



## Lesson 4: The Case of the Missing Wires – Conductors!

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### Overview

After reviewing the essential components of electrical circuits students will be guided through a mystery in which they investigate the conductivity of various materials. Explorations lead to a beginning understanding of the uses and safety concerns associated with conductors and insulators.

### Teacher Background

Current electricity requires an unbroken pathway, also known as a complete circuit, to power electrical devices. Materials differ in their ability to provide a pathway of electrical energy. Some materials allow electricity to flow better than others. Materials that allow electricity to flow readily through them are called conductors, and materials that do not allow electrical energy to flow through them readily or at all are called insulators. Common examples of conductors include metals, aqueous salt solutions (salts dissolved in water), graphite, water, and the human body. Common examples of insulators include plastics, porcelain, Styrofoam, paper, rubber, glass, and dry air. While this listing may imply that materials can be cleanly categorized as a conductor or an insulator, materials have varying levels of conductivity. It is more accurate to think of materials as being placed somewhere along a continuum of electrical conductivity.

Conductors and insulators play very important roles in the movement of electrical energy. The majority of metals conduct electrical energy but copper is the most commonly used metal because it is such a good conductor of electrical energy and it is relatively inexpensive. Humans have used this knowledge of conductors and insulators to control and direct the flow of electrical charges, delivering electrical energy safely to millions of people worldwide. If an electric current is desired then conductors are used. If a barrier is needed to prevent electrical energy from flowing, an insulator is used. An example is the plastic or rubber coated wires of a typical lamp cord. The wires that carry the electrical current are inside the coating and are made of a material that allows the electric current to flow freely and easily. On the other hand, the material for the coating does not allow an electric current to pass through and is chosen to prevent the electric current that is running through the wires from passing through into the surrounding environment, thus preventing electrical shock and/or fire.





## Key Ideas

- While electrical circuits can be connected in different ways, all circuits have three essential parts: a source, a pathway, and a receiver.
- A complete path to and from the source (loop) is needed for the electric current to flow.
- Current electricity can exist in and move through a conductor. A conductor is a material that allows an electric current to pass through it.
- An insulator does not allow an electric current to pass through it.

## Lesson Goals

Students will:

- recognize that all materials are not able to provide a pathway for the flow of electricity.
- examine the differences in electrical conductivity of a variety of common materials.
- use knowledge of conductors and insulators to explain why and how certain materials are used in simple electrical devices, i.e. light bulbs, extension cords, desk lamps, etc.



## Vocabulary

**conductor:** a material through which electric current readily flows.

**insulator:** a material through which electric current does not readily flow.

## Preparation

Gather a variety of common household items for students to use in conductivity tests.

## Materials

Item	Quantity
Aluminum foil strips (use heavy duty foil)	1 roll, (sheets or strips)
Basic Circuit Kit: <ul style="list-style-type: none"> <li>• Wire, 22-gauge, insulated (one 12" piece, stripped)</li> <li>• D battery</li> <li>• Replacement incandescent flashlight bulb</li> </ul>	1 per student  (Have spare materials on hand)
Supplementary Circuit Components: <ul style="list-style-type: none"> <li>• Bulb holder (some bulb holders may require a Philips head screwdriver)</li> <li>• Battery holder</li> <li>• Two additional 12" pieces of wire, stripped</li> </ul>	1 per student pair
Scientist's Notebook	1 per student
Chart paper and markers (optional)	1
A variety of miscellaneous familiar items for students to test the conductivity of, such as: <ul style="list-style-type: none"> <li>• Glass (marble)</li> <li>• Styrofoam</li> <li>• Plastic (bag, spoon, lid, straw)</li> <li>• Paper</li> <li>• Wax (birthday candles)</li> <li>• Ceramic mug</li> <li>• Rubber (erasers, stoppers)</li> <li>• Chalk</li> <li>• Sharpened pencil</li> <li>• Chenille stick</li> <li>• Various metal objects (old keys, paperclip, penny, quarter, brass fastener, bolt, screw, nail, washer, spoon, soup or soft drink can.)</li> <li>• Lemon juice</li> <li>• Salt water</li> </ul>	1 set per group of 4-6 students to share at tables
Student Handout 4.1 (optional): Conductors and Insulators	1 per student
Micro ammeter (optional)	1 per class

**Note:** Students should keep their circuit testers intact in case they need to complete more testing the next day. Students may put their names on sticky notes and attach them to a tray with their testing materials. The next day, their materials are ready for more testing.



## Safety Notes

- Aluminum foil may get hot to the touch as students use as a substitute wire.
- If students examine the internal components of old electronic equipment advise them of how to do so safely. Appliances should be unplugged (consider cutting cords) and research devices ahead of time to make certain they do not contain mercury (switches) and/or radioactive elements (smoke detectors)."

**Time Required:** 2-4 sessions

## Connection to *Benchmarks for Science Literacy (BSL)*, and *National Science Education Standards (NSES)*

- Electricity in circuits can produce light, heat, sound and magnetic effects. Electrical circuits require a complete loop through which an electrical current can pass. NSES B(K-4)
- Materials vary in how they respond to electrical currents, magnetic forces, and visible light or other electromagnetic waves. new BSL 4D/M9(6-8)
- Offer reasons for their findings and consider reasons suggested by others. BSL 12A (3-5)
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations. NSES A (K-4)
- Keeping records of their investigations and observations and not change the records later. BSL 12A (3-5)





# Teaching The Lesson

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## Engage

### 1 Review a complete circuit.

Begin by sharing with the class some of the typical solutions students suggested for the prompt on Student Handout 3.1. This reviews the essential parts of a circuit and the parts-wholes relationships discussed previously in Lesson 3. As solutions are shared, it may be beneficial to illustrate them on chart paper or on a white board/chalkboard. Reaffirm how the suggestions describe the movement of electrical current through the circuit. Continue to revisit and discuss the parts-wholes ideas by interspersing questions when appropriate such as:

- *If one of the components were missing or broken, how would this affect the circuit? Why?*
- *If this configuration did not have a power source, how would this affect the circuit? Why?* (Refer to sample student responses noted in Lesson 3.)



### 2 Unfold the mystery.

Present the following scenario to students: Hold up a battery and a bulb and explain to students that there is a problem. While preparing for electricity explorations this morning, you (the teacher) noticed that the wires that had been used before were missing. Explain that there is no way to go to the store and get more wire so you asked other teachers for suggestions about available materials in school that could be used in place of wires to light the bulbs. One teacher suggested using aluminum foil. Explain that you have not had a chance to try this idea, but were hoping the students might be willing to give this a try. With a note of skepticism in your voice ask: *How do you think aluminum foil can be used to light a bulb?* Ask students to write this focus question *“How do you think aluminum foil can be used to light a bulb?”* Use words and sketches and/or diagrams to describe your thinking in your scientist’s notebook. Instruct students to do a “quick write,” supported by reasoning, in their notebooks regarding their thoughts about the scenario presented. As students work, circulate among students and question their ideas. Guide students toward the idea of pathways, complete circuits, and making a drawing with descriptive text explaining why or why not they think foil could be used to light the bulb.

### 3 Share “quick writes.”

Ask students to share their ideas with a partner. Instruct students to refer to their quick writes as they discuss their ideas. Have two or three students share what their partner thought about using aluminum foil to light a bulb. Explain that momentarily students will be given the opportunity to test out this idea of whether or not foil could be used to complete a circuit

### Explore

### 4 Test foil wires.

Provide each student with a bulb, battery, and a strip of foil. Allow a few minutes for students to explore arrangements with the foil and ask that students to use words and diagrams or sketches to record their findings, such as configurations that work and other observations in their notebooks. As students work, circulate around the room and encourage them to try a variety of arrangements using the foil.

### 5 Share findings.

Gather students in a circle and direct them to use their notebooks to share some of the configurations that worked to light the bulb using the foil. Have a bulb, battery, and foil on hand to allow students to demonstrate or clarify their configurations. Through this discussion, students should recognize that the foil can be used to light the bulb in (much) the same way as wire. One difference that will most likely be mentioned is that the foil becomes noticeably hot as electricity passes through the foil.

Throughout the discussion encourage students to use their drawings to show the pathway of electricity through the various configurations. Students may or may not offer the term *conductor* during this discussion. If students do not suggest the word conductor, introduce the term. Write the word *conductor* on chart paper or white/blackboard and ask students to elaborate on what they think is meant by this term as it relates to the configurations. Encourage students to use the term in context as they explain what they think it means.

### 6 Develop focus question for investigation.

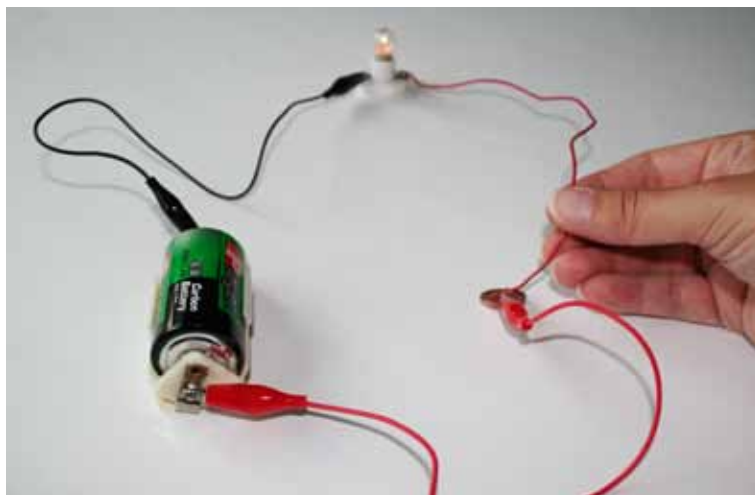
Pose the following question to students: *What would you like to find out about conductors?* Instruct students to work with a partner to develop a list of questions about conductors. After students have had a chance to develop questions with a partner, compile a class set of focus questions. As this list is being compiled, help students to



rephrase their questions from “yes” or “no” type questions to those that can be investigated. At this point in the lesson, guide students toward the class focus question: *Which materials conduct electricity?* Ask students to record the class focus question in their notebooks. Alternatively, depending on available time, student ability, class chemistry, and/or teacher familiarity with supporting students in developing focus questions, teachers may allow students to investigate one of the class questions.

## 7 Prepare to investigate conductors and insulators.

Remind students about the focus of the investigation by posing the following to students: *What are we trying to find out?* Refer students back to the class focus question: *Which materials conduct electricity?* Ask: *How can we find this out safely, given the available time and materials?* Ask students to suggest what they could do to find out if different materials can provide a pathway for electrical energy. Discuss with students a safe and simple way to test the conductivity of various materials. Demonstrate how to create a simple testing device by using their bulb, battery, and 3 wires. Two disconnected ends of wire are connected to the test materials. To make sure students understand how to test materials, demonstrate using a piece of aluminum foil. The picture below shows a penny being tested:



Work with students to develop a recording strategy or provide students with a copy of Student Handout 4.1 to paste in their notebooks. Be certain that the recording strategy incorporates student predictions. Model how to record data using the aluminum foil example, including the prediction using the recording strategy. Remind students that before they begin testing materials, they need to make a prediction about whether they think the material will conduct electricity and support their prediction with knowledge from past observations, first hand experiences, and prior knowledge.

## 8 Investigate conductors.

Introduce students to the materials available for testing. Have students work in pairs to test the conductivity of these materials. Remind students to use their notebooks throughout the investigation to record their predictions, observations, data, and questions. Circulate around the room listening to students' conversations and posing additional questions. If any students notice that some materials allow the bulb to light up, but not as brightly, encourage them to capture this detail in their data table.

**Note:** *Students may wish to test the conductivity of items that are not provided, but this is not advisable unless given prior approval from the teacher. Teachers should be made aware that because students are testing materials using a simple device, conductive materials such as water or the human body may appear not to conduct electricity. A "false" reading may give students the wrong idea with respect to electrical safety. Teachers may wish to address this idea stating that their testing devices are simple and somewhat limited and may not be able to detect small amounts of electrical energy flowing through them. Suggest to students that there are more sophisticated devices, such as a microammeter, that can more accurately determine the amount of electricity that passes through materials.*



## Reflect And Discuss



## 9 Write claims and discuss findings.

Ask students to individually reflect on the data they collected during the investigation. Prompt students to record one or two claims based on evidence about which materials conduct electricity. Provide students with the following sentence starter to support their writing: I claim \_\_\_\_\_ because \_\_\_\_\_. Alternately, students may write a group claim or the teacher may guide students in developing a class claim(s).

For example, students may write: "I claim that metals conduct electricity because when the key, washer, penny, and metal spoon were included in the circuit, the bulb lit up." Or conversely "I claim that glass and rubber are not conductors because when the marble and rubber stopper were included in the circuit, the bulb did not light up." Some students may write claims that focus on the variability of conductors: "I claim that some materials conduct electricity better than others because when \_\_\_\_\_ was included in the circuit the bulb lit dimly but when \_\_\_\_\_ was included in the circuit the bulb lit brightly."

**Note:** *Emphasize the importance of writing claims that can be supported by evidence found in their data.*



## 10 Discuss claims and evidence.

Ask students to share and discuss their claims in small groups at their tables. Alternately, this could be done as a class discussion. Discussions provide students with the opportunity to hear the claims supported by evidence of other students before they are asked to write their own conclusions in Step 11. It is important that students understand that their individual or group results may be different from others. Discrepancies can encourage students to replicate investigations or review methodologies. Discussions regarding differing results may also help reduce confusion regarding any seemingly irregular data that may have been collected.

During the discussion, make certain that the following points regarding conductors are addressed:

- *What are conductors? How would we describe a conductor?* Conductors are materials through which electric current will flow.
- *Which materials conduct electricity?* Metals are good conductors of electric current.
- *Did all of the materials conduct electricity in the same way? What evidence do you have that supports this?* Some conductors allow electric current to flow more readily than others. Students may cite bulbs not lighting as brightly as evidence.
- *Which materials did not conduct electricity?* Examples of materials that do not allow electric current to flow are glass, plastic, ceramic, and rubber. These materials are called insulators.



## 11 Write conclusions.

After students have had the opportunity to discuss their claims and evidence, prompt students to write a conclusion, summarizing their findings. Provide the following sentence starters:

- *Conductors are...*
- *Examples of conductors are...*
- *Examples of insulators (non-conductors) are...*

## 12 Bring lesson to a close.

Bring closure to the lesson by asking students to “Give Me 5.” Ask students to quietly and individually reflect on what they learned about conductors and insulators in this lesson. Ask five volunteers, one at a time, to share their reflection. Use ample wait time to encourage more hesitant students to respond. Hold up your fist, showing a finger each time a student shares a reflection until you have completed five responses. Explain to students that in the next lesson, students will use their knowledge of conductors and insulators to make suggestions for using electricity safely.

## Extensions

Student may:

- Watch *Mythbusters* episode that debunked Ben Franklin's kite/key experiment. History tells us that if this had happened, Franklin would have died. Videos are online through a subscription based service: <http://www.cosmeo.com/videoTitle.cfm?guidAssetId=0cc27279-5ed3-4eb3-aad3-35c0dfe16f79&&nodeid=>
- Examine other materials historically used as filaments.
- Investigate the effect of adding another battery to a circuit on materials that did not initially conduct electricity. Caution students to not use more than 3 batteries per light bulb, as the bulbs can be blown if connected to too many batteries.
- Discuss conductivity as a being on continuum as opposed to being an absolute. Students could devise a way to order materials along a scale from “good” conductors to “good” insulators. For example, students could use the brightness of the bulb or microammeter (if available).
- interview an electrical engineer to learn more about how they use their knowledge of conductors and insulators in their work.



## Connection to Maine Agencies

MEEP (Maine Energy Education Program) has an *Apple Battery* exploration and will come to interested schools, free of charge. Students experiment with making a battery by inserting different types of metals into an apple and measuring the electrical current they generate. The MEEP website is:

<http://www.mEEPnews.org/classroomactivities>

For schools in Aroostook County, a Maine Public Service (MPS) representative will come to interested schools, free of charge, to guide and support concepts developed in this lesson. A description of programs is available at [www.mainepublicservice.com](http://www.mainepublicservice.com). Click on the education section of the site. To schedule a visit contact Nancy Chandler at 207.760.2556 or [nchandler@mainepublicservice.com](mailto:nchandler@mainepublicservice.com).

## Online References and Resources

[http://www.allaboutcircuits.com/vol\\_1/chpt\\_1/2.html](http://www.allaboutcircuits.com/vol_1/chpt_1/2.html)