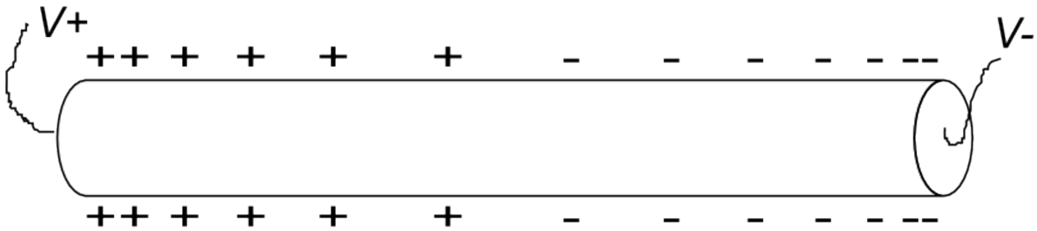
Electron drift velocity

What causes the electrons to move from low to high potential? The only way this can happen, of course, is that there is an electric field inside the conductor (which must be the case if there is a potential difference). Note: this is different than electro*statics*, which, by definition, was the state where no charges were moving.

We will see later that the electric field is set up by a non-uniform surface charge density on the wire. As shown in the figure charges are spread out in such a way that the field in the wire (if the wire is uniform) will be uniform.



We can calculate the average "drift" velocity of the electrons. The following figure, which shows a piece of the wire, shows how the electron sea has moved in time Δt.

The volume of the sea of electrons that flows through a point on the wire will be equal to $v\Delta tA$, where A is the cross-sectional area of the wire. And the charge that flows through a point will be equal to the density of free electrons, n, times the volume, times the charge on the electron.

$$\Delta Q = nev\Delta tA$$

$$I = \frac{\Delta Q}{\Delta t} = nevA$$

We can take an example of a copper wire with a 1mm^2 cross-sectional area and a current of 1 A and calculate the velocity of the "sea" of electrons. We need to know the density of copper (8.96 g/cc), its molar mass (63.54 g), and the fact that in copper there is one free electron for every copper atom.

$$n = \text{density} \times \frac{1}{\text{molar mass}} \times \text{Avogadros\#} \times \text{\#electron per atom}$$

$$v = \frac{I}{neA} = 7.5 \times 10^{-5}\ \mathrm{m/s}$$
$$I = 1.0\ \mathrm{A}$$
$$\mathrm{n}{=}8.48 \times 10^{28}\ \ \mathrm{m}^{-3}$$
$$A = 10^{-6}\ \ \mathrm{m}^2$$

This velocity is called the drift velocity of the electrons. Wow! It is really slow.

We know that the electrons lose potential energy equal to $e\Delta V$. Let's say the potential difference were 1V. How fast would an electron be traveling if all its initial potential energy were converted to kinetic energy:

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2e\Delta V}{m}} = 6 \times 10^{+5}\ \ \mathrm{m/s}$$

So why are the electons going so slowly? The answer is that they keep hitting things (Cu ions and other electrons) as they travel through the wire. Also, the electrons lose essentially all there initial potential energy, which is transferred to the internal energy of the wire. The temperature of the wire increases!

The path of the electron is a random one as it bounces around. Because of the force of the electric field, however, the electron will accelerate after each collision and its average velocity, the drift velocity will be in the direction of the force. The graph below shows the *v* vs *t* graph for an electron (the component of the velocity in the direction of the electric force):