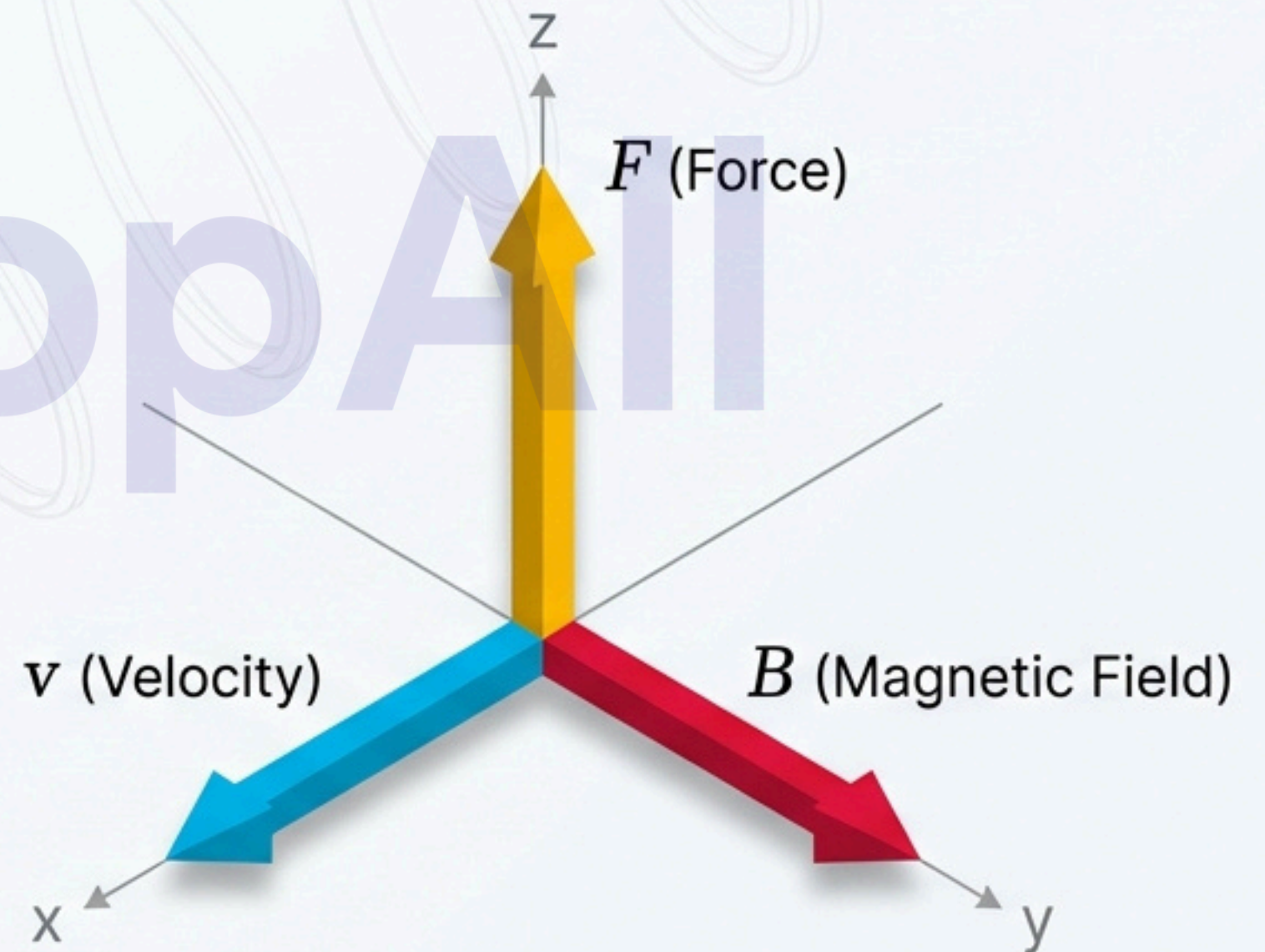


Magnetic Field & Lorentz Force

Deconstructing the Vector Blueprint
of Moving Charges



$$\mathbf{F} = q[\mathbf{E} + (\mathbf{v} \times \mathbf{B})]$$

ELECTRIC FORCE (F_e)

$$F_e = qE$$

CONDITION: ACTS REGARDLESS OF MOTION

Accelerates the charge in the direction of the electric field. Can transfer kinetic energy.

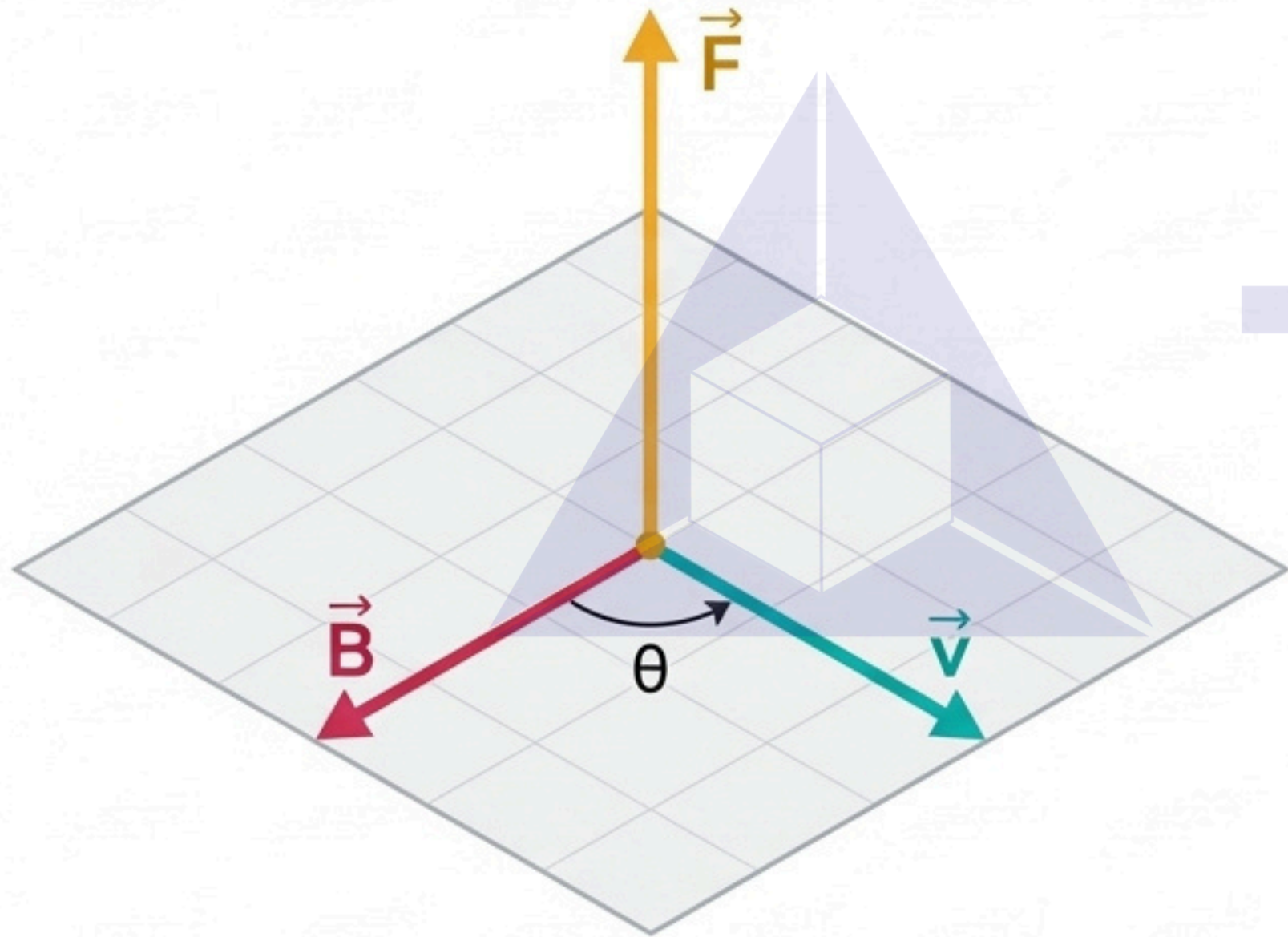
MAGNETIC FORCE (F_m)

$$F_m = q(\mathbf{v} \times \mathbf{B})$$

CONDITION: REQUIRES VELOCITY ($\mathbf{v} \neq 0$)

Acts perpendicularly to velocity. Does no work; only changes the direction of momentum.

The Magnetic Force Mechanics: $q(\vec{v} \times \vec{B})$



Magnitude Maxima

$$F_{\max} = qvB$$

Condition: $\mathbf{v} \perp \mathbf{B}$ ($\theta = 90^\circ$)

Direction Rule

Right-Hand Screw Rule

Force is always perpendicular to the plane containing both $\mathbf{v}$ and $\mathbf{B}$.

Zero-Force States

$$F_m = 0$$

State A: Stationary charge
($\mathbf{v} = 0$)

State B: Parallel motion
($\theta = 0^\circ$ or 180°)



**You've Learned the Theory.
Let's Test Them Now.**

$$E=mc^2$$



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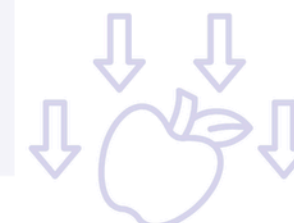
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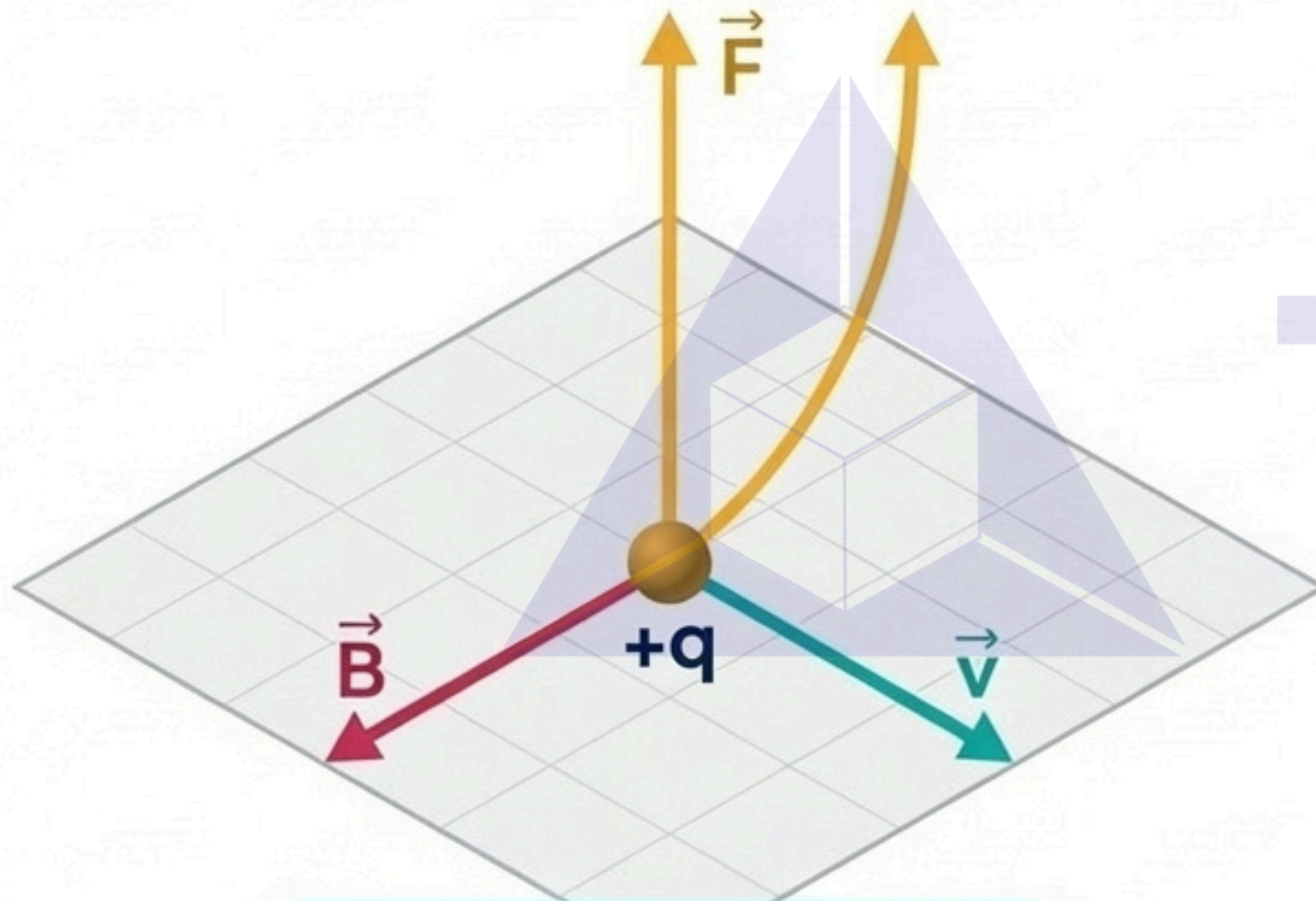
Key Highlights

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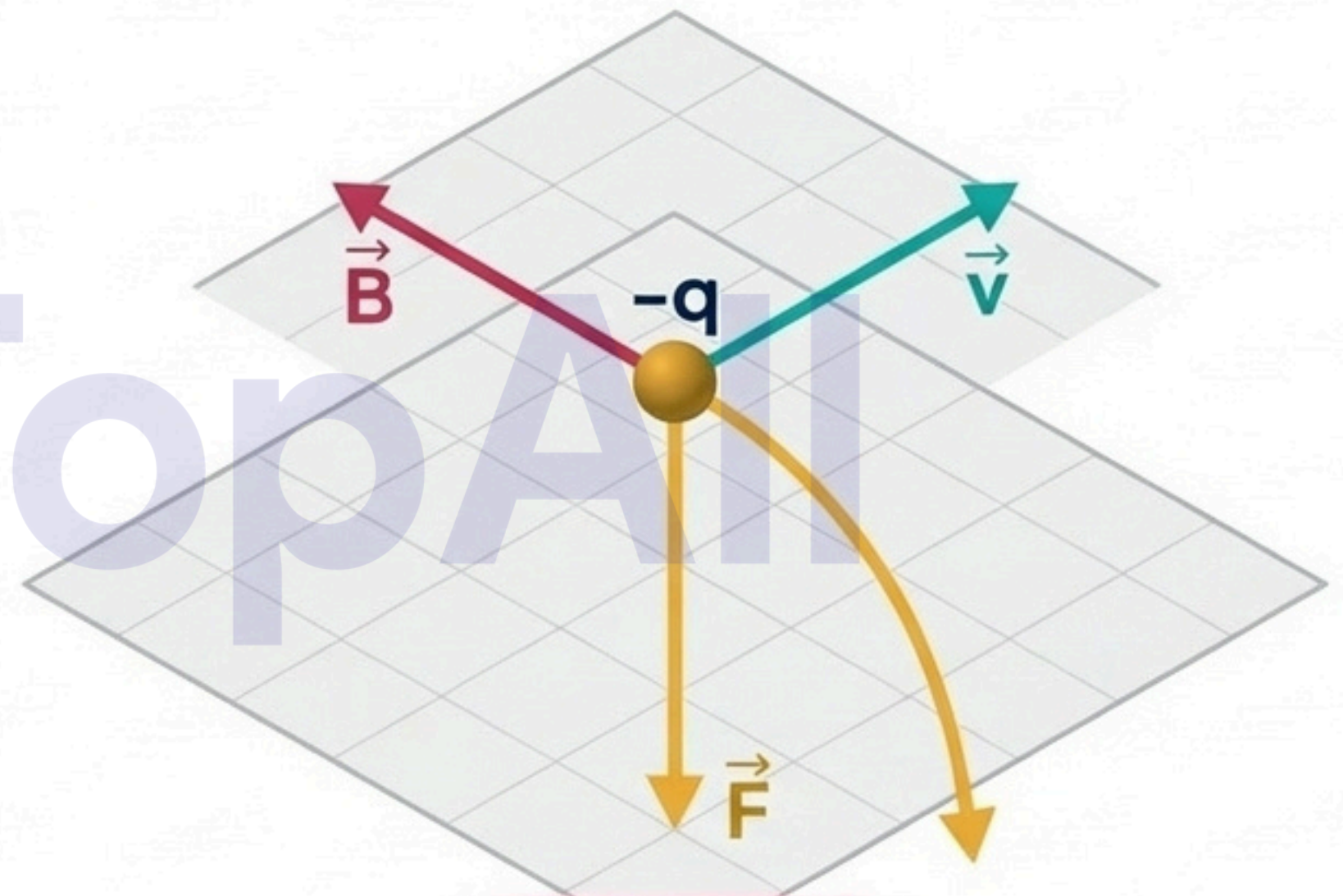
Vector Deflection: Positive vs. Negative Charges

Positive Charge (+q)



Follows Right-Hand Rule exactly.

Negative Charge (-q)



180° Vector Flip.

The scalar charge multiplier (q) flips the vector direction if negative. Deflection of $-q$ is in the exact opposite sense to $+q$.

Defining the Magnetic Field Unit: The Tesla

Unit Derivation Pipeline

1. Isolate **B**:

$$B = \frac{F}{qv \sin \theta}$$

2. Substitute SI units:

$$1 \text{ Tesla} = \frac{1 \text{ Newton}}{1 \text{ Coulomb} \cdot 1 \text{ m/s}}$$

3. Formal Definition:

“The magnitude of magnetic field **B** is 1 Tesla when the force acting on a unit charge (1 C) moving perpendicular to **B** with a speed of 1 m/s is exactly 1 Newton.

Tesla vs. Gauss

1 Tesla (named after Nikola Tesla) is a massive unit.



Earth's magnetic field
 $\approx 3.6 \times 10^{-5} \text{ T}$

1 Gauss (non-SI)
 $= 10^{-4} \text{ Tesla}$

Earth's field is roughly
 $\sim 0.36 \text{ Gauss}$

Key Takeaways: Lorentz Force



The Universal Law

$\mathbf{F} = q[\mathbf{E} + (\mathbf{v} \times \mathbf{B})]$. Combines static electric acceleration with velocity-dependent magnetic deflection.

The Zero-Work Consequence

Because magnetic force is always perpendicular to velocity ($\mathbf{F}_m \perp \mathbf{v}$), it does NO WORK. It cannot change a particle's kinetic energy or speed, only its trajectory.

Zero-Force Conditions

A magnetic field exerts 0 force if the charge is stationary ($\mathbf{v}=0$) or moving perfectly parallel/anti-parallel to the field lines ($\theta = 0^\circ, 180^\circ$).

Unit Conversions

1 Tesla (T) = 1 N·s/(C·m) = 10^4 Gauss.



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