

Ohm's Law



Potential
Difference
(Voltage)

$$V = RI$$

Resistance

Current

The fundamental macroscopic relationship between Potential Difference, Current, and Resistance in a steady state.

EXAM FOCUS: $R \propto l$

How Length Dictates Resistance

Placing two identical wires side-by-side in series doubles the length.

To push the same current through twice the distance requires twice the potential difference ($2V$). Therefore, the total resistance doubles.



Voltage required:
 $V + V = 2V$

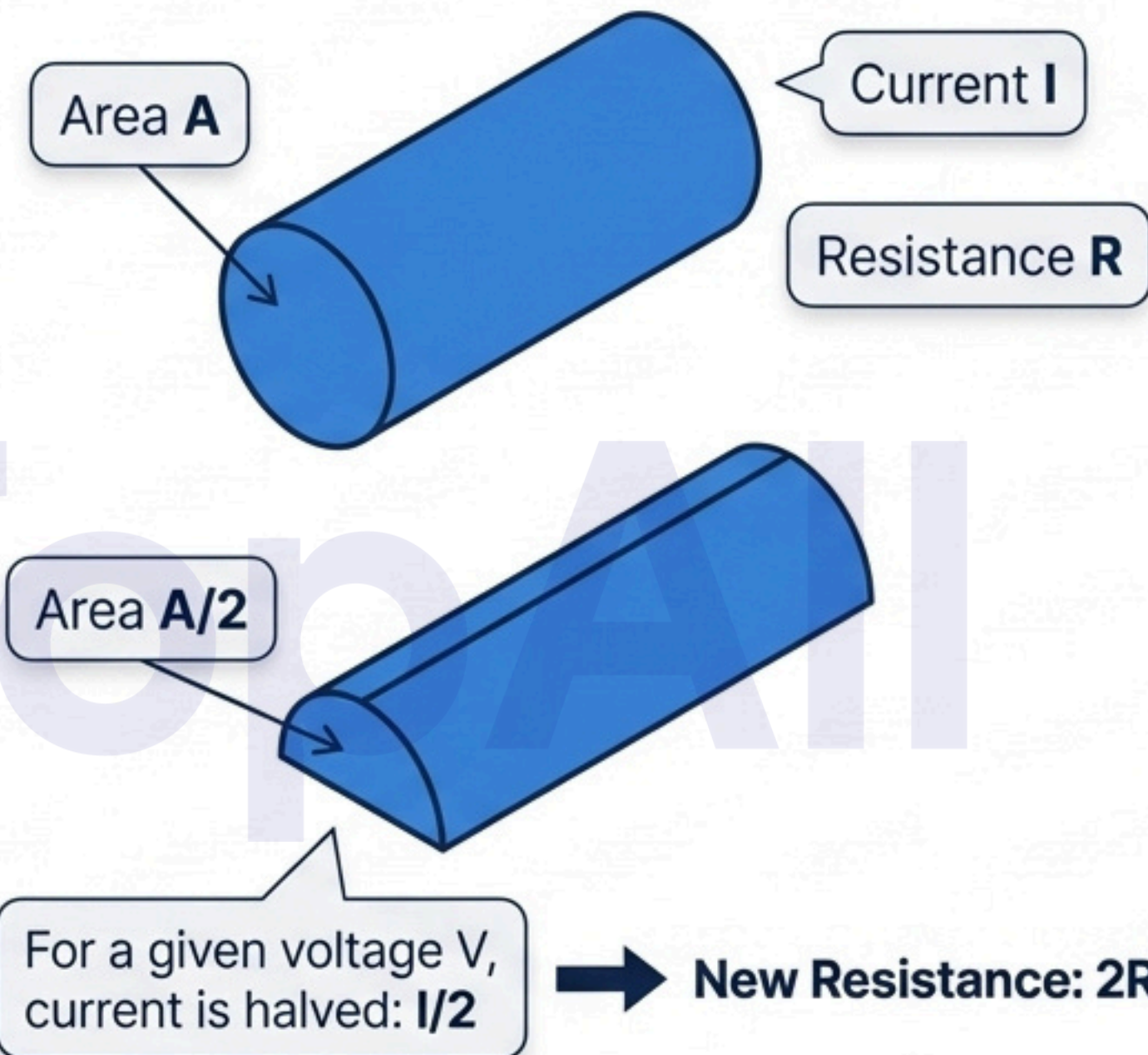


New Resistance: $2R$

EXAM FOCUS: $R \propto 1/A$

How Cross-Sectional Area Dictates Resistance

Halving the cross-sectional area gives charges less room to flow, cutting the current flow in half for the same applied voltage. Less current for the same voltage means double the resistance.



The Blueprint of Resistance: Geometry & Material

$$R = \rho \left(\frac{l}{A} \right)$$

→ Length (proportional)

→ Area (inversely proportional)

→ Resistivity (The constant of proportionality)

Resistivity (ρ) depends entirely on the nature of the material and its temperature—never on its dimensions.



Silver (Ag)

- ✓ Low ρ
- ✓ High Conductivity



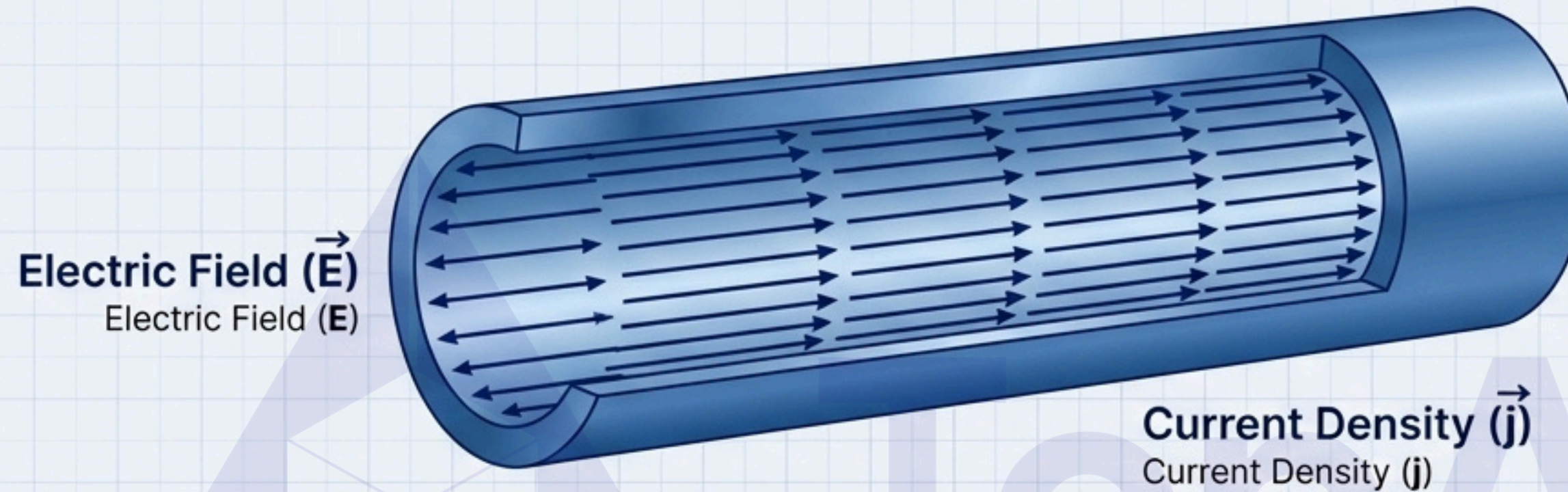
Nichrome

- ✓ High ρ
- ✓ Low Conductivity (Heating Element)

VECTOR FORM

Zooming In: The Field Form of Ohm's Law

Ohm's law expressed not by external wires, but by fundamental vector fields driving charge inside the conductor.



Electric Field ($\vec{E}$)
Electric Field (E)

Current Density ($\vec{j}$)
Current Density (j)

Current Density

$$j = I/A$$

Electric Field

$$E = V/l$$

Substitution

$$El = (jA)(\rho l/A)$$

$$E = j\rho \quad \text{and} \quad j = \sigma E$$

where $\sigma = 1/\rho$ is conductivity

Key Takeaways for Exams

- ✓ **Macro vs. Micro:** $V = RI$ is the macroscopic form for circuits; $E = j\rho$ is the microscopic field form.
- ✓ **Dependence of R :** Resistance depends on both geometry (length l , Area A) AND the material (ρ).
- ✓ **Dependence of ρ :** Resistivity depends ONLY on the material's nature and temperature (not on length or area).
- ✓ **Vector Alignment:** Current Density (j) is a vector quantity, always directed parallel to the electric field (E).