LAKSHYA BATCH

PW

Magnetism and Matter
Questions on Bar magnet

LECTURE - 4

GOALS OF THE DAY

❖ Questions on bar magnet

Units:

	SI	CGS
Magnetic field Intensity / Magnetic flux density / Magnetic induction $\vec{B}$	T Tesla, (Wb/m²)	Gauss 10^{-4} (G) $(1G = 10^{-4}T)$
Magnet Pole strength $(m) = \frac{M}{l}$	Am	
⇒ Magnetic Dipole moment:	Am²	Stat A cm² (3.3 x 10^{-14}) $1\,\text{Stat A cm}^2 = 3.3\times10^{-14}\,\text{Am}^2$
⇒ Magnetic flux	Weber	Maxwell or abweber 10^{-8} $\left(\begin{matrix}1\,\text{abWb}\\ 1\,\text{Mx}\end{matrix} = 10^{-8}\,\text{Wb}\right)$

$\vec{M} = ml$

$\vec{M} = I.A$

$\phi_B = B.A$

$B = \frac{\phi_B}{A} = \frac{\text{wb}}{m^2}$

An iron rod of length L and magnetic moment M is bent ion the form of a semicircle. Now its magnetic moment will be (March) 2021.

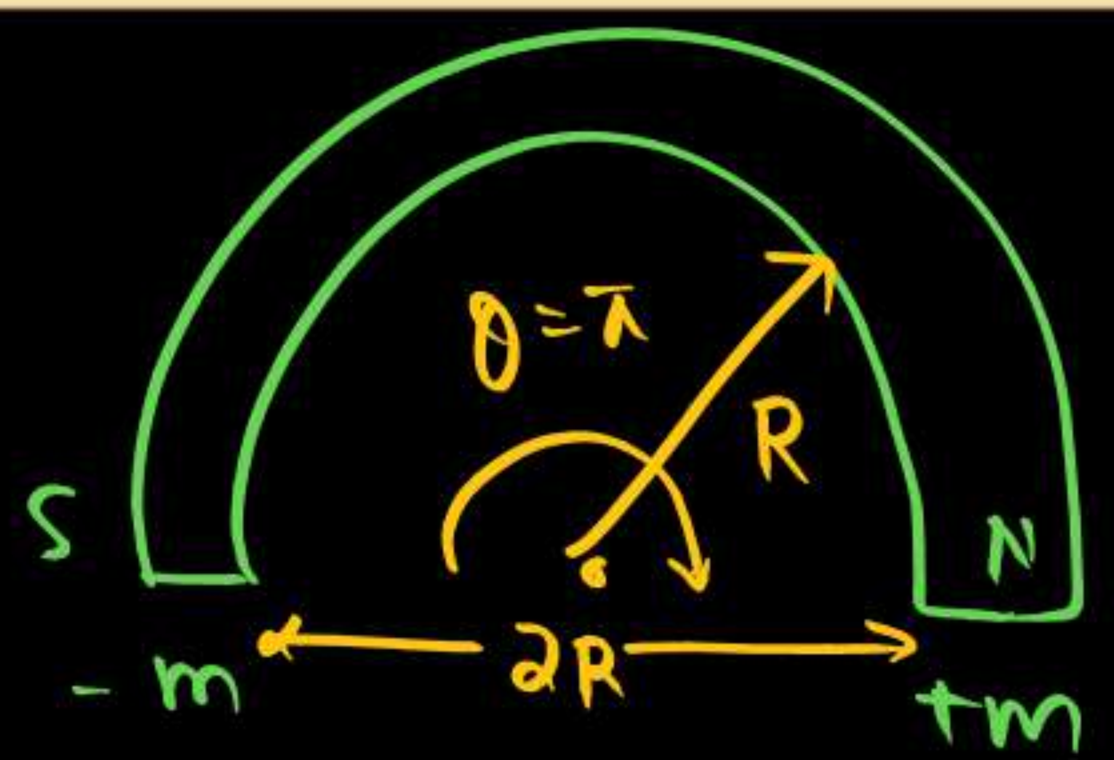
(a) M

(b) $\frac{2M}{\pi}$ Ans.

(c) $\frac{M}{\pi}$

(d) $M\pi$

$M = mL$



$\pi R = L$

$R = \frac{L}{\pi}$

$\vec{M} = (\text{either Pole Strength})(\text{Sep between them})$

(Magnetic length.

$\vec{M}' = m\,2R$

$= 2m\frac{L}{\pi} = \frac{2M}{\pi}$.

Gen for

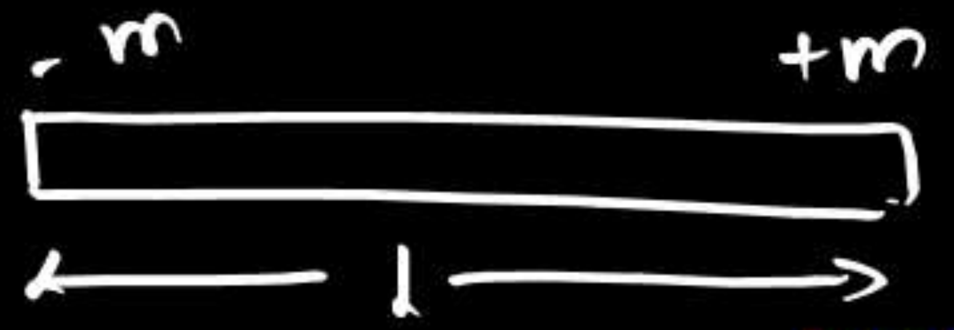
$\bar{m} = \frac{2M}{\theta}\sin\left(\frac{\theta}{2}\right)$

$\theta = \pi$

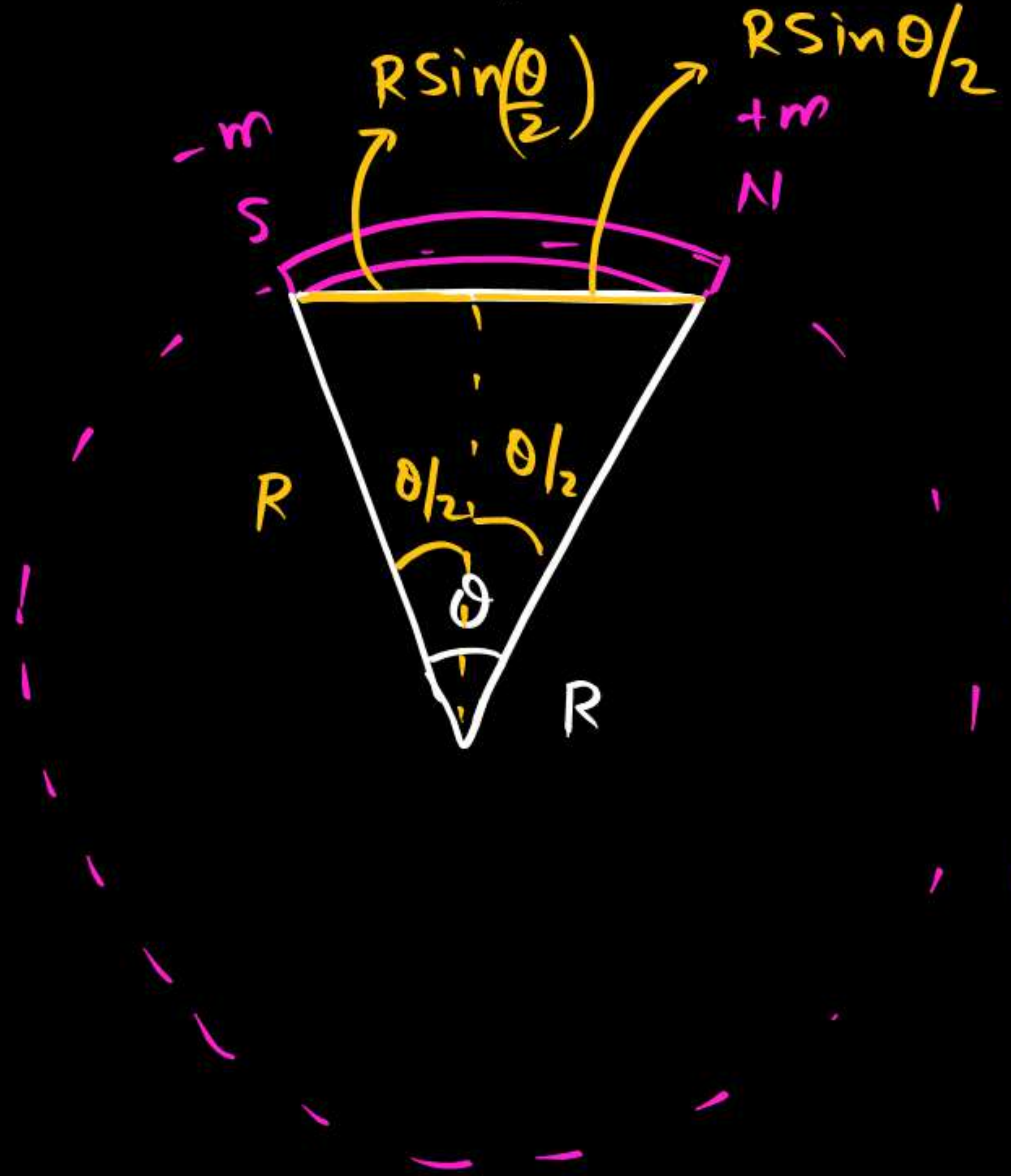
$= \frac{2M}{\pi}\sin 90$

$= \frac{2M}{\pi}$.

LAKSHYA KO HAR HAAL ME PAANA HAI

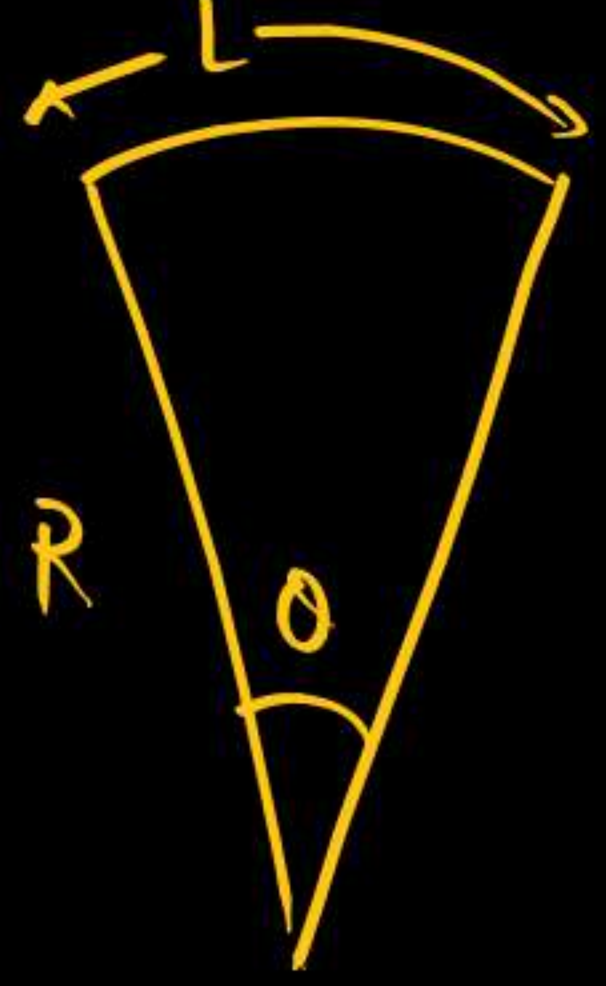


$\vec{M} = mL.$



$$\vec{M}_{new} = m\,2R\sin\left(\frac{\theta}{2}\right) = \frac{2mL}{\theta}\sin\left(\frac{\theta}{2}\right)$$

$$= \frac{2M}{\theta}\sin\left(\frac{\theta}{2}\right)$$



$$\boxed{\theta = \frac{L}{R}} \qquad R = \frac{L}{\theta}$$

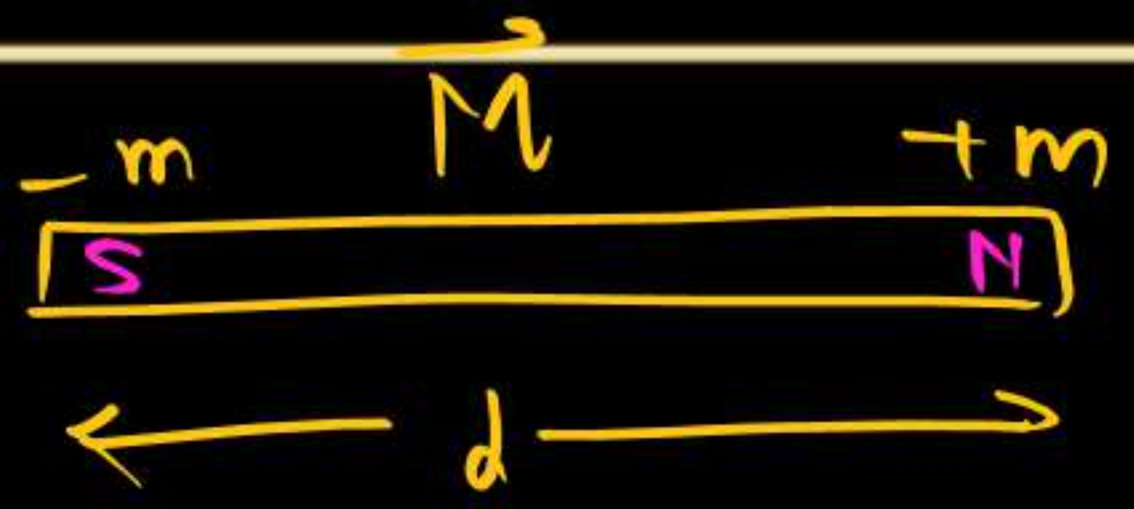
The length of a magnetized steel wire is l and its magnetic moment is M. It is bent into the shape of L with two sides equal. The magnetic moment now will be

(a) $\frac{M}{2}$

(b) $2M$

(c) $\sqrt{2}\,M$

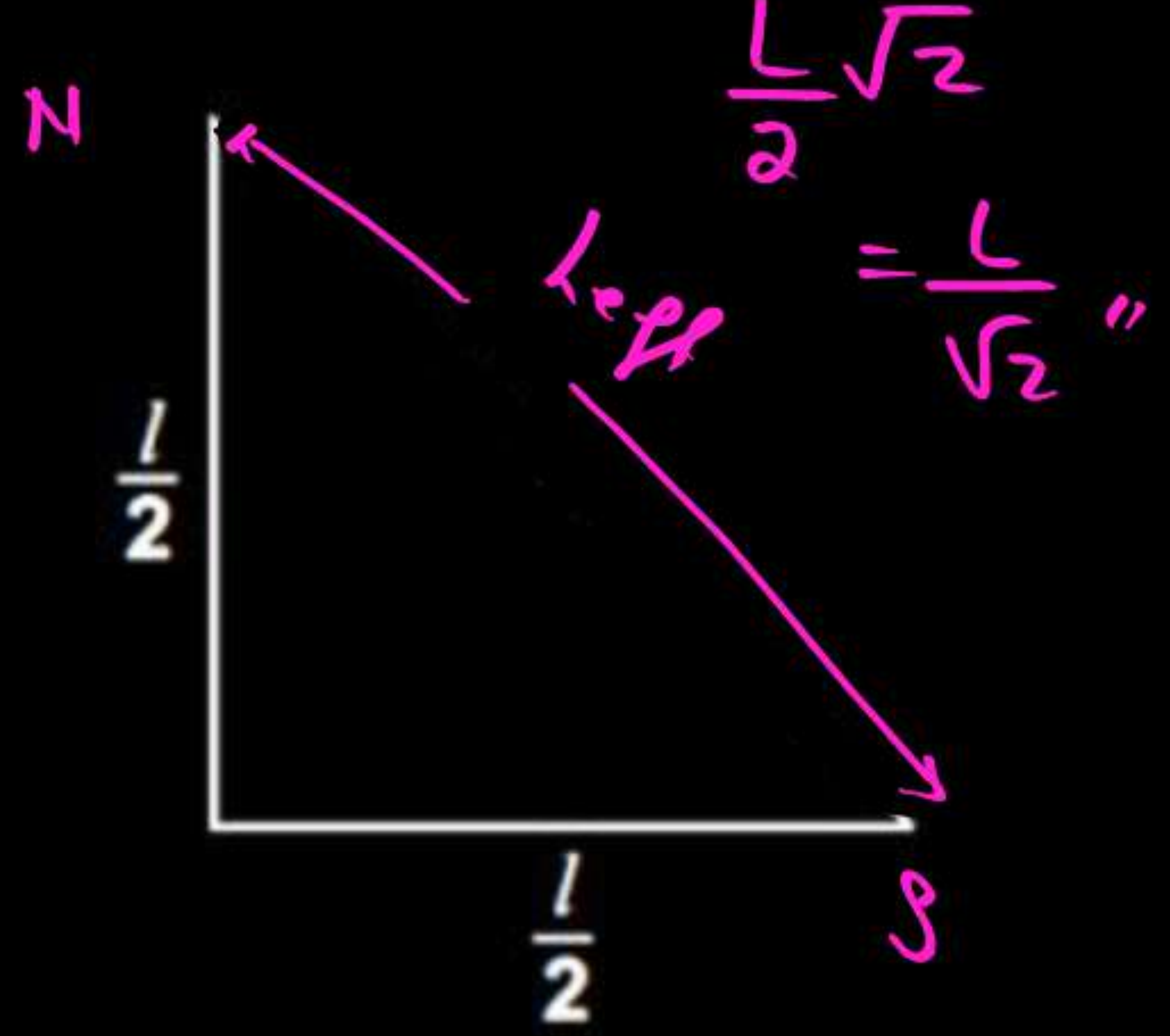
(d) $M/\sqrt{2}$ Ans



$|\vec{M}| = M = mL$

$M_{new} = \frac{mL}{\sqrt{2}}$

$= \frac{M}{\sqrt{2}}$



A long magnetic needle of length $2L$, magnetic moment M and pole strength m units is broken into two pieces at the middle. The magnetic moment and pole strength of each piece will be

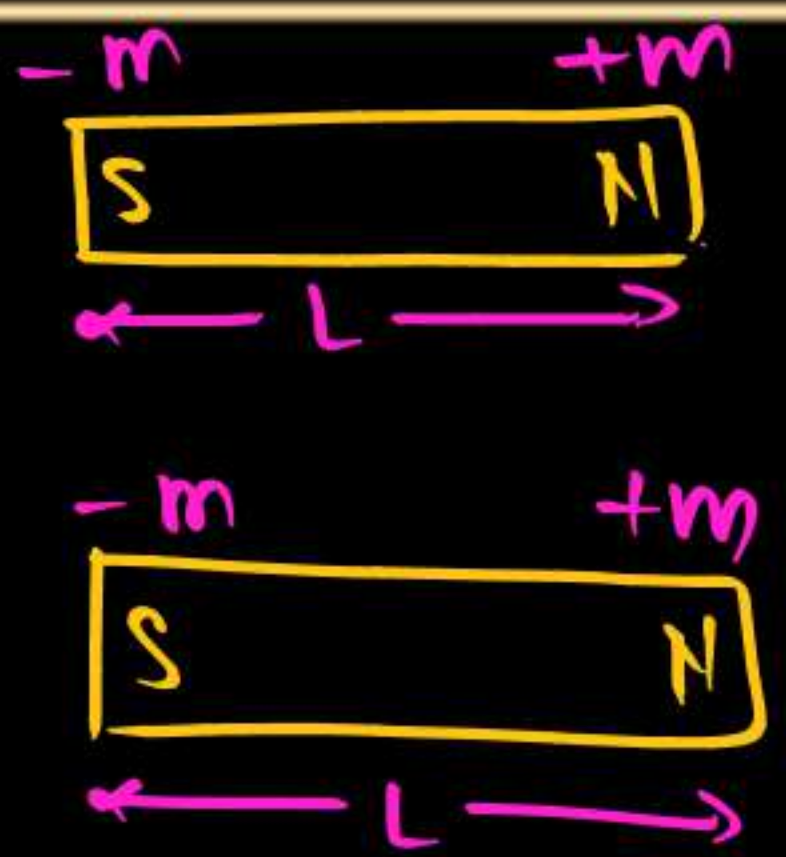
(a) $\frac{M}{2}, \frac{m}{2}$

(b) $M, \frac{m}{2}$

(c) $\frac{M}{2}, m$ Ans

(d) M, m

$\vec{M} = m(2L)$.



Pole Strength $= \pm m$ Same.

$\vec{M} = (\text{Pole strength})(\text{Sep})$.

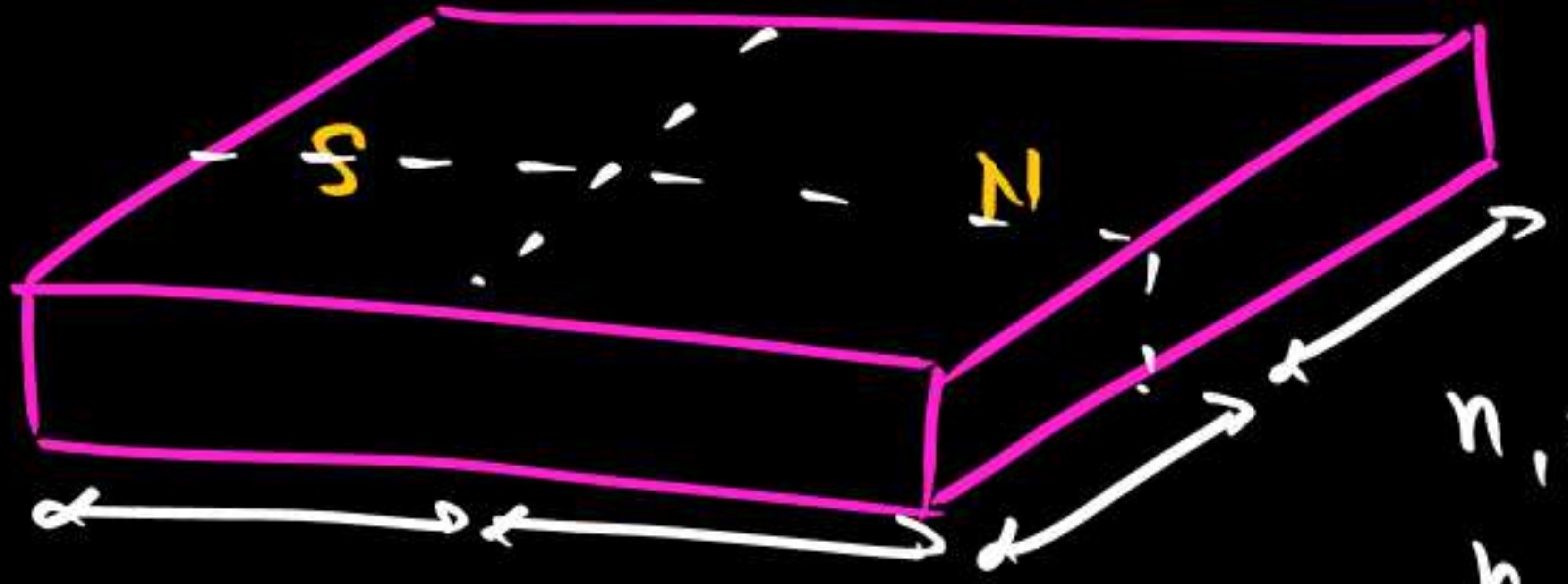
$= mL$

$|\vec{M}| = \frac{M}{2}$

If a magnet of pole strength m is divided into four parts such that the length and width of each part is half that of initial one, then the pole strength of each part will be

(a) $m/4$ Ans. (b) $m/2$

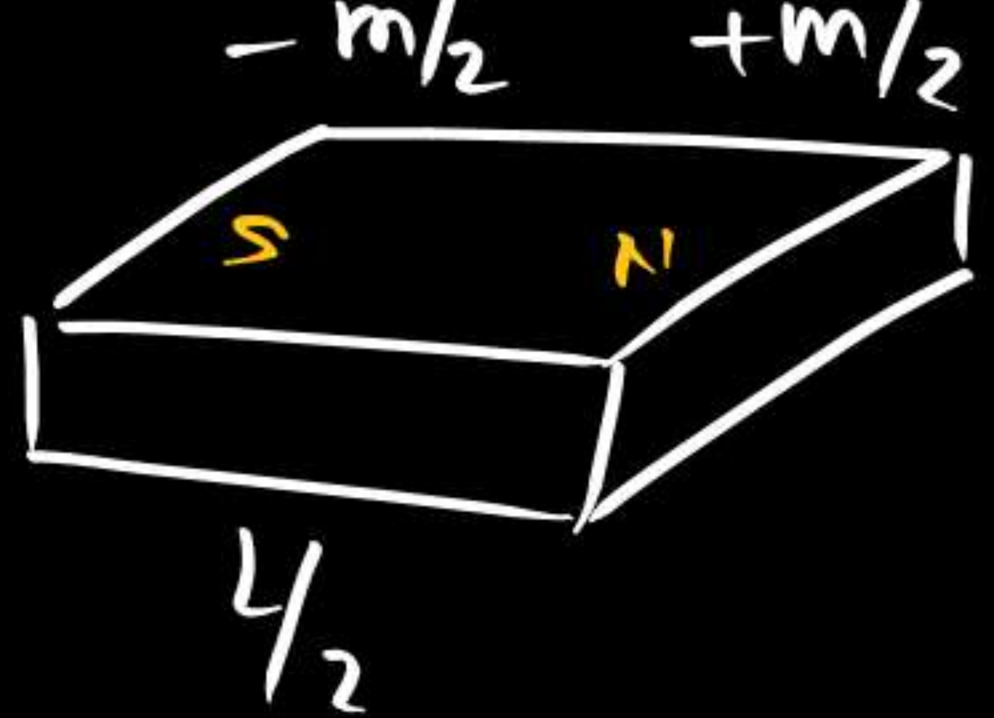
(c) $m/8$ (d) $4m$



$n_1 = 2$

$n_2 = 2$

$$\vec{M} = \frac{M}{n_1 n_2} = \frac{M}{4}.$$



$$\vec{M} = \left(\frac{m}{2}\right)\left(\frac{L}{2}\right) = \frac{mL}{4} = \frac{M}{4}.$$

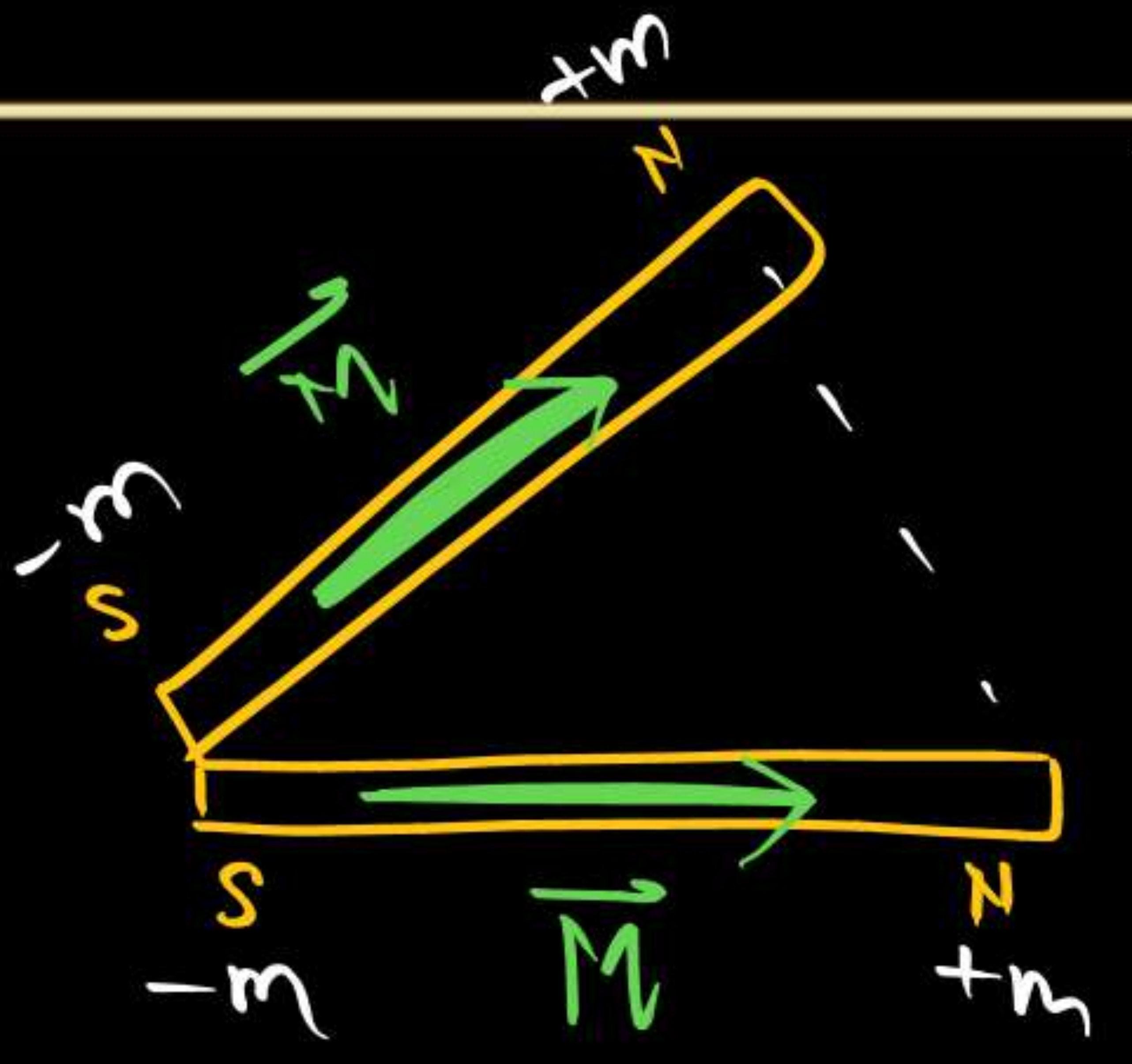
The magnetic moment of the system as shown in figure, will be :

(a) $\sqrt{3}\, ma$ Ans

(b) ma

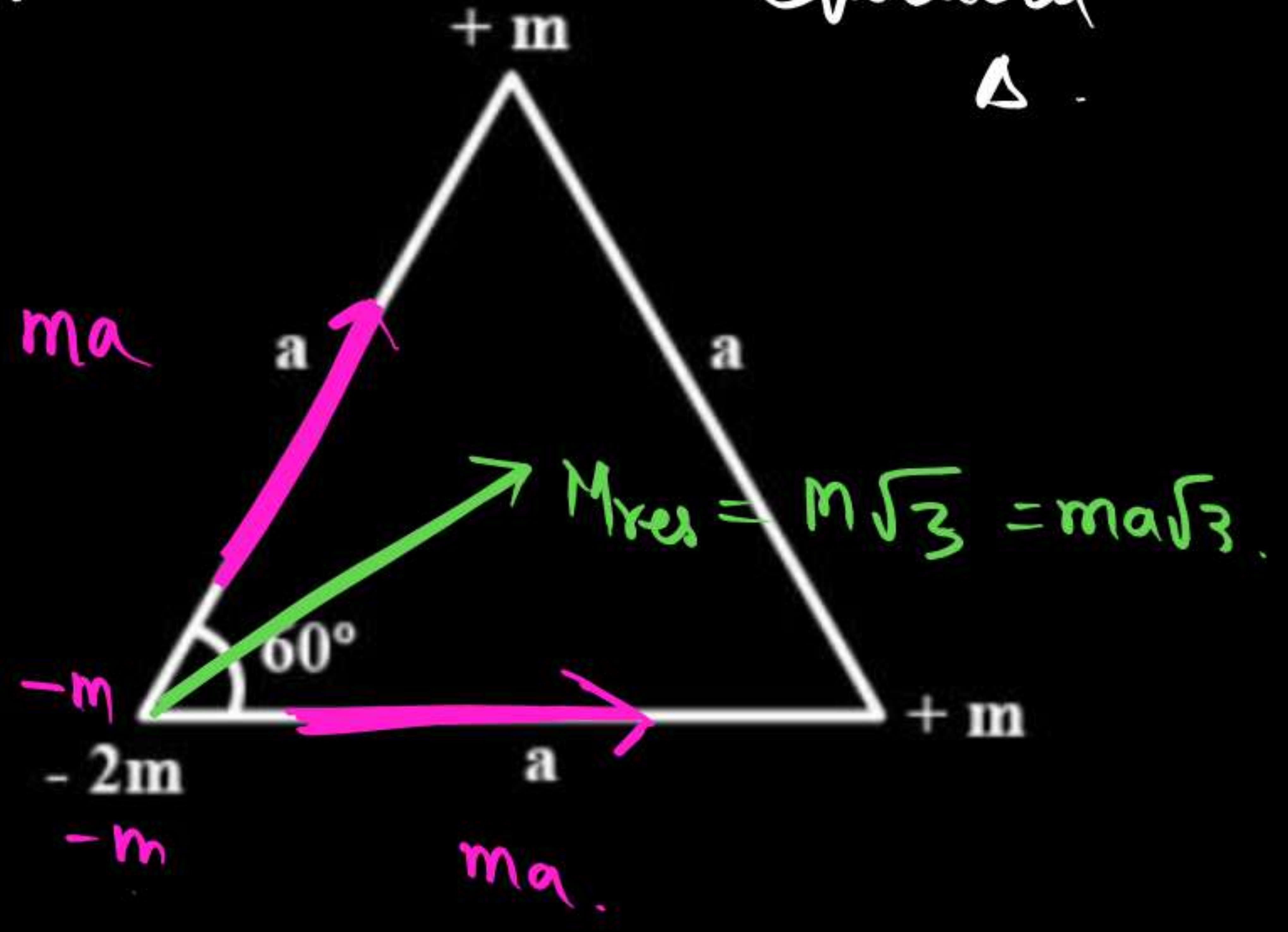
(c) $2\, ma$

(d) none of the above



$\vec{M} = \sum$(magnetic Pole strength with sign)(Position Vector)

Equilateral Δ



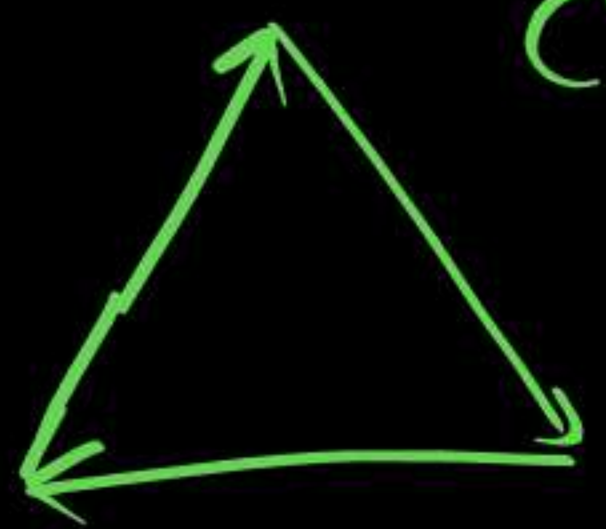
Vector Qty hence follows Vector Addition.

Three identical magnets are arranged as shown in the figure. The magnetic moment of each magnet is M. The effective magnetic moment of the given combination is:

(a) 6 m
(b) 3 m
(c) zero
(d) 2 m

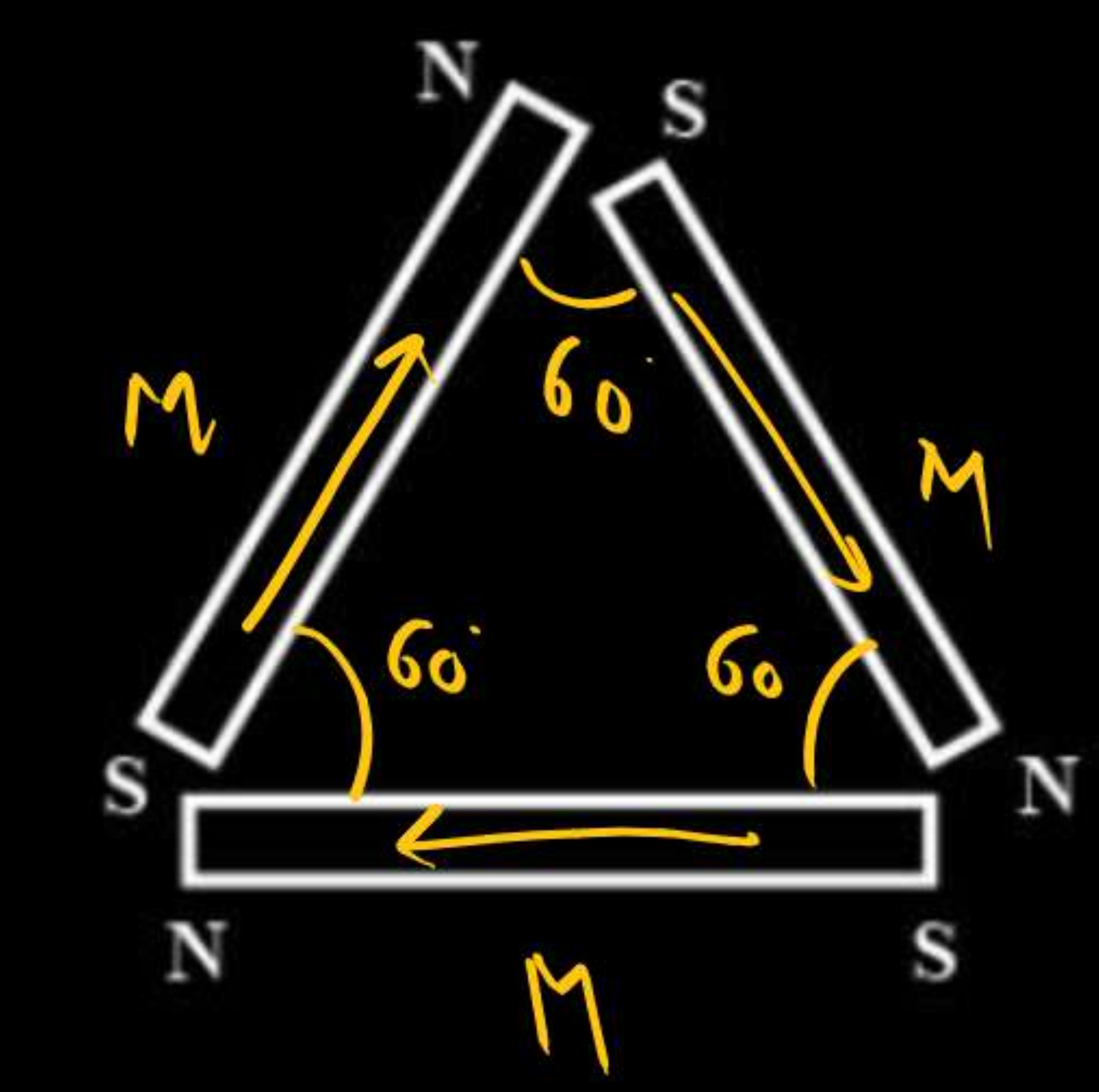
Equilitaral Δ

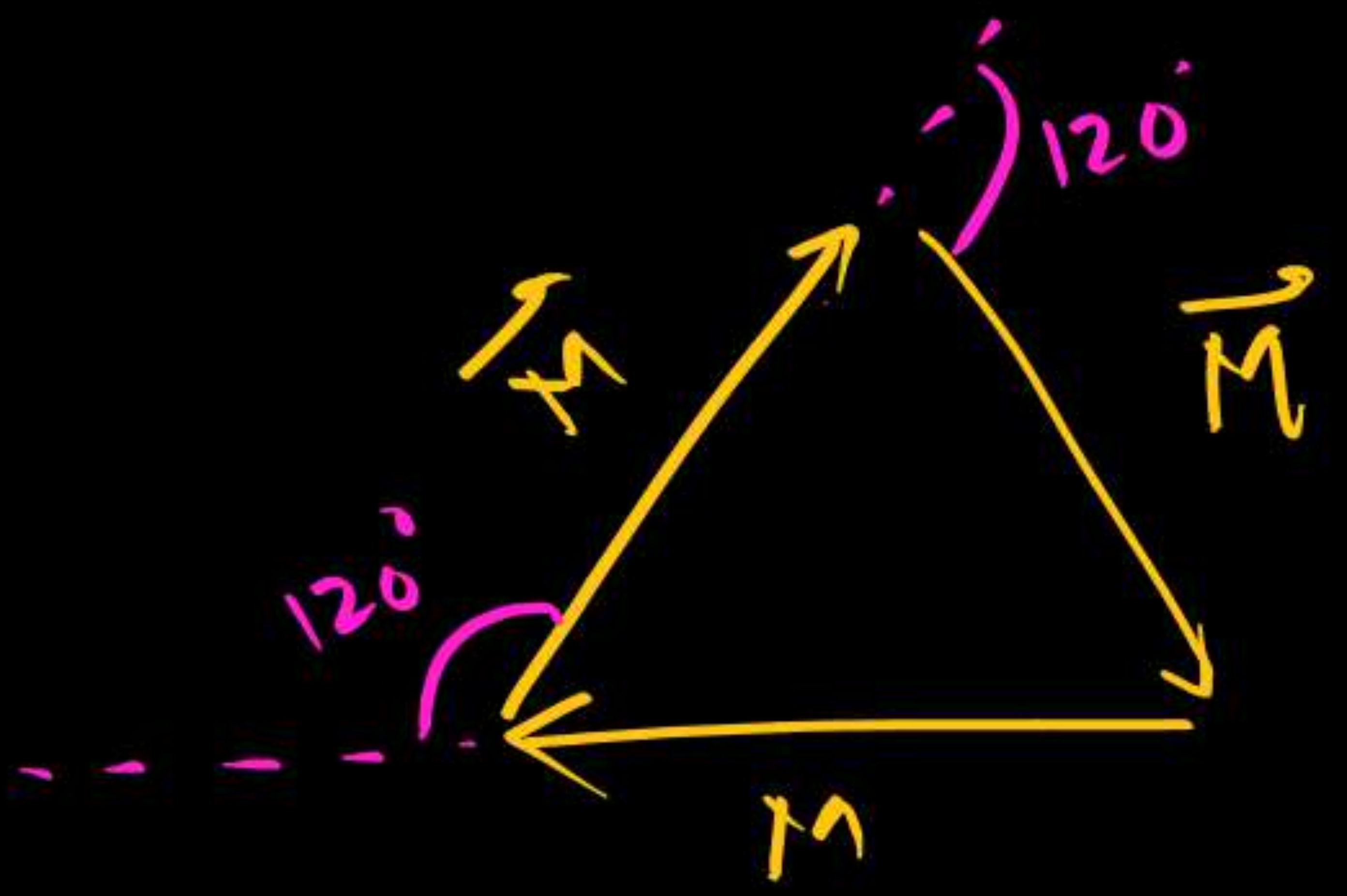
Polygon Law

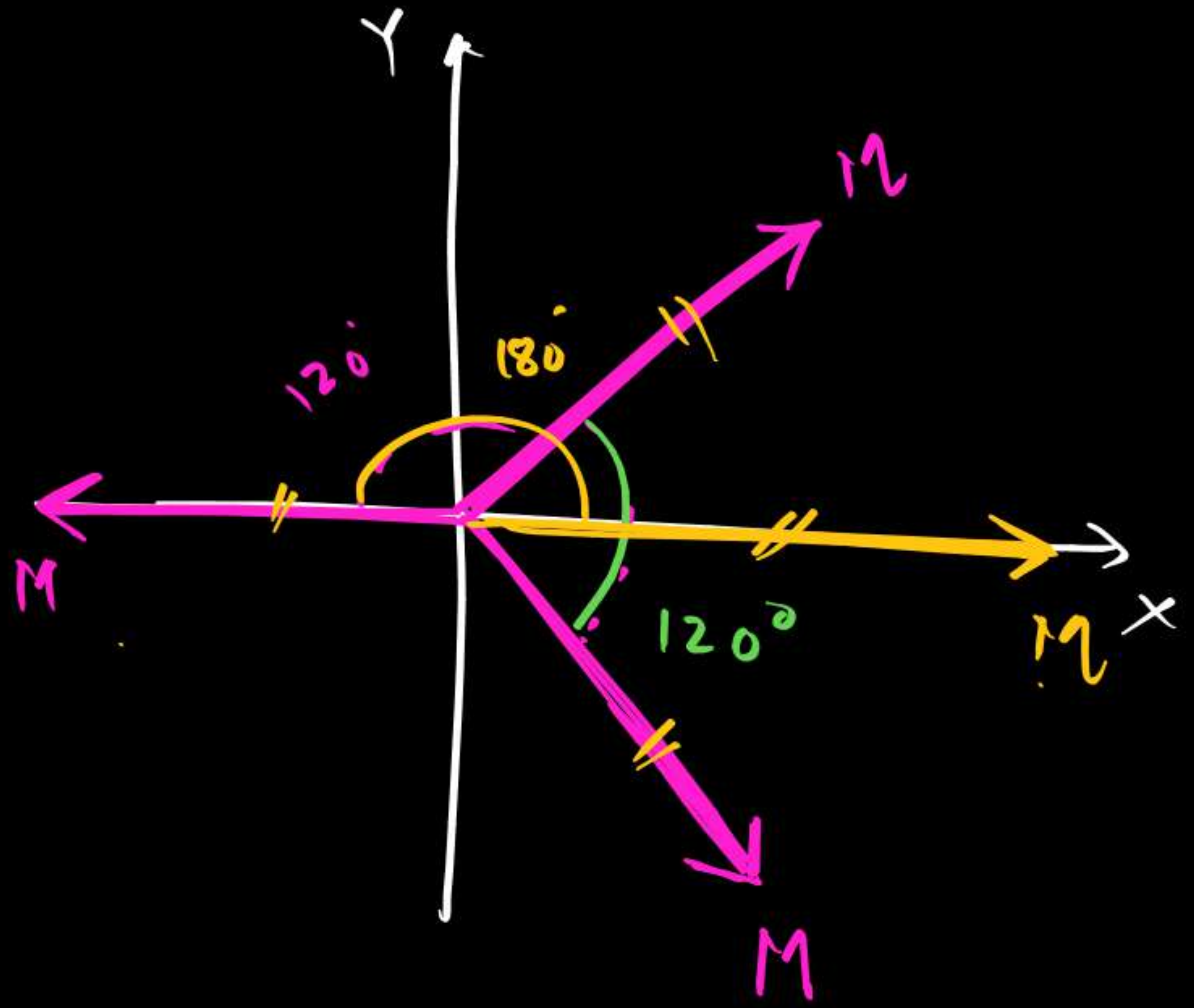


Closed Polygon

R=0





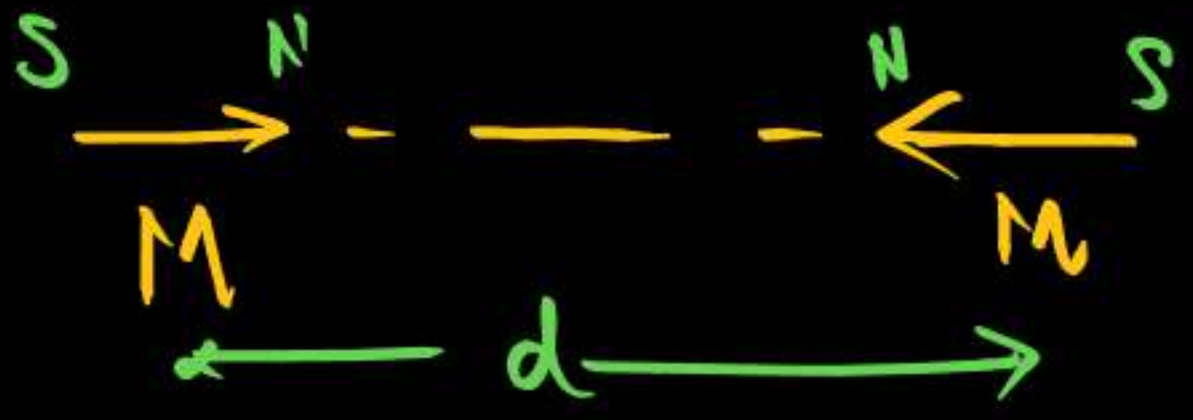


R=0

Two small bar magnets are placed in a line with like poles facing each other at a certain distance d apart if the length of each magnet is negligible as compared to d, the force between them will be inversely proportional to

(a) d (b) d^2

(c) $1/d^2$ (d) d^4 Ans



(In class discussed)

$$f = + \frac{6\mu_0 m_1 m_2}{4\pi r^4} \text{ (Repulsion)}$$

$$f \propto \frac{1}{r^4}$$

Two small magnets each of magnetic moment M_0 is placed parallel to each other (shown in figure). The magnetic field at point O is :

(a) zero (b) $4\,5\,10^{-4}$ N

(c) 2×10^{-4} N (d) none of these

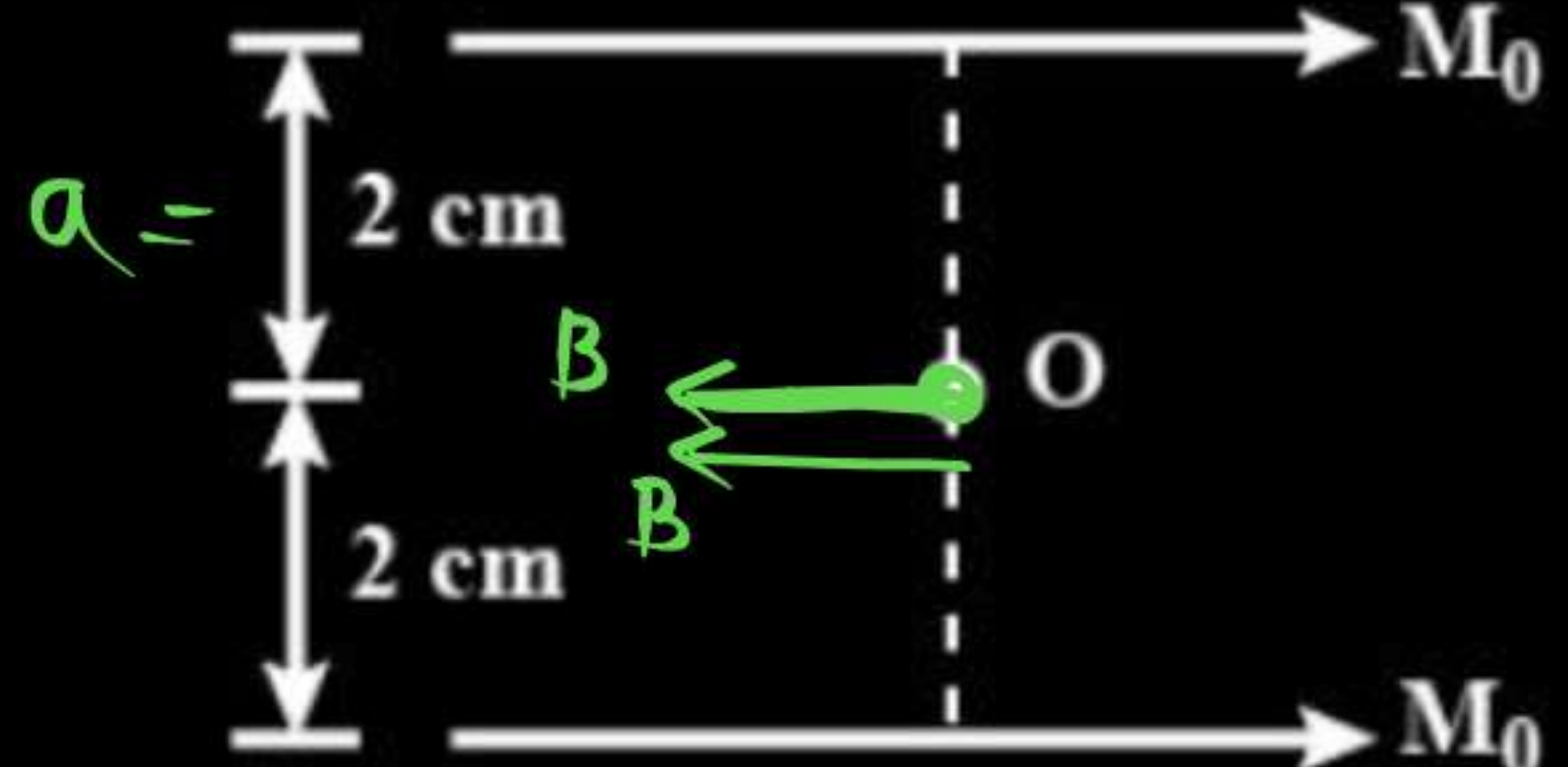
option should be in terms of M_0.

Electro | Magnets

Concept

$\frac{KP}{r^3}$ P $\frac{2KP}{r^3}$

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



$$B_{Total} = 2B_0 = 2\times\frac{\mu_0 M_0}{4\pi a^3} = \frac{10^{-7}\times 2M_0}{\left(\frac{2}{100}\right)^3}$$

$$B = \frac{\mu_0 M_0}{4\pi a^3}$$

In Ques

M_0

$B_0 \longleftrightarrow B_0$

M_0

Ans = 0

The magnetic field at point C as shown in figure is :

(a) $\frac{\mu_0 M_0}{2\pi r_0^3}$

(b) $\frac{\sqrt{2}\mu_0 M_0}{2\pi r_0^3}$

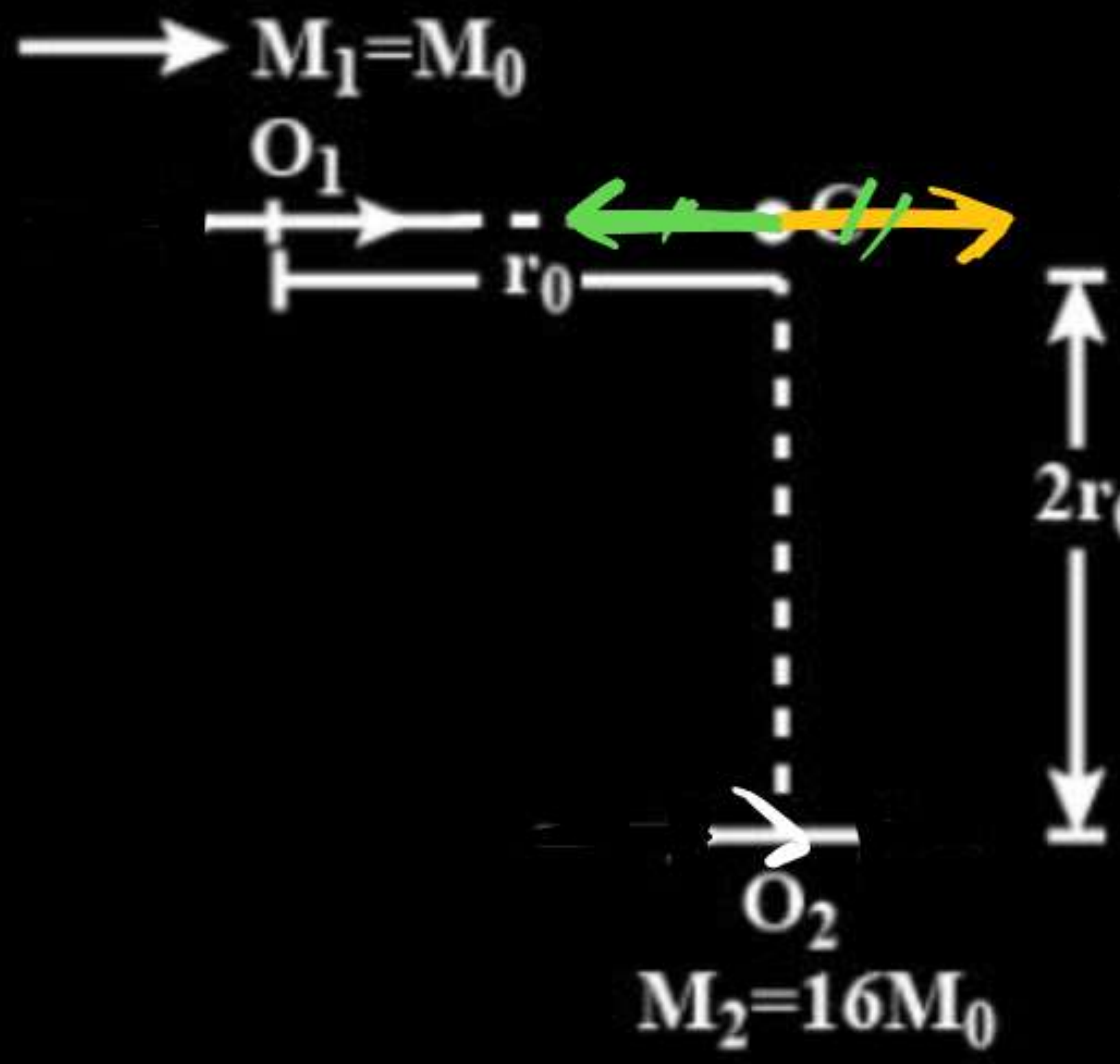
(c) zero Ans.

(d) $\frac{\sqrt{2}\mu_0 M_0}{4\pi r_0^3}$

$\frac{\mu_0 16 M_0}{4\pi 8 r_0^3} = \frac{\mu_0 2 M_0}{4\pi r_0^3}$

Pt C for M_1 (axial)

Pt C for M_2 (Equitorial).

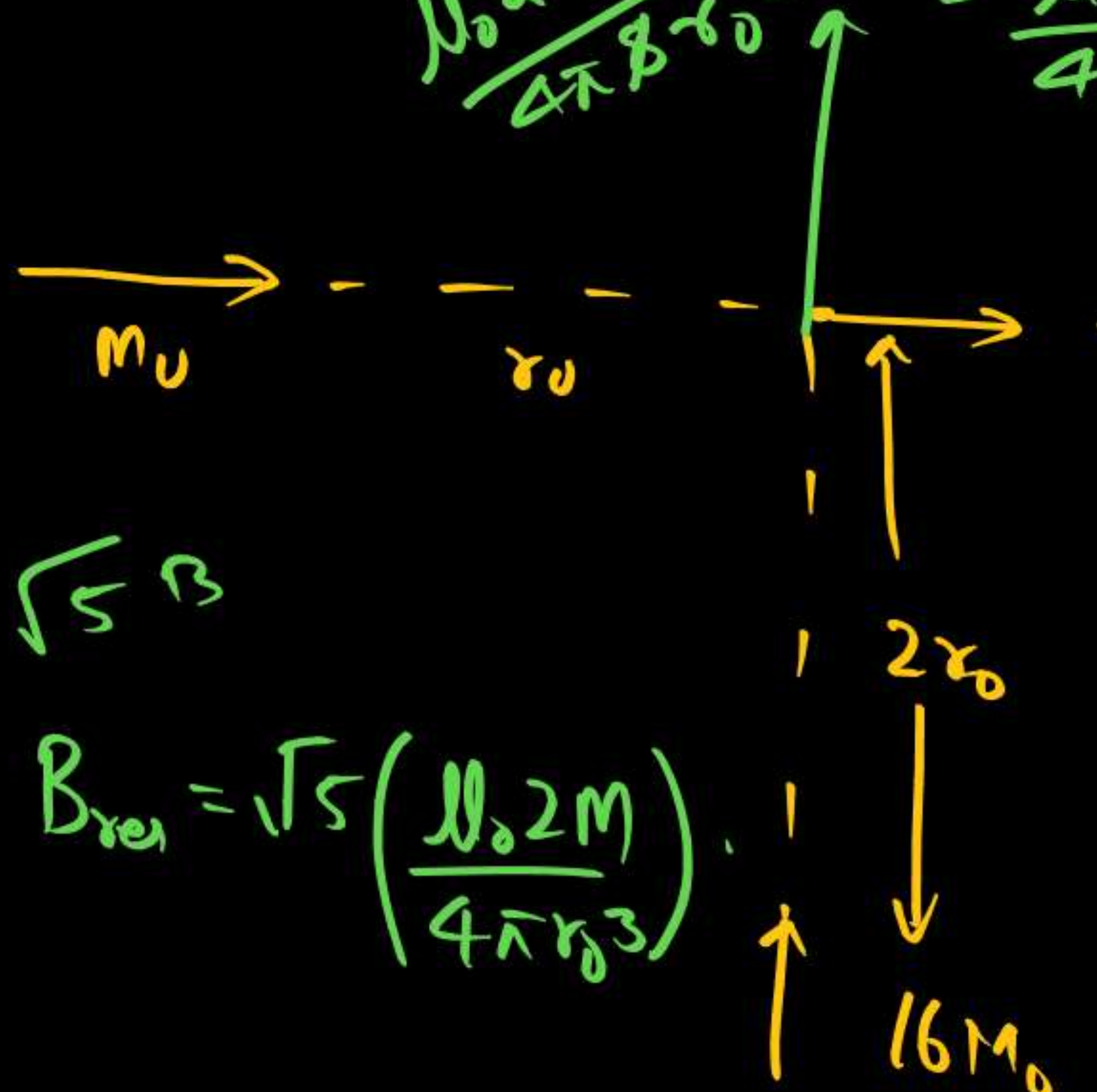


$\frac{\mu_0 2 M_0}{4\pi r^3}$

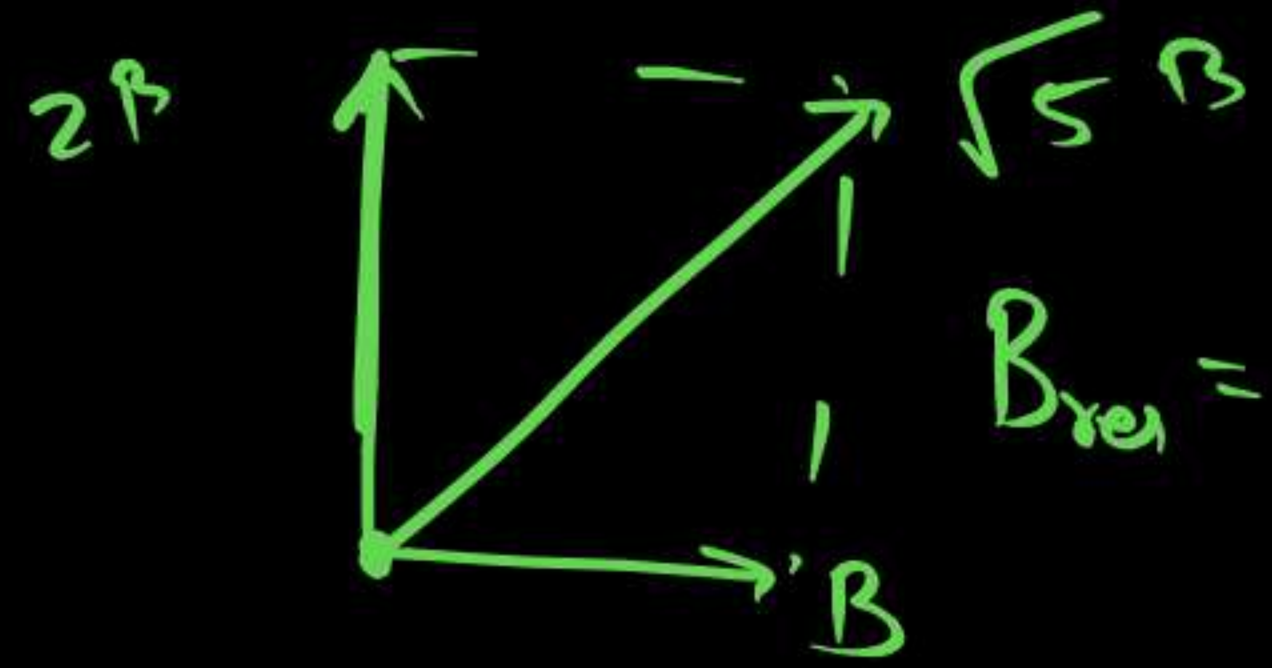
LAKSHYA KO HAR HAAL ME PAANA HAI

Qn Ques

$$\frac{\mu_0 2(\cancel{16}^{\,2} M_0)}{4\pi \cancel{8} r_0^3} = \frac{\mu_0 4 M_0}{4\pi r_0^3} = 2B$$



$$\frac{\mu_0 2M}{4\pi r_0^3} = B$$



$$B_{res} = \sqrt{5}\left(\frac{\mu_0 2M}{4\pi r_0^3}\right)$$

A magnetic needle is kept in a non-uniform magnetic field. It experiences

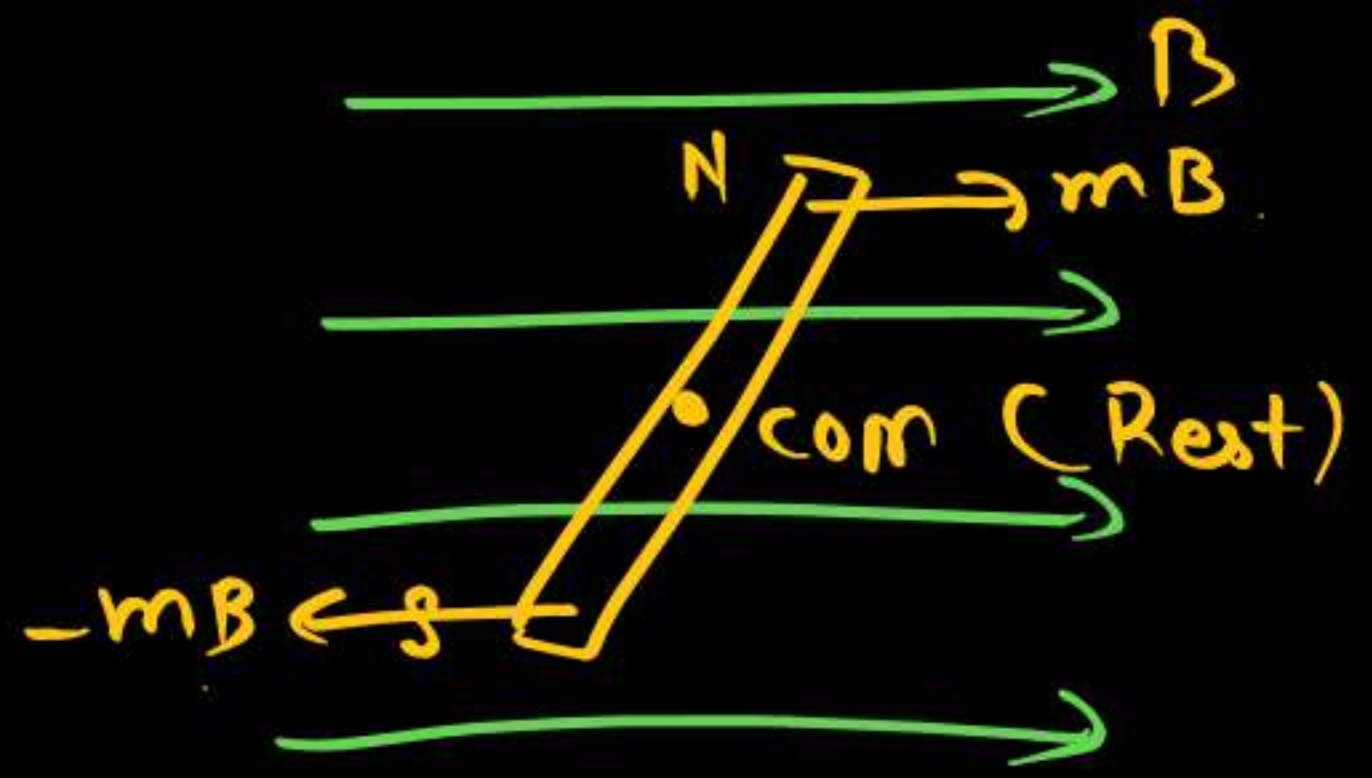
(a) A force and a torque Ans

(b) A force but not a torque

(c) A torque but not a force

(d) Neither a torque nor a force

In uniform $\vec{B}$



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

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

Non-uniform Magnetic field

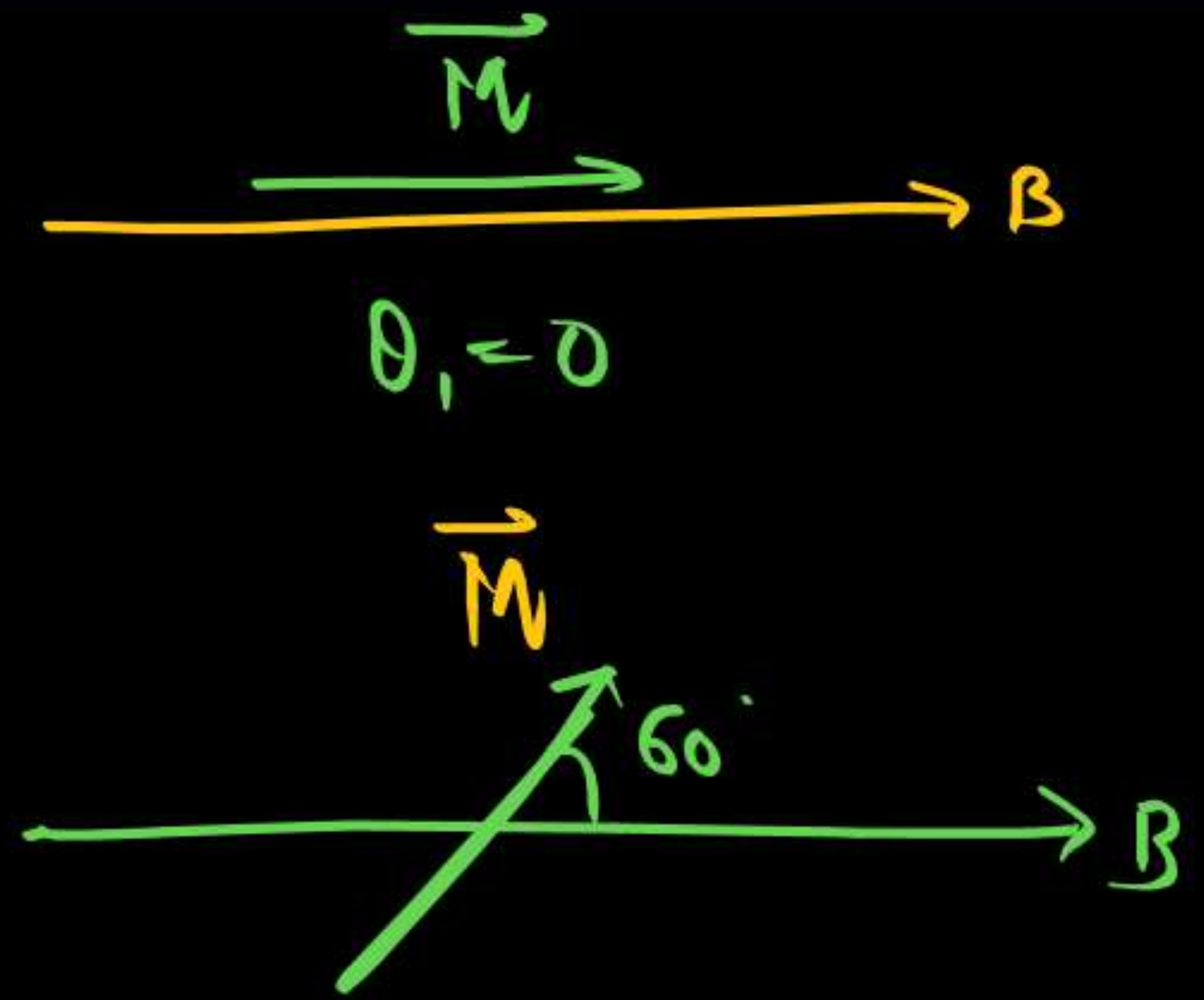
$\boxed{f_T \neq 0}$

$\boxed{\tau_T \neq 0}$

A magnetic needle lying parallel to a magnetic field requires W units of work to turn it through 60°. The torque required to maintain the needle in this position will be

(a) $\sqrt{3}$ W Ans. (b) W

(c) $\sqrt{3}/2$ W (d) 2 W



$$W = MB(\cos\theta_1 - \cos\theta_2)$$
$$= MB(\cos 0 - \cos 60)$$
$$= MB\left(1 - \frac{1}{2}\right)$$
$$\boxed{W = \frac{MB}{2}}$$

In Second Scenario

$$\bar{\tau} = \bar{M} \times \bar{B} \quad (-\hat{k})$$
$$|\tau| = MB \sin 60$$
$$= \frac{MB}{2}\sqrt{3}$$
$$\boxed{|\tau| = W\sqrt{3}}$$

External Torque to Keep it at Rest $W\sqrt{3}\,(\hat{k})$.

LAKSHYA KO HAR HAAL ME PAANA HAI

A small bar magnet placed with its axis at 30° ~~With~~ in an external field of 0.06 T experiences a torque of 0.018 Nm. The minimum work required to rotate it from its stable to unstable equilibrium position is: [Main 2021]

(a) 6.4×10^{-2} J

(b) 9.2×10^{-3} J

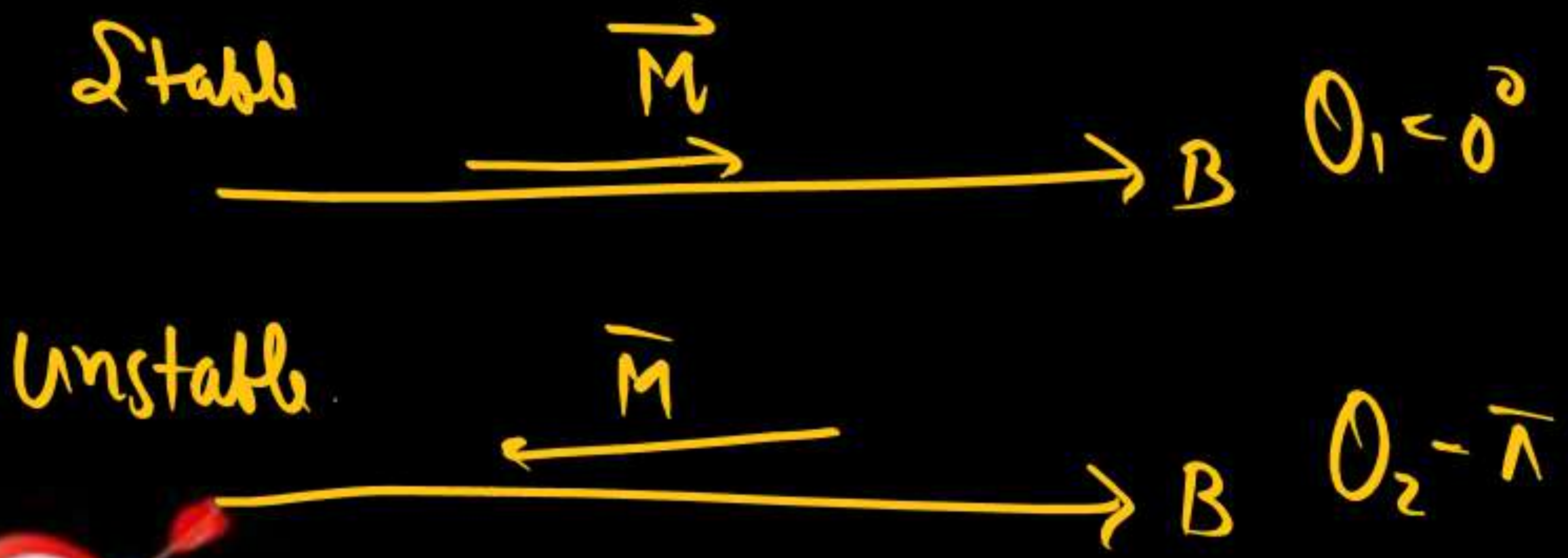
(c) 7.2×10^{-2} J Ans

(d) 11.7×10^{-3} J

$\tau = MB \sin 30$

$0.018 = \frac{MB}{2}$

$MB = 2 \times 0.018$



$W = MB(\cos 0 - \cos \pi)$

$= MB(1 - (-1))$

$= 2MB = 2 \times 2 \times 0.018$

$= 4 \times 0.018 = 7.2 \times 10^{-2}$ J.

LAKSHYA KO HAR HAAL ME PAANA HAI

The magnetic induction at P, for the arrangement shown in the figure, when two similar short magnets of magnetic moment M are joined at the middle so that they are mutually perpendicular, will be :

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

(b) $\frac{\mu_0}{4\pi}\frac{2M}{d^3}$

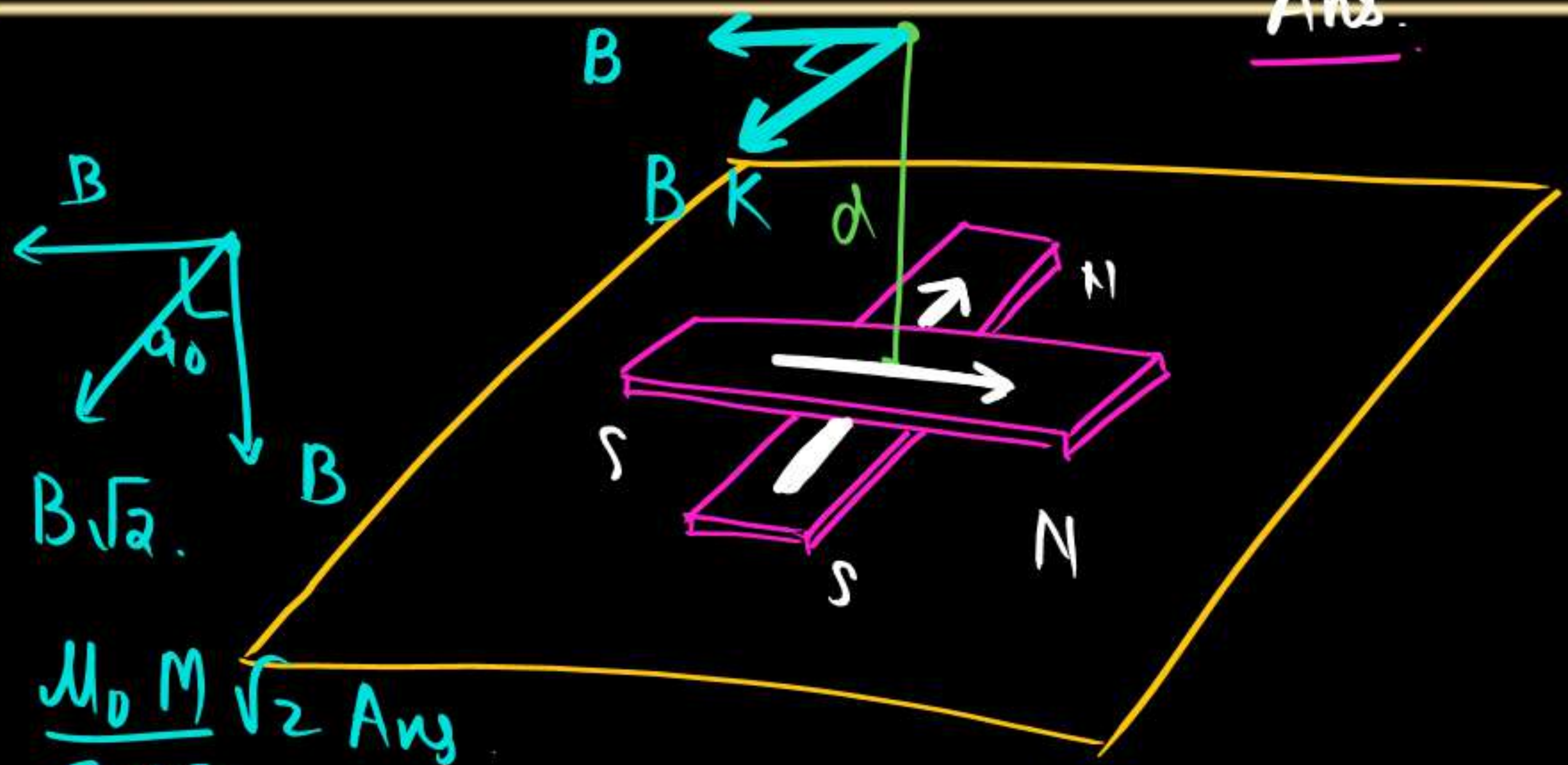
(c) $\frac{\mu_0 M\sqrt{5}}{4\pi d^3}$

(d) $\frac{\mu_0\sqrt{2}M}{4\pi d^3}$ Ans.

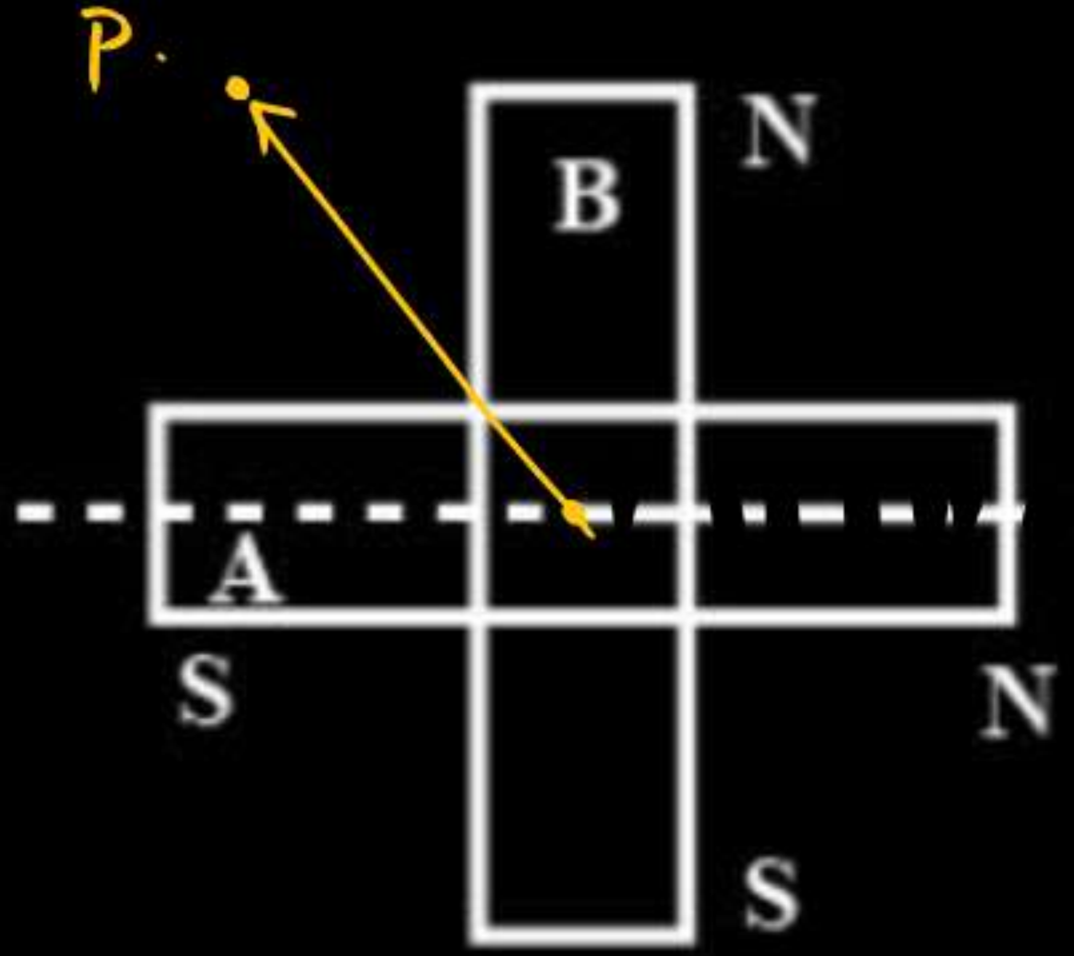
Equitorial pt for both magnets

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

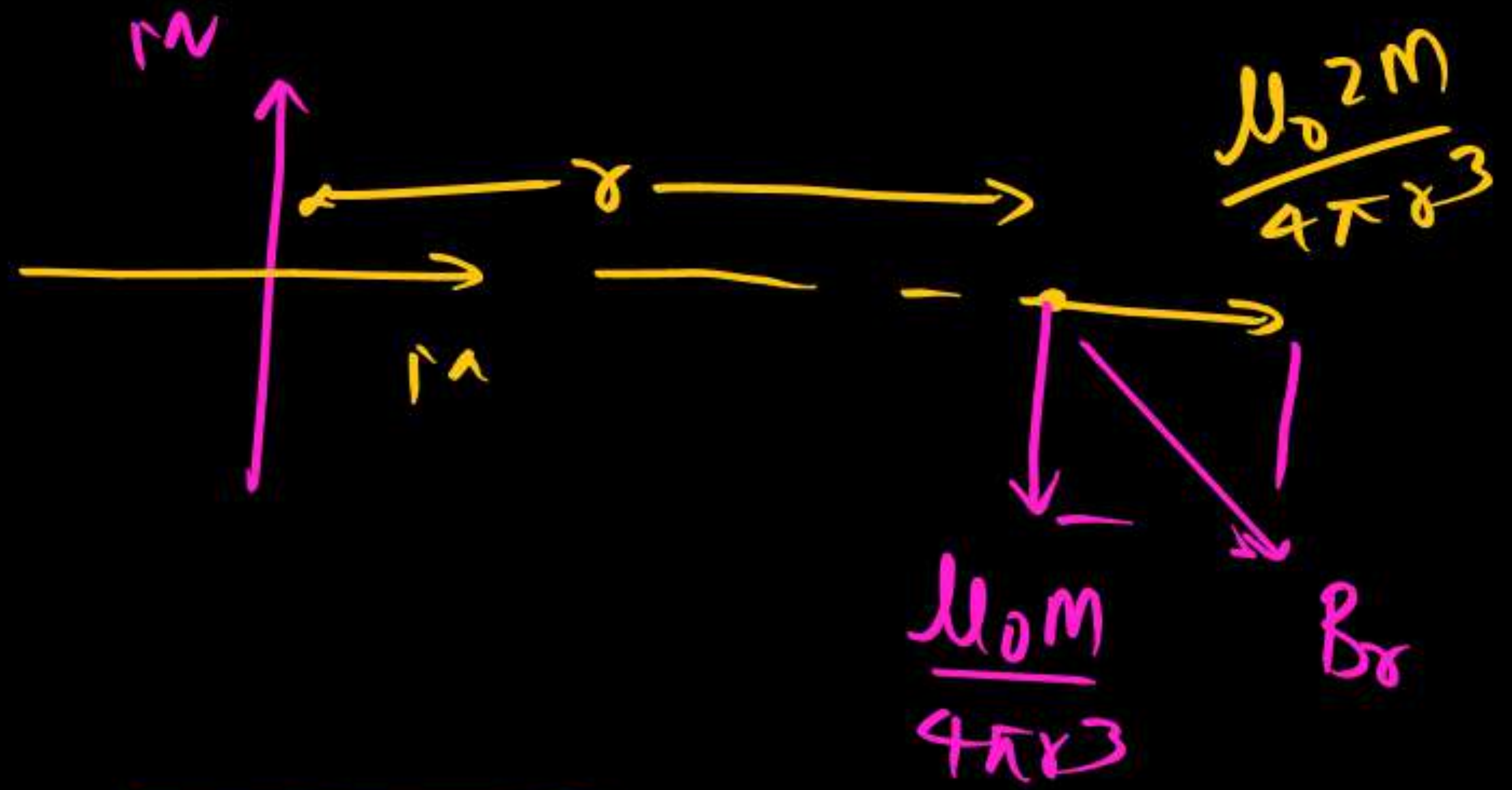
Axial $B_a = \frac{\mu_0 2M}{4\pi r^3}$



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



Alter



$$B_r = \sqrt{B_x^2 + B_y^2}$$

$$= \frac{\sqrt{5}\,\mu_0 M}{4\pi r^3}$$

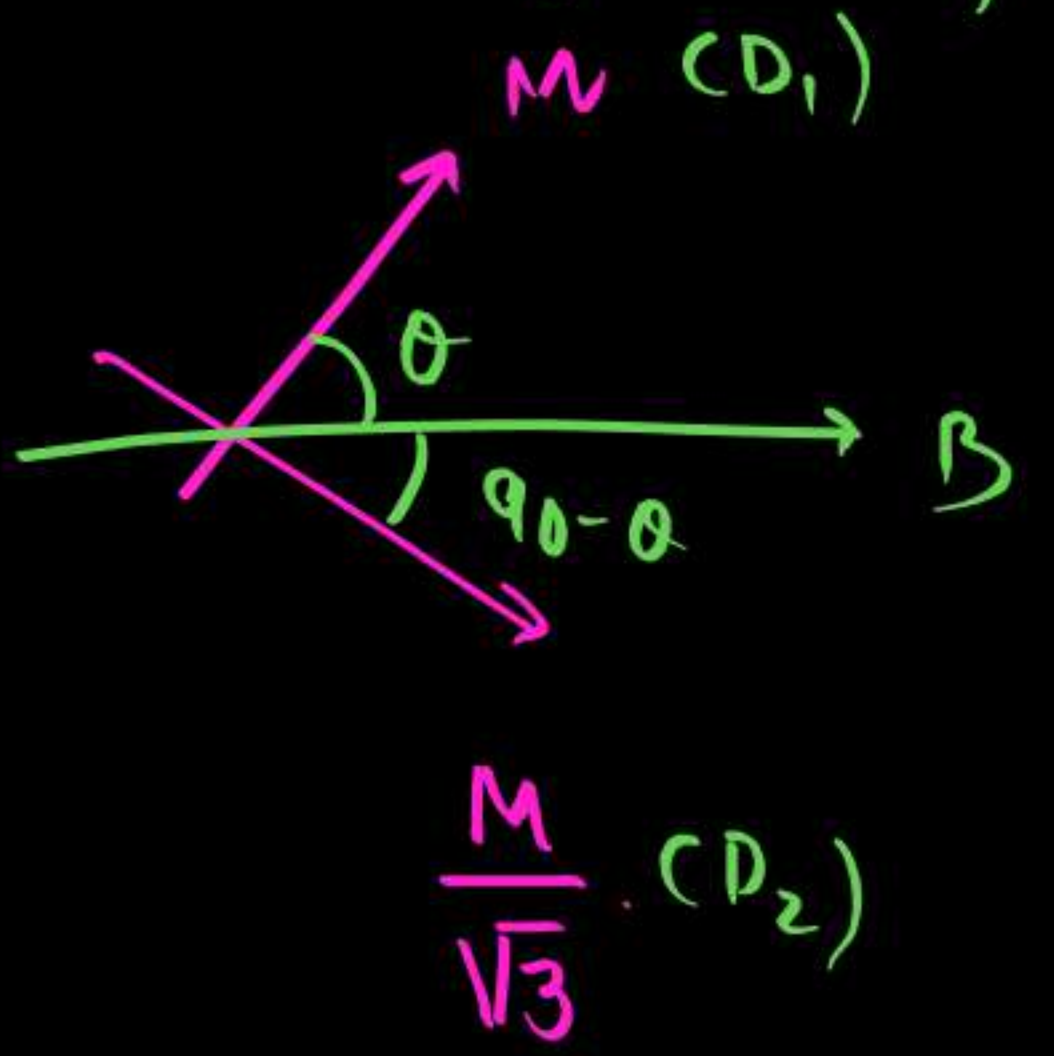
M and $M/\sqrt{3}$ are the magnetic dipole moments of the two magnets, which are joined to form a cross figure. The inclination of the system with the field, if their combination is suspended freely in a uniform external magnetic field B is :

(a) $\theta = 30°$ Ans (b) $\theta = 45°$

(c) $\theta = 60°$ (d) $\theta = 15°$

(JEE Main 25 Shift 2) but in terms of Electro

Since they are forming

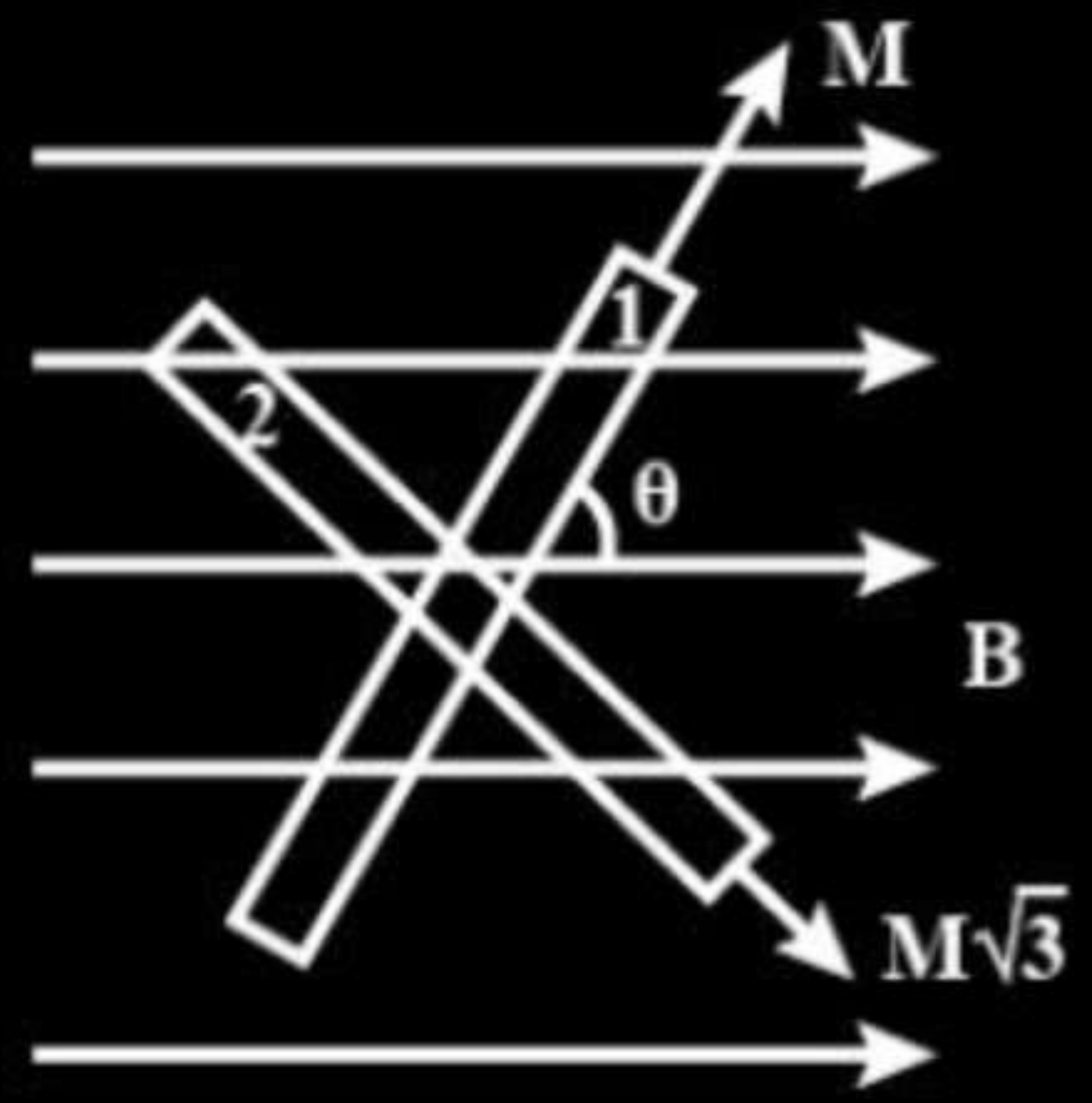


$$|\tau_{D_1}| = |\tau_{D_2}|$$

$$\cancel{M}\cancel{B}\sin\theta = \frac{\cancel{M}}{\sqrt{3}}\cancel{B}\sin(90-\theta)$$

$$\tan\theta = \frac{1}{\sqrt{3}}$$

$$\theta = 30°$$



Dipole is shifted from $(d, 0)$ to $(0, d)$ find work done

Same Can be Replicated in Magnetics.

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

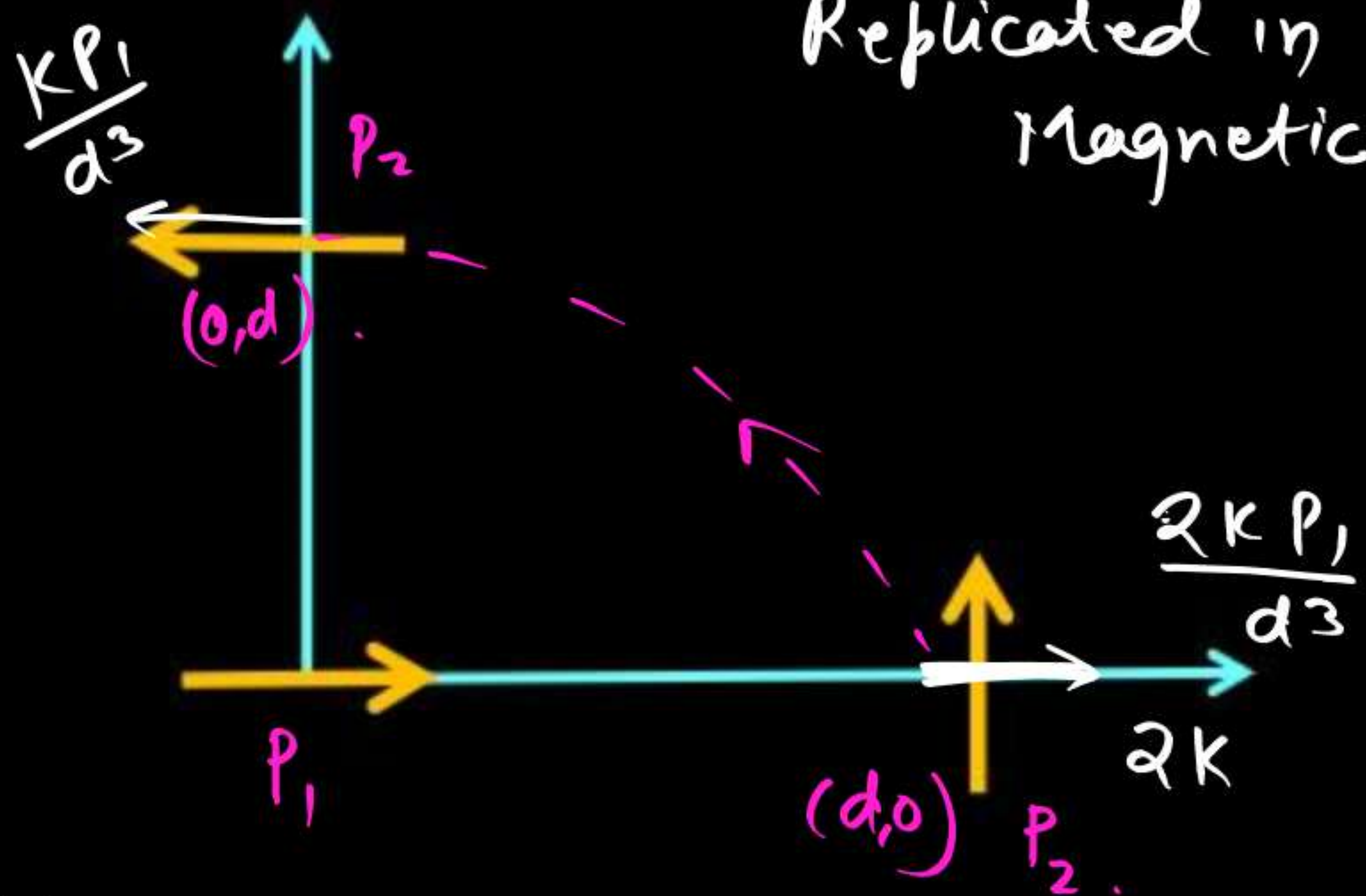
$$\text{Initial PE} = U_1 = -P_2\left(\frac{2KP_1}{d^3}\right)\cos 90$$

$$= 0.$$

$$\text{final PE} = -\bar{P}_2 \cdot \bar{E}_f$$

$$= -P_2 \frac{KP_1}{d^3}\cos 0$$

$$= -\frac{KP_1P_2}{d^3}$$



$$W_{ext} = U_f - U_i$$

$$\boxed{W = -\frac{KP_1P_2}{d^3} - 0}$$

Coupled Dipoles Oscillation

Let $|m_1| > |m_2|$

#

$$|\vec{M_T}| = m_1 + m_2$$

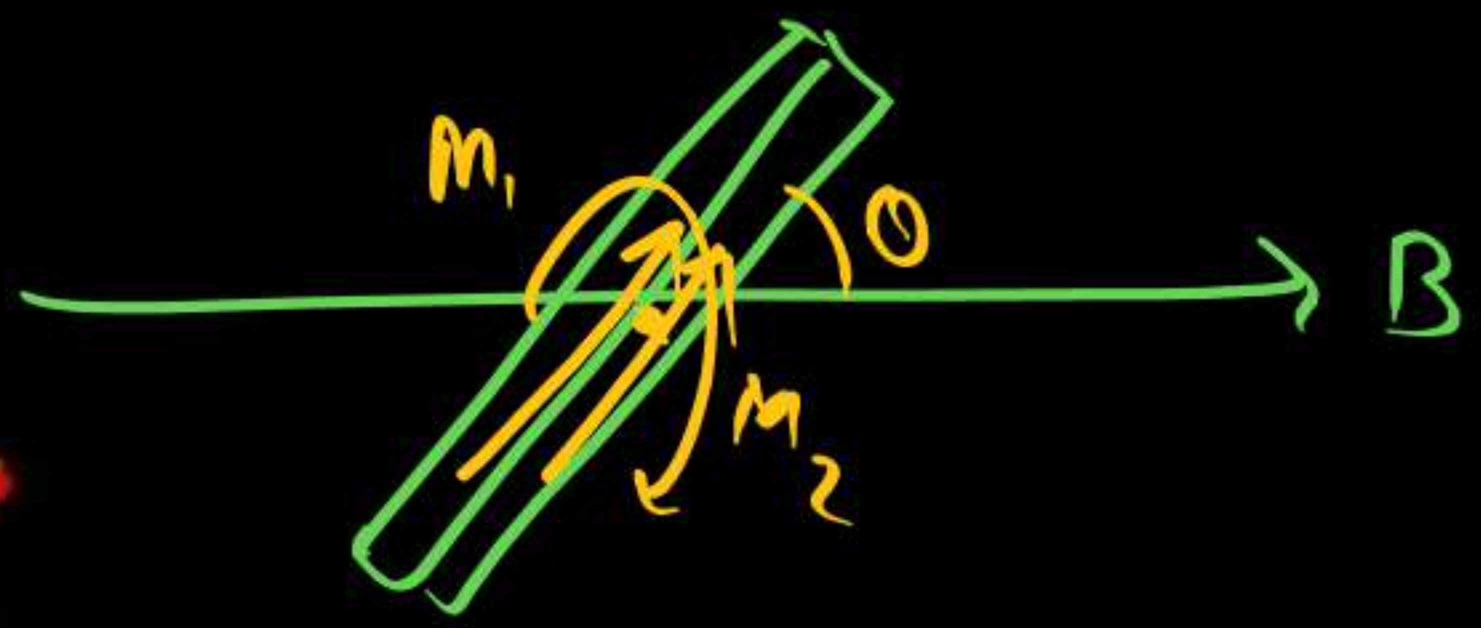
$\theta = 0^\circ$.

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

$$I_T = I_1 + I_2 \qquad T_S = 2\pi\sqrt{\frac{I_1 + I_2}{(m_1 + m_2)B}}$$

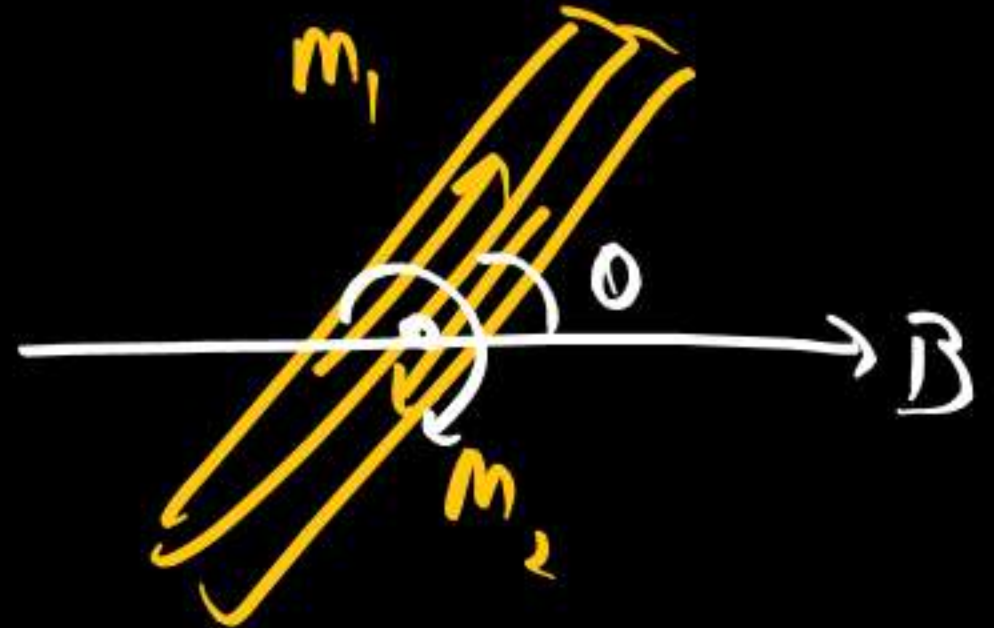
They are attached

Oscillated in $\vec{B}$.



In Second Scenario

also $I_T = I_1 + I_2$



$$|M_T| = m_1 - m_2$$

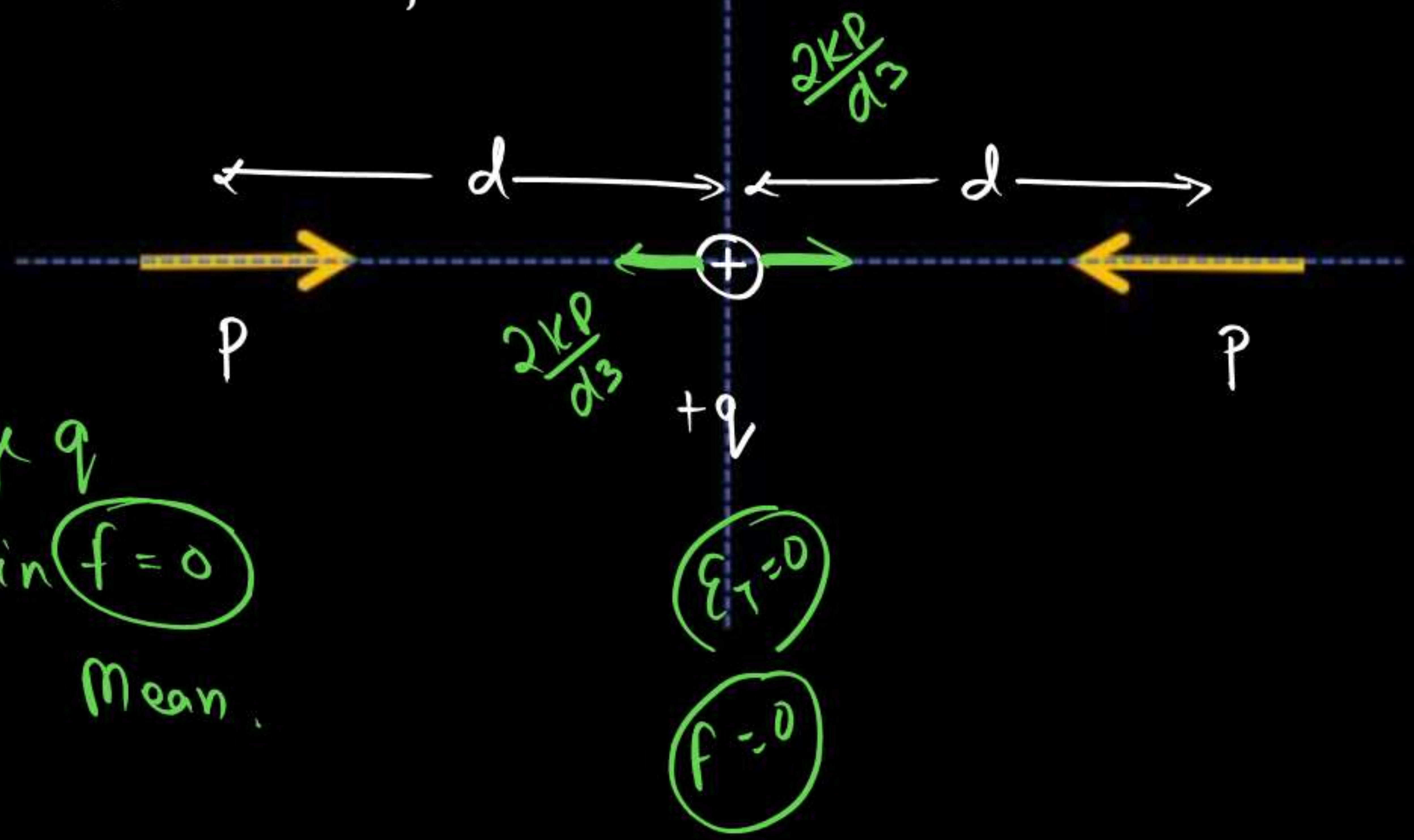
$$T_0 = 2\pi\sqrt{\frac{(I_1 + I_2)}{(m_1 - m_2)B}}$$

$$\boxed{\frac{T_S}{T_0} = \sqrt{\frac{m_1 + m_2}{m_1 - m_2}}}$$ Ans

Adv.

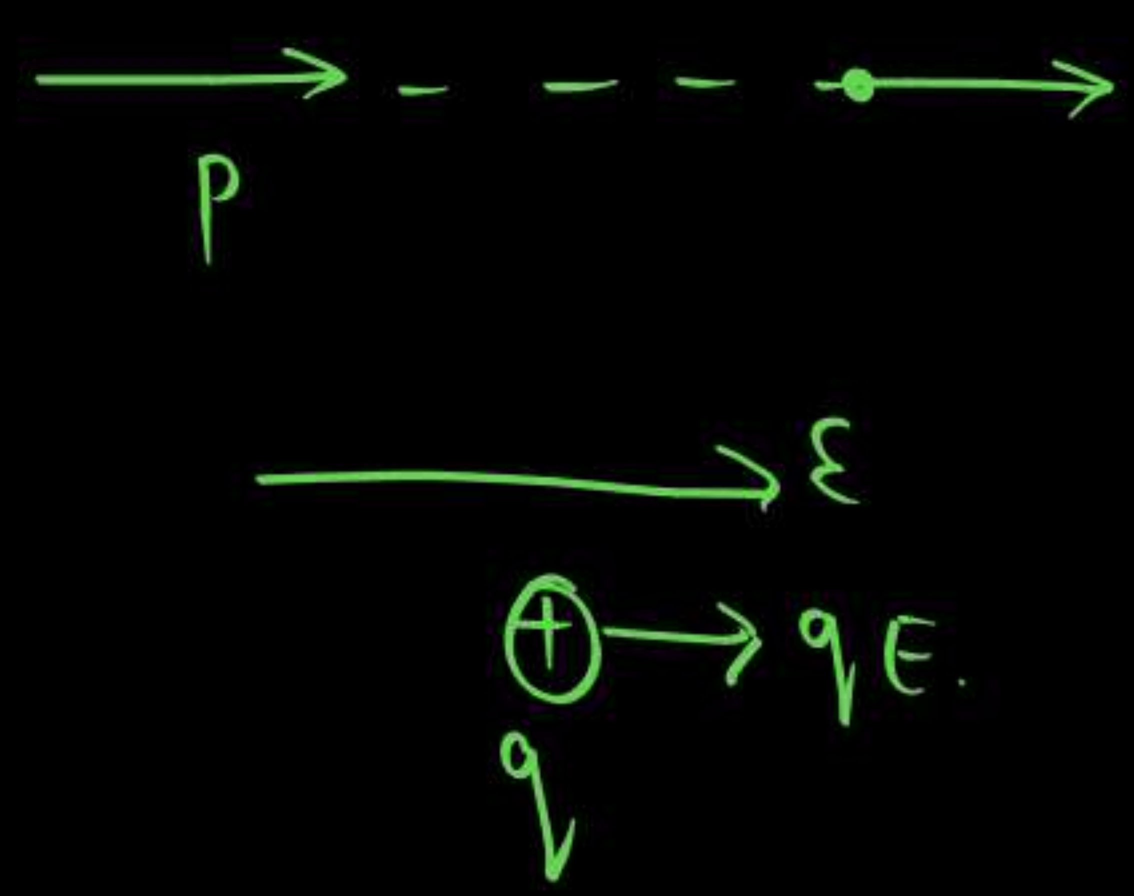
Time period of oscillation of a charge between two dipoles

Two dipoles P are Seperated by distance d on axis as shown. A point charge q is placed at origin & Shifted by Small distance 'x' towards Right. If mass of charge is m_0. Find Time period of Oscillation.



Known Info

$E = -\frac{2KP}{r^3}$

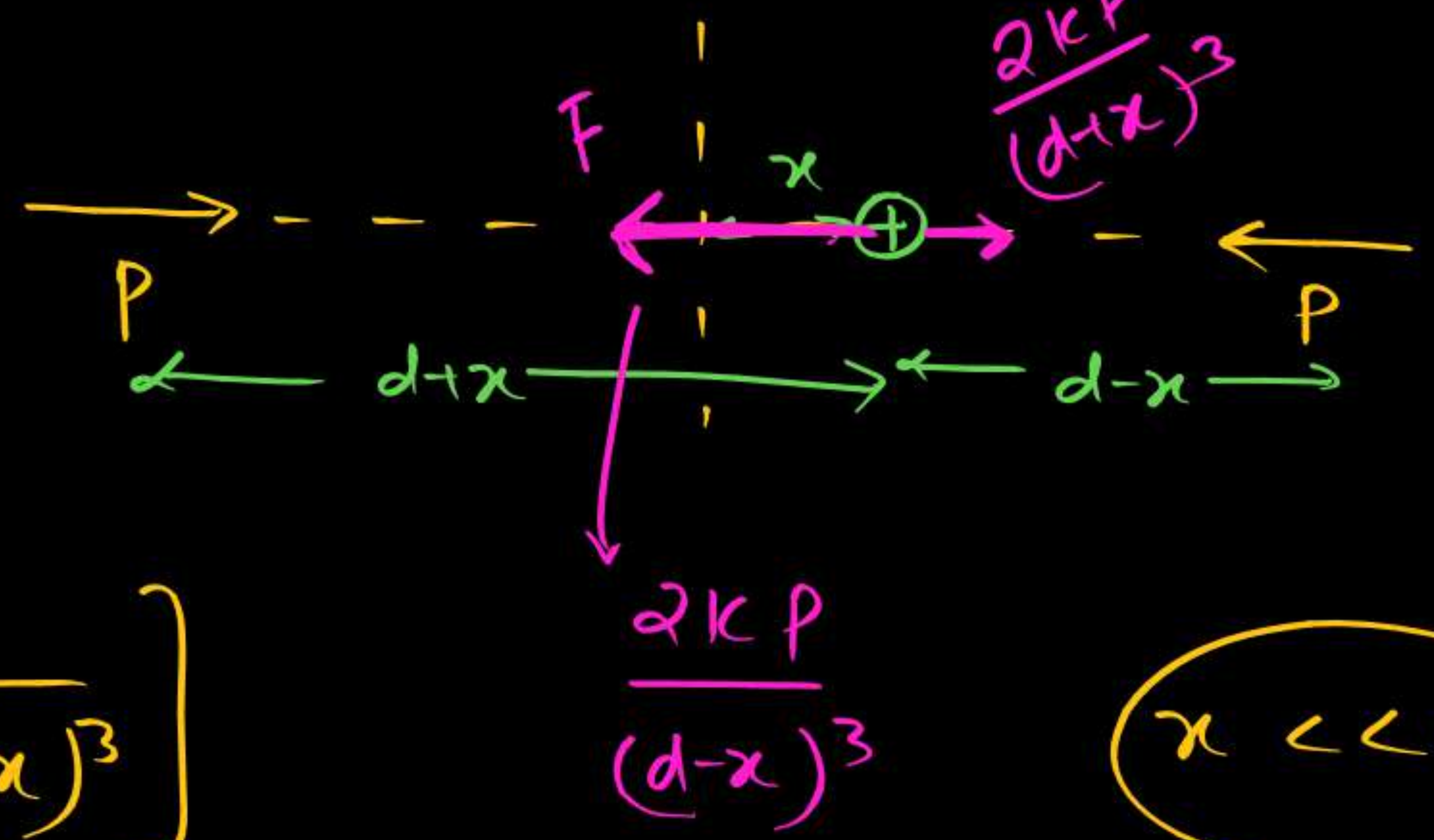


When charge q is at origin $f = 0$

Mean.

$E_{axial} \propto \frac{1}{r^3}$

$$f_{restoring} = q\left(\frac{2kP}{(d-x)^3} - \frac{2kP}{(d+x)^3}\right)$$



$$= 2kPq\left[\frac{1}{(d-x)^3} - \frac{1}{(d+x)^3}\right]$$

$$= \frac{2kPq}{d^3}\left[\frac{1}{\left(1-\frac{x}{d}\right)^3} - \frac{1}{\left(1+\frac{x}{d}\right)^3}\right]$$

$$= \frac{2kPq}{d^3}\left[\left(1-\frac{x}{d}\right)^{-3} - \left(1+\frac{x}{d}\right)^{-3}\right] = \frac{2kPq}{d^3}\left[\cancel{1} + \frac{3x}{d} - \cancel{1} + \frac{3x}{d}\right]$$

$x << d$

$(1+\square)^n = 1 + n\square$.

$\square \to 0$

$$\frac{2kPq}{d^3}\frac{6x}{d}$$

$$f_r = \frac{12kPq}{d^4}x$$

When $f_{rest} \propto x$

$$f_{rest} = m\omega^2 x$$

$$\frac{12KPq}{d^4}\cancel{x} = m\omega^2 \cancel{x}$$

$$\frac{2\pi}{T} = \omega = \sqrt{\frac{12KPq}{md^4}}$$

$$\boxed{T = 2\pi\sqrt{\frac{md^4}{12KPq}}}$$

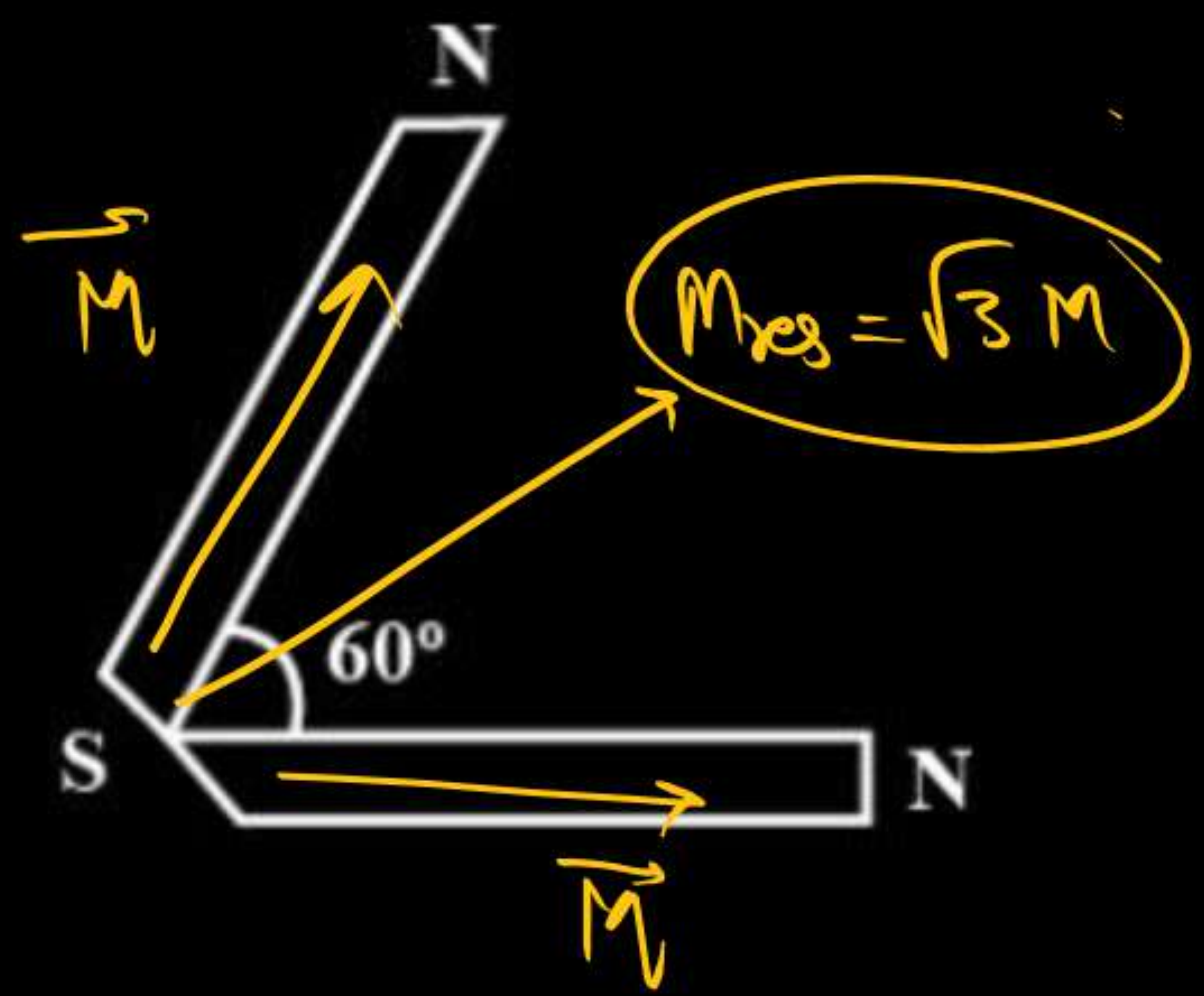
Two magnets of equal magnetic moments M each are placed as shown in figure. The resultant magnetic moment is

(a) M

(b) $\sqrt{3}\,M$ Ans.

(c) $\sqrt{2}\,M$

(d) $M/2$



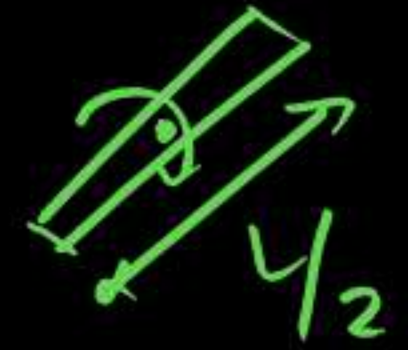
Time period for a magnet is T. If it is divided in two equal parts perpendicular to its axis, then time period for each part will be:

(a) $4T$ (b) $T/4$

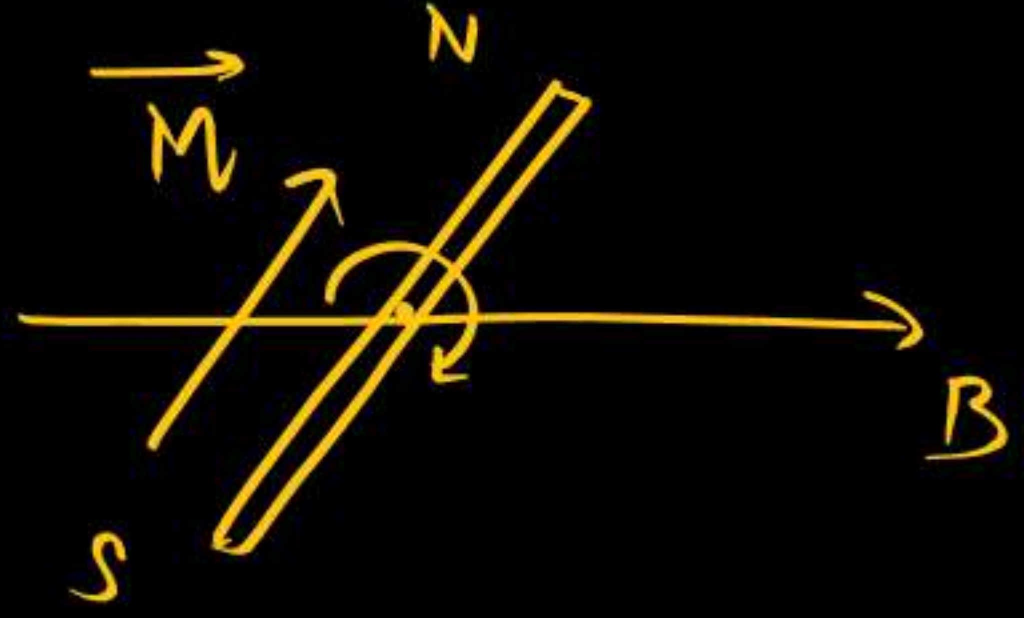
(c) $T/2$ Ans (d) T

$\frac{\text{Mass}}{2}$ $\vec{M}' = \frac{M}{2}$

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



$I = \frac{1}{12}(\text{Mass})L^2$



$T_0 = 2\pi\sqrt{\frac{\frac{1}{12}\text{Mass}\,L^2}{MB}}$

$T' = 2\pi\sqrt{\frac{\frac{1}{12}\left(\frac{\text{Mass}}{\cancel{2}}\right)\frac{L^2}{4}}{\frac{M}{\cancel{2}}\cdot B}} = \sqrt{\frac{1}{4}\left(\frac{\frac{1}{12}\text{Mass}\,L^2}{MB}\right)}$

$= \frac{1}{2}\sqrt{\frac{\frac{1}{12}\text{Mass}\,L^2}{MB}}$

$T' = \frac{T_0}{2}$

A bar magnet of magnetic moment 2.5 J/T, is placed in magnetic field 0.2 T. What work is done in turning the magnet from parallel to antiparallel position relative to field direction ?

(a) 1 J
(b) 2 J
(c) 3 J
(d) 4 J

Two dissimilar poles of strength x mWb and 2 mWb are separated by a distance 12 cm. If the null point is at a distance of 4 cm from 2 mWb, then the value of x is :

(a) 5
(b) 6
(c) 7
(d) 8

Thank You Lakshyians