Flipping Physics Lecture Notes:
Resistance and Ohm's Law
http://www.flippingphysics.com/resistance-ohms-law.html

Current density, J, is current per unit area:

- $J = \frac{I}{A} = \frac{nAv_d q}{A} \Rightarrow J = nv_d q$ & $J = \sigma E$
  - Materials which have this property are considered to be ohmic and follow Ohm's Law.
  - σ is the conductivity of the material.
    - Conductivity is a measure of how little a material opposes the movement of electric charges.
    - Conductivity is a fundamental property of a material.
- $\|\Delta V\| = Ed \Rightarrow \|\Delta V\| = EL$
  - An electric potential difference across a wire is what causes current in the wire and we are assuming the electric field created in the wire is uniform. Rather than using d for the distance in the electric field, we use L for the length of the wire.
- $\Rightarrow E = \frac{\Delta V}{L} \Rightarrow J = \sigma\left(\frac{\Delta V}{L}\right) \Rightarrow \Delta V = \frac{JL}{\sigma} = \frac{IL}{A\sigma} \Rightarrow \Delta V = \left(\frac{L}{\sigma A}\right)I$

The *resistance* of a wire, R, is defined as $R = \frac{L}{\sigma A}$

- However, usually resistance is defined in terms of *resistivity*, ρ.
  - Resistivity is a measure of how strongly a material opposes the movement of electric charges.
  - Resistivity is a fundamental property of a material.
  - $\rho = \frac{1}{\sigma} \Rightarrow R = \frac{\rho L}{A}$ & $E = \rho J$
  - This equation requires the resistor to have uniform geometry.
- Which brings us to the more common version of Ohm's law:
  - $\Delta V = \left(\frac{L}{\sigma A}\right)I = I\left(\frac{\rho L}{A}\right) \Rightarrow \Delta V = IR$
  - Again, not all materials are ohmic and follow Ohm's law.
- $\Rightarrow R = \frac{\Delta V}{I} \Rightarrow \text{ohms, } \Omega = \frac{\text{volts, } V}{\text{amperes, } A}$
- $R = \frac{\rho L}{A} \Rightarrow \rho = \frac{RA}{L} \Rightarrow \frac{\Omega \cdot m^2}{m} = \Omega \cdot m$

Resistance and *resistivity* are two terms which students often mix up:

- Resistance has units of ohms, Ω, and is a property of an object.
- Resistivity has units of Ω·m and is property of a material.
- Two objects can have the same resistivity but different resistances if they are made of the same material; however, they have different lengths or cross-sectional areas.

The resistivity of a conducting material typically decreases with decreasing temperature. Think of superconductors. Superconducting materials have zero resistivity, and require very, very low temperatures.

- In this class, unless otherwise stated, the resistivity of conducting materials is considered to be constant regardless of temperature.
- Resistors usually convert electric potential energy to thermal energy which can increase the temperature of the resistor and can increase the temperature of the resistor’s environment.