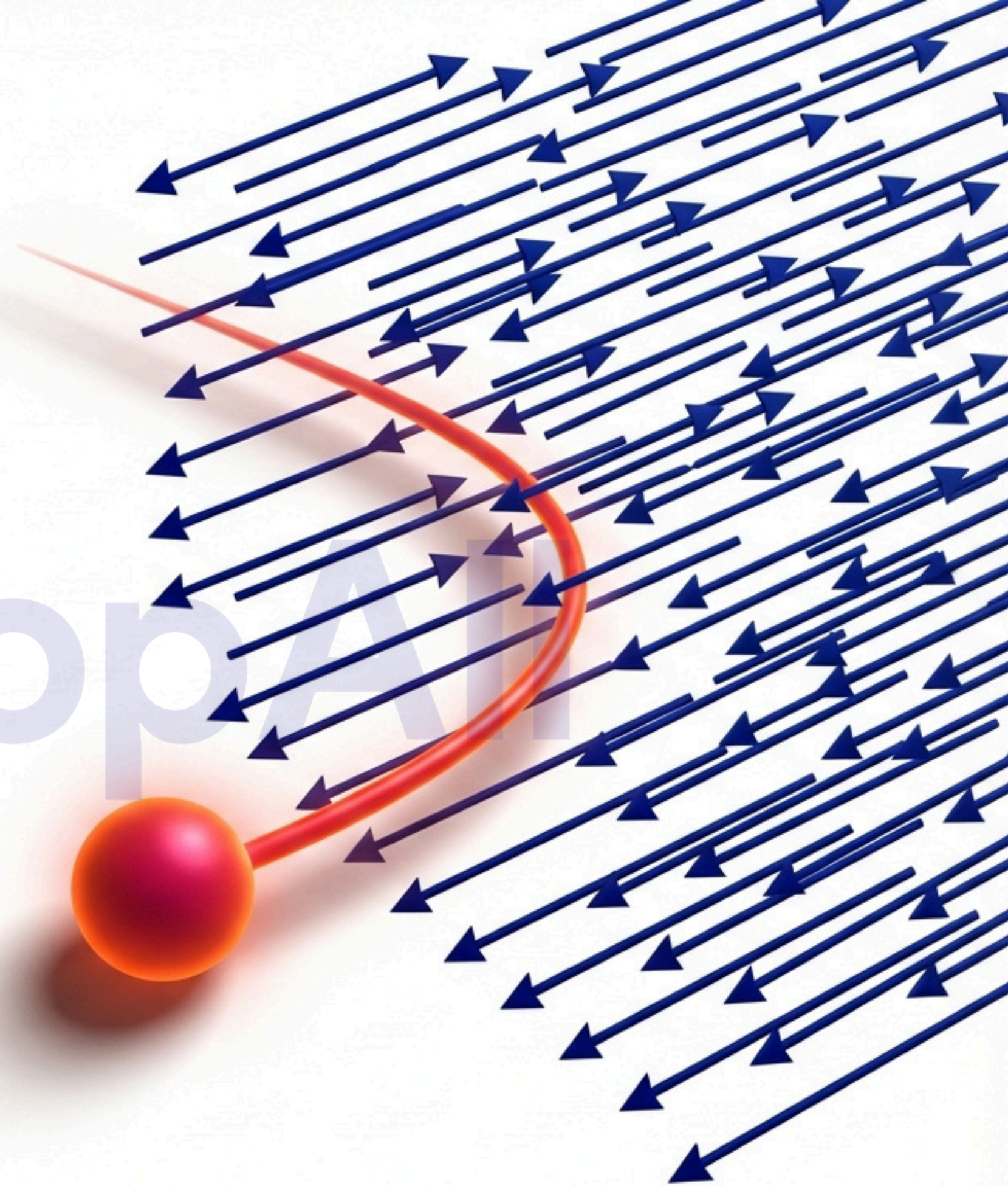


Magnetic Force

Understanding the force exerted by magnetic fields on moving charges.



Electric Force vs Magnetic Force



$$F_e = qE$$

- **State of Charge:** Acts on both stationary and moving charges.
- **Direction:** Acts parallel (or anti-parallel) to the electric field $\mathbf{E}$.
- **Work Done:** Can do work (changes the speed/kinetic energy of the particle).



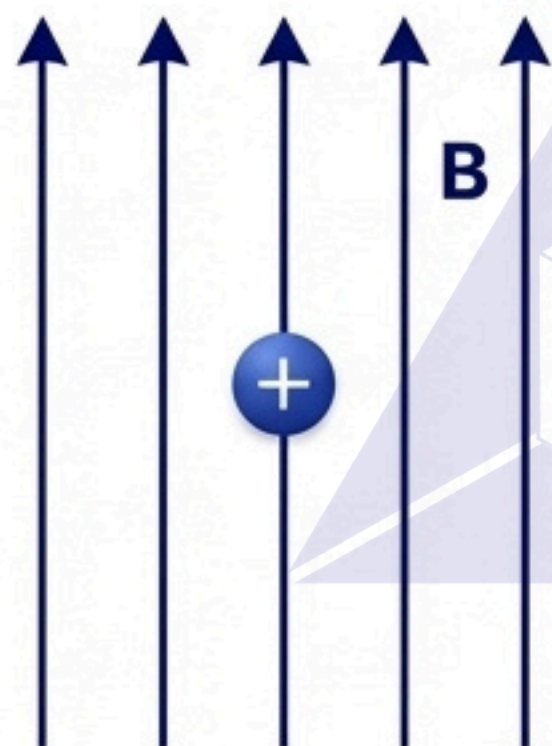
$$F_m = q(\mathbf{v} \times \mathbf{B})$$

- **State of Charge:** Acts ONLY on moving charges ($\mathbf{v} \neq 0$).
- **Direction:** Acts perpendicular to BOTH velocity $\mathbf{v}$ and magnetic field $\mathbf{B}$.
- **Work Done:** Does NO work (only changes direction, speed remains constant).

THE ROLE OF VELOCITY

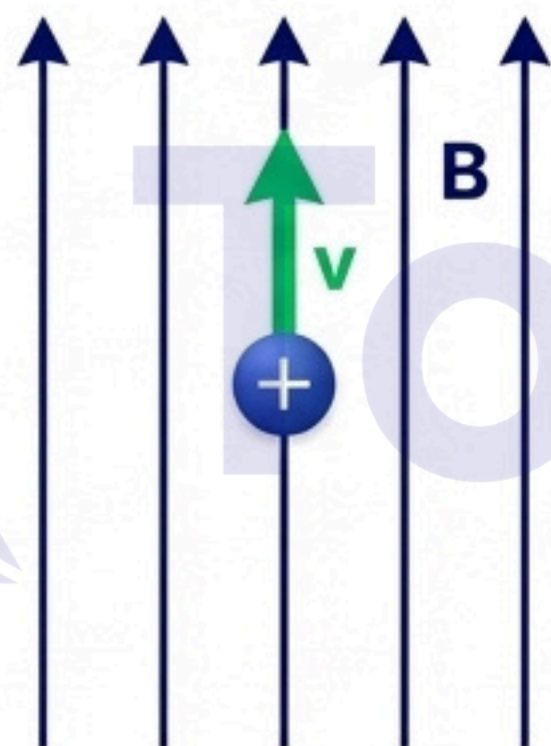
Why Motion Matters

$$\text{Magnitude: } F = qvB \sin(\theta)$$



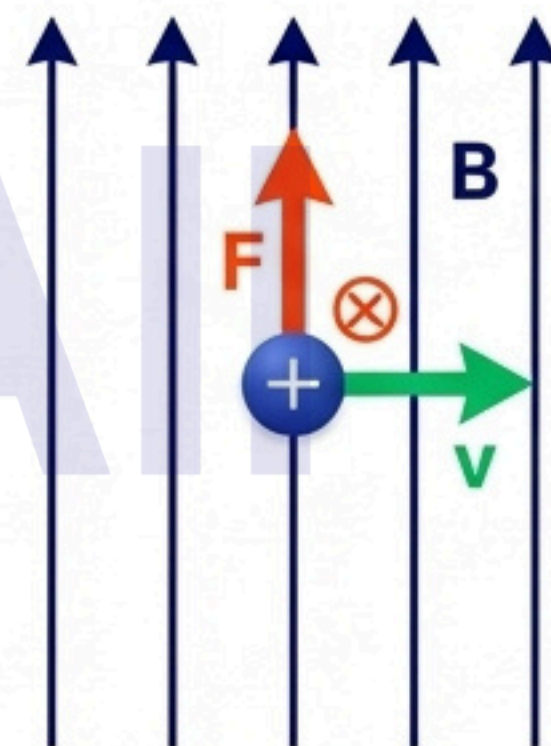
$$v = 0 \rightarrow F = 0$$

Note: No force. Magnetic fields ignore stationary charges.



$$\sin(0^\circ) = 0 \rightarrow F = 0$$

Note: No force. Moving along the field yields zero interaction.



$$\sin(90^\circ) = 1 \rightarrow F = qvB$$

Maximum force. The strongest deflection occurs here.



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$$E=mc^2$$



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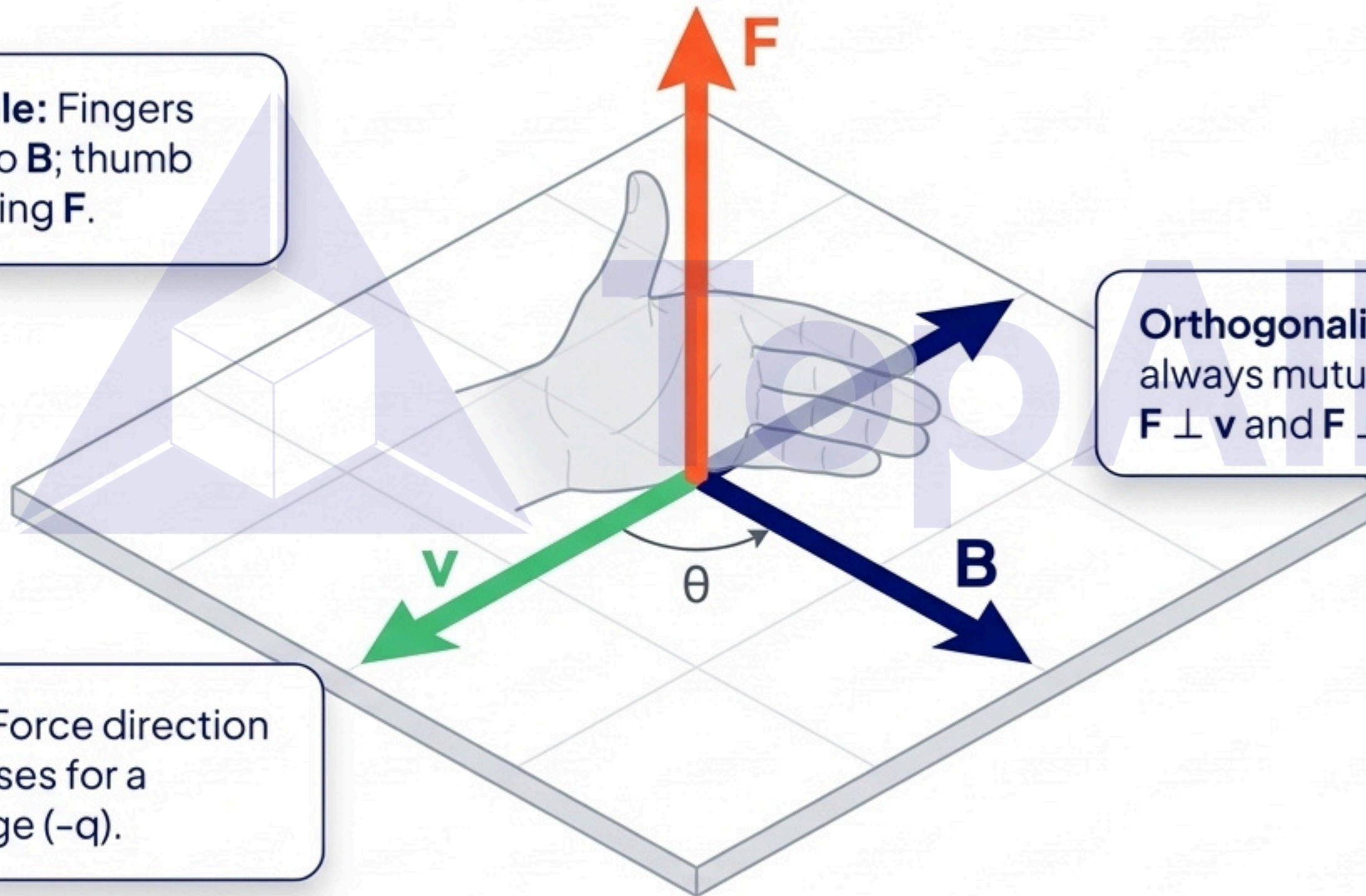


Direction-Based Nature of Magnetic Force

Right-Hand Rule: Fingers sweep from $\mathbf{v}$ to $\mathbf{B}$; thumb points to resulting $\mathbf{F}$.

Orthogonality: Force is always mutually perpendicular: $\mathbf{F} \perp \mathbf{v}$ and $\mathbf{F} \perp \mathbf{B}$.

Charge Sign: Force direction instantly reverses for a negative charge ($-q$).



Key Takeaways

- ✓ **The Lorentz Force:** The total force on a charge moving through both electric and magnetic fields is expressed as $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$.
- ✓ **Motion is an Absolute Requirement:** Magnetic fields exert absolutely zero force on stationary charges.
- ✓ **The Zero Work Principle:** Because magnetic force is always perpendicular to velocity, it does zero work. It alters trajectory but cannot change a particle's kinetic energy or speed.
- ✓ **SI Unit Definition:** The unit for Magnetic Field (B) is the Tesla (T), dimensionally derived from the force equation as $\text{N}\cdot\text{s} / (\text{C}\cdot\text{m})$.



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