LIGHT THE BULB INQUIRY

STEM CATEGORY

Science

CAREER PATH

Energy

TOPIC

Energy Transfer

OVERVIEW

In this investigation, students will design three different circuit arrangements with a switch capable of lighting a small light bulb. Then, students will draw circuit diagrams for each method that works. After discussing the energy transformations that take place within a circuit, they will use a simulation to explore the effect of multiple lights connected in series and parallel and compare the power output (light intensity) of each configuration. They will use the results of this investigation to determine the best configuration for wiring holiday lights.

STEM LESSON FOCUS

Engineering Design Cycle	**21st Century Skills**
• Creating or Protoyping	• Collaboration

OBJECTIVES

Students will be able to:

- Work in small groups to propose three different circuit configurations that will make the light bulb light up and test their methods by constructing each circuit.
- Describe the energy transformation in an electric circuit and compare the power output of series and parallel circuit arrangements.
- Apply knowledge from this investigation to determine the best configuration for wiring holiday lights.

LIGHT THE BULB INQUIRY

MATERIALS

- Small holiday light bulbs with attached wires (ends stripped)
- Type D batteries (1.5 V)
- Battery holders (that can be connected in series)
- 6-Volt lantern batteries
- Alligator clip wires
- On-off switches (jack knife)
- Computers connected to the internet (for completing the simulation)
- Copies of the Experimental Designs handout, one per student
- Copies of the Electrical Symbols chart, one per student
- Copies of the "Circuit Construction Kit" PhET Simulation capture sheet, one per student
- Copies of the Exit Ticket, one per student

HAVE YOU EVER WONDERED…

What makes an electric circuit work at the most basic level? Or, when one bulb goes out, why the entire string of some holiday lights is disrupted?

MAKE CONNECTIONS!

How does this connect to students?	**How does this connect to careers?**	**How does this connect to our world?**
From the lights in your home to the smartphone in your hand, just about everything you use in your daily life works by utilizing a series or parallel circuit.	**Electricians** typically are licensed professionals who work for electrical contracting or construction firms installing and repairing wiring and electrical components.	All around the world, electricity provides us with a swift means of communication and electric power allows for machinery to run efficiently and

	Power Plant Operators are responsible for controlling and maintaining the components that generate electricity for energy companies. **Electrical Engineers** design, develop, test, or supervise the manufacturing and installation of electrical components, equipment, or systems.	economically, thereby increasing the production of goods.

BLUEPRINT FOR DISCOVERY

In the first part of this investigation, students will design THREE different circuit arrangements with a switch capable of lighting a small light bulb. Then, they will draw circuit diagrams for each method that works.

1. Pass out the Experimental Designs student handout and Electrical Symbols chart to each student and direct them to form groups of 3–4 students.
2. Review the directions at the top of the student handout, as well as the additional instructions for how to use the chart to complete the circuit diagrams.
3. Groups that finish early should also complete the post-lab questions. Discuss these questions with the class when all groups have completed their diagrams, instructing them to record their answers if they have not yet done so.
4. Before starting the simulation, discuss the energy transformation that takes place within the circuit to allow the light bulb to light up.

   Key Points to Emphasize:

   - In a circuit consisting of a battery and a resistor, there is a sequence of energy transformations.
   - Chemical energy in the battery is transferred to potential energy of the charges in the current. As charges accelerate in the electric field, potential energy is transformed into kinetic energy.
   - The charges lose energy in collisions as they pass through the filament in the bulb. This energy is transformed into the thermal energy of the glowing filament in a light bulb.

- The rate at which the energy transfer takes place is the electric power output of the circuit.

5. In the second part of the exploration, students will work individually or in small groups (depending upon the number of computers with internet available) to use the "Circuit Construction Kit" PhET Simulation to differentiate between two types of circuits: series and parallel. https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc
6. Pass out the "Circuit Construction Kit" PhET Simulation capture sheet and go over the instructions and tips with students.

TAKE ACTION!

After the PhET analysis, direct students to watch the "Electric Analogies Walkthrough" to explore these concepts further: https://www.youtube.com/watch?v=t5XWeQuEhU4.

A key question for class discussion after watching the video: "How does the water wheel analogy help us understand the difference between voltage/current and series/parallel circuits?"

- As with an electric current and a lightbulb, water flows over the wheel, making it turn.
- The amount of water leaving the water wheel equals the amount of water entering it just like the number of electrons entering a light bulb equals the number leaving it.
- The water, like an electric current, is doing work, so there is an energy change.
- In a lightbulb, the energy is dissipated by atomic-level friction as the electrons move through the wire, making the wire hotter until it glows.

Direct students to complete the Exit Ticket to synthesize their learning.

LIGHT THE BULB INQUIRY

NATIONAL STANDARDS

Science	Next Generation Science Standards **HS-PS3-2.** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects). **HS-PS3-3:** Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy Technology Education
Technology Education	**ITEEA Standards for Technological Literacy** **Standard 16:** Energy and Power Technologies In order to select, use, and understand energy and power technologies, students in Grades 9-12 should learn that: J. Energy cannot be created nor destroyed; however, it can be converted from one form to another. K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.

Name:_____ **Date:**_____

LIGHT THE BULB EXPERIMENTAL DESIGNS

Directions: Working in small groups and using the materials provided, write descriptions below for THREE different proposed circuit arrangements that you think will light up the bulb when the switch is turned on. Test whether they light up the bulb by operating the switch in the circuit. If any of your methods do not work, modify the set-up until you get the light bulb to light up. (Indicate the changes you made to the design to get each to work at the end of your proposed method description.) Then, draw diagrams in the corresponding boxes for your designs.

Proposed Method #1:

Proposed Method #2:

Proposed Method #3:

CIRCUIT DIAGRAMS

After you've designed three circuit arrangements that work, draw corresponding circuit diagrams for each using appropriate circuit symbols (refer to the Electrical Symbols Chart). Include the number of battery cells with assigned voltage, switch, wires, and +/- terminals. Show the flow of conventional current through the circuit using circular flow arrows on each drawing. Also, show separately the flow of electrons through the circuit using regular arrows and symbolize electrons as "e^-." NOTE: Draw all wires as straight lines and junctions at right angles.

*Do NOT leave the circuits connected for an extended period as this will drain the batteries. If you think one of your batteries is dead or if you burn out a bulb, alert your teacher.

CIRCUIT DIAGRAM #1:

CIRCUIT DIAGRAM #2:

CIRCUIT DIAGRAM #3:

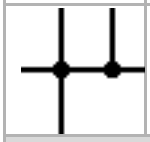
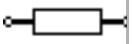
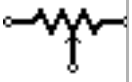
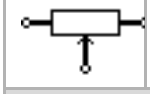
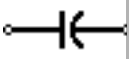
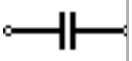
POST-LAB ANALYSIS

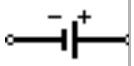
1) Which of your proposed methods worked? Which did not work? Explain.

2) What are the essential components of a simple circuit?

3) For some holiday lights, when one bulb goes out, the entire series of lights is disrupted. Explain why this happens.

ELECTRICAL SYMBOLS

Symbol	Component name	Meaning
Wire Symbols		
	Electrical Wire	Conductor of electrical current
	Connected Wires	Connected crossing
Switch Symbols and Relay Symbols		
	Toggle Switch	Disconnects current when open
Resistor Symbols		
	Resistor	Resistor reduces the current flow.
	Resistor	
	Potentiometer	Adjustable resistor—has 3 terminals.
	Potentiometer	
Capacitor Symbols		
	Capacitor	Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC.
	Capacitor	
Power Supply Symbols		

	Voltage Source	Generates constant voltage
	Current Source	Generates constant current.
	Battery Cell	Generates constant voltage
	Battery	Generates constant voltage
Meter Symbols		
	Voltmeter	Measures voltage. Has very high resistance. Connected in parallel.
	Ammeter	Measures electric current. Has near zero resistance. Connected serially.
	Ohmmeter	Measures resistance
	Wattmeter	Measures electric power
Lamp / Light Bulb Symbols		
	Lamp / light bulb	
	Lamp / light bulb	

*Adapted from https://www.rapidtables.com/electric/electrical_symbols.html

Name:_____ **Date:**_____

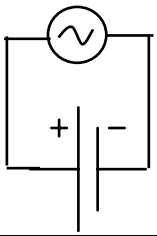
"CIRCUIT CONSTRUCTION KIT" PHET SIMULATION

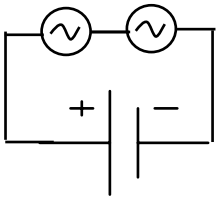
Directions: Go to tinyurl.com/circuitphet and click the play button on the simulation. Select the "Lab" option. Check the boxes for "show current", "labels", and "values" in the upper right corner of the screen. Use the tips to complete the activity below.

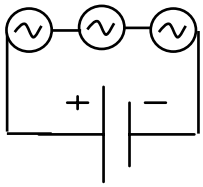
Tips for building circuits and recording data:

- Click and drag circuit components from the left side toolbar.
- To change the voltage of a battery, click on the battery and use the horizontal slider to adjust the value.
- To measure voltage, click and drag the voltmeter so that it is parallel to the circuit element to be measured.
- To measure current, wire in the ammeter in series.
- Remember to measure the voltage parallel to and current with *each bulb* in the circuit (i.e. three voltage and current measurements for circuits with three bulbs).
- Describe the "brightness" of the bulbs using the relative terms of dim, bright, or very bright.

1. Build the 3 series circuits below and measure the voltage and current. Describe the brightness of the lightbulbs. (Note: the circle with the squiggle inside represents a light bulb.)







# of Lightbulbs	Voltage (V)	Current (A)	Brightness
1			
2			
3			

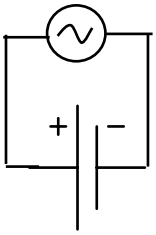
What happens as lightbulbs are added?

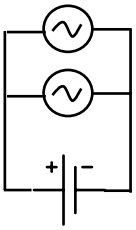
_____

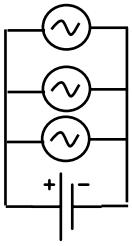
_____

_____

2. Build the 3 parallel circuits below and measure the voltage and current. Describe the brightness of the lightbulbs.







# of Lightbulbs	Voltage (V)	Current (A)	Brightness
1			
2			
3			

What happens as lightbulbs are added?

3. Compare the brightness of multiple bulbs connected in series and parallel configurations. Make sure you're comparing circuits with the same number of bulbs. How does the brightness compare in each case? Which circuit consumes more power (series or parallel)?

4. If you were wiring together a string of holiday lights, would you use a series or parallel configuration? Explain.

Name:_____ **Date:**_____

LIGHT THE BULB EXIT TICKET

Explain TWO concepts from the Electric Analogies Walkthrough video and relate them to what you learned while conducting the lab investigation and simulation.

(*Three Complete Sentences Minimum*)

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