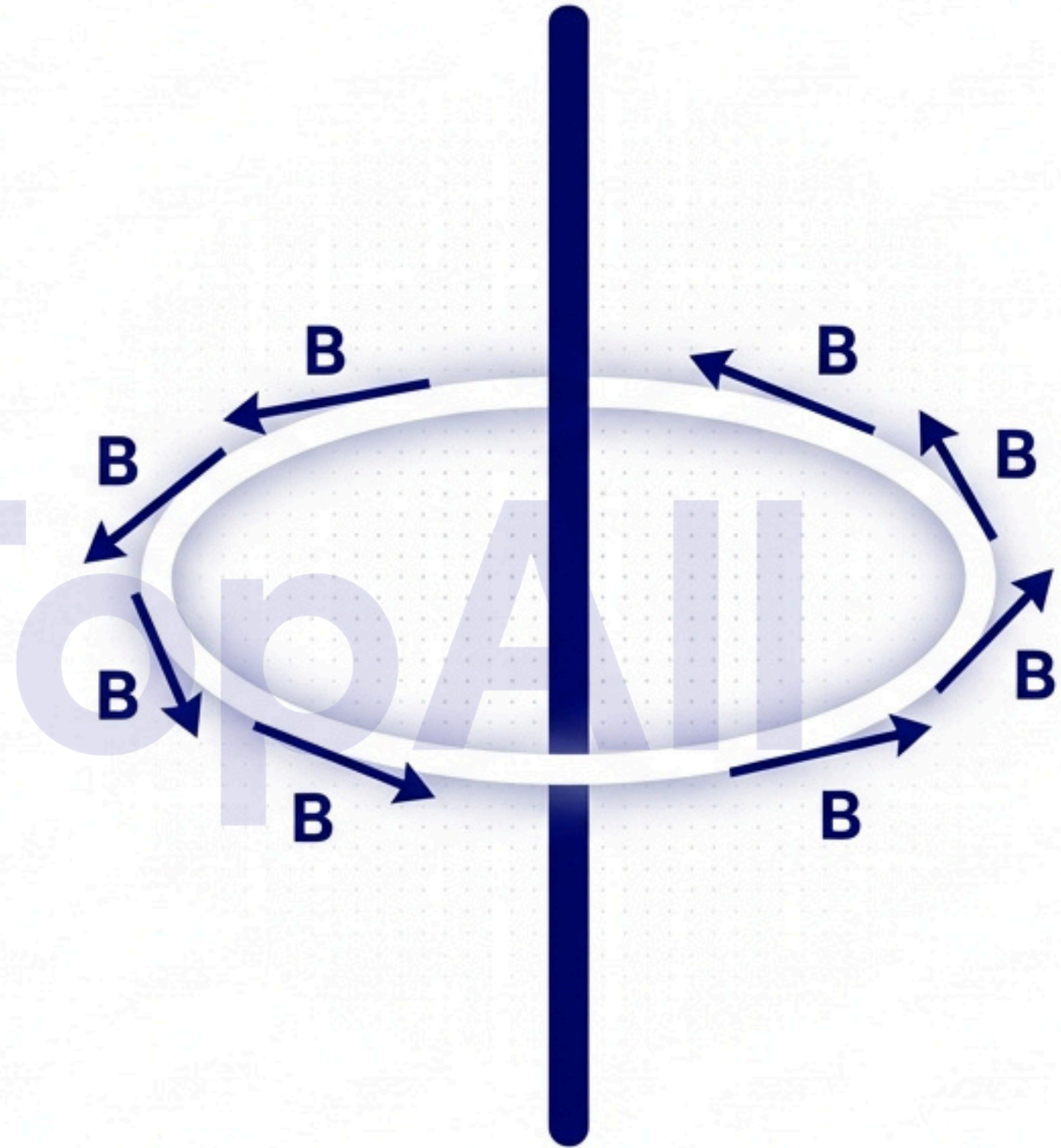


Ampere's Circuital Law

Exploiting symmetry to calculate magnetic fields effortlessly.



Beyond the Biot-Savart Law

The Problem: Biot-Savart Law

Analogous to: Coulomb's Law

Mathematics: Complex cross-product integration ($d\vec{l} \times \vec{r}$)

Drawback: Mathematically tedious for macroscopic, symmetric objects.

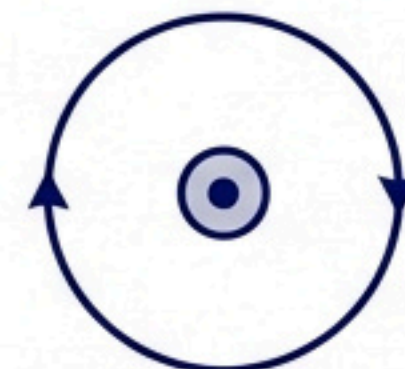

$$\oint d\vec{B} = \frac{\mu_0}{4\pi} \int \frac{d\vec{l} \times \vec{r}}{r^3}$$

The Solution: Ampere's Law

Analogous to: Gauss's Law

Mathematics: Simple dot product ($\vec{B} \cdot d\vec{l}$)

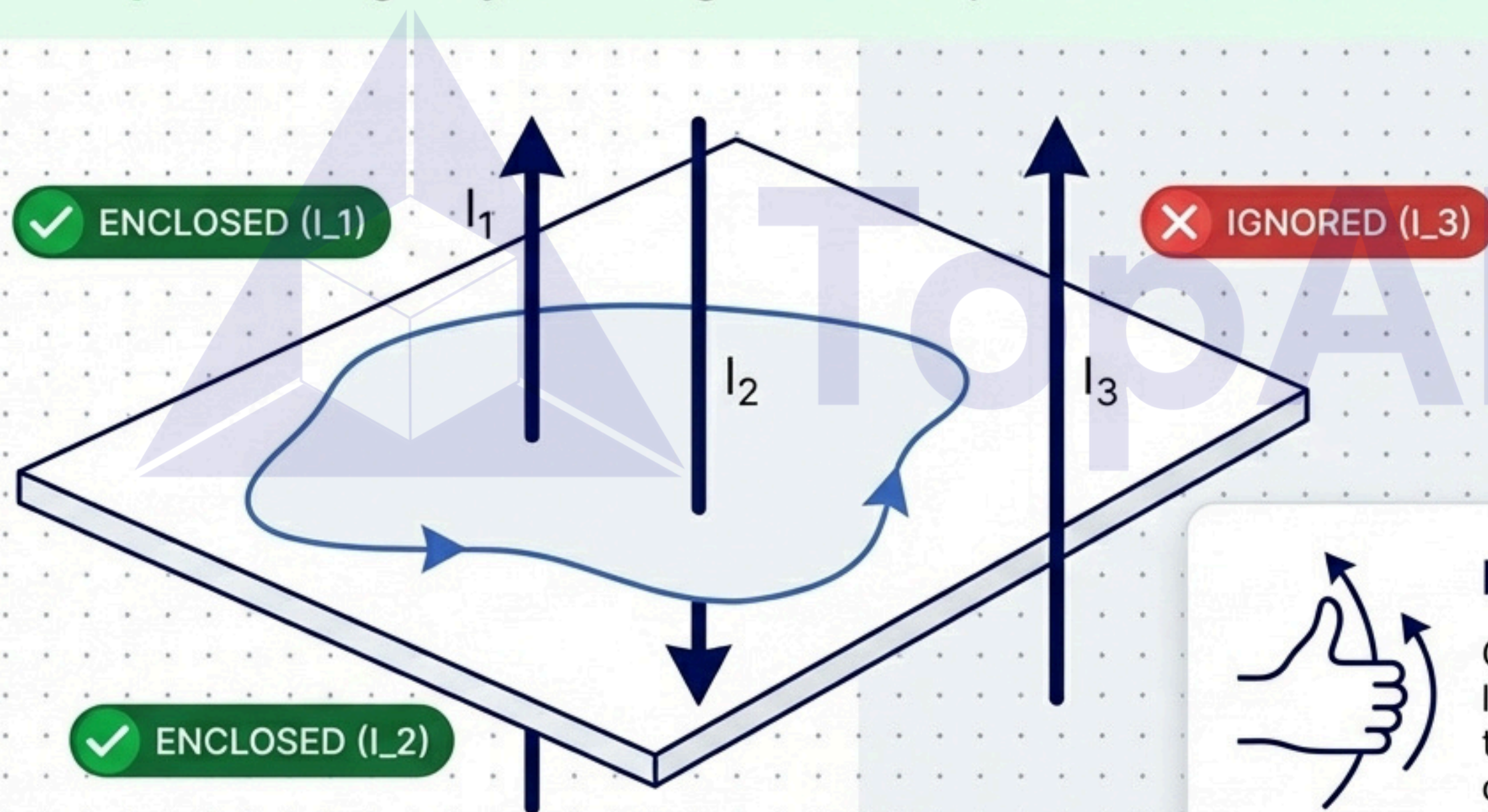
Advantage: Extremely fast and elegant for highly symmetric geometries (e.g., cylinders, infinite wires).



$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\text{enclosed}}$$

Mastering the Amperian Loop

An **Amperian Loop** is an imaginary, closed geometrical path chosen to evaluate the magnetic field.



Right-Hand Rule

Curl right fingers along the loop's integration path; the thumb defines the positive current direction.

The Line Integral of the Magnetic Field

Closed loop line integral
(summing around the
entire boundary).

The tangential component
of the magnetic field
multiplied by the
infinitesimal length
element. (Angle
between them matters!).

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 * I_e$$

Permeability of free space
($4 * \pi * 10^{-7} \text{ T m/A}$).

Net current threading
through the surface
bounded by the loop.



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Let's Test Them Now.**

$$E=mc^2$$



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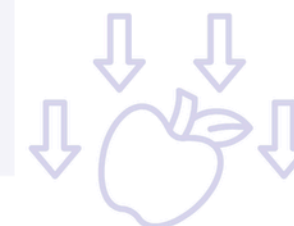
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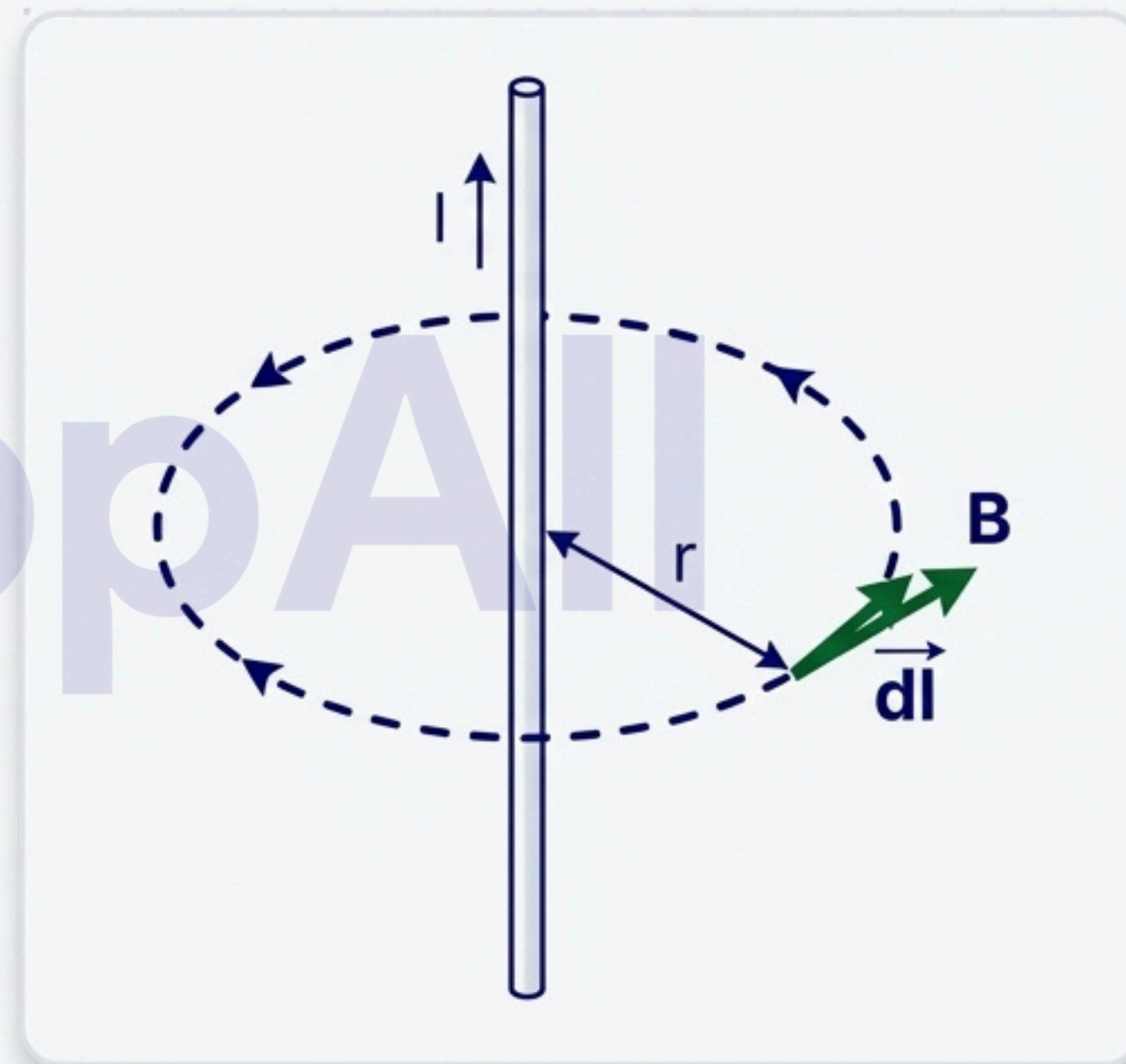
Magnetic Field of an Infinite Wire

1. Assume a perfectly circular Amperian loop of radius r .

2. **The Symmetry Exploit:** B is constant in magnitude and perfectly parallel to $d\mathbf{l}$ everywhere (angle = 0).

3. The dot product simplifies:
 $\text{Integral}(B \, dl \, \cos(0)) = B(2 * \pi * r) = \mu_0 * I.$

4. **Result:** $B = (\mu_0 * I) / (2 * \pi * r)$



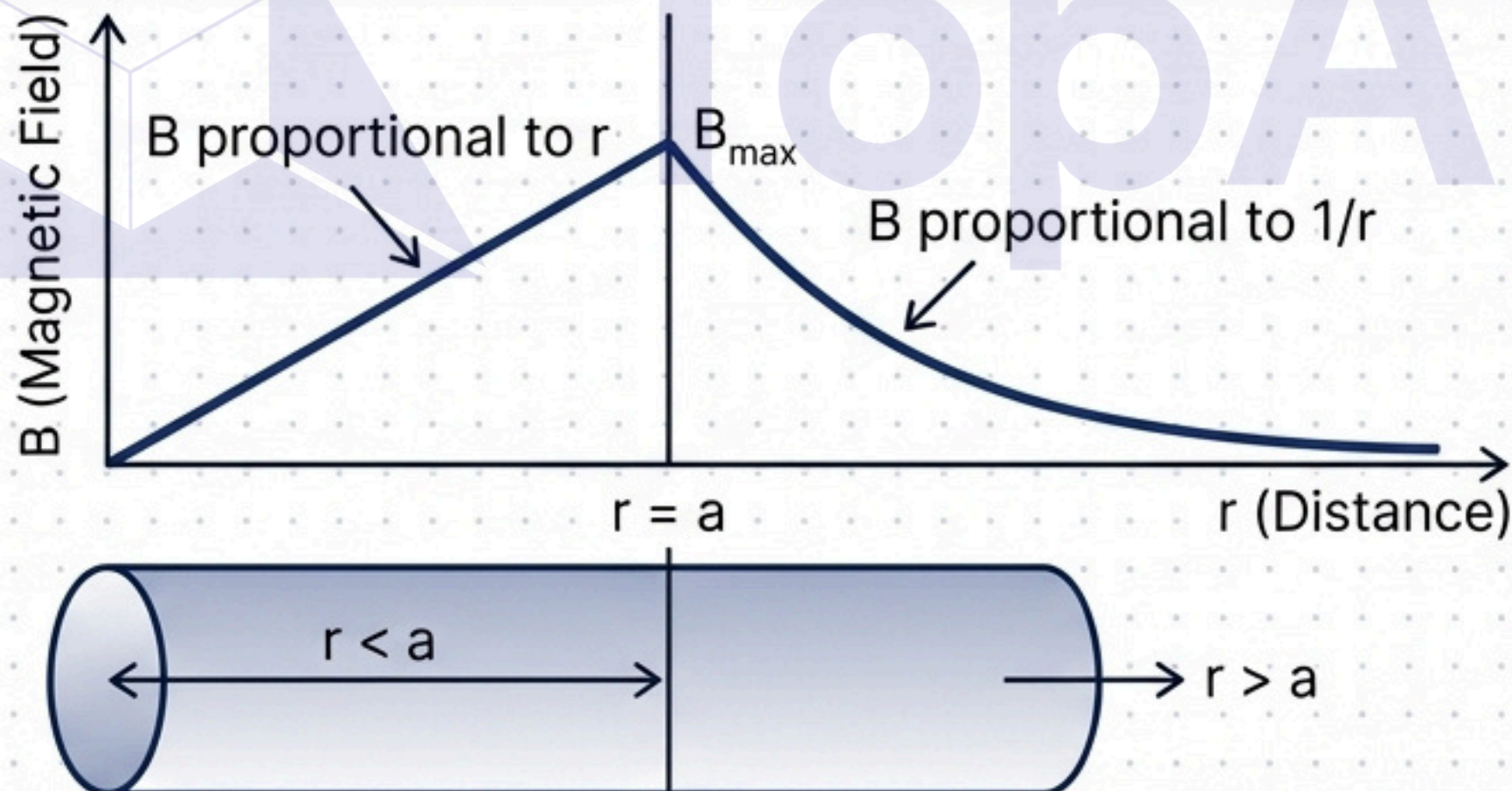
Thick Conductor: Inside vs. Outside

Inside ($r < a$)

Enclosed current is a fraction. Field increases linearly: B is proportional to r .

Outside ($r > a$)

Encloses all current. Field decays inversely: B is proportional to $1/r$.



High-Yield Review



The Core Link: Ampere's Law links the magnetic field on a boundary to the net current enclosed within it.



The Symmetry Rule: Best used when symmetry allows B to be constant and perfectly parallel (or perpendicular) to the loop.



Inside a Uniform Wire: Magnetic field grows linearly from the center (B is proportional to r).



Outside a Wire: Magnetic field decays inversely with distance (B is proportional to $1/r$).



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