ENERGY OFFICE

LESSON PLAN

Squishy Circuits

Grades 3 & 6

SUMMARY

Electrical circuits are the foundation of our modern, technology-driven lives. Everything from simple light bulbs to complex devices like the iPhone depend on electrical circuits in order to function. The basic structure of each of these devices is the same: there is a power source, which is connected to some wires, which are connected to a device that uses the power to do something useful (like lighting up a room or displaying a Facebook message from your friend).

In this lesson, the students will create a functioning electrical circuit using a battery pack, LEDs, and conductive and insulating playdough. By completing student-led experiments, groups of two to three students will work together to attempt to light their LED up using various materials.

Squishy Circuits® were created in the Playful Learning Lab at the University of St. Thomas. They are a design tool that allows everyone, from young children through adults, to create circuits and explore energy using playdough.

LESSON OBJECTIVES

Upon completing this lesson the students will:

- Develop models to illustrate and explain that energy can be transferred from place to place by electric currents and that electric currents flowing through a simple circuit can be used to produce light;
- Understand the difference between series, and parallel circuits;
- Construct explanations of how some materials allow electricity to flow through a circuit and some do not; and
- Understand the difference between conductive material and insulating material.

2014 S.C. SCIENCE STANDARDS CORRELATIONS

Standard 3.P.3: The student will demonstrate an understanding of how electricity transfers energy and how magnetism can result from electricity.	**Standard 6.P.3:** The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy, and the relationship between energy and forces.
CONCEPTUAL UNDERSTANDING	
3.P.3A. Energy can be transferred from place to place by electric currents. Electric currents flowing through a simple circuit can be used to produce motion, sound, heat, or light. Some materials allow electricity to flow through a circuit and some do not.	**6.P.3A.** Energy manifests itself in multiple forms, such as mechanical (kinetic energy and potential energy), electrical, chemical, radiant (solar), and thermal energy. According to the principle of conservation of energy, energy cannot be created nor destroyed, but it can be transferred from one place to another and transformed between systems.
PERFORMANCE INDICATOR	
3.P.3A.2 Develop and use models to describe the path of an electric current in a complete simple circuit as it accomplishes a task (such as lighting a bulb or making a sound).	**6.P.3A.3** Construct explanations for how energy is conserved as it is transferred and transformed in electrical circuits.
SCIENCE AND ENGINEERING PRACTICE (SEP)	
• Ask questions and define problems. • Develop and use models. • Plan and conduct investigations. • Analyze and interpret data.	• Use mathematical and computational thinking. • Construct explanations and design solutions. • Engage in scientific argument from evidence. • Obtain, evaluate, and communicate information.
CONNECTION TO CLASSROOM ACTIVITY	
Students can develop, use, and refine models to understand phenomena, processes, and relationships, test devices or solutions, or communicate ideas to others.	

MATERIALS

- Battery Packs and Batteries with Leads
- Conductive Dough
- Insulating Dough
- LEDs (should be appropriate for the source voltage)

Optional, but recommended:

- Buzzer
- Motor

CONDUCTIVE DOUGH RECIPE – http://youtu.be/cpUFL5LZpv4

- 1 Cup Water (tap)
- 1 1/2 Cups of Flour
- 1/4 Cup of Salt
- 3 Tbsp. of Cream of Tartar
- 1 Tbsp. Vegetable Oil Food Coloring (optional)

INSULATING DOUGH RECIPE – http://youtu.be/Wz8rGNt-iEQ

- 1 1/2 Cup of Flour
- 1/2 Cup of Sugar
- 3 Tbsp. of Vegetable Oil
- 1/2 Cup of De-Ionized (or distilled) Water
- 1 tsp. of Granulated Alum (optional)

TEACHERS PLEASE NOTE: The materials can be purchased for under $100 and most are highly reusable. Note that the dough is perishable and has a limited shelf life. Refrigerating the dough in sealed containers can extend its life considerably. You can find these materials in retail stores or at **https://squishycircuits.com/collections/all**. If making the dough, you may want to complete that part a few days before the lesson. Keep the dough in an air-tight container.

SAFETY NOTE

In general, Squishy Circuits is a very safe activity. ***However, some safety notes should be addressed.***

- The battery packs should never be shorted out (letting the wire/terminals touch each other directly). Some battery holders may have safety features that prevent overheating, but with other battery holders, they will quickly warm up and could cause burns if shorted. When doing any electrical project, batteries should never be shorted directly.
- LEDs should not be hooked directly to the battery packs. They will burn out and may pop. LEDs require a resistor to limit the amount of power flowing through them. With Squishy Circuits, the conductive dough acts as the wire and a resistor, so they're safe to use with the dough.
- Batteries should always be removed from the battery packs before they are stored to avoid risk of fire. It is also important that the students do not ingest the dough because it may be contaminated.
- Also note that LEDs are easily bent to the point where they break.

ESSENTIAL QUESTIONS

1. How are electrical circuits created?
2. What does it mean for a material to be conductive? Insulating?

DURATION

The activity, as is, requires at least 25 to 35 minutes, although this doesn't leave much time for exploration and experimentation. It can easily be extended to 50 or 60 minutes.

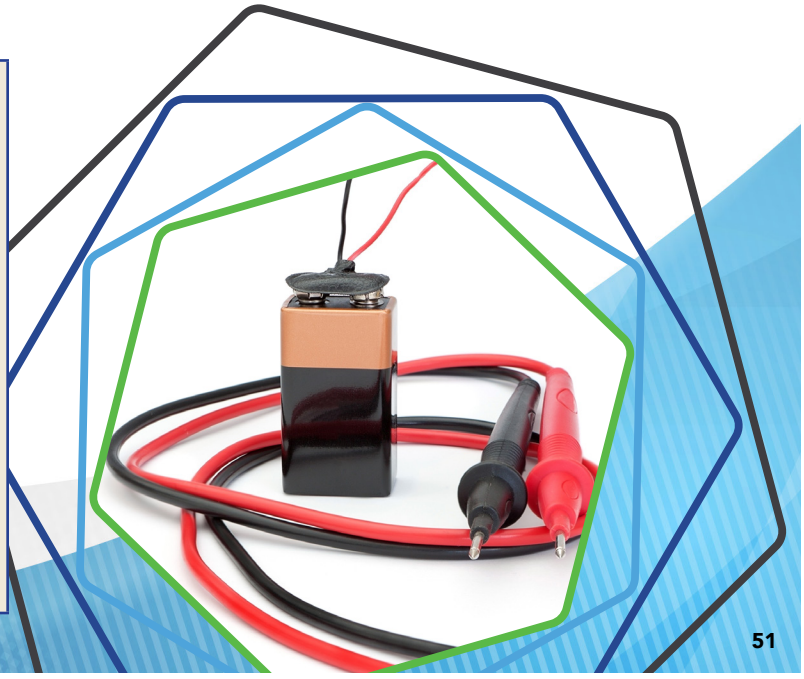
ENGAGE

Begin the class by sharing this ***TED Talk*** video about squishy circuits. Watch the video at **www.ted.com/talks/annmarie_thomas_hands_on_science_with_squishy_circuits?language=en#t-221869**.

After the students have been divided into pairs or trios, provide each student with the materials listed.

Next, provide the students with the following directions:

1. With your partner, discuss different ways to make the LED light up. (Use this time to investigate your materials, but don't hook anything up yet)
2. Draw in your Science journal how you will attempt to solve this challenge: ***"Make your LED light up using only the materials in front of you."*** Have the students share their ideas on how they would like to solve this challenge.

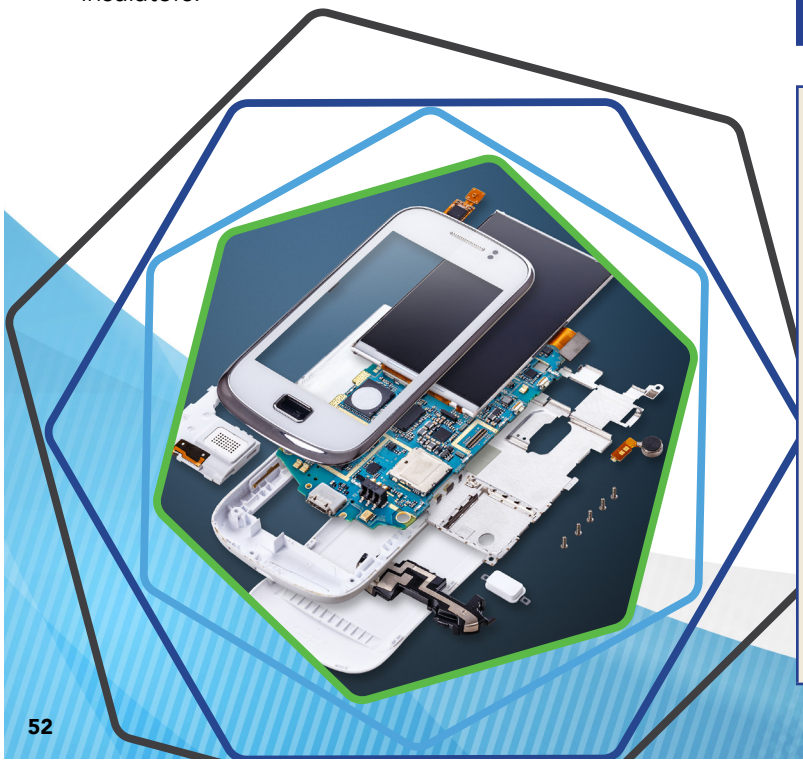


EXPLORE

1. Using the materials, work with your partner as a team to create a working circuit. The students will use the attached worksheet to build simple circuits to understand the fundamental concepts of circuits.
2. Spend time wandering the classroom to identify student misunderstandings, comprehension, and answer questions as well as ask questions. Provide guidance as you see fit.
3. Encourage the students to plan and document in their journals as a way of emphasizing the engineering design process.

EXPLAIN

1. Discuss which types of circuits worked and which didn't. Allow students the opportunity to construct explanations on why certain types of circuits worked and other types didn't.
2. Ask the 3rd-grade students, ***Why does one dough conduct electricity and the other doesn't?*** (Some materials allow electricity to flow through a circuit and some do not.) Ask the 6th-grade students, ***What is the difference between a series and a parallel circuit?***
3. Discuss why the ingredients in each dough affects how easily electricity can flow through each of them. (Guide the students toward explanations about conductors and insulators.) Discuss the concept of conductors and insulators.
4. Have students create a list of materials that are good conductors of electricity and good insulators. (conductors = metal, water, citrus fruit; insulators = wood, plastic)
5. Show the students images of items that may be good conductors and insulators. Show images of disassembled electronic devices (e.g., laptops, tablets, cell phones) to give the students a real-world representation of how circuits work.
6. Have the students think of different real-world applications for series and parallel circuits. If you have many lights in a room, typically they are connected in series with the switch – that way one switch can control all of the lights at once. Christmas lights are a good example of parallel circuits because if one bulb burns out, the rest continue to glow. Older sets of these lights actually were in series so if one burnt out, you had to try every single bulb to find the bad one and replace it to make the rest turn on!



ELABORATE

The students can design and build their own circuits. Provide students with another challenge – ***Can you design both series and parallel circuits?*** For example, they can build circuit sculptures.

First, have the students sketch their designs on paper. Then, they can build and test their designs. Encourage the students to plan and document in their journals as a way of emphasizing the engineering design process.

MORE FUN

Turn your body into a human conductor of electricity.

Create a giant circuit using an Energy Stick® (or similar device) – provided by the S.C. Energy Office (while supplies last) or available for purchase online. Have the students form a circle and hold hands. Explain how the circle compares to a circuit. Open the circuit by letting go of one student's hand while everyone else hangs on.

Grab a silver ring on one end of the Energy Stick® while the person next to you grabs the other one. The Energy Stick® flashes and buzzes because the circuit is complete again. Should anyone break the circuit, the detector stops. Explain that switches and breakers are nothing more than devices that either connect conductors to turn something "on" or separate them to turn something "off." Have students wash hands after this activity.

Try adding other elements to the closed circuit to search for electrical conductors and insulators. Conductors allow electricity to flow through them while insulators resist current flow. Test some conductors and insulators by bringing them into contact with both electrodes, simultaneously. Try items such as metals, woods, rubber, graphite, paper, plastic, etc. Does the connection work?

EVALUATE

Have the students to respond in writing to the following evaluation questions. Suggested answers are provided.

- ***What is electricity?*** (Electrical energy is the energy flowing in an electric circuit.)
- ***What is a conductor?*** (Conductors facilitate, or conduct, the transfer of heat energy.)
- ***What is an insulator?*** (Insulators inhibit, or insulate, the transfer of heat energy.)

Draw an electrical circuit with the following components: battery, wire, and Light Emitting Diode (LED). (Allow for student responses.)

- ***What is a series circuit?*** (Parts of the circuit are in a row.)
- ***What is a parallel circuit?*** (Independent paths of multiple rows.)
- ***How can you tell that energy is moving (transferred) from the battery pack and through the dough?*** (The light turns on.)
- ***When is there energy present in the circuit? How could you prove this?*** (Allow for student responses.)
- ***What components (parts) are needed to make a circuit work?*** (power source, wire connectors, switch)
- ***What configurations of insulating and conductive dough work to construct a functioning circuit?*** (Allow for student responses.)

E-LEARNING ACTIVITY

Use this Webquest activity will guide students through electricity basics, understanding circuits and the components needed to make a circuit work. Please visit **www.madison-schools.com/cms/lib/MS01001041/Centricity/Domain/3318/Electric%20Circuits%20webquest.pdf**.

This activity can also be used as an additional evaluation tool or an alternative to the ELABORATE Activity.

VIRTUAL LAB ACTIVITY

Students can access this BrainPOP activity – ***Circuit Construction Kit*** – to investigate how to construct a circuit. Visit **www.brainpop.com/games/circuitconstructionkitdc/**.

TIPS, TRICKS & SAFETY

It is best to always do these activities with adult supervision.

- Don't connect the battery directly to the LED, it may burn the LED out.
- Try not to mash the two types of dough into each other. This makes it difficult to separate them for future classes.
- The LED only works in one direction. This is called ***polarity***.
- Notice how one "leg" of the LED is slightly longer than the other one. The longer leg should always be attached to the positive (red) wire from the battery.
- Sometimes, thin strands of insulating dough will still conduct some electricity, and the LED will become dimly lit. If this happens, use it as an opportunity to discuss resistance!
- Don't cross the wires on the battery connectors – this will short out the battery! **It may heat up and explode.**
- Warn students to always be careful when experimenting with electricity. **High voltages and high currents can be deadly.** For example, they should never stick wires or other objects into wall sockets.

SOURCES

- Squishy Circuits Activity – **http://gk12.cs.ksu.edu/uploads/lesson_material/file/26/squishy-lessonplan.pdf**
- Lesson Plan for Squishy Circuits – **https://pdst.ie/sites/default/files/Lesson%20plan%20for%20Squishy_Circuits.pdf**
- Squishy Circuits NGSS Curricula and Educator's Guide – **https://cdn.shopify.com/s/files/1/2640/3158/files/Squishy-Circuits-NGSS-Curricula-and-Educators-Guide.pdf?12**

STUDENT WORKSHEET NAME: _____

SQUISHY CIRCUITS WORKSHEET

1. Begin with two lumps of the conductive dough. Plug one wire from the battery pack into each piece and bridge the gap with a LED.

   - Does the LED light up? (circle one) **YES NO**
   - Take the LED out and flip it around so that each "leg" is in the opposite piece of conductive dough. Does the LED light up? (circle one) **YES NO**
   - The LED only works in one direction. The longer terminal should be attached to the positive (red) wire from the battery pack. This is called a CLOSED CIRCUIT.

2. Next, pull one of the LED legs out of the dough.

   - Does the LED light up? (circle one) **YES NO**
   - In the last step, the LED went out because we broke the loop of electricity. This is called an OPEN CIRCUIT.

3. Put the LED leg back in so your LED is on. Now, push the two pieces of conductive dough together.

   - Does the LED light up? (circle one) **YES NO**
   - In the last step, the LED went out. This is called a SHORT CIRCUIT.

4. Separate the two pieces. The LED should again light up because the electricity must go through the LED to complete the circuit. Now create a "sandwich" with the insulating dough between two pieces of conducting dough.

   - Does the LED light up? (circle one) **YES NO**
   - The insulating dough does not let electricity flow through it easily. It acts like a wall to the electricity. The electricity has to go around the insulating dough and through the LED that lights up!
   - There is one continuous path for the electricity to flow through. This is a SERIES CIRCUIT.

5. Now we can create Squishy Circuits that do not have to be separated – like "sushi circuits!" There are multiple paths for the electricity to flow through. This is a PARALLEL CIRCUIT.

6. Now you can design your own circuit. Draw your design below.