

VANDERBILT SCIENTIST IN THE CLASSROOM PARTNERSHIP

Electrical Conductivity

Fall 2023

(Adapted from Student Guide for Electric Snap Circuits by Elenco Electronic Inc.)

TN Science Standards

6.PS3.1 Analyze the properties and compare sources of kinetic, elastic potential, gravitational potential, electric potential, chemical, and thermal energy.

7.PS1.5 Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter.

8.PS2.1 Design and conduct investigations depicting the relationship between magnetism and electricity in electromagnets, generators, and electrical motors, emphasizing the factors that increase or diminish the electric current and the magnetic field strength.

Lesson Outline

I. Introduction

Explain Static and Current electricity. Write the vocabulary words on the board and explain conductors and nonconductors.

II. Explaining the Circuit – Demonstration

Explain the circuit and demonstrate how the students will use the red and black lead wires to test conductivity.

III. Conductivity of Solids

Students will work in pairs. Hand out one grid and one bag of solids to each pair. Make sure all groups have a correctly assembled circuit by having them touch the ends of the black and red lead wires together and note the red LED glows brightly. Explain what conductors and nonconductors are. Students then test the solids and record their results on the Observation Sheet.

IV. Conductivity of Solutions

Explain that some solutions are conductors while others are nonconductors. Students will test a number of solutions. Make sure they understand the importance of rinsing off the metal leads of the red and black wires in distilled water between each conductivity test.

V. Optional Activity

If time permits, have students test one of the solutions: (the bag may contain Gatorade, Sprite, rubbing alcohol, sodium bicarbonate, lemon juice, Koolaid (unsugared), bottled water).

VI. Optional Activity #2 - Demonstration

Why use LED's?

VII. Review

Review the results of the lesson and the vocabulary words.

Materials

- 1 demonstration grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity
- 15 sets of grids with assembled circuit
- 15 bags of solid materials for checking conductivity (paper clip, aluminum foil, copper strip, golf pencil sharpened on both ends, paper
- 1 plastic box containing:
 - 6 jars labeled and containing: distilled water, tap water, vinegar, 0.1 M hydrochloric acid, distilled water for sugar to be added, distilled water for salt to be added.

- 8 bags containing:
 - 1oz wide-mouth bottle of sugar
 - 1oz wide-mouth bottle of salt
 - 2 taster spoons
 - 1 chemwipe tissue
 - 2 toothpicks
- 1 bag containing wide mouth bottles of Gatorade, Sprite, rubbing alcohol, bottled water, and lemon juice
- 1 quart distilled water
- 15 6oz cups for distilled water for rinsing leads
- 15 sets of Instruction Sheets
- 30 observation sheets
- 1 bag of 5 AA batteries (extras)

Do not hand out materials until you have discussed the following background information.

Write the following vocabulary words on the board: **conductors, insulators (liquids are referred to as nonconductors), semiconductors.**

I. Introduction

Materials

- 1 grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity.

Ask students if they know what the 2 types of electricity are.

1. **Static electricity** is the build-up of electrical charge. It does not flow.
2. **Current electricity** is moving electrical charge, usually electrons. Some materials have more “free” electrons than others. Current electricity flows through a circuit.

Tell the students that electricity flows through some materials better than others. All materials can be classified as conductors, insulators / nonconductors or semiconductors.

- **Conductors** are materials that allow the movement of electrons through them. Metals have many “free” electrons that can easily move, and therefore are *good conductors*. By “free” electrons, it means that the electrons in the metal atom are not strongly held by the atom’s nucleus. Since they are not strongly held, they are able to “jump” from one atom to

Your Notes:

another. Wires used for electric circuits are usually made out copper wire, but other materials also conduct electricity.

- **Insulators** resist the flow of electricity, so do not allow electricity to flow through them. Some examples of insulators are Styrofoam, plastic (e.g., the casing around electrical wires), and glass.
- **Semiconductors** allow small currents to flow. Sometimes they are conductors and sometimes they are insulators. Silicon is the material most often used in making semiconductors.

Background information for instructors:

Insulators generally cause static charge to build up since static charge is not able to flow. Insulators do not all the flow of electricity so the charge that builds up is not able to dissipate; it is only able to discharge. An example of discharge would be when a person rubs their feet on a carpet while wearing socks and then touches another person causing a small shock.

Tell the students that the **snap circuits** we will use today contain flattened wires. Remove one of the **#2 connectors** (blue bar with a 2 on it) and hold it up so that the students can see the metal underside. Tell the students that this metal is a good conductor of electricity.

II. Explaining the Circuit – Demonstration

Instructors should hold up the demonstration circuit to show the students.

Tell the students to look at **Diagram 1** and tell them it is a picture of this circuit. Point out the different parts – batteries, circuit connectors, black and red leads, resistor and LED light.

Your Notes:

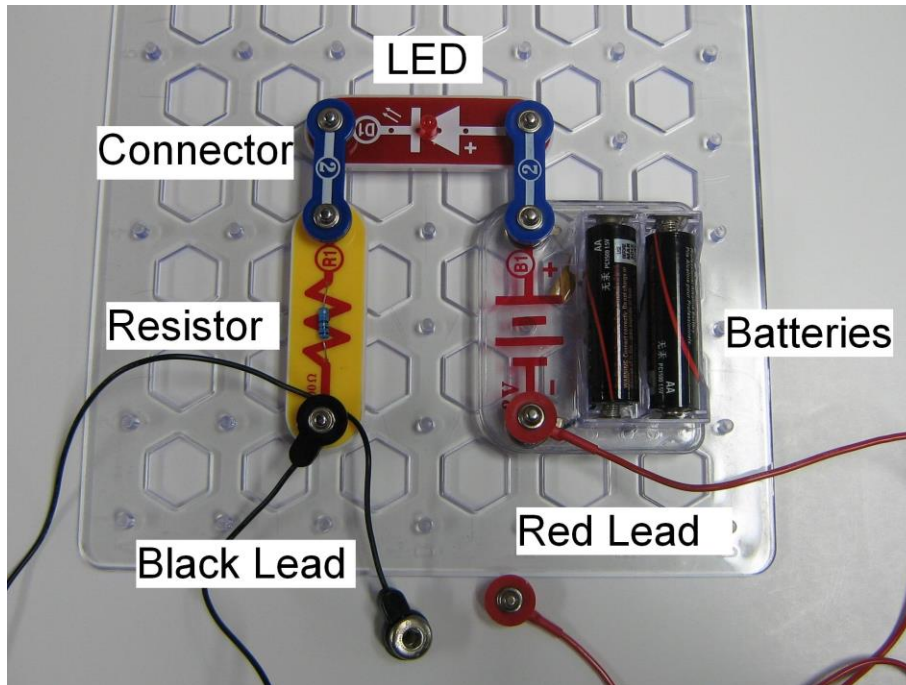


Diagram 1

Explain LED's to the students: LED's (Light Emitting Diodes) are more sensitive than light bulbs and glow brightly with small currents. They are made from semiconductors. They can be damaged by high currents and so are used with resistors to limit the current. Do NOT allow the students to remove the resistor.

Ask the students what you should do to make the LED glow. *Touch the black and red lead together.*

Show the students that this is correct, and that the LED emits light. **Tell the students that the circuit is now closed.**

Now touch the end of one lead wire to the head of the nail and the end of the other lead to the point of the nail. The LED again lights up indicating that the circuit is closed. The metal nail is a good conductor of electricity and completes the circuit.

Repeat with the bottle cap, putting the ends of the leads on opposite sides of the bottle cap. The LED will not light up, indicating the plastic bottle cap is not a conductor, it is an insulator.

Tell the students that in the first activity they will determine whether a solid is a conductor by testing whether it completes the circuit and causes the LED to light up.

Your Notes:

III. Conductivity Tests of Solids

Students will do this activity in pairs.

Materials

- 15 sets of grids with assembled circuit
- 15 bags of solid materials for checking conductivity (paper clip, aluminum foil, copper strip, golf pencil sharpened on both ends, paper)
- 15 sets of instruction sheets
- 30 observation sheets

- Hand out one grid and one bag of solid conductivity materials to each pair.
- Tell them they will be testing several materials to see if they are conductors.
 - A good conductor will complete the circuit and the LED will glow brightly.
 - An insulator will prevent completion of the circuit, and the LED will not glow at all.
 - A poor conductor will make the LED light glow dimly.
- Make sure all groups have a correctly assembled circuit by having them touch the ends of the black and red wires together and noting the brightness of the LED.
- Tell the students to follow the instruction sheet and to record their results.

Explain the history of why pencils are referred to as “lead” pencils even though the core of the pencil is actually graphite.

IV. Conductivity of Solutions

Materials per pair

- 1 6oz cup for distilled water for rinsing leads
- 1 set of jars labeled and containing: distilled water, tap water, vinegar, 0.1 M hydrochloric acid, distilled water for sugar to be added, distilled water for salt to be added.
- 8 bags containing:
 - 1oz wide-mouth bottle of sugar
 - 1oz wide-mouth bottle of salt
 - 2 taster spoons
 - 1 chemwipe tissue
 - 2 toothpicks

Note: One instructor should fill 6oz cups about 1/3 full of distilled water. Each pair will use one of these to rinse the metal ends of lead wires.

Background Information to tell the students:

Your Notes:

Some liquids are conductors while other liquids are nonconductors.

Hand out the jars of solutions, salt and sugar containers etc, and a cup with distilled water to each group. The pairs will share the jars. Make sure that only 1 jar is open at a time to avoid contamination.

Background information for instructors only:

Conducting liquids are called **electrolytes**. An **electrolyte** contains electrically charged ions that can conduct electricity. Some examples of electrolytic solutions are acids and bases and salt solutions such as sodium chloride (table salt) in water.

A **non-electrolyte** does not allow the flow of electric current because it does not have electrically charged ions that can conduct electricity. Some examples of non-electrolytic solutions are pure water, sugar water.

Electrolytes are important to humans because they are necessary for proper cellular function, muscle function, and neurological function. A greater level of electrolytes is needed during strenuous muscular activity because more electrolytes are lost due to increased sweating. This is the reason why Gatorade and other sports drinks constantly advertise that they replenish electrolytes.

Tell students to:

- Rinse the metal ends of the black and red lead wires by dipping them into the cup of distilled water. Tell the students they will need to do this in between each test, to avoid contaminating (make sure that the students know what contaminate means) the next test sample with the one just tested. They should then place the leads into the first jar containing distilled water to check that the leads are clean. The LED will not light up if the leads are clean. The rinse water will be contaminated enough after the HCl is tested so that the LED will be dimly lit. However, the test in the distilled water well should give a negative result (no glow).
- Place the labeled jars on top of the diagram on the instruction sheet. Make sure that the students have the order correct. Students must remove only 1 lid at a time, and replace it after both pairs have tested the liquid.
- Students **MUST** test the solutions in the order given, 1-6. The non-conducting solutions are tested first, followed by conducting solutions.

1. Testing distilled water:

Remove the lid of the first jar (contains distilled water).

Your Notes:

Put the metal ends of both lead wires in the jar, as far apart as possible, and note if the LED is glowing. (It should not).

Remove the leads.

The lid can remain off, since this jar will be used again in steps 4 and 5.

2. Testing sugar water:

Use the tissue to wipe off the small spoon.

Remove the lid of the 2nd jar (distilled water) and add a small amount of sugar (just a little on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again.

Repeat the conductivity test. Record your results.

Rinse the metal ends of the lead wires in the rinse cup.

Replace the lid.

3. Testing tap water:

Remove the lid of the 3rd jar (tap water). Repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Replace the lid.

4. Testing vinegar:

Remove the lid of the 4th jar (vinegar) and repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. Replace the lid.

5. Testing hydrochloric acid:

Remove the lid of the 5th jar (hydrochloric acid, HCl) and repeat the conductivity test.

Record your results. Rinse the metal ends of the lead wires in the rinse cup.

Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. If it does, rinse the leads in distilled water again. Replace the lid

6. Testing salt solution

Remove the lid of jar 6 (distilled water).

Use the small spoon to add a small amount of the salt into the same well (just a little salt on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again. Repeat the conductivity test Record your results. Rinse the metal ends of the lead wires in the rinse cup.

Replace the lid.

Explanation of results:

Your Notes:

1. **Distilled water** does not contain ions and thus does not conduct electrical currents.
2. **Sugar molecules** do not dissociate (split up) into ions in water, and so is a nonconductor.
3. **Tap water** comes from wells, lakes, or rivers, and so it often contains small amounts of dissolved mineral compounds that can be ionic. The LED did not light up very brightly, but tap water can conduct enough current to stop a person's heart.
4. **Vinegar** is a *weak* conductor of electric current– the LED glows dimly. Only a few of the vinegar molecules ionize.
5. **Hydrochloric acid** is a conductor of electric current - the LED glows brightly. All of the molecules ionize to H⁺ and Cl⁻ ions.
6. **Solid salt** will not conduct electricity because the sodium and chloride ions are not free to move around. However, when salt is dissolved in water, it dissociates completely into ions, and so is a *strong* conductor of electric current.

V. Optional Activity #1

Materials:

- 1 bag containing wide mouth bottles of Gatorade, Sprite, rubbing alcohol, sodium bicarbonate (baking soda), bottled water and lemon juice

If time permits, ask the students to choose one of the solutions.

Ask the students to predict if they think the solution will conduct an electrical current. Test it.

1. Gatorade caused the light to shine very brightly indicating that it is a *strong* conductor. The ingredients list citric acid, salt, sodium citrate, potassium phosphate.
2. Sprite contains citric acid, potassium citrate and other salts which make it a good conductor.
3. Rubbing alcohol does not conduct electricity.
4. Baking soda solid dissolves to form an ionic solution which conducts electricity.
5. Bottled water may or may not contain minerals, depending on how it is “processed”.
6. Lemon juice contains citric acid which conducts electricity.

VI. Optional Activity #2 - Demonstration

Why use LED's?

In a light bulb, electricity is converted into light energy. The brightness depends on the amount of electricity flowing through it. Regular light bulbs need a high current to be bright. Repeat the above experiment with the nail, using a regular light bulb in the circuit. It will not light up.

LED's Light Emitting Diodes are more sensitive than light bulbs and glow brightly with small currents. They are made from semiconductors and can be damaged by high currents and so are used with resistors to limit the current. **Do NOT** allow the students to remove the resistor.

Your Notes:

Electrical current can flow through them in one direction only.
Ask the students which way the electricity is flowing. Show the students the direction of flow.
Current flows from the positive end (“knob”) of the battery to the negative (“flat”) end.
Demonstration only: change the direction of the LED piece by unsnapping it, turning it around and snapping it back in to place.
What happens? *The LED does not light up.*

VII. Review

1. Go over the observation sheet with the students.

Lesson original written by Vanderbilt Students Volunteering for Science (VSVS)

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Your Notes:

Conductivity Observation Sheet

Name _____

A. Testing the Circuit.

What happens when you touch the ends of the red and black lead wires together?

Explain _____

B. Conductivity Tests with Solids

Which of the following materials makes the LED glow brightly, dimly, or not at all?

Circle your answer.

- | | | | |
|-----------------------|-----------|------------|--------------|
| 1. copper strip | no light, | dim light, | bright light |
| 2. paper clip | no light, | dim light, | bright light |
| 3. paper | no light, | dim light, | bright light |
| 4. pencil wood (only) | no light, | dim light, | bright light |
| 5. "lead" in pencil | no light, | dim light, | bright light |
| 6. aluminum foil | no light, | dim light, | bright light |

On the basis of your tests, which ones are conductors of electricity?

C. Conductivity Tests with Solutions

Which of the following solutions makes the LED glow brightly, dimly, or not at all?

Circle your answer.

- | | | | |
|----------------------|-----------|------------|--------------|
| 1. distilled water | no light, | dim light, | bright light |
| 2. sugar water | no light, | dim light, | bright light |
| 3. tap water | no light, | dim light, | bright light |
| 4. vinegar | no light, | dim light, | bright light |
| 5. hydrochloric acid | no light, | dim light, | bright light |
| 6. salt water | no light, | dim light, | bright light |

D. Optional Activity

Which solution did you test? _____

Circle your answer. no light, dim light, bright light

Conductivity Answer Sheet

A. Testing the Circuit.

1. What happens when you touch the ends of the jumper cables together?

The LED lights up.

Explain: **Touching the ends of the leads together completes the circuit.**

B. Conductivity Tests with Solids

Which of the following materials cause the speaker to produce sound?

Circle your answer.

- | | |
|----------------------|--------------|
| 1. copper strip | bright light |
| 2. paper clip | bright light |
| 3. paper | no light |
| 4. pencil wood(only) | no light |
| 5. "lead" in pencil | bright light |
| 6. aluminum foil | bright light |

On the basis of your tests, which ones conduct electricity?

Copper strip, paper clip, "lead" in golf pencil, aluminum foil

C. Conductivity Tests with Solutions

Which of the following solutions makes the LED glow brightly, dimly, or not at all?

Circle your answer.

- | | |
|----------------------|--------------|
| 1. distilled water | no light |
| 2. sugar water | no light |
| 3. tap water | dim light |
| 4. vinegar | dim light |
| 5. hydrochloric acid | bright light |
| 6. salt water | bright light |

D, Optional Activity

The following are good conductors: Gatorade, Sprite, sodium bicarbonate (baking soda), and lemon juice

Rubbing alcohol does not conduct electricity. Bottled water may.

Electrical Conductivity - Instruction Sheet

Vocabulary words: conductors, insulators, semiconductors.

I. Introduction

Look at Diagram 1 (it is a picture of this circuit).

Point to the different parts – batteries, circuit connectors, black and red leads, resistor and LED light.

II. Explaining the Circuit - Demonstration

Testing the Circuit.

Touch the ends of the red and black lead wires together. What happens?

(Write your answer on the observation sheet.)

III. Conductivity of Solids

Test the following materials. Record if the LED glows brightly, dimly, or not at all.

- Touch the ends of the black and red wires to opposite sides of the copper strip.
- Touch the ends of the black and red wires to the paper clip.
- Touch the ends of the black and red wires to the piece of paper.
- Touch the ends of the black and red wires to the wood part of the golf pencil.
- Touch the end of the black wire to one sharpened end of the golf pencil and the red wire to the other end of the sharpened pencil.
- Touch the ends of the black and red wires to opposite sides of the aluminum foil.

On the basis of your tests, record which ones are conductors of electricity.

IV. Conductivity of Solutions

- Place the jars on top of the diagram on the Instruction sheet. You **MUST** test the solutions in the order given, 1-6.
- Rinse the metal ends of the black and red lead wires by dipping them into the cup of distilled water.
- **BE SURE TO RINSE THE METAL ENDS OF THE LEAD WIRES IN DISTILLED WATER AFTER EACH TEST.**

The rinse water will be contaminated enough after the HCl is tested so that the LED will be dimly lit. However, the test in the distilled water well should give a negative result (no glow).

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1. Testing distilled water:

Remove the lid of the first jar (contains distilled water).

Put the metal ends of both lead wires in the jar, as far apart as possible, and note if the LED is glowing.

Remove the leads from the solution.

The lid can remain off, since this jar will be used again in steps 4 and 5.

2. Testing Sugar water:

Remove the lid of the 2nd jar (distilled water) and add a small amount of sugar (just a little on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again.

Repeat the conductivity test. Record your results.

Rinse the metal ends of the lead wires in the rinse cup.

Replace the lid.

3. Testing tap water:

Remove the lid of the 3rd jar (tap water). Repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Replace the lid.

4. Testing vinegar:

Remove the lid of the 4th jar (vinegar) and repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup. Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. Replace the lid.

5. Testing hydrochloric acid:

Remove the lid of the 5th jar (hydrochloric acid, HCl) and repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup.

Test that the leads are clean by putting them in the distilled water in jar 1. The LED should not glow. If it does, rinse the leads in distilled water again. Replace the lid

6. Testing salt solution

Remove the lid of jar 6 (distilled water).

Use the small spoon to add a small amount of the salt into the same well (just a little salt on the tip of the spoon is enough). Stir with a toothpick. Break toothpick so that it will not be used again. Repeat the conductivity test. Record your results. Rinse the metal ends of the lead wires in the rinse cup.

Replace the lid.

V. Optional Activity #1

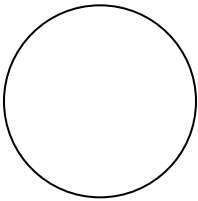
Choose one of the solutions from Gatorade, Sprite, rubbing alcohol, sodium bicarbonate (baking soda), bottles water and lemon juice and predict if you think it will conduct electricity.

Test your prediction by putting the wires **into** the bottle.

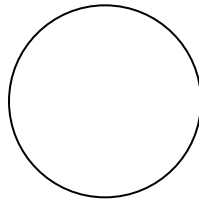
VI. Optional Activity #2 – Demonstration

Electrical Conductivity Instruction Sheet

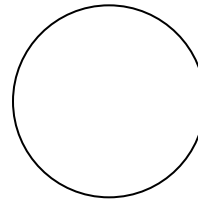
Place the jars on top of the diagram. Make sure that the labels match. Do not remove lids until you are ready to test the liquid.



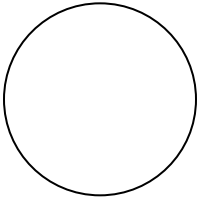
Distilled Water



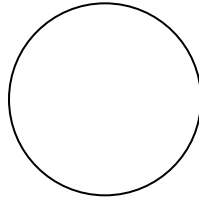
Distilled Water (add sugar)



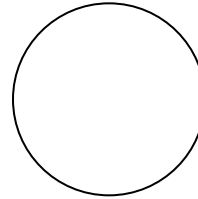
Tap Water



Vinegar



Hydrochloric Acid



Distilled Water (add salt)