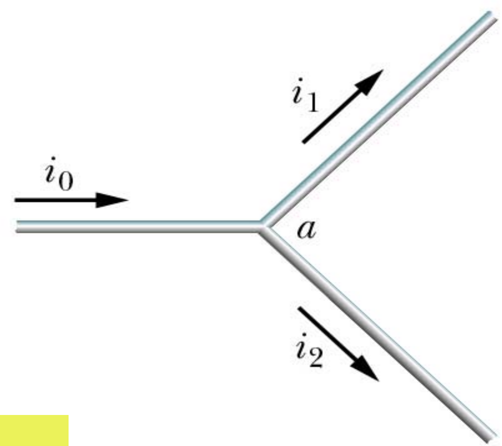
Current and Resistance

- Current $$i = \frac{dq}{dt}$$
- SI unit for current is ampere $$1\,A = 1\,C/s$$
- Current is a scalar
- Use arrows to indicate positive charge flow along conductor (electrons actually move in the opposite direction)



- q is conserved so $$i_0 = i_1 + i_2$$

Current Density

- Total current through a surface can be defined in terms of the Current density, *J* – flow of charge through a cross section
- If *J* is uniform and parallel to *dA*
- SI unit for *J* is A/m²

$$i = \int \vec{J} \bullet d\vec{A}$$

$$i = \int J dA = JA$$

$$J = \frac{i}{A}$$

Resistance

- Different types of materials, i.e. glass and copper, give very different *i* for the same *V*
- Define this characteristic as resistance

$$R = \frac{V}{i}$$

- SI unit is ohm, Ω

$$1\Omega = 1V/A$$

- A resistor is a device used to provide a specified resistance in a circuit.
- Given *V*, greater *R* means smaller *i*

$$i = \frac{V}{R}$$

Resistivity and Conductivity

- Resistivity, ρ, of a material is defined as the E field at a point in the material over the current density:

$$\rho = \frac{E}{J}$$

- SI unit is $\Omega\cdot m$

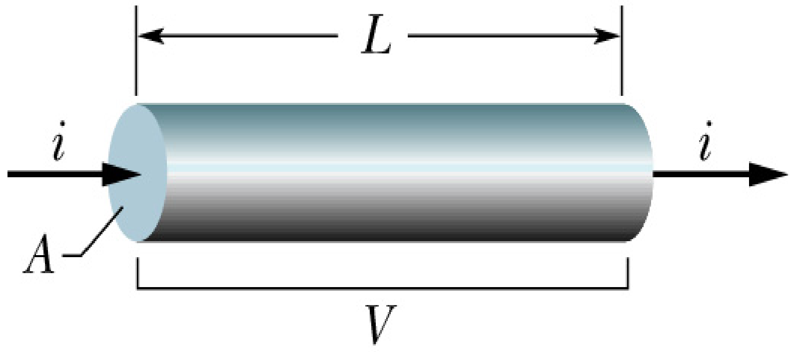
- Conversely speak of a material's conductivity, σ

$$\sigma = \frac{1}{\rho}$$

- SI unit is $(\Omega\cdot m)^{-1}$

Resistance and Resistivity

- Know ρ of material can calculate R for a length of wire of that material

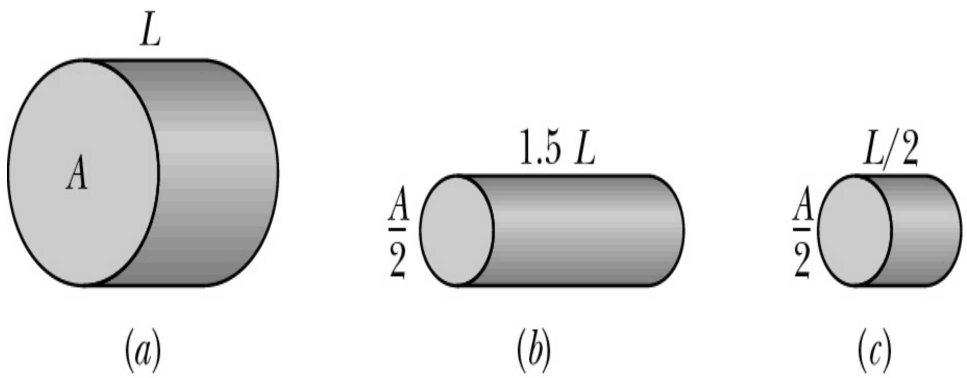


$$\rho = \frac{E}{J}$$ BUT $$E = \frac{\Delta V}{\Delta s} = \frac{V}{L}$$ $$J = \frac{i}{A}$$

$$\rho = \frac{V/L}{i/A} = \frac{V}{i}\frac{A}{L}$$ BUT $$R = \frac{V}{i}$$ SO $$R = \rho \frac{L}{A}$$

Exercise

- Three copper conductors with same applied V. Rank i through them, greatest first.



$$R = \rho \frac{L}{A}$$

- For b and c only the length differs so $R_b = 3R_c$.
- For c both A and L are divided by 2 so $R_a = R_c$.

$$i = \frac{V}{R}$$

a and c tie with largest i, then $i_b = i_a / 3$

Current and Resistance

- Macroscopic quantities *V*, *i* and *R* work well for electrical measurements
- Use microscopic quantities *E* , *J* , and *ρ* when talk about electrical properties of materials

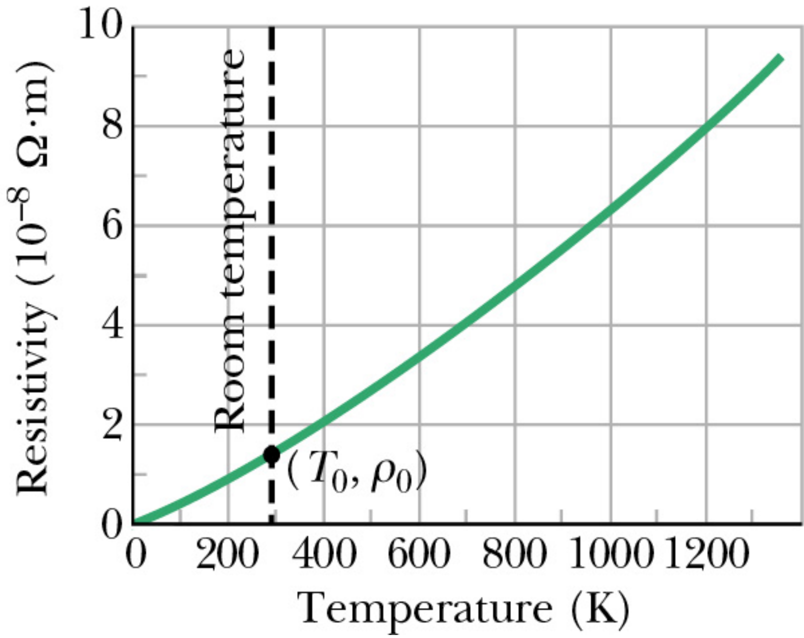
Resistivity of Materials

- Resistivities for some common materials (at room temperature)
  - Metal (Copper)
  - Semi-conductor (Silicon)
    - (n-type means doped with phosphorus impurities)
  - Insulator (Glass)
- Glass will conduct at high temperatures

Material	Resistivity, ρ
Copper	1.69×10^{-8}
Silicon	2.5×10^{3}
Silicon, n-type	8.7×10^{-4}
Glass	$10^{10} - 10^{14}$

Temperature & Resistivity

- Resistivity, ρ, varies with temperature due to thermal vibrations
- For metals, relation is fairly linear – e.g. copper →
- T_0 and ρ_0 are reference points measured at room temperature
- α is temperature coefficient of resistivity



$$\rho - \rho_0 = \rho_0 \alpha (T - T_0)$$