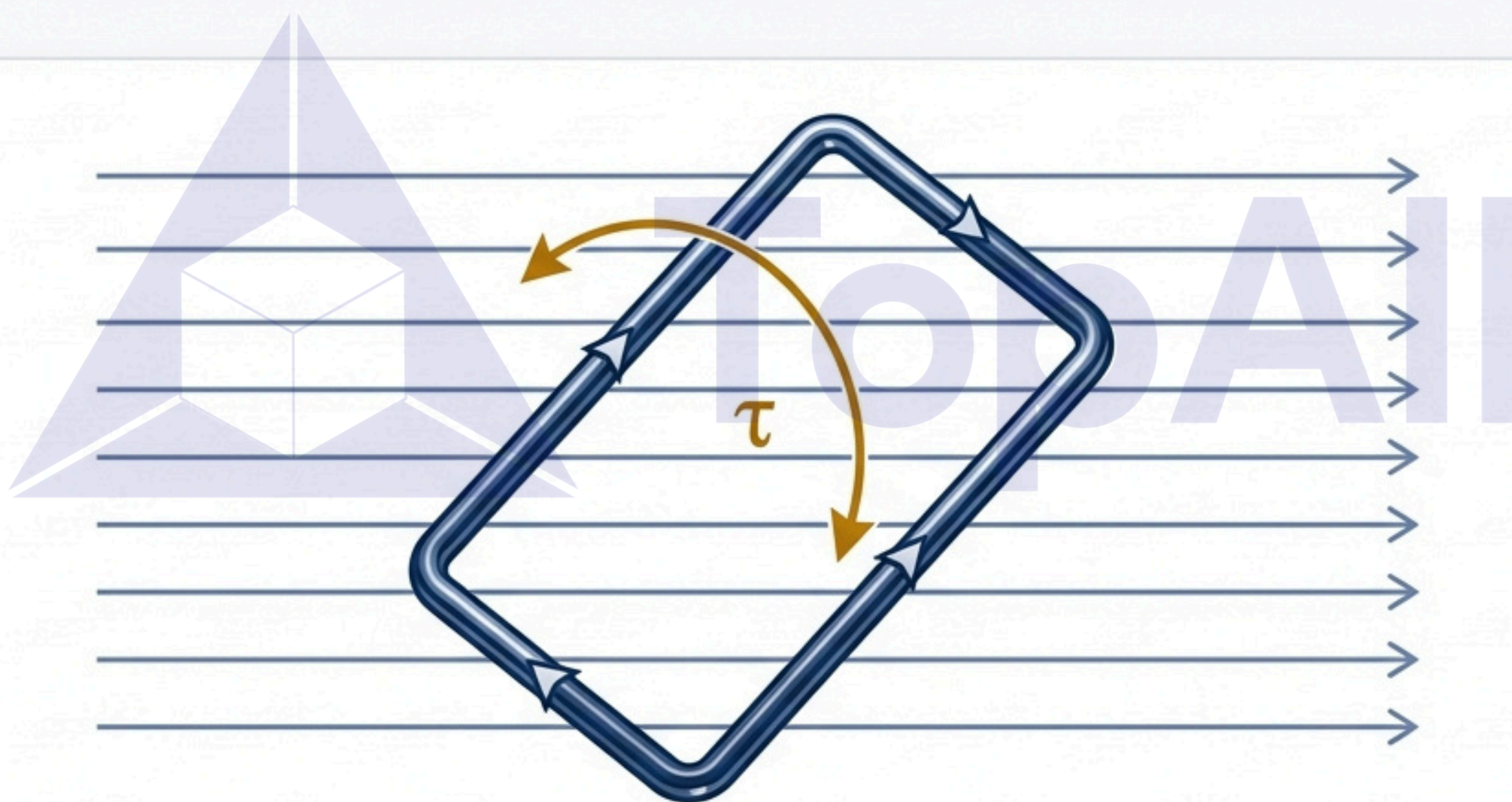
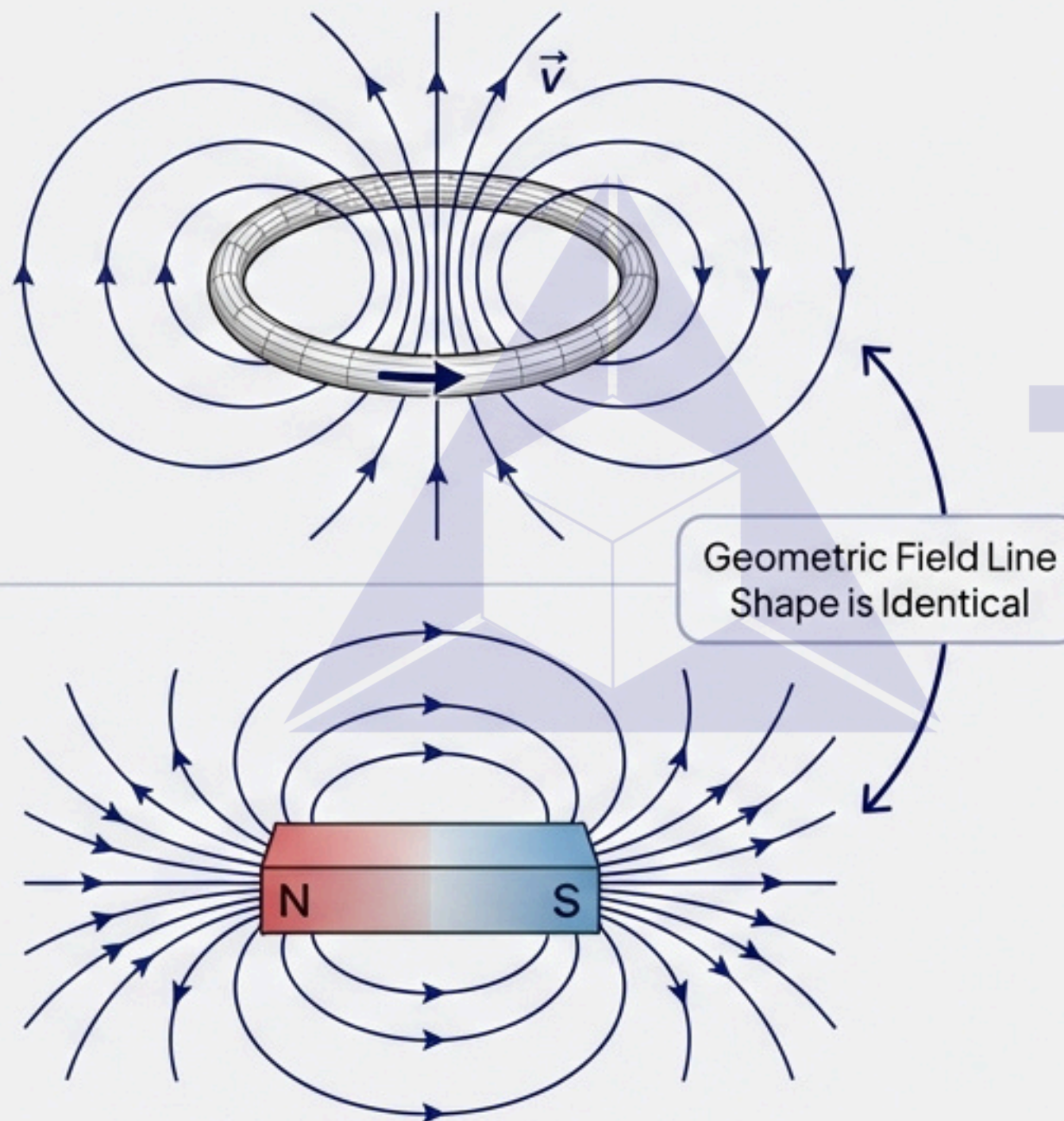


Torque on a Current Loop

Understanding the mechanics of magnetic dipoles in uniform fields.



The Loop is a Magnetic Dipole



Card 1

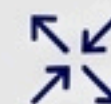
A planar current loop produces a magnetic field identical to a magnetic dipole. It acts exactly like a tiny bar magnet.

Card 2

When placed in a uniform external magnetic field, the loop experiences:

Net Force = 0

(Translational equilibrium. Forces on opposite arms cancel perfectly).



Net Torque $\neq 0$

(Experiences a rotational twist due to a force couple).



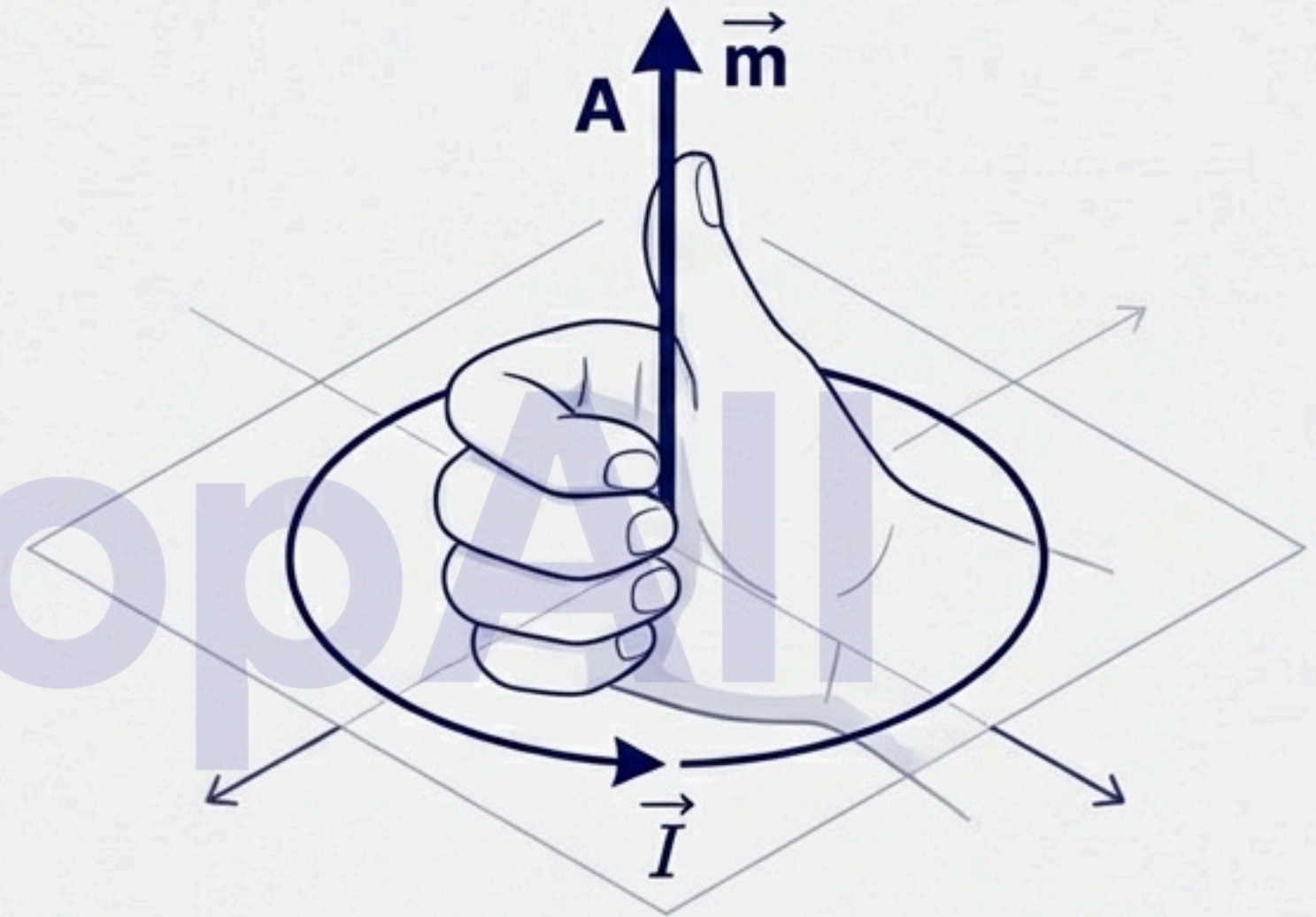
Magnetic Moment ($\mathbf{m}$)

$$\mathbf{m} = N I \mathbf{A}$$

Diagram illustrating the components of the magnetic moment equation $\mathbf{m} = N I \mathbf{A}$:

- N : Number of turns (indicated by an arrow pointing to N)
- I : Current (Amperes) (indicated by an arrow pointing to I)
- $\mathbf{A}$: Area Vector (m^2) (indicated by an arrow pointing to $\mathbf{A}$)
- N : Number of turns (indicated by an arrow pointing to N)

SI Unit: $\text{A}\cdot\text{m}^2$



Direction is defined by the Right-Hand Thumb Rule. $\mathbf{m}$ is always perpendicular to the plane of the loop.



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$$E=mc^2$$



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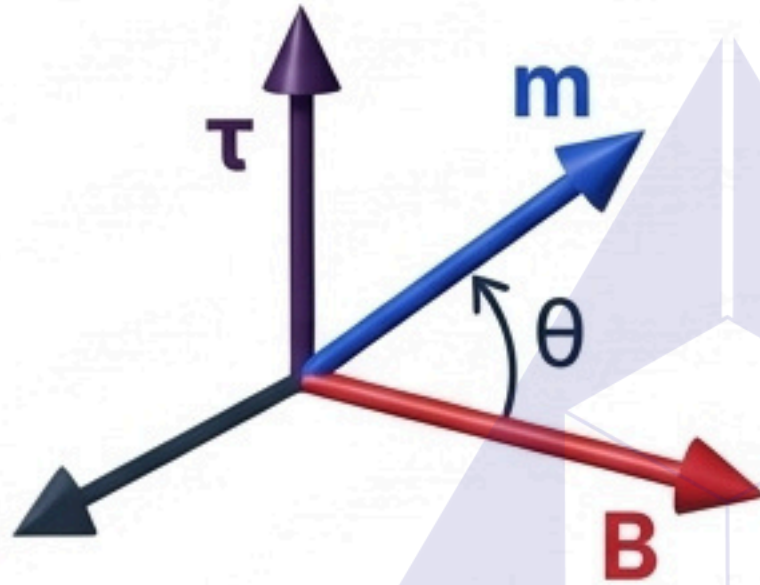
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Calculating the Torque

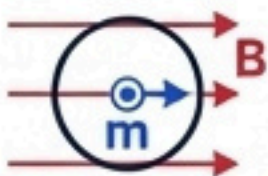
The external magnetic field exerts a couple on the loop, trying to align its magnetic moment with the field.



$$\boldsymbol{\tau} = \mathbf{m} \times \mathbf{B} \Rightarrow \tau = mB \sin\theta$$

(where θ is the angle between $\mathbf{m}$ and $\mathbf{B}$)

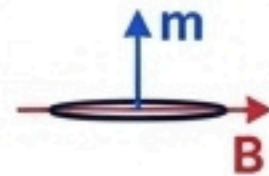
Stable Equilibrium



$$\theta = 0^\circ \Rightarrow \tau = 0$$

($\mathbf{m} \parallel \mathbf{B}$). Small rotations create a restoring torque.

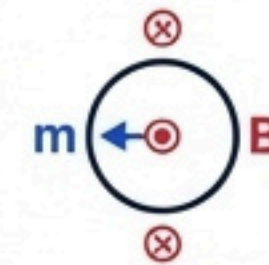
Maximum Torque



$$\theta = 90^\circ \Rightarrow \tau = mB$$

($\mathbf{m} \perp \mathbf{B}$). The plane of the loop is parallel to the field.

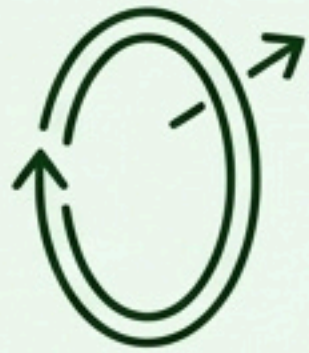
Unstable Equilibrium



$$\theta = 180^\circ \Rightarrow \tau = 0$$

($\mathbf{m}$ anti-parallel to $\mathbf{B}$). Small rotations cause the loop to flip.

Key Takeaways



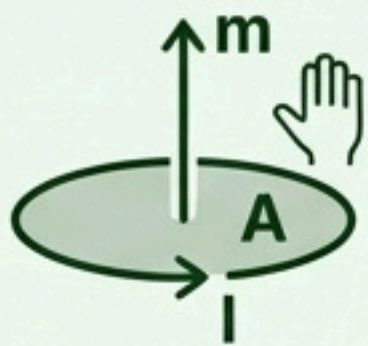
Loop = Dipole:

Any planar current loop (regardless of specific shape) fundamentally behaves as a magnetic dipole.



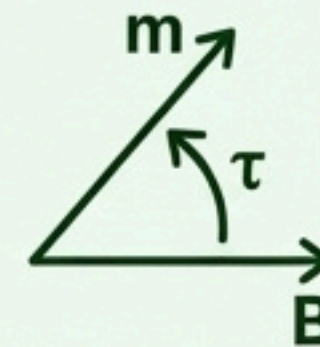
Zero Net Force:

In a uniform magnetic field, translational force on a closed loop is always strictly zero ($F_{\text{net}} = 0$).



Magnetic Moment:

Calculated as $m = NIA$. Direction is strictly determined via the Right-Hand Rule (normal to the area).



Torque Mechanics:

Defined by $\tau = m \times B$. The external field perpetually acts to align the loop's area vector with itself.



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