

## Light – Just Right!

**Grade Level:**

4

**Total Time Required:**

Six 30-minute periods

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**Lesson Objectives:**

*In this lesson, students will be able to:*

- Measure the electrical resistance of a material.
- Identify which materials are better conductors of electricity and which are better insulators of electricity.
- Design a way to control the brightness of a light bulb in an electric circuit by using materials with different electrical resistances.

**Indiana Standards:**

- 4.PS.4** Describe and investigate the different ways in which energy can be generated and/or converted from one form of energy to another form of energy
- 3-5.E.1** Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

**Next Generation Science Standards**

- 4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- 3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

**Science/Engineering Practices**

1. Asking questions (for science) and defining problems (for engineering)
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence

**Crosscutting Concepts**

2. Cause and effect: Mechanism and explanation.

**Common Core Mathematics:**

- 4.NBT.1 Recognize that in a multi-digit whole number, a digit in one place represents ten times what it represents in the place to its right.
- 4.NBT.2 Read and write multi-digit whole numbers using base-ten numerals, number names, and expanded form. Compare two multi-digit whole numbers based on meanings of the digits in each place, using  $>$ ,  $=$ , and  $<$  symbols to record the results of comparisons.
- 4.NBT.5 Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.

**Common Core English and Language Arts:**

- 4.RI.1/ 4.RL.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
- 4.L.1 Demonstrate command of the conventions of Standard English grammar and usage when writing or speaking.
- 4.L.2 Demonstrate command of the conventions of Standard English capitalization, punctuation, and spelling when writing.
- 4.L.6 Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal precise actions, emotions, or states of being and that are basic to a particular topic.

## Concepts and Vocabulary

<i>Term</i>	<i>Defined by a scientist or engineer</i>	<i>Defined by a student</i>
electricity	A form of energy resulting from the existence of charged particles, either statically as an accumulation of charge or dynamically as an electric current.	Something you turn on that gives power to things.
circuit	A complete and closed path around which a circulating electric current can flow.	The path of electrons.
open circuit	An electric circuit in which the normal path of current has been interrupted by the disconnection of one part on the pathway.	A bulb won't light.
closed or complete circuit	An electric circuit through which current can flow in an uninterrupted path.	A bulb lights.
short circuit	An electric circuit in which a direct connection exists along an unintended path such as directly connecting the plus and minus terminals of a battery which results in draining the battery, often with a large amount of heat. Short circuits can be dangerous.	An electric circuit that is not connected correctly.
leads	Wires that connect the battery to other parts of the circuit.	Wires for making a circuit.
conductor	A material that permits the flow of electric charges.	Electricity can travel through it.
insulator	A material that does not permit the flow of electric charges.	Doesn't allow electricity to flow through it.
resistance and conductance	Resistance (R, measured in Ohms) is the opposition to the passage of an electric charge through a material. Conductance is the inverse of resistance (1/R).	Not allowing electricity to easily flow in a circuit. Very high resistance means material is a good insulator. Low resistance means the material is a good conductor (high conductance).
Ohmmeter	A device that measures the electrical resistance of a material. Resistance is measured in Ohms.	Meter that measures resistance. A tool used to measure electrical resistance of a material. Helps determine if the material is a good insulator or conductor.

## Equipment, Materials, and Tools

<b>Materials</b>		
No. 2 pencils, 1 large box	Carpenter pencils, 5-6 total	Food coloring
Metal paperclips, 1 box	Distilled water, 1 gal. size from grocery store	Vegetable oil, 4 Tbsp
Plastic-coated (colored) paperclips, 1 box	Salt, 1 cup	Flour, 2 cups
Plastic forks, 5-6 total	Sugar, 1 cup	Ziploc bags, for dough storage
Metal forks, 5-6 total	Cream of tartar, 3 Tbsp	
Radio Shack 4 AAA battery holder (#270-0411)	Radio Shack 14" jumper leads (#278-1156)	Radio Shack 3 VDC, 5 mm LED Yellow (#276-0021)
Energy Ball	AAA batteries	

<b>Tools</b>		
Ruler	Ohmmeter	

### Safety Guidelines

- Working with low-voltage batteries and the circuits and materials described in this lesson is very safe. However, in general, when working with electrical circuits, students should not have wet hands or any liquids when conducting this design task. Stay away from sinks and drinking fountains when working with electricity.
- Information on electricity and water hazard can be found in the OSHA publication (p. 5; <http://www.osha.gov/Publications/osha3075.pdf>).
- More electrical safety information is also included in the Science Content section and at: <http://www.cableorganizer.com/articles/preventing-home-electrical-hazards.html>, <http://web.princeton.edu/sites/ehs/hazardcommguide/8.htm>.
- Supervise students when using sharp objects.
- Advise students not to eat the salt dough; though non-toxic, it does contain wheat as well as a large amount of salt.

## Synopsis of Engineering Design Activity

Synopsis of the Design Activity:

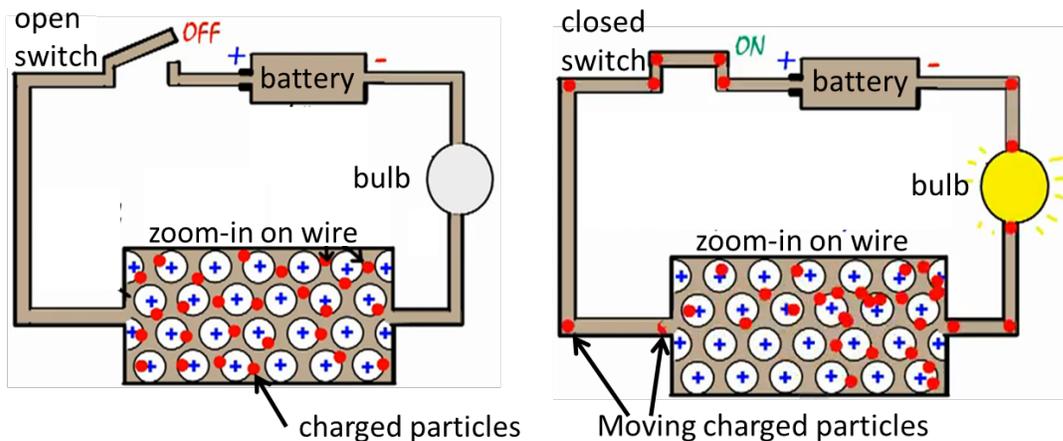
Problem:	(Option 1) Design a lamp for Ms. Goldilocks to present to the three bears. (Option 2) The children like to read and do their homework at desks in their rooms. They need to have a bright light from a lamp while working at their desk. However, when listening to music or playing electronic games, the lamp is a little too bright. Also, at night they like to have a dim light on while sleeping.
Goal:	Design and construct a series of salt dough-based electrical circuits that can be used to control the brightness of a glowing light bulb – specifically, to create a bright light, a dim light, and a light that is in-between bright and dim.
Who is the client:	Ms. Goldilocks (option 1) or Mr. and Mrs. Clark (option 2), parents of two school age children (option 2).
End-User:	(Option 1) three bears. (Option 2) Clark children or other students.
What is the design:	The choice of salt dough type(s) that is (are) selected for the construction of the circuit and how they are shaped (specifically, choice of length and thickness) will be used to change the overall resistance of the electric circuit (ex, low, medium, high resistance) in order to result in a glowing light bulb that has a controlled level of brightness (ex, high, medium, and low brightness).
Criteria:	<ol style="list-style-type: none"> <li>1. Design a series of electrical circuits from the materials that are provided to create a bright light, a dim light, and one in-between.</li> <li>2. Salt dough must be used as the “wires” that connect the bulb (LED) to the battery leads</li> </ol>
Constraints:	<ol style="list-style-type: none"> <li>1. Only available material should be used, specifically the three types of salt dough.</li> <li>2. Time.</li> </ol>

## Science Content – Electrical Properties of Materials

When you come home from school and turn on the lights in your house, the light bulbs will glow thanks to electricity. **Electricity** is the flow of electrical power through a material, by the motion of tiny particles within the materials that have an electric charge (ex, positive or negative charge). The electricity we use in our homes comes from a primary source like oil, nuclear power, coal, natural gas, hydroelectric power, sunlight, wind, or other material sources.

Electricity is carried through wires from the power plant to our homes. Wires are made of materials that are good **conductors** of electricity and allow the electrically-charged particles to travel or flow easily through the wire. Materials that are good conductors have low values of electrical **resistance**, which is measured in units of **Ohms** by a device called an **Ohmmeter**. Copper wires are an example of a material that is a very good conductor and has a very low value of electrical resistance (therefore high conductance).

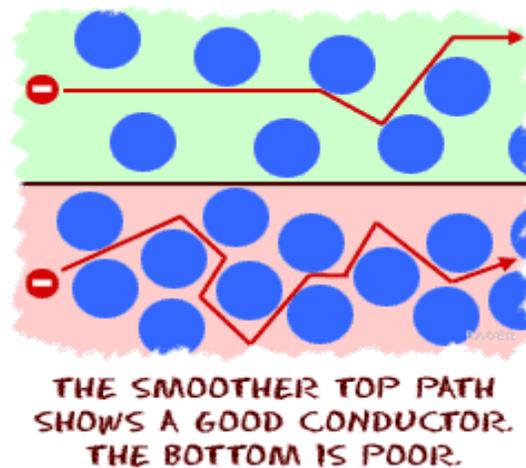
The electrically-charged particles will only flow through a material when that material is part of a **closed electric circuit**, such as shown in Figure 1. In the closed circuit, the flow of the charged particles (illustrated by red dots in Figure 1) from the battery to the light bulb and back through the battery will cause the bulb to glow. If the circuit is disrupted, such as if someone cut one of the wires or opened the switch, then the electric charges will no longer flow and the circuit is called an **open circuit**. The concept of closed and open circuits is easy to illustrate with a circle of people holding hands and using an “Energy Ball” (see Lesson Plan #1 for details).



**Figure 1:** Simple electric circuits are composed of a battery, a light bulb, connecting wires and a switch. The electric circuit at left is “open”, preventing the flow of charged particles (the red dots) through the wires. The electric circuit at right is “closed”, allowing the flow of charged particles through the wires and causing the light bulb to turn “on”. Note: normally, you cannot “see” the charged particles as they are traveling through the wires, bulb, and battery; here they are shown as red dots for instructional purposes. Adapted from <http://www.youtube.com/watch?v=DbKECtWNm8k> (useful movie!).

**Not all materials are good conductors.** Materials that hinder or prevent the flow of electrically-charged particles are called **insulators**. Insulators have very high values of **resistance** (small conductance), as measured in units of **Ohms** with an Ohmmeter. Rubber and plastic are examples of materials that are insulators. For example, most copper wire is coated with a layer of plastic to keep the charged particles traveling down the length of the wire and prevent the flow of charged particles out of the sides of the wire to nearby materials.

Materials that are good conductors of electricity have lots of freely moving charged particles in their volume. Metallic materials, like copper, silver and other metals, are good conductors because their internal structure is full of freely moving charged particles (in metals, these are called electrons and are negatively charged). Other materials also contain freely moving charged particles, like  $\text{Na}^+$  and  $\text{Cl}^-$ , that result from dissolving salt in water (these charged particles are called **ions**). Ions can move through a material just like electrons, allowing for the transport of electricity through the material. In materials that are poor conductors, like insulating materials, the flow of charged particles through the internal structure of the material is more difficult. This is illustrated in Figure 2.

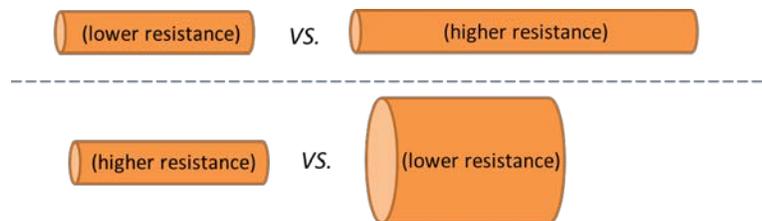


**Figure 2:** In the top material, it is easy for a charged particle to move through the material without bumping into other particles – the top material is therefore a **good conductor**. In the bottom material, it is much more difficult for a charged particle to move through the material – the bottom material is therefore a **poor conductor**.

*An appropriate classroom analogy to teach students the concept of a material's resistance to the flow of electricity is the following: a student trying to walk through a packed crowd of other students and desks (**high resistance** – difficult forward motion – **low conduction!**) vs. a student walking down an orderly aisle of desks (**low resistance** – easy forward motion – **good conduction!**).*

## Science Content – Electrical Properties of Materials (continued)

For a material to be a good conductor of electricity, it is not only what the material is made of that matters but also the shape of the material. Let's use a copper wire as an example (see Figure 3). A short length of copper wire is a better conductor (that is, it has a lower resistance, greater conductance) than a longer copper wire. The greater distance a charged particle has to travel through a material, the more difficult it is for the particle to complete its journey. So for wires, shorter is better (for conduction)! The thickness of the wire also matters. A thick copper wire is a better conductor (again, lower resistance) than a thin copper wire. This is because the charged particles have more space to travel within a thick copper wire and therefore encounter less resistance to their motion.



**Figure 3:** The shape of a copper wire, including the length of the wire and the thickness of the wire, will affect the wires value of resistance. Short wires have a lower resistance than longer wires. Thicker wires have a lower resistance than thinner wires. Short, thick wires make the best electricity conductors!

*An appropriate classroom analogy to teach students the effect of a material's shape on the flow of electricity is the following:* There are two covered slides on the playground – a short, wide one and a long, thin one. You and 9 friends want to race another team of 10 students, to see which team can all go down the slide in the shortest amount of time.

**Q:** Should your team choose the short, wide slide or the long, thin slide, in order to all slide down and reach the ground before the other team?

**A:** The short, wide slide is the best choice because more students can go down it in less total time compared to the long, thin slide.

\*\* The short, wide slide has **less resistance** to forward motion, similar to how short, thick metal wires are better conductors than long, thin metal wires!



## Science Content – Electrical Properties of Materials (continued)

When performing experiments with electricity, we must observe some basic safety rules to prevent harm to ourselves and the people around us. First, electrical appliances should never be used in or near wet areas (ex, bathtubs, sinks, in the rain). You should also never put your fingers or other objects into or near electrical outlets. Appliances that have been damaged and have bare wires that are visible should not be used. You should also never play near power lines (power lines are usually very high voltage and can therefore be dangerous) and in general you should stay far away from electric company equipment, including meters, transformers, and power lines.

Can you find the six safety dangers hidden in this picture?



**Figure 4:** This picture contains some common safety dangers associated with electricity, including the following: (1) Never climb a tree with a power line running through it; (2) Keep kites far away from power lines; (3) Be aware of overhead power lines; (4) Keep electrical cords far away from water; (5) Stay far away from power substations located on the ground; (6) Stay away from electrical utility boxes. From Alliant Energy, <http://www.alliantenergykids.com>.

## Lesson Plan #1

### Guiding Question – How do we measure a material's resistance?

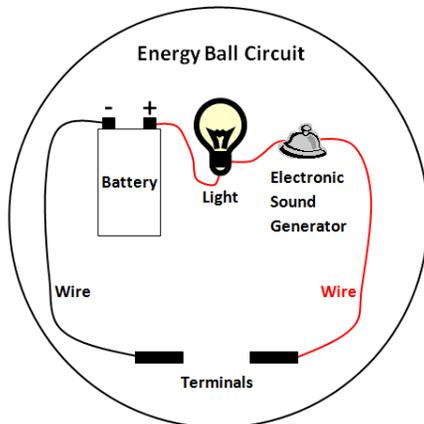
**Time:** 30 minutes

**Objective:** Brief introduction to closed and open electric circuits and materials that are conductors and insulators. The students will learn how to measure the value of resistance of a material by using an Ohmmeter.

#### Introduction and Group Activities:

a. Introduce the concept of **electricity** and how electricity travels through materials by the motion of electric charges (which can be in the form of electrons or ions). Explain the concept of an **electric circuit** by showing a schematic/drawing of a light bulb, wires, and battery and describing how the electric charges supplied by the battery will travel in a loop through the circuit and cause the bulb to light up. The concept of an **open circuit** and **closed circuit** can be then demonstrated with an “Energy Ball”:

- Introduce the “Energy Ball”, using Figure 5, if desired. The ball contains an open electrical circuit which includes a battery hooked up to an alarm and a light bulb and two metal terminals. When a material that conducts electricity is placed across the metal terminals (ex, a piece of metal wire), a closed electric circuit is formed and the ball will turn “on” by glowing and the alarm will sound.



**Figure 5:** Schematic of the open electrical circuit contained inside the Energy Ball. The Energy Ball can be purchased from Educational Innovations (<http://www.teachersource.com/>).

- To demonstrate a closed circuit, have the students stand, form a circle, and join hands. Have the teacher hold the Energy Ball (with one finger on a metal terminal) and have the neighboring student place their finger on the other metal terminal. This will form a closed circuit, with the students acting as the wires and allowing the electric charges to flow around the circle, causing the Energy Ball to turn “on”. This shows that our bodies, which contain water and free electric charges, are able to conduct electricity.
- Next, have one student in the circle release hands with their neighbor, causing a break in the circle. This will form an open circuit, halting the flow of electric charges around the circle and causing the Energy Ball to turn “off”.

**Lesson Plan #1 (continued)**  
**Guiding Question – How do we measure a material’s resistance?**

- b. Discuss the meanings of **insulators** (material that prevents the flow of electric charges) and **conductors** (a material that allows the flow of electric charges). The difference between conductors and insulators can be demonstrated with the Energy Ball:
- Have the students again form a closed circuit that includes the Energy Ball, which should turn “on” once the students are all holding hands.
  - Next, have two neighboring students release hands (breaking the circuit and turning the Energy Ball “off”). Now, have those two students hold on to the opposite ends of an item that is made of metal (such as an unfolded paperclip, metal fork, ends of a metal desk, etc). The Energy Ball should now turn back “on”, because the metal item is a good conductor of electricity and forms a closed circuit once again, allowing the flow of electricity around the circle of students.
  - Next, have the two students hold on to opposite ends of an item made of plastic or wood (such as a popsicle stick, yard stick, edges of a wooden table, etc.). The Energy Ball should remain “off”, because the plastic or wooden item is an insulator (or bad conductor of electricity) and results in the formation of an open circuit, preventing the flow of electricity around the circle of students.
- c. We can determine how well a material can conduct electricity by measuring the material’s value of **resistance** with a device called an **Ohmmeter**. A material with a low value of resistance is a better conductor than a material with a high value of resistance. A method of describing the concept of resistance to the students is described in the box on page 7.

**Procedure:**

1. Display the materials to be tested – a piece of wire and a piece of plastic (note: could also use a piece of copper wire that has a plastic coating).
2. Display the Ohmmeter and identify the main components of the device (the two wire leads, the scale, the display) and describe how to determine the value of the material’s resistance from the Ohmmeter’s display.
3. Demonstrate for the students how to test the two materials using the Ohmmeter and how to read the value of the resistance (units of Ohms) from the Ohmmeter’s display.
4. In their notebooks, have the students make a list of the required steps to measure a material’s resistance. Have the students practice on the two materials that were used in the demonstration, so that they can become familiar with using the Ohmmeter and recording resistance measurements.

**Note:** This procedure may vary, depending on the type of Ohmmeter used in this activity. Here, we have assumed the use of a digital Ohmmeter, where the numerical value of the resistance is displayed (see following page).

## Lesson Plan #1 (continued)

### Guiding Question – How do we measure a material's resistance?

*Instructions for how to use an Ohmmeter to measure resistance (in Ohms):*

Ohmmeters (also called VOMs or Voltmeters) can be used to measure voltage (in Volts), resistance (resistance to current flow, in Ohms) and current (amount of current, in Amperes or amps). Ohmmeters are relatively inexpensive (starting at about \$10), and can be purchased at most hardware stores, Radio Shack and other electronics suppliers, and online such as at amazon.com. Analog (dial display) and digital Ohmmeters are available. Most Ohmmeters can be used for DC (direct current; battery power) and AC (alternating current, such as house electrical current) measurements. See Figure 6 for photos of Ohmmeters and brief instructions on use.

YouTube videos explaining the use of Ohmmeters can be found at:  
<http://www.youtube.com/watch?v=BCd1nk1b5AY> (digital Ohmmeter)



**Figure 6:** Analog (left) and digital (right) Ohmmeters. The red (positive) and black (negative) test leads are connected to the meters for DC voltage or resistance. On the analog meter (dial scale, numbers in green, measures resistance), the resistance settings are Rx 1 (measures resistance in Ohms directly), Rx 10 (multiply the resistance reading by 10 for actual resistance), and Rx 1K (multiply the resistance reading by 1000 for actual resistance). On the digital meter, the resistance settings are 2K (measures resistance in Ohms directly for 0-2000 Ohms range), 20K (multiply the resistance reading by 1,000 for actual resistance), 200K (multiply the resistance reading by 1,000 for actual resistance), and 2M (multiply the resistance reading by 1,000,000 for actual resistance). Always begin by using the highest setting (Rx 1K for the analog meter and 2M for the digital meter) and work your way to the lower settings until the dial can be easily read on the analog meter or until an appropriate digital number appears on the digital meter.

## Lesson Plan #2-A

### Inquiry Activity – Measuring the resistance of different materials

**Time: 30 minutes**

**Objectives:**

- (1) With assistance from the teacher, students will measure and record the resistance of different materials using an Ohmmeter.
- (2) Students will identify materials that are good conductors, poor conductors, and very poor conductors (good insulators).

**Equipment and Materials:** Ohmmeter and various materials to test, as listed in the table.

Note: the regular pencils are all same brand (ex, Staples, No. 2), and are sharpened at both ends to yield different lengths of pencil, “long”, “medium”, and “short” (remove eraser/metal before sharpening); the carpenter pencil (which has a thicker core of graphite) can be purchased from a local hardware store and should be sharpened to match the length of one of the pencils (ex, the “medium” or “short” pencil length).

**Procedure:**

1. Organize the students into small groups, based on the number of Ohmmeters that are available. **Note:** If only one Ohmmeter is available, this activity can instead be performed as a demonstration led by the teacher but allowing for student participation.
2. If using a digital Ohmmeter (recommended), set the scale to the lowest setting, typically labeled as “200” Ω. This Ohmmeter setting displays the resistance in units of Ohms on the digital screen. For convenience in describing conductors and insulators, which vary significantly in resistance, use the following table for classifying the material as a *good conductor*, a *poor conductor* or a *very poor conductor (good insulator)*.

**Safety Note:** Although very poor conductors (resistance greater than 1 million Ohms) can be good insulators, if voltages are very high, electric current can flow through very poor conductors. This current flow through very poor conductors will occur most often with high voltages and very small distance between two wires connected to positive and negative terminals of a battery (or other electrical power source) separated by an insulator (very poor conductor). To see an example of this phenomenon (a spark carrying current though air – a very poor conductor), see the “spark” video listed in the supplemental materials section.

Type of Conductor	Resistance (R, Ohms)	Examples
<i>Good Conductor</i>	$R < 1$ (less than 1 Ohm)	most metals (copper, iron, aluminum, etc.) are very close to zero Ohms
<i>Poor Conductor</i>	$1 < R < 1 \text{ million}$ (between 1 and 1,000,000 Ohms)	graphite, drinking water, river, lake and sea water, salt dough, our bodies
<i>Very Poor Conductor (Good Insulator)</i>	$R > 1 \text{ million}$ (greater than 1 million Ohms)	air, dry wood, plastic, glass, ceramic, rubber – most good insulators will have resistances much greater than 1 million Ohms

**Lesson Plan #2-A (continued)**  
**Inquiry Activity – Measuring the resistance of different materials**

3. In their notebooks, have the students make a three-column data table as shown below (to save time, a copy of a blank table is supplied as a Handout in the Appendix). Approximate values and labels shown in *grey* are for the teacher’s reference.

<b>Objects/Material</b>	<b>Resistance (Ohms)</b>	<b>Type of Conductor?</b>
Metal Paperclip	<i>0.2</i>	<i>Good Conductor</i>
Plastic-Coated Paperclip	<i>Too large</i>	<i>Very Poor Conductor (Good Insulator)</i>
Metal Fork	<i>0.5</i>	<i>Good Conductor</i>
Plastic Fork	<i>Too large</i>	<i>Very Poor Conductor (Good Insulator)</i>
“Long”No. 2 Pencil	<i>40</i>	<i>Poor Conductor</i>
“Medium”No. 2 Pencil	<i>30</i>	<i>Poor Conductor</i>
“Short”No. 2 Pencil	<i>20</i>	<i>Poor Conductor</i>
Carpenter Pencil (graphite)	<i>10</i>	<i>Poor Conductor</i>

4. Following the steps that were described in Lesson #1, the students will measure the resistance of each object and record the resistance value in the table in their notebooks or on their handout. The teacher may wish to demo the first measurement. The resistance value may fluctuate at first; instruct the students to “count to 5” and then record the value that they observe in the display.
5. After the students have completed their table or handout, have the students answer the following questions in their notebooks:
- How did you know if an object was a good conductor?
  - What types of materials are good conductors?
  - How did you know if an object was a good insulator?
  - What types of materials are good insulators?
  - Does the shape of the object (such as length or thickness) affect the value of resistance that you measured?
  - What shape(s) of materials are the best conductors?

**Lesson Plan #2-A (continued)**  
**Inquiry Activity – Measuring the resistance of different materials**

6. After the students have completed their table or handout, have the students answer the following questions in their notebooks:
  - a. How did you know if an object was a good conductor?
  - b. What types of materials are good conductors?
  - c. How did you know if an object was a good insulator?
  - d. What types of materials are good insulators?
  - e. Does the shape of the object (such as length or thickness) affect the value of resistance that you measured?
  - f. What shape(s) of materials are the best conductors?
  
7. Compare the values of resistance that the students measured for the different materials (to do this, it may be useful to fill in the table on the chalkboard/smartboard together as a class). Discuss the questions together as a class. Points to emphasize during the discussion:
  - a. A material with a low value of resistance is a better conductor than a material with a high value of resistance.
  - b. Materials made of metal are typically excellent conductors while materials made of plastic are typically insulators (poor conductors).
  - c. In addition to what the material is made of, the actual *shape* of the material strongly affects its ability to conduct electricity – for example, the short pencil and the pencil with the thickest lead had the lowest values of resistance compared to the other pencils that were tested.

Suggested extension: To incorporate additional math skills, the teacher can ask the students to measure the lengths of the pencils using a ruler and record these lengths in their tables.

**Additional Option for Inquiry Activity:** If an Ohmmeter is not available, or if the teacher wishes to do the inquiry activity without an Ohmmeter, it is possible to demonstrate resistance measurements with the brightness of an LED bulb. For this approach, use the circuit shown in the photo and drawing in Lesson #3. Also, use a short section (about 5-6 cm long and 2 cm diameter) of the “high salt” dough to make the connection, as shown in the illustrations. You will also need an additional alligator clip (2 leads). Then, remove the black clip from the nail and connect it to one end of the material to be tested (wood, paper, paper clip, graphite in pencil, salt dough, etc.). With the extra alligator clip cable, connect one clip to the other end of the material being tested and the other clip to the nail in the salt dough. If the material to be tested is a good conductor, the light will remain bright; if it’s a poor conductor, it will dim noticeably; if it is a very poor conductor (good insulator), the LED will not light up at all. This approach is less quantitative and does not introduce appropriate technology and measurement, but is easier and the testing results are very visible.

## Lesson Plan #2-B

### Inquiry Demo – The effect of salt on a material’s resistance

*Note: This “advanced” inquiry activity is a teacher-led demonstration because it will require changing the scale of the ohmmeter in order to measure the material’s resistance; this may be considered to be too advanced for students to do by themselves.*

**Time: 30 minutes**

**Objectives:** Through teacher-guided demonstration, students will learn how the addition of salt to a material will change its resistance.

#### **Equipment and Materials:**

Ohmmeter

Distilled water (can purchase from local grocery store)

Salt water (ocean equivalent, ~ 3.5% by weight) = 1 cup distilled water + 1tsp. of salt

salt dough\* – three salt dough mixtures with three different levels of salt

\* For salt dough, see recipes in lesson plan #3.

#### **Procedure:**

1. Material prep: pour equal amounts of each type of water into three different, clearly labeled cups; create cylindrical shapes of roughly equivalent length and thickness with the two different types of salt dough.
2. To obtain a measurement, a higher scale will need to be selected on the digital Ohmmeter. To measure the resistance of the water, the suggested scale is the “2M”  $\Omega$  scale, which stands for million Ohms – for a reading of “0.200” on this scale, the resistance is  $0.200 \times 1,000,000 = 200,000$  Ohms. For the salt dough, the suggested scale is “20K”  $\Omega$ , which stands for thousand Ohms – for a reading of “5.0” on this scale, the resistance is  $5.0 \times 1,000 = 5,000$  Ohms. See Figure 7 for example of measuring resistance in water.
3. In their notebooks, have the students add the following rows to the data table they made in the previous inquiry activity (Lesson #2-A; or a Handout is included in the Appendix with a blank table for the students to complete). Approximate values and labels shown in *grey* are for the teacher’s reference.

**Figure 7.** Example of using an Ohmmeter to measure resistance of water. In this case, the water is distilled. The resistance setting on the Ohmmeter is “2M” so the reading 0.207 is multiplied by 1 million, so the resistance measurement is 207,000 Ohms – a poor conductor. With this test procedure, one can also show that the distance between the electrodes is a factor in the resistance, similar to the length of a conductor. If the electrodes are moved closer together, the resistance will decrease, yielding a better conductor.



## Lesson Plan #2-B (continued)

### Inquiry Demo – The effect of salt on a material’s resistance

Objects/Material	Resistance (Ohms)	Type of Conductor?
1 cup distilled water	200,000 - 400,000**	Poor Conductor
1 cup salt water	50,000 - 100,000**	Poor Conductor
“low-salt” dough	40,000 - 50,000	Poor Conductor
“medium-salt” dough	20,000-40,000	Poor Conductor
“high-salt” dough	10,000 - 20,000	Poor Conductor

\*\*Note about the water measurements: readings may tend to fluctuate. For these reported resistance values, the tips of the Ohmmeter leads are submersed in the water and held at a spacing of approximately 1 inch. To get the best reading, first measure the distilled water and note the average resistance after 5 seconds (it may steadily increase). Second, dry off the Ohmmeter leads and then measure the resistance of the salt water. Though the values may fluctuate, the salt water should display a resistance that is less than the distilled water.

4. The teacher will now measure the resistance of each material that is listed in the table and record the value of resistance for each material on the chalkboard/smartboard. Have the students copy the values into their tables or on their handouts.
5. Ask the students to identify in their notebooks/handouts which type of water is the best conductor and which type of salt dough is the best conductor.
6. Discuss the results with the students, referencing the resistance values of the objects listed in their tables. Emphasize to the students that materials which contain more salt are typically better conductors than materials that contain less salt (or no salt).

Possible extension: To incorporate additional math skills, the teacher can walk the students through the multiplication step that is necessary to determine the material’s resistance value in Ohms from the value reported by the ohmmeter when using the higher scales.

**Safety Note:** Due to the low voltage of the battery packs used in this activity, water is not a significant hazard with the circuits. However, it is always good practice to avoid using electrical devices near water, and to avoid possible short circuits (for example, see the short circuit YouTube video listed in the Supplemental Materials section). Water and electricity can be very dangerous for several reasons. Although pure, distilled water has very high resistance, tap water, spring water, river and lake water (and the water in our bodies) have dissolved compounds and acids that produce charged particles (ions) that allow partial conduction of electricity. The high voltage of most electrical devices (house and building wiring, and especially high voltage power lines) can create large and dangerous currents in water. Furthermore, because water is a liquid, it can easily penetrate electrical devices and create a short circuit between the positive and negative current wires (or electronic parts) that are often very close together in the device leading to low resistance, even with water making the connection or short circuit.

## Design Activity (option 1)

### *Light - Just Right!*

After visiting the three bears, Goldilocks wanted to send the Bear family a special gift to thank them for their hospitality. She decided on a nice lamp that would provide light that was *juusstttt* right for Papa Bear, Mama Bear, and Baby Bear. Goldilocks contacted *This Little Light of Mine Company* and asked them to design a lamp with adjustable brightness levels. As a *This Little Light of Mine Company* engineer, you and your team must plan, build, and test a salt dough electrical circuit that creates a **bright light**, a **dim light**, and a **light that is in-between**.

You will be provided with the following materials to create your electrical circuits:

- a battery pack, with wires and alligator clips
- an LED light bulb
- a few nails, to connect the wires and clips to the dough
- three salt dough materials, each with different amounts of salt

Hint: Use your experiences from the inquiry activities to design an electrical circuit that can be connected in **three different ways** to produce **three levels of brightness** of the light bulb (LED). It is suggested that you begin by designing and testing a circuit that produces a bright light. Then you can proceed to modify that circuit to produce the “in-between” and the dim light. Remember that resistance of a material is determined by the **type** of material and **shape** of the material. Be sure to connect the positive side (longer wire) of the LED to the **positive** battery lead (terminal).

Warnings: **Do not connect the LED light bulb directly to the battery without salt dough in the circuit** (this will cause the LED to **burn out**). The salt dough is not toxic, but do not eat the salt dough. Also, do not create a **short circuit** in your electrical circuit by allowing a direct connection (such as with a copper wire) between the plus and the minus terminals or leads of the battery or battery pack.

## Design Activity (option 2)

### *Light - Just Right!*

Mr. and Mrs. Clark have two children in school. Both children like to read and do their homework at desks in their rooms. They need to have a bright light from a lamp while working at their desk. However, when listening to music or playing electronic games, the lamp is a little too bright. Also, at night they like to have a dim light on while sleeping. The Clarks have not been able to find a lamp that provides the three levels of brightness. Mrs. Clark is friends with Ms. Olsen who is the manager of the *Bright Engineering Design Company*, so she contacted Ms. Olsen and asked her if her company could design a lamp with adjustable brightness levels. Because Ms. Olsen wants to help her friend, and the lamp design could lead to a popular product to sell, she agreed to help with the design. As a *Bright Engineering Design Company* engineer, you and your team must plan, build, and test a salt dough electrical circuit that creates a **bright light**, a **dim light**, and a **light that is in-between**.

You will be provided with the following materials to create your electrical circuits:

- a battery pack, with wires and alligator clips
- an LED light bulb
- a few nails, to connect the wires and clips to the dough
- three salt dough materials, each with different amounts of salt

Hint: Use your experiences from the inquiry activities to design an electrical circuit that can be connected in **three different ways** to produce **three levels of brightness** of the light bulb (LED). It is suggested that you begin by designing and testing a circuit that produces a bright light. Then you can proceed to modify that circuit to produce the “in-between” and the dim light. Remember that resistance of a material is determined by the **type** of material and **shape** of the material. Be sure to connect the positive side (longer wire) of the LED to the **positive** battery lead (terminal).

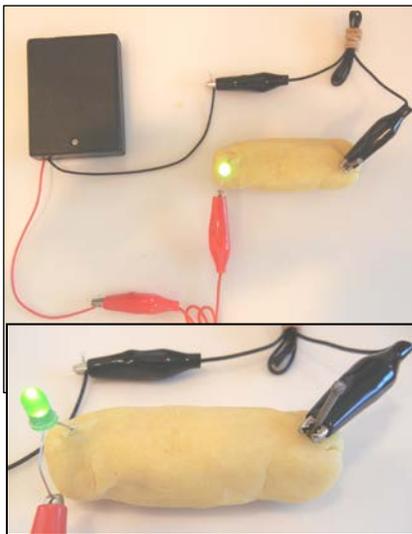
Warnings: **Do not connect the LED light bulb directly to the battery without salt dough in the circuit** (this will cause the LED to **burn out**). The salt dough is not toxic, but do not eat the salt dough. Also, do not create a **short circuit** in

your electrical circuit by allowing a direct connection (such as with a copper wire) between the plus and the minus terminals or leads of the battery or battery pack.

### Preparation for Lesson Plan #3

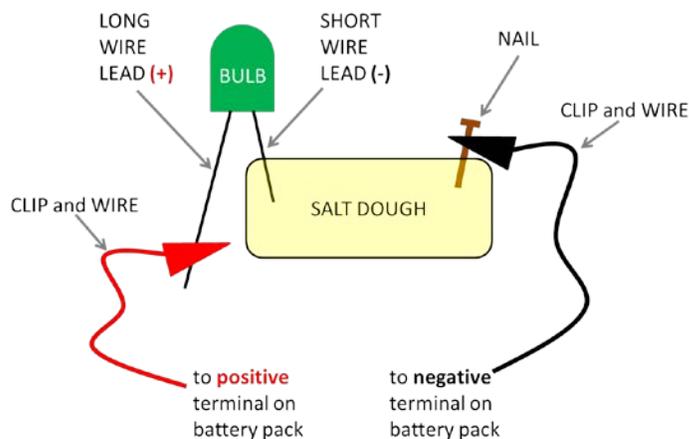
### Design Challenge: Light – Just Right!

The following are some instructions for the teacher in preparation for the Design Activity described in Lesson Plan #3. We have provided two options for the Design Activity (handout for the student teams) – use the one that you think will work best with your students.



**Example salt dough circuit:** In the example circuit shown here (picture at top left), the black rectangle is a 6-volt battery pack, the positive voltage terminal is connected with the red wire and alligator clips, and the negative voltage is connected with the black wire and alligator clips. The yellow salt dough (approximately the shape of a short cylinder) is connected to the black alligator clip by a nail (or metal paper clip) inserted into the salt dough. The LED light bulb is connected to the salt dough by inserting the short wire lead of the LED into the salt dough. The red alligator clip is connected to the long wire lead of the LED, completing the circuit. A close-up picture of the connections to the salt dough is shown in the picture at

bottom left and a zoomed-in view is also shown in the following schematic.



**Note:** Students should be given all materials at the start of the activity with the exception of the battery pack, which should only be provided after the students have completed their circuit design and are ready for testing. **Be sure that there is salt dough in their circuit to avoid burning out the LED.** Also, remind the students that the LED must be connected with the long wire lead to the **positive** battery terminal. The salt dough sometimes displays “*contact resistance*” – usually

for a long time or left out of its plastic bag for 20 minutes or  
ce the effectiveness of connections and cause variable results.  
little water into the dried salt dough by kneading with wet  
d the LED wire in the circuit or the leads on the Ohmmeter

## Preparation for Lesson Plan #3 (continued)

### Design Challenge: Light – Just Right!

**Instructions for home-made salt dough** (Note: salt dough is not toxic, but should not be eaten. We recommend using distilled water for making the dough so that the resistance is controlled primarily by the amount of salt in the dough.)

1. Conductive Salt Dough (large amount of salt, **yellow**) – Use **cooking recipe** (below) Makes a little less than 1 cup of salt dough (recipe can be doubled if necessary). Dough can be stored for weeks in a zip-lock plastic bag (will last longer stored in refrigerator). For use in circuits, make sure that it is slightly wet – a little bit sticky instead of very dry. If dough is dry when taken out of the plastic bag, you can work some water into the dough by kneading with wet hands.
2. Moderately conductive Salt Dough (moderate amount of salt, **purple**) – Use **no-cook recipe** (below) and also add 2 teaspoons of salt. Makes a little less than 1 cup of salt dough (recipe can be doubled if necessary). Dough can be stored for weeks in a zip-lock plastic bag (will last longer stored in refrigerator). For use in circuits, make sure that it is slightly wet – a little bit sticky instead of very dry. If, dough is dry when taken out of the plastic bag, you can work some water into the dough by kneading with wet hands.
3. Poorly conductive Salt Dough (small amount of salt, **red**) – Use **no-cook recipe** (below) and also add ½ teaspoon of salt. Makes a little less than 1 cup of salt dough (recipe can be doubled if necessary). Dough can be stored for weeks in a zip-lock plastic bag (will last longer stored in refrigerator). For use in circuits, make sure that it is slightly wet – a little bit sticky instead of very dry. If, dough is dry when taken out of the plastic bag, you can work some water into the dough by kneading with wet hands.

**Cooking Recipe** (adapted from <http://www.abc.net.au/science/articles/2012/04/17/3479415.htm>):

- 1) In a saucepan, completely dissolve ¼ cup of salt in ½ cup of warm water (dissolving the salt first ensures a good texture). Add food coloring. Next, add 1 tablespoon cream of tartar, ½ tablespoon of vegetable oil and ½ cup of plain flour. Stir thoroughly.
- 2) Cook the play dough mixture on low heat, stirring constantly with a wooden spoon until a ball forms (it takes just a few minutes). Place the ball and flatten it out on a lightly floured baking tray to cool (again, just a few minutes is enough).
- 3) Knead in more flour until the dough stops feeling sticky and you're done.

**No-Cook Recipe** (adapted from <http://www.abc.net.au/science/articles/2012/04/17/3479415.htm>):

- 1) Use distilled water instead of tap water if possible. Mix ½ cup of plain flour and ½ cup of white sugar in a mixing bowl. Add 1 tablespoon of vegetable oil and mix thoroughly. Now add ½ tablespoon of water at a time until the dough forms baked-bean sized clumps.
- 2) Transfer the lumpy dough onto a baking tray (not floured yet) and knead into a ball. Add more water, ½ tablespoon at a time and knead. Continue adding water until the dough becomes sticky. Now knead in more flour until the ball stops feeling sticky and reaches the texture of play dough.

## Lesson Plan #3 (continued)

### Design Challenge: Light – Just Right!

**Time:** 90 minutes (3x – 30 minute periods; procedures 1-3, 4-6, and 7-10)

**Objective:** Work as a team to design a way to control the brightness of a light bulb (LED) in an electric circuit by using materials with different electrical resistances. (**Note:** students who are not experienced with team projects should be provided instructions on teamwork – different roles, listening and considering input from all, etc.; also see procedures 4-6 below.)

#### Procedures:

1. Review with the students the different components of an electrical circuit and what kinds of materials are good conductors and good insulators. Demonstrate how to build an electrical circuit using the materials supplied for the design activity (see previous pages for instructions and pictures).
2. Distribute, read aloud, and discuss the design brief. Ask the following:
  - What is the problem?
  - Who is the client?
  - Who is the user?
  - What are the criteria?
  - What are the constraints?
  - What materials and tools have been provided?
3. Have students respond to the above questions in their notebooks. Discuss responses with class. Show the students the materials that are available for the activity.
4. Instruct students to individually brainstorm ideas applying what they have learned about electric circuits and to think about the following two questions:
  - (1) What could you do to cause the bulb to brightly glow?
  - (2) What could you do to cause the bulb to glow less brightly?Ask the students to think back to the observations made during the inquiry lessons (Lesson Plan #2-A and #2-B). The salt dough allows the students to design solutions by choosing different materials (different levels of salt) and/or changing the shape (thickness, length, combinations of materials, etc).
5. Have students list or sketch their own ideas in their notebooks. Then have them choose their best idea to use as an individual design plan. Remind students that sketches should be large, neatly drawn, and clearly labeled showing dimensions and materials.
6. Students should then meet with their team and share plans, explaining how they expect their design to solve the problem. Each team should decide on a ‘final’ group design, which can be a combination of ideas or a specific design from an individual within the group. Have each team member sketch the final design. Each of the students’ sketches should be detailed to allow anyone else to construct the design by looking at the drawing.



**Lesson Plan #3 (continued)**  
**Design Challenge: Light – Just Right!**

7. Student teams will construct their design for a way to control the brightness of the light bulb. After completing the design, groups will obtain a battery pack from the teacher and test their design, and modify as needed.

CREATE AND TEST

8. Each group presents their design to the whole class and then demonstrates their prototype for the class.

COMMUNICATE  
RESULTS  
GATHER FEEDBACK

9. After all groups have presented, each student will answer the following questions in their notebook:

- How effective (good) was your design? How do you know?
- What would you change in your design? Why?

10. If time permits, encourage students to redesign based on test results. If time does not permit, instruct students to sketch a new design in notebook based on change mentioned above. Remind students to note any changes if design is modified from the original sketch.

IMPROVE AND  
RETEST

## Assessment

The following are possible sources of formative and summative assessment:

From Lesson Plan #3, use a simple rubric to assess student notebooks for the following Design Process Standards:

- Identify a need or problem to be solved.
- Document the design throughout the entire design process. (individual, group, redesign sketches)
- Create the solution through a prototype.
- Evaluate and test the design.
- Communicate how to improve the solution.

Individual participation within group

- Note level of engagement
- Ability to work well with other team members during design process
- Contribution during team presentation

Create a short pre- and post-test

- Student must explain what resistance is and how it is measured (in basic terms).
- Student must explain how a material's measured value of resistance is related to whether or not that material is a good conductor or a good insulator.
- Students must identify what types/shapes of materials are good conductors and what types/shapes of materials are good insulators.

## APPENDIX: Lesson Extensions and Resources

<b>Trade Books for Light – Just Right!</b>			
Title	Author	Publisher Date	Comments
Thomas Edison	Jan Adkins	DK Publishing 2009	Biography; Timeline; Sketches from Edison’s notebook
Thomas Edison Wizard of Light and Sound	Amy Graham	Enslow Publishers 2008	Biography MyReportLinks.com Book
Thomas Edison Inventor with a Lot of Bright Ideas	Mike Venezia	Children’s Press 2009	Biography; Accelerated Reader Cartoon-style illustrations
Thomas Alva Edison	Brian Williams	Heinemann Library 2001	Biography; Sketches from Edison’s notebook (Out of print)
Thomas Edison: The Great Inventor	Caryn Jenner	DK Publishing 2007	Biography Lower reading level
Inventing the Future A Photobiography of Thomas Alva Edison	Marfé Ferguson Delano	National Geographic 2002	Biography Edison quotes
Electricity and Magnetism Science Fair Projects Using Batteries, Balloons, and Other Hair-Raising Stuff	Robert Gardner	Enslow Publishers 2004	Chapter on circuit projects
Electrical Experiments (Do It Yourself) Electricity and Circuits	Rachel Lynette	Heinemann Library 2008	Experiments, activities, and information Colorful graphics
Zap It! (Design It) Exciting Electricity Activities	Keith Good	Lerner Publications 1999	Circuit Activities Colorful graphics
Electricity (Science Detective Investigates)	Harriet McGregor	Windmill Books 2011	Electrical facts and investigations
When Charlie McButton Lost Power	Suzanne Collins	G.P. Putnam’s Sons 2005	Fiction Charlie has a meltdown when power is lost due to a thunderstorm
Goldilocks and the Three Bears	Jim Aylesworth	Scholastic Press 2003	Fiction Traditional retell
Goldilocks and the Three Bears	Emma Chichester Clark	Candlewick Press 2009	Fiction Traditional retell
Goldilocks and the Three Bears	James Marshall	Puffin Books 1998	Fiction; Modern retell Caldecott Honor Book
Believe Me, Goldilocks Rocks!: The Story of the Three Bears as Told by Baby Bear	Nancy Loewen	Picture Window Books 2012	Fiction Modern retell by Baby Bear
Goldilocks Returns	Lisa Campbell Ernst	Simon & Schuster 2000	Fiction Goldilocks grows up and tries to set things right.
Goldilocks on CCTV	John Agard	Frances Lincoln Children’s Books 2011	Poetry Modern day telling on TV news report.
Ricitos de Oro y los Tres Osos	Percy Graham	Peralt Montagut	Fiction Retell in Spanish

**Handout for Lesson Plan #2-A:**

<b>Objects</b>	<b>Resistance (Ohms)</b>	<b><u>G</u>ood Conductor (G), <u>P</u>oor Conductor (P), or <u>V</u>ery <u>P</u>oor Conductor (<u>I</u>nsulator) (VP/I)? (circle G, P or VP/I)</b>
Metal Paperclip		<b>G   P   VP/I</b>
Plastic-Coated Paperclip		<b>G   P   VP/I</b>
Metal Fork		<b>G   P   VP/I</b>
Plastic Fork		<b>G   P   VP/I</b>
“Long” Pencil		<b>G   P   VP/I</b>
“Medium” Pencil		<b>G   P   VP/I</b>
“Short” Pencil		<b>G   P   VP/I</b>
Carpenter Pencil		<b>G   P   VP/I</b>

**Handout for Lesson Plan #2-B:**

<b>Objects</b>	<b>Resistance (Ohms)</b>	<b><u>G</u>ood Conductor (G), <u>P</u>oor Conductor (P), or <u>V</u>ery <u>P</u>oor Conductor (<u>I</u>nsulator) (VP/I)? (circle G, P or VP/I)</b>
Distilled water		<b>G   P   VP/I</b>
Salty water		<b>G   P   VP/I</b>
“Low-salt” dough		<b>G   P   VP/I</b>
“Medium-salt” dough		<b>G   P   VP/I</b>
“High-salt” dough		<b>G   P   VP/I</b>

## Supplemental Materials:

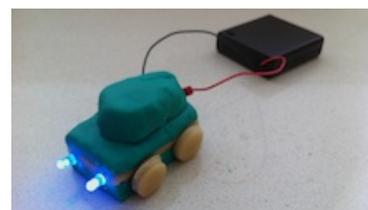
Good conductors: Any metals, including wires, paperclips, the spirals on spiral-bound notebooks, coat hangers. All metals will typically have a resistance of  $< 1$  Ohm. Can measure on the lowest scale of the Ohmmeter (e.g., “200”  $\Omega$ , Ohms).

Poor conductors: Graphite in a pencil, will typically have a resistance of 10-100 Ohms – can measure on the lowest scale of the Ohmmeter (e.g., “200”  $\Omega$ , Ohms). Homemade salt dough, will typically have a resistance of 10,000-100,000 Ohms (depending on the amount of salt) – can measure on the 200k scale of the Ohmmeter. Pure water and water containing salt will have resistance values ranging from 50,000-500,000 Ohms. Can measure on the highest scale of the Ohmmeter (e.g., “2M”, will need to multiply the value displayed by 1,000,000).

Very poor conductors (good insulators): Dry wood, paper, plastic, glass, pure distilled water. All will typically have a resistance greater than 1 million Ohms or larger – often too large to measure using a digital Ohmmeter (Ohmmeter will show a 1 and a decimal point).

More information on salt dough circuits and interesting activities (see photo on right):

<http://www.abc.net.au/science/articles/2012/04/17/3479415.htm#.UZTLLMrEVjs>.



## Videos

Why metals conduct electricity: <http://www.youtube.com/watch?v=DbKECtWNm8k>

Why ionic compounds conduct electricity: <http://www.youtube.com/watch?v=aKTmn2YLP2A>

A short circuit of a battery pack resulting in dangerous overheating of the batteries:

<http://www.youtube.com/watch?v=4fj5BL027yw>

Spark (through air) between two wire leads from high voltage battery source:

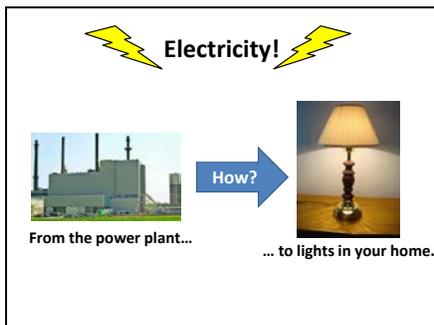
<http://www.youtube.com/watch?v=mOpsWctz9wk>

### **Example of salt dough LED circuit testing:**

<http://web.ics.purdue.edu/~braile/new/SaltDoughLEDCircuit.mp4>. The first part of this video shows a salt dough and LED circuit connected to a large-diameter salt dough connector and then connected to a small-diameter salt dough connector. Note that the light is brighter with the large-diameter connector because of the lower resistance of the large-diameter connector. The second part of the video shows a long, small-diameter salt dough connector that is connected to an LED. By completing the circuit at different points (with a nail attached to the negative terminal wire) along the salt dough, one can see that the light is dimmer for a long connector and brighter for a short connector. This demonstration shows that the length of the salt dough connector (a poor or partial conductor) controls the resistance, with higher resistance for longer paths.

**Suggested PowerPoint Slides (PPT file available at <http://web.ics.purdue.edu/~braile/new/SaltDough.ppt>):**

Slide 1



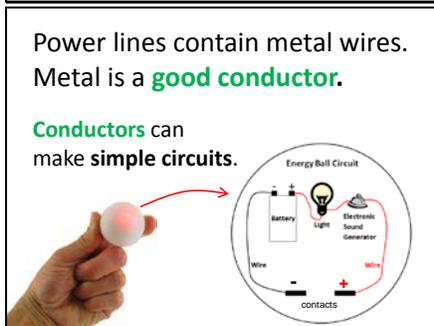
Introduction

Class discussion

Q: How does electricity travel from the power plant to the lights in your home?

A: By power lines!

Slide 2



Introduction/discussion continued...

Let's make a simple circuit using an Energy Ball!

(classroom demonstration described in SLED Lesson Plan #1)

Slide 3



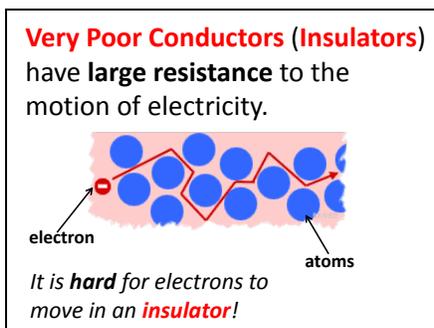
Recap: The Energy Ball demo shows us that some materials are better than others for carrying electricity and completing an electrical circuit.

Metals – good carriers of electricity - Good Conductors!

Salty Water – can carry electricity but not as well as metals – Poor conductors!

Plastics – poor carriers of electricity – Very Poor Conductors (aka Good Insulators)!

Slide 4



Big question: Why are some materials good conductors and others are poor conductors?

A: Materials have different amounts of RESISTANCE.

Class demonstration (what is resistance?)

Classroom analogy for the LARGE resistance of a Very Poor Conductor (Insulator):

- a student trying to walk through a packed crowd of other students and desks

- large resistance → difficult forward motion → good insulator!

Slide 5

**Good Conductors** have a \_\_\_\_\_ **resistance** to the motion of electricity.

electron

atoms

It is **easy** for electrons to move in a **good conductor**!

If Very Poor Conductors (Insulators) have a **LARGE** resistance, this means that Good Conductors will have a <<**SMALL**>> resistance!

Class demonstration continued

Classroom analogy for the **SMALL** resistance of a Good Conductor:

-a student walking down an orderly aisle of desks

-small resistance → easy forward motion → good conductor!

Slide 6

Engineers measure a material's **resistance** using an Ohmmeter.

Small number = **Good Conductor**!  
Large number = **Poor Conductor**!

We can measure a material's resistance using a tool called an Ohmmeter!

Slide 7

Objects	Resistance (Ω)	Good Conductor, Poor Conductor or Very Poor Conductor (insulator)?
Metal Paperclip		G P VP/I
Plastic-Coated Paperclip		G P VP/I
"Long" Pencil		G P VP/I
"Short" Pencil		G P VP/I
"Thick" Pencil		G P VP/I
"Low-salt" dough		G P VP/I
"High-salt" dough		G P VP/I

Small number = **Good Conductor**! Large number = **Poor or Very Poor Conductor**!

Activity #1: short demo/overview of the inquiry activity.

*Based off of SLED Lesson Plan #2-A and #2-B, combined and shortened to save time.*

OBJECT	RESISTANCE (Ohms)
Metal Paperclip	0.2
Plastic-Coated Paperclip	too big
"Long" Pencil	40
"Short" Pencil	20
"Thick" Pencil	10
"Low-salt" dough	40,000
"High-salt" dough	10,000

Questions to ask the students during the demo:

- How did you know if an object was a **good conductor**?
- What types of materials are **good conductors**?
- How did you know if an object was a **good insulator**?
- What types of materials are **good insulators**?
- Does the shape of the object (such as length or thickness) affect the value of resistance that you measured?
- What shape(s) of materials are the **best conductors**?

Slide  
8

Some materials are **better conductors** than other materials! And a material's **shape** also matters!

### SUMMARY:

A material with a small resistance is a better conductor than a material with a large resistance. Materials made of metal are typically excellent conductors while materials made of plastic are typically insulators (poor conductors).

In addition to what the material is made of, the actual *shape* of the material matters – for example, the short pencil and the pencil with the thickest lead had small resistance values compared to the other pencils that were tested.

Helpful analogy for shape effect:

*Q:* Should your class choose the short, wide slide or the long, thin slide, in order to all slide down and reach the ground before the other class?

*A:* The short, wide slide is the best choice, because more students can go down it in less total time compared to the long, thin slide.

\*\* The short, wide slide has a smaller resistance to forward motion, similar to how short, thick metal wires are better conductors than long, thin metal wires!

Slide  
9

Some materials are **better conductors** than other materials! And a material's **shape** also matters!

Ex) Your class wants to race Mr. Davis's class down the playground slide. There are two slides on the playground. To win the race, which slide should your class use?



Slide  
10

### Now for a Design Challenge!

After visiting the three bears, Goldilocks wanted to send the Bear family a special gift to thank them for their hospitality. She decided on a nice lamp that would provide light that was *juusstttt* right for Papa Bear, Mama Bear, and Baby Bear.

Goldilocks contacted *This Little Light of Mine Company* and asked them to design a lamp with three brightness levels. As a *This Little Light of Mine Company* engineer, you and your team must plan, build, and test a salt dough electrical circuit that creates a bright light, a dim light, and a light that is in-between.

Remember that a material's **resistance** is determined by the **type** of material and **shape** of the material.

*From SLED Lesson Plan #3*

\*\*\* Read aloud and discuss the design brief. Ask the following:

- What is the problem?
- Who is the client?
- Who is the user?
- What is your design task?

Students will need to provide a sheet of paper and something to write with. Students will be given the following materials to create their electrical circuits:

- an LED light bulb
- wires and alligator clips
- a few nails, to connect the wires and clips to the dough
- three salt dough materials, each with different amounts of salt
- a battery pack (provided once the students complete their design and are ready for testing)

Hint: Use your experiences from the inquiry activities to design an electrical circuit that can be connected in three

different ways to produce the three levels of brightness of the light bulb. Remember that resistance of a material is determined by the **type** of material and **shape** of the material.

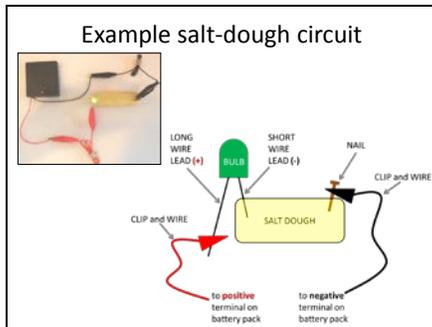
Warnings: Do not connect the LED light bulb directly to the battery without salt dough in the circuit (this will cause the LED to burn out). The salt dough is not toxic, but do not eat the salt dough.

*(follow steps 4-10 in SLED Lesson Plan #3)*

*From SLED Lesson Plan #3*

While the students are planning/designing their circuits, show them this image to help get them started.

Slide  
11



Slide  
12

#### Electricity Safety Rules

- Never use electrical appliances near wet areas (bathtubs, sinks, in the rain)
- Never put fingers or other objects near electrical outlets
- Never use appliances with cords showing bare wire
- Never climb trees near power lines
- Stay away from outdoor electric company equipment (meters, transformers, power lines, etc.)