Electrical Conductors and Insulators

Introduction

Why is the inside of wires used for electrical circuits made of thin metal threads? And why are the thin metal threads in these wires coated with plastic?

You may be familiar with the concept of electricity and how certain materials and objects allow electricity, or an electric current, to pass through them. Metals are known for their ability to conduct or allow electricity to travel through them. This is why wires used in electrical appliances and circuits in general are made with some type of metal.

Electrical conductivity is a physical property of matter that describes the ability of a material to allow electricity to pass through them. Materials that conduct electricity are called *conductors*; most metals are good conductors and even carbon, a non-metal, conducts electricity.

On the other hand, materials that do not conduct electricity are called *insulators*. Plastics, sand, and wood are examples of insulators.

In the laboratory, an instrument known as a conductivity meter is used to determine the electric conductivity of various types of materials including solids, liquids and solutions. In this investigation, you will build your own conductivity meter to test the conductivity of household solids and liquids.

Concepts

- Conductivity
- Conductor
- Electricity
- Electron
- Insulator
- Physical Properties

Background

Electricity is a type of energy—just like heat, sound, chemical, and nuclear energy. Electricity can flow or move in the form of electric currents, or it can be static and confined to an object or place. Static electricity or simply “static” is what you may experience as an electric shock when touching a doorknob during a dry, cold winter day.

Electricity is related to the presence of charges (negative or positive) in matter. To get a better grasp of what this means, one must think about the properties of matter at the level of atoms.

Atoms make up every material and living organism you can think of, yet they are tiny and invisible to the naked eye. Each atom has a nucleus made up of nuclear particles called protons and neutrons. Each proton has a positive charge (+) while neutrons—like the name neutron implies—are neutral and have no charge. Surrounding the atom nucleus are the electrons, which are much smaller than protons and neutrons. Each electron carries a negative charge (–).

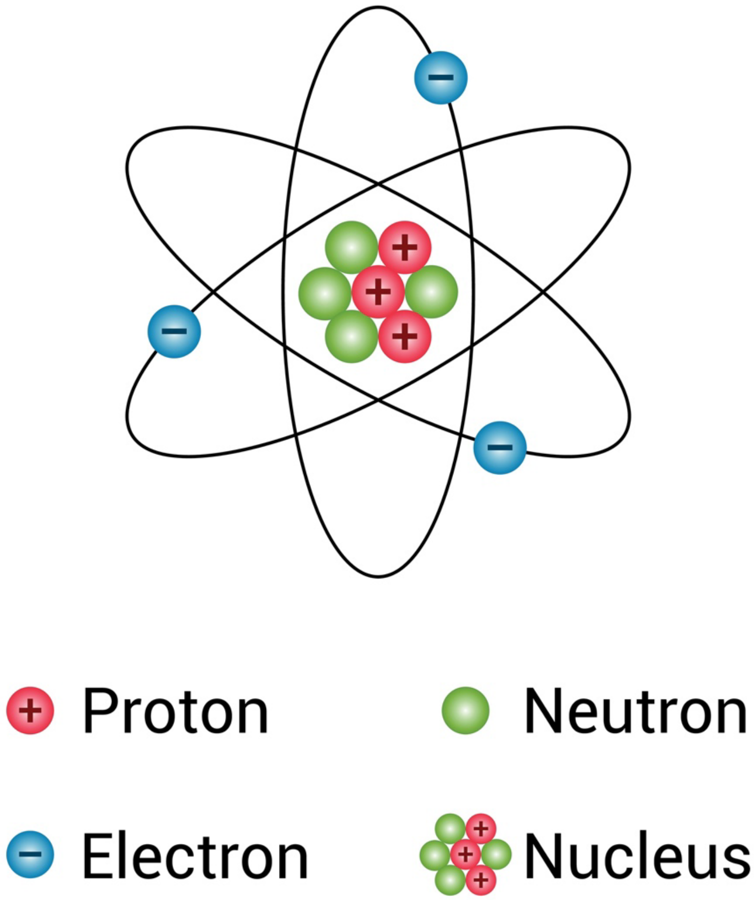

Figure 1. Model of an atom showing protons and neutrons in the nucleus (i.e., the core or center of the atom) and electrons surrounding the nucleus.

Atoms tend to have an equal number of protons and electrons, such that the number of positive (protons) and negative charges (electrons) are equal, and the atom stays neutral. However, some atoms may gain or lose electrons, and become negatively charged (gaining electrons) or positively charged (loosing electrons). When atoms become charged (positively or negatively), electrons tend to move or "jump" between atoms.

The continuous movement of electrons between atoms in a material is called an electric current. Metals like copper and gold are examples of materials in which electrons can easily move through forming electric currents. These types of materials are called *conductors*.

On the other hand, glass, wood, and pure water are examples of materials that do not conduct electricity. These materials are called *insulators* because electric currents can't flow or pass through them.

In this investigation, you will build a conductivity tester to test various household substances and materials for their ability to conduct electricity.

Experiment Overview

In this investigation, you will build a small device that can be used to test the electrical conductivity of various household substances and materials.

Materials

- Button battery, 3.0 V
- Copper tape
- Fine tip marker, or pen
- LED light
- Paper clips, 3
- Paper cups, or small beakers, 2
- Ruler
- Scissors
- Small sample objects for testing, 5
- Table salt (sodium chloride)
- Tape
- Teaspoon, or scoop (optional)
- Water, distilled
- Wooden stick

Pre-Lab Questions

1. Lightning rods are used to protect buildings from structural damage that lightning may cause. A lightning strike or lightning bolt is a powerful discharge of electricity from the atmosphere to the ground. Lightning rods receive the electricity discharge from the atmosphere and direct it to the ground so that it doesn't pass through the building's structure.

Figure 2. Image of a lightning rod set on a roof.

If lightning rods are to protect buildings from lightning strikes, should lightning rods be made of materials that are conductors or insulators? Explain.

2. Why do electrical appliances such as straightening irons and hair dryers come with warning tags not to use them while in the shower or bathtub?

Safety Precautions

Please follow all laboratory safety guidelines. Wear safety glasses. Tie back long hair. Do not eat or drink anything in the lab. Use caution when handling scissors and other sharp objects such as metal wire and tape. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Part A. Introductory Activity

Follow these steps to build your conductivity tester:

1. To start, notice that the LED light has two prongs, one longer than the other. The longer prong is called the “anode” and it is represented or marked with a plus sign (+). The shorter prong is called the “cathode” and it is represented or marked with a negative sign (–).
2. Examine the battery and note that it has a positive and a negative side. The positive side is typically engraved with a plus sign (+), which leaves the opposite side as the negative one (–).
3. Place the battery between the LED prongs such that the positive (longer) prong on the LED is in contact with the positive side of the battery. The negative prong on the LED should contact the negative side of the battery. The LED should immediately light up. **Note:** If the LED doesn’t light up, make sure the battery is correctly positioned between the LED prongs. If the light is not coming up still, invert the position of the battery between the LED prongs (see **Figure 3**).

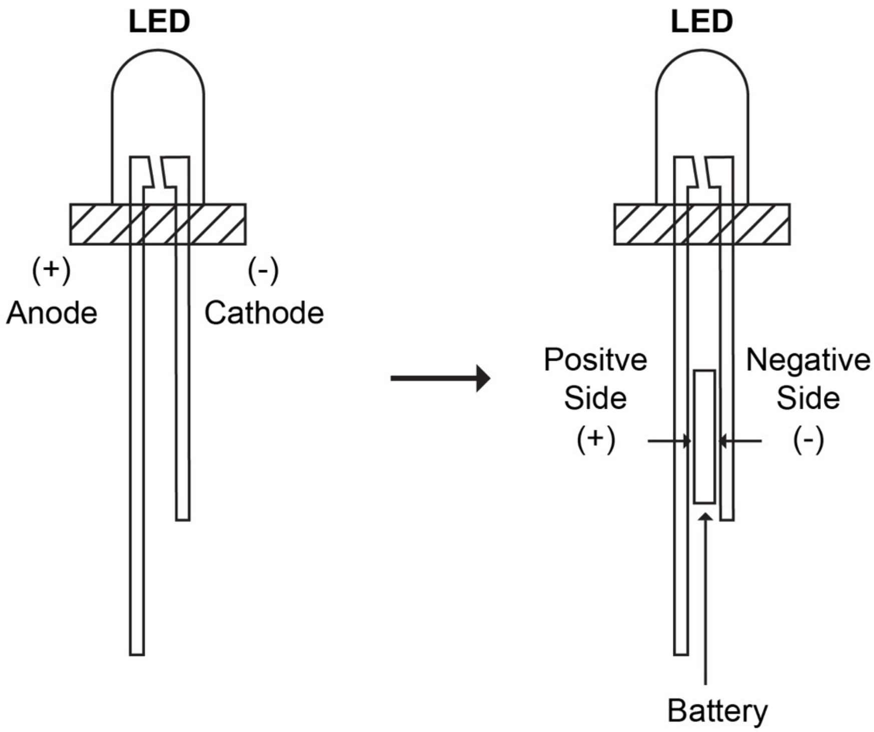

Figure 3. Testing the LED light with a battery.

4. Use scissors to cut two strips of copper tape. Each strip should have a length of approximately 14 cm.
5. Mount the LED on the end of the wooden stick so one prong extends downward on each side of the stick (see **Figure 4**). Use a marker to write a plus sign (+) on the side of the stick with the positive LED prong.

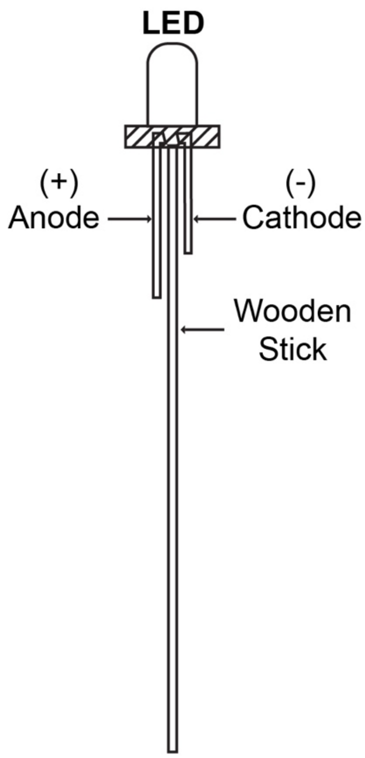

Figure 4. Mounting the LED on the wooden stick.

6. Gently peel the backing from one strip of copper tape and stick it to one side of the wooden stick, covering first the LED prong and then moving down the stick. Be sure to completely cover the prong of the LED so there is a permanent connection between the prong and the tape (see **Figure 5**).

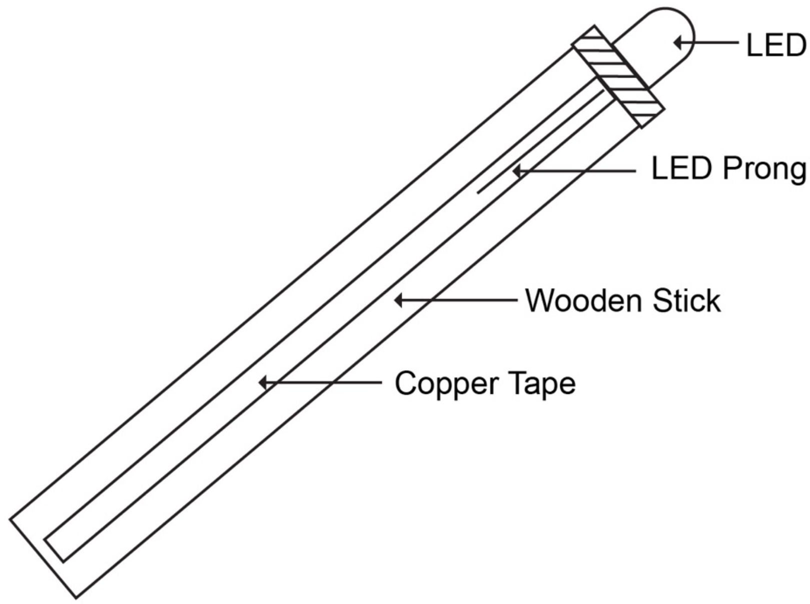

Figure 5. Using copper tape to attach the LED to the wooden stick.

7. Repeat step 7 with the other side of the wooden stick. Make sure to completely cover the LED prong with the copper tape strip on this side.
8. Place the battery with its negative pole on the side of the wooden stick that has the negative LED prong. The battery should be placed 1.0-1.5 cm from the bottom of the wooden stick. (see **Figure 6**).

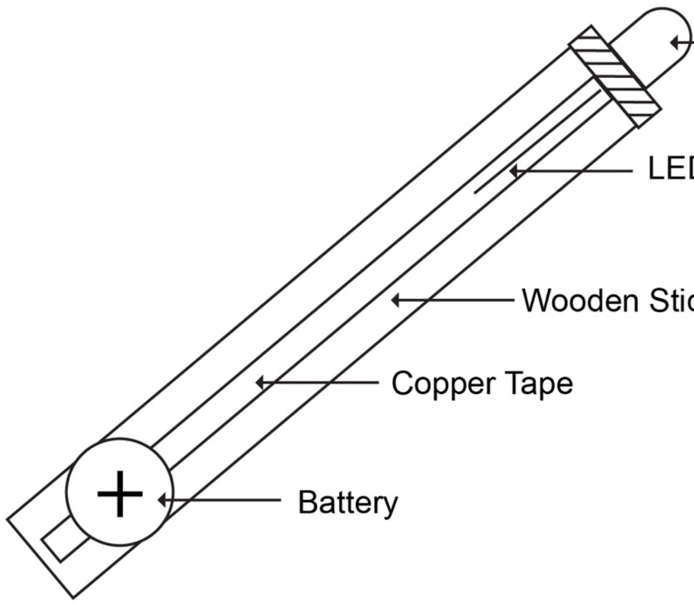

Figure 6. Adding the battery to the device.

9. Place a paper clip against the positive side of the battery, and another one on the opposite side of the wooden stick. About half the length of each paper clip should stick out from the bottom tip of the wooden stick.
10. Wrap a piece of tape around the paper clips and battery to hold them tight in place. At this point the device should look like the sketch show in **Figure 7**.

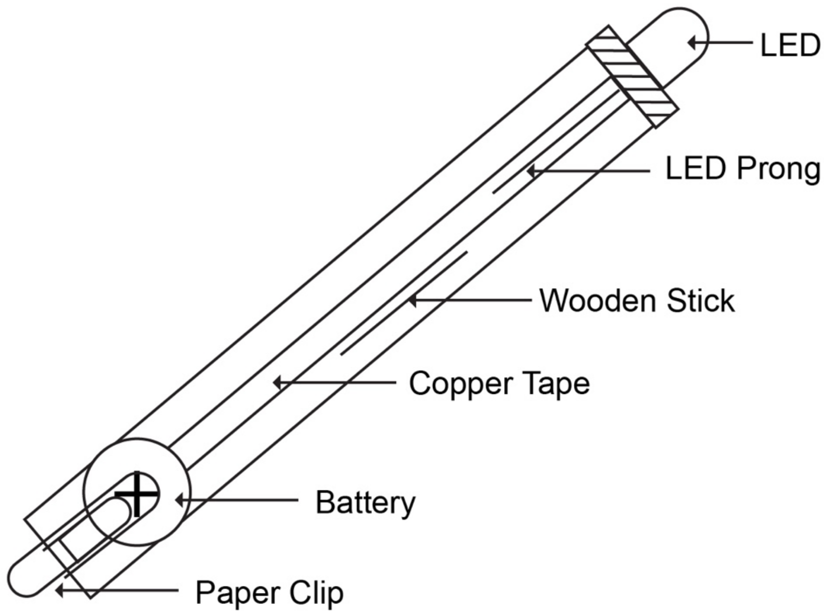

Figure 7. Diagram of the conductivity tester device.

11. To test your conductivity tester, touch the tips of the paper clips on the device with another paper clip. The LED should light up. The paper clip used to contact the two clips attached to the device closes the electric circuit loop of the device. When the loop is closed, electricity can flow from one side of the battery, through the LED and back into the opposite side of the battery.

Part B. Experimental Challenge

Congratulations! You have built your own conductivity tester device!

Now your challenge is to test the conductivity of different samples described in **Table 1**. Conductors will cause the LED on the conductivity tester to light up, while insulators will not cause the LED to emit light.

12. To test the electrical conductivity of each sample, touch the surface of the sample with the paper clip leads of the conductivity tester. Test all the dry samples first.

13. Now test the distilled water. Only the tips of the paper clips on the conductivity tester must be immersed into the liquid.

14. Dissolve one teaspoon of table salt (sodium chloride) in one cup of distilled water and test the conductivity of this solution.

Table 1. Electrical conductivity of various household substances and materials.

Sample	Conductor or Insulator?	Observations
Distilled Water		
Distilled Water + Table Salt		

Post Lab Questions

1. Reflect on the results and observations from the Introductory Activity. What happened when a third paper clip is used to contact both paper clips attached to the device? What is the role of this third paper clip?

2. Think about the objects and substances that you determined to be conductors or insulators in the Experimental Challenge.

   a. Why does the LED light up when both paper clips touch a conductor?

b. Why doesn't the LED light up when both paper clips touch an insulator?

Electrical Conductors and Insulators Teacher Notes

Materials

Materials Included in Kit

- Button battery, 3.0 V
- Copper tape
- LED light
- Paper clips, 3
- Table salt (sodium chloride)
- Tape
- Wooden stick

Additional Materials Required (for each lab group)

- Fine tip marker, or pen
- Paper cups, or small beakers, 2
- Ruler
- Scissors
- Small sample objects for testing, 5
- Teaspoon, or scoop (optional)
- Water, distilled

Prelab Preparation

To prepare for this activity, gather all the materials that student groups will require to complete their investigation. Each group will need access to a clear and clean bench or desktop to conduct this activity.

You may prepare the distilled water + table salt solution that students will need for the Experimental Challenge in advance. To do this, you may dissolve approximately 5 teaspoons of sodium chloride in 300 mL of distilled water, stir, and then add more water to complete a final volume of 500 mL. Prepare this solution in a large beaker or clean plastic bottle and distribute it in portions of 50 mL to each group.

Safety Precautions

Make sure students follow all laboratory safety guidelines. They must wear safety glasses, tie back long hair, and they must not eat or drink anything in the lab. Also, they must use caution when handling scissors and other sharp objects such as metal wire and tape. At the end of this activity, students should wash their hands thoroughly with soap and water before leaving the laboratory.

Lab Hints

- Enough materials are provided in this kit for 30 students working in groups of 3 students, or for 10 groups of students.
- This investigation can be reasonably completed in a 50-minute class period. To avoid running out of time, students may answer the pre-lab questions before the laboratory

period. You may also choose to perform Introductory Activity and the Experimental Challenge during two separate class periods or perform only one of the two parts in a single class period.

- In part A. Introductory Activity, you may want to demonstrate to the class how to identify the anode (positive prong) and cathode (negative prong) of the LED, and the positive and negative sides of the battery. Also, you may want to demonstrate how to test the LED and battery as described in step 3. After this demonstration, students may begin their investigation from step 4.
- In Part B. Experimental Challenge, make sure that students do not immerse the conductivity tester device into any of the liquid samples past the tips of the paper clip leads. Also, they must not press too hard on any of the samples to avoid disrupting electrical contact between the paper clips and the copper tape or the battery.

Teacher Tips

- Before students perform their investigation, conduct a brief class discussion in which students express their ideas about electrical conductivity. Students may be able to mention a few materials or substances that they recognize as electricity conductors, including metals like copper, stainless steel, etc.
- To illustrate the importance of electricity conductors and insulators, you may discuss how commonly used tools such as pliers have their handles coated with insulating sleeves to minimize the risk of injuries that might be caused if the tool contacted a source of electricity.
- Once students have completed the Introductory Activity, in step 11, take a minute to discuss with students how the conductivity tester they built is essentially a simple circuit with a LED, a battery, and connectors (copper tape, paper clip leads). Because the paper clip leads don’t touch, the circuit is permanently open. When the paper clip leads come in contact with a conductor (e.g., another paper clip or a metallic object) the circuit is closed, electricity flows through it, and the LED lights up.

Correlation to Next Generation Science Standards (NGSS)

MS-PS1.A: Structure and Properties of Matter

Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

Sample Data

Table 1. Electrical conductivity of various household substances and materials.

Sample	Conductor or Insulator?	Observations
Penny (or any metallic coin)	Conductor	The LED lights up instantly.
Rubber stopper	Insulator	The LED doesn't light up.
Paper sheet	Insulator	Paper does not conduct electricity.
Iron nail	Conductor	Iron is a conductor of electricity.
Wooden stick	Insulator	The LED doesn't light up.
Distilled Water	Insulator	The LED doesn't light up.
Distilled Water + Table Salt	Conductor	Table salt makes water conduct electricity,

Answers to Pre-Lab Questions

1. Lightning rods are used to protect buildings from structural damage that lightning may cause. A lightning strike or lightning bolt is a powerful discharge of electricity from the atmosphere to the ground. Lightning rods receive the electricity discharge from the atmosphere and direct it to the ground so that it doesn't pass through the building's structure.

Figure 2. Image of a lightning rod set on a roof.

If lightning rods are to protect buildings from lightning strikes, should lightning rods be made of materials that are conductors or insulators? Explain.

Sample answer: Lightning rods must be made of conductor materials. Typically, they are made of metals like copper or iron. Lightning rods must be made of conductive materials so that they can conduct electricity from lightning strikes down to the ground. Insulators don't conduct electricity so they would not work for this purpose.

2. Why do electrical appliances such as straightening irons and hair dryers come with warning tags not to use them while in the shower or bathtub?

Sample answer: Appliances such as straightening irons and hair dryers have tags warning not to use them while in the shower or bathtub because people could get electrocuted if they did so. These appliances are powered by electricity that could be transmitted through the body especially when wet or in the presence of water.

Post Lab Questions

1. Reflect on the results and observations from the Introductory Activity. What happened when a third paper clip is used to contact both paper clips attached to the device? What is the role of this third paper clip?

   Sample answer: When a third paper clip was used to contact both paper clips attached to the device, the LED lit up. The role of the third paper clip was to close the loop or electric circuit so that the battery could power the LED with electricity.

2. Think about the objects and substances that you determined to be conductors or insulators in the Experimental Challenge.

   a. Why does the LED light up when both paper clips touch a conductor?

   Sample answer: The LED lights up when both paper clips touch a conductor because a conductor closes the loop or electrical circuit of the device. When the electric circuit loop is closed, the battery can power the LED. In other words, when the electric circuit loop is closed, electricity can flow through the circuit to power up the LED.

   b. Why doesn't the LED light up when both paper clips touch an insulator?

   Sample answer: The LED does not light up when both paper clips touch an insulator because an insulator can't close the electric circuit loop of the device. An insulator doesn't allow electricity to flow through, so the battery can't power the LED and it doesn't light up as it does when a conductor is used to contact both paper clips.