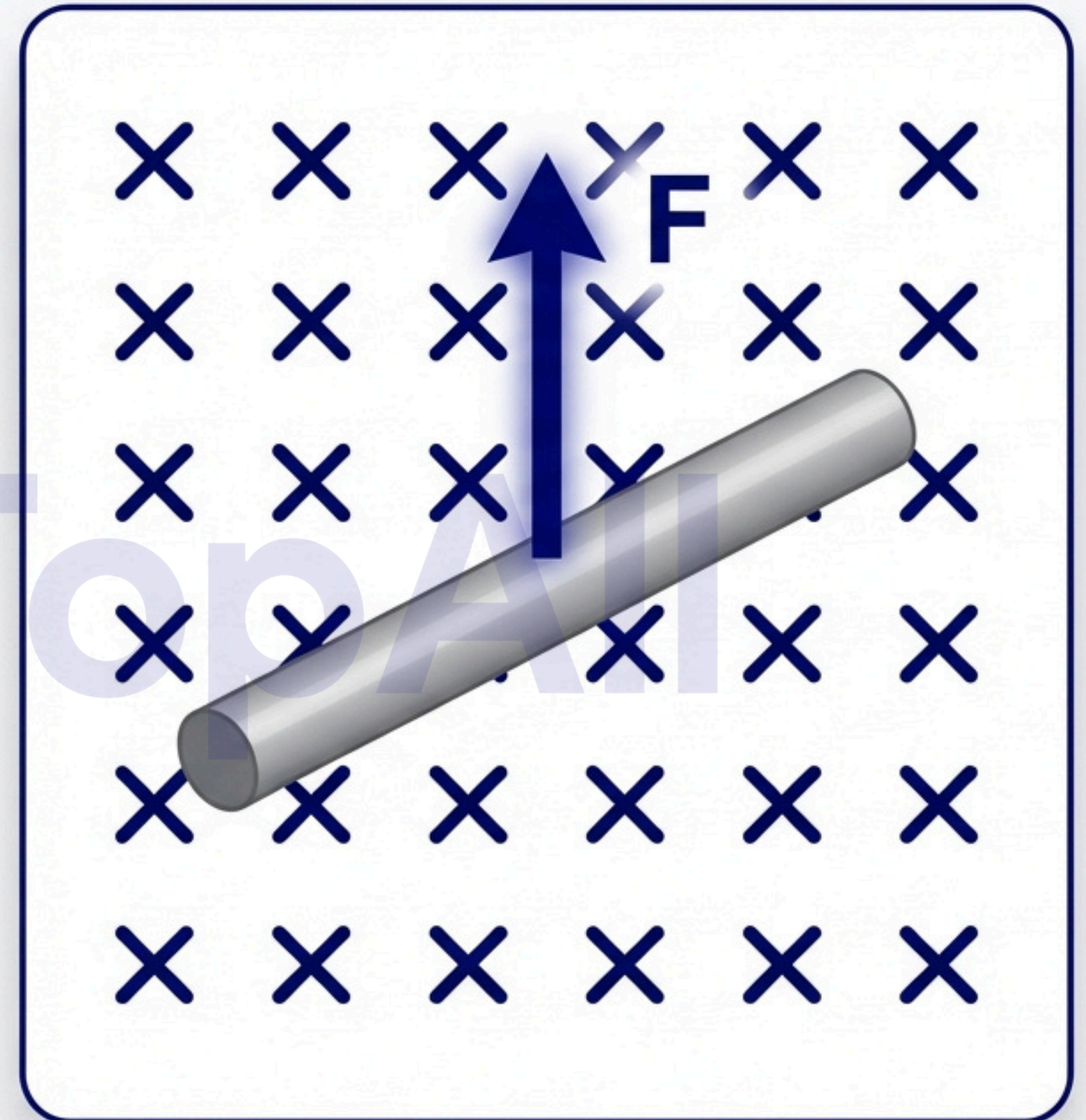


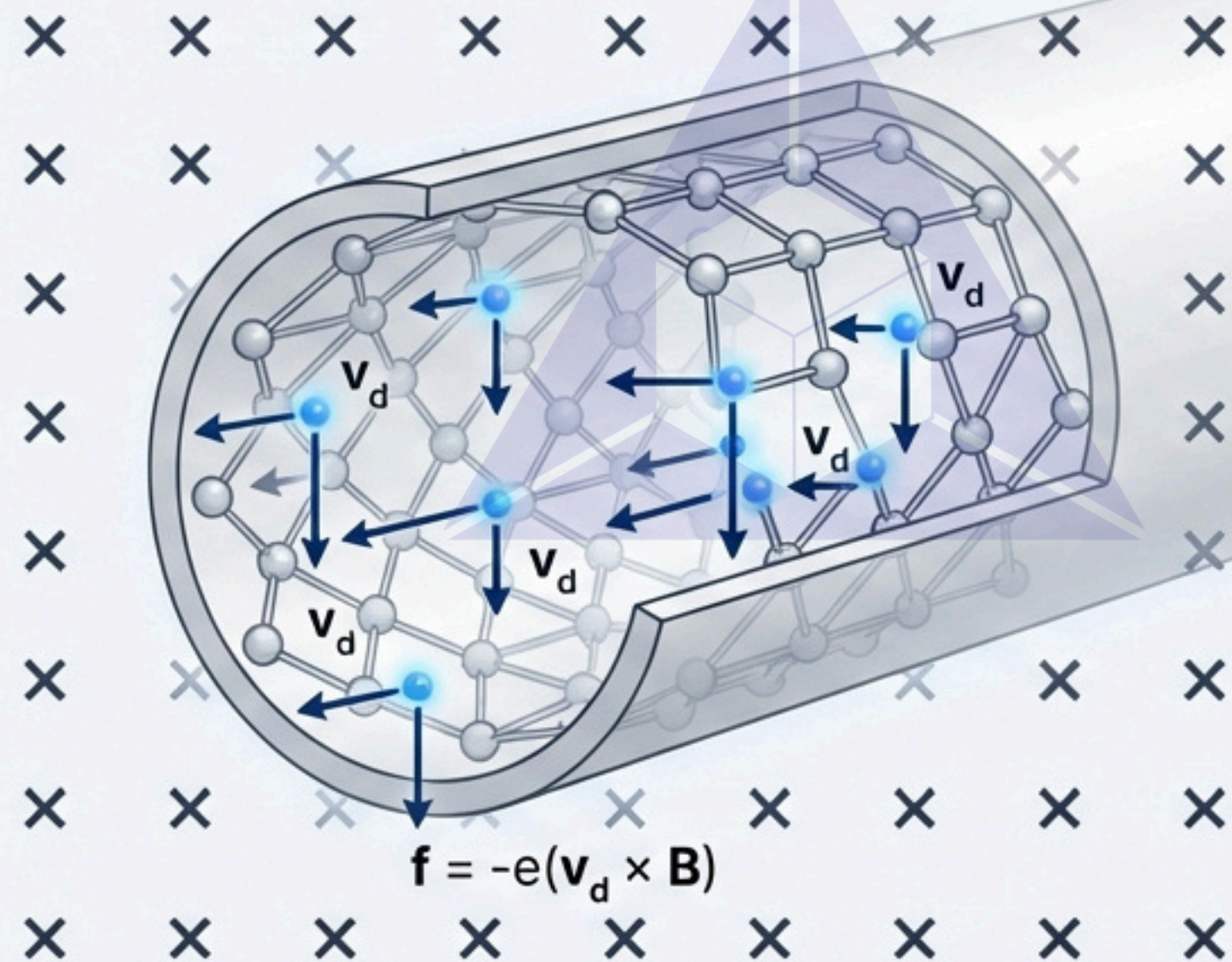
Magnetic Force on a Current-Carrying Conductor

Deriving macroscopic wire forces from microscopic Lorentz interactions.



The Confinement Principle

The Confinement Visual



Observation

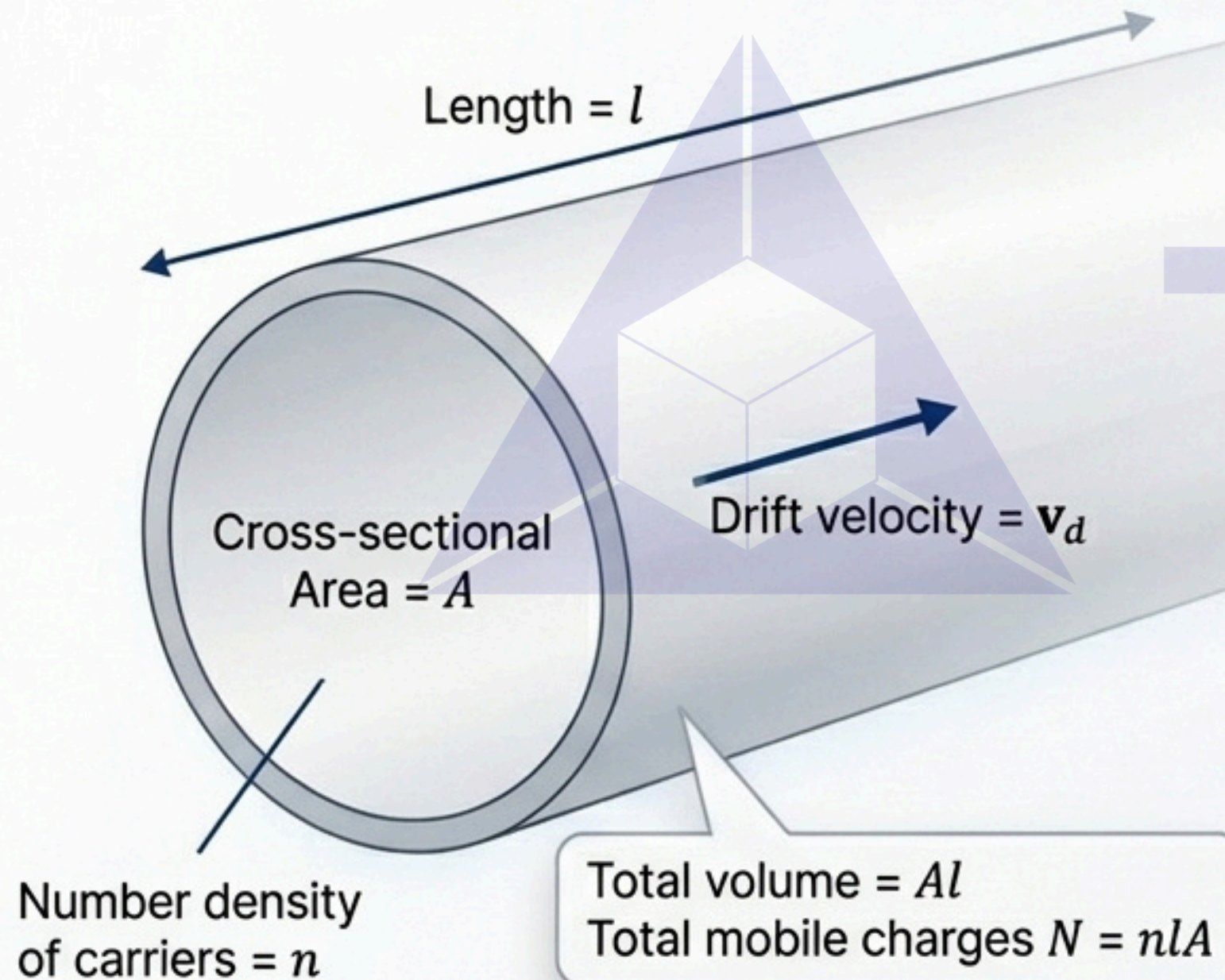
Magnetic fields act exclusively on moving charges, not the static atomic lattice.

The Mechanism

Electrons experience a sideways magnetic push. Because they are confined within the wire and bound to the lattice, their collective sideways push is transmitted directly to the entire physical structure of the conductor.

$$\text{Macroscopic Force} = \sum \text{Microscopic Forces}$$

Scaling Up: From Charge to Current



Step 1: Single Charge Force.

$$\text{Force on one electron: } \mathbf{f} = q(\mathbf{v}_d \times \mathbf{B})$$

Step 2: Total Volume Force.

$$\text{Multiply by total carriers } N: \mathbf{F} = (nlA) \cdot q(\mathbf{v}_d \times \mathbf{B})$$

Step 3: Macroscopic Substitution.

Using current density $\mathbf{j} = nq\mathbf{v}_d$ and Current $I = jA$:

$$\mathbf{F} = [(nq\mathbf{v}_d)lA] \times \mathbf{B}$$

$$\mathbf{F} = I\mathbf{l} \times \mathbf{B}$$



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$$E=mc^2$$



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Key Highlights

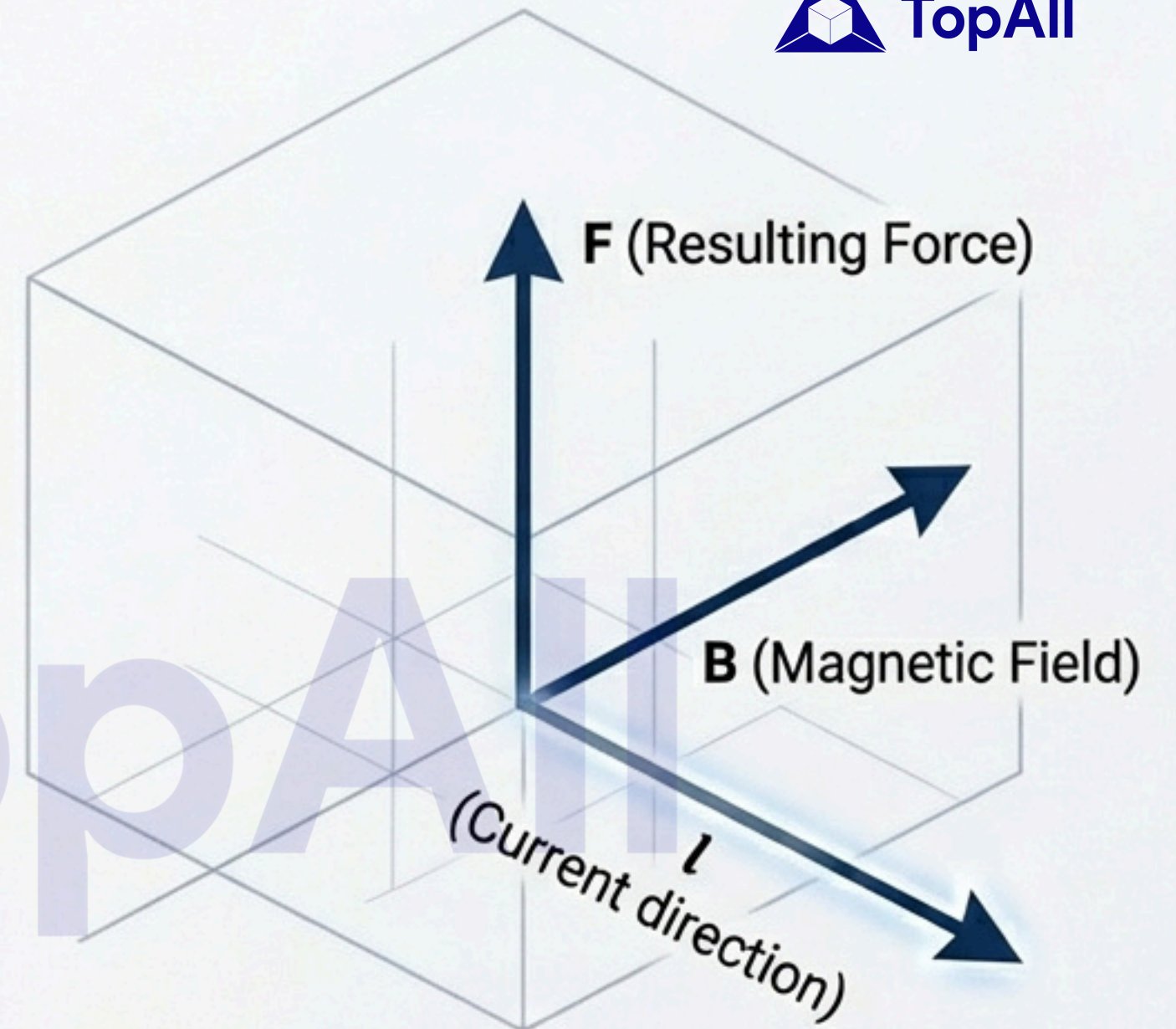
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The Vector Formula

$$\mathbf{F} = I \mathbf{l} \times \mathbf{B}$$

$$F = IlB \sin \theta$$



The Right-Hand Rule 3D Block

Vector $\mathbf{l}$: Magnitude is the length of the conductor; direction is identical to the current I .

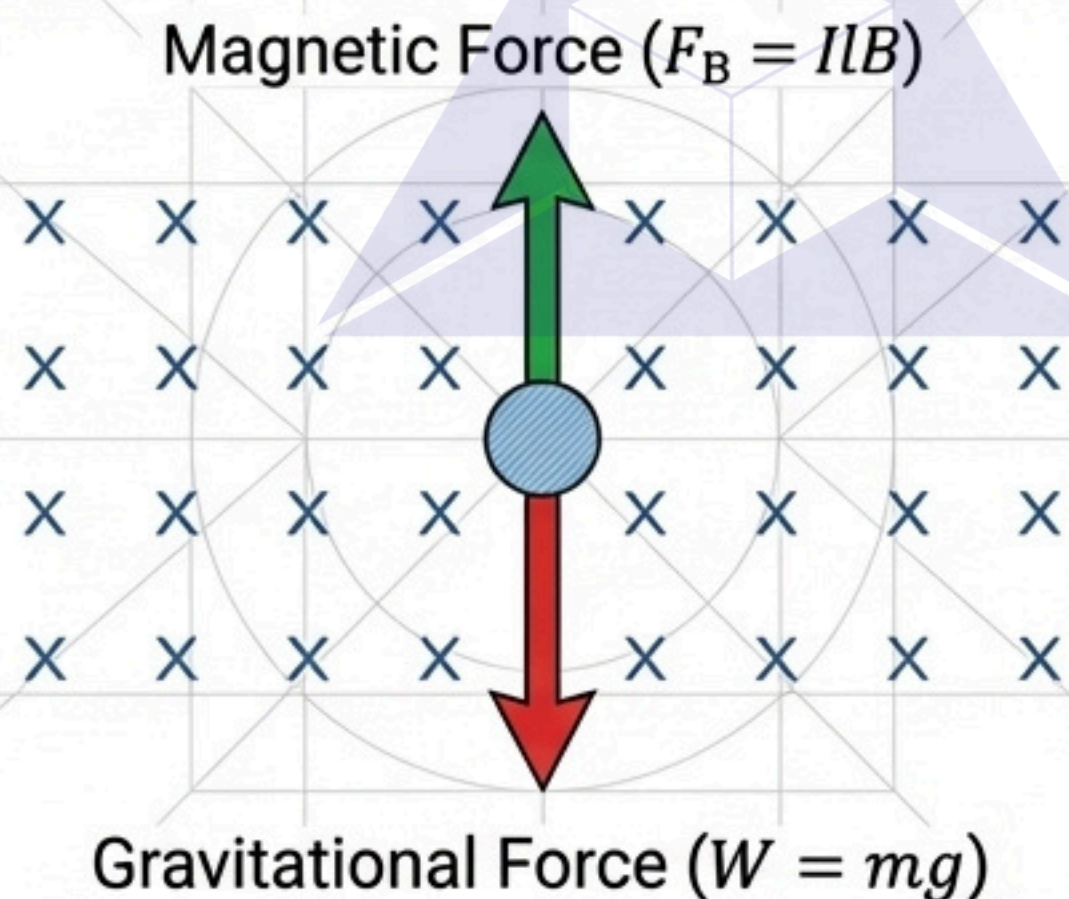
Arbitrary Shapes: For non-straight wires, the force is the integral of linear strips: $\mathbf{F} = \int I d\mathbf{l} \times \mathbf{B}$.

The Suspended Wire (Example 4.1)

Problem Setup Card

A straight wire ($m = 200\text{g}$, $l = 1.5\text{m}$, $I = 2\text{A}$) is suspended in mid-air by a uniform horizontal magnetic field B . Find B .

The Suspended Wire Schematic



Mathematical Resolution

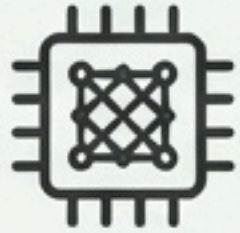
1 Condition: $F_{\text{net}} = 0$

2 Balance: $IlB = mg$

3 Solve for B : $B = \frac{mg}{Il}$

4 Calculation: $B = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.65 \text{ T}$

Key Takeaways



The Core Mechanism

Macroscopic magnetic force on a wire is the cumulative sum of microscopic Lorentz forces acting on confined conduction electrons.



Angular Dependencies

Force magnitude is $F = IlB \sin \theta$.

- **Maximum Force:** When current is perpendicular to field ($\theta = 90^\circ$).
- **Zero Force:** When current is parallel/anti-parallel to field ($\theta = 0^\circ$ or 180°).



Equilibrium Dynamics

In suspension problems, the upward magnetic force ($F = Il \times B$) must perfectly counterbalance the downward weight (mg). Direction is verified via the right-hand cross-product rule.



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