LAKSHYA BATCH

Magnetism and Matter
Questions on Bar magnet

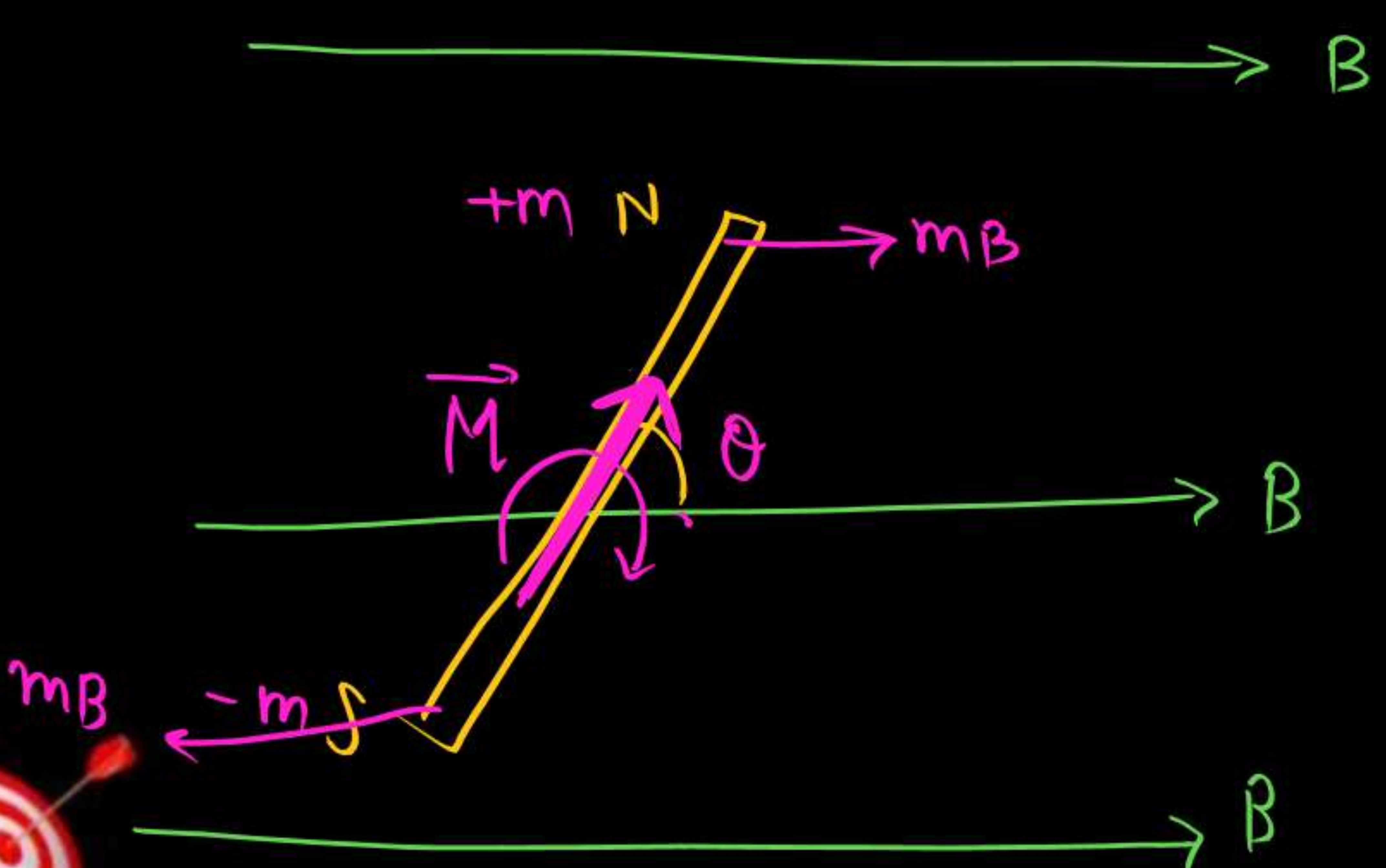
LECTURE - 3

GOALS OF THE DAY

- Questions on bar magnet

Time Period of oscillation

Compt There is a Stable Equillibrium point when a Magnet is placed in External field.



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

When this dipole is Released it will Oscillate in $\vec{B}$.

Let the dipole is Rotated by Small angle θ

$$\tau_{restoring} = -MB\sin\theta$$

$-$ → restoring Nature.

for Small θ

$$\tau = -MB\theta$$

$$\cancel{-}I\omega^2\cancel{\theta} = \cancel{-}MB\cancel{\theta}$$

$$I\omega^2 = MB$$

$$\frac{2\pi}{T} = \omega = \sqrt{\frac{MB}{I}}$$

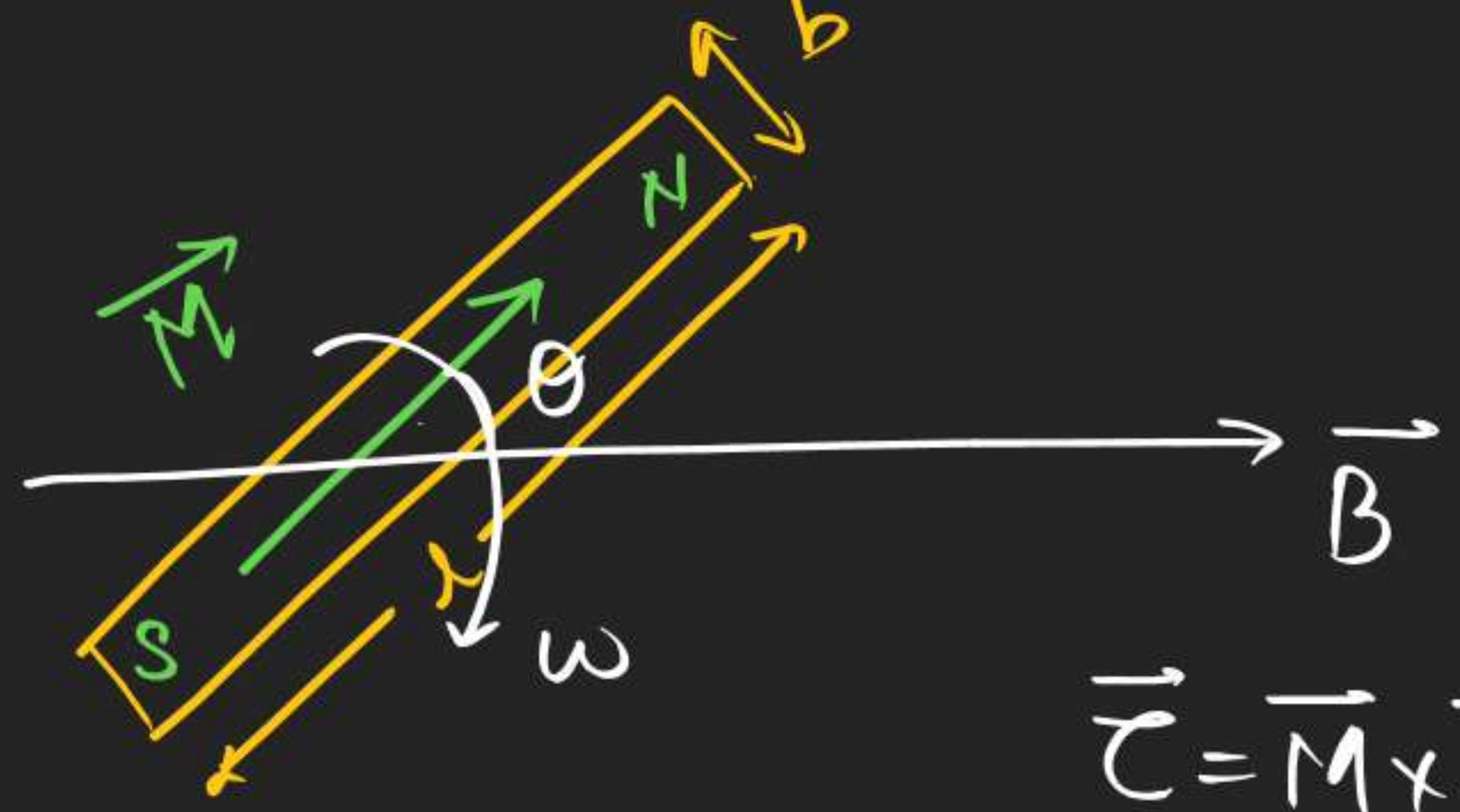
$$\boxed{T = 2\pi\sqrt{\frac{I}{MB}}}$$

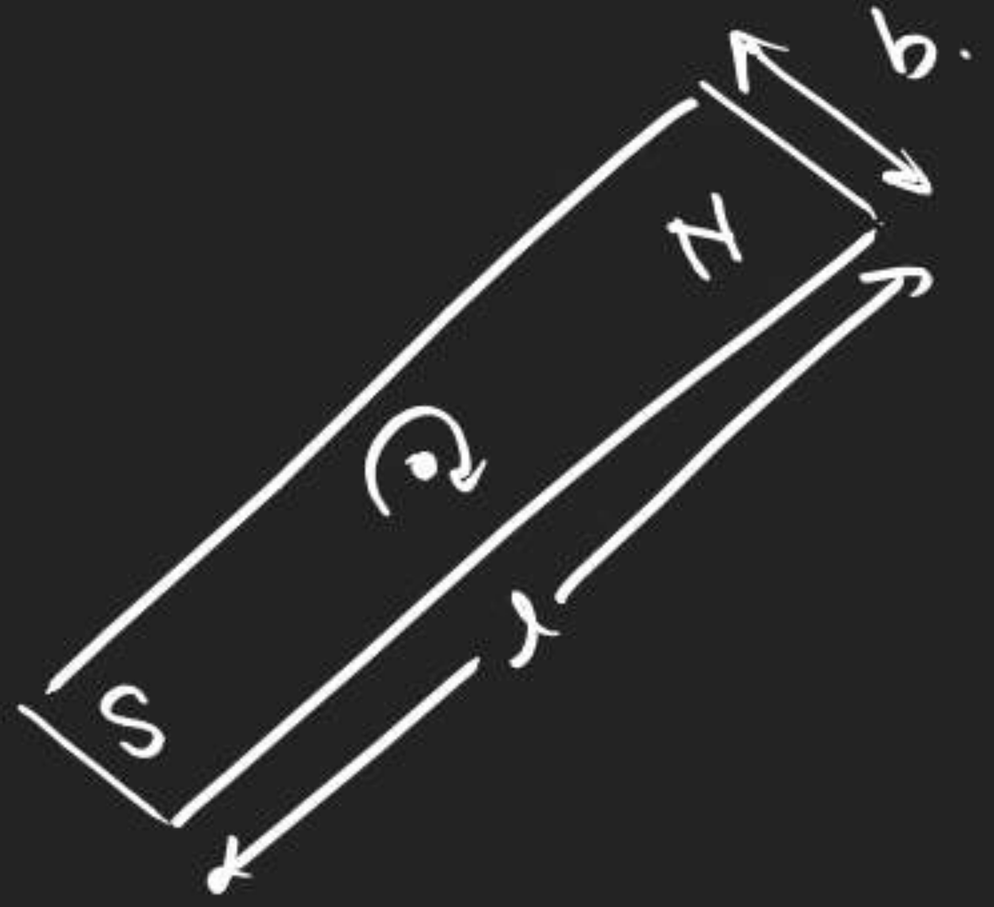
{Simple Harmonic Motion} SHM

SHM → Linear SHM, Angular SHM.

Linear SHM	Angular SHM
① $f_{restoring}$	① $\tau_{restoring}$
② $f = -m\omega^2 x$	② $\tau = -I\omega^2\theta$
③ $\omega = \frac{2\pi}{T}$	③ $\omega = \frac{2\pi}{T}$

I = Moment of Inertia.





Mass of Magnet $= M_0$

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

$(-\hat{k})$.

That will axis of Rotation

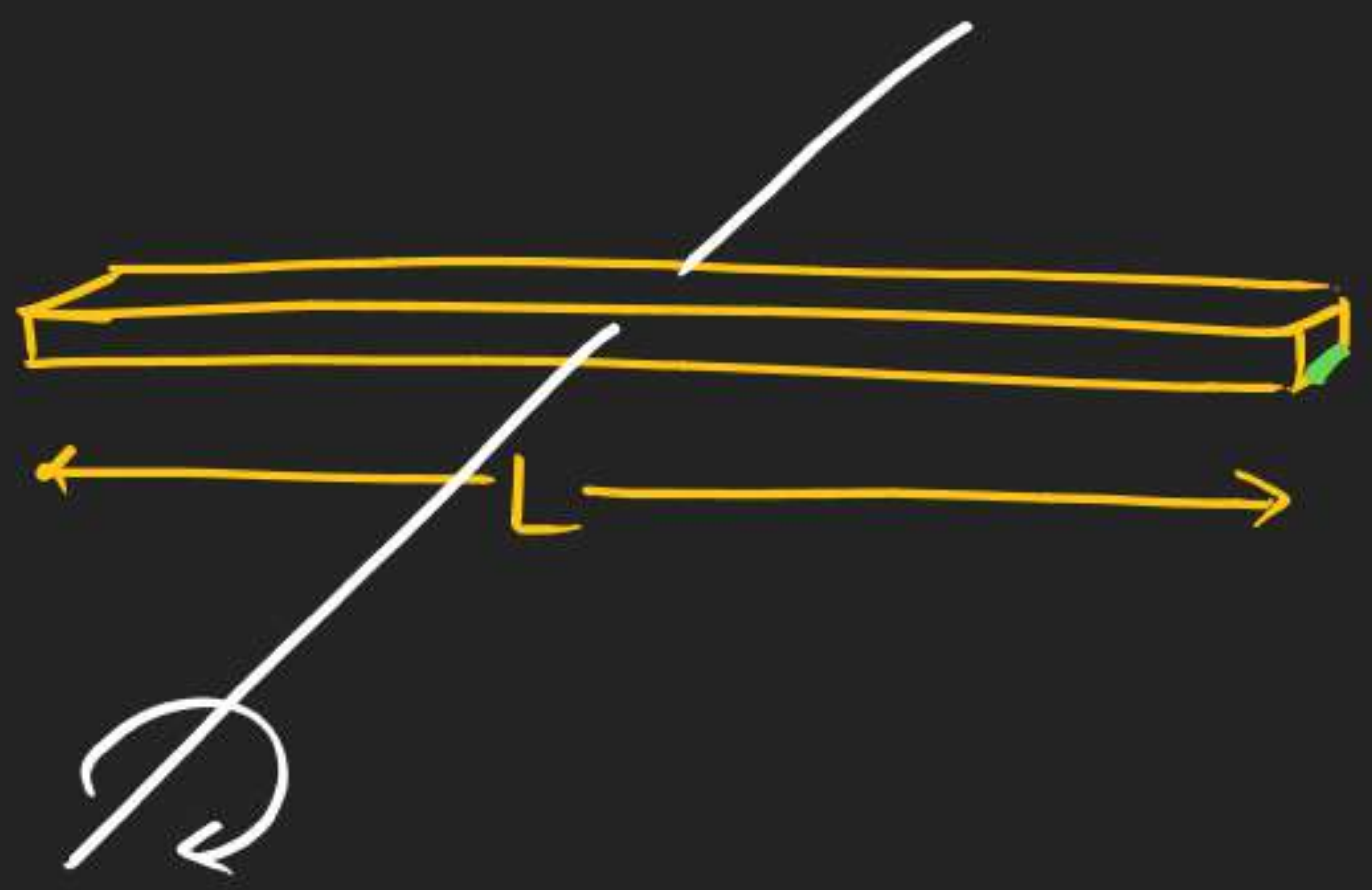
$$\boxed{\text{MoI about Centre} = \frac{1}{12} M_0 (l^2 + b^2)}$$

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

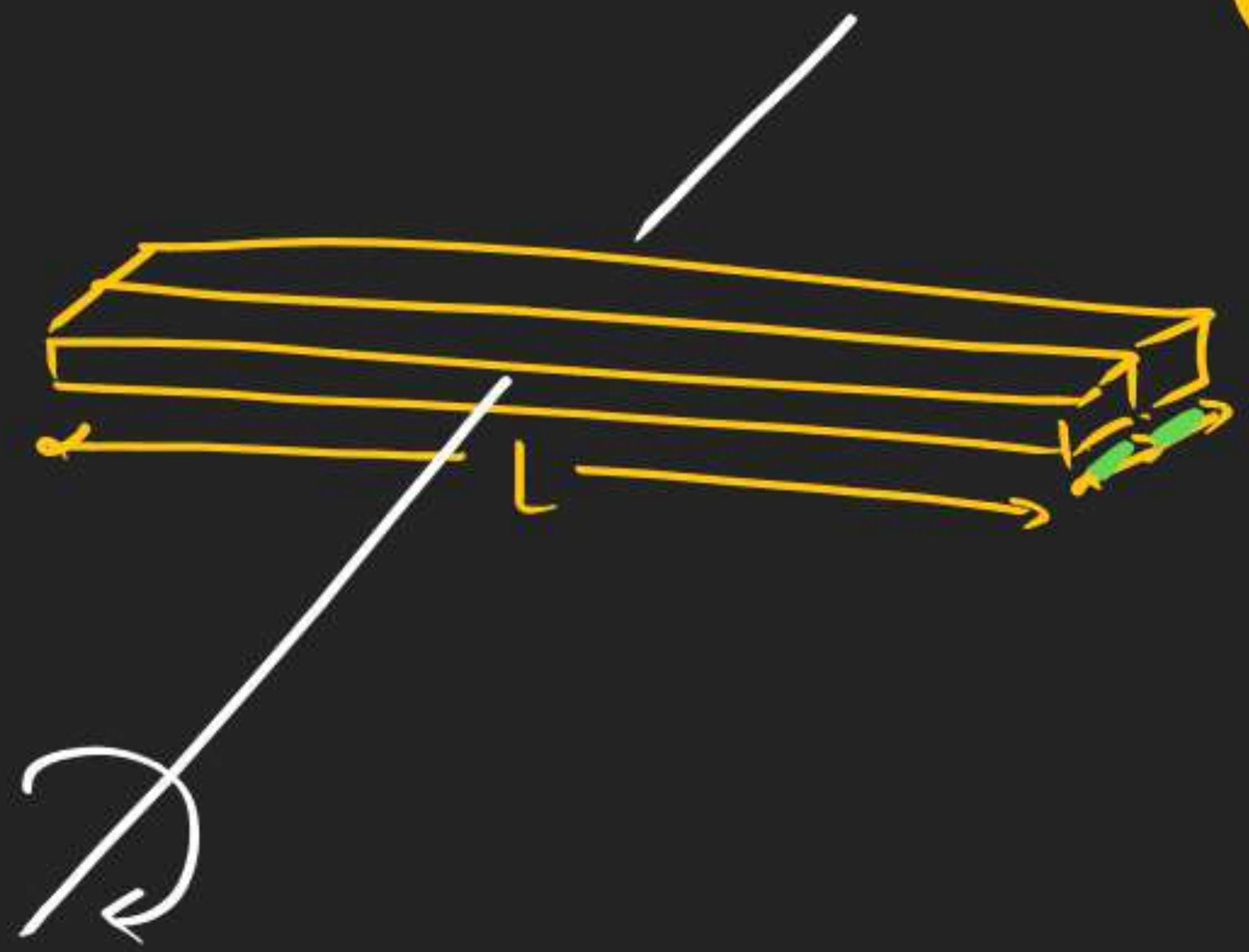
$$\boxed{\vec{M} = ml}$$

MoI. Class XI

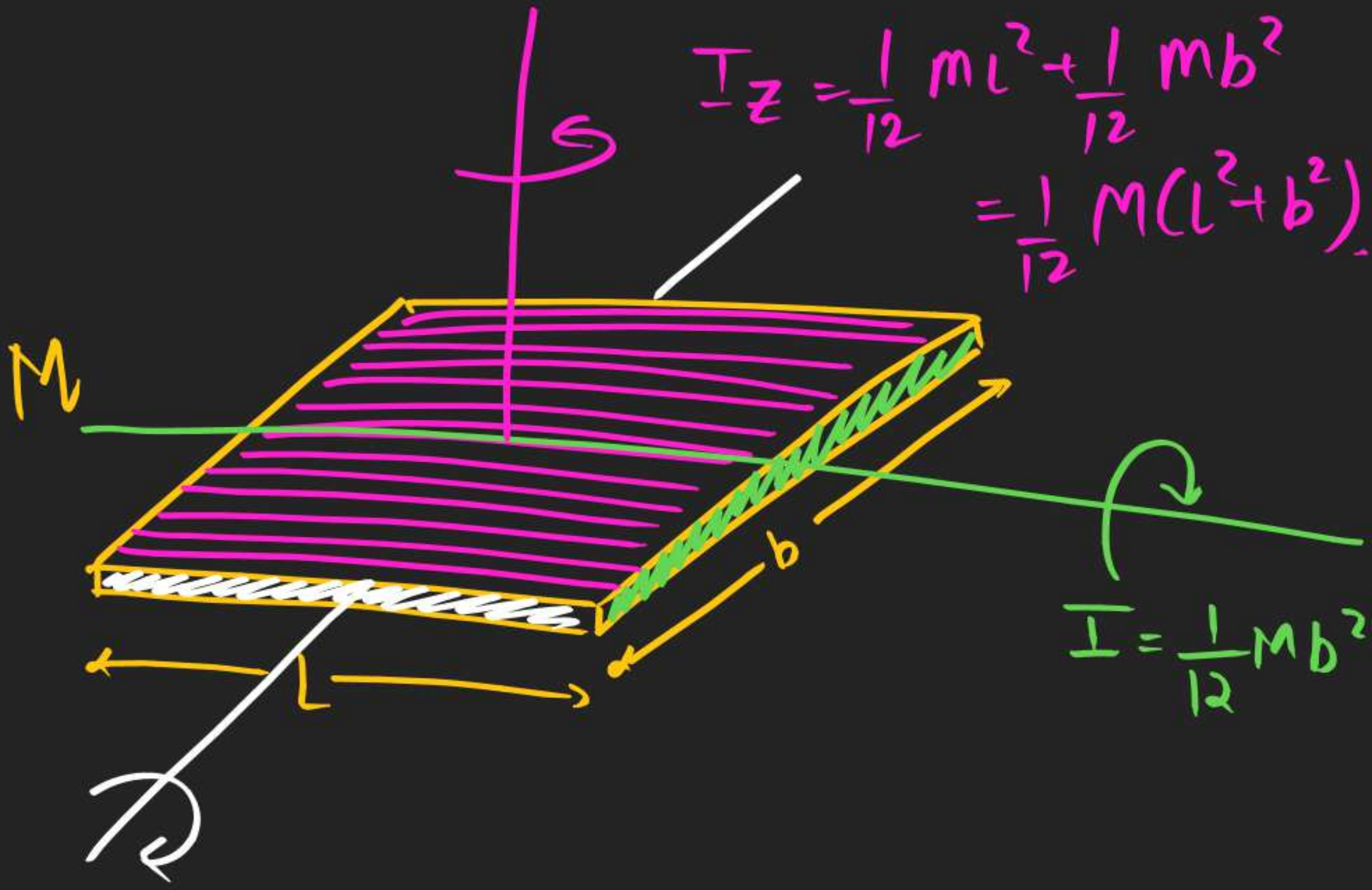
m_1



$$I_{Rod\,centre} = \frac{1}{12} m_1 L^2$$



$$I_T = \frac{1}{12} m_1 L^2 + \frac{1}{12} m_2 L^2 = \frac{1}{12}(m_1 + m_2) L^2$$



$$I_z = \frac{1}{12}ml^2 + \frac{1}{12}mb^2$$

$$= \frac{1}{12}M(l^2+b^2)$$

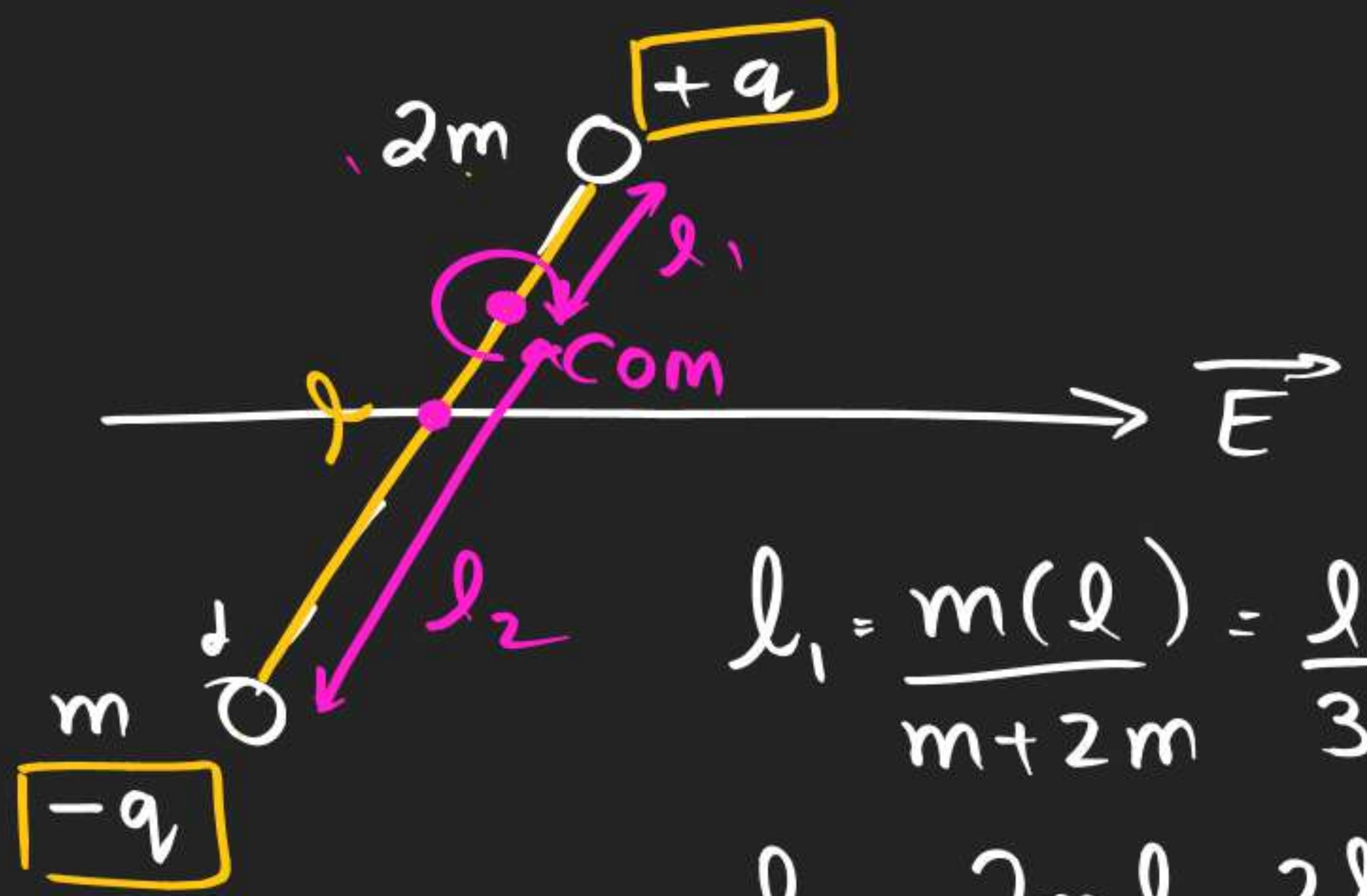
$$\boxed{I_z = I_x + I_y}$$

$$I = \frac{1}{12}Mb^2$$

$$I = \frac{1}{12}(m_1 + m_2 + m_3 + \cdots)L^2$$

$$= \frac{1}{12}ML^2$$

Compbt



$$l_1 = \frac{m(l)}{m+2m} = \frac{l}{3}$$

$$l_2 = \frac{2ml}{m+2m} = \frac{2l}{3}$$

MoI will be about COM

$$I = 2m(l_1^2) + m(l_2^2)$$

$$= 2m\left(\frac{l^2}{9}\right) + m\left(\frac{4l^2}{9}\right) = \frac{6ml^2}{9} = \frac{2ml^2}{3}$$

Time period in Electro $= 2\pi\sqrt{\frac{I}{PE}}$

$I =$ $\quad = 2\pi\sqrt{\frac{\frac{2}{3}ml^2}{qlE}}$

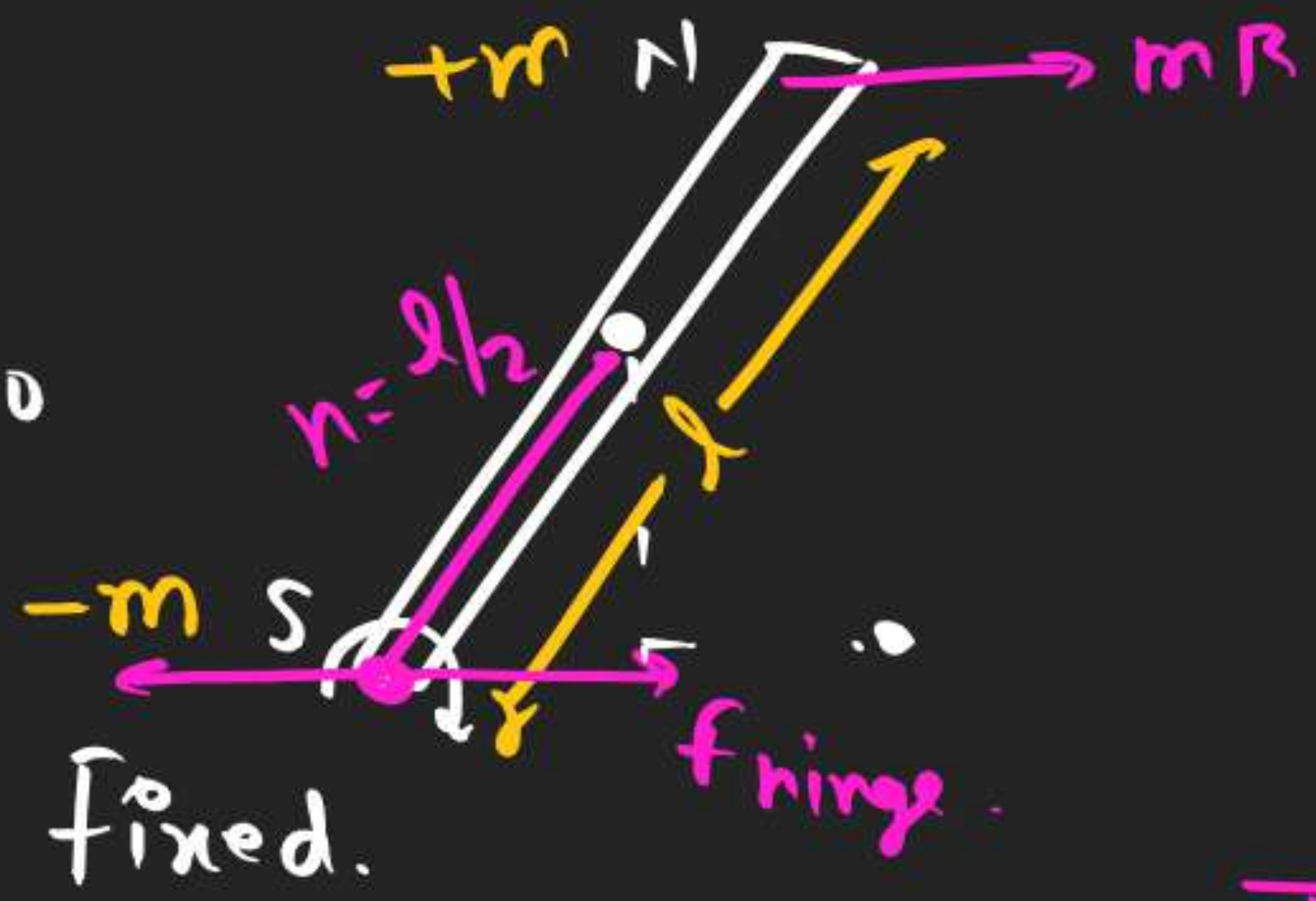
$\vec{P} = (\text{either charge})\left(\begin{matrix}\text{Seperation} \\ \text{between} \\ \text{them}\end{matrix}\right)$

$$\boxed{|\vec{P}| = ql}$$

"IIT"

$\longrightarrow B$

Mass = M_0

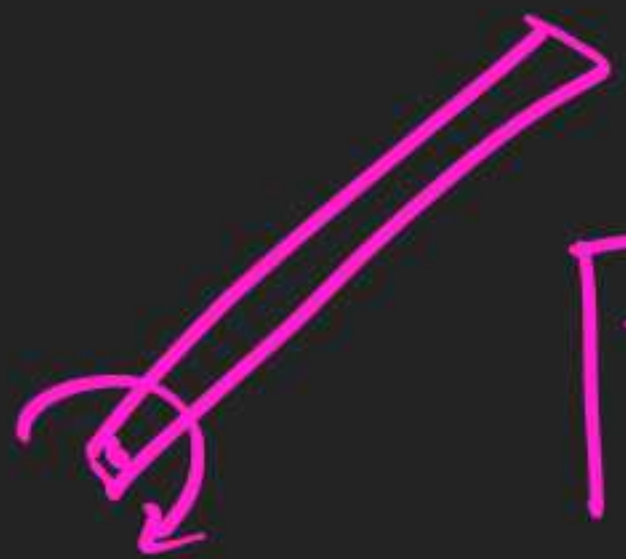


$$T = 2\pi\sqrt{\frac{I}{mB}}$$

$$|\vec{M}| = ml.$$

$$I = \frac{1}{3}M_0 l^2$$

$$\boxed{I = \frac{1}{12}M_0 L^2}$$



$$\boxed{I = \frac{1}{3}ML^2}$$

Time Period

Parallel Axis th

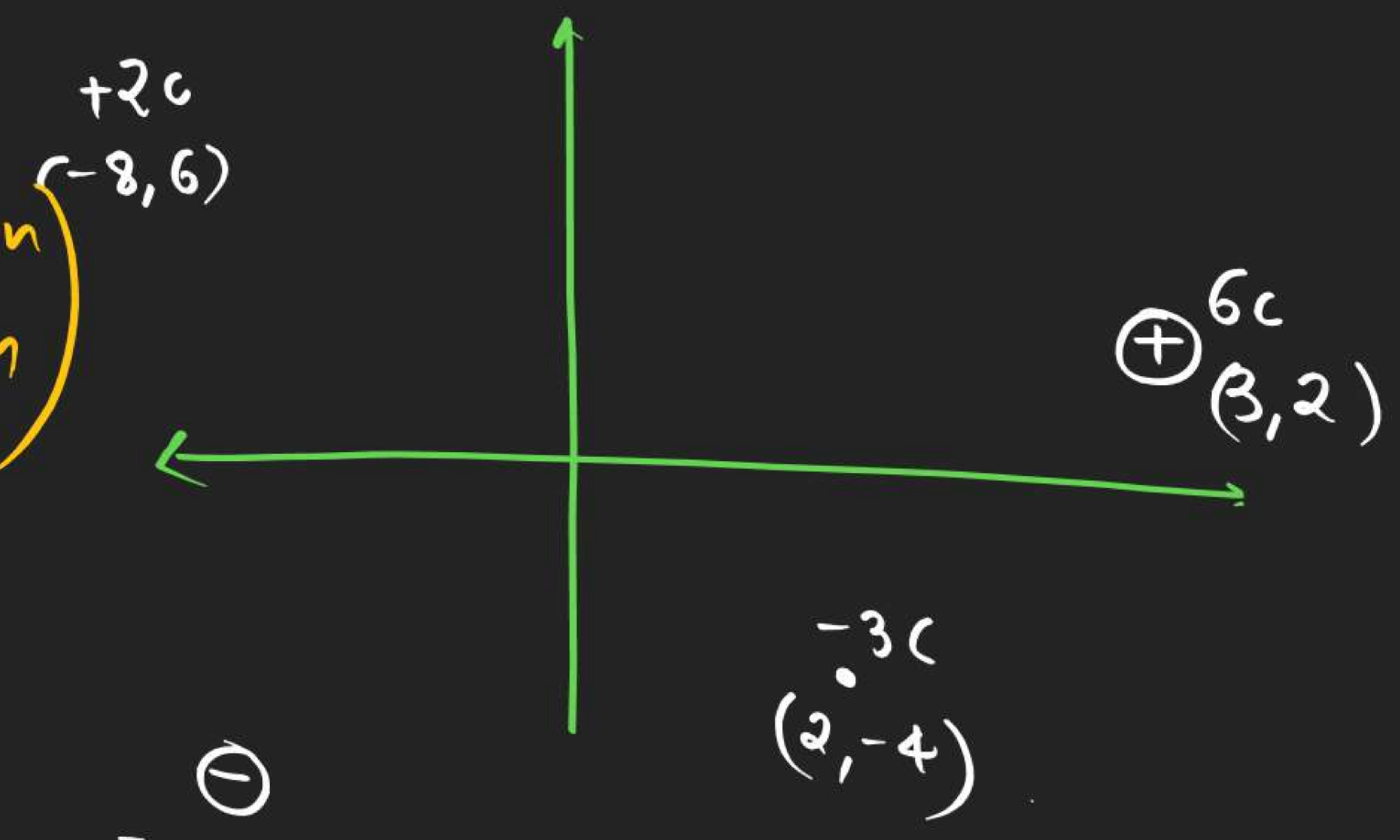
$$I_{KL} = I_{com} + Mh^2 = \frac{1}{12}ML^2 + \frac{Ml^2}{4} = \frac{1}{3}ML^2.$$

How to find dipole Moments of Isolated charges

hypothetical monopoles

Find dipole Moment?

$\vec{P}$ = (either charge)(Sepration between them)

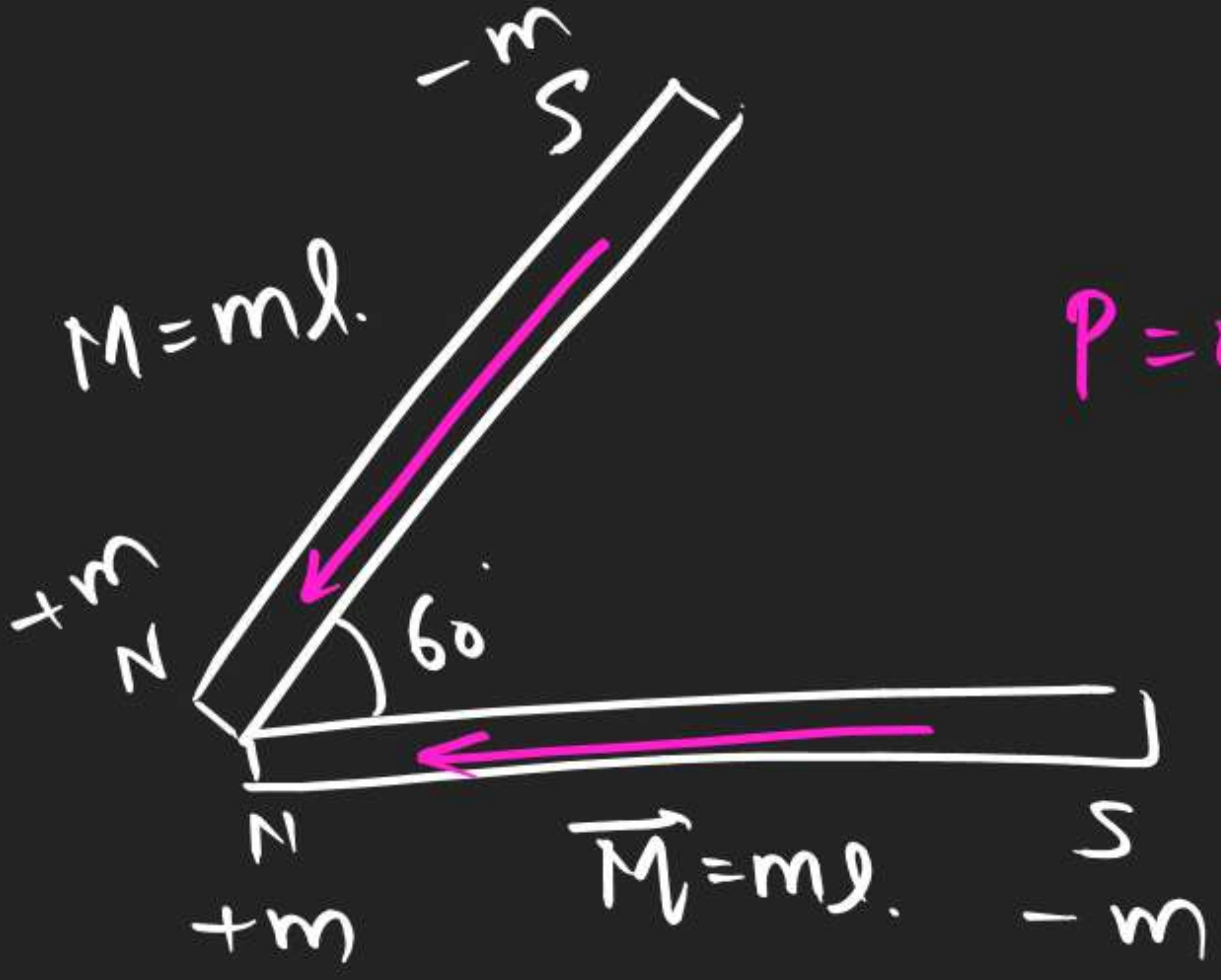


Rambaan :-

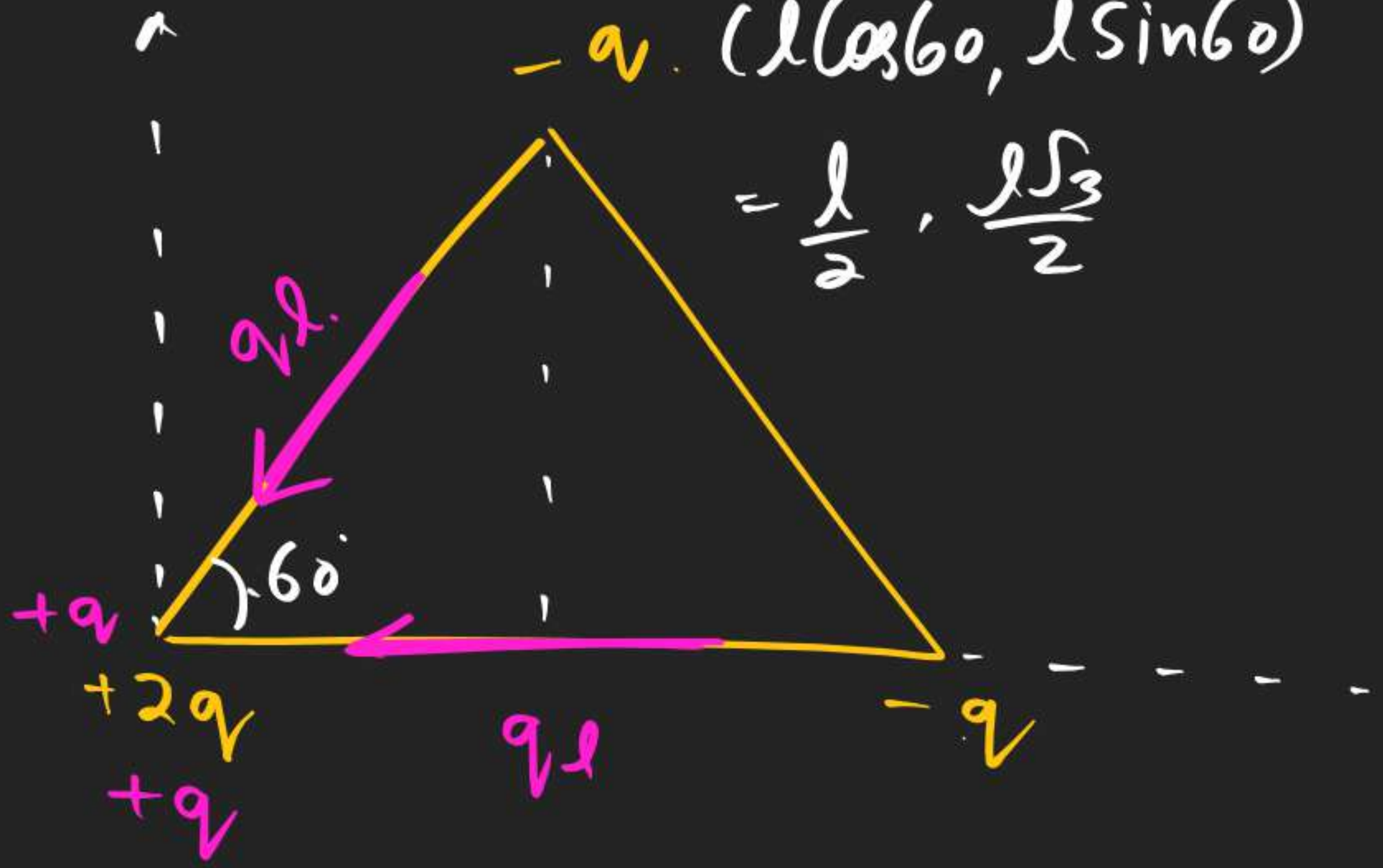
1. $Q_{\text{Total change}} = 8c - 8c = 0$
   (Monopole)

2. $\vec{P} = \sum$ (Charge with Sign)(Position Vector).

$$\vec{P} = +6(3\hat{i}+2\hat{j}) + 2(-8\hat{i}+6\hat{j}) - 5(-3\hat{i}-2\hat{j}) - 3(2\hat{i}-4\hat{j}).$$

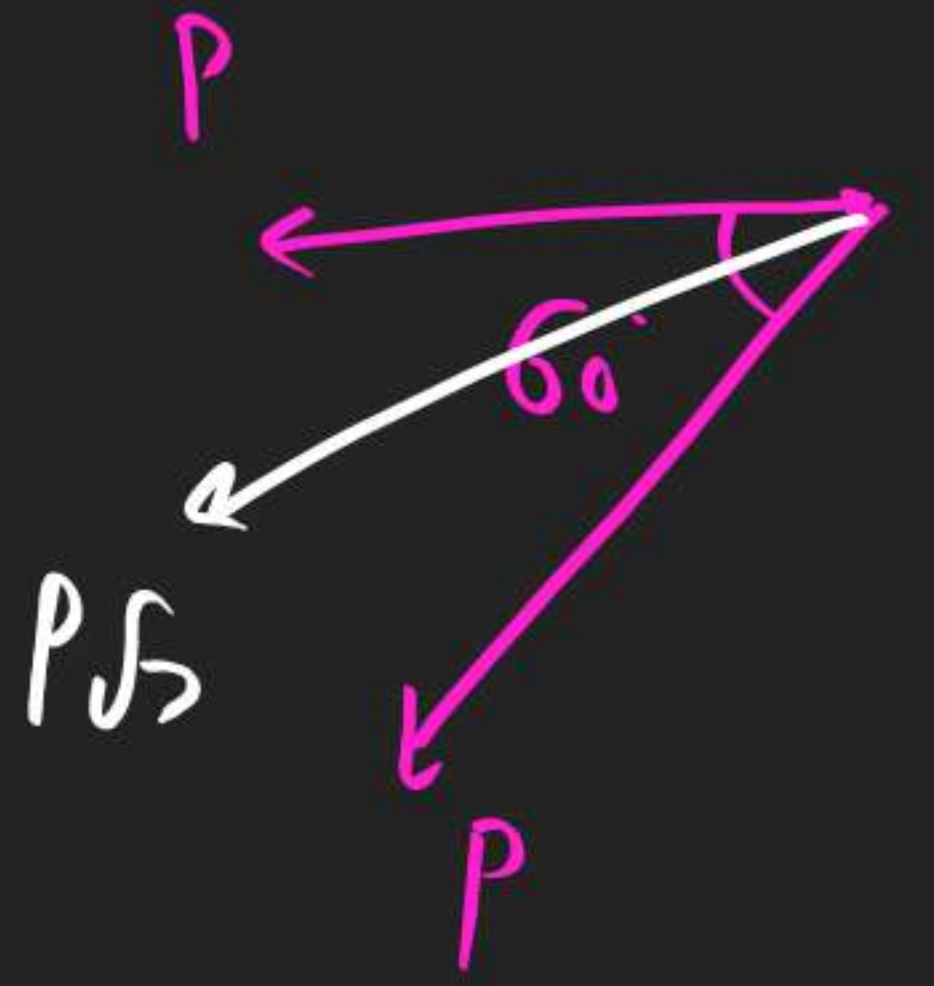


$P = ml$



$(l\cos 60, l\sin 60)$

$= \frac{l}{2}, \frac{l\sqrt{3}}{2}$



$R_{net} = P\sqrt{3}$

$= ml\sqrt{3}$ Ans.

$$\vec{P} = 2q(0\hat{i}+0\hat{j}) - q(l\hat{i}+0\hat{j})$$

$$-q\left(\frac{l}{2}\hat{i} + \frac{l\sqrt{3}}{2}\hat{j}\right)$$

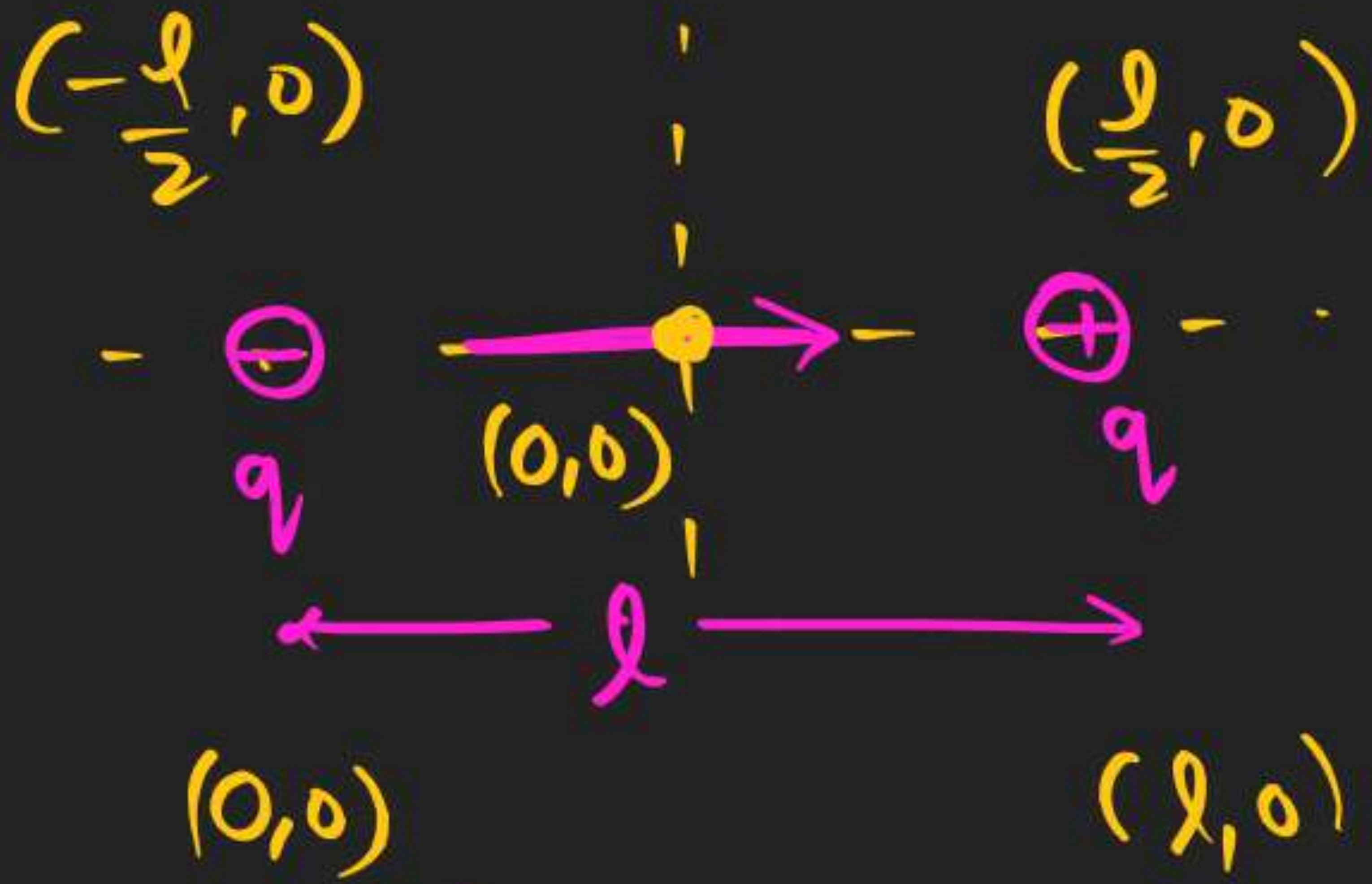
$$= q\left(-\frac{l}{2} - l\right)\hat{i} - q\frac{l\sqrt{3}}{2}\hat{j}$$

If $Q_T \neq 0$
the dipole Moment depends on origin { Not in Syllabus }

If $Q_T = 0$ $\longrightarrow$ $\vec{P} = \sum \text{charge (Position Vector)}$

dipole Moment Can be Calculated about any point

dipole Moment is dependent on point about which dipole is Calculated.



$\vec{P} = ql\,(\hat{i})$

By definition.

$Q_T = 0$

$$\vec{P} = +q\left(\frac{l}{2}\hat{i} + 0\hat{j}\right) - q\left(-\frac{l}{2}\hat{i} + 0\hat{j}\right)$$

$$= \frac{ql}{2}\hat{i} + \frac{ql}{2}\hat{i} = ql\hat{i}.$$

$$\vec{P} = -q(0\hat{i} + 0\hat{j}) + q(l\hat{i} + 0\hat{j})$$

$$= ql\hat{i}.$$

Solenoid as a Bar Magnet

In your boards

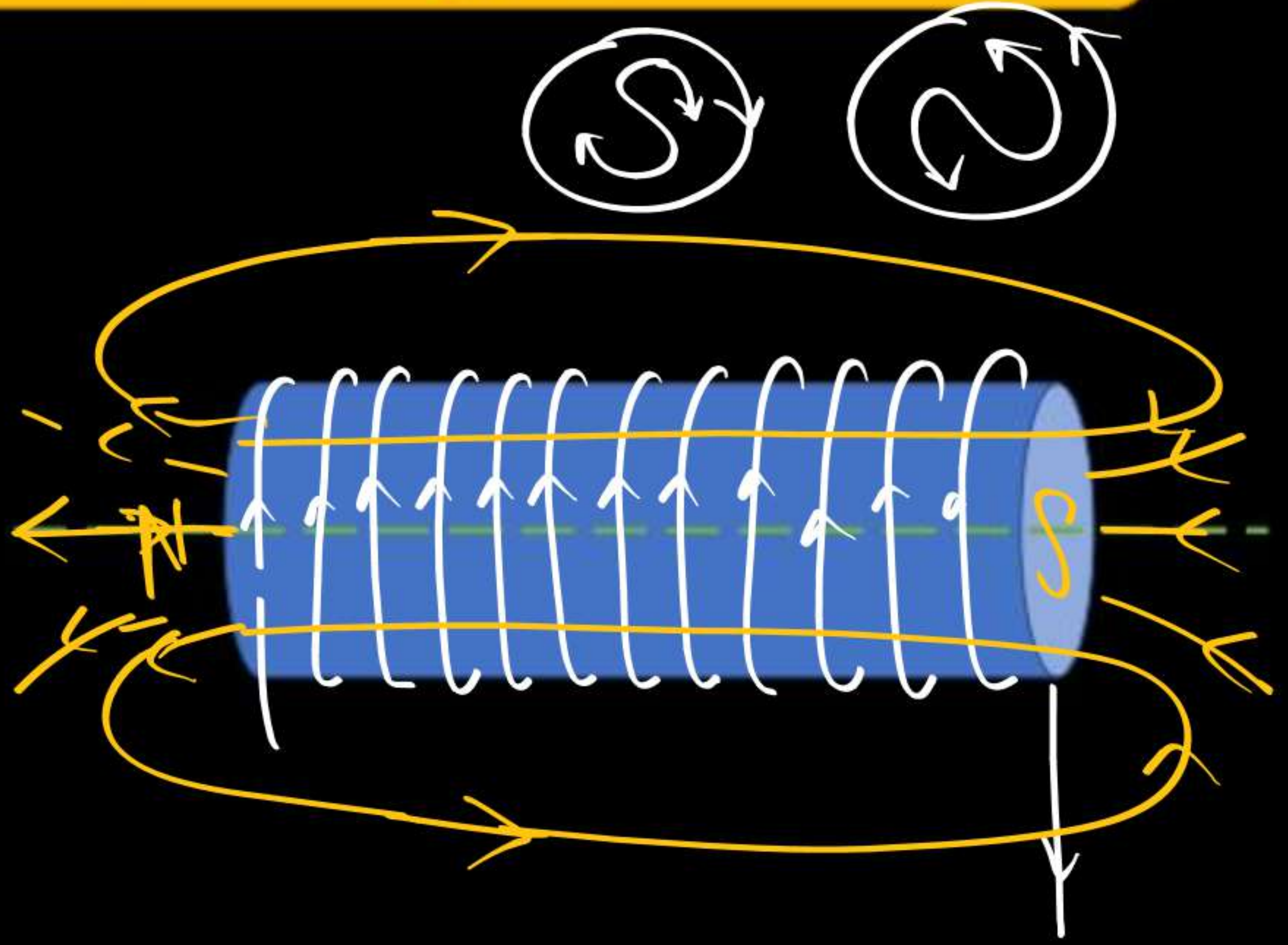
r $(r >> l)$

$+m$ $-m$

N S

l l

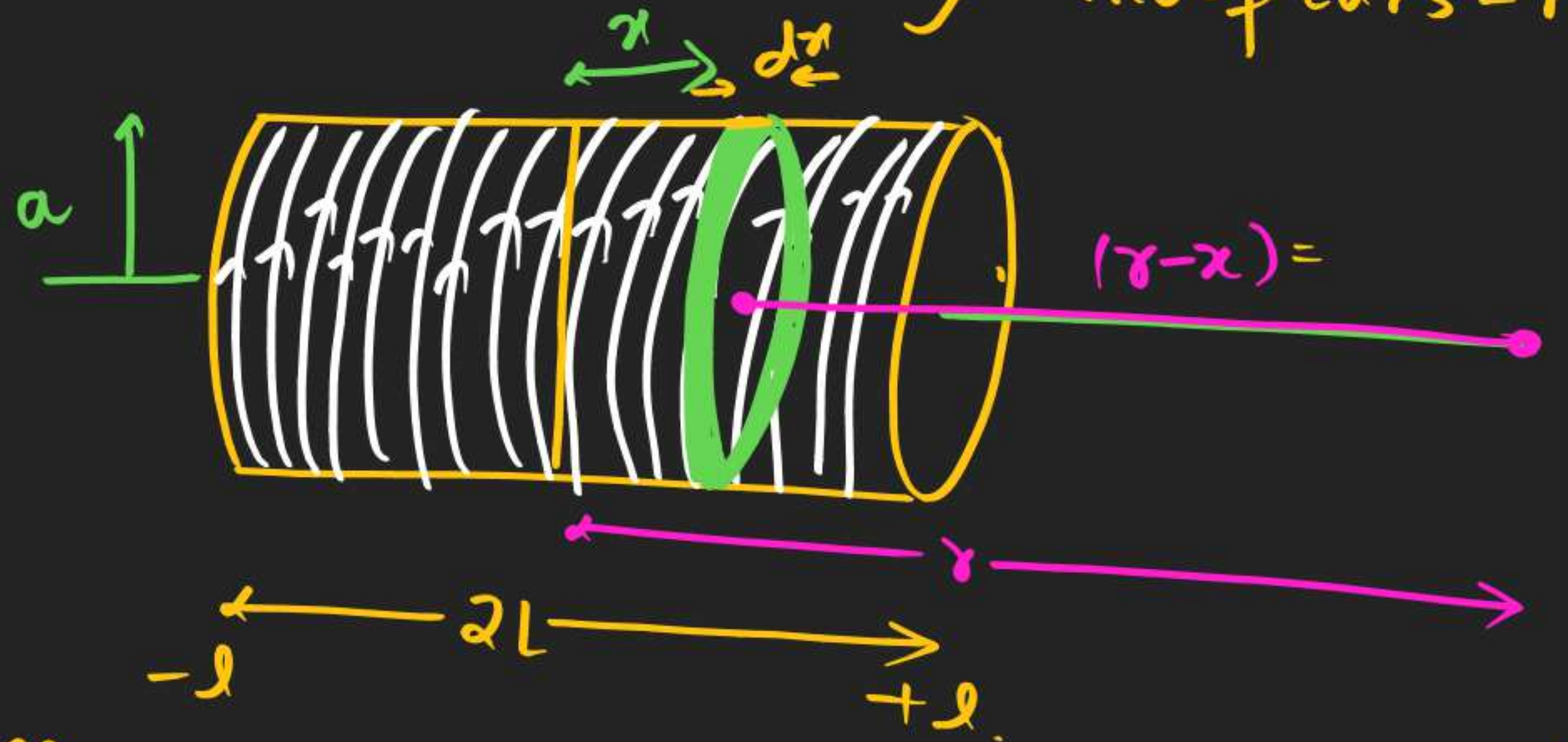
$$B = \frac{\mu_0 2M}{4\pi r^3}$$



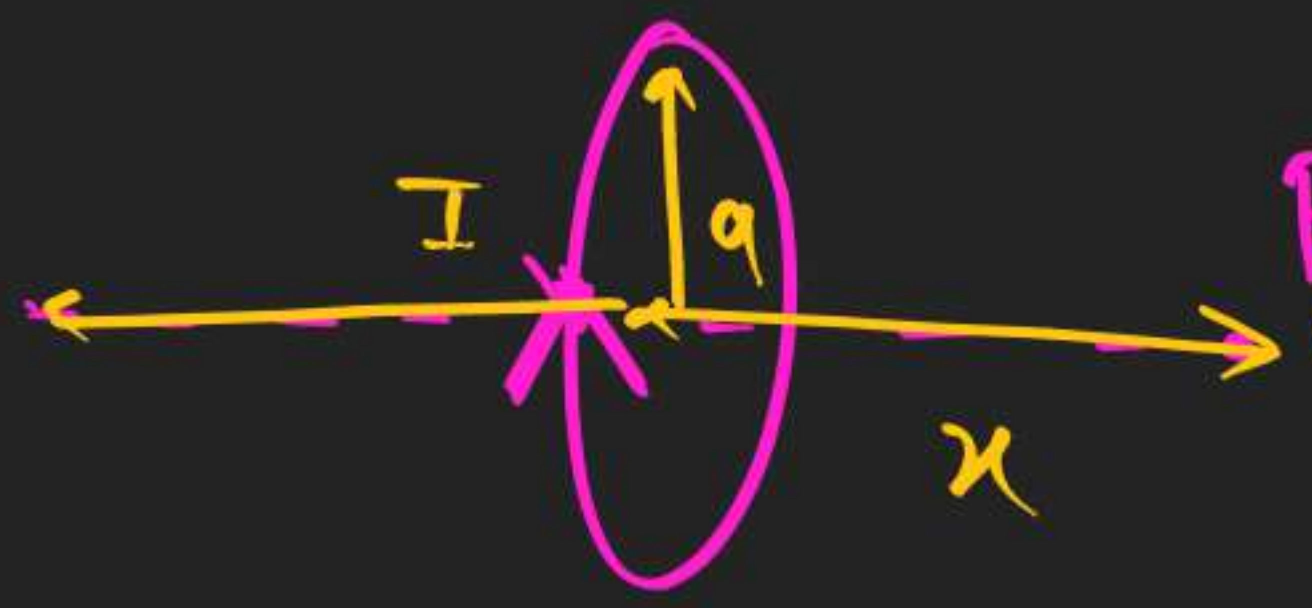
Total turns = N

no of turns Per unit Length $= "n" = \dfrac{N}{2L}$

no of turs = $n\,dx$



We take a Elemental Ring at distance x from Centre of thickness dx.



no of turn

$$B_{axis} = \frac{\mu_0 n I a^2}{2(a^2+x^2)^{3/2}}$$

no of turns

$$dB = \frac{\mu_0 (n\,dx) I a^2}{2\left((r-x)^2+a^2\right)^{3/2}}$$

$r \ggg l$

$r \gg a$

$r \gg x$

$$dB = \frac{\mu_0 n\,dx\,I a^2}{2 r^3}$$

$$B_T = \int dB = \int \frac{\mu_0 n\, dx\, I a^2}{2r^3}$$

Total turns $= N$

$IA = \vec{M}$

$\vec{M} = NIA$

N = Total turns

$$n = \frac{N}{2L}$$

$$n(2L) = N$$

$$= \frac{\mu_0 n I a^2}{2r^3} \int_{-l}^{+l} dx$$

$$= \frac{\mu_0 (n\, 2l) I a^2}{2r^3} = \frac{\mu_0 N I \pi a^2}{2\pi r^3}$$

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

Thank You Lakshyians