SCIENCE IS BETTER at Oregon State

Understanding Batteries & Capacitors

The Classroom Electric Circuit

Timeframe

1-2 Fifty minute class periods

Materials

- Participants: ~10 or 15. If there are more participants, consider having half participate in the activity while the other half watches and then switching.
- Introductory Powerpoint slides
- 1 object (such as a pencil, eraser or ball) for each participant (preferably the same) with 6 extras
- Additional ~10 objects (preferably different shape or color)
- Space to form a group circle
- *Optional:* labeled signs worn by participants: "Battery," "Negative Electrode," "Positive Electrode," "Electrolyte," "Light Bulb" and "Capacitor"
- *Optional:* 2 baskets or vessels to hold extra objects

Objectives

- Students will understand the main components of batteries how they produce electricity within a circuit via chemical reactions.
- Students will be able to explain the difference between a non-rechargeable and rechargeable battery as well as the difference between a battery and a capacitor evidence.

Teacher Background

Although they have been used as an energy source for over 100 years, many people don't understand the basic principles of batteries. In this lesson, students begin to develop an understanding of how batteries and capacitors work by acting out the components of electrical circuits with a disposable battery, a rechargeable battery, and a capacitor. The concept is difficult to grasp by simply looking at diagrams, and the kinesthetic process of acting out the parts of the circuit will strengthen students' understanding.

The Powerpoint is a great tool that provide the necessary background information to your students and introduce the activity. There is also an excel spreadsheet with characterisitics of different battery types that can be used for potential extension activities.

Description

Students explore how electricity works by acting out the parts of primary and secondary battery circuits with capacitors.

Activity Introduction

Use the Powerpoint to introduce the lesson to the students. The Powerpoint will provide background information and lead into the kinesthetic activity below.

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SMILE Program
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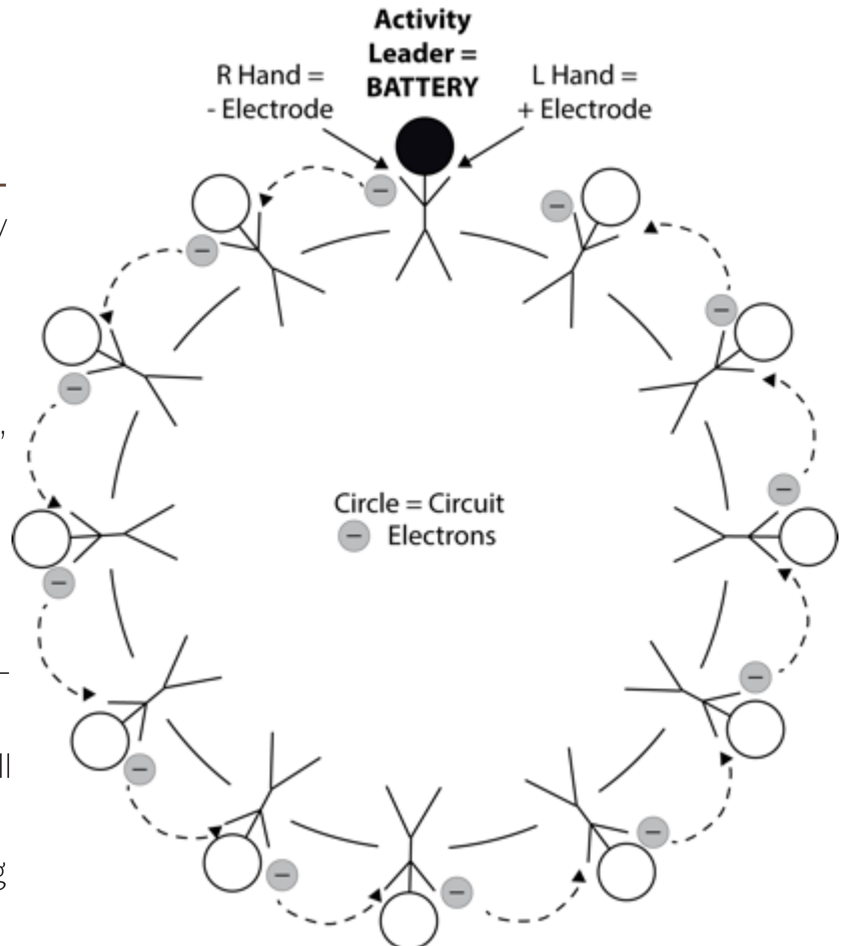
Part 1: Simple Electric Circuit



Act out a simple series primary cell electric circuit, as follows:

1. **Ask participants to form a circle. One person will represent a battery** (the teacher/ activity leader is recommended), the rest of the participants represent a wire conductor, and the circle represents a circuit. **Distribute an object** (such as ball, pencil, or eraser) **to each person in the circle.** Ideally, everyone has the same object.
   - Explain that these objects represent electrons inside a wire conductor. Explain that wire conductors are full of electrons, although they are too small to see even under a microscope!
   - Remind participants of who is playing the part of the battery, which has a positive end or electrode (represented by the "battery's" left hand) and a negative end or electrode (represented by the "battery's" right hand.
2. **The "battery" passes their "electron" to the participant on their right.**
   - Explain that because electrons share the same negative charge, they repel one another, which keeps them moving along in the same direction.
3. **The participant receiving the "electron" should in turn pass the one he or she is holding to the right. Have participants continue passing on electrons to the person to their right.**
   - State that the flow of electrons through a conductor is called an electrical current.
4. To illustrate what happens when a circuit breaks, or *opens*: **create a gap in the circle of participants that is too wide across to pass "electrons"** – the current will stop as a result.
   - As long as the circle remains intact and the electrons continue to flow, their circuit is *closed*.

Guiding Questions

- Why do electrons repel each other? *Objects of the same charge always repel each other*
- What components are we missing in our circuit? *An object to receive the power (eg. A light bulb) and potentially a switch*
- What do the hands of the "battery" represent?

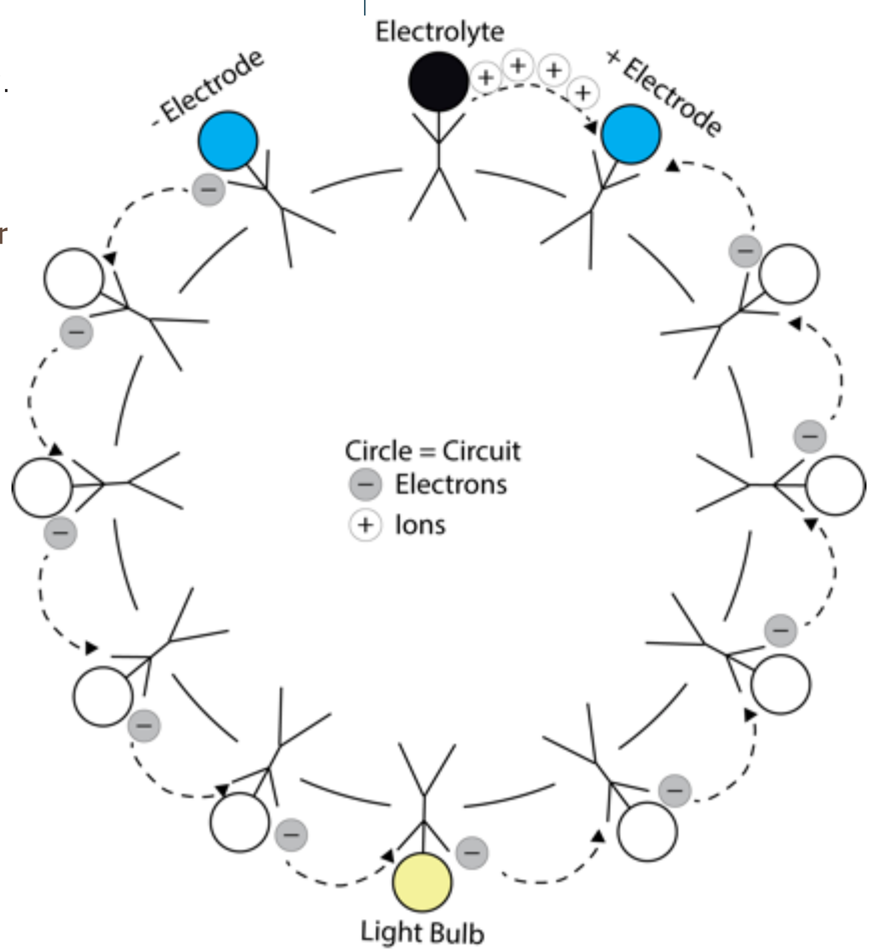
Part 2: Electric Circuit with Battery Components and Light Bulb

Act out an electric circuit with parts of battery as follows:

1. This time, let's add an object to draw the power. **Let one participant represent a light bulb** or a different object that requires electricity (anywhere in the circle). Additionally, three people will represent the battery.
2. A battery has three main parts: the negative electrode, the positive electrode, and a liquid or solid separating them call the electrolyte. **The participant to the left of the "battery" from the activity above will represent the positive electrode and the participant to the right of the "battery" above will represent the negative electrode; the "battery" from the exercise above will now represent the electrolyte,** which is un-passable by electrons.
    - Explain that when a circuit is closed, chemical reactions start happening within the battery, which generate positive ions and negative electrons. The positive ions flow through the electrolyte to the positive electrode while the electrons flow around the outside circuit to the positive electrode, releasing energy.
3. This time, **the "negative electrode" to the right of the "electrolyte" will release an electron to the student to their right. In the meantime, the "electrolyte" will pass a different object (representing ions) towards the "positive electrode" on their left. Ask the "light bulb" to make a beeping noise every time he/she receives a electron to signify they are receiving electricity.** When all of the "electrons" are passed around to the "positive electrode," the battery has exhausted the chemicals necessary to produce electricity and it is exhausted.

Guiding Questions

- What causes the battery to release electrons? *Chemical reactions that begin once the circuit is closed*
- What does it mean that the battery is exhausted?



Part 3: Rechargeable Battery

Act out a rechargeable "secondary cell" circuit as follows:

1. Secondary cell batteries are recharged by passing a current through in the reverse direction to normal, which causes the chemical reactions to run in reverse as well. **Ask the "light bulb" to step out of the circle and close the circuit in their absence.** To recharge our battery, after the circuit is plugged into a power source **the "positive electrode" will pass "electrons" to their left until they reach the "negative electrode," while the "positive electrode" passes the ions back to the "electrolyte."** Once the battery is fully charged, **ask the light bulb to step back into the circle.**
2. We can run our rechargeable battery to power the light bulb by passing the electrons from the "negative electrode" around the circle to the right and passing the ions from the "electro-lyte" to the "positive electrode".

Guiding Questions

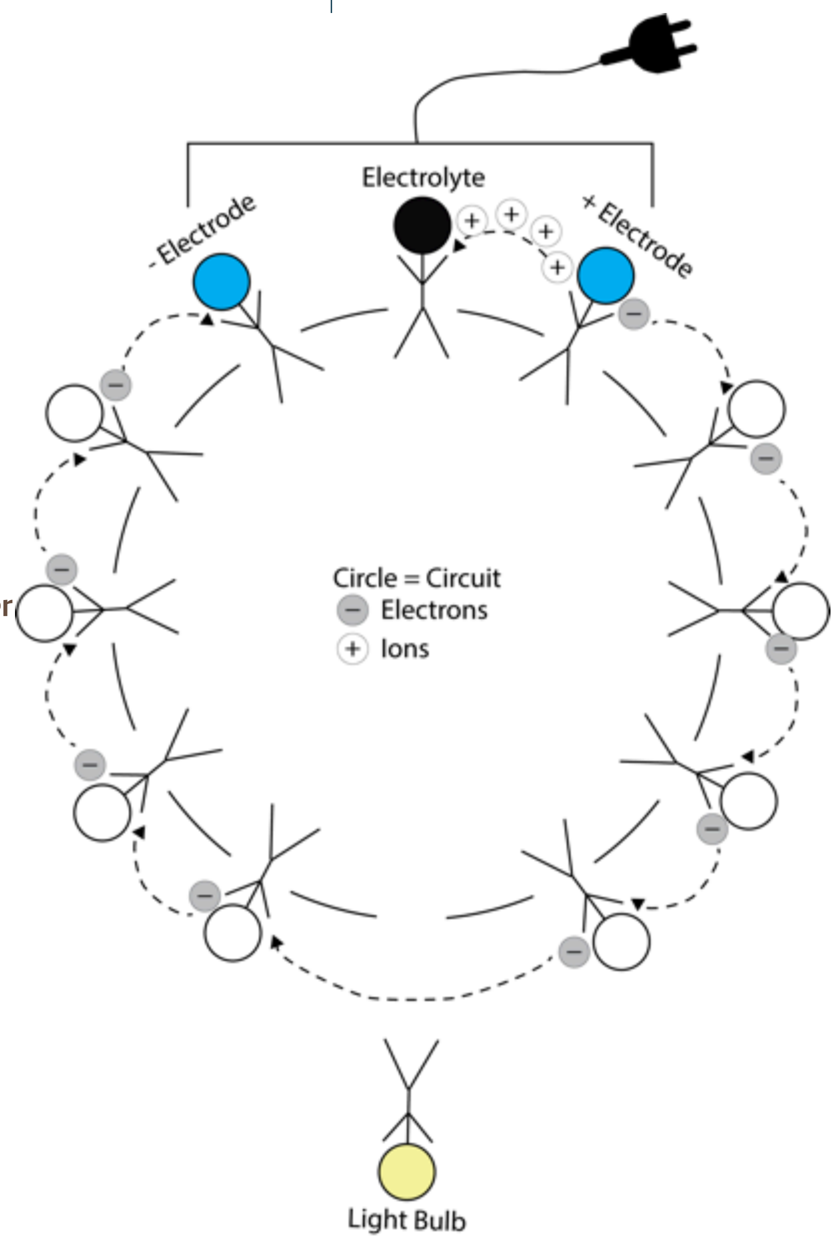
- What is missing from our circuit during recharge of the battery?

  A power source
- What does recharging the battery do chemically? *Reverses the chemical reactions that form electrons and ions within the battery*
- Why does the light bulb have to step out of the circuit while the battery is recharging?

Part 4: Electric Circuit with a Capacitor

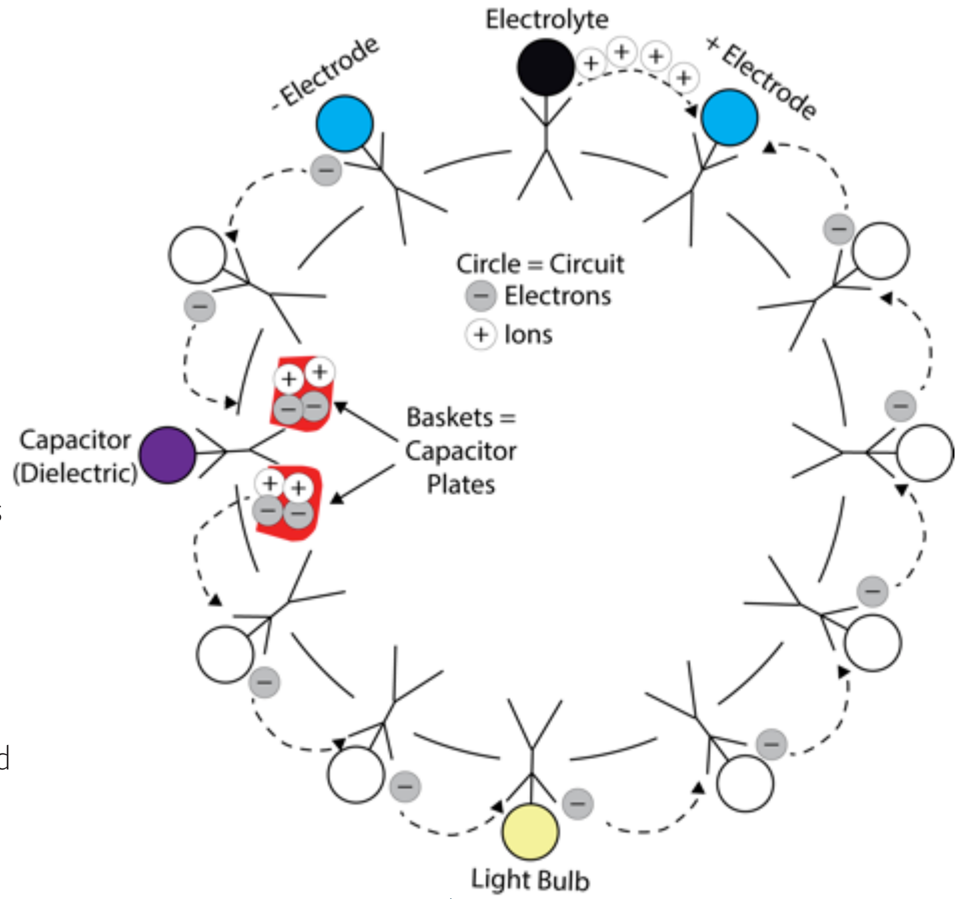
Act out a circuit with a capacitor as follows::

1. **Ask another participant to volunteer to play the roll of the capacitor's dielectric.** The capacitor can realistically be at any position in the circuit. **Give the dielectric the baskets/vessels with an equal number of ions and electrons in each and have the capacitor place one on either side of them.**
   - Explain that capacitors are similar to batteries, except that they cannot produce new electrons – they only store them. Instead of slowly creating energy from chemical reactions and releasing them into a device, capac-itors are designed to release their energy quickly.



Part 4: Continued

- **The baskets/vessels represent the two plates of the capacitor, and the person between them represents the dielectric.** The two plates are separated by a dielectric, which is un-passable by electrons. At this point, because there is an equal number of ions and electrons in each basket (representing the storage within each "plate" of the capacitor), the capacitor has no charge.



3. This time, as electrons are passed around the circle, the capacitor will store up energy. **Each time the capacitor receives an "electron" from the participant to their left, he/she will place it in the basket/vessel or "plate" on the left side, and will take an "electron" from the basket/vessel on the right side and "release" it to the participant to their right.**
   - The "plate" on the dielectric's left, which now has more electrons than ions is becoming increasingly negatively charged, whereas the "plate" to the dielectric's right is becoming increasingly positively charged because it has more electrons than ions.
4. Once the capacitor has "charged" up, meaning the baskets/vessels both have uneven numbers of electrons and ions, **have the battery components (the electrolyte, the positive electrode, and the negative electrode) step out of the circle. Tell the remaining participants to make a smaller circle to fill in the gap.**
   - The circle must remain closed to have a closed circuit. Now the capacitor is responsible for providing electricity to the "light bulb."

Guiding Questions

- How is a capacitor different from a battery?
- Why are the electrons not passed through the capacitor? *the dielectric acts as a barrier*
- Can you think of any situations that would require a capacitor in addition to a battery?
- *Bonus question:* Can you think of examples of capacitors in nature? *A cloud that produces lightning!*

Part 4: Continued

- **The capacitor releases electrons from their negatively charged "plate" to the participant next to them, who passes their electron as well,** and when electrons reach the "light bulb" it will be powered. This can continue until the capacitor is "discharged," meaning both baskets have an equal number of ions and electrons again.

Activity Wrap Up:

Afterwards, use the discussion questions below to debrief the activity. Perhaps continue the lesson with one of the extensional activities in the right column.

1. Where was the electrical current in the activity?
2. What makes a battery go "bad"?
3. Why do devices require different amounts/different sizes of batteries?
4. What happens inside the batteries to produce electrons and ions?
5. What does it mean to have a closed circuit vs. an open circuit?
6. What is the difference between a disposable battery and a rechargeable one in terms of chemical and electrical processes? What about in terms of materials?
7. How does a capacitor differ from a battery? What are some applications of a capacitor?
8. What do you think will be next in terms of energy storage technology?

Potential Extensional Activities

1. Use the excel spreadsheet with different types of batteries and their applications to think about why different batteries are ideal for different uses, and how upcoming energy technology will be impacted by the resources it takes to build batteries and store energy.
2. Build your own battery: http://blogs.oregonstate.edu/smile/2013/11/21/battery-building/
3. Build a battery and circuit using lemons: http://blogs.oregonstate.edu/smile/2014/03/14/follow-batteries/
4. Consider other ways that energy is stored in nature as well as society. Can you develop a diagram of other energy circuits?

Next Generation Science Standards

DISCIPLINARY CORE IDEAS:
PS1.A: Structure and Properties of Matter
PS3.A: Definitions of Energy
PS3.B: Conservation of Energy & Energy Transfer

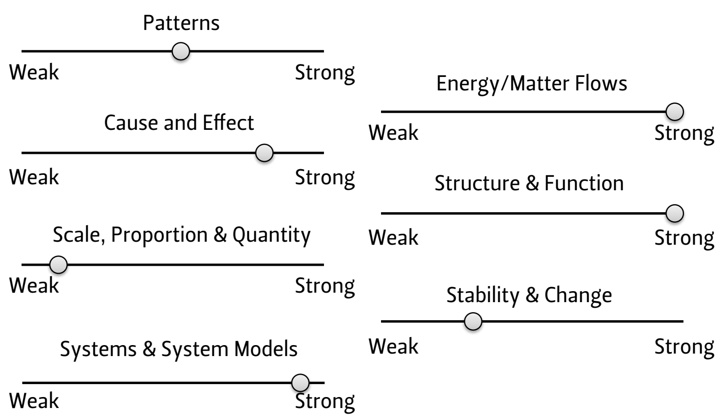
PERFORMANCE EXPECTATIONS:
4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

HS-PS2-2: Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles and energy associated with the relative positions of particles.

PRACTICES:
Developing and Using Models

Crosscutting Concepts



VIDEO RESOURCES
How Batteries Work by Adam Jacobson
This TEDEd video provides a great basic background to the history of batteries and how they work.

OREGON STATE SUPPORT

This project is supported by Dr. Xiulei (David) Ji's NSF Grant # 1507391 and his research group in the Chemistry Department at Oregon State University.

Additional Resources:

- Dr. David Xiulei Ji's Chemistry Research Group (http://jigroup.chem.oregonstate.edu/) has information about ongoing research in alternative materials for batteries and capacitors.
- ExplainThatStuff (http://www.explainthatstuff.com/batteries.html) provides basic information about battery components and function.
- HowStuffWorks (http://electronics.howstuffworks.com/capacitor.htm) provides basic information about the components and function of capacitors.
- Bright Hub Engineering (http://www.brighthubengineering.com/power-generation-distribution/123909-types-of-batteries-and-their-applications/) has a great description of different battery types and their applications.
- E-Missions (http://www.e-missions.net/elabs/style/doc/ActingOutanElectricCircuit.pdf) provides an alternative version of this lesson.
- PBS Learning Media (http://www.pbslearningmedia.org/resource/phy03.sci.phys.mfe.lp_electric/electric-circuits/) provides an alternative version of this lesson as well.