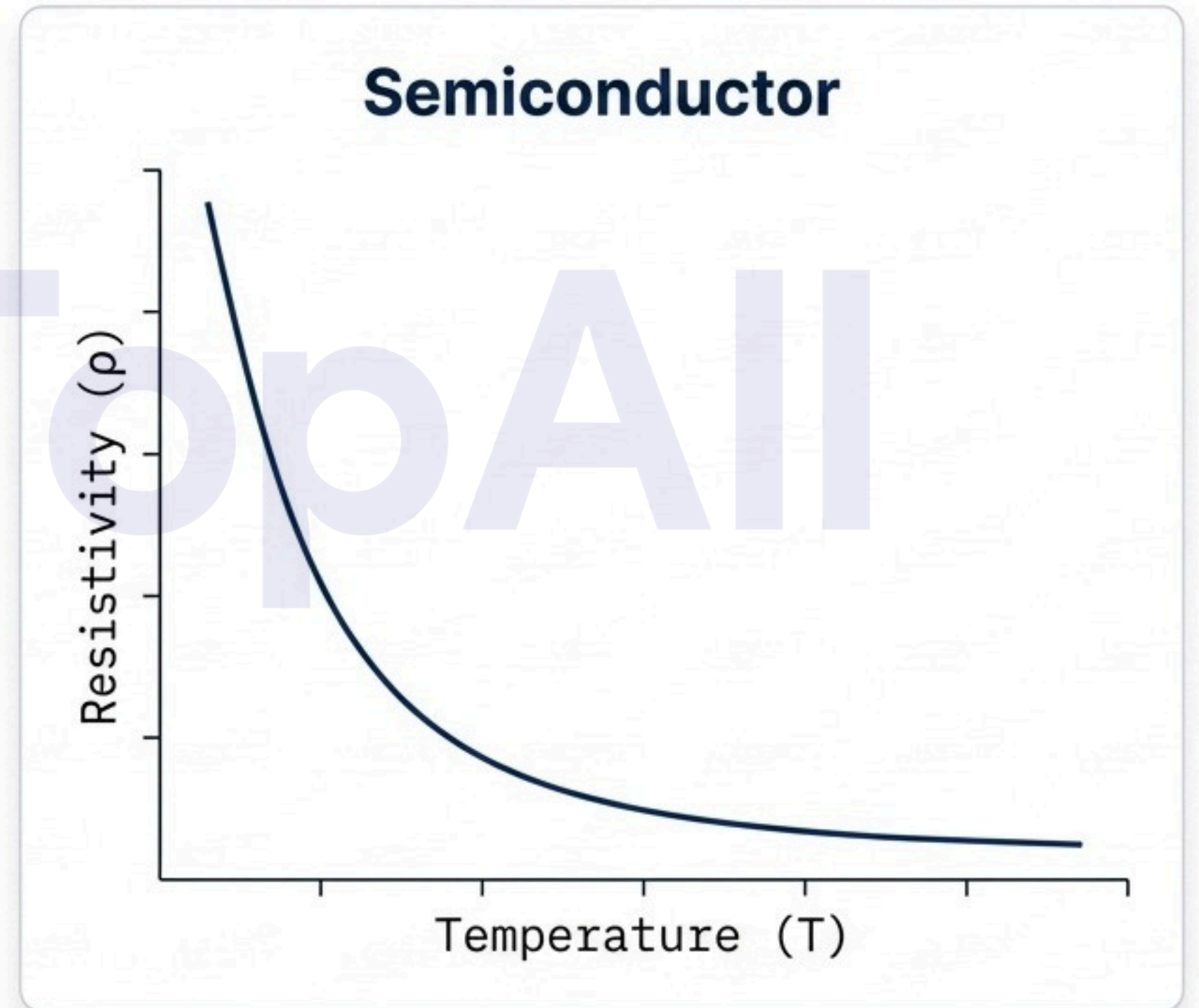
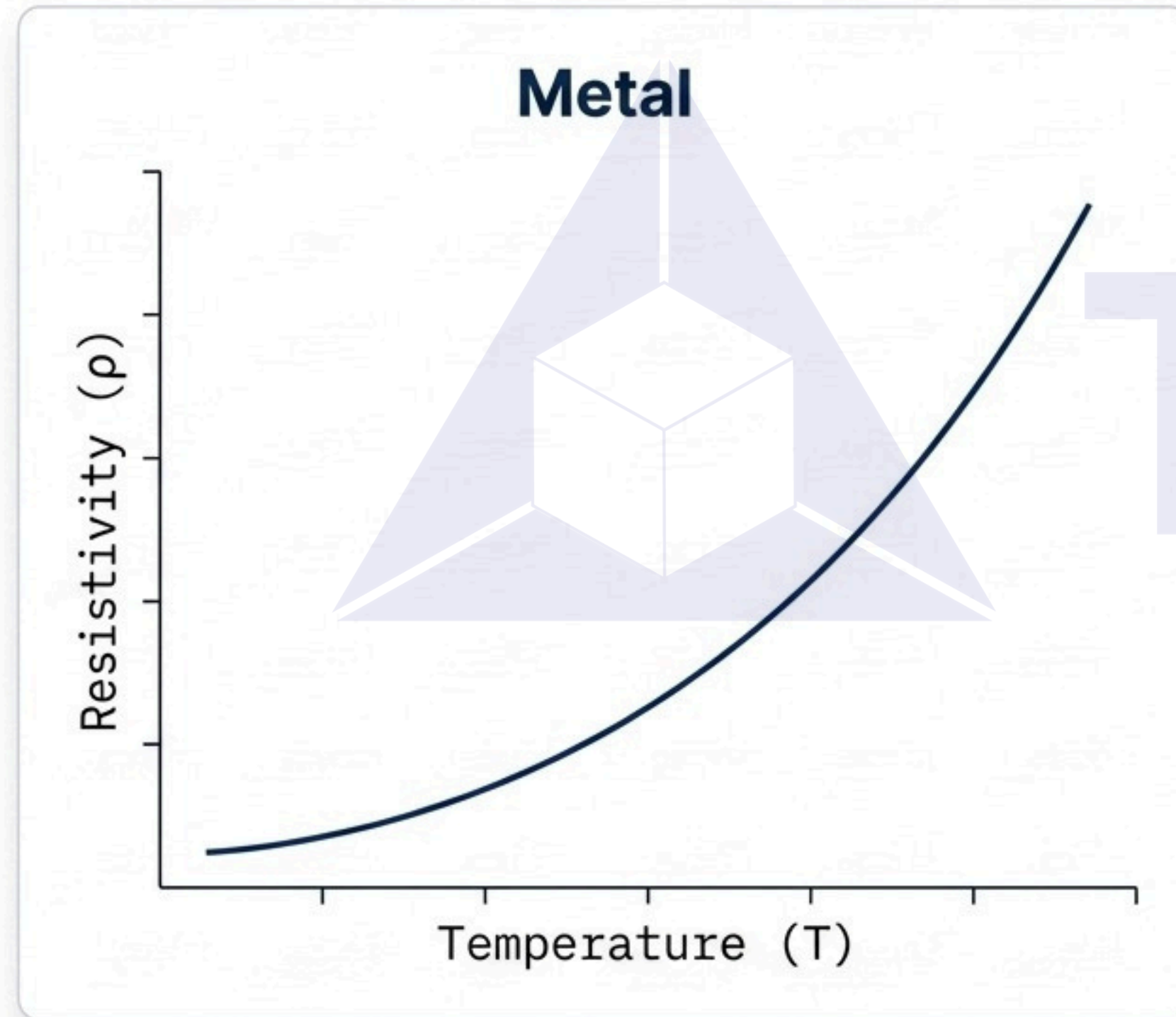


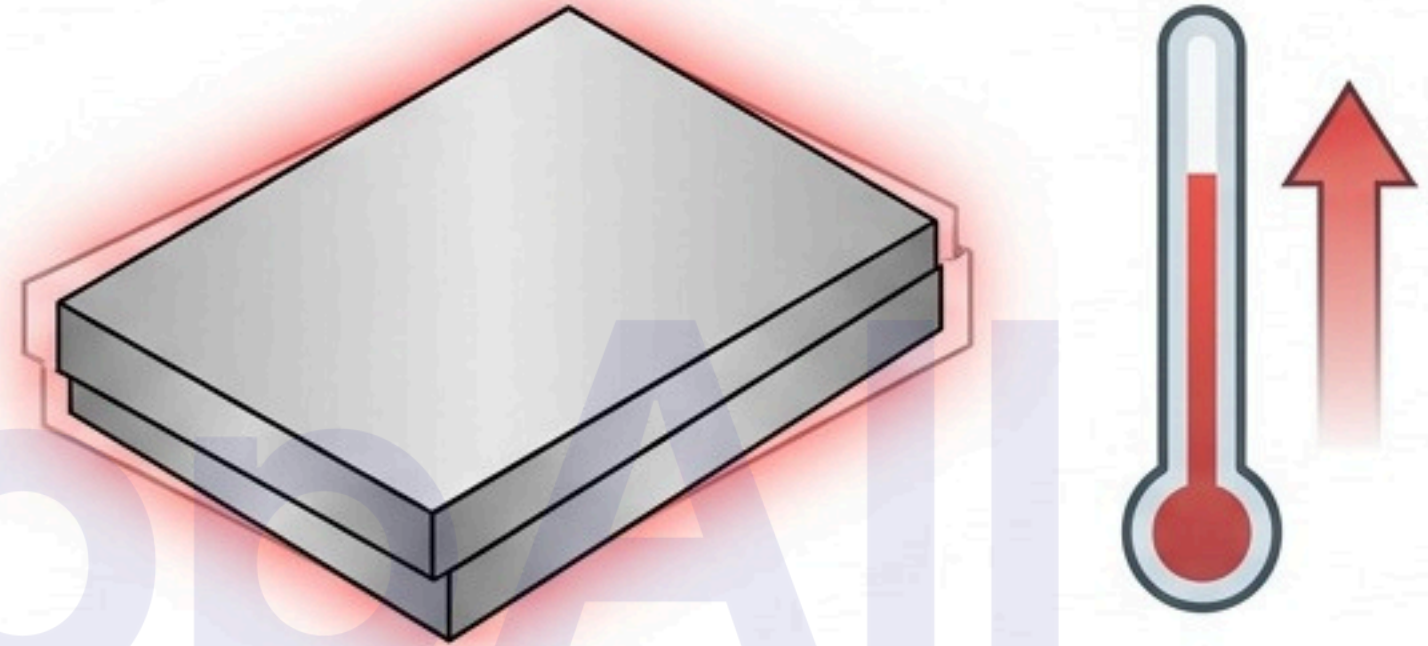
How Temperature Changes Resistivity

From Macroscopic Formulas to Microscopic Electron Dynamics



The Temperature Coefficient of Resistivity (α)

- Over a limited temperature range, the resistivity of a metallic conductor changes approximately linearly with temperature.
- Different materials exhibit entirely different dependencies on temperature.



Key-Takeaway Card

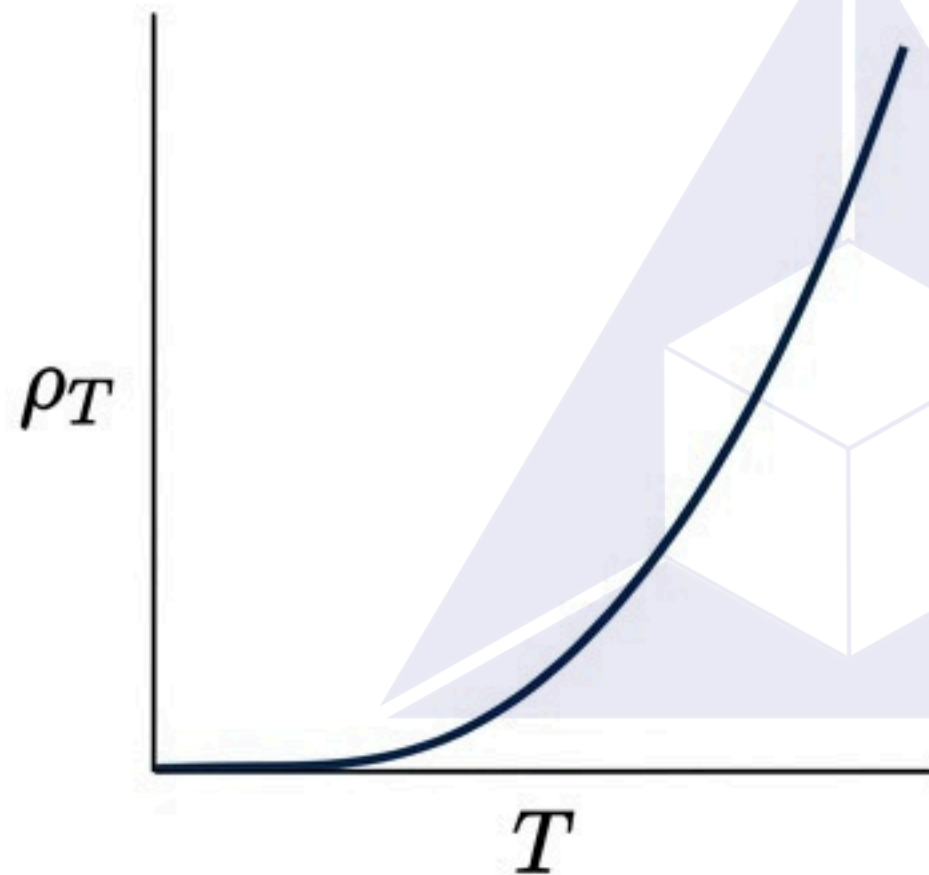
Definition: α is the fractional increase in resistivity per unit increase in temperature.

Dimensions: $(\text{Temperature})^{-1}$ (Typically $^{\circ}\text{C}^{-1}$ or K^{-1}).

Sign: For metals, α is always positive.

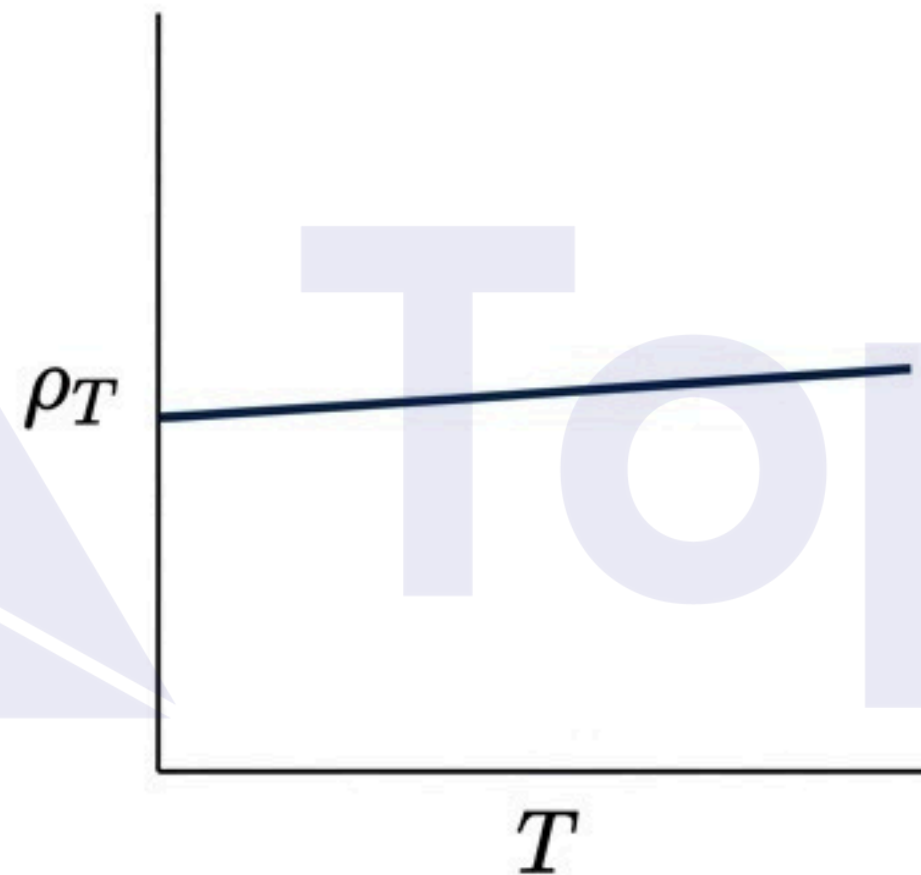
Material Signatures: Resistivity vs. Temperature

Copper (Metal)



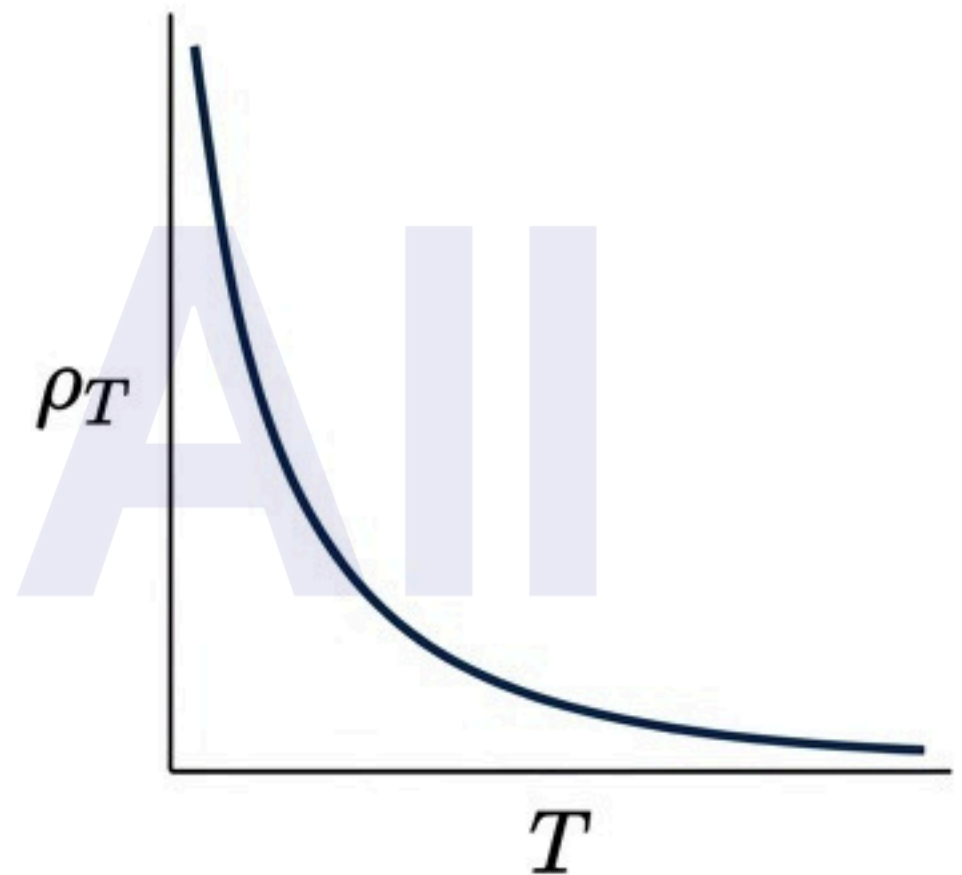
Deviates from a straight line at temperatures much lower than 0°C .

Nichrome (Alloy)



Very weak temperature dependence. Ideal for standard wire-bound resistors.

Typical Semiconductor



Resistivity decreases rapidly with a rise in temperature.



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$$E=mc^2$$



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The Dual Framework of Resistivity

The Macroscopic/Empirical Framework

$$\rho_T = \rho_0 [1 + \alpha(T - T_0)]$$

Where:

ρ_T = Resistivity at temp T

ρ_0 = Resistivity at reference temp T_0

α = Temperature coefficient of resistivity

The Microscopic/Theoretical Framework

$$\rho = \frac{m}{n e^2 \tau}$$

Where:

m = Electron mass

n = Number density of free electrons

e = Electron charge

τ = Average relaxation time (time between collisions)

The Microscopic Battle: n vs. τ

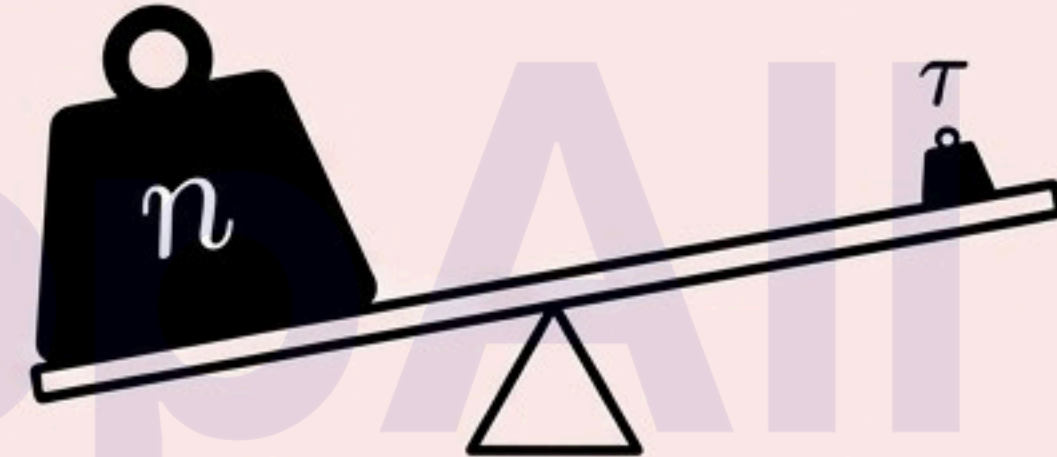
⚠ **JEE Trap Alert: Why does metal ρ rise, but semiconductor ρ fall?**

Metals



- Number density (n) is practically constant.
- Heating increases thermal speed $\rightarrow$ more frequent collisions $\rightarrow$ relaxation time (τ) decreases.
- **Result:** Resistivity (ρ) **INCREASES**.

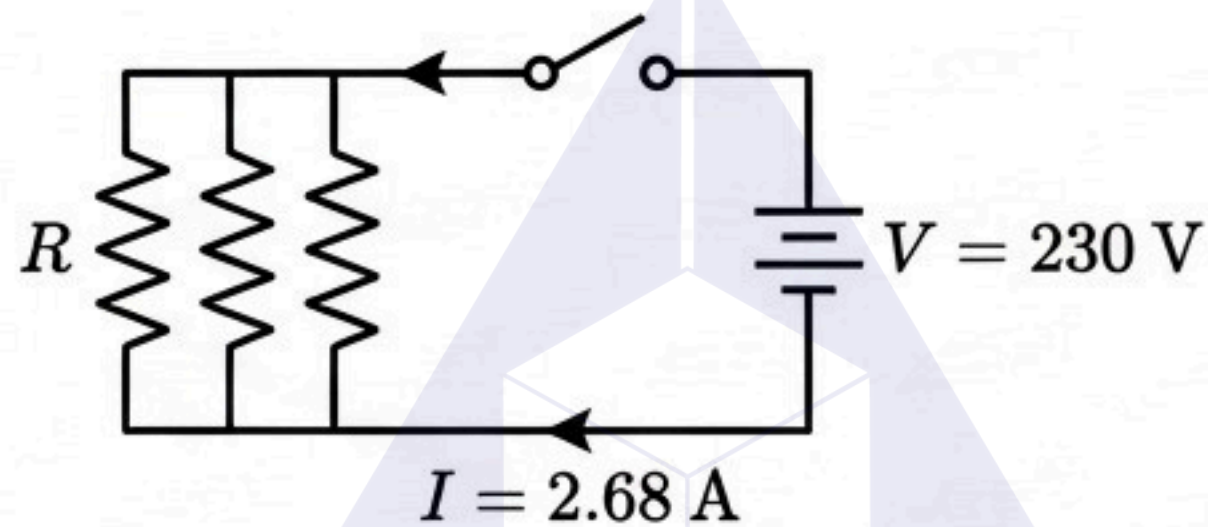
Semiconductors



- Heating causes number density (n) to increase exponentially.
- This massive increase in n more than compensates for any decrease in τ .
- **Result:** Resistivity (ρ) **DECREASES**.

Mini Application: The Nichrome Toaster

The Setup



Given:

- Element: Nichrome
- $R_{27^\circ\text{C}} = 75.3 \Omega$
- Supply = 230 V
- Steady Current = 2.68 A
- $\alpha = 1.70 \times 10^{-4} \text{ }^\circ\text{C}^{-1}$

Find: The steady temperature (T_2)

Step-by-Step Execution

Step 1: Find Steady State Resistance

$$R_2 = \frac{V}{I} = \frac{230}{2.68} = 85.8 \Omega$$

Step 2: Apply Temperature Formula

$$R_2 = R_1 [1 + \alpha(\Delta T)]$$

$$\Delta T = \frac{85.8 - 75.3}{75.3 * 1.70 * 10^{-4}}$$

$$\Delta T = 820 \text{ }^\circ\text{C}$$

Step 3: Calculate Final Temperature

$$T_2 = \Delta T + T_1 = 820 + 27.0 = 847 \text{ }^\circ\text{C}$$

Master Revision: The Determinants of Resistivity

Material Type	Number Density (n)	Relaxation Time (τ)	Net Resistivity (ρ)
Metals	Constant with heating	Drops sharply with heating	Increases ($\alpha > 0$)
Semiconductors	Rises massively with heating	Drops slightly with heating	Decreases ($\alpha < 0$)
Alloys (Nichrome)	–	–	Very weak dependence ($\alpha \approx 0$)

Insight: In metals, temperature-dependent resistivity is driven by collision time (τ). In semiconductors, it is driven by charge carrier density (n).



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