# Power Up

**Grades:** $6^{th}$-$12^{th}$

**Duration:** 55 minutes

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## Program Description

Discover how to hook up and use simple electrical circuits like those that are in your house! Students will build series and parallel circuits to light up light bulbs, switches, and a door bell. Though the science behind electricity and circuits can sometimes be very difficult to understand students will gain a basic understanding of what happens when they flip a light switch.

## Louisiana GLE:

**Grade 5-8**
**Science and Inquiry**
1.Generate testable questions about objects, organisms, and events that can be answered through scientific investigation (SI-M-A1)
2.Identify problems, factors, and questions that must be considered in a scientific investigation (SI-M-A1)
12.Use data and information gathered to develop an explanation of experimental results (SI-M-A4)
14.Develop models to illustrate or explain conclusions reached through investigation (SI-M-A5)

**$6^{th}$ Grade Science**
18.Explain how the resistance of materials affects the rate of electrical flow (PS-M-B2)
25.Compare forms of energy (e.g., light, heat, sound, electrical, nuclear, mechanical) (PS-M-C1)
30.Trace energy transformations in a simple system (e.g., flashlight) (PS-M-C2)
39.Describe how electricity can be produced from other types of energy (e.g., magnetism, solar, mechanical) (PS-M-C6)

**Grade 9-12**
**Science and Inquiry**
1.Write a testable question or hypothesis when given a topic (SI-H-A1)
2.Describe how investigations can be observation, description, literature survey, classification, or experimentation (SI-H-A2)

**Physical Science**
5.Identify the three subatomic particles of an atom by location, charge, and relative mass (PS-H-B1)
45.Evaluate diagrams of series and parallel circuits to determine the flow of electricity (PS-H-G2)

**Physics**
21.Explain and calculate the conversion of one form of energy to another (e.g., chemical to thermal, thermal to mechanical, magnetic to electrical) (PS-H-F1)
30.Construct basic electric circuits and solve problems involving voltage, current, resistance, power, and energy (PS-H-G2)

## Key Terms:

**Amperage**- called current, is the amount of electrical energy flowing through a circuit.

**Ampere (Amp.)**-The measure of current flowing through a wire.

**Circuit** – pathway through with electric current can continuously flow

**Conductor** - a material (like a metal) through which electricity and heat flow easily

**Electric current** – movement of electrical charge

**Electron** – negatively charged atomic particle that is easily transferred from atom to atom in some materials

**Insulator** - a material through which electricity or heat does not flow easily (like many plastics, glasses and ceramics)

**Nucleus** - the central part of an atom, which makes up 99.9% of the atom's mass

**Load**- the power consumed by a circuit

**Power source**-device supplying electrical energy

**Resistance** - a measurement of how much a material opposes the flow of electricity (Wood has high resistance so it is a poor conductor of electricity. Copper has low resistance, so it is a good conductor of electricity.)

**Voltage (V)**- electrical force or pressure (measured in volts)

**Watt (W)-**A basic unit of electrical power used for measuring the rate of work done.

## Connections to Permanent Exhibits: All of these exhibits are found in the Physical Sciences Gallery on the second floor.

**Voltage Divider:** Slide the contact of a rheostat and see the light bulbs wired between the slider and the ends change in intensity; balance the lights; meters show how the voltages are changing.

**Polar Power-Electric Wand**: Move the bar back and forth through the coil. What happens? Why?

**Polar Power-Magnetic Force**: Push the button. What happens? Why?

**Polar Power-Motors**: Push the button. What happens? Why?

**Polar Power-Generators**: Crank the handle on the right. Crank the handle on the left. How are they different? What do they do? Why?

**Plasma Tower:** Touch a glowing tube of gas. The glow intensifies and reaches toward your fingers.

**Series and Parallel Circuits:** Wire up bulbs and other circuit elements in series and parallel circuits and observe the effects.

**Bulbs and Batteries:** Your students can connect bulbs and batteries to light up the bulbs.

**What's a Watt?:** Pedal a bicycle generator; select a light bulb, hand drill or hair dryer to power by yourself.

**Horsepower:** Crank the engine. How much horsepower do you generate?

**Jumping Ring:** When you push a button; electric charge causes an aluminum ring to leap up into the air.

**Jacob's Ladder:** Send a high voltage charge between two metal rods to see electrical ionization.

## Web Resources:

Bill Bowden's Hobby Circuits Bill Bowden
http://ourworld.compuserve.com/homepages/Bill_Bowden/

An interesting collection of circuits for students using easily obtainable materials at Radio Shack or salvaged from old electronic equipment. This website is really for high school.

Articles about "Electricity"-New Explanations, Alternate Mental Toolkit
William J. Beaty
http://www.eskimo.com/~billb/ele-edu.html

Great informational website for teachers and students with a build-it yourself section.

Learning Circuits William Beaty
http://www.eskimo.com/~billb/ele-edu.html

This is an interactive game for students just beginning electricity. It covers insulators, conductors, circuits, circuit diagrams, electricity basics, and changing circuits. Up to 3 people may play the game.

CLECO Circuit World CLECO
http://www.cleo.net.uk/consultants_resources/science/circuitWorld/index.html

Build and test your won electrical circuits with CLEO circuit world. You can save or print, use symbol or character modes or "reveal the real-world components in your circuits. Functions as an e-whiteboard or on individual computers.

## Pre-Visit Activities

**Introduction to Electricity**
Explore the initial concepts of electricity with your 4$^{th}$-6$^{th}$ grade students. Download the lessons at the website below. Look at the right hand side of the web page and find the Introduction to Electricity.pdf. Click on the icon to download.

This lesson is found at the following link:
http://science-coach-site.mcdowell.groupfusion.net/modules/groups/integrated_home.phtml?&gid=396388&sessionid=d2810686d89654949542b600d3636c17

**IPPEX Electricity and Magnetism Interactive**
**Internet Plasma Physics Education Experience**
Have your students do this interactive from Internet Plasma Physics Education Experience (ippex). This will give them the understanding of certain vocabulary. It could be done in groups with a teacher developed handout or as a class. This interactive covers magnetism also. (The interactive requires shockwave.) This interactive is appropriate for 6$^{th}$-9$^{th}$ grade students.

This interactive is found at the following address:
http://ippex.pppl.gov/interactive/electricity/

## Post-Visit Activities

**Elementary Article: What's a Short Circuit?**
Have your students read this story about a short circuit and use split page note taking to record the important information in the story.

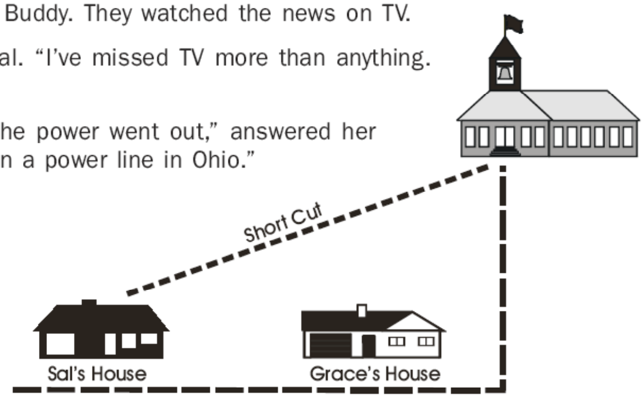
# ELEMENTARY ARTICLE: What's A Short Circuit?

Sal sat on the couch with her mother, patting Buddy. They watched the news on TV.

"I'm so glad the power is back on," sighed Sal. "I've missed TV more than anything. Can we change the channel?"

"In a minute, Sal. They're talking about why the power went out," answered her mother. "They think there was a short circuit in a power line in Ohio."

"What's a short circuit?" asked Sal.



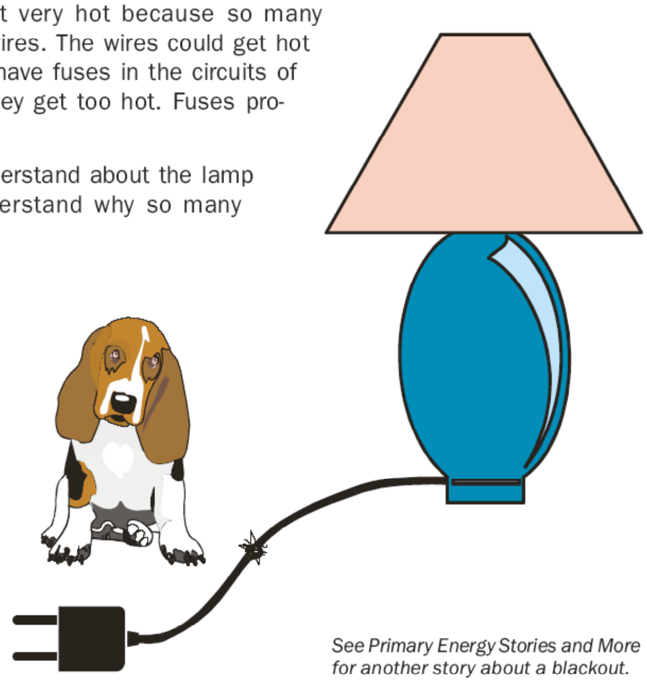

"A short circuit is electricity taking a shorter path because a wire is broken. It's like when you take the short cut through the field to school. You get to school faster, but you don't get to walk with Grace, because you don't go by her house.

"Short circuits are the reason we make sure Buddy doesn't chew on the electric cords. When a lamp is plugged in, it is connected to an electric circuit through the outlet. Electricity runs from the outlet to the lamp and back to the outlet through two wires in the cord. The two wires don't touch each other. They are separated by an insulated covering. The electrons flow to the lamp through one wire in the cord, through the light bulb, and back to the outlet through the other wire in the cord.

"If Buddy chews on the cord, he can break the insulation covering the wires. The wire going to the lamp could touch the wire going back to the outlet. The electrons would flow from one wire to the other through this shorter path, the short circuit. No electrons would flow to the lamp.

"The short circuit could make the wires get very hot because so many electrons are flowing so quickly through the wires. The wires could get hot enough to cause a fire. To keep us safe, we have fuses in the circuits of our house. Fuses shut down the circuits if they get too hot. Fuses protect our house from electrical fires."

Sal looked at Buddy and the lamp. "Ok, I understand about the lamp and the short circuits. But I still don't understand why so many people lost power for so long."

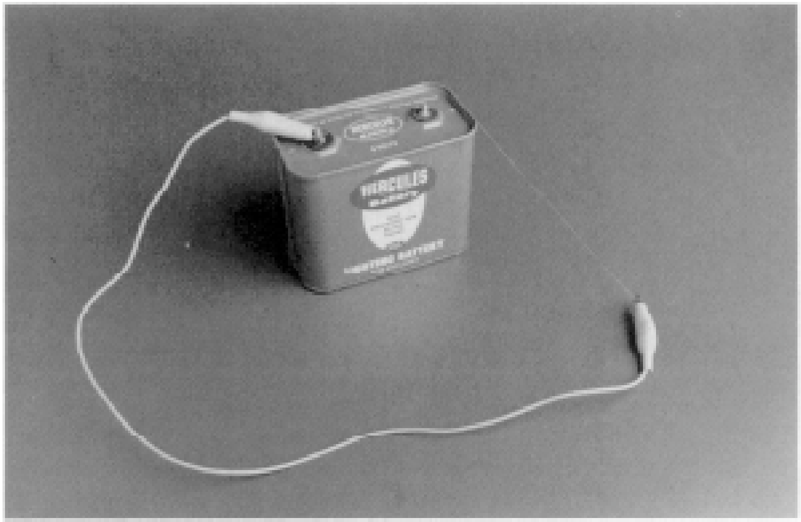


Her mom answered, "Lots of power lines are connected to each other in the United States and Canada. One of the big lines had a short circuit. The electricity flowed through the other power lines. Some of these became too hot and also short-circuited. Just like in our house, these big circuits shut down if they are getting too hot. A lot of power plants shut their lines down so they would not burn. It took a long time to make sure all the short circuits were fixed and get everything working again."

Sal smiled and said, "I'm glad the power's back on. Can I watch my show now?"

*See Primary Energy Stories and More for another story about a blackout.*

**Investigate a Short Circuit**

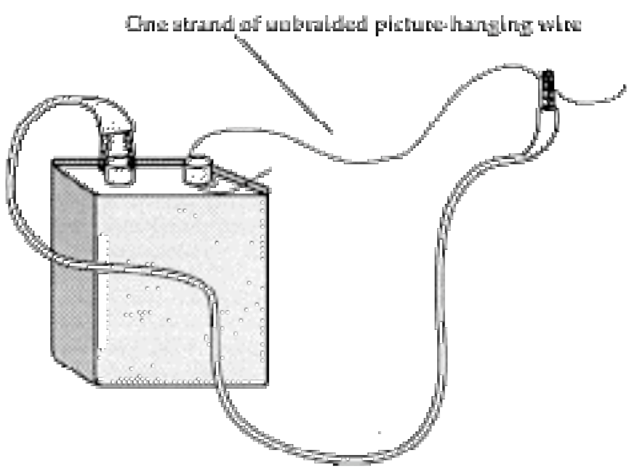


## What happens when you blow a fuse?

**Current flowing through a wire heats the wire. The length of a wire affects its resistance, which determines how much current flows in the wire and how hot the wire gets.**

### Materials

- **A fresh 6-volt or 12-volt lantern battery.**
- **A length of copper wire** A length of copper wire with alligator clips attached to each end (or a test lead) from any electronics supply store.
- **A strand of very fine iron wire,** about 5 to 6 inches (13 to 15 cm) long. (You can get this by unbraiding a short length of picture-hanging wire or any braided iron wire.)
- **Adult help**




**Assembly** (5 minutes or less)

Attach one end of the clip lead to one of the battery terminals. Attach one end of the fine iron wire to the other terminal. Attach the other end of the clip lead to the other end of the iron wire, placing the clip as far from the terminal as possible.

### To Do and Notice

(15 minutes or more)

Observe what happens to the iron wire after you connect the clip. Move the clip on the iron wire a little closer to the battery and watch what happens. Keep moving the lead closer until you see the final dramatic result. (*CAUTION:* The wire gets very hot!)

### What's Going On??

The thin iron wire is a good conductor of electricity, but not as good as the copper wire, which is deliberately chosen to have very low resistance. Thus, most of the resistance of the circuit is in the iron wire. When you connect the clip to the iron wire, the voltage of the battery pushes electrons through the circuit against the resistance of the iron wire, causing the iron wire to heat up. As you move the clip closer to the battery, the resistance of the iron wire decreases. Because the same voltage is applied across a lower resistance, more current flows, and the wire heats up more. Eventually, when you make the iron wire short enough, so much current flows that it melts the wire. Even the copper wire becomes warm.

In a normal electric circuit, an electric current powers an appliance, such as a refrigerator or TV. Every such appliance has a certain amount of resistance to the current flow, which keeps the current from reaching very large values. A *short circuit* occurs when the current finds a way to bypass the appliance on a path that has little or no resistance - for example, where frayed insulation bares a wire and allows it to touch the frame of the appliance, so the current can flow straight to ground. In this situation, a very large current can occur, producing a lot of heat and a fire hazard.

Although houses today often contain circuit breakers rather than fuses, fuses are still around. A fuse contains a thin strip of wire, somewhat like the thin iron wire in our experiment. The current that goes to appliances must also pass through this strip of wire. If a short circuit occurs - or even if too many appliances get hooked up to one wire, so that too much current flows - the wire in the fuse heats up quickly and melts, breaking the circuit and preventing a fire from breaking out.

Try this with pieces of aluminum foil 1/4 inches (6 mm) wide and 6 inches (15 cm) long. Observe the striking colors made by the aluminum oxide layers formed when the aluminum gets hot.

### Build An Electric Motor

In this activity your students can build a simple electric motor using common materials and magnets obtained from Radio Shack. This activity is appropriate for 4$^{th}$-6$^{th}$ grade students.

The lesson is available at the following link:
http://www.exploratorium.edu/snacks/stripped_down_motor/index.html

### Measuring Electricity

Have your students read the following article and take notes using split page note taking. This is an excellent article to discuss the components of Ohm's Law. This activity is appropriate for 9$^{th}$ – 12$^{th}$ grade students.

# INTERMEDIATE/SECONDARY ARTICLE: Measuring Electricity

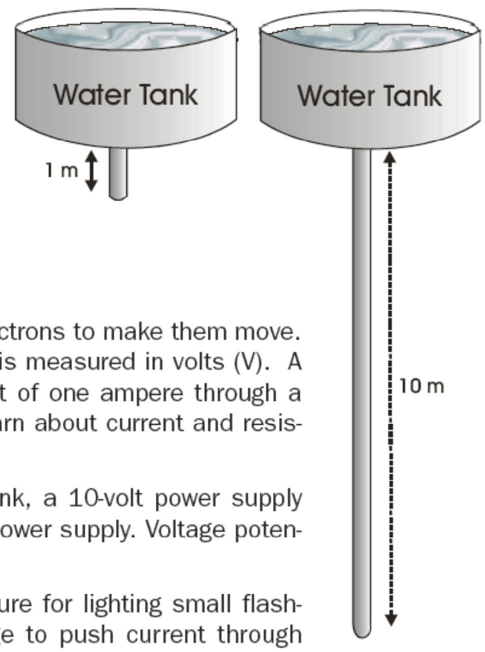
We use electricity for hundreds of tasks every day. It makes our lives productive and enjoyable, yet it remains a mysterious force to most of us. Understanding electricity and how it is measured is confusing because we cannot see it. We are familiar with terms such as watt, volt, and amp, but most of us do not have a clear understanding of these terms. We buy a 60-watt lightbulb, a tool that requires 120 volts, or a vacuum cleaner that uses 8.8 amps, and don't really think about what those measurements mean. We are confident that when we plug them in, they will work.

It is important to understand electricity, because we rely on it for so many things. Electricity is the flow of electrons. Using the flow of water as an analogy can make concepts of electricity easier to understand. The flow of electrons in a circuit is similar to water running through a hose.

If you could look into a hose at a given point, you would see that a certain amount of water passes that point each second. The amount of water depends on how much pressure is being applied—how hard the water is being pushed. It also depends on the diameter of the hose. The more forceful the pressure and the larger the diameter of the hose, the more water passes each second. The flow of electrons through a wire depends on the electrical pressure pushing the electrons and on the cross-sectional area of the wire.

## Voltage

The pressure that pushes electrons in an electrical circuit is called voltage. Using the water analogy, if a tank of water were suspended one meter above the ground with a one-centimeter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you. (If you jumped from a one-meter diving board, the force when you hit the water would not be too great. If you jumped from a 10-meter board, the force would be much greater.)



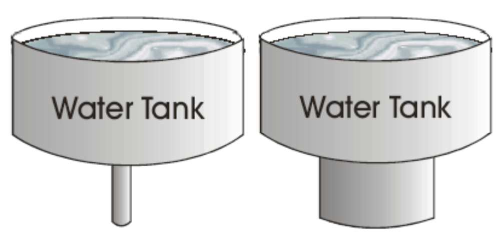

Voltage (V) is a measure of pressure, or electromotive force, applied to electrons to make them move. It is a measure of the strength of the electric current in a circuit. Voltage is measured in volts (V). A volt is the amount of electromotive force (emf) needed to push a current of one ampere through a resistance of one ohm. This definition will make more sense after you learn about current and resistance.

Just as the 10-meter tank applies greater pressure than the 1-meter tank, a 10-volt power supply (such as a battery) would apply greater electromotive force than a 1-volt power supply. Voltage potential is the electrical term that is analogous to water pressure.

AA batteries are 1.5-volt; they apply a small amount of voltage or pressure for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a potentially dangerous amount of voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous amount of voltage.

## Current

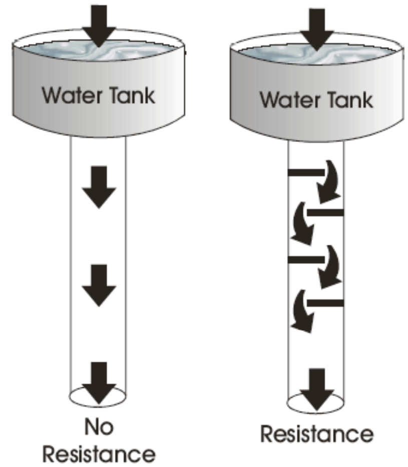
The flow of electrons can be compared to the flow of molecules of water. The water current is the number of molecules flowing past a fixed point; electrical current is the number of electrons flowing past a fixed point. Electrical current is defined as electrons flowing between two points having a difference in voltage potential. Current is measured in amperes or amps (A). One ampere is $6.25 \times 10^{18}$ electrons per second passing through a circuit.




With water, as the diameter of the pipe increases, so does the amount of water that can flow through it. With electricity, a conducting wire is the pipe. As the cross-sectional area of the wire increases, so does the amount of electric current (number of electrons) that can flow through it.

## Resistance

Resistance is a property that slows the flow of electrons—the current. Using the water analogy, resistance is an impediment to water flow. It could be a smaller pipe or fins on the inside of a pipe. In electrical terms, the resistance of a conducting wire is dependent on the metal used to make the wire, and the diameter of the wire. Copper, aluminum, and silver—common metals used in conducting wires—all have different resistance properties. Resistance is a characteristic property of a conducting material.




Resistance is measured in units called ohms (Ω). There are electrical devices, called resistors, designed with specific resistance that can be placed in circuits to reduce or control the flow of the current. Every electrical appliance contributes resistance to a circuit, as well. Any appliance or device placed within a circuit to do work is called a load. The lightbulb in a flashlight is a load. A television plugged into a wall outlet is a load. Every load introduces resistance in a circuit.

## Ohm's Law

George Ohm, a German physicist, made an important discovery about electricity in the early 19th century. He found that in many materials, especially metals, the current that flows through a material is proportional to the voltage across the material. In the substances he tested, he found that if he doubled the voltage (V), the current (A) also doubled. If he reduced the voltage by half, the current dropped by half. The resistance (Ω) of the material remained the same whether the voltage and current increased or decreased. This relationship is called Ohm's Law, and can be written in three simple formulas. If you know any two of the measurements, you can calculate the third using these formulas:

**voltage (volts) = current (amperes) x resistance (ohms)** or **$V = A \times \Omega$**

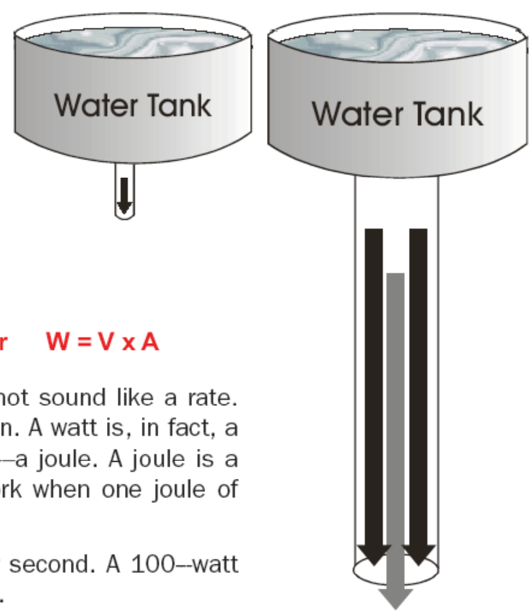
**current (amperes) = voltage (volts) / resistance (ohms)** or **$A = V / \Omega$**

**resistance (ohms) = voltage (volts) / current (amperes)** or **$\Omega = V / A$**

## Electrical Power

Power is a measure of the rate of doing work or the rate at which energy is converted. Electrical power is the rate at which electricity is produced or consumed. Using the water analogy, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work.

A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater force (voltage potential) than water at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from a height of 10 meters.




Electrical power is defined as the amount of electric current flowing due to an applied voltage. It is the amount of electricity required to start a device or operate a load for one second. Electrical power is measured in watts (W). The formula for power that quantifies this relationship is:

**power (watts) = voltage (volts) x current (amperes)** or **$W = V \times A$**

Measuring electrical power can be confusing because a watt does not sound like a rate. Usually we think of rates as ratios—miles per hour or miles per gallon. A watt is, in fact, a ratio; you must learn about another measurement to understand it—a joule. A joule is a measurement of work performed. One watt is the rate of doing work when one joule of energy is used in one second (1 watt = 1 joule/second).

A 50–watt lightbulb uses electrical power at a rate of 50 joules per second. A 100–watt lightbulb uses electrical power at the rate of 100 joules per second.

**Ohm's Law-Learning Technology Project-Glenn Research Center**
This interactive website from NASA's Glenn Reseach Center presents some Ohm's Law problems. This is appropriate for 9th-12th grade students.

The interactivity is found at the following link:
http://www.grc.nasa.gov/WWW/K-12/Sample_Projects/Ohms_Law/ohmslaw.html

**Build a Computer**
Build a computer using simple materials the lesson below. This activity is appropriate for 9th-12th grade.

## Background

Computers are made up of 1000's of simple circuits like this one.

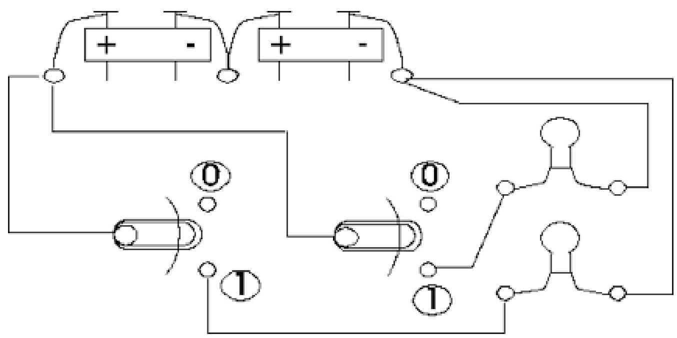
## Materials Needed

| | | |
|---|---|---|
| 2 batteries in holders | 2 paper clips | push pins |
| 1 breadboard | 6 wires with washers | 2 washers |
| 2 light bulbs | 4 labels | |

## Procedure

1. Look at the schematic below and try to predict how many lights will be lit when the switches are in different positions. Use the table below to record your predictions.

2. Build the switched, parallel circuit shown in the diagram. Label the switches as shown.




3. Use your circuit to complete the following table:

| | | Number Of Bulbs Lit | |
|---|---|---|---|
| First Switch | Second Switch | Predicted | Observed |
| 0 | 0 | | |
| 0 | 1 | | |
| 1 | 0 | | |
| 1 | 1 | | |

4. What type of calculation is your circuit performing?