3.16.1.1: Ohm's Law

Atoms are made of protons, neutrons and electrons. The protons and neutrons (each of which is 1800 times heavier than the electron) are found at the center of the atom in the nucleus. The electrons surround the nucleus and occupy most of the space in the atom. ***Charge*** is measured in ***coulombs***; a proton has a positive charge of $+1.6 \times 10^{-19}\ \mathrm{C}$ while the electron has a negative charge of $-1.6 \times 10^{-19}\ \mathrm{C}$ and the neutron has no charge. The nuclear force holds the protons and neutrons together; the electrical force between the protons and electrons keeps the electrons from wandering off. The electrons associated with metal atoms such as iron, aluminum or copper can move freely from one atom to another in a solid made of these atoms. A flow of electrons is called an electrical ***current*** which is measured in *amperes*. An ampere is a flow of one coulomb of charge per second.

What is required for a current to flow? We already know there must be a metal conductor so that there are free electrons. There also must be energy to make them start moving. Recall earlier in the semester we said that if you raise a mass up to a certain height it would store gravitational potential energy, measured in joules. In electricity, instead of measuring potential energy we measure the potential energy *per charge* which is called *voltage*. A volt is a joule of potential energy per each coulomb of charge. When electrons flow through an electrical component such as a light bulb, toaster or radio they give up some of their energy but the same number of electrons per second flow out as are flowing in (charge is conserved; we don't lose any of it). Although the same current (electrons per second) flows out of the component as flows in, the total current in the circuit is controlled by the ***resistance*** of the circuit. Resistance is measured in *ohms*. The relation between resistance (R), current (I) and electrical potential (V) is ***Ohm's law***: $V = IR$. Ohm's law says that a larger voltage makes more current flow if resistance is fixed. Or if resistance is lower at the same voltage, more current will flow.

A good analogy for Ohm's law is water flowing in a system of pipes. Current is like the water, voltage is like the pressure and resistance is analogous to the size and number of pipes. There is pressure in the pipes (potential energy in the battery or power supply) even if the water isn't flowing right at the moment. Flipping a switch in an electrical circuit is equivalent to turning a valve on in a water flow system. If the pipes are bigger or there are more of them (less resistance) there is more flow (more current) at the same pressure (same voltage).

Video/audio examples:

- Ohm's law simulation (turn in answers on a separate sheet of paper): Electrical circuits. Requires JAVA.

> **Note**
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> There is a simplified HTML5 version of this simulation also available from PhET.

1. Download or run the simulation from the web page. Drag a battery, light bulb, switch and several wires from the panel onto the screen. Connect them so that you get current to flow and the light bulb to light. Draw a sketch of your circuit. Hint: The different items connect together automatically; you can separate them by using a control click on the junction.
2. Click the box for adding a non-contact ammeter. Drag it over different parts of the circuit. What is the current in the circuit? Is it the same everywhere? If the current isn't used up in the circuit, what is?
3. Click on the box to add a voltmeter. You will notice there are two leads to the voltmeter; this is because it measures the potential energy *difference* between two locations. What is the voltage difference across the battery? What about the voltage across the light bulb? What about the voltage from one end of a wire to the other end?
4. Separate one of the junctions and add a resistor. What happens to the current compared to the circuit with no resistor? What happens to your voltage readings?
5. Replace the battery with the AC source. What is the difference between a battery (which provides DC or direct current) and the AC (alternating current) source?
6. Add a current chart to the circuit. Move the probe over various parts of the circuit. Describe or sketch what the current is doing, according to the current chart.

- The basics of Ohm's law.
- It's not the voltage that kills you .... or is it?

Questions on Ohm's Law ($V = IR$):

1. Suppose you have a wire in a circuit that has $10\ \mathrm{A}$ flowing in it and it branches into two other wires. If there is $7\ \mathrm{A}$ in one of the wires, how much must be flowing in the other?

2. Which is more like an electrical circuit, the cooling system of your car or the plumbing in your house? Explain.
3. Why is it incorrect to say that voltage flows around a circuit? (Hint: start with definitions of current and voltage.)
4. A person standing on an insulated stool touches a charged insulated conductor. What happens?
5. Birds sit on high-tension wires and do not get electrocuted, even when the wire is bare, yet a squirrel which steps from a bare wire to a pole or to another wire dies instantly. Why?
6. What happens to the brightness of a light bulb if more current flows through it?
7. What is the difference between current (in Amperes) and voltage (in Volts)?
8. If you want make a brighter light bulb, do you want to increase the resistance or decrease the resistance of the filament? (Hint: The brightness increases if more current flows.)
9. What is the difference between AC and DC?
10. What do batteries supply to an electric circuit?
11. When a battery dies, is it out of electrons or out of energy? Explain.
12. If the same amount of current (electrons per second) flows into a light bulb flow out of it, what is being 'used up' in the circuit?
13. If the same current flows into your house as flows out of it, why do you have to pay for electricity?
14. Is it current or voltage that cause electric shock?
15. Wet feet reduce the resistance between you and the ground. From this fact explain why the same 120 V outlet is much more dangerous if you have wet feet than if you have dry feet.
16. Why do warnings on power relay stations say 'Warning, High Voltage' when it is the current that is dangerous?
