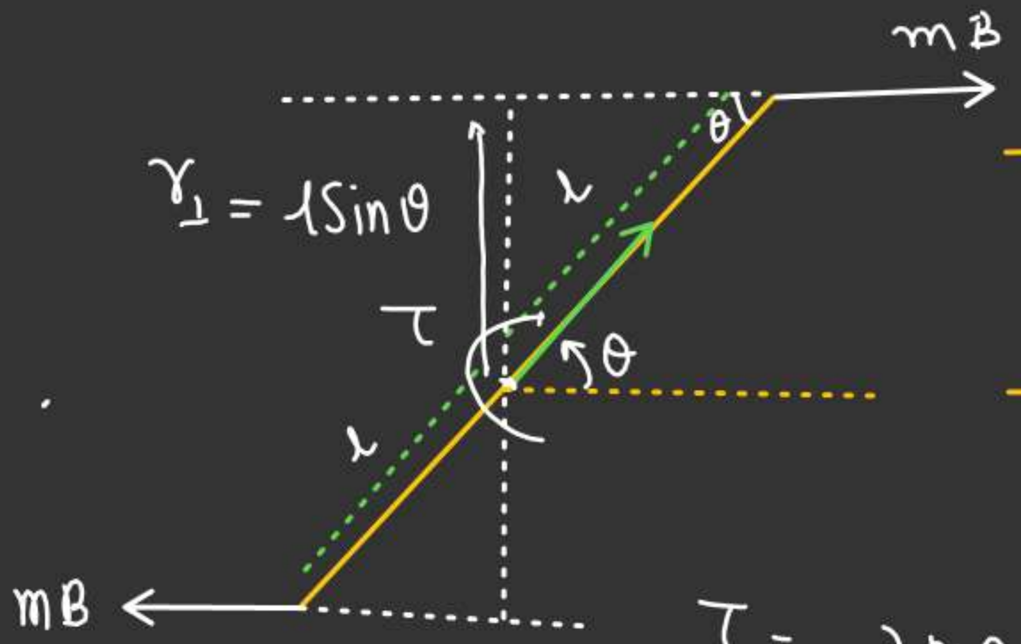
Nishant Jindal

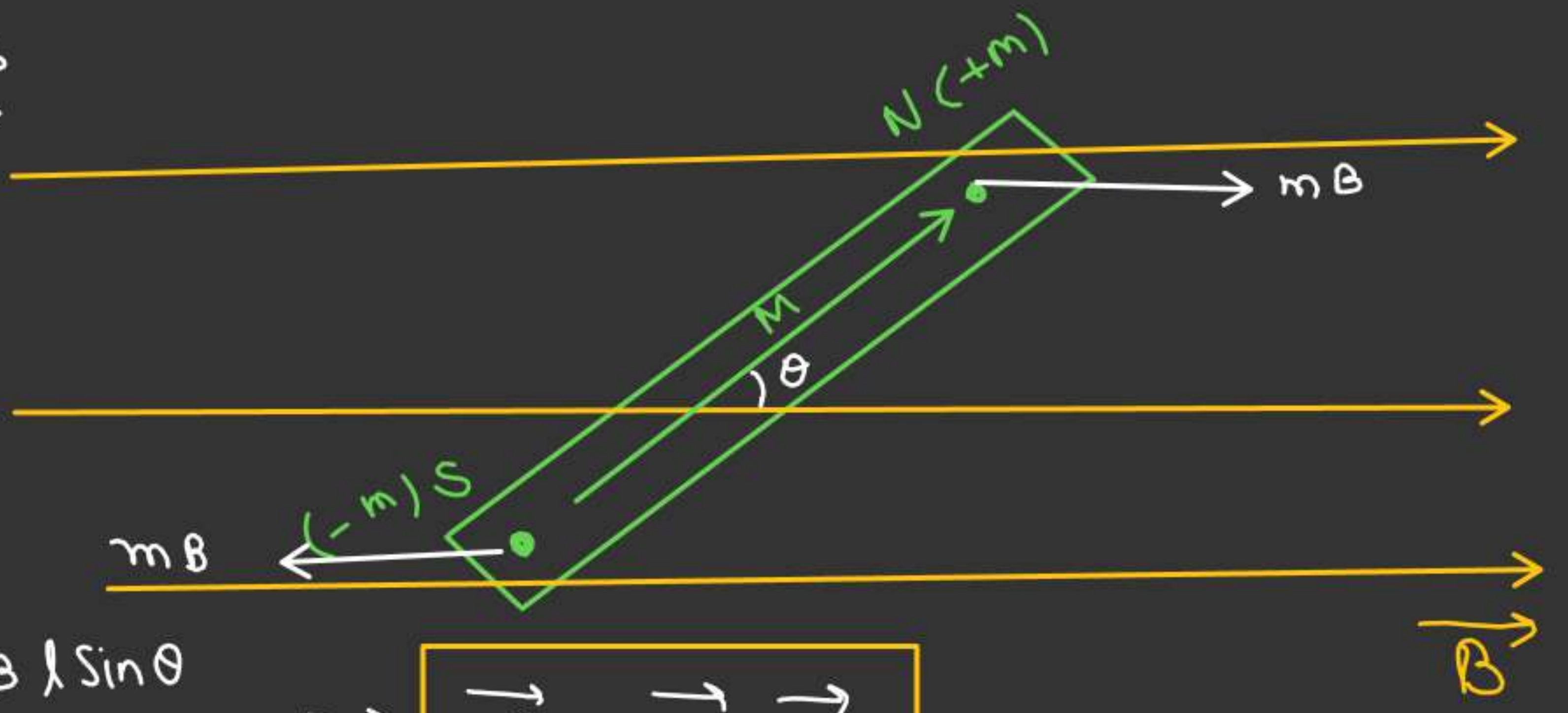
MAGNETISM [JEE MAINS].

$[\tau = F \cdot r_\perp]$

Torque acting on a bar magnet place in a uniform Magnetic field

$[M = m \cdot 2l]$





$\tau = 2mBl\sin\theta$

$\tau = (\underbrace{m \cdot 2l}_{M}) B\sin\theta$

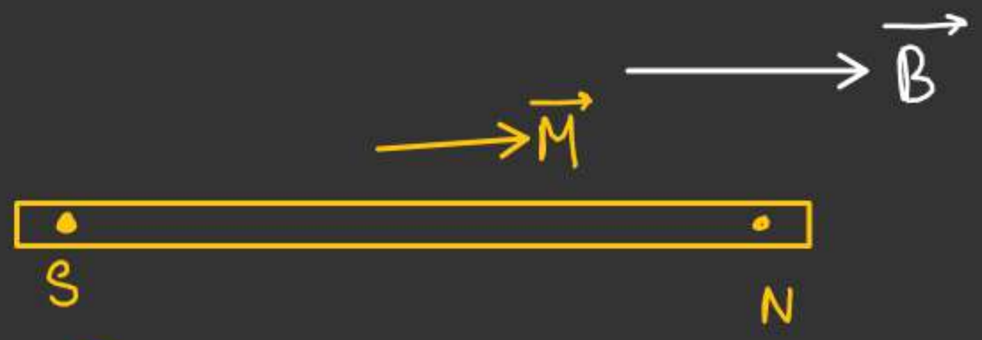
$\tau = MB\sin\theta$

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

Nishant Jindal

$\vec{M} \parallel \vec{B}$, $\tau = 0$,

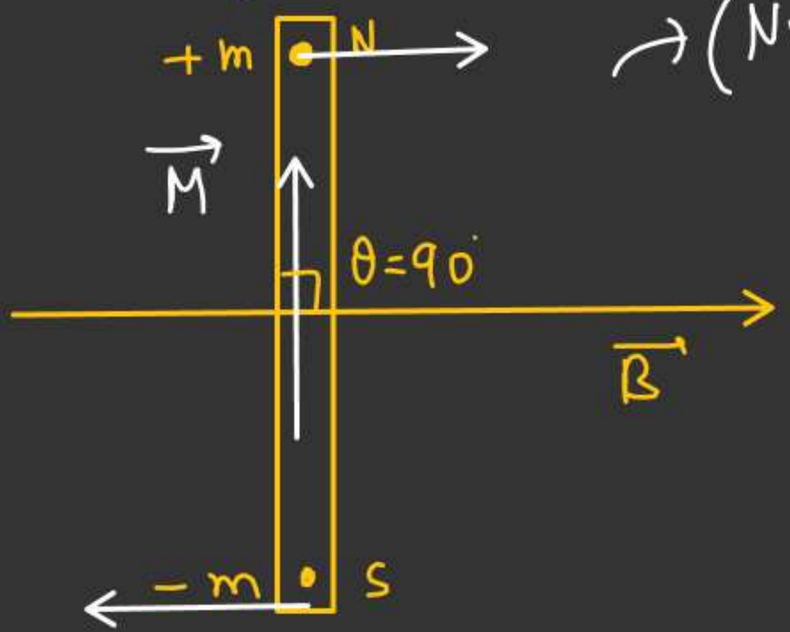
$\vec{M} \uparrow \vec{B}$



[Stable Equilibrium position]

τ_{max}, $\theta = 90^\circ$

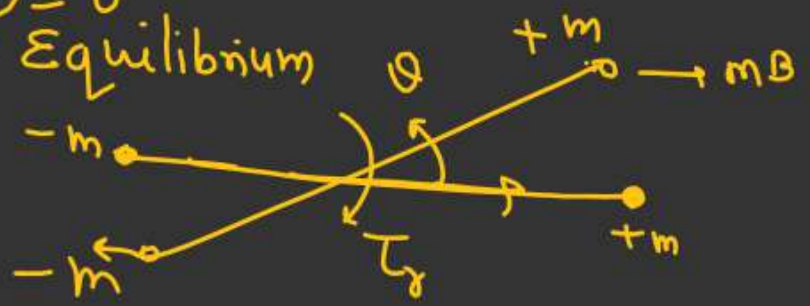
→ (Not an equilibrium)

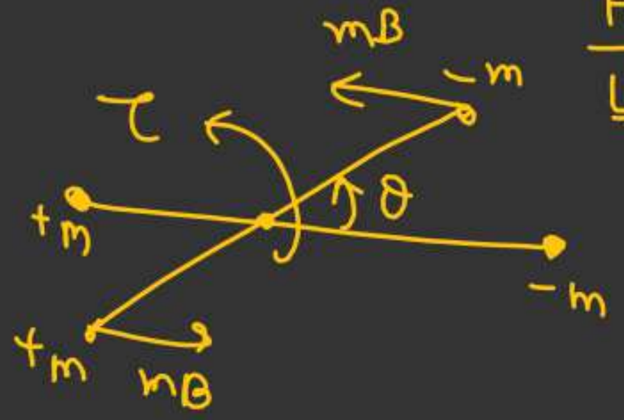


$\tau_{max} = MB$ ✓

$\theta = 0$

Stable Equilibrium





For $\theta = \pi$

↳ Unstable Equilibrium

Nishant Jindal

Motion of a bar-Magnet in a Uniform Magnetic field :→

$\theta \Rightarrow$ Very Small, $\sin\theta \simeq \theta$.

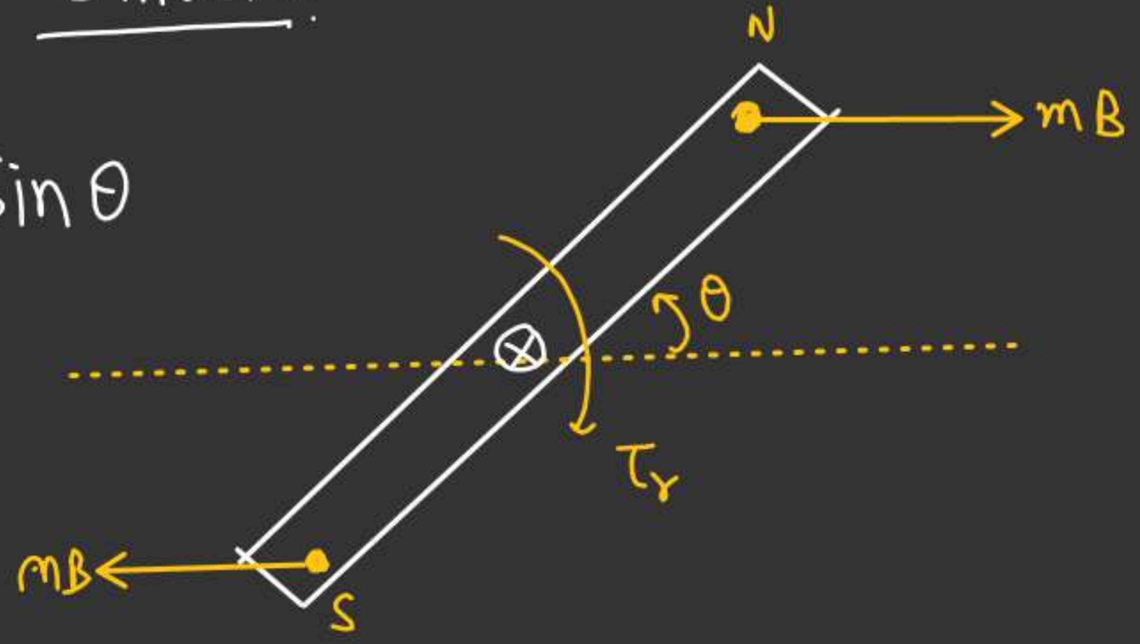
$$\tau_r = -MB\sin\theta$$

$$\tau_r = -MB\,\theta$$

$$\alpha = \frac{\tau_r}{I}$$

$$\boxed{\alpha = -\frac{MB}{I}\theta} \Rightarrow \text{S.H.M}$$

$$\alpha = -\omega^2\theta$$



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

I = Moment of Inertia of bar Magnet about axis of Rotation

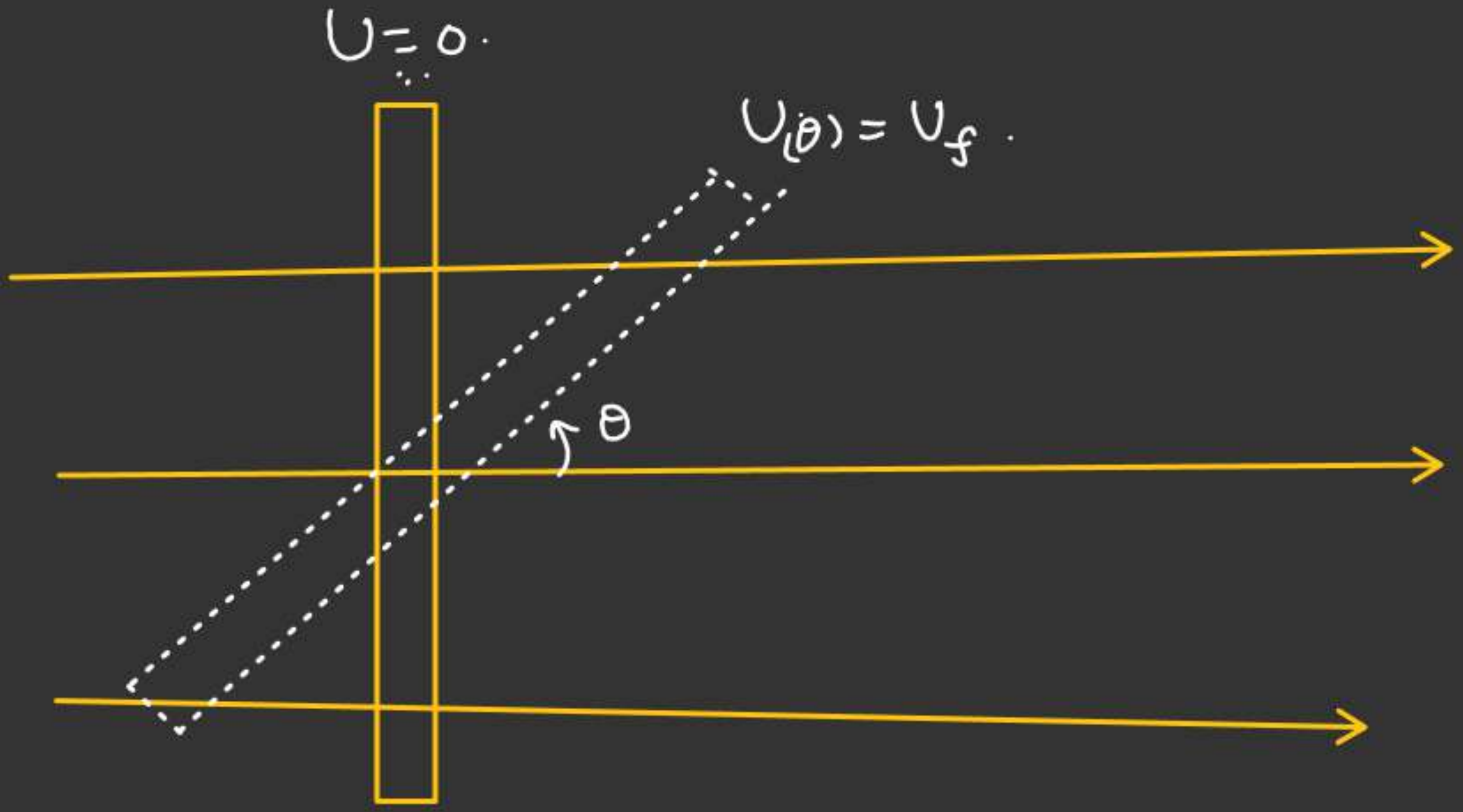
$$\boxed{T = 2\pi\sqrt{\frac{I}{MB}}}$$

$$\boxed{f = \frac{1}{T}}$$

Nishant Jindal

** : P.E of a bar magnet placed in a uniform magnetic field.

$$\int_{U(\theta_1)}^{U(\theta_2)} dU = \int_0^{W_{ext}} dW = \int \tau \cdot d\theta = MB\int_{\theta_1}^{\theta_2} \sin\theta \cdot d\theta \qquad \tau = MB\sin\theta$$



$$U_{(\theta_2)} - U_{(\theta_1)} = -MB[\cos\theta_2 - \cos\theta_1]$$

$$U_{(\theta_2)} - U_{(\theta_1)} = MB[\cos\theta_1 - \cos\theta_2]$$

$\theta_1 = \frac{\pi}{2}$, $U_i = 0$

$\theta_2 = \theta$, $U_{(\theta)} = U_f$

$$\Downarrow$$

$$U_{(\theta)} = -MB\cos\theta \Rightarrow \boxed{U_{(\theta)} = -\vec{M} \cdot \vec{B}} \;**$$

Nishant Jindal

(4) Force of Interaction b/w two bar Magnet placed at a large distance $[r >> l_1 \text{ or } l_2]$

$$U = -\vec{M_2} \cdot \vec{B_1}$$

$$\vec{M_2} \parallel \vec{B_1}$$

$$\vec{B_1} = \left(\frac{\mu_0}{4\pi}\frac{2M_1}{r^3}\right)\hat{i}$$

$$U = -\vec{M_2} \cdot (\vec{B_1})$$

$$U = -(M_2\hat{i}) \cdot \left(\frac{\mu_0}{4\pi}\frac{2M_1}{r^3}\right)\hat{i}$$

$$U = -\left(\frac{\mu_0}{4\pi}\right)\left(\frac{2M_1M_2}{r^3}\right)$$

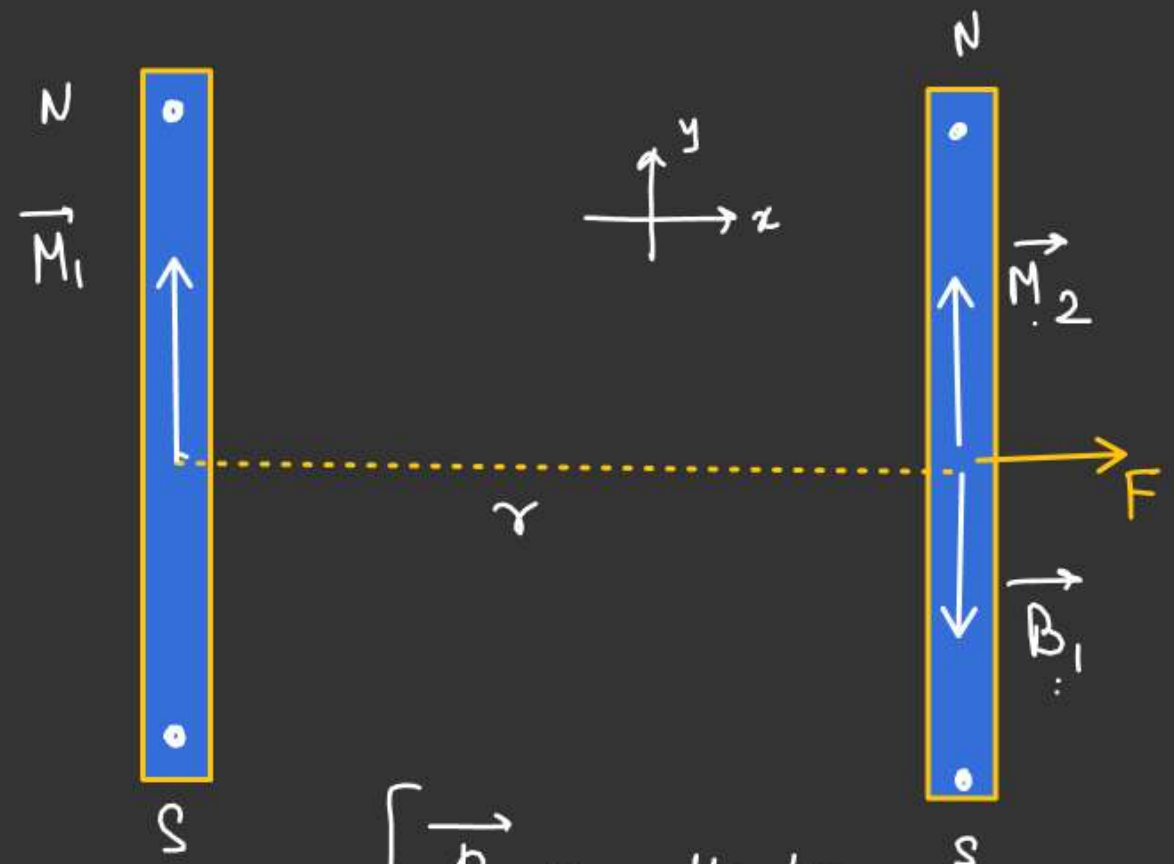
$$F = -\frac{dU}{dr}$$

$$F = \left(\frac{\mu_0}{4\pi}\right) 2M_1M_2 \frac{d}{dr}(r^{-3})$$

$$F = \frac{\mu_0}{4\pi}\left(\frac{-6M_1M_2}{r^4}\right)$$

$$\boxed{F \propto \frac{1}{r^4}}$$

[Attractive force]



$$U = -\vec{M}_2 \cdot \vec{B}_1$$

$$U = M_2 B_1$$

$$U = M_2 \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)$$

$$U = \frac{\mu_0 M_1 M_2}{4\pi}\left(\frac{1}{r^3}\right)$$

$$\vec{B}_1 = \frac{\mu_0}{4\pi}\left(\frac{M}{r^3}\right)(-\hat{j})$$

$$\vec{M}_2 = M_2(+\hat{j})$$

$$F = \left(-\frac{dU}{dr}\right)$$

$$F = \left(+\frac{3\mu_0 M_1 M_2}{4\pi r^4}\right)$$

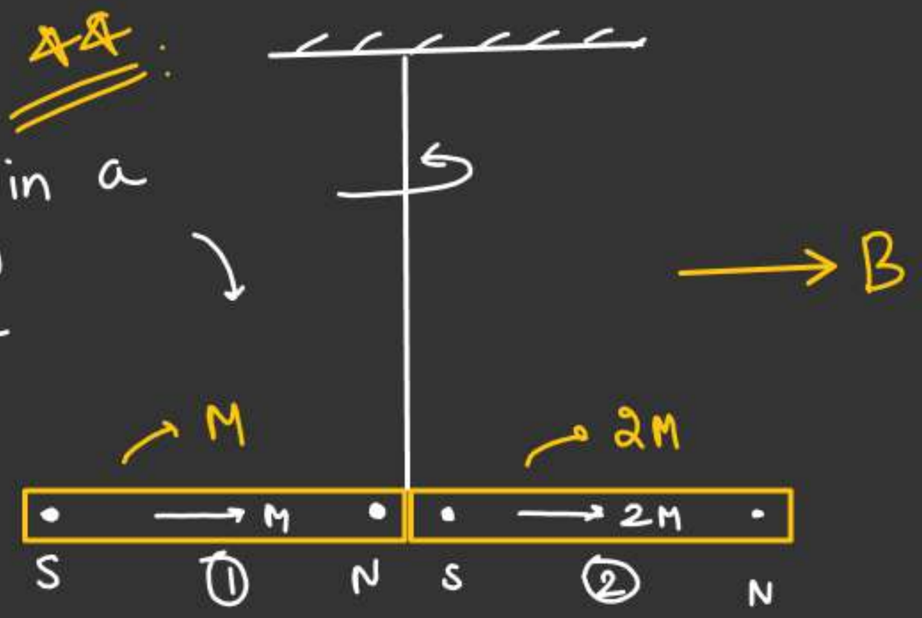
$\Downarrow$

Repulsive

Nishant Jindal

:

Placed in a Uniform Magnetic field.



$$\frac{T_1}{T_2} = ??$$

T_1 Is the time period.

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

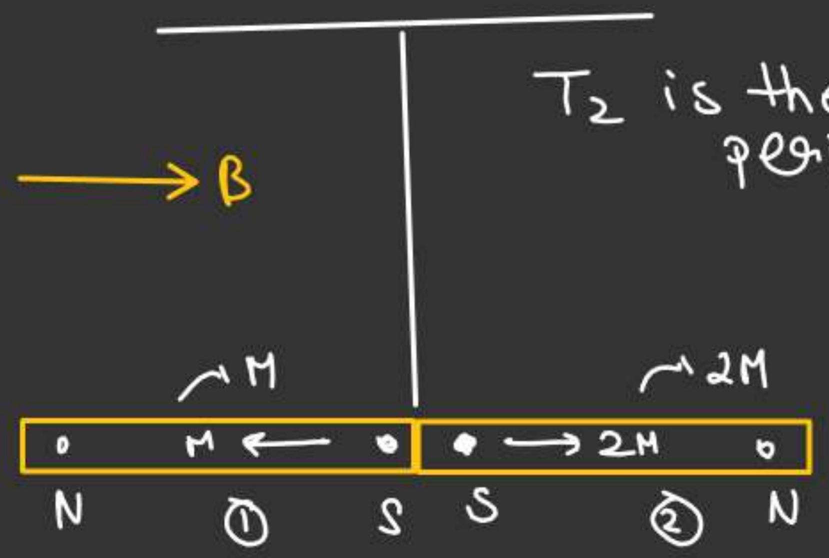
let I_1 & I_2 be the M-I of bar-Magnet.

$$T_1 = 2\pi\sqrt{\frac{I_1+I_2}{(3M)B}}$$

$$\frac{T_1}{T_2} = \left(\frac{1}{\sqrt{3}}\right)$$

$$T_2 = \sqrt{3}\,T_1$$ ✓

The Same-Step is Suspended in the Same magnetic field by Changing the polarity of bar-Magnet as Shown in fig.



T_2 is the time period.

$$M_2 = 2M - M$$

$$M_2 = M$$

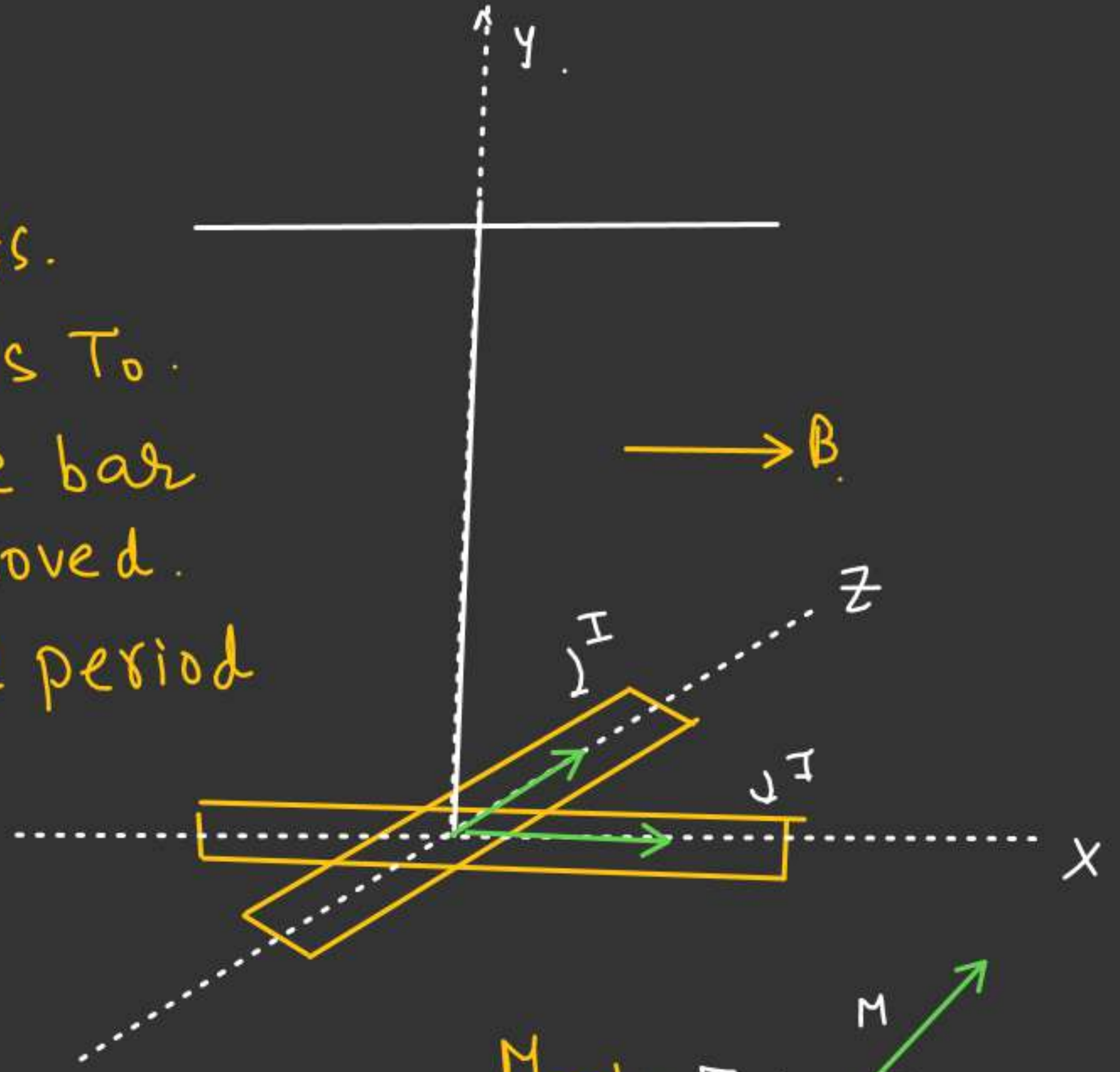
$$T_2 = 2\pi\sqrt{\frac{I_1+I_2}{MB}}$$

Nishant Jindal

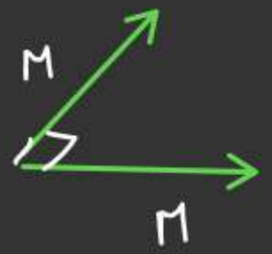
Identical bar magnets.

Time period is T_0.

If one of the bar magnet is removed. find new time period



$M_{net} = \sqrt{2}M$



$$T_0 = 2\pi\sqrt{\frac{2I}{\sqrt{2}MB}}$$

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

If one of the magnet is removed. let, T_1 be the time period.

$$T_1 = 2\pi\sqrt{\frac{I}{MB}}$$

$$\frac{T_1}{T_0} = \frac{1}{(2)^{1/4}}$$

$$T_1 = \frac{T_0}{(2)^{1/4}}$$ Ans