

Lesson Plan for Squishy Circuits

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Introduction/Background Info

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).



Figure 1. Electrical circuits are used in a wide variety of applications, from a simple light bulb (top left) to complex printed circuit boards (top right, bottom left) for computers and smartphones (bottom right).

The main point of this lesson is that you don't need to be an electrical engineer to get some hands-on experience with circuits. You don't need to use a soldering iron or a prototyping board or circuit diagrams in order to start learning about electricity. In fact, all you need is some playdough to start building your own circuits. This non-traditional circuit technology is a fun way to introduce kids to circuit design with a toy that is familiar, safe, and easy to manipulate.

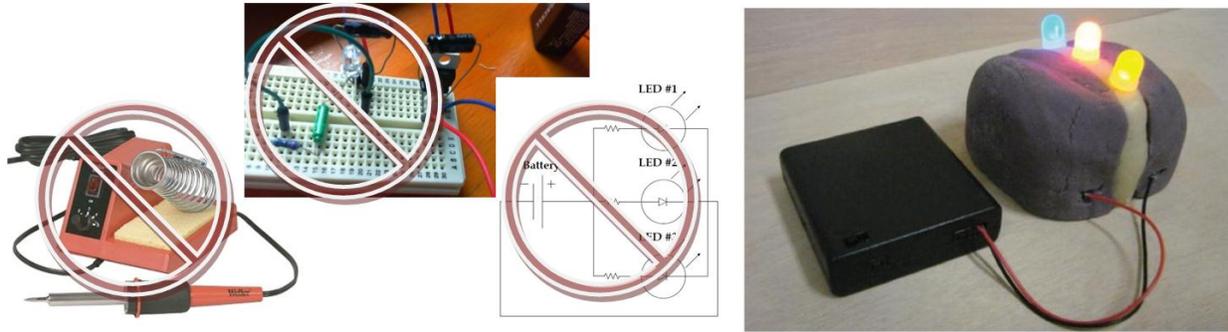


Figure 2. Would you rather teach a kid about circuits with soldering irons, prototype boards, and circuit diagrams ... or would you rather teach them with playdough?!

This lesson plan includes recipes for two kinds of playdough: conductive dough and insulating dough. These two kinds of playdough can be used together to introduce kids to the fundamental concepts that make electrical circuits work.

A **conductor** allows electricity to easily flow through it. The conductive dough contains salt, which helps electricity flow through the dough because the salt (sodium chloride, or NaCl) dissociates into sodium (Na⁺) and chlorine (Cl⁻) ions. An **insulator** does not let electricity flow through it easily. Because of this, they act as a wall to electricity and the electricity must go around them. If a path around the insulator is not available, the circuit cannot be completed. The insulating dough recipe does not use salt, so no ions are available to allow electricity to flow. (The insulating dough also uses distilled water that contains little or no ions, whereas the conductive dough uses tap water that usually contains some ions.)

All materials have a property called **resistance**, which is related to how easily it allows electricity to flow through it. We say that insulators have a *high* resistance, while conductors have a *low* resistance. Thought of another way, insulators act as “walls” that block electricity from flowing; conductors act as “roads” that allow electricity to easily travel along them.

In order to build a circuit, we must provide a continuous path for electricity to flow from a power source (for example, a battery), through a conductor, into a device that uses the power (for example, a light bulb), and back through another conductor to the power source. This is called a **closed circuit**. If this continuous path is broken anywhere, electricity will not flow and the light bulb will not work. This is called an **open circuit**. If the conductors in a closed circuit are touched together, it forms a new type of undesirable circuit called a **short circuit**. Electricity will still flow through the circuit, but the light bulb will not work. This is because the light bulb has a higher resistance than the conductors, and the electricity is “lazy” – it would rather travel through the conductors when they are touching than exert extra effort to travel through the light bulb.

There are two types of closed circuits: series and parallel circuits. **Series circuits** only provide one path for electricity to flow. **Parallel circuits** provide multiple paths for electricity to flow.

Student Objectives

After completing this lesson, students should understand the following concepts:

- Conductors vs. insulators; resistance
- Open circuits vs. closed circuits; short circuits
- Series circuits vs. parallel circuits

Overview of Lesson Process

- Survey students' prior knowledge (5-10 min). Introduce concepts of conductors, insulators and resistance. Demonstrate open, closed, and short circuits. Also demonstrate series and parallel circuits. Finally, briefly discuss safety when experimenting with electrical circuits!
- Activity (30 min). For the first ten minutes, students should use the attached worksheet to build their own simple circuits to understand the concepts just introduced. For the last twenty minutes, students can design and build their own circuits to further explore these concepts.
- Wrap-up discussion (5-10 min). Which circuits worked and which didn't work? Discuss why the ingredients in each dough affects how easily electricity can flow through each of them. Show images of disassembled electronic devices, like laptops, iPods, iPhones, etc .

Materials

Item	Price	Retailer
Flour	\$2.99	Ralphs
Salt	\$2.83	Ralphs
Cream of tartar	\$4.99	Ralphs
Vegetable oil	\$3.99	Ralphs
Food coloring	\$6.75	Ralphs
Sugar	\$3.49	Ralphs
Distilled water	\$1.34	Ralphs
Granulated (powdered) alum	\$2.49	Ralphs
9V battery (4-pack)	\$9.89	Radio Shack
Heavy-duty 9V snap connectors (5-pack)	\$2.69	Radio Shack, Catalog #: 270-324
10 mm LED assortment	\$20	Evil Mad Science, http://evilmadscience.com/productsmenu/partsmenu/368
Total	\$61.45	

Conductive dough recipe [<http://youtu.be/cpUFL5LZpv4>]

- 1 cup (tap) water
- 1 1/2 cups flour
- 1/4 cup salt
- 3 Tbsp. cream of tartar
- 1 Tbsp. vegetable oil
- food coloring (optional)

Insulating dough recipe [<http://youtu.be/Wz8rGnt-iEQ>]

- 1 1/2 cup flour
- 1/2 cup sugar
- 3 Tbsp. vegetable oil
- 1/2 cup deionized (or distilled) water
- 1 tsp. granulated alum (optional)

Procedures

Mentors must prepare batches of conductive and insulating dough ahead of time. Each recipe above makes enough dough for 2 groups of 4-5 students.

Phase 1 (10 min): Students use the attached worksheet to build simple circuits to understand fundamental concepts of circuits.

Phase 2 (20 min): Students design and build their own 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.

Wrap up discussion

- Discuss which types of circuits worked and which didn't.
- What is the difference between a series and parallel circuit?
- Why does one dough conduct electricity and the other doesn't?

Tips, tricks, and safety

- Don't connect the 9V 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. It's best to always do these activities with adult supervision.

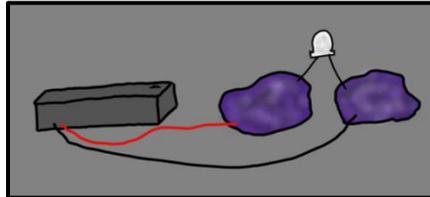
Resources

1. <http://courseweb.stthomas.edu/apthomas/SquishyCircuits/index.htm>
2. http://www.ted.com/talks/annmarie_thomas_squishy_circuits.html
3. <http://courseweb.stthomas.edu/apthomas/SquishyCircuits/PDFs/Squishy%20Circuits%20Classroom%20Guide.pdf>
4. <http://www.toysaretools.com/2011/12/electrify-your-childs-learning-through.html>
5. <http://www.wellersolderingiron.co.uk/images/2.jpg>
6. <http://lochieferrier.files.wordpress.com/2011/10/2011-10-11-11-47-21-422.jpg>
7. <http://bidboomerang.com/wp-content/uploads/2011/10/light-bulb-battery-circuit.jpg>
8. <http://www.blogonono.net/wp-content/uploads/2011/08/Printed-Circuit-Board.jpg>
9. http://4.bp.blogspot.com/-a5CFI3hL_TA/TsliL7FTcII/AAAAAAAAAVg/hTYTV7oNU0A/s1600/disassemble-iPhone-4s.jpeg
10. <http://www.onlytechnews.com/wp-content/uploads/2011/12/iphone-4s.jpg>

Squishy Circuits Worksheet

(adapted from Squishy Circuits Classroom Guide, <http://courseweb.stthomas.edu/apthomas/SquishyCircuits/PDFs/Squishy%20Circuits%20Classroom%20Guide.pdf>)

1a. 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.



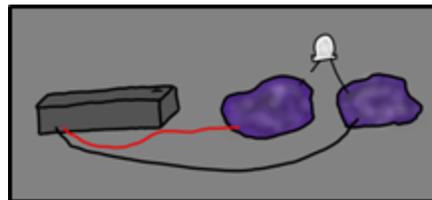
Does the LED light up? (circle one): YES NO

1b. 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**.*

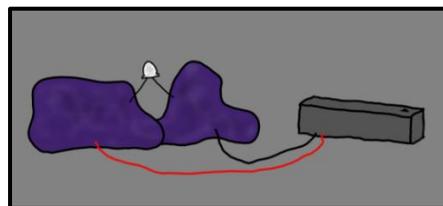
2. Next, pull one of the LED legs out of the dough.



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**.*

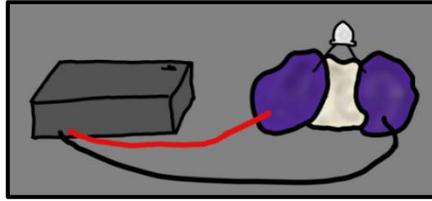
3. Put the LED leg back in, so your LED is on. Now, push the two pieces of conductive dough together.



Does the LED light up? (circle one): YES NO

*In the last step, the LED went out – this is called a **short circuit**.*

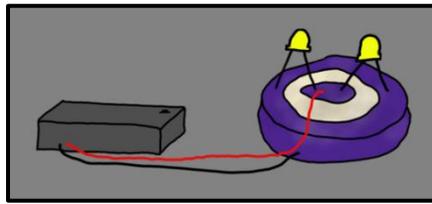
4. Separate the two pieces. The LED should once again light up, because the electricity must go through the LED to complete the circuit. Now, create a “sandwich” with the insulating dough between two pieces of conducting dough.



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 electricity. Therefore, the electricity has to go around the insulating dough, and through the LED which 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 here:

Now, try to build and test your design with the materials provided!