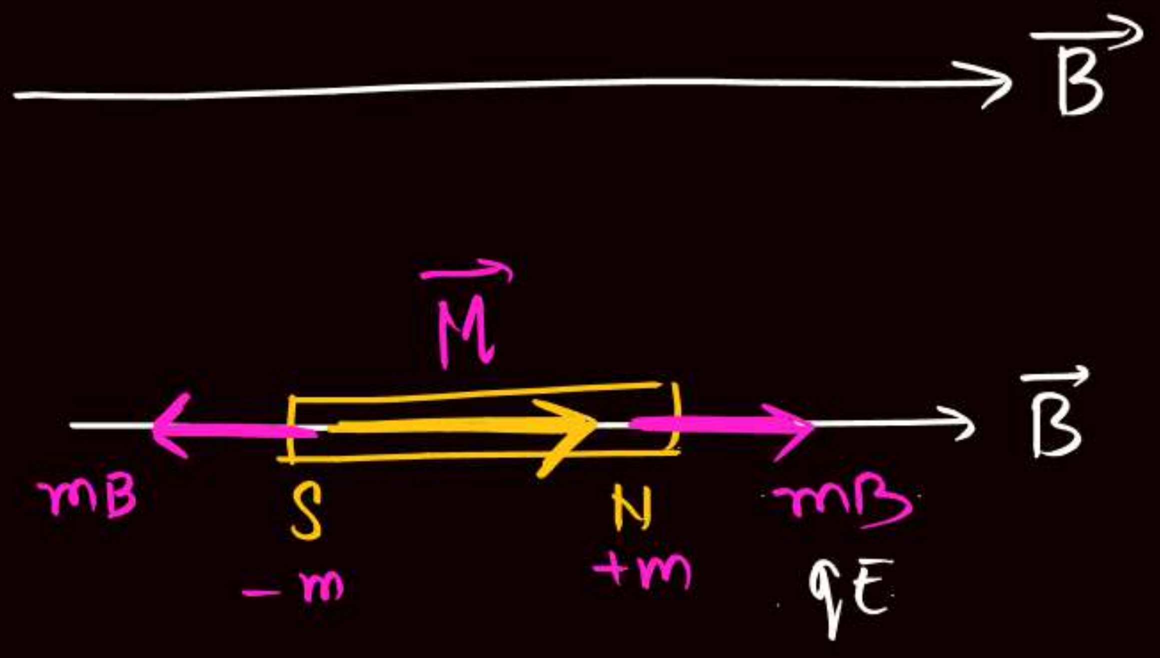


Neutral

PE = Const

Is dipole in Equilibrium

uniform B $\left(F_{net} = 0 \right)$

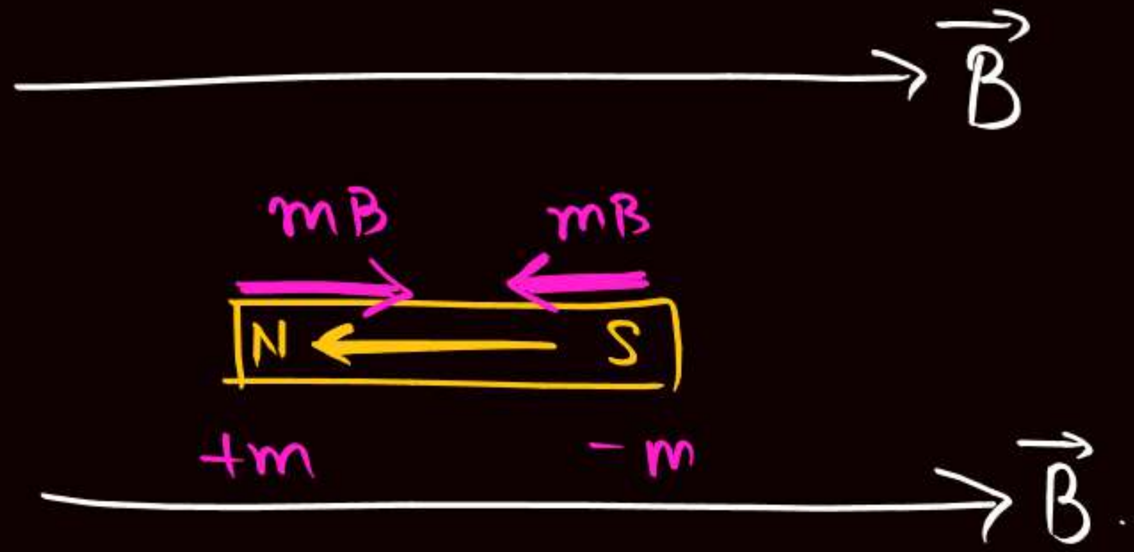


"Stable"

$\tau = \bar{M} \times \bar{B}$
$= MB \sin 0$
$= 0$

$PE = -\vec{M} \cdot \vec{B}$
$= -MB \cos 0$

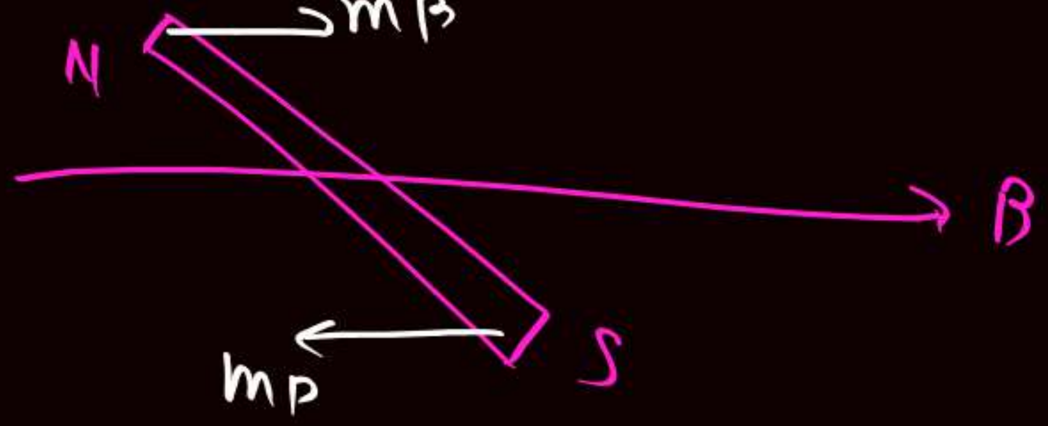
$\boxed{PE = -ve}$ Stable

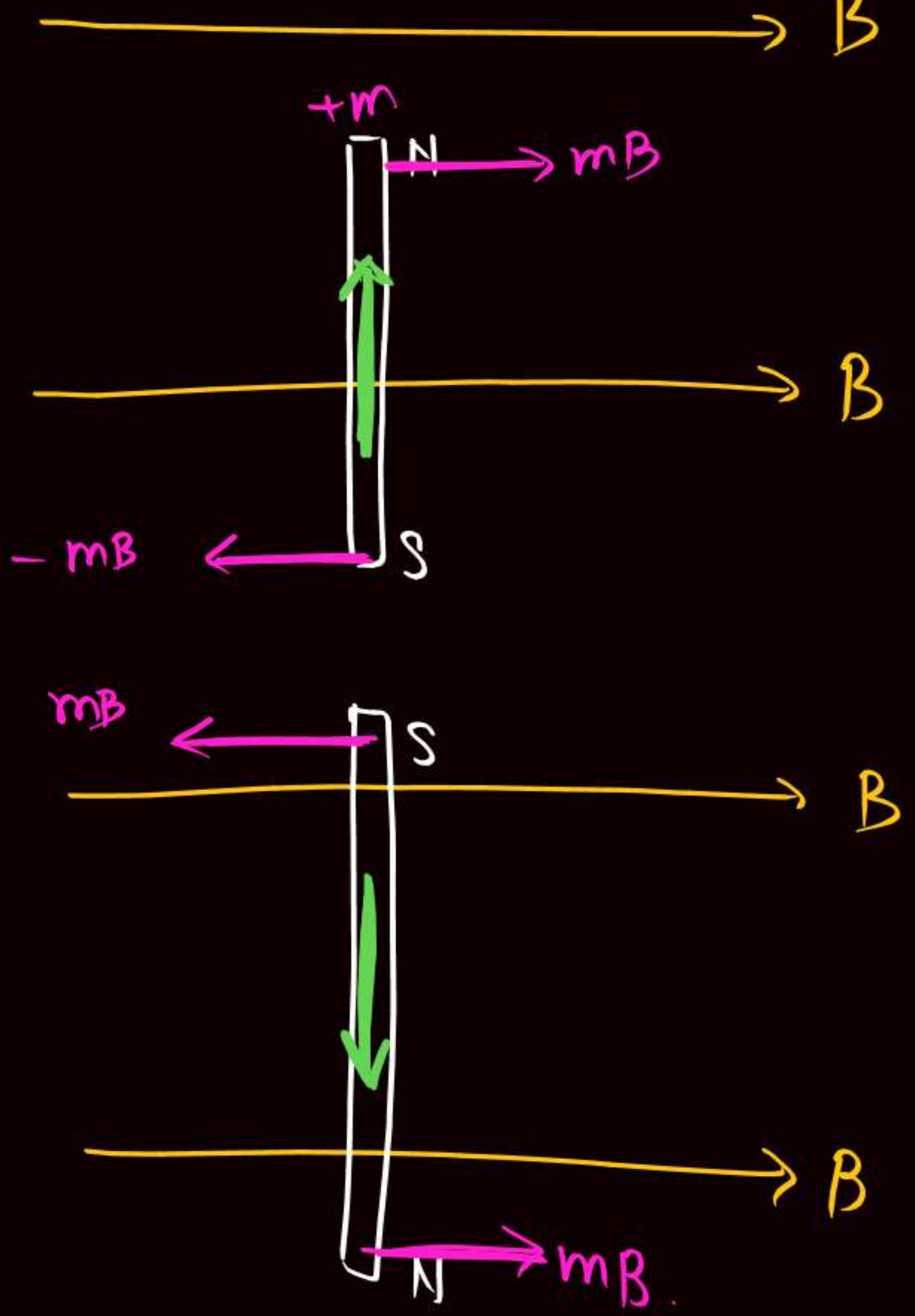


Unstable

$\tau = 0$

$PE = -\bar{M}\bar{B}$
$= -MB \cos 180$
$= +ve$ (unstable)





Equillibrium type.

Not in Equillibrium

$$\boxed{F_{net} = 0}$$

$$\boxed{\tau_{net} \neq 0}$$

$$\vec{\tau} = \vec{M} \times \vec{B}$$

$$\tau_1 = -MB\sin 90\,\hat{k}.$$

$$= -MB\hat{k}$$

$$\tau_2 = +mB\sin 90\,\hat{k}.$$

$$= +MB\hat{k}.$$

$$\vec{\tau}_2 =$$

$$\boxed{\vec{\tau}_1 \neq \vec{\tau}_2}$$

$$|\tau_1| = |\tau_2|.$$

Time Period of oscillation

Thank You Lakshyians