Circuits: Application of Physical and Chemical Properties

Topic	Physics & Chemistry
Program	Brown Science Prep
Developed by	Nicole Palacino & Wolfgang Breves
Developer Type	High School Teachers

Overview / Purpose / Essential Questions

- Physics: How do series circuits and parallel circuits differ?
- Chemistry: What is the difference between a physical and chemical property?
- Synthesis: Is a material's conductivity a physical or chemical property?
- Synthesis: How can we use the knowledge of conductivity to determine if a material can be used to complete a circuit?

Time Required to Complete Activity: 5 Days

Performance / Lesson Objective(s)

I can identify conductivity as either a chemical or physical property, and use my knowledge of circuits to create a circuit using a conductive liquid. By the end of this activity, students will be able to:

- Identify the difference between physical and chemical properties of materials.
- Understand the effect that series and parallel circuits have on voltage, current, resistance, etc.
- Determine the conductivity of materials based on observation and theoretical knowledge.

Lesson Motivation

Although there are many aspects of the physical world that are intuitive to humans, there are many more counterintuitive phenomena. Of the four natural forces, none is more confusing to the average person than electromagnetism. In our day-to-day lives, it is nearly as relevant as gravitation— and yet much harder for people to wrap their heads around due to E&M's complicated interactions with the natural world.

Knowledge of the electromagnetic force is a powerful and practical tool that can keep you safe, save you money and, above all, inspire you with the beauty of our universe. Many students are interested in pursuing technical jobs after their education. Professions such as electrician, car mechanic, housing contractor and the like all require a thorough understanding of the electromagnetic force and its applications. This week-long activity is designed to teach you the basics of electromagnetism and its most fundamental interactions with various materials that you may come across in your daily life.

Lesson Activities

In this unit, students will investigate properties of matter and use this to evaluate a variety of materials on their potential uses in a circuit. First, they will be introduced to circuits through a worksheet where they must determine if the circuit shown will cause a variety of bulbs to turn on. Then they will test different physical and chemical properties (including conductivity) of a variety of materials and make a conclusion about if conductivity is a physical or chemical property. Finally, they will be asked to combine their knowledge into a creation of their own circuit where they have a variety of materials available. They will then analyze which material they believe is best for production of a circuit.

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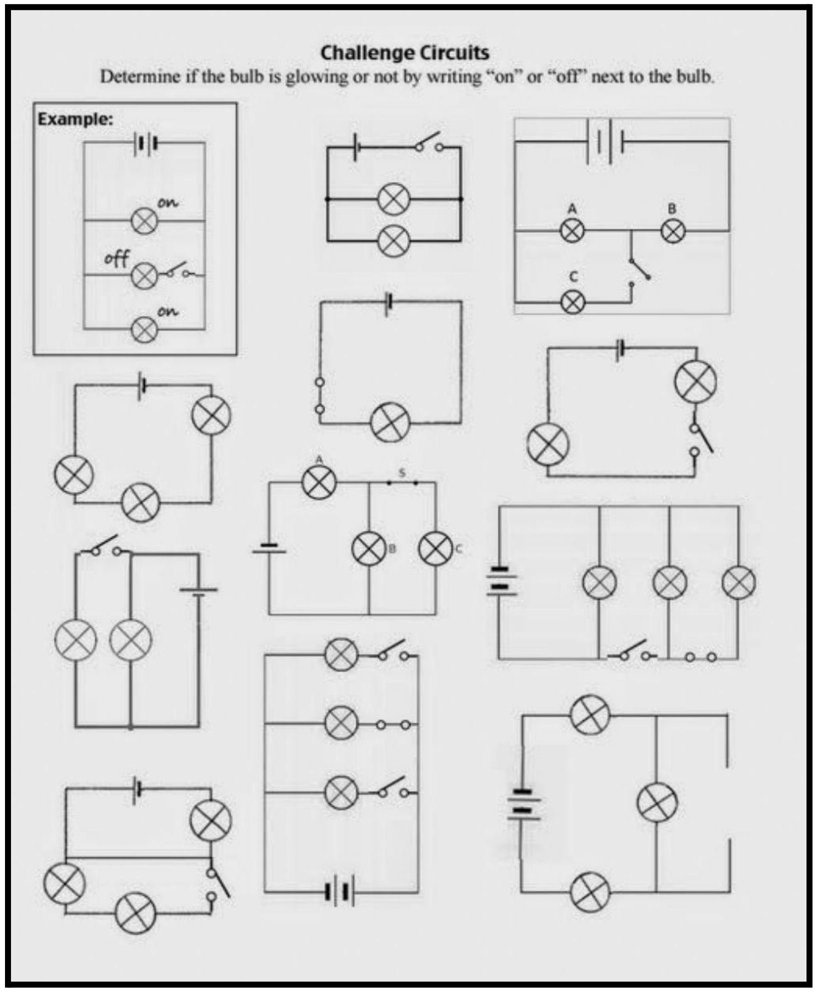
Day I: Currents and Circuits

Essential Question: How do series circuits and parallel circuits differ?

Materials:

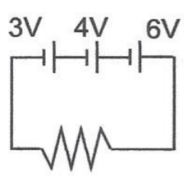
- Circuits Worksheet
- Circuits Problem Set



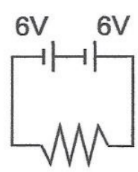
Instructions: A series circuit comprises a path along which the whole current flows through each component. A parallel circuit comprises branches so that the current divides and only part of it flows through any branch. Fill out the worksheet below. Determine if the bulb in each diagram is glowing or not by writing "on" or "off" next to the bulb.

Voltage Problems:

1) Determine the total voltage for each of the following circuits below by adding each voltage source.



3V+4V+6V=13V



6V+6V=12V

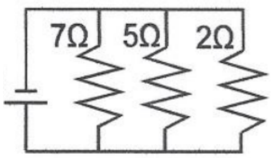
2) What do you think would happen if you connected two equal voltages in parallel?

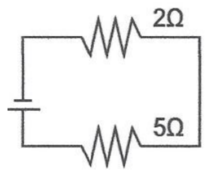
When two equal voltages are connected in parallel (such as when two car batteries are connected in order to jump start a car) the voltage of the system does not change but the current will increase to match the sum of the currents of each individual source.

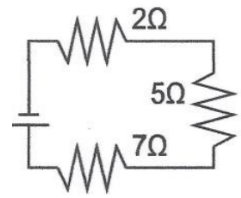
3) What happens when you connect two different voltages in parallel?

When two *different* voltage sources are connected in parallel, issues will ensue. The higher voltage battery will attempt to "charge" the lower voltage battery— causing it to overheat and most likely break.

Resistance Problems:
4) Determine the total resistance for each of the following circuits below.







$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
$$= \frac{1}{7} + \frac{1}{5} + \frac{1}{2} = \frac{59}{70}$$
$$R_{eq} = \frac{70}{59} = 1.2\Omega$$

$$R_{eq} = R_1 + R_2$$
$$= 2 + 5$$
$$R_{eq} = 7\Omega$$

$$R_{eq} = R_1 + R_2 + R_3$$
$$= 2 + 5 + 7$$
$$R_{eq} = 14\Omega$$

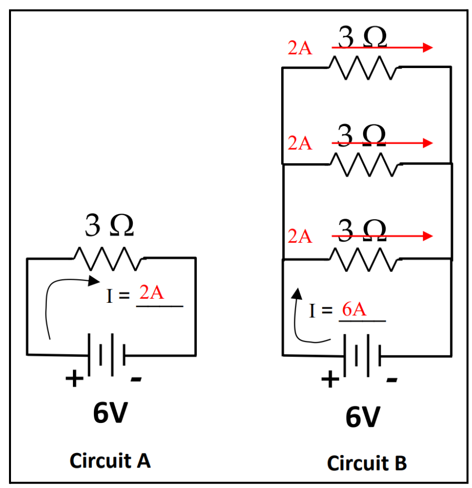
Current Problems:
4. In a parallel circuit, there is more than one loop or pathway so charge flow gets split up or recombined at junction points. Therefore current is not the same at every point in the circuit.

a) How does the current through the one resistor in circuit A, compare to the current through each resistor in circuit B?

The current through each resistor in circuit B is the same as the current through the resistor in circuit A (I = V/R. V across R in circuit B is same as circuit A)

b) How does the sum of the currents through the three bulbs in circuit B compare to current from the battery in circuit A?

Since the current across each bulb in circuit B is the same as in circuit A and there are three pathways, the sum of the currents in B is 3x current in circuit A



Exit Ticket/Power Check: What do you notice about the relationship between voltage, resistance and current? If they were to be related in the form of a simple relationship, what would that equation look like?

Given the diagrams and information given above, it should be clear that voltage is equal to resistance times current. As a result we get the following formulation of Ohm's Law: V = IR.

Day II: Physical and Chemical Properties Lab

Essential Question: What is the difference between a physical and chemical property?

Materials:

- Paper scraps
- Watch glass
- Lighter
- Multimeter
- Copper electrode
- Silicone
- Chalk
- Salt water (300 mL water and 11 g salt)
- Copper sulfate (“blue crystals”)
- Mortar and pestle
- Crucible
- Glass stirring rod
- Tongs
- Hot plate
- Tea light with wick
- Tea light without wick
- 100 mL graduated cylinder
- 10 pre-1982 pennies
- 10 post-1982 pennies
- Test tubes
- Iron nails
- Copper sulfate solution (“blue solution”)

Predict what you think will happen in each of the activities and write down your predictions in your data table. Before you begin, put on your goggles and apron, and wear them properly throughout the investigation. Five stations, A through E, have been set up around the laboratory. At each station, you will complete the investigations indicated for that station. The stations can be completed in any order but always be sure to return each station to its starting condition after finishing. Record your complete data and observations.

Station A: Paper

Investigation 1

1. Tear a small piece of paper into smaller pieces and place the pieces on a watch glass.
2. Record your observations in your data table.

Investigation 2

1. Place the watch glass and pieces of paper on the heat resistant lab bench.
2. Light the pieces of paper with a match and allow them to burn completely.
3. Record your observations in your data table.
4. Discard the paper as directed by your teacher, clean the watch glass, and reset the station.

Station B: Conductivity

Investigation 3

1. Using the multimeter at your station, place the red and black probes on the copper electrode. Make sure the probes are not touching each other.
2. If the multimeter beeps, the copper can conduct electricity. If not, it cannot.
3. Repeat steps 1 and 2 for the silicone, chalk, and salt water.

Station C: Blue Crystals

Investigation 4

1. Place a blue crystal into the mortar.
2. Use the pestle to grind the blue crystal.
3. Record your observations in your data table.
4. Put the powder into a crucible to use for Investigation 5.

5. Clean and reset the station as instructed by your teacher.

Investigation 5

1. Turn on the hot plate to a setting of “high.” (Caution: Do not touch the hot plate surface. It may already be hot.) **The appearance of a hot plate surface does not change when it is hot. Always exercise caution when using hot plates.**
2. Measure and record the mass of the crucible and blue powder from Investigation 4. (Record in your data table)
3. Place the crucible on the hot plate and heat for 3 minutes, stirring gently with the glass stirring rod. Use tongs to hold the crucible as you stir.
4. Use tongs to remove the crucible from the hot plate and allow it to cool for several minutes.
5. Measure and record the mass of the crucible and its contents.
6. Record your data and observations in your data table.
7. Put the powder into a waste container as directed by your teacher.
8. Turn off the hot plate and reset the station.

Station D: Tea lights

Investigation 6

1. Turn on the hot plate to a setting of “high.” (Caution: Do not touch the hot plate surface. It may already be hot.)
2. Measure and record the mass of the tea light without the wick.
3. Use tongs to place the tea light (in the metal holder, without a wick) on the hot plate.
4. Observe for three to five minutes.
5. Use tongs to carefully remove the tea light.
6. Turn off the hot plate.
7. Measure and record the mass of the tea light.
8. Record your observations in your data table.

Investigation 7

1. Measure and record the mass of the tea light with the wick.
2. Light the wick on the second tea light with a match.
3. Observe for three to five minutes.
4. Carefully extinguish the flame.
5. Measure and record the mass of the tea light.
6. Record your observations in your data table.
7. Reset the station.

Station E: Metals

Investigation 8

1. Count and use 10 post-1982 pennies to make the measurements that follow.
2. Make sure the 10 pennies are completely dry. Then measure and record the mass of the 10-penny sample and record in your data table.
3. Pour about 50 mL of water into a 100-mL graduated cylinder. Accurately measure and record the volume of water in the cylinder.
4. Carefully place your 10 pennies into the graduated cylinder. Accurately measure and record the volume of water (plus objects).
5. Remove the pennies from the cylinder and dry them.
6. Repeat steps 1-5 using 10 pre-1982 pennies.

7. Clean and reset the station.

Investigation 9

1. Fill a clean test tube to a height of 2 to 3 cm with blue solution.
2. Use forceps to carefully place an iron nail into the test tube so that it is partially, but not totally, immersed in the blue solution.
3. Record your observations in your data table over several minutes.
4. Remove the nail from the solution and record any additional observations you have in your data table.
5. Dispose of the solution and the nail as directed by your teacher, clean the test tube, and reset the station.

End of Lab Checklist:

- ☐ Dispose of chemicals as instructed by teacher
- ☐ Put goggles in cabinet
- ☐ Return glassware to front
- ☐ Wipe down lab bench
- ☐ Wash hands

Data Table:

Investigation Number	Predictions	Observations
1		
2		
3		
4		
5		
6		
7		
8		
9		

Day III: Physical and Chemical Properties Lab Analysis

Essential Question: What is the difference between a physical and chemical property?

1. In which investigations did you collect quantitative data?

2. The density of solid objects is often reported using units of g/cm3. A cubic centimeter (cm3) is equal to 1 milliliter (mL). Recall that density refers to the mass of a material within a given volume. How can you use your data from Investigation 12 to determine the density of post-1982 pennies?

   a. Calculate the density of post-1982 pennies.
   Density= __________ g/cm3 b.

   b. Calculate the density of the other metal object(s) you tested in Investigation 12.
   Density= _____________ g/cm3

3. Did either treatment of the paper at Station A create a new material? How do your observations support your thinking?

4. Which of the materials at Station B conducted electricity? Did you make a new material with any of them?

5. Did either treatment of the blue crystals at Station C create a new material? Why do you think that?

6. Was the burning tea light different from the melting tea light at Station D? Describe the observations that led to your conclusion.

6. Identify one investigation in which your observations closely matched your predictions. Why do you think your prediction was so accurate?

7. Identify one investigation in which your observations were different from your predictions.
   a. Describe what you were thinking when you made the prediction.

   b. Write one question you have about the investigation now that your observations did not match your prediction.

8. In your own words,
   a. Describe what it means to make observations during investigations in the laboratory.

   b. Based on your experience in these investigations, what types of evidence will you look for as you make observations in future investigations?

Physical and chemical properties worksheet:

UNIT 1: PHYSICAL AND CHEMICAL PROPERTIES
Physical properties are properties that can be determined without altering the chemical makeup of a substance. Chemical properties relate to the types of chemical changes that a substance undergoes (or doesn't undergo).

Using the space provided, classify each of the following statements as describing either a physical property or a chemical property.

1. Paper is flammable and will create ash. Chemical Property
2. Gallium, used primarily in semiconductors and light emitting diodes (LEDs), is a soft, silver-colored metal. Physical Property
3. Helium is used to fill blimps because its density is lower than that of air, thus enabling these crafts to float. Physical Property
4. Zinc metal burns in air to form zinc oxide. Chemical Property
5. Sodium metal must be stored under kerosene or nitrogen because of its high reactivity with oxygen and water. Chemical Property
6. Bromine is a reddish-brown element and is the only nonmetallic element that exists in the liquid state at room temperature. Physical Property
7. Isopropyl alcohol (also known as rubbing alcohol) readily evaporates when it is placed on your skin. Physical Property
8. Carbon dioxide and water are produced when gasoline undergoes combustion in a car engine. Chemical Property
9. More energy is required to raise the temperature of 1 g of water than is needed to raise the temperature of 1 g of any metal. Physical Property
10. The compound boron nitride is almost as hard as diamond and is used for glass and diamond shaping and cutting. Physical Property
11. Hydrogen sulfide is removed from the natural gas used to heat homes through a reaction with oxygen. Chemical Property

Exit Ticket/Power Check: Answer the following question on your index card: Is water's ability to conduct electricity a chemical or physical property? How do you know?
It is a physical property, since you do not have to change the chemical makeup of a material in order to test its ability to conduct electricity.

Day IV: Building a Circuit

Essential Question: How can we use the knowledge of conductivity to determine if a material can be used to complete a circuit?

Materials:

Per Group

- 2 Electrodes
- 4 pieces insulated copper wire, each 4-6 inches (10-15 cm) long
- 9-volt battery
- battery cap, usually with red and black wire leads
- 3.7 volt light bulb
- 1 miniature light bulb socket
- eye protection (goggles or safety glasses)
- (optional) multimeter and multimeter leads with alligator clips

Per Class

- Electrical tape
- Salt, one 26 oz (737 g) container
- Screwdrivers, to tighten wires in light bulb sockets
- Samples of:
    - Chalk
    - Copper Wire
    - Salt Water
    - Rubber
    - Paper
    - Wood

Procedure:

1. Gather a set of materials with your group.
2. Connect one wire to each electrode using electrical tape. Make sure the bare end of the wire touches the aluminum foil.
3. Connect the opposite end of the wire from one electrode to one terminal of the light bulb socket. Insert the bare wire around the socket terminal and tighten with a screwdriver. Add a piece of electrical tape to secure the connection.
4. Connect a wire to the opposite terminal of the light bulb socket. Again tighten with a screwdriver and cover with a piece of electrical tape.
5. Use electrical tape to connect the wire from the light bulb socket to the red wire of the 9-volt battery cap.
6. Use electrical tape to connect a wire to the black wire of the 9-volt battery cap.
7. **If using a multimeter:** Connect the free wire to the negative terminal of the multimeter. Then connect the positive terminal of the multimeter to the free electrode.
8. **If not using a multimeter:** Use electrical tape to connect the free wire of the battery cap to the free electrode.
9. **Test your circuit** by touching the two electrodes together. This completes the circuit, allowing electricity to flow from one terminal of the battery to the other, and illuminates the light bulb in the process. If the bulb does not light up, check your wire connections to make sure they are all secure and try again.

Solutions, Data Collection and Analysis

Once you have checked to make sure that your circuit works when you touch the two electrodes together, send one group member to the front of the classroom to gather the materials that will be tested for conductivity in between each of the electrodes. Each group should receive one piece of: chalk, copper wire, salt water, rubber, paper, and wood.

Data Table:

Material	Predictions	Observations
Chalk		
Copper Wire		
Salt Water		
Rubber		
Paper		
Wood		

Day V: Analysis and Conclusions

Essential Question: How can we use the knowledge of conductivity to determine if a material can be used to complete a circuit?

Materials: Analysis Questions, Post Assessment

Work in lab groups to answer the following questions.

1. Which of the six materials that you tested were able to complete the circuit and cause the light bulb to turn on?

2. How did the data you gathered compare to your predictions? Were there any results that surprised you?

3. Do you think that the materials that completed the circuit can conduct electricity?

4. What do you think is required for a material to be a good conductor of electricity?

5. Based on the experiment, is conductivity a physical or chemical property? How does this compare to your answer to the Exit Ticket on Day 3?

6. Relate what you have learned about conductivity to prior knowledge of ions in solution.

7. How can you use your knowledge of conductivity to predict what materials would be useful in making a circuit?

Summation of Lesson

Students will conclude the unit by answering the analysis questions for the circuit lab. They will also retake the evaluation they took before beginning the unit.

Pre Assessment Plan

Students will answer the pre assessment questions before beginning the circuit activity on day 1.

Post Assessment Plan

Students will answer the pre assessment questions after completing the analysis questions on day 5.

Alignment Info

Audiences	High School Students
STEM Area(s)	Physics and Chemistry
Standard(s)	HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. HS-PS3-3. Dsign, build, and refine a device that works within given restraints to convert one form of energy into another form of energy.
Activity Type(s)	Worksheet Hands-on laboratory exercises Group lab analysis
Grade Level(s)	High School
Version	1
Created	07/15/2022
Updated	08/2/2022

Sources

(1) *Circuit A Circuit B - Livingston Public Schools*. https://www.livingston.org/cms/lib9/NJ01000562/Centricity/Domain/833/circuitsolutions.pdf.

(2) Cornelius, K. "Electric Circuits." *OBU*, http://plaza.obu.edu/corneliusk/ec/.

(3) BatteryGuy. "Home." *The BatteryGuy.com Knowledge Base*, https://batteryguy.com/kb/knowledge-base/connecting-batteries-in-parallel/.

(4) "Saltwater Circuit - Activity." *TeachEngineering.org*, 17 June 2022, https://www.teachengineering.org/activities/view/cub_desal_lesson01_activity1.

(5) Powers, Angela, editor. *Teacher's Resource Materials for Chemistry in the Community, ChemCom*. 6th ed., W.H. Freeman and Company, 2012.

Pre/Post Assessment

Students will complete the following pre assessment to evaluate prior knowledge and to compare to knowledge after completion of the unit.

1. Identify the following as either physical or chemical properties:
    a. Copper wire is malleable.
        i. Physical
        ii. Chemical

    b. Gold is unreactive with most acids.
        i. Physical
        ii. Chemical

    c. Water boils at 100 degrees celsius.
        i. Physical
        ii. Chemical

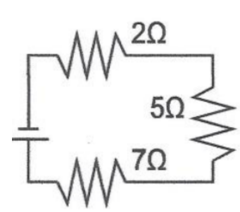
    d. Sugar can dissolve in water.
        i. Physical
        ii. Chemical

    e. Mixing ammonia and vinegar results in a neutralization reaction.
        i. Physical
        ii. Chemical

2. Which of the following would be good materials to create a circuit? Circle all that apply.
    a. Chalk
    b. Copper
    c. Salt Water
    d. Rubber
    e. Paper

3. Imagine an open circuit with two energy sources. Assume that these two energy sources are batteries with a voltages of 6V and 8V respectively.
    a. What happens to each battery when the circuit is closed?
    b. How is this different from when there are two equal voltage sources in parallel?

4. Determine the total resistance for the circuit diagram on the right.



5. What do you notice about the relationship between voltage, resistance and current? If they were to be related in the form of a simple relationship, what would that equation look like?

6. What do you think is required for a material to be a good conductor of electricity?

Solutions, Data Collection and Analysis

Once you have checked to make sure that your circuit works when you touch the two electrodes together, send one group member to the front of the classroom to gather the materials that will be tested for conductivity in between each of the electrodes. Each group should receive one piece of: chalk, copper wire, salt water, rubber, paper, and wood.

Data Table:

Material	Predictions	Observations
Chalk		
Copper Wire		
Salt Water		
Rubber		
Paper		
Wood		