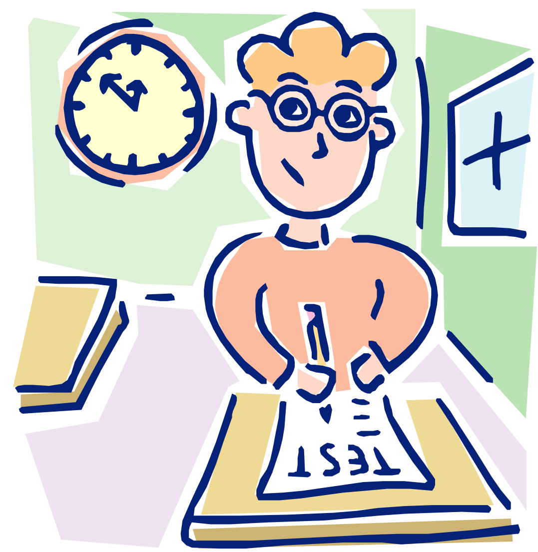
September 22nd

Chapter 27
Current and Resistance

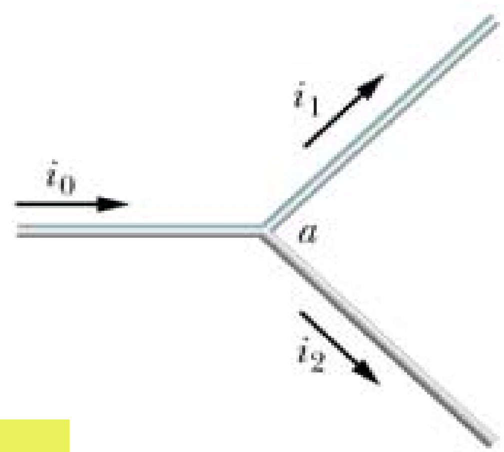
Midterm-1

- Wednesday Sept. 24th at 6pm
  - Section 1 (the 4:10pm class) exam in – BCC N130 (Business College)
  - Section 2 (the 6:00pm class) exam in – NR 158 (Natural Resources)
- Allowed one sheet of notes (both sides) and calculator
- Need photo ID
- Send Prof. Tollefson email if you need to take the make-up exam and explain why (tollefson@pa.msu.edu)
  - Make-up exam is at 8am Thursday (meet at 3234 BPS by 7:55am)
- Use the help-room to prepare
- Review in class on Tuesday



Current and Resistance (Review)

- 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 and Resistance (Review)

- Total current through a surface can be defined in terms of the Current density, J – flow of charge through a cross section

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

- If J is uniform and parallel to dA

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

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

- SI unit for J is A/m^2

Current and 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*

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

Current and Resistance

- 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 $\Omega \cdot m$

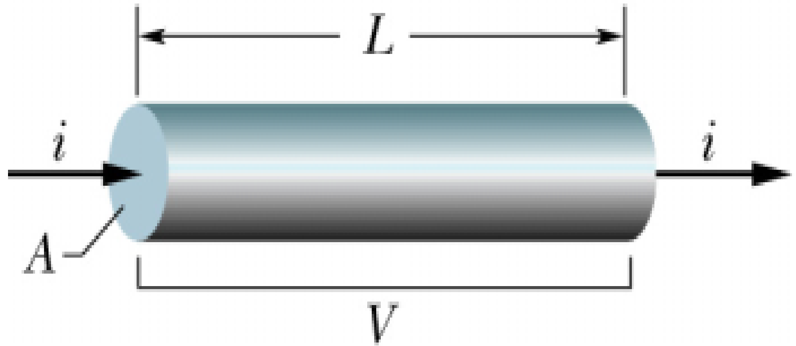
- Conversely speak of a material's conductivity, σ

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

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

Current and Resistance

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

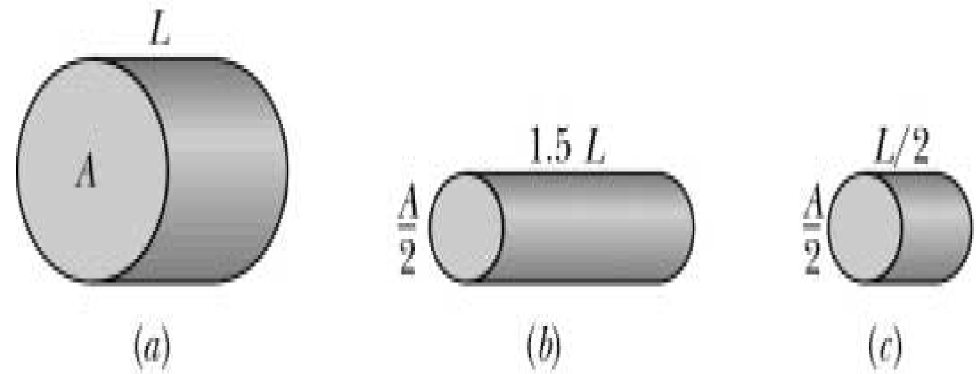


$$\rho = \frac{E}{J}$$ BUT $$E = \frac{\Delta V}{\Delta s} = \frac{V}{L}$$ $$J = \frac{i}{A}$$

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

Checkpoint #3

- 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

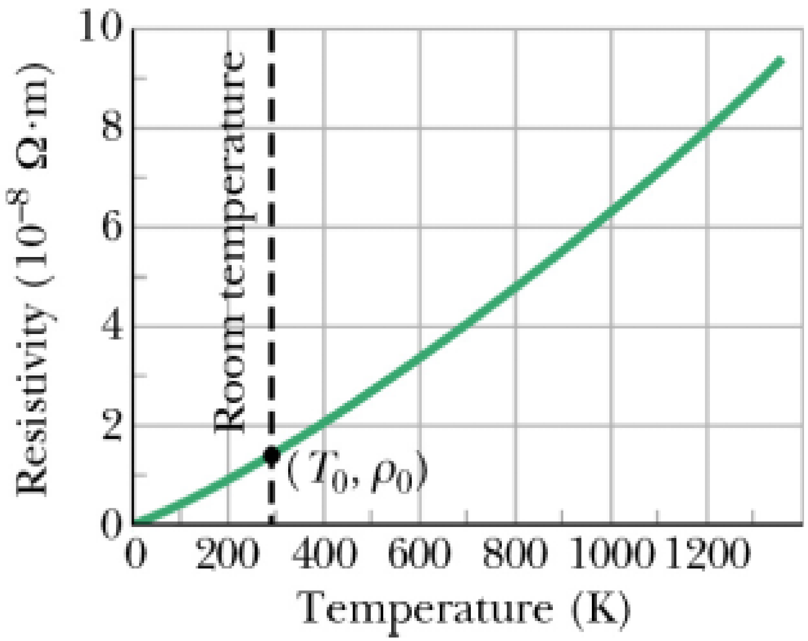
Current and Resistance

- 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}

Current and Resistance (Fig. 27-10)

- 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



$$\rho - \rho_0 = \rho_0 \, \alpha \left(T - T_0\right)$$

Current and Resistance

- So far have assumed that R is independent of the magnitude and polarity of the applied V

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

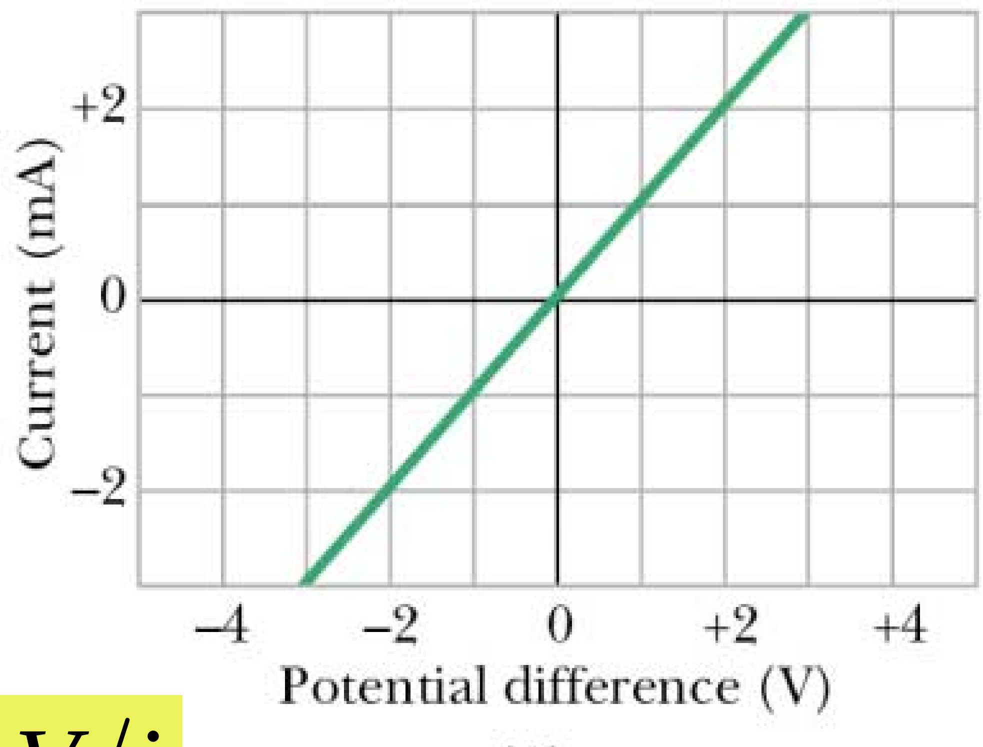
- This is known as Ohm's law

$$V = iR$$

- Ohm's law is not generally valid, but it is a good empirical rule for most systems

Current and Resistance (Fig. 27-11)

- Ohm's law asserts that current through a device is always directly proportional to the *V* applied to the device
- Plot of *i* vs. *V* is a straight line
  - Slope (i/V) is the same for all values of V

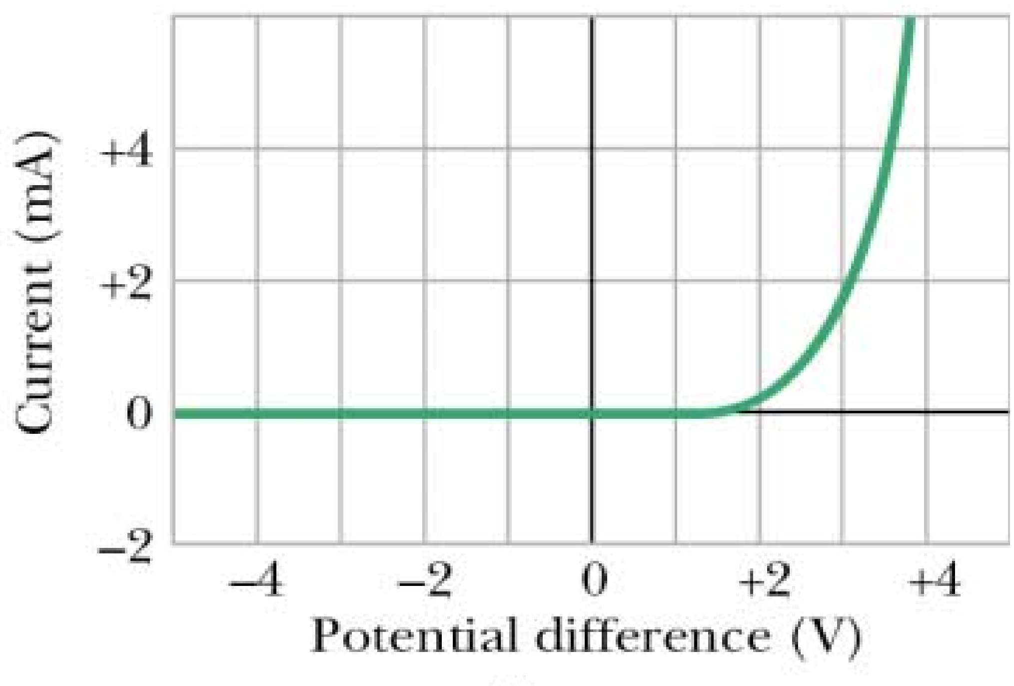


$$R = V/i$$

- A conducting device obeys Ohm's law when *R* is independent of size and direction of *V*

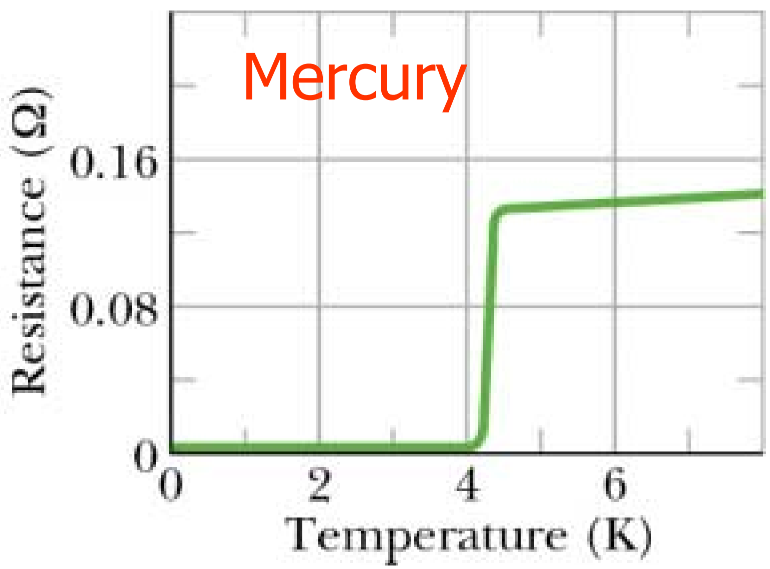
Current and Resistance (Fig. 27-11)

- What about this graph?
- It's for a semiconductor
  - (Not all materials obey Ohm's law)



Current and Resistance (Fig. 27-14)

- Superconductors: *R* goes to zero at some finite *T*
- Once charges start moving no thermal losses - current forever
- Temperatures are usually very low (4-20 K)



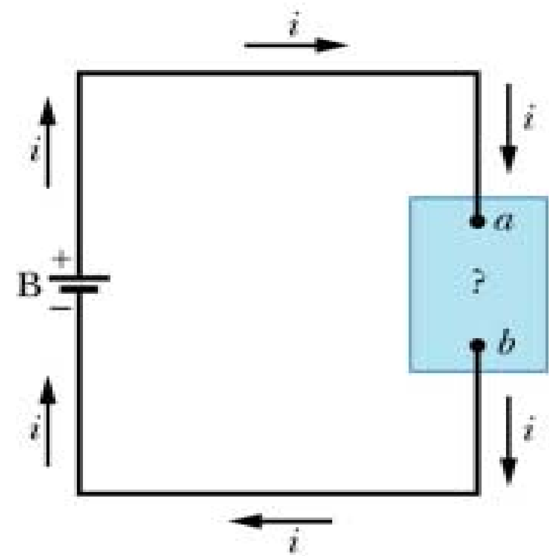
Current (Fig. 27-13)

- Calculate the amount of power, *P*, in a circuit

$$P = \frac{dU}{dt}$$

$$dU = dq\,V = i\,dt\,V$$

$$P = iV$$



- SI unit is watt, W

$$1W = 1V \cdot A$$

Current and Resistance

- Transfer potential energy, *U*, to some other form

$$P = iV$$

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

- For resistors energy is transferred to thermal energy – heat

- Use resistance definition to find

$$P = i^2 R$$

$$P = \frac{V^2}{R}$$