Magnetic Moment and Torque

Magnetic Moment of a loop in two different Plane :→

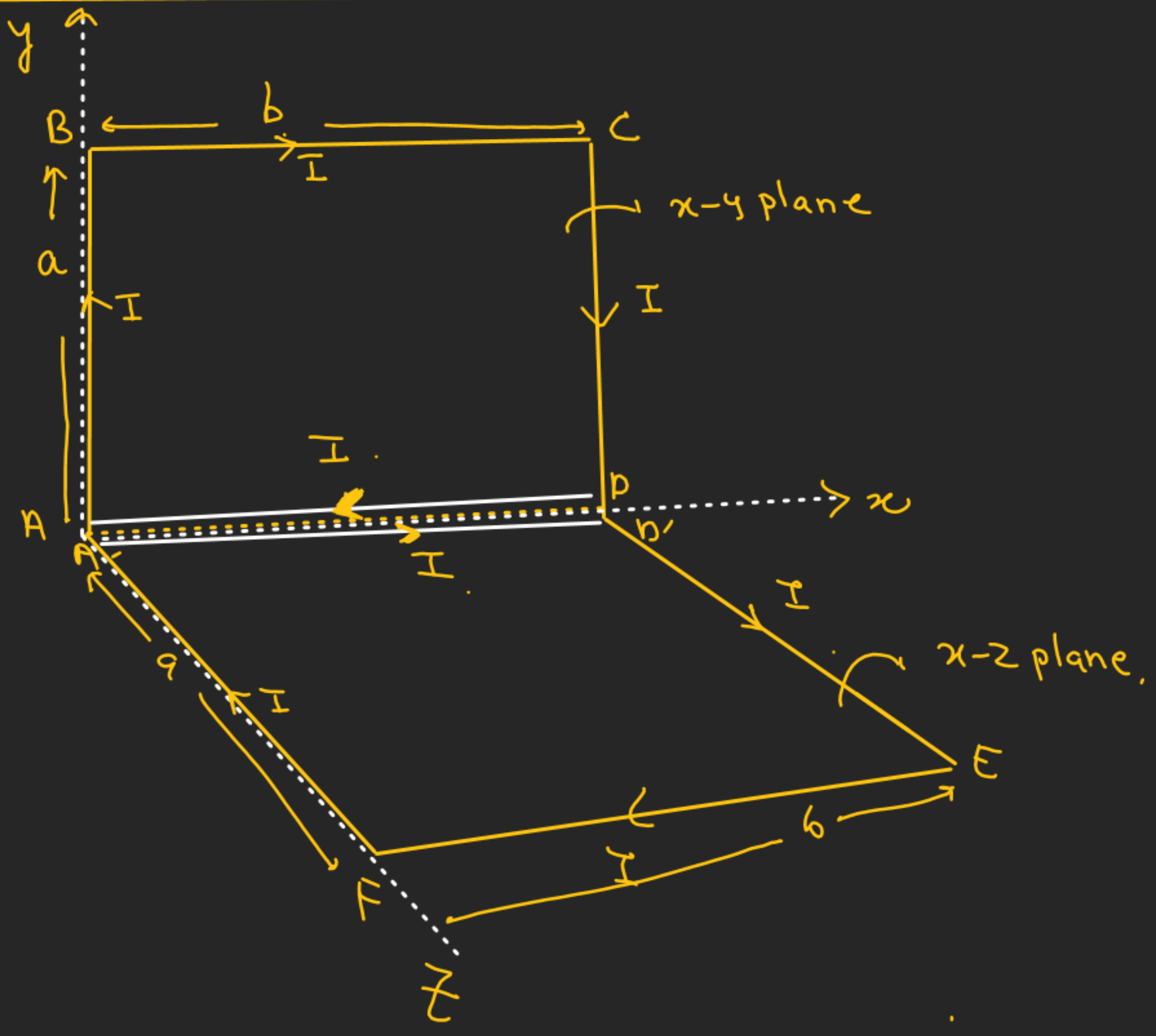
$$\vec{M}_{ABCDA} = (Iab)(-\hat{k})$$

$$\vec{M}_{A'D'EFA} = (Iab) - \hat{j}$$

$$\vec{M}_{net} = \vec{M}_{ABCDA} + \vec{M}_{A'D'EFA}$$

$$= -Iab(+\hat{k} + \hat{j})$$

$$|\vec{M}_{net}| = \sqrt{2}\, Iab$$



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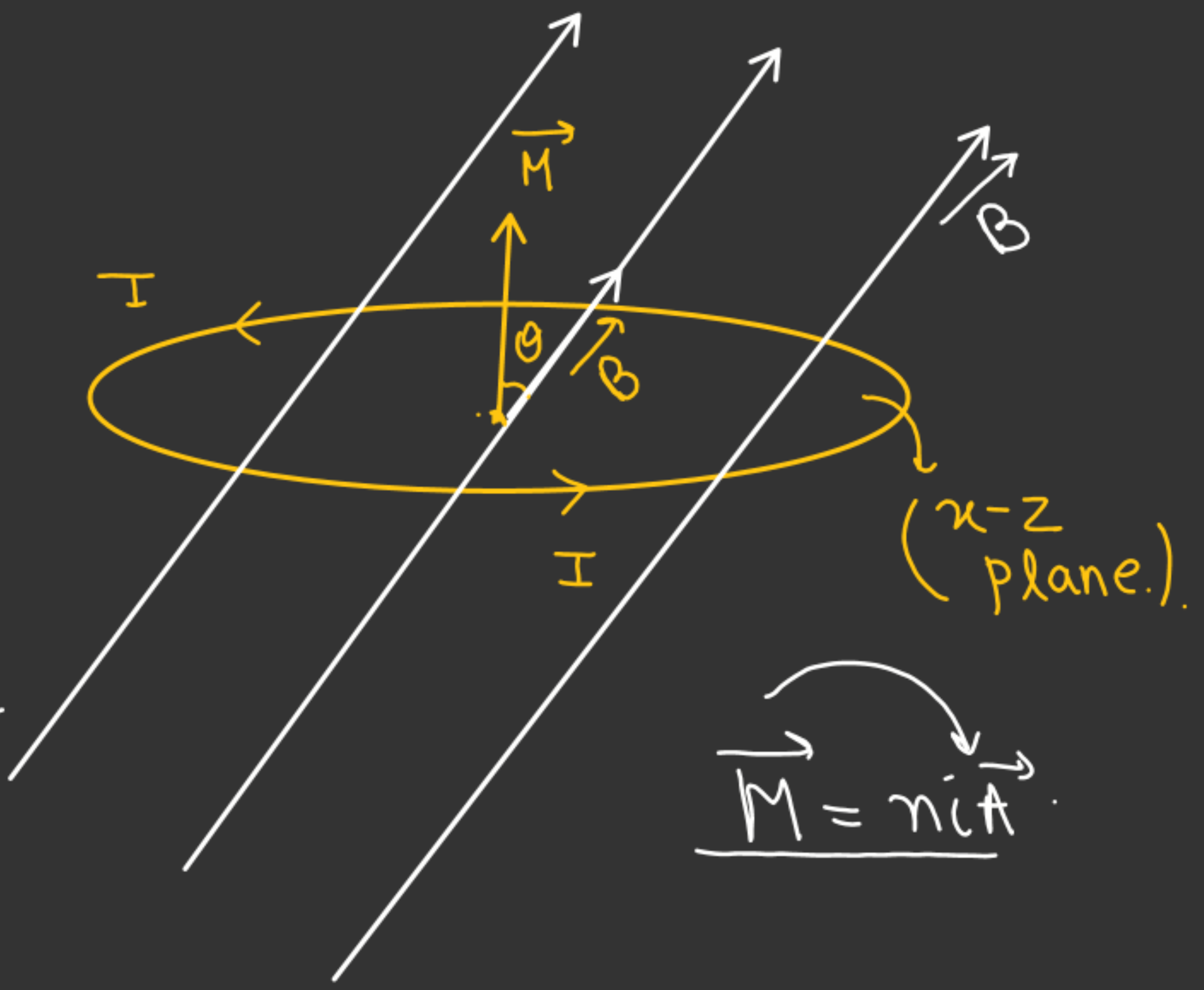
Torque acting on a Current Carrying loop placed in a Uniform Magnetic field :→

$$\left[\vec{\tau} = \vec{M} \times \vec{B}\right]$$

$$|\vec{\tau}| = [MB\sin\theta]$$

→ $\vec{\tau}$ is always perpendicular to the plane contaning $\vec{M}$ & $\vec{B}$.



$$\vec{M} = ni\vec{A}$$

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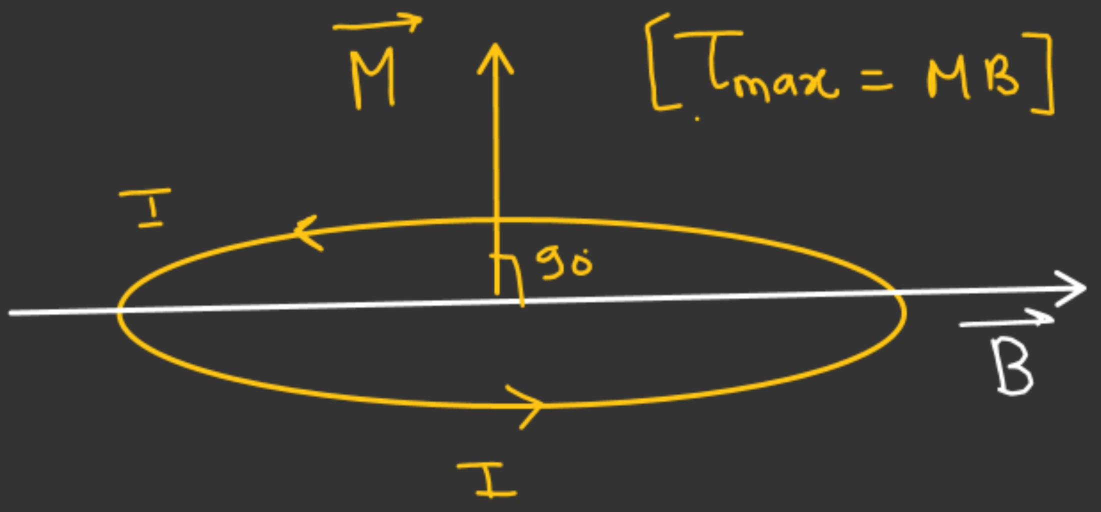
τ_{max} :- [$\vec{B}$ in the plane of the loop]

$\theta = 90^\circ$

$\tau_{max} = MB\sin 90^\circ$

$[\tau_{max} = MB]$



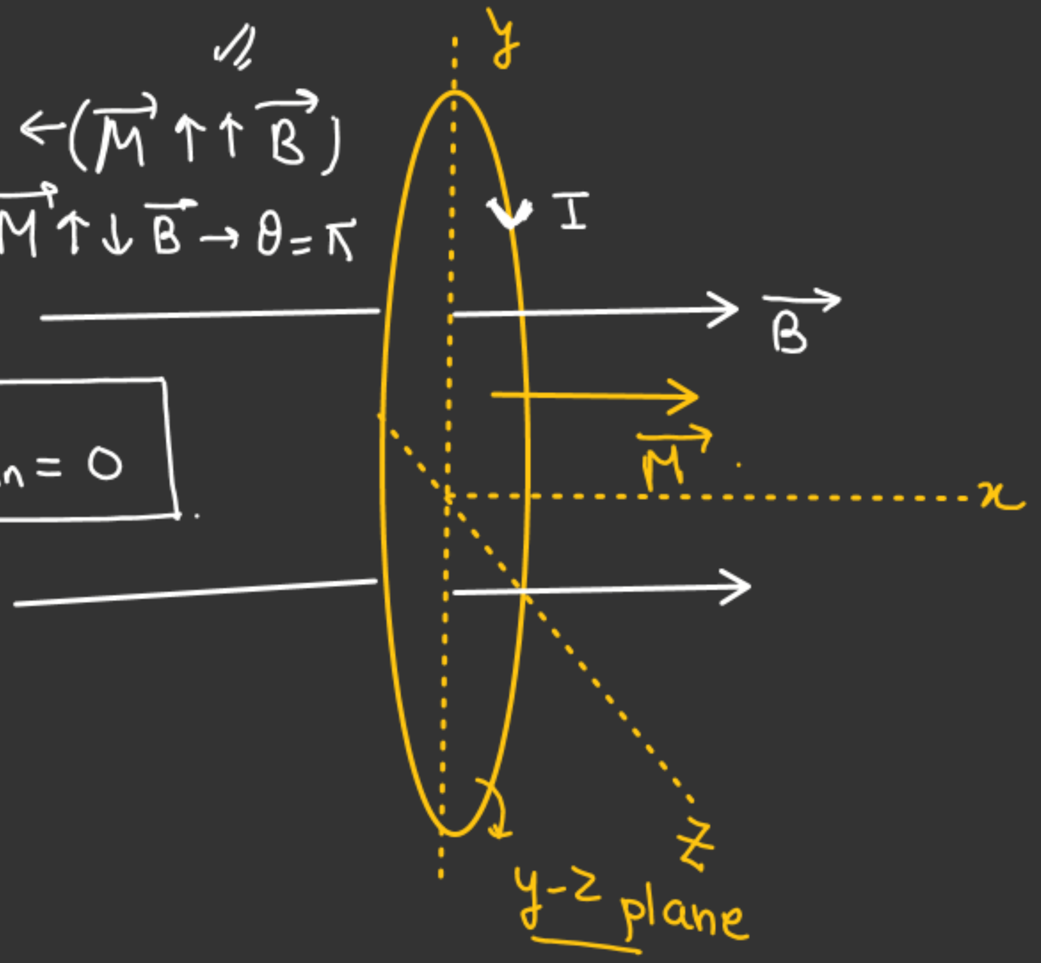
$\tau_{min} = ??$

$\Downarrow$

$\theta = 0 \leftarrow (\vec{M} \uparrow\uparrow \vec{B})$

$\vec{M} \uparrow\downarrow \vec{B} \rightarrow \theta = \pi$

$\boxed{\tau_{min} = 0}$



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$$\left[W = \int_{\theta_1}^{\theta_2} \tau \cdot d\theta\right]$$

P.E in a Current Carrying loop placed in a uniform Magnetic field :-

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

$$\int_{U(\theta_1)}^{U(\theta_2)} dU = \int_0^{W_{ext\,agent}} dW_{ext\,agent} = MB \int_{\theta_1}^{\theta_2} \sin\theta \cdot d\theta.$$

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

$$\Downarrow$$

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

$[U_{(\theta_2)} = 0]$

$\theta_2 \to 90^\circ$

$\theta_1 \to \theta$

$$U = -MB\cos\theta$$

** $\boxed{U = -\vec{M} \cdot \vec{B}}$

$U_{(\theta_1)} = 0.$

$\theta_2 \to 0,\ \theta_1 = \theta$

** $\boxed{U = MB(1 - \cos\theta)}$

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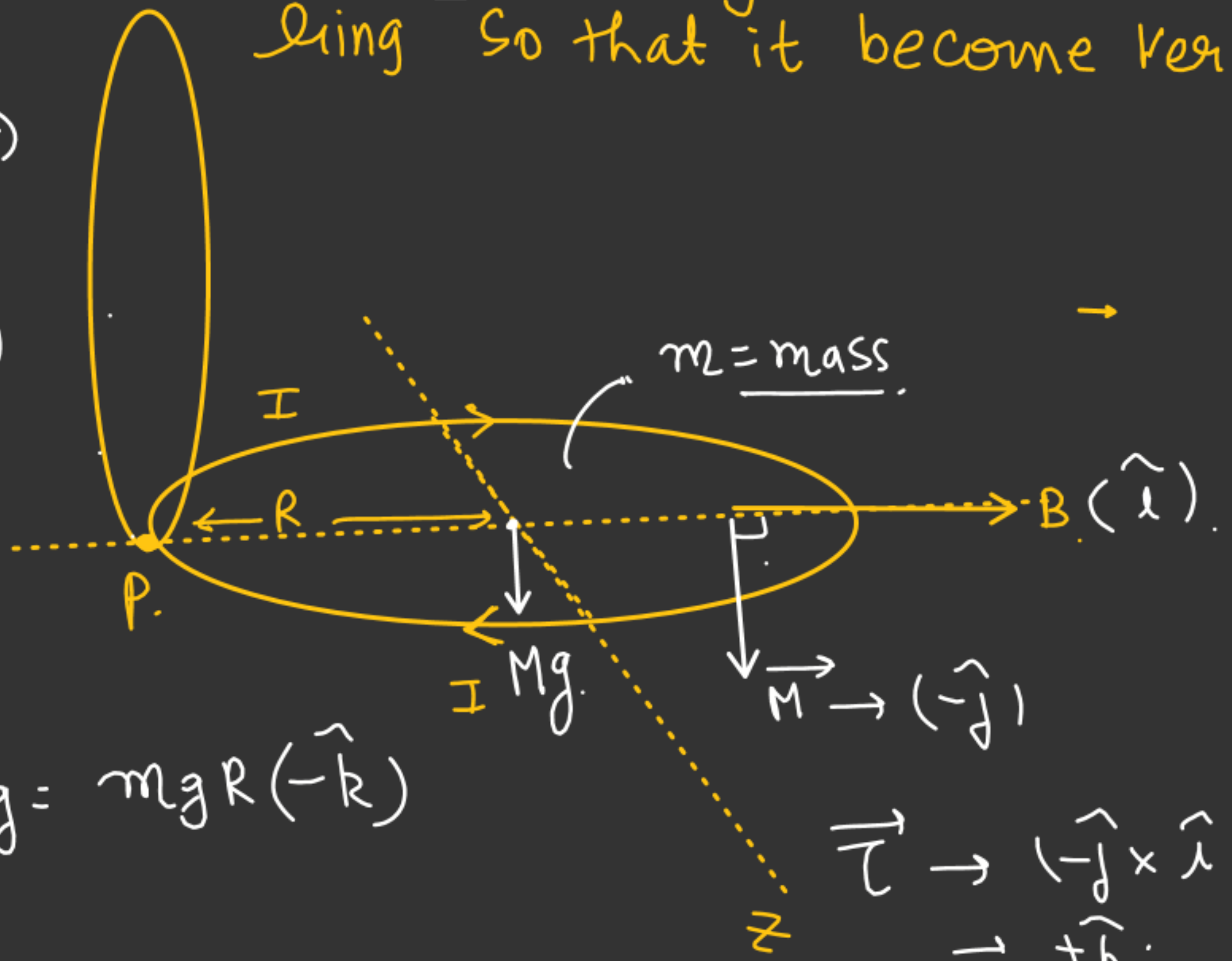
Find min B to just lift the ring so that it become vertical.

$\vec{\tau} = \vec{r} \times \vec{F}$

$|\vec{\tau}| = (F\, r_{\perp})$



$\vec{\tau}_{Mg} = mgR(-\hat{k})$

$\vec{\tau} \rightarrow (-\hat{j} \times \hat{i})$

$\rightarrow \underline{+\hat{k}}$

For ring to lift.

$\vec{\tau}_B \geq \vec{\tau}_{mg}$

$M.B. \geq mgR$

Magnetic Moment

$I\pi R^2 B \geq mgR$

$B \geq \left(\frac{mg}{\pi I R}\right)$

$\left(B_{min} = \frac{mg}{\pi I R}\right)$ <u>A</u>.

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MAGNETIC FIELD

Magnetic Moment and Torque

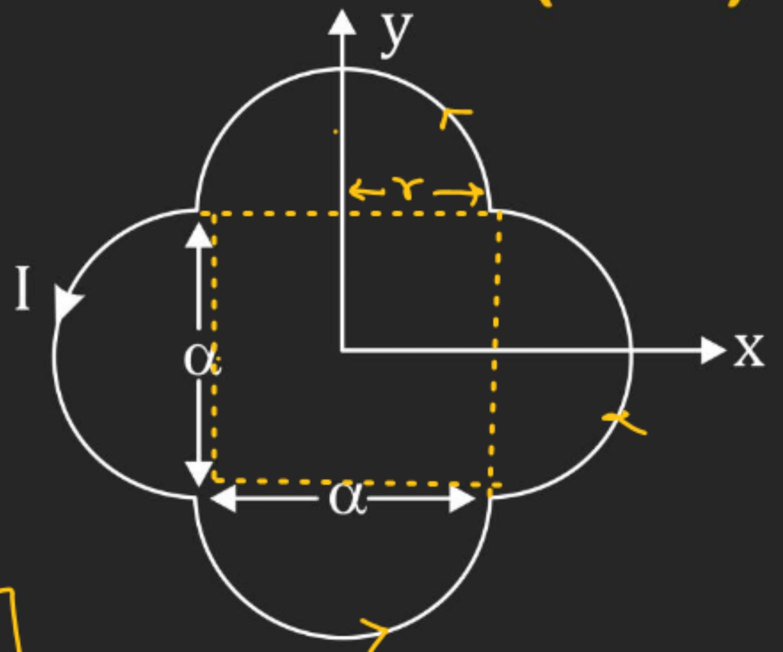
Q.3 A loop carrying current I lies in the $x - y$ plane as shown in the figure. The unit vector $\hat{k}$ is coming out of the plane of the paper. The magnetic moment of the current loop is **(2012)**

(A) $a^2 I\hat{k}$

(B) $\left(\frac{\pi}{2} + 1\right) a^2 I\hat{k}$

(C) $-\left(\frac{\pi}{2} + 1\right) a^2 I\hat{k}$ ✗

(D) $(2\pi + 1)a^2 I\hat{k}$



$\alpha \to a$

$r = \left(\frac{a}{2}\right)$

$\vec{M} = Ia^2\left(1+\frac{\pi}{2}\right)\hat{k}$

$A = $ (Area of Square) $+$ 4 (Area of Semi Circle)

$A = a^2 + 4\left[\frac{\pi}{2}\left(\frac{a^2}{4}\right)\right]$

$A = \left(a^2 + \frac{\pi a^2}{2}\right) = a^2\left(1+\frac{\pi}{2}\right)$

Magnetic Moment and Torque

Q.1 H.W A particle of charge q and mass m moves in a circular orbit of radius r with angular speed ω. The ratio of the magnitude of its magnetic moment to that of its angular momentum depends on **(2000)**

(A) and q

(B) ω, q and m

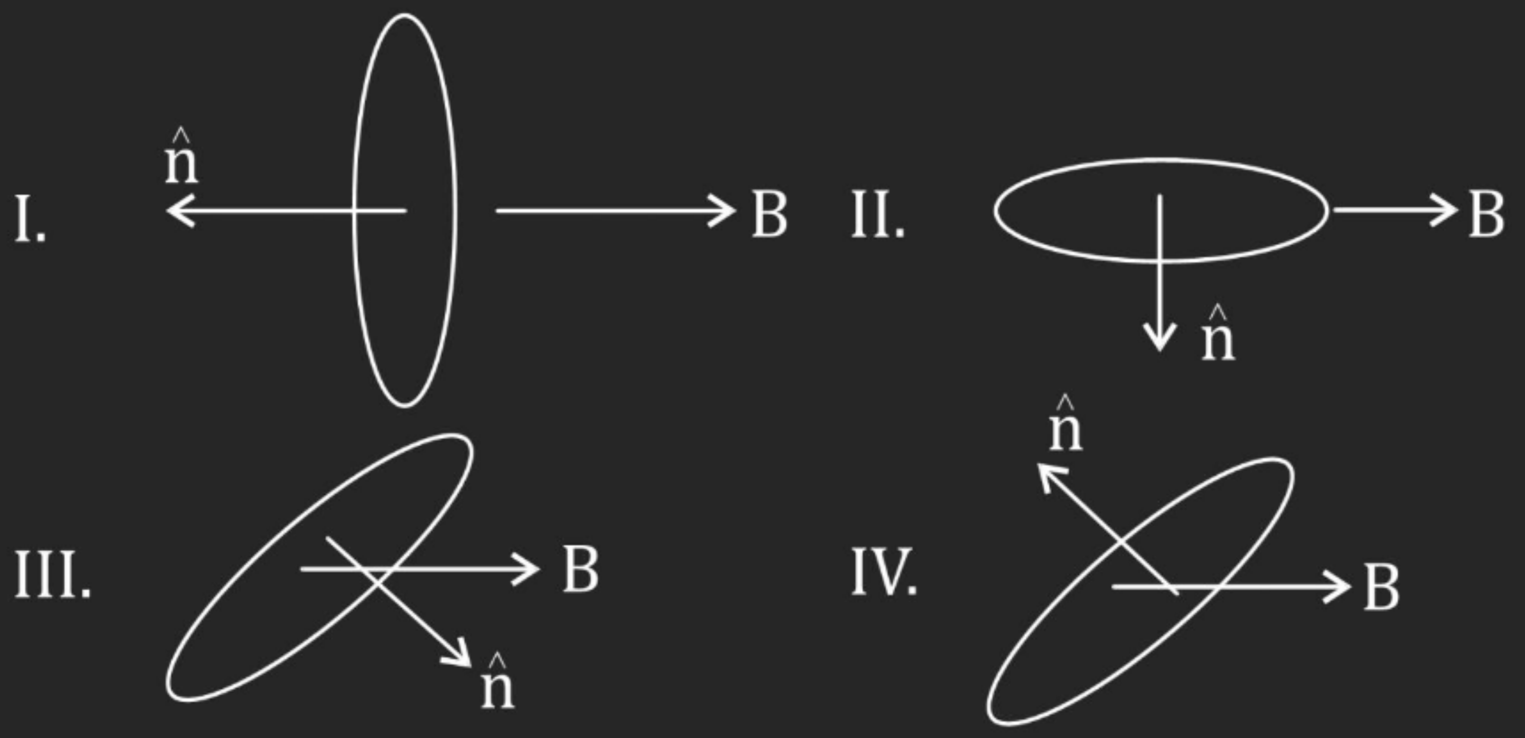
(C) q and m

(D) ω and m.

MAGNETIC FIELD

Magnetic Moment and Torque

Q.2 A current carrying loop is placed in a uniform magnetic field in four different orientations. I, II, III & IV. Arrange them in the decreasing order of potential energy (2003)



(A) I > III > II > IV

(B) I > II > III > IV

(C) I > IV > II > III

(D) III > IV > I > II

MAGNETIC FIELD

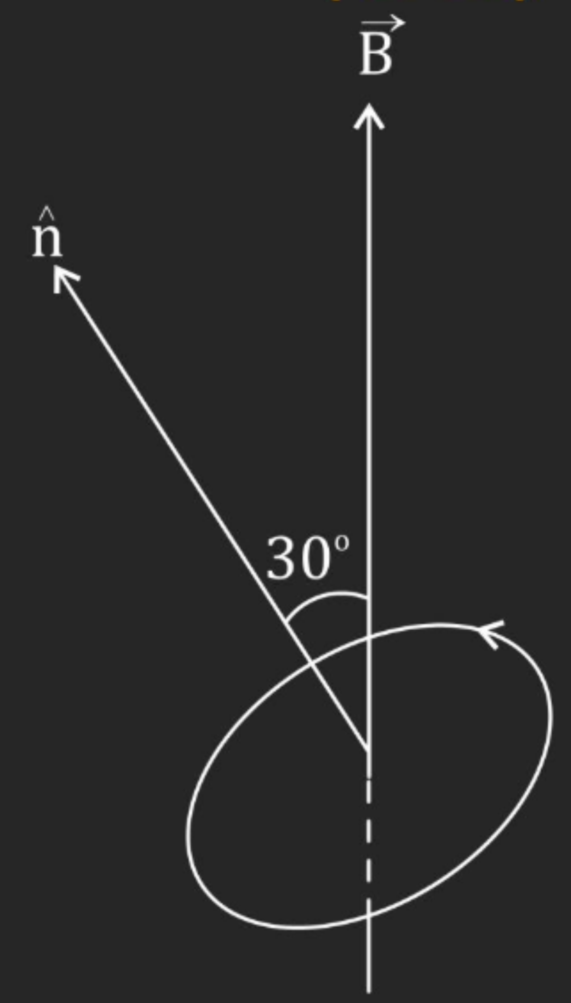
Magnetic Moment and Torque

Q.5 An electron in the ground state of hydrogen atom is revolving in anticlock-wise direction in a circular orbit of radius R. (1996)

H-W

(i) Obtain an expression for the orbital magnetic dipole moment of the electron.

(ii) The atom is placed in a uniform magnetic induction $\vec{B}$ such that the plane-normal of the electron-orbit makes an angle of $30°$ with the magnetic induction. Find the torque experienced by the orbiting electron.



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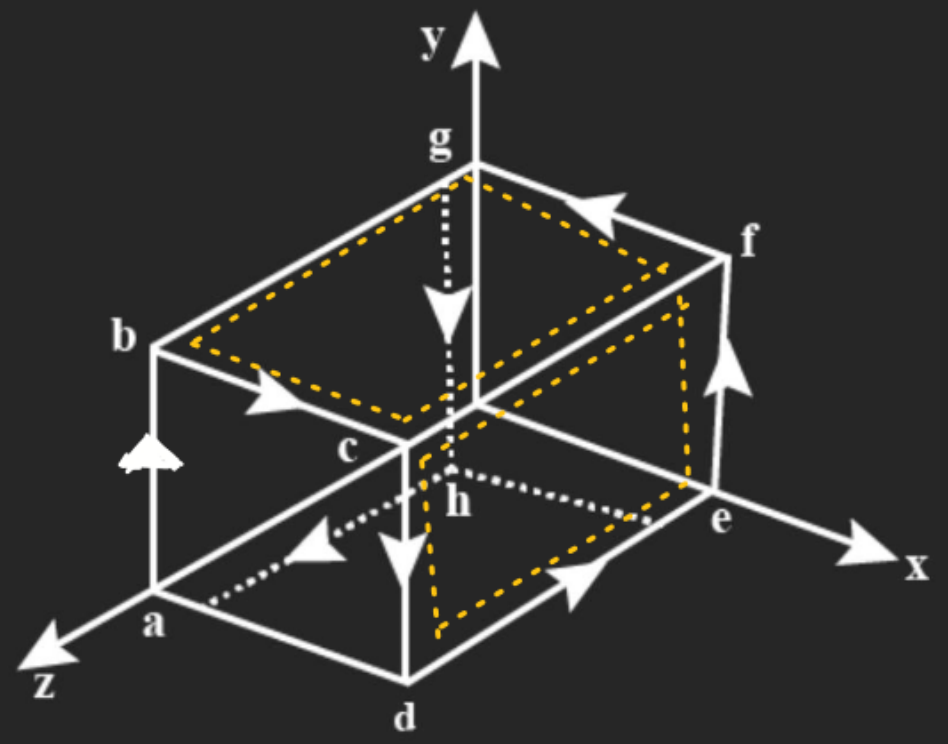
MAGNETIC FIELD

Magnetic Moment and Torque

Q.9 A conductor carries a constant current I along the closed path abcdefgha involving 8 of the 12 edges of length 1 . Find the magnetic dipole moment of the closed path.



MAGNETIC FIELD

Magnetic Moment and Torque

Q.10 A wire carrying a $10\ \mathrm{A}$ current is bent to pass through various sides of a cube of side $10\ \mathrm{cm}$ as shown in Fig(a). A magnetic field $\vec{B} = (2\hat{i} - 3\hat{j} + \hat{k})\mathrm{T}$ is present in the region. Then find :

H.W

(a) the net force on the loop shown.

(b) the magnetic moment vector of the loop.

(c) the net torque on the loop.