Electric Excitement
4-H ELECTRIC SERIES

National 4-H Curriculum
BU-06849

Electric 2

Investigating Electricity

Project Activity Guide

Name____________________

County ____________________

REVIEWED & RECOMMENDED
National 4-H Curriculum

Investigating Electricity

Contents

Note to the Electric Project Helper

Welcome to *Electric Excitement!* You will enjoy helping youth demystify the "magic" of electric circuits, magnetism, motors and electronics. From building burglar alarms to learning how to select stereo equipment, this curriculum contains dozens of hands-on, useful and fun projects. These activities can be used in a variety of settings such as in the classroom, with special interest clubs, after school groups or community clubs, or one-on-one.

You will be a key individual with whom young people can share the experiences outlined in this activity guide. You will provide encouragement and recognition, as they develop technical and scientific electrical literacy. In addition, these young people will learn important life skills such as creative thinking, decision making, problem solving and participating as members of a team.

Investigating Electricity is designed for youth who understand basic electric principles such as the concept of magnetism, electron flow and circuit design. It is recommended that youth have already completed the first guide in this series.

Your Role

- **Review this guide and the Electric Group Activity Guide**
- **Support the youth in his or her efforts to set goals and complete the Planning Guide and Electric Achievement Program**
- **Help select electric projects to construct, give assistance in doing the activities and answer questions**
- **Help the young person to think about why something happened the way it did**
- **Serve as a resource person to help connect the young person with the community, resource materials and others knowledgeable about electricity**

The Electric Excitement Series

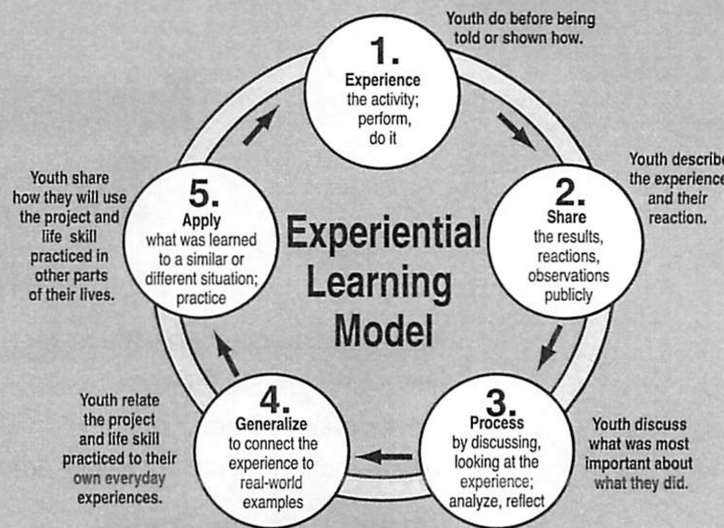
This is the second activity guide in the *Electric Excitement* Series.

Activity Guide	Level 1	Age	Grade
Magic of Electricity	1	9–11	4–5
Investigating Electricity	2	11–13	6–7
Wired for Power	3	13–16	8–9
Electronics I	4	16–18	10–12

These activity guides may be used by youth at any grade-level based on their electric skills, knowledge and expertise. A fifth activity guide, the *Electric Group Activity Guide*, provides additional group activities that can be adapted to the family, classroom or youth group. These activities strengthen understanding of electrical concepts and reinforce electrical skills.

The Experiential Learning Model

The experiential learning model is used in each activity as a means to help the young person gain the most from the experience.



Pfeiffer, J.W., & Jones, J.E., "Reference Guide to Handbooks and Annuals" © 1983 John Wiley & Sons, Inc. Reprinted with permission of John Wiley & Sons, Inc.

The five steps in this learning model encourage the young person to try to do the activity before being told or shown how. The activity is the experience part of the cycle. Use the questions listed in the *Making Connections* section of each activity to encourage the young person to think about what he or she has learned from the experience. The reflect and application questions ask the youth to **share** what they did; **process** what was most important about the experience; **generalize** the life skill and electric skill practiced to their own lives; and think through how they could **apply** the life skill or science process skill to a new situation.

To fulfill the experiential learning process, you must complete all the steps, including the review questions in *Making Connections*. The experiential model enhances learning and adjusts to a wide variety of learning styles.

Evaluating the Experience

1. By asking the questions under *Making Connections* you can evaluate your youth's understanding of the key concepts and life skills practiced in each activity. Listening to and encouraging consideration of each question results in conclusions and opportunities for further application. In addition, the *Success Indicator* shown in the introduction of each activity will help you evaluate the experience.
2. In the *Electric Group Activity Guide* you will find an assessment sheet, *Evaluating the Impact*. Use this sheet to help you evaluate your youths understanding of electricity and circuits as he or she completes these activities.
3. Youth and volunteer helper assessments of the Electric Excitement series can be found on page 35, *Electric Group Activity Guide*.

How This Book Works

In order for you to get the most from each of the activities, take a few minutes and review why each section of the activities has been included. Each activity in the Electric Excitement series is designed to help you learn something about electricity as you practice a life skill you can use every day.

The Activities
Invite a family member or a friend to work with you on these activities and projects. These projects can even be done with your classmates or in a special interest club, after-school group or community club. Sometimes it is more fun and interesting to explore new things together. Here is a quick look at the various sections found in each activity.

Skills
Each activity lists electric skills, science process skills and life skills that you will learn and use. You will practice these types of skills when you answer the questions and discuss each activity with your electric helper.

Success Indicators
Can you do what these say, and can you do it more than once? If so, you have mastered this skill. If you have trouble with this skill, just keep practicing until you can.

Tools
These are the materials you'll need to complete the activity. By organizing and planning for each activity you'll be practicing an important skill.

Power Up
This is the "do" part of the activity. You will usually get to share part of what you do with others.

Closing the Circuit
Here is an extra activity which will help you understand or practice what you have learned in each activity.

Making Connections
This is where you and your helper get together to see what you have learned about electricity. You will use these questions to help you discuss what you learned, what you did, what was important about what you did, what it meant to you and how you could use what you learned in the future. The *Making Connections* questions are found at the end of each chapter. Check the box after talking over each question with your helper.

Light Bulb Icon
Here you will find tips to help you complete the activity or general information about electricity.

Brain Boosters
These are more challenging activities for you to do. They will help you expand your knowledge and skills to other areas. Each time you successfully complete one of these, record it on your achievement program page and have your helper initial and date it.

Safety Icon
These are helpful hints to keep yourself safe when working with electricity. The activities in this guide are designed to be safe, but remember you are dealing with electricity, which can be dangerous.

Kite Icon
Check the kite for interesting facts and trivia about the magic world of electricity.

Glossary Words
All definitions for the words listed here are found in the glossary on page 34.

Web Connection
Here you will find web sites that you can visit to learn more about magnets and electricity.

Journal
Use a journal to record your answers to *Making Connections* found at the end of each chapter.

My Project Helper ______________________

Phone # ______________________

E-mail address ______________________

Your Project Helper

Your electric project helper is an important part of your overall experience in the electric project. The choice of a helper is yours. This person may be your project leader or advisor, troop leader, teacher, family member, neighbor, friend or anyone who has the interest to work with you to complete the electric achievement program for this guide. Involve your helper as you set your goals, discuss the questions following each activity and sometimes work together on an activity.

Investigating Electricity

Planning Guide

My Plans

- Select an electric project helper
- Complete all four steps of the *Investigating Electricity* Planning Guide
- Do at least seven activities each year
- Take part in at least two leadership experiences each year

My Name ______________________________

My Project Helper ______________________________

Helper's Phone Number ____________________ E-mail Address ____________________

1 My Electric Project Goals

I plan to complete my *Investigating Electricity* activity book by ____________________.

2 Leadership Experiences

Participate in at least two of these experiences each year. Put a check mark by the ones you plan to do.

Experience	Plan To Do	Date Completed
Give an electric demonstration		
Teach someone something about electricity		
Encourage a friend to be a part of the electric project		
Attend an electric workshop		
Give a speech on an electric subject		
Tour an electric facility		
Exhibit an electric project		
My own activities:		

3 Electric Project Highlights

List and record the date every time you do and learn something exciting in *Investigating Electricity.*

	Date

4 Electric Project Review

Once you have completed what you planned, arrange to talk with your helper about what you have learned. You will want to have your planning guide, achievement program and the *Making Connections* section of this guide up-to-date.

Achievement Program

Guidelines

- Do at least three Required Activities and four Optional Activities (Brain Boosters) this year and check them off.
- Have your electric helper date and initial this log as you complete the activities

Required Activities			Optional Activities (Brain Boosters)			
Activity Name	**Date Completed**	**Helper's Initials**	**Page/No.**		**Date Completed**	**Helper's Initials**
Get It Together						
Going Back and Forth						
The Electric Detective's Most Important Tool						
Investigating Ohm's Law						
To Flow or Not to Flow						
Decoding Circuit Diagrams						
Case of the Series Circuit						
Case of the Parallel Circuit						
Circuit Sense						
The Off and On Case						
The Case of the Switching Circuit						
Stronger Connections						
Stop the Crime						

Electric Excitement
4-H ELECTRIC SERIES

Investigating Electricity

Achievement Program Certificate

I certify that ______________________________

has successfully completed the requirements of Electric Excitement: *Investigating Electricity*

Helper's Signature______________________________

Date ______________________

Activity 1

Get It Together

Activity:	*Gather materials for Investigating Electricity activities*
Life Skill:	*Solving Problems—Devising a plan of action and evaluating information*
Electric Skill:	*Becoming familiar with electrical equipment*
Science Process Skill:	*Making decisions*
Success Indicator:	*Acquires all materials needed*
National Science Standard:	*Tools help scientists make better observations, measurements and equipment for investigations*

Tools

Pencil

Before you can dig deeper into the science of electricity, you must gather the tools needed for investigation. You probably already have some of the things you will need, but not all of them. In this activity you will get organized by taking inventory of what you have and deciding what you need. Once you know what you need, you can decide on the best place to get it.

Power Up

This table lists the materials you will need for the activities in this book. For each item, indicate in the table whether or not you already have it, where you will buy it if necessary and how much it will cost. You may want to call, visit several stores, or check catalogs (many are on the Web!), to see who has the best price on an item.

MATERIAL PLANNING TABLE

ITEM	ACTIVITY USED	AMOUNT NEEDED	ALREADY HAVE?	WHERE YOU FOUND IT	COST
D-cell battery	2, 3, 5, 7, 8, 9, 10, 11	4			
Volt-Ohm meter	3, 5, 7, 8, 9	1			
Good light bulb	3	1			
Burned out light bulb	3	1			
Pencil lead for mechanical pencil	5	1			
Compass	2	1			
Aluminum foil	5, 10	1 box			
22 or 24 gauge insulated copper wire	2, 7, 8, 9, 10, 12	25 feet			
Glass jar or drinking glass	5	1			
Piece of cardboard	5, 11	2 pieces			
Copper wire	5	1 piece			
Plastic item	5	1			
Flashlight bulbs (1.5 Volts)	2, 7, 8, 9, 10, 11	2			
Light bulb holder	2, 7, 8, 9, 10, 11	2			
Battery holders for single D-cell battery	2, 7, 8, 9, 10, 11	2			
Pencil	1, 6	1			
Wire strippers	2, 7, 8	1			
Plastic bottle with adjustable nozzle	4	1			
Screw driver	7, 8	1			
Hammer	10	1			
Tin snips or strong scissors	10	1			
Clean tin can lid	10	1			
Brass paper fasteners	11	6			
Soldering iron and solder*	12	1			
Sponge*	12	1			
Needle nose pliers	12	1			
Switch	7, 8, 9	1			

*See Light Bulb Icon for more information

Closing the Circuit

Go and visit the cereal isle of a grocery store with your helper. Look at all of the different types, sizes and brands of cereals you could buy. How can you decide which cereal to purchase? List the questions you need to ask yourself when deciding on a cereal to buy:

Examples:

What type of cereal do I like to eat?

How much money do I have to spend?

Questions:

____

____

____

____

____

____

____

Were you able to eliminate cereals by asking these questions? Did asking questions make it easier to decide what type, size and brand of cereal to purchase?

Soldering

Three of the items on your list are for **soldering** — a process used to make strong connections in electrical circuits. These items are relatively expensive. If you plan to continue your study of electricity and complete Electric 4, *Entering Electronics*, you will need to learn to solder and you should purchase these items. If you do not plan to study electronics, you may skip these purchases.

Brain Boosters

1. Think about the decisions you make everyday. What time do I get up? What will I wear today? What shall I have for breakfast? What homework assignment should I do first? Some of these decisions are easy to make and some are much harder. Discuss with your helper how you make decisions everyday. Discuss how people set priorities when making a decision between several options.

2. Select something you would like to purchase in the near future and do some comparison shopping. Discuss with a parent or your electric helper the answer to the following questions: • Is there more than one brand name for the item you want? • Is one brand more expensive than another? • Which brand do you like best and why? • Is the item available at more than one store? • If so, what is the difference in price of the item in the different stores?

In 1827, a German scientist, named George S. Ohm, wrote a book that stated that an electric current has to push against the **resistance** *of the conductor. This was such an unusual idea that many scientists at the time refused to believe it— they thought Ohm was crazy! Ohm made so many enemies because of his new ideas that he had to leave his home. Today, everyone accepts Ohm's ideas because there* is *resistance to current. This resistance can be measured in units that are called* ***Ohms!***

Glossary Words

- Ohm
- Resistance
- Solder

Activity 2

Going Back and Forth

Activity:	***Learn about alternating and direct current***
Life Skill:	***Acquiring/Evaluating Information—Obtaining information***
Electric Skill:	***Identifying alternating and direct current circuits***
Science Process Skill:	***Experimenting and comparing***
Success Indicator:	***Understands the difference between direct and alternating current***
National Science Standard:	***Electrical circuits require a complete loop through which an electrical current can pass***
Tools	***Compass, 3 feet of insulated 22 or 24 gauge copper wire, light bulb, light bulb holder, D-cell battery, wire strippers***

When you flip a computer switch, you expect the computer to start working. When you push the button on a flashlight, you expect the light to turn on. Each time you flip a switch or plug in an appliance you are completing an electrical circuit. The electric current moves through the circuit and accomplishes the desired task. However, there are two different types of electrical current at work here. The computer uses **alternating current (AC)** and the flashlight uses **direct current (DC)**. In this activity you will learn about these two types of electrical current.

Power Up

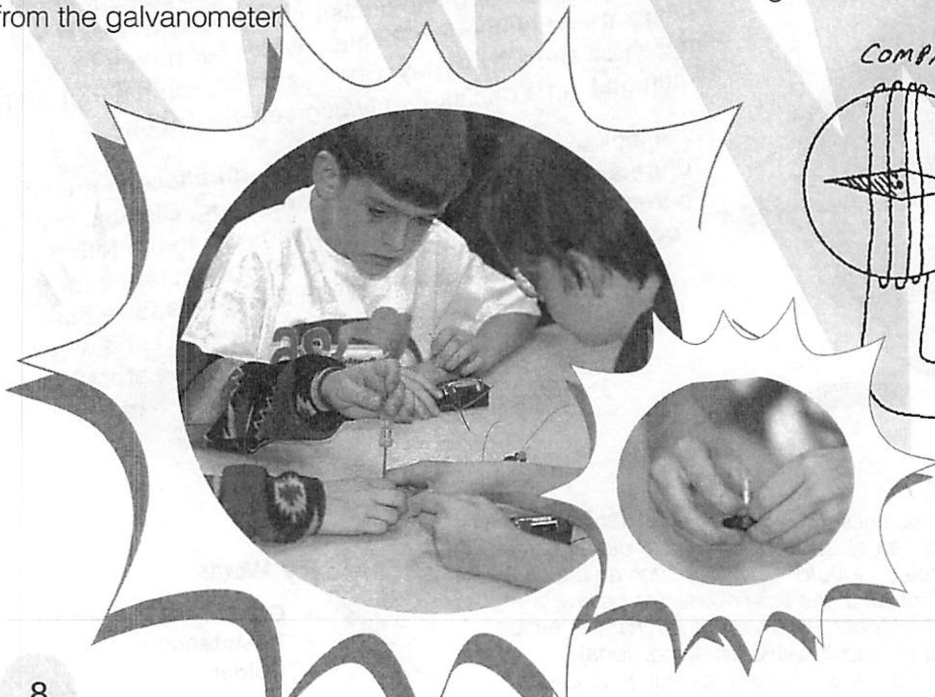
In this activity you will demonstrate alternating and direct current by building a galvanometer and using it in a circuit that includes a light bulb (Refer to *The Magic of Electricity,* Activity 11).

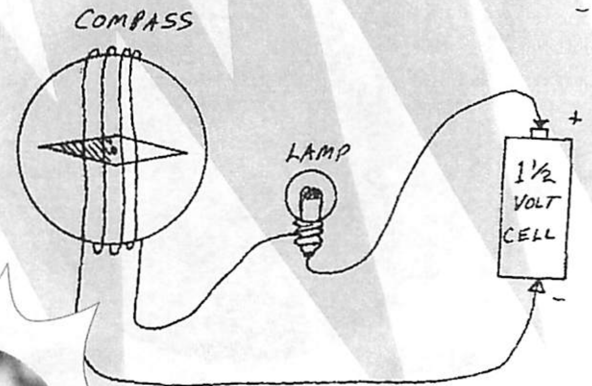
Wrap several (10 to 20) turns of small wire around a magnetic compass. To make a complete circuit:

- Connect one of the wires from the galvanometer to a D-cell battery
- Connect another wire from the other side of the D-cell battery to one side of the light bulb
- Connect the other side of the light bulb to the other wire from the galvanometer.

The circuit will be easier to handle if you use a battery holder for the battery and a light bulb holder for the light bulb. Once you finish your circuit, you will see that the needle of the compass will turn one direction and then stop. The electric current is moving in only one direction. This is called direct current.

If you reverse the two wires that are connected to the battery, the needle of the compass will turn and point in the other direction. This shows a change in the direction of the current. If you switch the D-cell connection back and forth quickly, you are making an alternating current.





Closing the Circuit

A transformer converts electric energy to magnetic energy and then back to electric energy at a different **voltage**. A transformer may be used to increase or decrease voltage. Very small transformers are found inside plugs used for cordless telephones and video games. Transformers are also found inside remote controlled equipment such as TVs, garage door openers and thermostat controls for furnaces.
Very large transformers are found in electric power substations. Your home gets its power from a power transformer located near your home.

Count and record the number of small transformers used in your home. Locate the power transformer that serves your home. Most power transformers are mounted overhead on poles, but some are on the ground and have underground wiring.

Transformer Location	How many in your home?	Indoors or Outdoors?
Ex. *telephone*	*4 telephones*	*indoors*

Glossary Words

- **Alternating current**
- **Direct current**
- **Hertz**
- **Transformer**
- **Voltage**

In the 1880's, a German scientist, Heinrich Hertz, was experimenting with electromagnetism. Hertz was using a wireless transmitter, an early type of telegraph, which sparked whenever ultraviolet light was shone on the transmitter. This was the first step toward the photoelectric devices that we use today, such as the doors that open like magic at the grocery store and other buildings!

Direct and Alternating Current

The electricity coming from a battery is called direct current. Direct current electricity always flows in the same direction.

The electricity that comes from an electrical generating plant, which is the same electricity that is available at the receptacle in the wall of your home, is different from the electricity in a battery. The electricity from the generating plant flows in one direction and then in the other direction; it is called alternating current. The alternating current used in the United States changes direction, back and forth, 60 times per second (called 60-cycle or 60-**Hertz** electricity). Electricity in much of the world is 50-Hertz. That is one reason why an electrical appliance built to work with electricity generated in America will not always work with electricity generated in another country.

Why use AC current instead of DC?

AC electricity has a major advantage over DC electricity. To move large amounts of DC electricity a few miles requires very large wires. AC electricity can move large amounts of electricity several miles on relatively small wires (which you see on electric poles) by using **transformers** to increase the voltage.

Brain Boosters

Make a list of the things in your house that use direct current. Make another list of things in your house that use alternating current. Describe to your helper how you determined if an item used direct or alternating current.

Author: Wayne Newhart, Tipmont REMC

Activity 3

The Electric Detective's Most Important Tool

Activity:	*Use a Volt-Ohm meter*
Life Skill:	*Acquiring/Evaluating Information—Obtaining information and analyzing data*
Electric Skill:	*Using a Volt-Ohm meter*
Science Process Skill:	*Gathering data*
Success Indicator:	*Reads Volt-Ohm meter correctly*
National Science Standard:	*Tools help scientists make better observations, measurements and equipment for investigations*
Tools	*Volt-Ohm meter, battery (or batteries) for the meter, two D-cell batteries*

Some of the tools used to study electricity are Volt-Ohm meters, galvanometers, circuit diagrams and circuit components. Meters, such as the Volt-Ohm meter and the galvanometer, help to measure what is going on in a circuit. Circuit diagrams help us to figure out how to put the pieces of the circuit together, and circuit components actually do the work of conducting the electricity (and more). In addition to good observation skills, every electric detective needs to know how to use these different tools. In this activity you will test your skill using a Volt-Ohm meter.

Never try to measure a voltage unless the meter dial is set for voltage. If you try to read a voltage with your meter set to read resistance (Ω) it will damage your meter! Set the meter on voltage DC if you are reading the voltage of a battery or voltage AC if you are reading voltage from a wall socket.

Power Up

Obtain an analog or digital **Volt-Ohm meter** (see *Light bulb*). When you get new equipment, it is always a good idea to read the manual instructions on proper usage.

You may need to install a battery, or it may have come with one already installed. Some meters require that you connect the red lead wire to the positive terminal on the meter, and the black lead wire to the negative terminal. Now you are ready to take some readings with your meter and fill in the data table.

1. Using the meter by itself, set the meter to read direct current (DC). Notice what the meter output shows when you touch the ends of the red and black lead to each other, and when they are separated. Record these meter readings in the table.
2. Next, change the Volt-Ohm meter to read alternating current (AC). Again, record the meter readings when the ends of the red and black leads are touching and when they are separated.
3. To measure **electrical resistance**, change the meter to read **Ohms** (Ω). Record the resistance values when the ends of the two leads are touching and when they are separated.

Check your manual to see if your meter can measure **electrical continuity**. If it can, change the setting to measure continuity Record the meter readings when the ends of the two leads are touching and when they are separated.

WARNING: The meter cannot measure resistance when voltage is present in a circuit, so you must disconnect the battery from the circuit before you use your Volt-Ohm meter to read an electrical resistance. The meter can be harmed if resistance is read while voltage is present.

VOLT-OHM DATA

Meter Setting	*Leads Touching*	*Leads Separated*
Direct Current (DC)		
Alternating Current (AC)		
Resistance (Ohms)		
Continuity		

Glossary Words

- **Analog**
- **Digital**
- **Electrical resistance**
- **Electrical continuity**
- **Ohm**
- **Volt**
- **Voltage**
- **Volt-Ohm meter**

Closing the Circuit

Use your Volt-Ohm meter to read the voltage in a D-cell battery and record what you see. What setting did you need to put the meter on? Does it matter which battery terminal the red lead attaches to? Put two batteries together end-to-end (like they go together in a flashlight) and read the voltage of the two. What did the Volt-Ohm meter read?

Brain Boosters

In the space provided sketch a simple circuit showing a light bulb, battery, switch and wire; then answer the questions.

What provides the energy for the circuit?

____

What is the electrical load?

____

What do the wires do?

____

How do the electrons travel through the circuit?

____

Why do you put a switch in a circuit?

____

Analog or Digital Meter?

As its name implies, a Volt-Ohm meter is a device to measure the **voltage** (both AC and DC) and resistance in electrical components to help understand what is happening in an electrical circuit. If your meter has a needle that moves from one side of a scale to the other it is an **analog** meter. A **digital** meter has a number read out.

The meter cannot measure resistance when voltage is present in a circuit, so you must disconnect the battery from the circuit before you use your Volt-Ohm meter to read an electrical resistance. The continuity check on a meter lets you see if a circuit has a break in it somewhere. A broken wire can act just like an open switch. If the continuity checks, there is not a break in the circuit. If the continuity does not check, then the circuit is open. The circuit may be open because a switch is open, but it may be open because a wire is broken or a connection is bad! If a meter has a continuity check built in, it will generally buzz or light an indicator light if the circuit is good.

Electricians often check for continuity in circuits that aren't working. If you have a light bulb that you know is burned out, check it for continuity or use your meter to read the resistance across the light bulb. To do this, touch one lead on the side of the screw part of the bulb, and another lead on the end of the light bulb that sticks out (just like the way you made connections in book one to get the "broken flashlight" to work!) Try the same test with a good light bulb. Are the readings different? Explain what you discovered to your helper.

Simple Circuit

Alessandro Volta, an 18th century Italian scientist, believed that electricity had something to do with the interaction of two different metals. In his efforts to prove his theory, Volta became the first person to produce a continuous electric current. The unit by which electric pressure is measured is called the "Volt" in honor of Alessandro Volta.

Activity 4

Investigating Ohm's Law

Activity:	***Investigate Ohm's Law using a squirt bottle***
Life Skill:	***Identifying facts and principles***
Electric Skill:	***Understanding Ohm's Law***
Science Process Skill:	***Observing and processing***
Success Indicator:	***Understands relationship of voltage, current and resistance to Ohm's Law***
National Science Standard:	***Electricity is involved in the transfer of energy into or out of a system***

Tools

Detergent bottle with adjustable nozzle, water

How are *voltage*, *current* and *electrical resistance* related? In this activity, you will use an *analogy* to help you understand *Ohm's Law*. An analogy is the use of familiar experiences to learn about new ideas. How are voltage, current and electrical resistance related? In this activity, you will use an analogy to help you understand Ohm's Law. An analogy is the use of familiar experiences to learn about new ideas. For example, your friends might describe their afternoon of ice-skating as a cold form of roller-blading. You might describe your first ride on a horse as a ride on a county fair bumper car. These are both analogies and they help us to explain ideas and experiences to each other.

George Ohm Figures It Out!

In 1827, George Ohm discovered the mathematical relationship between current, voltage and resistance. This relationship is known as Ohm's Law. He found that the current flowing **(amperage)** *in a circuit is equal to the voltage in the circuit divided by the resistance. Ohm's Law can be written as an equation:*

$i = v/r$

i = *current in* **amperes**

v = **voltage** *in Volts*

r = *resistance in Ohms.*

Using algebra, it is possible to write this equation another way:

$v = ir$

Ohm's Law tells us that the current in a circuit will equal the voltage in the circuit divided by the resistance in the circuit. But what does all of this fancy math tell us? By using Ohm's Law, you can design electrical circuits that are safe. If you know the voltage that the circuit uses and you measure the resistance of the circuit, you can calculate the amount of current that will flow in the circuit. Once you know the amount of current, you can select a wire that is big enough to safely carry the current.

Look at the electrical cord on a table lamp, and then look at the electrical cord on an air conditioner or refrigerator. Is one bigger than the other? Which do you think carries the most current?

Power Up

In this activity you will need to think of the water as being electricity.

Fill your bottle with water. As you try the experiments below, you will need to refill your bottle whenever it starts to get empty. This activity should be done outside or over the bath tub.

1. Make sure the nozzle is all the way open. Push on the bottle to make the water come out. Change the nozzle so that it is almost closed. Push on the bottle again, just as hard as you did before. What happened?

____

____

2. With the nozzle still almost closed, try pushing on the bottle so that the water comes out as quickly as it did when the nozzle was all the way open. Describe the "push" required to make the water flow as quickly as before.

____

____

How does the water flow correspond to an electrical circuit?

____

What does the pressure you put on the bottle when you squeezed it correspond to?

____

What does the nozzle setting correspond to?

____

Glossary Words

- **Amperes (amps)**
- **Amperage**
- **Analogy**
- **Current**
- **Electrical resistance**
- **Ohm's law**
- **Voltage**

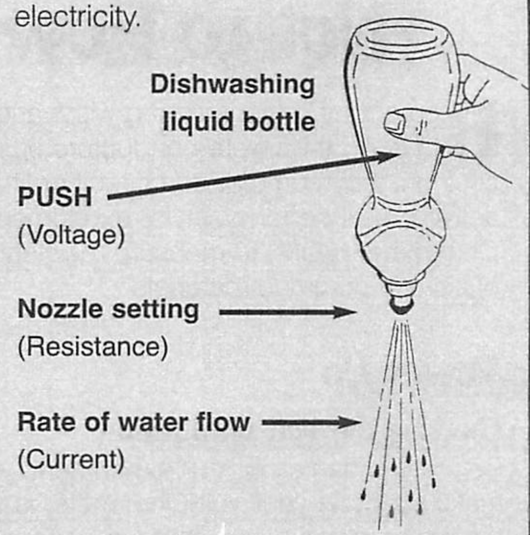
Closing the Circuit

Ohm's law tells us how much current flows in a circuit. Remember, Ohm's law states that I =v/r. Plug some numbers into Ohm's law and see what you get:

- Assume you have a circuit that uses 2, D-cell batteries that provide 3 V. Next, assume that every light bulb you add in the circuit has a resistance of 1000 Ohms. From Ohm's Law, calculate how much current will flow in the circuit with 3V and 1000 Ohms.
- How much current will flow if you have 2 light bulbs in the circuit (still using 2 batteries)? Hint, the resistance values add so the new circuit has 1000 + 1000 = 2000 Ohms.
- The current in the circuit with two bulbs is half as much as the current with the circuit with one bulb. With half the current, the bulbs burn half as brightly.
- What happens if we add a third battery? Now the voltage in the circuit is 4.5 v and the current with one bulb is I = v/r = 4.5/1000 = 0.0045 **amps**. Will the light bulb burn dimmer or brighter?
- Finally, if we have four batteries and two bulbs, how much current will flow?

An Electrical Analogy

Imagine the water as the flow of electricity.



Brain Boosters

Another analogy that is often used to describe electricity is that of a garden hose.

Consider a garden hose attached to the spicket at your house. What would correspond to the flow of electricity? What would correspond to the electrical resistance? What would correspond to voltage? Can you change the voltage (or "push") on the garden hose? Share your answers with your helper.

George Ohm is credited with discovering the relationship between voltage, current and resistance in 1827 before there were electricity measurement tools and meters.

Activity 5

To Flow or Not to Flow

Activity:	*Use your Volt-Ohm meter to decide if something is a conductor or insulator*
Life Skill:	*Acquiring/Evaluating Information—Obtaining information and interpreting data*
Electric Skill:	*Identifying conductors and insulators*
Science Process Skill:	*Organizing and classifying*
Success Indicator:	*Correctly classifies materials as insulators or conductors*
National Science Standard:	*Objects have many observable properties that can be measured and used to separate or sort a group of objects or materials*
Tools	*Pencil lead from a mechanical pencil, copper wire, aluminum foil, piece of glass, piece of cardboard, something made out of plastic, other materials you want to test, Volt-Ohm meter*

Remember experimenting with various materials to test if they were conductors or insulators by seeing if they completed a circuit or lit a bulb? In this activity you'll perform similar experiments with a Volt-Ohm meter (VOM) to measure resistance in Ohms of several common materials.

Power Up

Checking the Volt-Ohm meter

Before you can start your experiment, you will need to make sure that your Volt-Ohm meter is set. First turn on the meter to make sure that the batteries are OK. Next, set the dial to measure resistance in Ohms and touch the leads to each other. The Volt-Ohm meter should stay on zero. If not, check your manual.

Testing Materials

Set the Volt-Ohm meter dial to read resistance or Ohms (Ω).

Connect the black meter lead to one end of a material and the red meter lead to the other end. Be sure the leads only touch the material. Record the reading in Ohms on the data table in the columns labeled "Resistance Value." Repeat these two steps for all the materials you have collected.

To measure the resistance of different lengths of pencil lead, lay the lead down on a piece of paper near a ruler. Place the meter leads on the pencil lead, one inch apart, and record the meter reading. Next place the meter leads on the piece of pencil lead three inches apart and record the reading on the meter. Finally, repeat with the leads at each end of the pencil lead. Record the resistance reading from the meter. Make sure to measure and record the length of the pencil lead under the Material heading.

Which materials acted as conductors? Which acted as insulators?

Material	Resistance Value (Ohms)	Conductor or Insulator	Conductor Rank	Insulator Rank
Copper				
Cardboard				
Glass				
Pencil Lead 1"				
Pencil Lead 3"				
Pencil Lead ___"				
Other:				

Conductors and Insulators

All materials have some resistance to the flow of electric current. Some have a low resistance and are called **conductors**. The electrons in a conductor are held very loosely and when voltage from a battery is placed across a conductor the electrons in the material begin to flow.

Other materials hold their electrons very tightly and have high resistance to letting any electrons through. These materials are called **insulators**. Remember, conductors will have low resistance values, generally less than one Ohm, whereas insulators will have a very high resistance, often above several thousand Ohms.

Glossary Words

- Conductor
- Insulator
- Super conductor

Brain Boosters

Is water an insulator or conductor? Try this experiment to find out.

Fill a glass with water. With your Volt-Ohm meter set on resistance, place the two probes in the water about 1-inch apart. Record the resistance. Now add one teaspoon of salt to the water, stir it up and repeat the measurement. Record the result. Keep adding salt to the water, one teaspoon at a time, and reading and recording the resistance of the salt/water mixture. Is water a good conductor? Does salt change the electrical resistance of water?

Making Connections

Share With Your Helper

- ☐ What type of Volt-Ohm meter do you have? What can it measure? What did you have to do before you could use your new meter?
- ☐ How did you decide if a material was an insulator or a conductor? Based on your measurements, which materials were the best conductors?

Process What's Important

- ☐ Why do you think the Volt-Ohm meter requires two leads to measure Volts or Ohms?
- ☐ In terms of electrons, what makes a material a good or poor conductor or insulator?

Generalize To Your Life

- ☐ Why is it important to read the owner's manual before you operate a piece of equipment?
- ☐ Analogies are one way to explain something new to someone who has never experienced it. Name two other ways you could teach something new to a friend.
- ☐ Scientists classify items to help better understand them. Name one way you classify things you use every day.

Apply What You Learned

- ☐ How does asking questions help you make decisions?
- ☐ What skills do you need to develop to become a better decision-maker?
- ☐ Scientist often use data tables to organize information. Name another way to keep track of important information.

Scientists are searching for materials that have little or no resistance to the flow of electrons. These materials are called **superconductors** *because their resistance is much lower than commonly used conductors such as copper. The challenge in making superconductors is to find materials that have extremely low resistance at normal temperatures.*

Decoding Circuit Diagrams

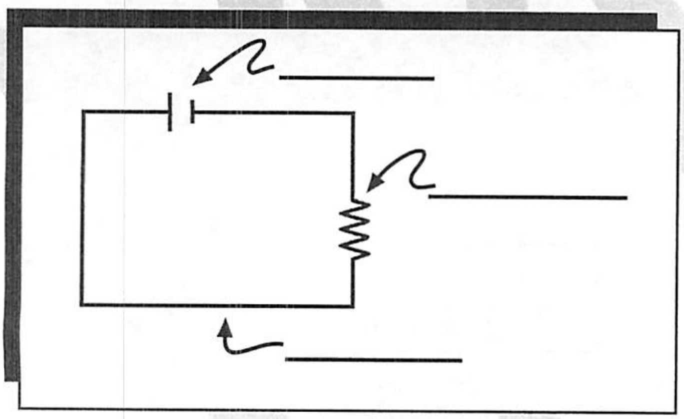
Activity:	*Learn to read circuit diagrams*
Life Skill:	*Acquiring/Evaluating Information—Obtaining information and interpreting data*
Electric Skill:	*Learn basic symbols used in circuit diagrams*
Science Process Skill:	*Communicating*
Success Indicator:	*Correctly labels components on wiring diagrams*
National Science Standard:	*Electrical circuits require a complete loop through which an electrical current can pass*
Tools	*Pencil*

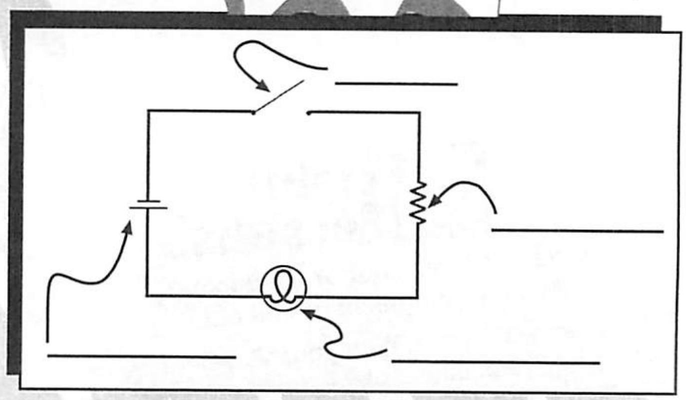
We often use **symbols**, instead of words, to convey information. Stop signs, no-smoking signs and school crossing signs are examples of symbols we all recognize and understand. Symbols also help cross language barriers. Different languages make communication difficult between nations, but pictures and symbols can be made into an international language that all people can learn and understand.

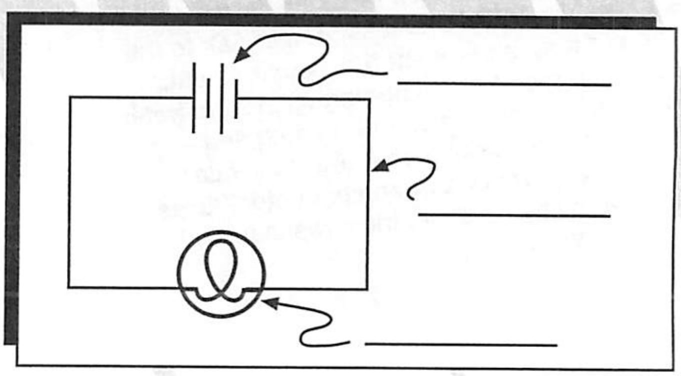
For these reasons, symbols are used in the science of electricity and electronics. In circuit diagrams, symbols are used to represent the physical objects used in a circuit such as batteries, light bulbs, wires and switches. In this activity you will learn to identify the symbols used to represent different parts of an electrical circuit.

Power Up

Study the following circuit **diagrams**. On each diagram, label the battery, conductor, light bulb, resistor or switch.







Closing the Circuit

Draw a line from the symbol to its meaning. What other symbols can you think of that we see every day? How do symbols make communication easier?

1.
2.
3.
4.
5.
6.
7.

Handicap

School Crossing

Recycle

No Parking

Medical

Poison

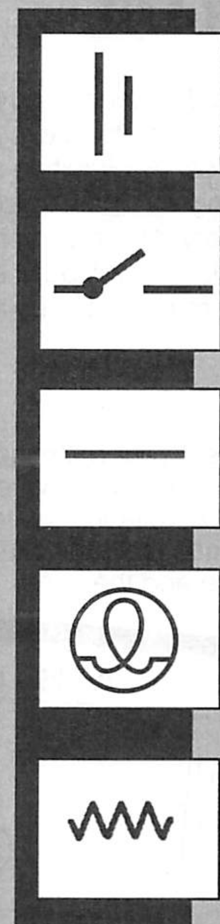
Yield

Brain Boosters

Look at the photographs of circuits in Electric 1 Activity #7 (pg. 18) and draw each one using symbols instead of pictures for the batteries and bulbs.

Circuit Symbols

These symbols are used to represent components in circuit diagrams.



Battery

Switch

Conductor

Light bulb

Resistor

The symbol for the battery is composed of two lines—one long, and one short. The long line is the positive terminal of the battery and the short line is the negative terminal of the battery. Be sure to check how the battery is positioned when making an electrical circuit using a diagram.

Distance can be measured in miles; weight measured in pounds; and volume measured in quarts or pints. How can the number of electrons in a current be measured? Since electrons are so very small, they cannot be readily counted one by one. A larger unit, called a ***coulomb****, is used to measure when 6.3 billion, billion electrons have passed a given point in a wire. The coulomb was named after the French scientist Charles A. de Coulomb, who measured the forces that act between electric charges.*

Glossary Words

- **Coulomb**
- **Diagram**
- **Symbol**

Activity 7

Case of the Series Circuit

Activity:	*Build a circuit and measure voltages*
Life Skill:	*Acquiring/Evaluating Information—Predicting outcomes and analyzing data*
Electric Skill:	*Using a Volt-Ohm meter*
Science Process Skill:	*Gathering data*
Success Indicator:	*Measures voltage across light bulbs and batteries*
National Science Standard:	*Electrical circuits require a complete loop through which an electrical current can pass*

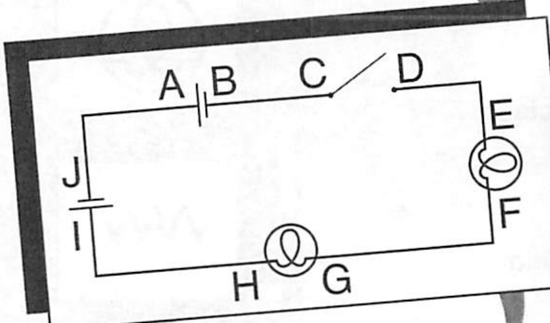
Tools

Volt-Ohm Meter, 2 D-cell batteries, 2 D-cell battery holders, 2 light bulbs, 2 light bulb holders, switch (you may use the paper clip switch you built in Electric 1 or you may purchase a switch such as a knife-blade switch or a push button switch), wire strippers, small screw driver to fit the screws on the light sockets, 2 feet of number 20 or 22 gauge insulated wire, one square foot piece of board

In Electric 1, *The Magic of Electricity*, you learned that there are two types of circuits. A circuit is either a parallel circuit or a series circuit. In a series circuit, the electricity has only one path to follow. Circuits built in series act very differently from circuits built in parallel. In this activity you will build a series circuit and use your Volt-Ohm meter to see how series circuits respond.

Power Up

Follow the diagram to connect your batteries, switch and light bulbs in series using pieces of wire as needed. Now that you have a Volt-Ohm meter and have learned to use it, you can test the voltages across the batteries, the wire and the lights in the circuit you built. Answer the following questions, using your Volt-Ohm meter to make the test measurements (look at the diagram to see where to take the measurements.)



1. Using the VOM with the meter set on the lowest range and the dial set to DC volts, close the switch and measure the following:

Voltage across the first battery?
(leads attached at A and B) _________ volts DC

Voltage across the second battery?
(leads attached at I and J) _________volts DC

Voltage across both batteries?
(leads attached at I and B) _________volts DC

Voltage across bulb no.1?
(leads attached at E and F) _________ volts DC

Voltage across bulb no.2?
(leads attached at H and G) _________ volts DC

Total voltage across both bulbs?
(leads attached at E and H) _________ volts DC

2. Loosen bulb no. 1. What happened?
______________________________.

Make the following measurements with your Volt-Ohm meter (with the bulb still loosened) :

Battery voltage: (leads attached at I and B)
_________ volts DC

Voltage across bulb 1:(leads attached at E and F)
_________ volts DC

Voltage across bulb no. 2: (leads attached at H and G) _______ volts DC

Closing the Circuit

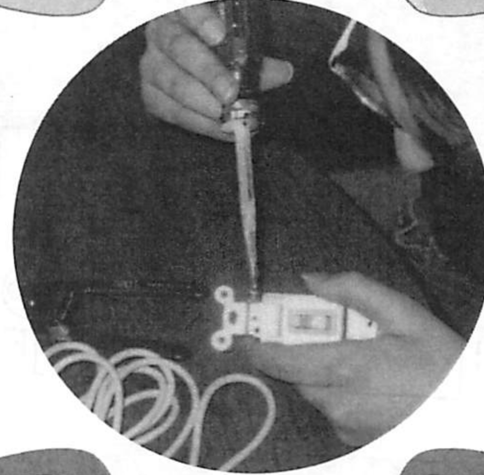
Now that you have built and worked with a series circuit, see if you can answer these questions:

- How did the voltage across the two light bulbs compare to each other and to the total battery voltage?
- How did the voltage compare when one of the light bulbs was loosened?
- What happens to the voltage across two batteries when you connect them in series?

The voltage across bulb #1 should be about the same as the voltage across bulb #2 and the total voltage across both bulbs should be the same as the total battery voltage (3 Volts).

When one of the bulbs is loosened, the voltage across the loosened bulb should be the same as the total voltage across the battery (3 Volts). The voltage across the unloosened bulb should be 0 Volts. When you put batteries in series their voltages add.

Can you explain why this happens? When you put the leads across the unscrewed bulb (at EF) the meter leads provide the path for the current and you read the 3.0 V. When you leave the bulb at EF loosened and measure voltage at HG, you have an open circuit due to the loose bulb, so you measure 0 V across HG.



Remember, NEVER read a resistance when there is voltage present in a circuit. You must open a switch or remove the batteries before reading resistance!

Brain Boosters

1. Add a third light to your circuit and test the voltage across each light. Explain to your helper what happened to the brightness of the light and why.

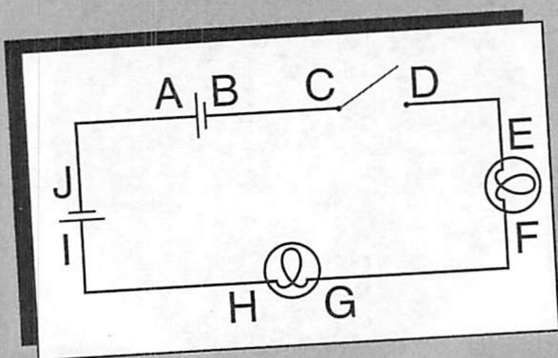
2. The only series circuits in a home are circuits designed for one load only (usually a large user of electricity), such as the hot water heater. What other household appliances are connected to a single series circuit?

French scientist, André M. Ampere, discovered that the magnetic effects produced by electricity could be used to measure electric current. The ampere, or unit of measure of an electric current, is named after him.

Glossary Words

- **Circuit**
- **Series Circuit**

Building a Series Circuit



Using the diagram shown, connect your batteries, switch and light bulbs in series following these steps:

1. Lay out the battery, switch and bulb holders as shown in the diagram. Mount this on a circuit board that is approximately one foot long and one foot wide. Glue the individual components to the board to help keep it better organized.
2. Cut five pieces of wire of the correct length to reach between the switch and the first light socket, the first socket and the second socket, between the second socket and one side of the first battery, between the first battery and the second, and between the other side of the second battery and the remaining side of the switch.
3. After the glue has dried on the circuit board you can begin to attach the wires between the parts completing your series circuit. When you have the parts wired in series, check to see if the switch, bulbs and batteries are all wired into a single circle which makes up the series circuit. You are now ready to test the circuit and to make some measurements with your Volt-Ohm meter, using it as a volt meter.
4. Close the switch to see if the light bulbs turn on. If they do not, go back and check the circuit diagram to see if you have your circuit wired correctly. Make sure all the connections are making good electrical contact and that the batteries and light bulbs are not burned out.
5. To check the batteries, set your Volt-Ohm meter to read DC Volts. Attach the red lead to the positive side of the battery (the end that sticks up) and attach the black lead to the negative side. If the battery is good the Volt meter should indicate a voltage near 1.5 Volts.
6. To check a light bulb with your Volt-Ohm meter, use the resistance or (Ω) setting, or the continuity setting (if your meter has one). With the meter set on (Ω), hold one lead on each side of the bulb holder. If the meter needle goes to the far right (on an analog meter) or does not give a number on a digital meter, than the bulb is no good and will need to be replaced. You can also check a light bulb by setting your meter on the continuity setting. Attach the meter leads across the bulb holder and the buzzer will sound if the bulb is good, indicating that you have continuity in the bulb. When you have your circuit working properly, you are ready to take your measurements.

Activity 8

Case of the Parallel Circuit

Activity:	***Build a parallel circuit and take measurements with a Volt Ohm meter***
Life Skill:	***Acquiring/Evaluating Information—Predicting outcomes and analyzing data***
Electric Skill:	***Using a Volt-Ohm meter***
Science Process Skill:	***Gathering data***
Success Indicator:	***Records data collected using a Volt-Ohm meter***
National Science Standard:	***Electrical circuits require a complete loop through which an electrical current can pass***

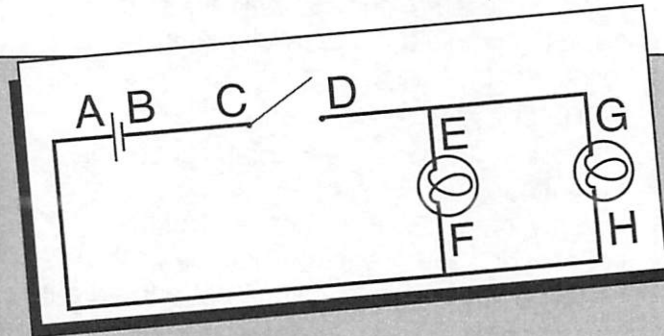
Tools

1 Volt-Ohm meter, 1 D-cell battery, 1 battery holder, 2 light bulbs, 2 light bulb holders, 1 switch, 1 wire stripper, 1 small screw driver to fit the screws in the bulb sockets, 2 feet of number 20 or 22 gauge hook up wire

When you connect two light bulbs in a parallel circuit each bulb burns as brightly as if only one bulb were in the circuit. How can this be? Your challenge as an Electric Detective is to use your Volt-Ohm meter to find out why this happens.

Power Up

Build the **parallel circuit** shown in the diagram and use your Volt-Ohm meter to take the measurements across each of the circuit components. With the meter set on the lowest voltage range and the dial set to measure DC volts, close the switch and measure the following:



Voltage across the battery
(place leads at A and B) ______ volts DC.

Voltage across bulb no. 1
(place leads at E and F) ______ volts DC.

Voltage across bulb no. 2
(place leads at G and H) ______ volts DC.

Loosen bulb no. 1. What happened?

____

____

____

____

With bulb no. 1 loose, make the following measurements:

Battery voltage
(place leads at A and B) ______ volts DC.

Voltage across bulb no. 1.
(place leads at E and F) ______ volts DC.

Voltage across bulb no. 2.
(place leads at H and G) ______ volts DC.

Explain your results to your helper.

Closing the Circuit

In your house, you have many electrical outlets wired on the same circuit. In your kitchen, you might have two sets of lights on the same circuit and each set has its own switch so that you can turn one on or off without effecting the other. Using two batteries in series, wire two light bulbs and two switches in the circuit so that you can control each light bulb separately.

Draw a wiring diagram showing how you did it.

Building a Parallel Circuit

Remove the wires from the circuit board you built in Activity 7, *Case of the Series Circuit.* Connect the lights in parallel as shown on the diagram.
Note: *For this circuit, you are using one battery so one of the batteries used in the series circuit will not be connected. It is OK to leave it attached to the board.*

The wires you used in the series circuit can be used here if they are the right length. If the wires are not the right length, you will need to measure, cut and strip some new wires to complete the parallel circuit. Be sure to include the switch in the circuit so you can turn it on and off.

Turn the switch on to see if both light bulbs burn. If they don't, check the wiring in the circuit with the diagram, check all of the connections and finally check to see if the battery and the light bulbs are not burned out.

When you have your parallel circuit working, you are ready to inspect your circuit using your Volt-Ohm meter and to make the measurements. Remember, if your meter doesn't read zero when you turn it on, check the owners manual to learn how to "zero" your meter.

Making Connections

Share With Your Helper

- ☐ How did the circuit diagram help you build the series circuit?
- ☐ What is the difference between the parallel circuit and the series circuit?

Process What's Important

- ☐ What do you think are the advantages and disadvantages of having symbols for circuit diagrams as compared to a more artistic drawing?
- ☐ What happens to the voltage across batteries when they are wired together in series?

Generalize To Your Life

- ☐ What are some of the important things to consider when you use instruments to collect data?
- ☐ Comparing series and parallel circuits, and remembering how light bulbs can go out, which circuit do you think would be better to use to wire the lights in your home? Explain.

Apply What You Learned

- ☐ How could you use what you learned about using symbols to communicate in another situation?
- ☐ If you were the electrician for a new home construction, where would you install series circuits?

Glossary Words

- **Parallel circuit**
- **Gauge**

The power delivered by an electric current determines whether it can run a computer, turn a motor, or light a lamp. Power is the rate at which work is done and is measured in Watts. The Watt was named after James Watt, a British engineer, who invented many improvements on steam engines. One Watt of power is equal to one ampere of current under a pressure of one Volt.

Brain Boosters

1. In this activity you learned to gather data using a Volt-Ohm meter. Another measuring device that is commonly used is a pressure gauge. Use a pressure gauge to measure the pressure in your bike tires or the tires on you family's automobile.

2. Explain to your helper why the circuits in your house that serve more than one outlet or appliance are wired in parallel instead of in series.

Activity 9

Circuit Sense

Activity:	*Build circuits and test voltages*
Life Skill:	*Reasoning—Applying principles to a process*
Electric Skill:	*Understanding voltage in circuits*
Science Process Skill:	*Recognizing and predicting*
Success Indicator:	*Determines voltages in circuits shown*
National Science Standard:	*Electrical circuits require a complete loop through which an electrical current can pass*
Tools	*3 feet of insulated wire, 2 light bulbs (3 volt), 2 light bulb holders, 2 D-cell batteries, 2 battery holders, 1 switch, Volt-Ohm meter*

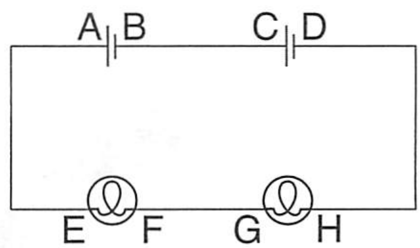
Now that you can read circuit diagrams and use a Volt-Ohm meter, you have the tools to start your first electrical investigation. In this activity you will use your skills in reading circuit clues, and your experience with series and parallel circuits, to discover what is happening in several different circuits.

Power Up

Look at each of the circuit diagrams. Guess what the voltage will be across each of the locations listed in the associated table. Remember that the voltage for D-cell batteries is 1.5 Volts. Build the circuits and measure the voltages to see if you were correct.

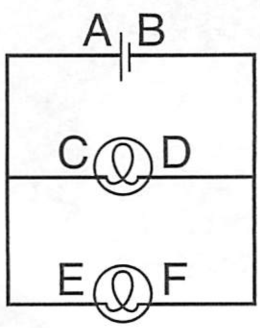
1

Voltage Across	Predict	Measure
AB		
CD		
AD		
EF		
GH		
EH		



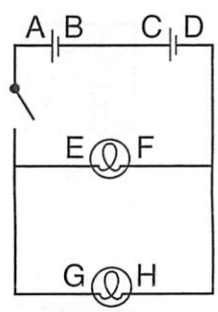
2

Voltage Across	Predict	Measure
AB		
CD		
EF		



3

Switch Open Voltage Across	Predict	Measure
AB		
CD		
AD		
EF		
GH		
EH		
Close Switch and Repeat		
AB		
CD		
AD		
EF		
GH		
EH		



Closing the Circuit

Connect a light bulb to a single D-cell battery. Measure the time it glows before it goes out. To do this, write down the time and date when you turned the bulb on, and check your bulb every few hours to see if it is still glowing. Keep notes each time you check on it. Record the date and time when you see it getting less bright, and record the date and time when it is no longer on. Note: this activity will use up your battery.

Next, connect two bulbs in series to a single D-cell battery. Record the date and time that you started your bulbs. Note that the two bulbs are less bright than the single bulb in the first observation. Again, check your circuit often and each time you check it record the date, time and what you see. Again, this experiment will use up your battery.

Which circuit burned for the longest time? Can you explain what happened?

Many different kinds of scientists have improved our understanding of electricity. Theoretical scientists, such as Albert Einstein, search for an understanding of the basic forces of nature and the laws that govern them. Applied scientists, such as Thomas Edison, use the laws that others discover and apply them to their inventions. Today we have refrigerators, electric heaters, televisions, computers and many, many more helpful things as a result of theoretical and applied scientists working together.

Short Circuit

If electricity is moving through a parallel circuit, and has a choice of going down a branch with a very high resistance OR a branch with a very low resistance, almost all of the current will take the path with less resistance. IF the low resistance path was not planned, it is called a **short circuit**.

To see what happens when a short circuit occurs, take a piece of insulated wire and strip about 1/4 inch of insulation off of each end. Next, tape the stripped ends of the wire to the battery terminals (or use your battery holder and make a circuit with a battery and a piece of wire.) Let the circuit sit for a minute and then feel the battery. Is it warm? Why? What do you think would happen if you left the wire connected to the battery for an hour?

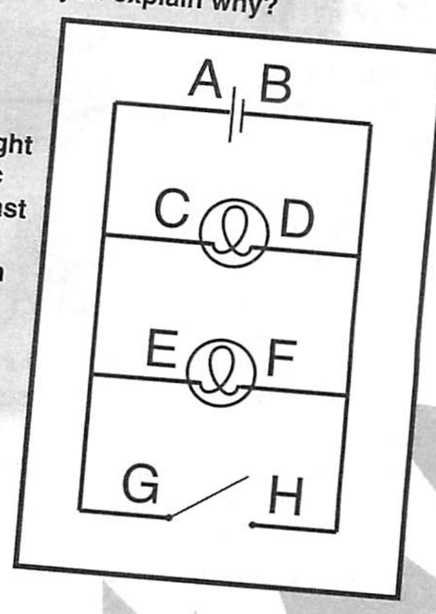
Answer: The circuit with a battery and wire does not have much resistance (remember, wire, which is made out of aluminum or copper, is a good conductor. So, according to Ohm's law, $i = V/r$, if r is a small number, i, the current, will be relatively large). The large current draw heats up the battery. If you left the wire connected to the battery for an hour, the battery would probably lose its ability to make electrical current.

Short circuits that occur in household circuits can cause fires. To disconnect these dangerous short circuits when too much current is flowing, household circuits contain either fuses that burn out, or circiut breakers that open, resulting in an open circuit. The open circuit stops the flow of electricity and the danger of fire.

Brain Boosters

Build the circuit shown. With the switch open, predict the voltages across the points listed, then measure the voltage and record the results. Next, predict what will happen when you close the switch. Try it and see what happens. Can you explain why?

(Hint: Which do think is better conductor—a light bulb filament or conducting wire?)



Closing the switch does not light the bulbs because the electric current takes the "path of least resistance" through the switch rather than through the light bulb filaments.

Glossary Words

- Short circuit

Activity 10

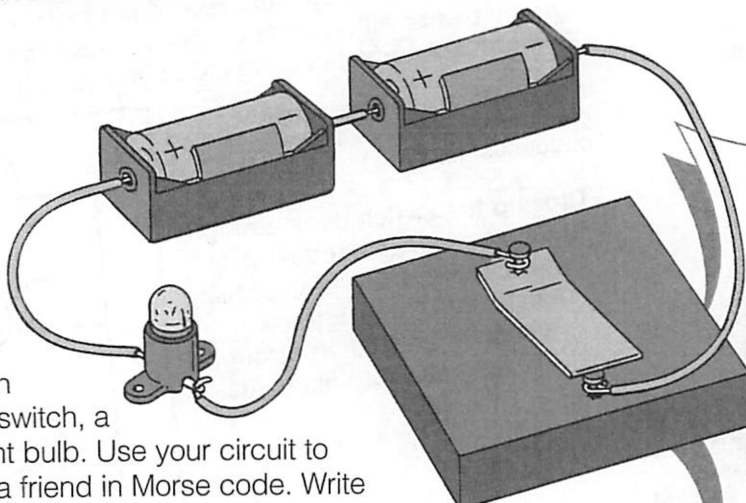
The Off and On Case

Activity:	***Build a momentary switch and use it to communicate in Morse code***
Life Skill:	***Reasoning—Applying principles to a process***
Electric Skill:	***Understanding momentary switches***
Science Process Skill:	***Communicating***
Success Indicator:	***Builds a circuit with a momentary switch***
National Science Standard:	***Electromagnetic waves result when a charged object is accelerated or decelerated.***
Tools	***2 feet of insulated wire, light bulb, light bulb holder, 2 D-cell batteries (1.5 Volts), 2½-inch nails, hammer, tin snips or strong scissors, clean tin-can lid, aluminum foil, 4 x 4 x 1-inch piece of wood***

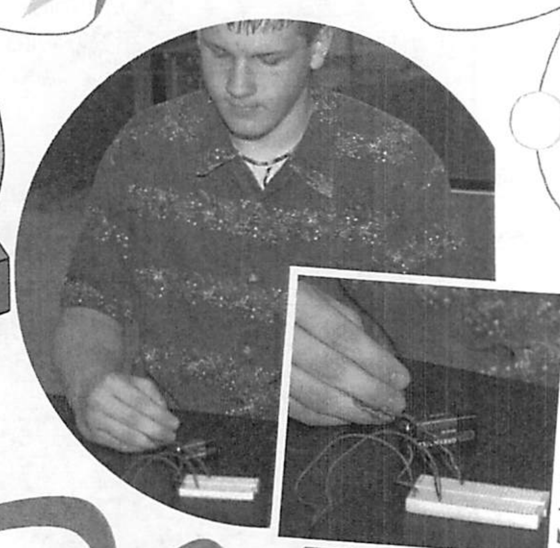
There is little mystery to the workings of switches. They are important because they can control a circuit by keeping it open or closed. They do this by interrupting or completing the continuous flow of electrons. **Momentary switches** are designed to open (or close) a circuit for a very short time—the length of time that the switch is pushed. In this activity you will build a momentary switch and use it to communicate in **Morse code**.

Power Up

Building a Momentary Switch



Build a momentary switch and then build a circuit with your momentary switch, a battery and a light bulb. Use your circuit to communicate to a friend in Morse code. Write down a short sentence on a piece if paper. Use the Morse code dots and dashes to send it to someone. Although old-time telegraphs used a buzzer to relay the dots and dashes, you will use the flashing light of the light bulb in your circuit to send your message.



1. Carefully cut a strip from the tin can lid about an inch wide and three inches in length. Cover the tin strip with aluminum foil (remember to be very careful in cutting the can, cover all sharp edges with the foil).

2. Hammer one nail into the wood block. Leave enough space between the head of the nail and the wood to wrap wire around the nail. Next, nail the tin strip into the wood as shown in the diagram. Wrap wire around the second nail.

3. Finish wiring the circuit as shown in the diagram.

4. Using the code provided, tap out a message and see if someone else (friend, family member) can decode it. Remember, a dot means the light is on very briefly and a dash means it is on longer. Practice a bit on dots and dashes before trying to send your coded message.

Glossary Words

- **Electromagnetic**
- **Momentary switch**
- **Morse Code**
- **World Wide Web**

Closing the Circuit

To illustrate how sparks were used to send Morse code messages, all you will need is a wool carpet, a doorknob and a radio.

Turn on the radio and tune it to a frequency where no signal is detected. The radio should broadcast a low level of static when the volume is turned up. Now, walk across a wool carpet, towards the doorknob, wearing a pair of shoes. Reach out and touch the knob while listening to the radio. What do you hear on the radio when you make a spark touching the doorknob?

Hint: *This works best on a dry, winter day when there is little moisture in the air.*

Sparks create a form of energy called an **electromagnetic** wave. This wave travels through space, and the antenna of the radio detects the energy. The signals it captures are carried along the radio wires to the circuitry, where they are turned into sound. The sound becomes amplified and is broadcast through the radio's speakers.

Brain Boosters

1. Morse code is one way that electricity has helped people communicate. Make a list of other ways that electricity is used in communication. Share your list with your helper.

2. Find out about other ways that momentary switches are used in electrical circuits.

Morse Code Circuit

Communication in our society has evolved into a highly technical science. Today, millions of people share information over a computer network known as the **World Wide Web** (www for short). The www is often called the "Information Superhighway."

Communication has advanced from its most modest beginnings. The first form of communication with which humans exchanged information was by "word of mouth." The great oral traditions of the Native Americans and other ancestors of modern cultures (European, the Middle East), date back many centuries. Written languages evolved and messengers carried important letters between nations during war and peace. Book printing emerged in the 1600's in Europe and even earlier in Asia. This greatly improved the storage of information but not the speed of its delivery. Horses gave way to boats which gave way to trains as a means of quick message delivery.

In the 1830's, Samuel Morse developed his plans for the telegraph. The telegraph used electrical circuits to transmit information. Morse created a "language," known as Morse code, that could utilize only one sound to send information. The code is made up of dots and dashes as in the box below. A dot means the sound lasts a short time and a dash means the sound lasts longer. Telegraphs make use of momentary switches, briefly making contact in the circuit for as long as the switch is held down.

Morse Code Diagram							
A	·–	H	·····	O	–––	V	···–
B	–···	I	··	P	·––·	W	·––
C	–·–·	J	·–––	Q	––·–	X	–··–
D	–··	K	–·–	R	·–·	Y	–·––
E	·	L	·–··	S	···	Z	––··
F	··–·	M	––	T	–	Comma	–··––
G	––·	N	–·	U	··–	Period	·–·–·

As the Titanic *sank, its radio officer sent out the SOS distress call using Morse code. Each letter required the click of the Morse code's key as it momentarily closed an electric circuit. This circuit produced a spark, which created an invisible, electromagnetic energy wave that traveled out from the sinking ship and was detected by the antennae of boats nearby. The antennae's signal was carried by wire to a receiver where the invisible waves were changed into a click that could be heard. Morse code has been used to communicate from ships, trains, military installations and many other places where verbal communication is difficult.*

Activity 11

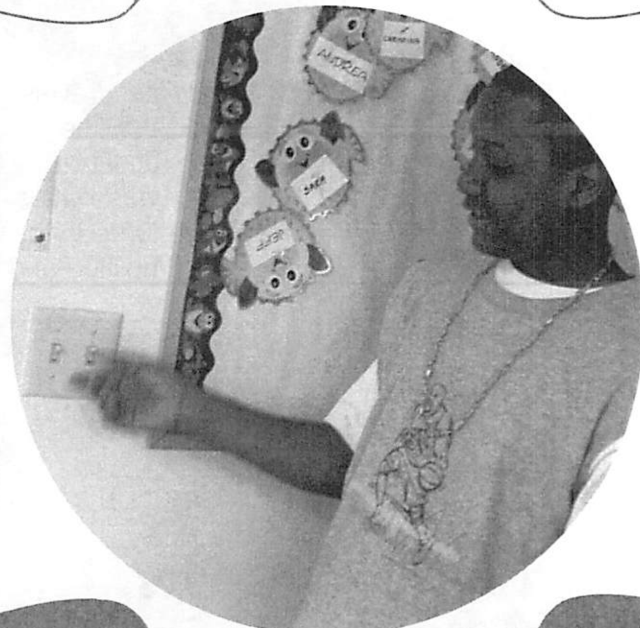
The Case of the Switching Circuit

Activity:	***Build a three-way switch***
Life Skill:	***Reasoning—Identifying facts and principles, and applying them to a process***
Electric Skill:	***Understanding three-way switches***
Science Process Skill:	***Recognizing patterns***
Success Indicator:	***Builds a three-way switch***
National Science Standard:	***Electrical circuits require a complete loop through which an electrical current can pass***

Tools

2 D-cell batteries (1.5V), 2 battery holders, light bulb, light bulb holder, 1 piece of cardboard (3 inches by 6 inches), 6 brass paper fasteners (brads), 2 feet of 24 gauge insulated wire

Have you ever noticed lights in a hallway or kitchen that can be controlled by more than one switch? You know, the ones that you can turn on from one wall switch and turn off from another? Did you every wonder how they work? The circuit you are going to build in this activity will control one light bulb with two switches. As you build and test this circuit, think about how it might be used in your house.



Power Up

Build two **three-way switches** on the same piece of cardboard. Test them to see how they work. The circuit shown in the diagram under *Building a Three-way Switch* can be built and used to test the switches. Now experiment with different combinations of switch settings, observing how the light reacts. Record your results in the table.

Switch Position		Result
Switch 1	**Switch 2**	**(Light On or Off?)**
A	B	
B	A	
B	B	
A	A	

Closing the Circuit

Are there any lights in your house that can be turned on and off from two places? Three-way switches can control one light from two locations. Search your home and see how many three-way switches you can locate. Why do you think they were put where they are?

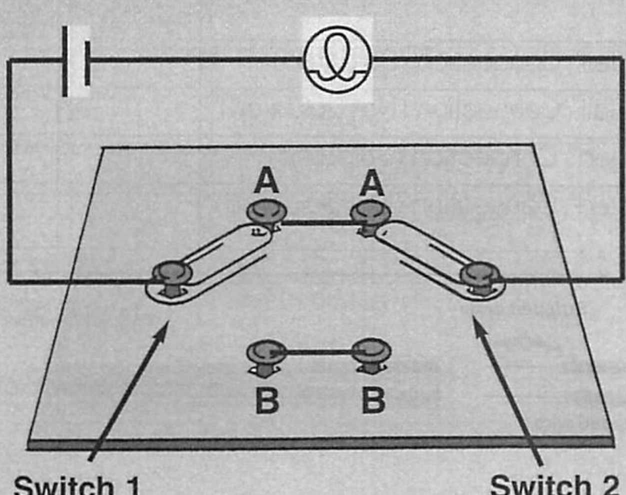
It is called a three-way switch because it has three wires. The wire that connects the two switches is called the traveler.

Some animals can make their own electric currents. Catfish use electricity to feel their way along the bottom of a stream or river. Electric eels, related to the catfish, can stun their prey with an electric shock. The eel produces strong shocks that reach 200 to 300 Volts. This shock can stun a horse or light a neon lamp!

Building a Three-way Switch

To build a three-way switch circuit:

1. Cut a piece of wire into five pieces, each 6 inches long. Strip the ends of each piece of wire about ½ inch.
2. The diagram provided shows a circuit that contains two, three-way switches. Start by building a simple switch using two brass paper fasteners and a paper clip. Next, add another brass paper fastener so that the switch can sit in two positions and touch one brass paper fastener when it is in one position, and the other brass fastener when it is in the other position.
3. Repeat step 2 so that you have two, three-way switches.
4. Add connecting wires as shown in the diagram.
5. Wire the battery and bulb to the switches as shown.



Making Connections

Share With Your Helper

- ☐ How did you make your momentary switch?
- ☐ How did you build a three-way switch?

Process What's Important

- ☐ Why do you think circuits in houses are generally wired in parallel instead of in series?
- ☐ What importance do you think switches have in electrical circuits? What would happen to a battery or light if we didn't use switches?

Generalize To Your Life

- ☐ Name some important uses of switches in your everyday life.
- ☐ Have you ever noticed that if you do something enough times you begin to be able to predict what will happen if the problem changes just a little? Name something you do every day where you know what is needed or how something will respond, even before you do it.

Apply What You Learned

- ☐ How do you see yourself using code to communicate with others in the future?
- ☐ As a scientist, it is important to recognize patterns so that you can apply what you already know to new situations. Look at the three-way switch that you built. Is it a parallel or series circuit? How do you know?

Brain Boosters

Think about the different ways that three-way switches are used in schools, homes, or businesses. Describe how three-way switches make our lives easier.

Glossary Words

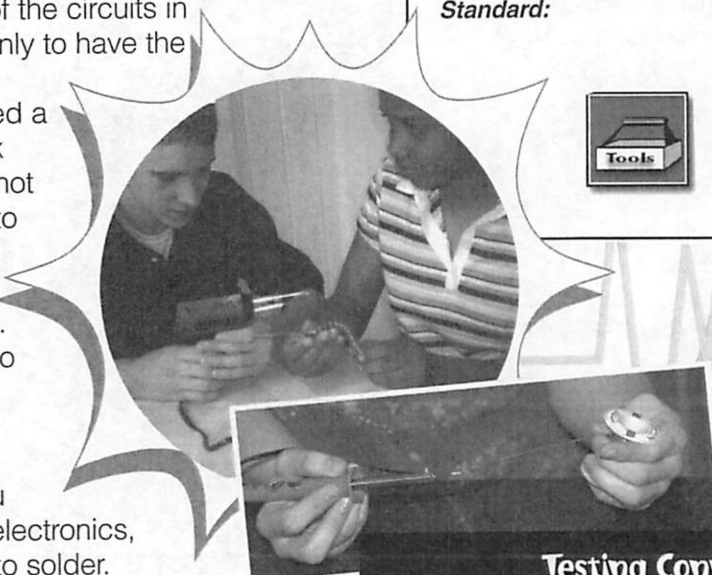
- **Three-way switch**

Stronger Connections

Activity:	***Solder connections and compare twisted wire connections***
Life Skill:	***Reasoning—Applying rules and principles to a process***
Electric Skill:	***Learning how to solder***
Science Process Skill:	***Experimenting—understanding the need for repeated trials***
Success Indicator:	***Solders and tests strength of connections***
National Science Standard:	***Electrical circuits require a complete loop through which an electrical current can pass***

Tools: ***Soldering iron, solder (a soft metal), 8 feet of insulted wire, pliers, sponge, safety goggles or glasses***

Have you built some of the circuits in this electric series, only to have the wires fall off of a battery connection? Have you tried a circuit and had it not work because something was not connected? The solution to these problems is called **soldering** (it is pronounced "soddering"). Soldering is a great way to make strong connections between two wires and between wires and other circuit components. If you want to build projects in electronics, it is important to be able to solder.

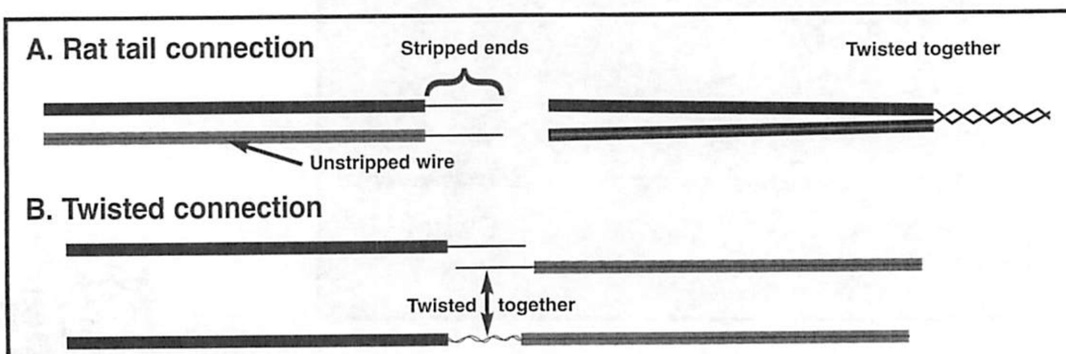


Power Up

Cut sixteen pieces of wire, each about six inches long. Strip one-half inch of insulation from one end of each wire. Make four rat tail connections, and four twisted connections (see below). Next, solder two of the rat tail connections and two of the twisted connections. Test the strength of each pair of wires by trying to pull them apart. Record your results in the data table. Write "poor" if it was very easy to pull apart, "fair" if it was somewhat hard to pull apart and "good" if it was very hard to pull apart.

Testing Connection Strength

	Test #1	Test #2
"Rat Tail" Connection (Soldered)		
"Rat Tail" Connection (Not Soldered)		
"Twisted" Connection (Soldered)		
"Twisted" Connection (Not Soldered)		



Electricity can be a useful tool, but it also can be very dangerous. Here are a few rules for the safe use of electricity:

- *Never touch anything electrical when your hands or feet are wet—water lowers resistance because it is a good conductor of electricity.*
- *Never run an electric extension cord or any other electric wire under a rug. If the insulation on the wire wears off, a short circuit might occur and could cause a fire.*
- *Never stand under a tree or near a pole during an electrical storm. Lightning may strike the top of the tree or pole and jump t o your body. Your body makes a better conductor than a dry tree trunk or a pole.*
- *Don't play "Benjamin Franklin" and fly a kite near a transmission line or during an electrical storm. Mr. Franklin was unusually lucky when he performed his kite experiment to show that lightning is electricity!*

Closing the Circuit

Look around your house and find at least two places where push button switches are used. Does the switch open the circuit or close it when it is pushed? How many push button switches did you find?

Keep your fingers away from the hot tip of the soldering iron to protect yourself. Always place the iron in a soldering iron stand and avoid breathing in the fumes of the melting solder. Wear safety goggles or glasses

Brain Boosters

1. Conduct a scientific experiment to measure solder joint strength on the two types of joints you made. How will you measure how strong a joint is? How many of each type of joint will you test? Prepare your data table and write you conclusion at the bottom of the table.

2. Why do you think circuit boards in computers and other electronic equipment are soldered? Explain your reasons to your helper.

Soldering

In order for an electrical circuit to work and for it to be safe, it is important that all electrical connections be tight. One method is to solder the connections.

To solder:

1. Work in a will-ventilated place on a surface that can be easily cleaned if solder drips on it. Remember to wear your safety goggles or glasses while soldering.
2. Heat up the soldering iron.
3. **"Tin"** the soldering iron by holding the solder against the tip of the iron. Hold it there until the solder begins to melt. As it melts, spread it over the whole tip surface to cover it well. Wipe the tip with a wet sponge.
4. Firmly press the soldering iron against the place to be soldered (where the two wires are twisted). Hold the iron at a 30 to 40 degree angle to the wires. Hold the solder next to the place on the wires where the iron is and wait until the solder begins to melt. Quickly move the iron tip away from the joint and allow solder to flow around it. Never apply more heat than is necessary to a piece of electrical work. Prolonged heat can ruin an electrical component.
5. Wait until the solder has cooled before moving the wires.
6. Inspect your work by tugging on the wires that have been soldered. A good solder joint is strong, bright and shiny in appearance.

Soldering tips:

- Do not burn the insulation on the wire
- A good solder job will have a smooth clean surface
- Do not use an excess of solder
- It takes a lot of practice to be good at soldering

(Adapted from Wayne Newhart, TIPMONT REMC)

Glossary Words

- **Solder**
- **Tin**

Activity 13

Stop the Crime

Any detective will tell you that possibly the easiest crime to solve is the one that never happens! This project lets you apply your knowledge of circuits to build a burglar alarm. Your alarm will alert you if anyone opens the lid of the box where the circuit is mounted.

Power Up

Shop for materials, build your burglar alarm and organize a talk to share with your friends how you built your alarm and how it works.

Activity:	*Build a burglar alarm*
Life Skill:	*Reasoning—Applies rules and principles to a process*
Electric Skill:	*Soldering and reading a circuit diagram*
Science Process Skill:	*Communicating*
Success Indicator:	*Builds burglar alarm and discusses it with a group*
National Science Standard:	*Energy is transferred in many ways*

Tools

The materials needed for this project were not included in the first activity. You can find all the things you will need at an electronics store. On-off push button switch, mercury switch (or other "tilt" switch)*, a vibrating or piezoelectric buzzer (make sure the buzzer will operate with a 9-Volt battery), 9-Volt battery, 9-Volt battery holder, 4- x 4- x 1/8-inch perforated board to mount circuit on, drill bits (1/8" and 1/4" or size of push button switch—see "Building an Alarm," step 2), rosin core solder, soldering iron, 2 feet of 22 gauge wire, wire strippers, hot glue sticks, hot glue gun, a box with a lid to mount your burglar alarm circuit on, dowel rods or other wooden "legs" to hold Board.

** Mercury is a poisonous metal. However, the mercury is contained in the switch so that you will not be exposed to it. Radio Shack does not carry mercury switches, but other companies such as Moser do.*

Making Connections

Share With Your Helper

- ☐ Demonstrate to your helper how to solder a joint.
- ☐ How did you build your burglar alarm? What was the hardest part?

Process What's Important

- ☐ Explain why soldering is important in building electronic equipment.
- ☐ How does a mercury switch work? Why do you need one to build a burglar alarm?

Generalize To Your Life

- ☐ Why do you need to conduct more than one test in order to be able to contain results you can trust?
- ☐ Name three places where burglar alarms are used. What other types of alarms are there?

Apply What You Learned

- ☐ What did you learn about speaking to others that you could use the next time?
- ☐ What skills do you need to develop to become an even better decision-maker?

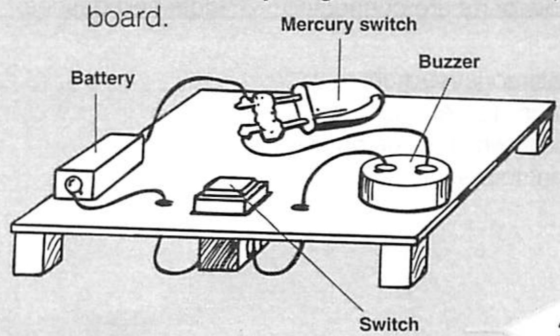
Electricity is found in almost every home, school, or business in the United States. It is a form of energy that provides us with light, heat and power. We use electricity to run everything from electric toasters and microwave ovens to giant telescopes and space stations! Congratulations on learning more about a wonderful resource—electricity!

Building an Alarm

1. Layout the buzzer, battery holder, push button switch and **mercury switch** on perforated board according to the circuit diagram.
2. Drill a hole in the board to slip the push button switch through. You can accomplish this by using drill bits without the drill. Turning a small diameter bit with your fingers, drill a small hole. Use a larger bit to enlarge the hole. The perforated board is soft enough that you can make the holes easily. You may want to ask your adult helper for help with this step.
3. Cut three pieces of wire of the correct lengths to:
   - attach from one lead of the mercury switch to one terminal of the on-off switch. You will have to push the lead through the board since the terminals of the push button switch are below the board.
   - attach from the other terminal of the on-off switch to the negative terminal of the battery holder. Bring the lead up through the board.
   - attach from the red lead of the buzzer to the positive lead of the battery holder.
4. Attach the black lead of the buzzer to the remaining lead of the mercury switch. This completes the series circuit. Check to make sure you have wired it correctly before proceeding to the soldering steps.
5. Plug in the soldering iron and let it heat up.
6. Solder the following joints:
   - wire to mercury switch lead
   - wire to each terminal of the on-off switch
   - wires to connection to battery holder
   - red lead of buzzer to positive terminal of battery holder
   - buzzer black lead to mercury switch
7. Unplug the soldering iron.
8. Test the circuit:
   - turn the push button switch on and put the mercury switch in the on position and then the off position. When the push button switch is on, the mercury switch should turn the buzzer on and off when tilted back and forth. This test is to see if the circuit will work before it is mounted to the inside of a box lid.
   - next, turn the push button switch to the off position and switch the mercury switch on and off. The alarm should not sound.
9. Position the circuit to its final location on the perforated board. Hot glue the following:
   - the lead of the mercury switch to the perforated board. Glue the leads so that the angle of the mercury switch glass bulb can be adjusted to turn on when the lid of the box is moved.
   - the buzzer and battery holder to the perforated board.
   - the four wooden spacers in each corner of the board. The spacers make room for the push button switch to stick out below the perforated board.

Be careful with hot melt glue. It is hot and can burn you. Ask an adult for help.

10. Mount the perforated board circuit board onto the inside of the box you want to protect with the alarm circuit by hot gluing the four wooden spacers to the lid. A pencil box works well. Any box with a hinged lid is fine.
11. Adjust the mercury switch so that the alarm will sound when the lid is opened. This adjustment is made by bending the leads to the mercury switch where you glued them to the perforated board.



Glossary Words

- **Mercury switch**
- **Piezoelectric**

High Voltage 2 Glossary

A

Alternating current (AC) – Electrical current where the flow of electrons change direction. In the US the flow changes 60 times per second. All typical electric power is generated and transmitted to homes and industry as alternating current.

Amperes (amps) – A unit of measure for electrical current, named for Andre Ampere. 6,200,000,000,000,000,000 (6.2 x 1018) electrons passing a point in one second equals one amp.

Amperage – The rate of flow of electrical current.

Analog – A continuous read-out, like the face of a clock, or a meter that uses a needle to point to a scale. Opposite: digital, which takes on discrete numbers.

Analogy – Comparison to something similar.

C

Circuit – A path followed by electrons from the point they leave an electrical source, such as the negative terminal of a battery, until they return to the source, which is the positive terminal of the battery.

Conductor – A material that allows electrons to flow easily (with little resistance).

Coulomb – A unit of electricity equal to the charge carried by about 6.3 billion billion electrons. Also stated as the amount of electricity furnished by a current of one ampere in one second.

Current – The flow of electrons in an electrical circuit; analogous to the flow of water through a pipe.

D

Diagram – A drawing or chart, such as a wiring diagram, showing how parts are connected or put together.

Digital – A continuous read-out that gives a reading in discrete numbers. Opposite: analog, which takes on uses a needle to point to a scale.

Direct current (DC) – Current, usually from a battery, where electrons flow in only one direction.

E

Electrical continuity – A completed circuit has a continuous flow of current. Any break in a circuit, such as when a switch is opened, or a light bulb burns out, causes a lack of continuity.

Electrical resistance – Opposition to the flow of current in a circuit.

Electromagnetic – Magnetism produced by the passage of an electric current.

G

Gauge – Usually a device to measure something, such as inflation pressure in a tire, or the flow of electrical current in a circuit.

H

Hertz – A unit of frequency, equal to one cycle per second.

I

Insulator – A material that provides a very high resistance to the flow of electrons.

M

Mercury switch – A switch that uses liquid mercury to complete the circuit.

Momentary switch – A switch that stays closed only as long as it is held closed; usually used where a closed circuit is desired for only a very brief time.

Morse code – The basis for the telegraph, invented by Samuel Morse. A momentary switch is closed to produce a short (dot) or long (dash) electrical flow, with each letter of the alphabet having its own pattern of dots and dashes.

O

Ohm – A unit of measure of electrical resistance, named for George Ohm, who also discovered the close relationship between voltage, current and resistance.

Ohm's law – Current (amps) equals voltage (volts) divided by resistance (ohms).

P

Parallel circuit – A circuit that provides several paths through which electrons may flow. It differs from a series circuit in that the electrons have more than one path to follow. At the point where the circuit divides into more than one path, the number of electrons going each way depends on the resistance of the load in each path.

Piezoelectric – Alternately expanding and contracting in response to an alternating electric field.

R

Resistance – The degree to which a substance retards the passage of an electric current.

S

Series circuit – A single path through which all the electrons must pass.

Short circuit – A mistake in wiring where the electrons flow in a path without going through the intended load, such as a light bulb or motor.

Solder – A metal used when melted for joining or patching metal parts or surfaces; also, the act of joining metal objects with solder.

Super conductor – A material that conducts electricity, even at extremely low temperatures approaching absolute zero (–273 degrees Celsius).

Symbol – A mark or simple design representing something more complicated. Electrical symbols are used in circuit diagrams.

T **Three-way switch** – A switch designed so that with two of them in a circuit, the current can be switched on or off from either switch location. For example, a room with two doors often has a light controlled by a three-way switch near each door.

Tin – To cover or plate with tin.

Transformer – A device containing no moving parts and consisting essentially of two or more coils of insulated wire that transfers alternating current energy by electromagnetic induction from one winding to another at the same frequency but usually with changed voltage and current values.

V **Volt** – A measure of the potential electrical force to push electrons, named after Alessandro Volta.

Voltage – The amount of force causing an electrical current to flow, usually measured as volts.

Volt-Ohm meter – A device that can be used to measure both voltage and electrical resistance.

W **World Wide Web** – The Internet, or the inter connection of telephone communication systems, which makes e-mail communication possible throughout the world.

Answers - Investigating Electricity

Closing the Circuit, page 11

The Volt-Ohm meter had to be set on **Volts**-DC. The reading should be 1.5 V. The red lead had to attach to the positive battery terminal (the one that sticks out). The voltage across two batteries placed together (they have to be placed so that the end that sticks out of one touches the recessed terminal of the other—positive to negative) should read 3.0 V.

Brain Booster, page 11

- The battery provides the energy for the circuit
- The light bulb is the electrical load
- The wires provide a path for the electricity
- The electrons travel from the battery through the wires, closed switch and bulb, back to the battery.
- The switch allows you to control the flow of electricity by opening and closing the path of electricity.

Closing the Circuit, page 13

I=v/r = 3/1000 = 0.003 amps

I = v/r = 3/2000 = 0.0015 amps

I=v/r = 6/2000 = 0.003 amps. That's the same as two batteries and one bulb. If you can share materials with a friend, you can build one circuit with two batteries and one bulb and see if it is the same brightness as a circuit with four batteries and two bulbs. This will prove that Ohm's law really works.

Brain Booster, page 13

- The flow of water corresponds to the flow of electricity.
- The resistance due to the spicket setting and hose corresponds to electrical resistance.
- Water pressure corresponds to voltage.
- You cannot change the water pressure but you can change the resistance.

Power Up, page 20

1.5 V, 1.5 V, 3V, 1.5V, 1.5V, 3V

Bulb number 2 went out, 3V, 3V, 0V

Power Up, page 21

- *Voltage across A and B: 1.5V*
- *Voltage across E and F: 1.5V*
- *Voltage across H and G: 1.5V*

When you loosen bulb one, it goes out, but bulb 2 remains lit
With bulb one loosened the following are measured:

- *Battery voltage: 1.5V*
- *Voltage across bulb 1: 1.5 V*
- *Voltage across bulb 2: 1.5V*

Closing the Circuit, page 24

Remember, Ohm's law? i = v/r? For the first circuit, the voltage, V, is 1.5 V and the resistance, r, is 1000 Ohms, so the current is 1.5/1000 = 0.0015 amps

For the second circuit, the voltage is still 1.5 V, but the resistance is 2000 Ohms (since you have 2 bulbs in the circuit). Now you have 1.5/2000 = 0.00075 amps, or half the current in the previous circuit. Since the battery is only producing half as much current, it will last twice as long!

Power Up, page 24

Circuit 1: AB 1.5V; CD = 1.5V; AD= 3.0 V; EF = 1.5 V; GH = 1.5 V; EH = 3.0 V

Circuit 2: AB = 1.5 V; CD = 1.5 V; EF = 1.5 V

Circuit 3:

Switch open: AB = 1.5 V; CD = 1.5 V'; EF ; AD = 3.0; EF = 0; GH = 0; EH = 0

Switch Closed: AB = 1.5; CD = 1.5; AD = 3.0; EF = 3.0; GH = 3.0; EH = 3.0

Closing the Circuit, page 31

The push-button switch in a refrigerator or freezer turns the light off (opens the circuit) when the door is closed.

A doorbell switch closes the circuit when pushed.

Push button switches are found in music boxes, car doors, and other home appliances.

Electric Resources

Electric Power Suppliers

Start with your local utility or electric cooperative. These companies often have educational materials, presentations and tours geared to youth.

National Electric Associations

The Information and Electrical Technologies Division, ASAE
The Society for engineering in agricultural, food, and biological systems,
2950 Niles Road
St. Joseph, MI 49085-9659
Phone: 616-429-0300
http://www.ASAE.org

Institute for Electrical and Electronics Engineering (IEEE)
Website: http://www.IEEE.org
www.4hengineering.org

National Food and Energy Council
601 Business Loop 70W, Suite 216D
Columbia, MO 65203
Phone: 573-875-7155
www.nfec.org

Exploring Electricity on the Internet

Using one of the 'search engines', look for 'electricity' references on the Internet. Your helper can aid you in selecting useful sources from the dozens of available sites.

Cooperative Extension Service Resources

Ask your land grant university's county extension office for information on electricity.

4-H Electric Excitement Series

Five 4-H publications are available for learning about electricity, magnets and electronics:

Magic of Electricity
Investigating Electricity
Wired for Power
Entering Electronics
Electric Helper's Guide

Electric Resource Catalogs

American Association for Vocational Instructional Materials (AAVIM)
220 Smithonia Road
Winterville, GA 30683
1-800-228-4689
www.aavim.com
Catalog includes books (#305.2 Electrical Wiring, #303.2 Understanding Electricity and Electrical Terms, #302.2 Electric Motors, #306.2 Electrical Controls), manuals, videotapes and software.

Herbach and Rademan Company
16 Roland Ave.
Mt. Laurel NJ 08054-1012
1-800-848-8001
www.herbach.com
Catalog includes parts, kits, etc.

Instructional Materials Laboratory (IML)
University of Missouri
1-800-669-2465
http://www.iml.coe.missouri.edu
Catalog includes books (*Wiring Simplified* - IML #10-7721-S, *Basic Electrical Wiring* - IML #70-2071-S, and *Residential Wiring* - IML #70-2072-S) and instructor manuals.

Pitsco, Inc.
1002 E. Adams
PO Box 1708
Pittsburg, KS 66762-1708
1-800-835-0686
www.pitsco.com
Request a catalog of electric books (Level 1 #40668 *Electricity: The Way it Works* by Neil Ardley, #40813 *Electricity* by Dan, Dave and Dean Mackie, #40848 *Electricity and Magnetism* by Peter Adamczyk and Paul-Francis Law, #G51054 *Electricity: The Usborne Young Scientist*, #G50955 *Physics: An Usborne Introduction* by Amanda Hunt; *Do Your Own Wiring* by M. E. Armpriester; Level 4 *Understanding Electronics* by R. H. Warring) and other educational supplies. (Note - these publications may also be found in libraries and bookstores.)

Mouser Electronics
958 N. Main Street
Mansfield, TX 76063-4827
1-800-346-6873
www.mouser.com

Radio Shack
300 W. Third St., Suite 1400
Fort Worth, TX 16102
1-800-613-7080
www.radioshack.com
Catalog includes most electronic parts

Electronic References

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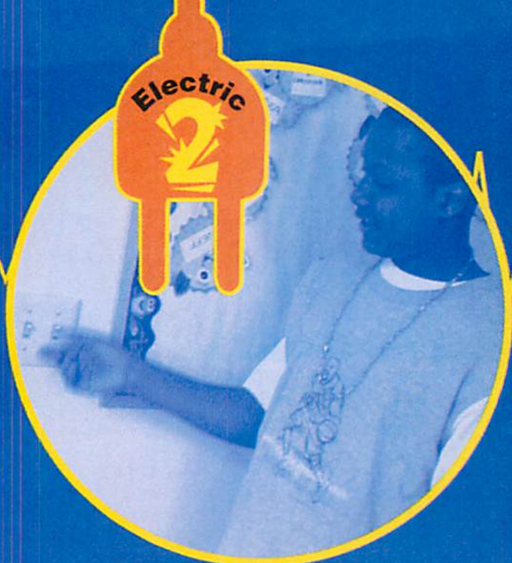

The 4-H Pledge

I pledge
my Head to clearer thinking,
my Heart to greater loyalty,
my Hands to larger service, and
my Health to better living,
for my club, my community,
my country, and my world.