



Electricity

Grade Level: 3-6

Group Size: 20-30

Time: 45-60 Minutes

Presenters: 3-5

Objectives

This lesson will enable students to:

- Observe positive and negative charges
- Visualize static electricity
- Generate electricity using a lemon battery
- Build a circuit
- Build and identify series and parallel circuits

Standards

This lesson aligns with the following National Science Content Standards:



- Science as Inquiry, K-4
- Physical Science, K-4

This lesson aligns with the following Next Generation Science Standards (NGSS):



- Physical Science: PS2: Motion and Stability: Forces and Interactions
- Physical Science: PS3: Energy

Materials

Introduction

- “Electricity” Presentation (overhead slides or flash drive)
- Clear 2-liter soda bottle
- 2-3 feet of surgical tubing (small diameter)
- Soda bottle top with hole drilled slightly smaller than the surgical tubing
- Shallow dish pan or bucket
- Food coloring
- Water

Van de Graaff Generator demonstration

- Van de Graaff Generator and plug strip
- Play-action doll with long hair (e.g. Barbie®)
- Small aluminum pie plates

Static Electricity Activity

- Balloons
- Small bits of cut paper
- Cellophane adhesive tape
- Ping pong balls
- Empty aluminum can
- Round oat cereal pieces
- String or thread
- 6” Plastic ruler

Lemon Battery Activity

(need one setup per two students)

- Multimeter
- 1 D-Cell Battery
- 2 alligator clip wires
- 1 lemon
- Other citrus fruit, if desired
- 4-inch galvanized nails (1 per fruit)
- Copper rods (1/8” dia. X 4”) (1 per fruit)
- “Lemon Battery Series/Parallel Data Sheet” – Appendix A

Circuits Activity

(recommend one item per pair of students)

- D-cell battery
- Battery holders with Fahnestock clips
- Small bulb and bulb holder
- Wires with alligator clip connectors OR
- 6-inch pieces of wire with ends stripped
- Electric buzzers
- Small motors

Preparation

Set up each of the stations with the necessary equipment. Request the teacher divide the class into four groups and assign one presenter to each group. At the end of the introduction have the class divide into the groups and go to the assigned station. The students will work at each station approximately 10 minutes and then will rotate to the next station.

Introduction

Have all volunteers introduce themselves. Use the Electricity presentation for the introduction.

Today we are going to talk about electricity.

Q: What items in your classroom use electricity?

A: *Encourage participation. Answers will include the obvious like lights and the computer, but encourage them to think of things they might not realize use electricity such as the intercom for announcements, clock, bell, etc.*

Q: What happens when there is a bad storm and the power goes out?

A: *Answers will vary.*

Q: Do you know how electricity is made?

A: *Answers will vary.*

Today's lesson is about positive and negative charges and how electricity is made.

Q: Who knows what electricity is?

A: Electricity is the movement of electrons. Every single item in the whole world is made up of tiny, tiny things called atoms. Electrons are inside each of these tiny atoms circling around the nucleus.

Pull out one hair. Atoms are so small that it takes a million of them to stretch across the width of one hair.



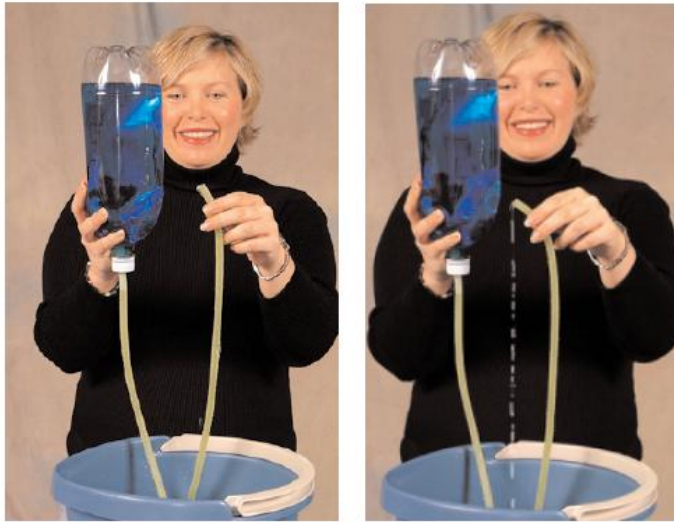
Q: What type of a charge do electrons have?

A: Electrons have a negative charge. Most electrons stay attached moving around the nucleus of their own atom, but in conductive materials some of their electrons can easily move from one atom to the next. As electrons move from one atom to the next they generate an electric current.

Q: What do you think the word current means?

A: Current is defined as a steady flow, as in water, air or electric charge. You have probably observed water current in a river or stream. When electrons run or flow through conductive material it is known as an electric current.

Water Demonstration



Fill the clear bottle $\frac{3}{4}$ full with water, add food coloring, and assemble it with the tubing as shown.

To visualize the concept of electricity, electrons, and electric current, envision electrons as water. The water in the bottle represents electrons. Water movement through the tube represents the flow of electrons that is electrical current.

Hold the tubing higher than the bottle.

Q: Is the water coming out of the tube?

A: No.

Describe where the water is in the tube.

Q: What do I have to do to make the water move through the tubing?

A: Move the height of the tubing below the height of the water.

We say the water has the “potential” to come out of the tube. This is like voltage. Voltage is the potential for the flow of electrons.

Q: Where would I hold the tubing to create a slow stream of water through the tubing?

A: Slightly below the level of the water in the bottle.

Q: Where would I hold the tubing to speed the flow of the water?

A: Move the end of the tubing further away from the level of the water in the bottle.

The greater the distance, the more potential there is for the flow.

Q: What are we comparing the flow of water to?

A: The flow of water is like the flow of electrons through conductive material.



Let's think about what is happening as we change the height of the tubing in relation to the level of the water in our bottle. As we raise the tubing higher we decrease the potential for the water (or electrons) to flow through the tubing. As we lower the tubing we increase the potential for flow. This change in potential relates to another electrical term called voltage.

Voltage is defined as the difference of electrical potential between two points of a conductor carrying a current.

Q: What does that mean?

A: For our example we know the current is the flow of water, which represents the flow of electrons. The difference of potential is then the difference between the height of the opening at the end of our tubing and the level of water in the bottle. When there is no difference between their heights or level there is no flow of water (or current). When there is a large difference, with the tube lower than the level of water, there is a maximum flow of water (or current). The difference between the water level in the bottle and the height of the tube represents the potential for the water to flow. When working with electrons, rather than water, this potential is called voltage. Voltage represents the amount of potential there is for electrons to flow. Volts measure the "push" of electric current. The higher the voltage, the more pressure there is to push the current through the wire.

Q: How could you increase the volume flow rate of the water that comes out of the bottle?

A: You can increase the flow rate by increasing the size of the tubing.

Think about the cords used for electrical devices.

Ask students to compare the size of a cell phone charger's electrical cord to that of a power tool.

Q: Which cord carries more current?

A: The thicker cord carries more current. The size of the cord (or the diameter of the tubing) determines how much current (water) can flow through a line.

The flow of electrons is called the current. The amount of current flow is measured in amperes (amps). In our demonstration, amps can be likened to the measure of how much water moves through the tubing over time. One amp is equivalent to 6.24 million trillion (6.24×10^{18}) electrons moving past one point in one second.

To summarize:

- Current is the flow of electrons through a conductor (water flowing through our tube in this demonstration).
- Voltage is the potential for a conductor to carry current (height of the tube in relation to the water level in the bottle).
- Amps measure the amount of current flow (how much water flows through our tube).

Conductivity

Some materials make good paths for electric current, and others block electric current.

Q: What does it mean for a material to be conductive?

A: It means that current runs through the material easily. The electrons are loosely bound, and travel easily from atom to atom.

Q: In our demonstration what type of material would the tubing have to be if we wanted electricity to flow through it?

A: A conductive material.

Q: What are some examples of conductive materials?

A: *Help the students think of materials that transmit electric current.* Examples include: gold, copper, aluminum, titanium, and other metals.

Q: What is the opposite of a conductor? Who can give an example?

A: Insulators are the opposite of conductors. Insulators are materials that have tightly bound electrons, and electric current does not pass through them. Some examples are plastic, wood, rubber, glass, and cardboard.

Electricity exists in nature because the atoms and molecules that make everything up are characterized by their charge. Electricity can be generated through mechanical or chemical action. In the activity stations today we will explore static electricity, magnets, batteries and building circuits.

The Van de Graaff generator demonstration on the next page can be done as part of the introduction or incorporated into the Static Electricity activity station.

At the end of the introduction have the class divide into the four groups and go to the assigned stations. The students will work at each station approximately 10 minutes and will then rotate to the next station.

Van de Graaff Generator demonstration

The demonstration of the Van de Graaff generator can be done as part of the introduction, as part of the conclusion, or added to the Static Electricity activity station.

Plug the generator into a plug strip so that there is an on/off switch.

Explain to the students that the generator creates static electricity because there is a rubber conveyor belt inside that strips electrons off of the roller it goes around, similar to the cellophane tape demonstration in the static electricity activity. The electrons are gathered by a metal brush and distributed to the metal sphere. The cord that goes to the wand sphere takes the oppositely charged particles to the other sphere.

Q: Since the spheres have opposite charges on them, what do you expect will happen when the wand sphere is placed close to the generator?

A: The opposite charges will attract to each other.

Turn on the generator and bring the wand close to it, producing a spark. You can also cause sparks by moving your hand close to the generator, resulting in a mild shock. You may want to dim the lights for the full effect!

We see the attraction of charges as a flash, much like lightening. This is how lightening works. One type of charge accumulates in the upper atmosphere, and then it is attracted to the opposite charge on the ground, or a building, or your umbrella!

Crazy Hair

1. Sit the toy doll next to the generator and turn it on. Enjoy the crazy hair show!
2. With the generator off, have a student gently put a hand on the sphere. Turn the generator on and watch the crazy hair! (caution – don't touch the student, you will both receive a shock!)

Flying Pie Plates

1. With the generator off, place the aluminum pie plates on top of the sphere.
2. Turn the generator on, and observe the plates.

Q: What is happening?

A: The pie plates are flying off of the sphere because as they accumulate the same charge, they repel each other.

Have fun with the generator. A note of caution, some children can receive an uncomfortable static shock if they touch it. Instruct them to approach the generator with their elbow if they want to receive a mild, yet bearable, shock!

Static Electricity

We are going to talk about static electricity. Before we describe what it is, let's talk about what it does.

Q: How can you tell if static electricity is around you?

A: *Encourage students to describe any experiences they may have had with static electricity such as their hair standing on end after they have brushed it a lot, or clothes clinging to their body when they have been dried in a dryer without conditioner, or shocking themselves when they shuffle across a carpet and touch a doorknob.*

Q: How is static electricity different from an electric current?

A: Static electricity is electrons that are transferred from one place to another rather than flowing in a current. If some of the electrons are transferred from one object to another by vigorous rubbing and separation, the other object becomes negatively charged while the object that loses electrons becomes positively charged. Remember, electrons are negatively charged particles. An electric field is set up around each object.

Unlike charges, one negative and one positive, always attract each other; and like charges, both negative or both positive, always repel each other. Rubbing or brushing creates a charge and, therefore, an electric field. The field affects objects nearby, producing an unlike charge in them, and the unlike charges are drawn together.

Generate Static Electricity Using Cellophane Tape



Vigorously pull off two strips of cellophane tape about 8 - 12 inches long. Hold the strips of tape at the top with the non-adhesive sides together and ask the students to observe what is happening.

Q: What is happening with the tape?

A: The two pieces repel or push away from each other. When you pull the tape off of the roll, the piece that is torn off loses electrons, thus both pieces have a positive charge and repel each other.

Q: What do you think will happen to the charges when I insert my hand between the two pieces of Scotch tape?

A: *Answers will vary.*

Slowly insert your hand between the two pieces of tape, and then slowly remove your hand. Next, bring a finger near one of the strips of tape from the outside, careful not to get stuck to the sticky part of the tape.

Q: What's happening? What's causing it to happen?

A: The strips of tape move to the hand. The hand is neutral, and contains both positive and negative charges. The charged pieces of tape are attracted to your neutral hand.

If there is time, give each student two strips of tape about 2-3 inches long and stick one on the index finger of the right hand, the other on the thumb of the right hand (sticky sides facing away from one another). Encourage the students to observe how the two pieces of tape repel each other due to the positive charges on both pieces of tape.

Generate Static Electricity Using Balloons

Have a few balloons already blown up.

1: Rub the balloon back and forth several times on your head and then touch the balloon to your hair.

Q: What happens when you do this, and why?

A: Your hair is attracted to the balloon, and it stands on end. The balloon has collected electrons, making it negatively charged, leaving your hair with all the opposite charge. You might notice that even after you take the balloon away your hair may still stand on end. That is because since your hair now has the same charge, the strands repel each other.



You can also rub the balloon on other things to gather a static charge, such as your sleeve, the carpet, etc. You need to rub the balloon on a synthetic material to create static electricity. Cotton clothing or hair with conditioner will not give the desired results. Materials that are good generators of static are polar fleece, nylon, and polyester.

Static electricity will also pick up small particles.

Put out a few piles of small bits of paper.

2: Hold your static charged balloon over the pile of small bits of paper and observe how many pieces the balloon attracts.



Q: What happens when you do this?

A: Again, you have a negatively charged balloon. The negative charge induces a positive charge on the paper, creating the attraction and the paper 'jumps' to the balloon.

3: Hold your static charged balloon slightly above and to the side of a ping pong ball on a smooth surface. Observe what happens to the ping pong ball. Be sure the balloon is not directly to the side of the ball, but slightly above it and to the side.

The ping pong ball should roll toward the balloon.

4: Hold your static charged balloon to the side of an empty aluminum can on a smooth surface.

Q: What happens when you do this?

A: In a metal, the negatively charged electrons are free to move around inside the metal (metal is conductive). The negatively charged balloon repels those negative electrons to the other side of the can, leaving a positive charge on side of the can near the balloon. The can is more strongly attracted to the balloon than the ping pong ball, because the electrons were not as free to move in the ping pong ball material.

5: Tie a round oat cereal piece to the end of a string. Hang the cereal piece near the charged area of the balloon.

Q: What happens when you do this?

A: The negative charge on the balloon induces a positive charge on the cereal, creating an attraction so that the cereal will stick to the balloon.

You can repeat the above steps 2-5 using a small plastic ruler instead of a balloon. Simply rub the ruler on your clothing or carpet to create a negative charge on the ruler and experiment with steps 2-5.

Lemon Battery

Hold up an alkaline battery.

Q: How does a battery work?

A: Within a battery a chemical reaction takes place between an electrolyte (such as a liquid acid or dry chemical) and electrodes. The electrodes are two different conducting materials, such as copper or zinc. Atoms from one conductor travel through the acid to the other conductor, releasing electrons. When all the mobile atoms have been transferred, and no additional electrons may be released, the battery is “dead.”

Q: How many volts of electricity does a D cell battery generate?

Measure the voltage of the alkaline D cell battery. The voltage measurement should be close to 1.5 volts if the battery is good.

A: 1.5 volts of electricity.



Build a Lemon Battery

We are going to build a wet-cell battery like those used in cars, but the electrolyte for our battery will come from a lemon.

Q: What do you think is in a lemon that could start a chemical reaction?

A: *Answers will vary. Encourage students to think about what makes lemons sour.*

The acid in the juice of the lemons encourages the chemical reaction to activate the battery.

It is recommended that an adult volunteer insert the electrodes when there are multiple station rotations. This prevents the lemons from becoming mush. Students can take turns attaching the wires between the electrodes and taking voltage (V) measurements. Before starting, press down on the lemon and roll it on the table to get the juices flowing inside.

Step one: Insert the zinc electrode (nail) into the lemon so that approximately half of the electrode is still protruding out.

Step two: Insert the copper electrode in the same manner 3-5 centimeters from the zinc electrode. Ensure that the two are not touching.

Step three: Attach alligator clips to each electrode and then connect the alligator clips to the multi-meter.



Step four: Measure the voltage of the lemon battery.

The lemon battery voltage typically measures approximately 0.90 volts.

Have the students compare the voltage of the lemon battery and the alkaline battery.

Q: How can we get the same amount of voltage (or more) from the lemons?

A: Use more than one lemon!

Put another lemon battery in series with the first one. (see diagram on page 14)

Q: What do you think the voltage of two lemons will be?

A: Answers will vary. Measure the voltage for confirmation. The voltage should be approximately double.

If other fruit is available, observe the difference between the voltage from those fruits and the lemon.

Q: Will the lemon battery continue to produce electricity forever?

A: No, like a regular battery, the lemon battery only has a certain number of electrons available for transfer. When all of the available electrons are taken from one electrode and plated on the other, the battery will stop working.

Extension: Build a Series and Parallel Circuit Using a Lemon Battery

Have the students use the Lemon Battery Series/Parallel data sheet – Appendix A to record their observations.

Q: How many kinds of circuits are there?

A: There are three kinds of circuits.

Q: Who knows what they are?

A: Simple, series, and parallel.

A simple electrical circuit consists of three main elements: a current source, wiring, and an electrical load.

The current source provides power, wiring carries power to the load, and the load uses the power.

Electricity flows in a continuous loop from source to load and back again.

If students are unfamiliar with series and parallel circuits, ask the question below after you have built the two circuits.

Q: What is the difference between a series and parallel circuit?

A: A series circuit is a simple circuit with multiple components. A series circuit works by providing a single wire that powers every point on the circuit. The circuit is one continuous line. In a parallel circuit, there is more than one path through which electricity can follow.

Build a Series Circuit

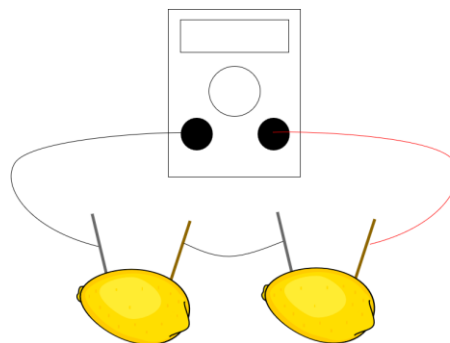
If you have just built a simple circuit, begin with step four and simply add on to your simple circuit. Three total alligator clips are used to wire the series circuit.

Step one: Follow the steps given in “Build a Lemon Battery”. Prepare two or more lemons with the electrodes.

Step two: Using an alligator clip, connect the zinc electrode in the first and second lemons with the copper electrode.

Step three: Attach an alligator clip to the copper electrode in the first lemon and connect the other end of the alligator clip to the multi-meter.

Step four: Attach the third alligator clip to the zinc nail in the second lemon and connect the other end of the alligator clip to the remaining probe on the multimeter.

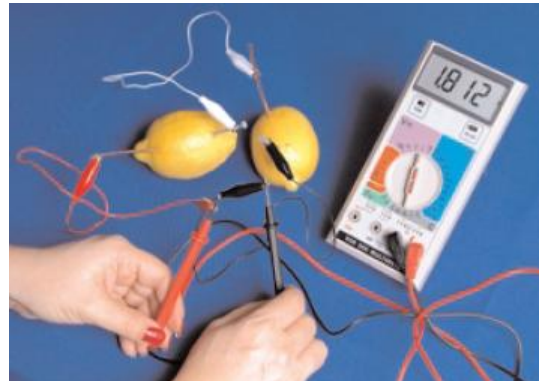


Have students use their fingers (held 1-2 inches above the wire) to trace the path of the series circuit.

Predict whether the series circuit will produce more voltage than the single circuit (initial lemon battery).

Q: How much voltage does the lemon battery produce when two lemons are wired in series?

A: Approximately 1.8 volts.



Have students observe and record the voltage generated by the series circuit.

Q: Why does the series circuit generate more voltage than the single circuit?

A: There are more electrons being generated with the two lemon batteries, and we are adding them together.

Q: How much current is generated by the series circuit?

Turn the multimeter to read Amps for the current.

Have students observe and record the current generated by the series circuit.

Q: What is an example of a series circuit in everyday life?

A: Some strands of Christmas lights are wired as a series circuit.

Q: What happens when the strand of lights is missing one light bulb?

A: The entire strand won't work because the electricity only has one path to travel and the current stops flowing when it hits the gap in the path caused by the missing light. It is for this reason that series circuits are not often used in everyday electrical applications.

Use the series circuit to power an LED light. LEDs are low-voltage, low-current semiconductor devices that produce light. LED stands for "Light Emitting Diode".

To do this, replace the multimeter in the circuit with an LED.

Build a Parallel Circuit

If you have just built a series circuit, begin with step four and simply rewire your series circuit. The materials from the series circuit can be reused and then added onto. Four total alligator clips are used to wire the circuit in parallel.

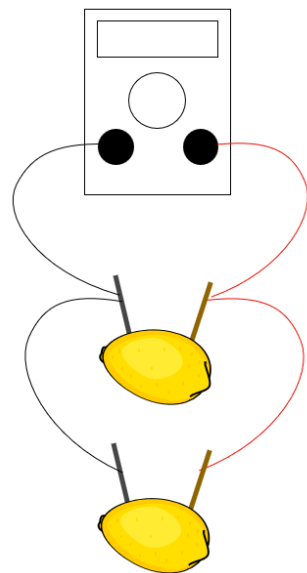
Step one: Follow the steps given in “Build a Lemon Battery”. Prepare two or more lemons with the electrodes.

Step two: Using an alligator clip, connect the copper electrode in the first lemon to the copper electrode in the second lemon.

Step three: Using another alligator clip, connect the zinc electrode in the first lemon to the zinc electrode in the second lemon.

Step four: Attach the third alligator clip between the copper electrode of the second lemon and one probe of the multimeter.

Step five: Attach the fourth alligator clip between the zinc electrode of the second lemon and the remaining probe on the multi-meter.

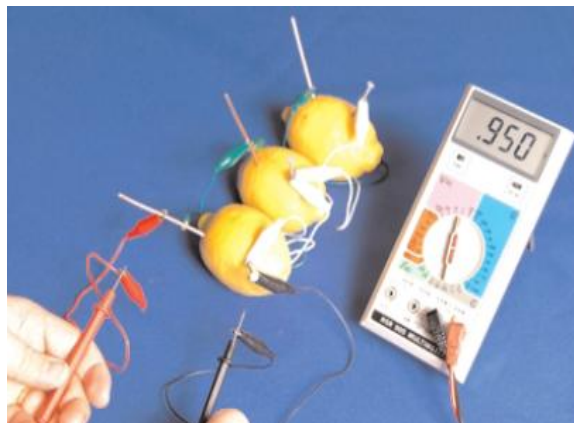


Have students use their fingers (held 1-2 inches above the wire) to trace the path of the parallel circuit.

Predict whether the parallel circuit will generate more voltage than the series circuit and support your prediction with an explanation.

Q: How much voltage does the lemon battery that is wired in parallel generate?

A: 0.8 to 1.0 volts



Have students observe and record the voltage generated by the parallel circuit.

The parallel circuit generates about the same voltage as the single circuit we initially built, but the circuit that is wired in parallel has the potential to increase the amount of electrical current that is generated without increasing the voltage. Each lemon has a limited number of electrons that can move. When we

put the lemons in parallel (side by side) then there are twice as many electrons available to move, thus increasing the potential current that can be generated.

Turn the multimeter to read Amps for the current.

Have the students observe and record the current generated by the parallel circuit.

Q: How does the current of the parallel circuit compare to that of the series circuit?

A: The current has doubled.

Q: Why does the parallel circuit generate less voltage but more current than the series circuit?

A: In series, the voltages are additive. In parallel, the voltages are unaffected, but the current capability is increased.

Q: What are some examples of when parallel and series circuits are used?

A: Your house is wired in parallel. When you have two different lamps plugged into the same electrical outlet and turn one on, they do not both illuminate. Only the lamp that you turned on will light up. This is because your house is wired in parallel. If your home were wired in series and you turned on one light your whole house would light up!

Q: What do you think would happen if we added more lemons in series?

A: The voltage would increase.

Q: In parallel?

A: The current would increase but the voltage would not.

Q: What mathematic principle could we use to make an educated guess about what would happen without wiring more lemons?

A: Multiplication skills.

Circuits

Build a simple circuit

Q: What is a simple circuit?

A: A complete path for electrons to travel from the negative side to the positive side of a battery. If the electric path along the wire is complete, the circuit is complete, and any device in the circuit will be turned on.

The students can work alone or in pairs, each pair with a set of materials: 1 D-cell battery and holder, 1 bulb & socket, alligator clip wires, buzzer, small motor. Walk students through building a circuit with the light bulb, then let them explore with the other devices.

Step one: Insert the light bulb in the bulb socket.

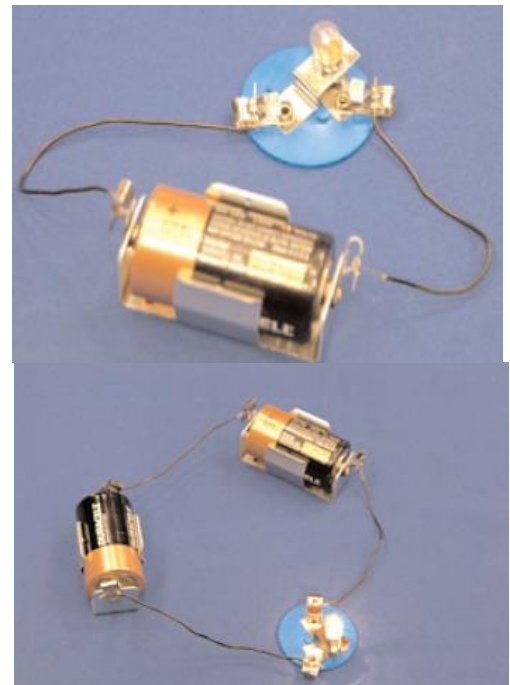
Step two: Insert the battery in the battery holder.

Step three: Connect one wire end to the negative side of the battery holder and the other end to the bulb socket clip.

Step four: Connect one end of the second wire to the positive side of the battery holder and the other end to the remaining bulb socket clip.

Step five: Substitute the buzzer or small motor for the bulb socket.

Step six: Explore wiring devices and/or batteries in series and parallel.



Encourage the students to make observations about the circuits they are building, for example:

- *How to build a circuit with more than one device*
- *How to make the bulb burn brighter (or the buzzer louder!)*

Troubleshooting:

Q: If the light does not illuminate, what can you check prior to assuming that the battery is dead?

A: Check that the wire path is making a good connection at all points. If so, check that the battery is good.

Lemon Battery Series/Parallel Data Sheet

Name: _____

Record your observations about the series and parallel circuits built using the lemon battery.

	Voltage		Current	
Device	Predicted	Measured	Predicted	Measured
D-cell battery			n/a	n/a
Single lemon				
Two lemons/Series				
Two lemons/Parallel				

1. Were your predictions accurate? Explain why or why not. _____
