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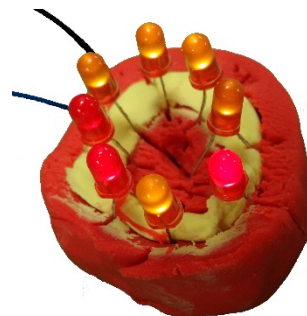
GSC's products are intended for use in labs and classroom settings under the supervision of qualified professionals.
The item contains small parts. This is not a toy – adult supervision required.

WARNING: Do not connect the battery to the LED's directly, they are not designed to withstand 9 volts for an extended period.
LED's can pop, so please wear eye protection.

ELECDGH-CK ELECTRA DOUGH

Key Concepts:

- An electrical circuit is a pathway for a current of electricity. The electrical current is used to do work such as light an LED.
- Conductors allow electrical current to flow through them.
- Insulators do not allow electrical current to flow through them.
- A circuit can be open or closed.
- A circuit can be parallel or series.



Technical terms such as circuits, current, voltage, polarity and parallel versus series circuits can sound intimidating when you first begin to explore electrical circuits. However, understanding the basic principles of electricity is a necessary foundation for higher level work in science and engineering. The Electra Dough Kit allows students to play with materials that are fun, non-threatening and familiar, while learning the basic concepts of electrical circuits.

The Electra Dough Kit includes everything you need for four groups of students working in pods to build both an open and closed circuit and parallel and series circuits. You will light the LED's and sound buzzers from the circuits you build out of the conducting and insulating dough! Experiment and have fun!

What you should know:

Electrical current is created by the flow of electrons through a material that is *conductive*. What materials are conductive? Metals are conductive, some metals do a better job of conducting electricity than others do. The Electra Dough is conductive because of the salt content (salt is sodium chloride or NaCl that disassociates into sodium Na⁺ and chlorine Cl⁻ ions) in the dough which allows the electricity to flow through the dough.

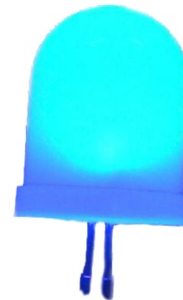
There are also materials that do not allow the flow of electricity, they are called *insulators*. An insulator acts like a wall to electricity and the electricity must go around them or find another path. What types of materials are insulators? Glass is an insulator as is rubber. The Electra Dough Kit includes a dough like substance that is made from a glass like polymer which is a good insulator of electricity.

All materials have a property called *resistance*, which tells you how easily it allows electricity to flow through it. Insulators have a high resistance while conductors have a low resistance. You can think of insulators as walls that block electricity and conductors as roads that allow electricity to travel along them.

A *closed circuit* is an electrical pathway for the flow of electricity. It's like an electrical race track. The circuit or electrical race track must have a continuous path for electricity to flow from the power source (battery) through a conductor (dough) and into a device that uses the power (LED) and then back through another conductor to the power source. The Conducting Dough in the kit will act like our road or a wire. If the continuous path is broken anywhere on our electrical road, electricity will not flow and the light bulb will not work. This is called an *open circuit*. If the conductors in a closed circuit touch together, it forms a new type of undesirable circuit called a *short circuit*. Electricity will flow through the wire (conducting dough) and not through the LED so it won't light up. The wire or dough has a lower resistance than the LED and electricity is lazy, it would rather travel through the conductor than the LED because it takes extra effort to travel through the LED. Said another way, the LED resists the electricity more than the dough race track so the electricity takes the dough race track instead of traveling through the LED. The insulating dough is used to buffer the conducting dough putting up a wall to block the electricity and preventing a short circuit.



Electricity also likes to travel in a certain direction going from positive to negative or rather the electrons travel from positive to negative. This is called *polarity*. An LED has one long leg which is positive and one short leg which is negative. A battery has a positive terminal (+) and a negative terminal (-). When building your circuit, remember polarity and attach the red or positive lead wire to the positive side of the battery and the black or negative lead wire to the negative side of the battery. When inserting the LED into the dough, insert the long leg which is positive into the dough with the red lead and the short leg which is negative into the dough with the black or negative lead.



Let's build our first circuit! To begin we to become familiar with the materials in our Electra Dough Kit.

Included in your kit are the following materials:

- 1 Tub of Conducting Dough
- 1 Tub of Insulating Dough
- 4 Each Leads with Mini-Grabber and Spade Terminals
- 4 Each Battery Connectors for a 9 Volt Battery
- 4 Each Buzzers
- 16 Each LED's – Light Emitting Diodes

What you will need that is not included in the kit:

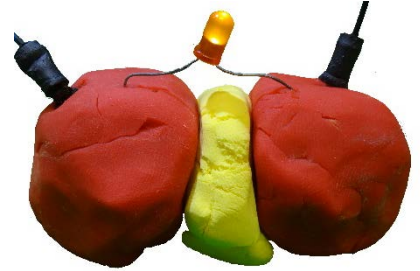
- 4 Each 9 Volt Batteries

Let's build a basic circuit!

1. Using the Conducting Dough, make two round balls about the size of a golf ball.
2. Using the Insulating Dough, make one ball about the same size.
3. Place the Insulating Dough ball between the two Conducting Dough balls and make a ball sandwich.
4. Attach the battery connector to the top of a 9 volt battery.
5. Using the lead wires with the Mini-Grabber and Spade Terminal, attach the Mini-Grabber end of the lead wire to the battery adapter. Insert the spade terminal end of the lead into the Conducting Dough balls – one in each ball.

- Next take the LED and bend the wires so they look like legs with a little bend at the knees.
- Insert the long leg into the ball with the positive lead wire and the short leg into the ball with the negative lead wire.
- What happens? You should have light!

If your LED is not glowing, think about what you have learned thus far and try and determine the cause of the problem. Think about the parts of a closed circuit. Is your insulating dough wall up and preventing electricity from flowing between your two conducting balls? Think about polarity, are your wires positive to positive and negative to negative? What about the LED; is the long positive leg of the LED in the positively charged conducting ball?



Now let's talk about types of closed circuits; *parallel* and *series* circuits.

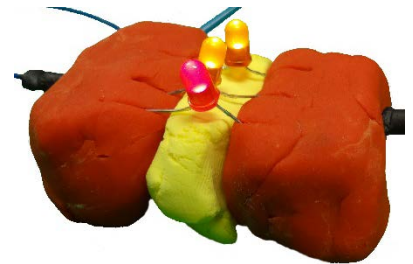
A *series circuit* only allows one path for the electricity to flow through. You can think of it as water flowing out of your garden hose. The water flows in one direction through the hose. The same is true with a series circuit, the electricity flows in one direction. You can build a series circuit with the electricity flowing in one direction with your Electra Dough Circuit Kit.

A series circuit will have a series of LEDs connected in a row with insulating dough between each block of conducting dough. As additional LED's are added to the series, the light will get dimmer because there is less electricity available to power them. If one LED is removed, the circuit is broken and all the lights will go out.



A more common type of circuit is a *parallel circuit*. A parallel circuit allows multiple paths for electricity to flow through. You can think of this circuit like a bath tub full of water with a hole in the bottom of the tub. Water will flow through the hole in the bottom of the tub but if you added more holes the water would flow more quickly. Electricity in a parallel circuit is like the water flowing from the holes in the tub.

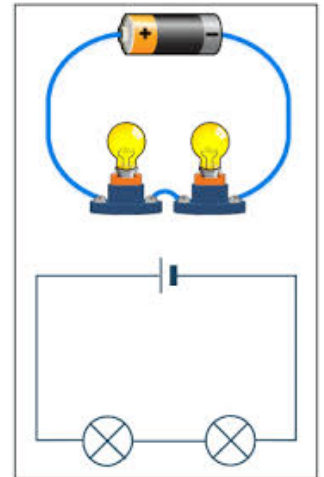
LEDs are connected to the dough each in their own circuit. Since the electricity flows through each LED independently, if one LED is removed, the others will continue to shine.



Let's build a series circuit!

- Using the Conducting Dough, make three round balls about the size of a golf ball.
- Using the Insulating Dough, make two balls about the same size.
- Place the Insulating Dough ball between the three Conducting Dough balls and make a ball sandwich.
- Attach the battery connector to the top of a 9 volt battery.
- Using the lead wires with the Mini-Grabber and Spade Terminal, attach the Mini-Grabber end of the lead wire to the battery adapter. Insert the spade terminal end of the lead into the Conducting Dough balls – one in each of the balls on the ends.
- Next take the LED and bend the wires so they look like legs with a little bend at the knees.

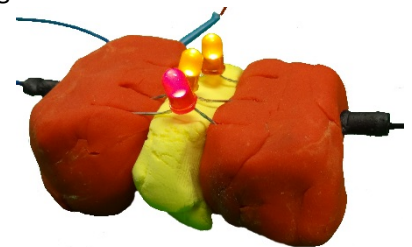
7. Insert the long leg into the ball with the positive lead wire and the short leg into the ball with the negative lead wire.
8. Using additional LEDs repeat step 7. Be sure to remember polarity and continue the pattern by connecting the conducting dough in a series of positive to negative using the LEDs.
9. What happens if you add more balls, alternating with conducting dough and insulating dough and connecting them in series with the LEDs? Does the light grow dimmer?



Let's build a parallel circuit!

Follow steps 1-7 above but this time add at least 3 LEDs each with the positive leg (long leg of LED) in the conducting dough with the positive lead and the negative leg (short leg of LED) in the conducting dough with the negative lead. Arrange the LEDs in the dough as illustrated.

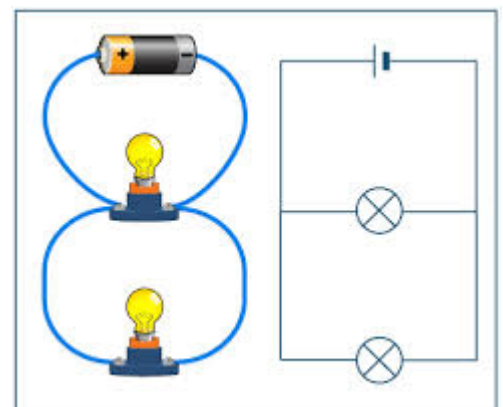
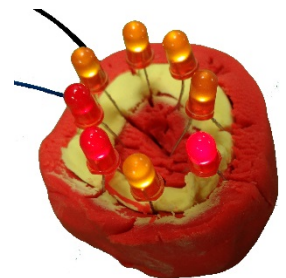
You can build other types of parallel circuits, like the round circuit in the illustration. Be creative and enjoy creating your own circuit designs!



Let's build a circuit to demonstrate resistance!

Adding a playful, but noisy, addition to the circuit will demonstrate *resistance*! We do this by adding a buzzer to the circuit. The conducting dough which acts as our wire in the closed circuit is also a resistor. You will be able to hear the resistance!

1. Make two long snake-like pieces with your conducting dough.
2. Make a small ball of insulating dough and place it between the snake-like conducting dough sections.
3. Using the lead wires, connect the battery holder with the Mini-Grabbers.
4. Insert the spade terminal end of the lead into the ends of your snakes; one spade terminal in each snake.
5. Using your buzzer, insert the black wire (negative wire) into the negatively charged snake and the red wire (positively charged) wire into the positively charged snake.
6. Is your buzzer sounding off loud and clear?
7. Now, stretch either snake making the conducting dough (wire) thinner and thinner. What happens? Is the sound growing faint? This is because you are increasing the resistance by reducing the size of the wire. You can also break the circuit and the re-connect it. Breaking the circuit will quiet the buzzer.



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 because it's difficult to separate.
- Don't cross the wires on the battery connectors. This will short out the battery and it may heat up and explode.
- Due to the high salt content in the conducting dough corrosion of the spade connector, LEDs and buzzer wires occurs very quickly if not wiped off after used.
- This normal occurrence of corrosion is a great opportunity to teach how corrosion can create resistance in a circuit. If your connectors due corrode they can be easily cleaned with some sandpaper, steel wool or sometimes just a piece of cloth.
- Warn students to always be careful when experimenting with electricity. High voltages and high current 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. Thomas Polsenberg Ph.D. AnnMarie, University of St. Thomas. Squishy Circuits.
<http://courseweb.stthomas.edu/apthomas/SquishyCircuits/index.htm>
2. Johnson-Roth, Perry Y Nguyen Chris, Beam UCLA
http://beam.ucla.edu/sites/default/files/docs/Squishy_Circuits.pdf