Lab 26: Electric Current

Concepts to explore:

- Current
- Electrons in current
- Voltage
- Electric resistance
- Ohm's Law

Figure 26.1: Lighting is one of the most common examples of electricity in nature that you are familiar with. A single lightning bolt carries with it a current on the order of 100kA and has a voltage in the millions of volts.

All matter is made up of atoms. In an atom, the number of positive charges (protons) is precisely balanced by the number of negative charges (electrons). However, when energy is provided, atoms can release some of their electrons to become positive ions. Electrons can jump from one atom to another, taking their negative charge with them. As you learned in Lab 25, this movement of charge is electricity. When you have a source of electricity (e.g. a battery or a wall outlet), it causes a pushing force that moves the electrons along a path (a circuit) and an electric current is produced. Current is defined as the rate of flow of electric charge through a cross-sectional area. If ΔQ is the charge that flows through the cross-sectional area A in time Δt, the current I is

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

The SI unit of current is the ampere (A). This ratio of the quantity of charge and time has become one of the most important values in electricity.

Figure 26.2: A battery is nothing more than a device that stores metals and chemicals, and has become an important part of our lives. They are used to start cars, power alarm systems, and power computers and MP3 players.

Electricity flows from areas of high resistance to areas of low resistance. In other words, it flows in the direction in which a positive electron would move. But how does energy actually move? Well, a solid conductive material contains a large number of mobile electrons. These weakly bound electrons in a metal are pushed through the battery by a chemical reaction going on in that battery. As electrons move through the battery, the chemical reaction in the battery increases the electrons' potential energy. This energy results in the electrons being slightly closer together at the output of the battery than they were when they entered the battery. These electrons then flow slowly through the circuit until they come to a light bulb. As these electrons flow through the light bulb they lose some of their potential energy by doing work on the filament of the light bulb. This work translates into heat, which causes the filament to glow. Through this process the electrons again move farther apart and now contain less potential energy. These same electrons then return to the battery where the cycle begins anew, with the electrons in the circuit acting as energy transporters.

Voltage is an electric potential difference, defined as the difference in electric potential of two points in an electric field. This difference is directly proportional to the force that tends to push electrons from one point to the other. Voltage measures the potential energy of an electric field to cause a current in a conductor, in energy per unit charge. Electrical potential difference can be explained as the ability to move electrical charge through a resistance.

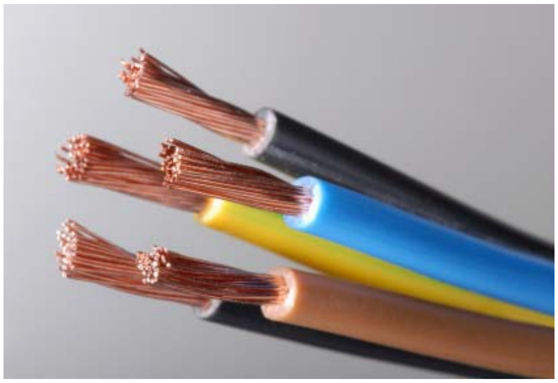


Figure 26.3: Copper is a typical metal used for standard electrical wire due to its high conductivity (low resistance). Other common wire metals are gold, silver, and aluminum. The colored material on the outside of each wire is the insulation, which prevents electricity from flowing into anything that isn't in contact with the stripped portion on the end.

Similar to a mass falling a certain distance through a gravitational field, electrons experience an energy change when traveling through a voltage difference. There is resistance, which is defined as the ratio of the degree to which an object resists the flow of electric current. Resistance is measured in Ohms (Ω). The resistance of an object determines the amount of current through the object for a given potential difference across the object. Resistance shares a relationship to voltage and current as shown in Ohm's Law:

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

or

$$V = IR$$

where R is resistance measured in Ohms, V is voltage, and I is current. Resistors develop a voltage across their terminals proportional to the amount of current through the device. In other words, the voltage measured across a resistor at a given instant is strictly proportional to the current through the resistor at that instant.

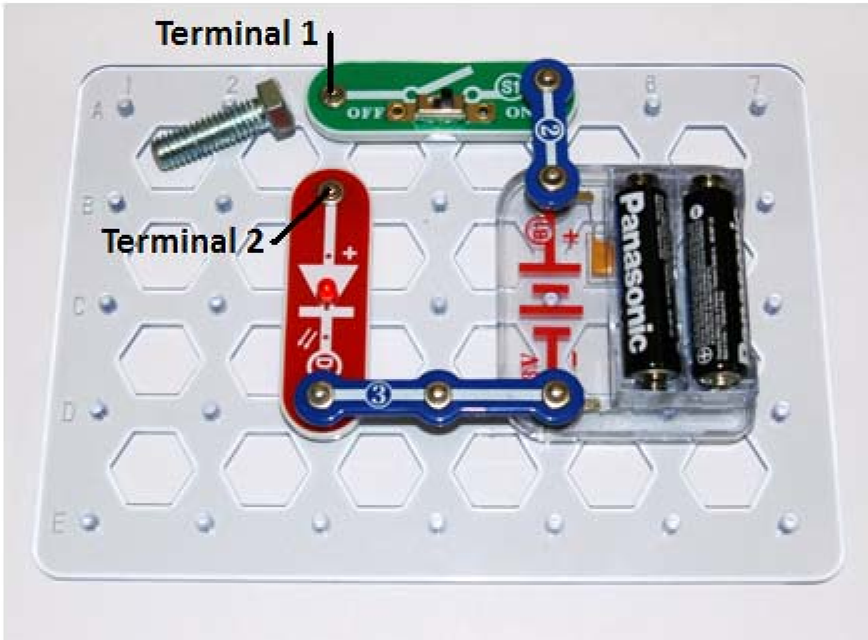
Lab 27.1: Electric Current and Conduction

In this lab you will test the electrical conductivity of different materials using Snap Circuits. You might be surprised to hear that some liquids can even conduct electricity! In the circuit that you build, you will leave an open section across which you can lay different objects to test their conductivity. These two points can be called *terminals*—there will be a voltage across the terminals depending on which end of the battery they are connected to. As soon as a conductor lies across the terminals, this voltage will translate to an electric current in the material!

Materials:

- Snap Circuits kit
- Batteries
- Styrofoam cup
- Salt
- Paperclip, steel bolt, or other small objects
- Procedure:

1. Set up the Snap Circuits so that you have the circuit shown below:



2. With the switch set to “on,” Place a bent paperclip across the terminals as shown in the picture—the LED should light up.
3. Place any other objects you would like to test between the terminals marked 1 and 2 in the diagram. Test materials like wood, metal, and plastic.
4. Connect the Snap Circuit wire leads to terminals 1 and 2. Fill the Styrofoam cup about three-fourths full with water, and submerge one end of each leads in the cup. Turn the switch to “on” and note any changes in the LED.
5. Turn the switch to “off,” and add 1 tablespoon of table salt to the cup, and mix until it’s dissolved. Flip the switch and note any changes in the LED brightness.

Questions:

1. Which terminal is *positive* and which one is *negative* in the setup above? What could you do to quickly reverse the polarity of the terminals?

2. What is the voltage across the terminals? (Hint: look for the voltage of a single AA battery—the battery voltages add together.)

3. What types of materials caused the LED to light up? Did any of your materials make the LED light up only slightly?

4. Did the LED light up when you placed the wires in the regular water? What about after you added the salt?

5. Salt water does not conduct electricity in the same way as metals, where free electrons can move throughout the material easily. Instead, when sodium chloride dissolves in water its molecules are broken up into charged particles called *ions*. Based on how much the LED lit up in step 5, what can you conclude about how well the ions in the solution carry charge compared with electrons in a metal conductor?

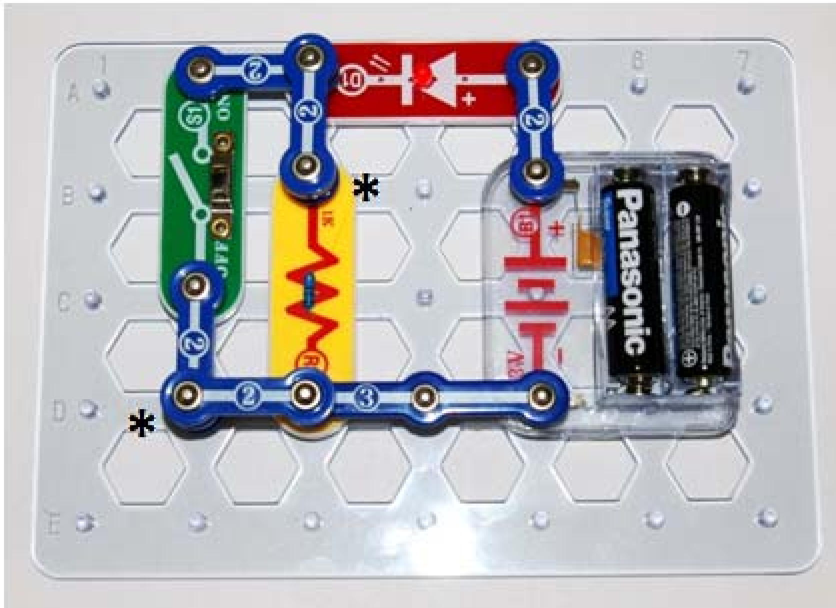
Lab 27.2: Electric Resistance

Materials:

- Snap Circuits kit
- Batteries

Procedure:

1. Set up the Snap Circuits like the picture below, paying close attention to where the single snap (1 small round segment, marked by a * in the figure) spaces are located.



2. Make sure the LED lights up when the switch is in the *off* position. Note the brightness of the LED.
3. Flip the switch into the *on* position. Note any changes that occur.

Questions:

1. Is this circuit *parallel* or *series*? Draw a circuit diagram for the setup in the space below. Use Figure 27.2 for reference, and draw the batteries as two uneven vertical lines. You can draw the switch as a small section of wire that looks like this:

2. While the switch is closed, label which branch of the circuit is an *open circuit* and which part is a *closed circuit.*

3. What happened when you flipped the switch to *on*? How does the current move through the circuit differently?

4. What can you say about the current through the LED when the switch is *on* compared to *off*?

5. Why doesn't current flow through the resistor while the switch is *on*? What does this tell you about the resistance of the switch compared to the resistor?

6. Use Ohm's Law to calculate the current (in Amps) traveling through a 100Ω resistors in series with a 4.5 V battery.