- Let’s write this in another way for currents in a wire:
For a wire of length L and area A, suppose that there is a potential difference $\Delta V$ across the ends of the wire – this is supplied by a battery or power supply. The potential difference produces an electric field $E$ in the wire. If it is a uniform electric field, then we have the magnitude of the potential difference is
\[
\Delta V = \int \vec{E} \cdot d\vec{s} = EL,
\]
where we have integrated along the length L of wire. Substituting for $E$ in our previous equation for Ohm’s law we have
\[
J = \sigma E = \sigma \frac{\Delta V}{L},
\]
But using the definition of $J$ we can further write that
\[
I = \frac{\sigma A}{L} \Delta V \quad \text{or} \quad \Delta V = \frac{L}{\sigma A} I = RI = IR,
\]
where we have introduced the electrical resistance $R$, defined as
\[
R = \frac{L}{\sigma A}.
\]
This is the more common form of Ohm’s Law written in terms of the potential and the current as $V = IR$.
- We can also introduce the resistivity $\rho$, given by $1/\sigma$, so that we can also write the resistance as
\[
R = \frac{\rho L}{A}.
\]
- Units for resistance are given from Ohm’s law as $1 \, \text{V/A} = 1 \, \Omega$ (1 ohm)
- Units for $\rho$ are given as $(A/L)R = \Omega \cdot \text{m}$
- (Examples in class) Not all materials obey Ohm’s Law. Resistors are specific devices that are manufactured to have a specific value of $R$. These are of two types: wire wound or composition- containing carbon. They have a color code on them to indicate the rough value of $R$. These resistors do obey Ohm’s Law and have a current through them which is proportional to the applied voltage across them. In a graph they have a linear dependence shown in Fig. 27.11b (p. 621). As an example of a non-Ohmic material, the other graph (c) is for a semiconducting diode.

**Example:** Calculate the resistance of a 5 m length of 22-gauge copper wire, which has a radius of 0.321 mm. Then find the current through the wire when 10 V is applied across it.

From $r$, we can find $A = \pi r^2 = 3.24 \times 10^{-7} \, \text{m}^2$. Then $R = L \rho / A = (\text{looking up the resistivity in Table 27.1}) (5)(1.69 \times 10^8)/(3.24 \times 10^{-7}) = 0.26 \, \Omega$. This is a relatively small value. With 10 V across the wire $I = V/R = 10/0.26 = 38.3 \, \text{A}$, a huge current.