CAL RIPKEN, SR. Foundation

TRANSFORM COMMUNITIES
CHANGE KIDS' LIVES

STEM™

Ripken Foundation STEM Center

Middle School Curriculum Guidebook

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INTRODUCTION

INTRODUCTION

ABOUT THE CAL RIPKEN, SR. FOUNDATION

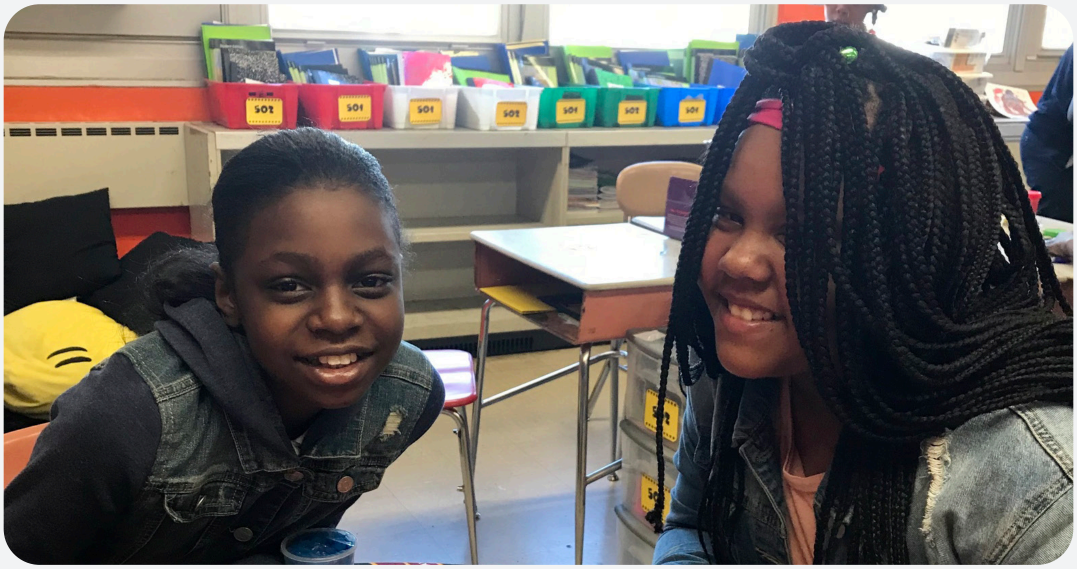
During his 37-year career with the Baltimore Orioles organization, Cal Ripken, Sr. taught the basics of the game and life to players big and small. After he passed away, his sons Cal and Bill recognized that not every child is lucky enough to have such a great teacher/mentor and role model. In this spirit, the Ripken family started the Cal Ripken, Sr. Foundation, a national 501(c)(3) nonprofit organization, in 2001.

By teaching kids how to make positive choices no matter what life throws at them, the Cal Ripken, Sr. Foundation strives to help underserved youth fulfill their promise and become healthy, self-sufficient, and successful adults.

ABOUT THE CAL RIPKEN, SR. FOUNDATION'S MIDDLE SCHOOL STEM PROGRAM

The Cal Ripken, Sr. Foundation provides programs, resources, training, and support to community-based youth organizations and schools across the country that directly impact the lives of underserved kids. When it comes to the fields of science, technology, engineering, and math (otherwise known as STEM), we have created a program that makes STEM activities and learning easy to implement.

The Ripken Foundation's Middle School STEM program was created for older students to continue learning STEM concepts through middle school. Each Ripken Foundation Middle School STEM Center is equipped with this customized STEM curriculum guidebook paired with age-appropriate, grade level, STEM Center products and activity kits which provide a comprehensive, experiential learning environment for kids. The activities in the guidebook are designed to offer teachers and mentors different ways to teach critical thinking and problem-solving skills, all while having fun.



GUIDING PRINCIPLES OF THE CAL RIPKEN, SR. FOUNDATION

Cal Ripken, Sr. was a player, coach, and manager in the Baltimore Orioles organization for nearly four decades. He developed great players and, more importantly, great people through his style of coaching which we use as our guiding principles at the Foundation. No matter what you are teaching, you can use these four key ideas as your guide:

Keep It Simple

Lessons on the field and in life are best learned when presented in a simple manner. Teach the basics and keep standards high.

Explain Why

By helping kids understand the connections between everyday decisions and real-life outcomes, we can help them make smarter choices for brighter futures.

Celebrate The Individual

When kids are encouraged to be themselves, respected for their opinion, and are encouraged to share it, they are more likely to have a higher self-esteem and feelings of self-worth.

Make It Fun

If kids aren't paying attention or participating, how much are they learning? Whether it's using a game to teach a concept or motivating kids with a little friendly competition, keeping kids engaged is essential.

Want to hear Bill Ripken explain the guiding principles of the Foundation?
Go to **http://www.RipkenFoundation.org** *and sign up for a free account today!*

EDUCATIONAL PRINCIPLES BEHIND STEM EDUCATION

EDUCATIONAL PRINCIPLES BEHIND STEM EDUCATION

Ripken Foundation Middle School STEM Centers allow kids to learn and explore their curiosities without the confines of standardized lesson plans and testing. This curriculum guidebook is designed to give you background on the supplies we have provided, along with a set of lessons to enrich your mentoring program.

To help you curate a successful STEM program, we have provided a selection of tools that will strengthen your skills as a STEM teacher/mentor. Having these tools in your back pocket will enrich your understanding of the best practices, which will enable you to teach important principles while having fun! Remember, some of these tools youth have already encountered in the classroom, so using them in afterschool mentoring programs will reinforce the skills and instill the confidence kids need to excel in STEM subjects, leading to careers in related fields.

5E MODEL OF INSTRUCTION

The 5E Model of Instruction leads students through five different stages: Engage, Explore, Explain, Elaborate, and Evaluate. This model encourages middle school-age youth to construct an understanding of scientific concepts that promote active learning and interest in intermediate STEM skills.

Engage

The first stage of the 5E Model engages students to focus on a problem or situation. Activities in the Engagement stage are designed to help students create associations between past and present learning experiences and to establish thinking towards essential questions. In this stage, teachers structure initial discussions to understand the ideas and experiences of students for the topic. Then, students will be presented with a situation and be given an instructional task with rules and procedures for the activity.

Explore

Once students have completed their initial activity, there is still a need to explore ideas. In the Exploration stage, activities are designed so students have shared, distinct experiences that can be used later when introducing and discussing scientific and technological concepts and explanations. As a result of their mental and physical involvement in these activities, students question events, monitor patterns, classify and test variables, and create causal relationships. Teachers should facilitate learning during the Explore stage, allowing students to investigate the problem and provide support as a guide as they record and analyze observations or data, creating models or initial explanations.

Explain

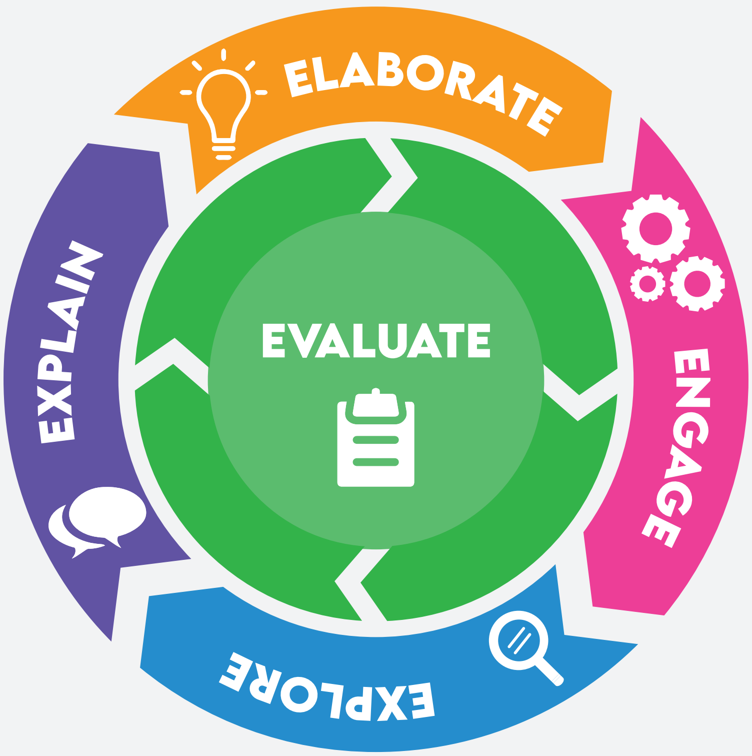
The Explanation stage consists of two parts: the teacher asking students to share their initial models and/or explanations from the previous stages and the teacher providing resources and information to support student learning, while introducing scientific or technological concepts. Once students receive the resources, they will construct or revise their evidence-based models and/or explanations.

Elaborate

After explanations and models are constructed to solve the problem, it is important to involve them in further practices that apply, extend, or elaborate the concepts, processes, or skills they are learning. During this stage, some students may still have misunderstandings or they may only understand a concept in terms of the investigative experience. The Elaboration stage gives students the opportunity to apply their understanding of concepts and skills to be able to grasp the concepts of the activity.

Evaluate

It is important for teachers to give students feedback on the quality of their works, especially, their explanations. This can occur throughout the learning process or more formally, the teacher can administer a summative evaluation at the end of the learning sequence. The Evaluation stage encourages students to assess their knowledge and abilities while allowing teachers to evaluate student development toward learning goals and outcomes.



WHAT IS A RIPKEN FOUNDATION MIDDLE SCHOOL STEM CENTER?

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The Cal Ripken, Sr. Foundation helps at risk youth to engage in age-appropriate STEM learning in a structured environment with trained teachers/ mentors who make science, technology, engineering, and math compelling and fun. Middle school children participating in well-implemented, high quality out-of-school programs reap a range of positive benefits, including, higher reading and math scores, increased self-esteem, higher school attendance, and decreased dropout rates.

The Ripken Foundation Middle School STEM Center includes the following:

PRODUCTS

Organizations that implement the Ripken Foundation STEM program will receive a selection of materials to enhance STEM learning with their kids in the form of STEM Center products and STEM Kits.

RIPKEN FOUNDATION MIDDLE SCHOOL STEM CURRICULUM

This curriculum included in the Ripken Foundation Middle School STEM Center, provides guidance on how to use the products and activities in the STEM program.

RIPKEN FOUNDATION PORTAL

The Ripken Foundation's online portal offers digital copies of our curriculum as well as other resources for mentoring youth.

PRODUCT GUIDE

PRODUCT GUIDE

Each Ripken Foundation Middle School STEM Center will receive a set of STEM equipment, our Middle School STEM Curriculum, and a STEM Kit.

RIPKEN FOUNDATION STEM CENTER EQUIPMENT

The Ripken Foundation provides a variety of products to foster STEM learning in our Ripken Foundation Middle School STEM Centers. We work with our program partners to select products for their specific needs. Here is a list of some of the products available to each center:

3D Printer:

Centers receive a 3D printer capable of bringing digital, three-dimensional models to life! Several spools of printing filament and a replacement nozzle are also included.

Curriculum

Computers:

Each Center has a choice of computers to meet their needs. Some of the models include: Notebooks, Chromebooks, or laptops.

Furniture:

Centers can receive up to: 28 Flavor Stackable Chairs, seven Elemental Clover Tables that seat up to four students per table, and one workbench.

STEM Kits:

The Ripken Foundation STEM Kit includes fun and captivating activities that teach STEM concepts that cater to a variety of ages. The Ripken Foundation Middle School STEM Kits could include:

- **littleBits Pro Library**
- **Makey Makey**
- **Snap Circuits 750-R**
- **STEM Pathways**

LITTLEBITS PRO LIBRARY

OVERVIEW

Often described as electronic building blocks, littleBits Pro Library is an easy-to-use educational tool that teaches critical thinking and problem-solving through engineering and design. The kits are comprised of multiple electronic components (called bits) that each serve a specific function. The bits are color-coded and snap together using magnets making it fun and easy to use for kids and adults alike! littleBits Pro Library comes with directions for assembling several projects which are easy to follow. The STEAM (Science, Technology, Engineering, Art + Design, and Math) Education Class Pack comes with lesson plans and resources to use in an educational setting.

PRODUCT SPECIFICS

littleBits Pro Library Kit includes:

- **1 Pro Library Kit**
- **316 bits**
- **STEAM student set and code kit content**

TEACHER AND MENTOR NOTES

The materials are easy enough for middle school-aged children to use but complex enough to allow high schoolers to create and explore. There are activities provided in the Teacher's and Student's Guides that come with the Pro Library Kit, but there are many other lessons found on the littleBits educator's community website. You can sign up for a free account and gain access to many resources and ideas for using littleBits with your kids.

ONLINE RESOURCES

- http://littlebits.com/
- http://littlebits.com/education
- http://littlebits.com/education/resources

MAKEY MAKEY

OVERVIEW

Makey Makey is a computer chip that you can connect to any computer, and it will act as a keyboard, game controller, or other controlling device. Kids can play games, play a banana piano, and other neat activities, all while learning basic circuitry. Kids can also go as deep as applying it to coding and programming lessons. Makey Makey is ready to use right out of the box, so just plug it in and start the fun!

PRODUCT SPECIFICS

Makey Makey Kit includes:

- **1 STEM Class Pack**
- **12 Makey Makey Chips**
- **Connecting wires**
- **USB computer connecting wires**
- **Graphite pencils optimized for use with Makey Makey**
- **Organizing carrying case**
- **Getting started guides**

TEACHER AND MENTOR NOTES

Makey Makey has a wide offering of online resources available to teachers/mentors. The Makey Makey website has instructions for some of the more popular projects such as banana bongos or dough game controller. Makey Makey has also created an educational website where teachers/mentors from around the world can contribute and share ideas and lesson plans. There is also an online forum to ask questions and get ideas and insight on ways to use Makey Makey with your kids. Makey Makey pairs well with Scratch, a visual-based programming language. Using Scratch, kids can create colorful games and animations to use with their Makey Makey.

ONLINE RESOURCES

- http://makeymakey.com/
- https://makeymakey.com/pages/how-to
- http://makeymakey.com/education/
- https://labz.makeymakey.com/dashboard
- https://scratch.mit.edu/

SNAP CIRCUITS 750R

OVERVIEW

Snap Circuits 750R from Elenco is a fun learning kit that teaches the basics of circuitry and electronics. The kit is comprised of different pieces that can be snapped together (like buttons) to create circuits which turn on lights, fans, radios, and other fun components! The kits are easy to use and assemble, and each comes with directions on how to put together different circuits. The kits can also be combined to make larger circuits.

PRODUCT SPECIFICS

Snap Circuits 750R includes:

- **1 Snap Circuits 750R Kit in a lightweight, durable case including:**
  - **Wire**
  - **Resistor**
  - **Speaker**
  - **Motor**
  - **LED**
  - **Switch**
- **Five project books**
- **Student guide**
- **Teacher guide**

TEACHER AND MENTOR NOTES

Snap Circuits 750R allows kids to learn the concepts of electronics through easy-to-use components. The activities in the guide provided offer different projects that range in complexity from simply turning on a light to complex circuits using resistors and switches. One realistic feature of Snap Circuits 750R is the use of actual electrical symbols on the products as they would be seen in a schematic drawing or circuit diagram. Also, some of the pieces are made with clear plastic, so the internal wiring can be seen.

ONLINE RESOURCES

- http://www.snapcircuits.net/

STEM PATHWAYS LAB

OVERVIEW

The STEM Pathways Lab focuses on structural and mechanical engineering, applied mathematics, rapid prototyping and 3 printing, and coding and robotics. The materials give students confidence in their ability to use technology to solve problems and create solutions.

PRODUCT SPECIFICS

STEM Pathways Kit includes:

- **6 STEM Pathways Labs**

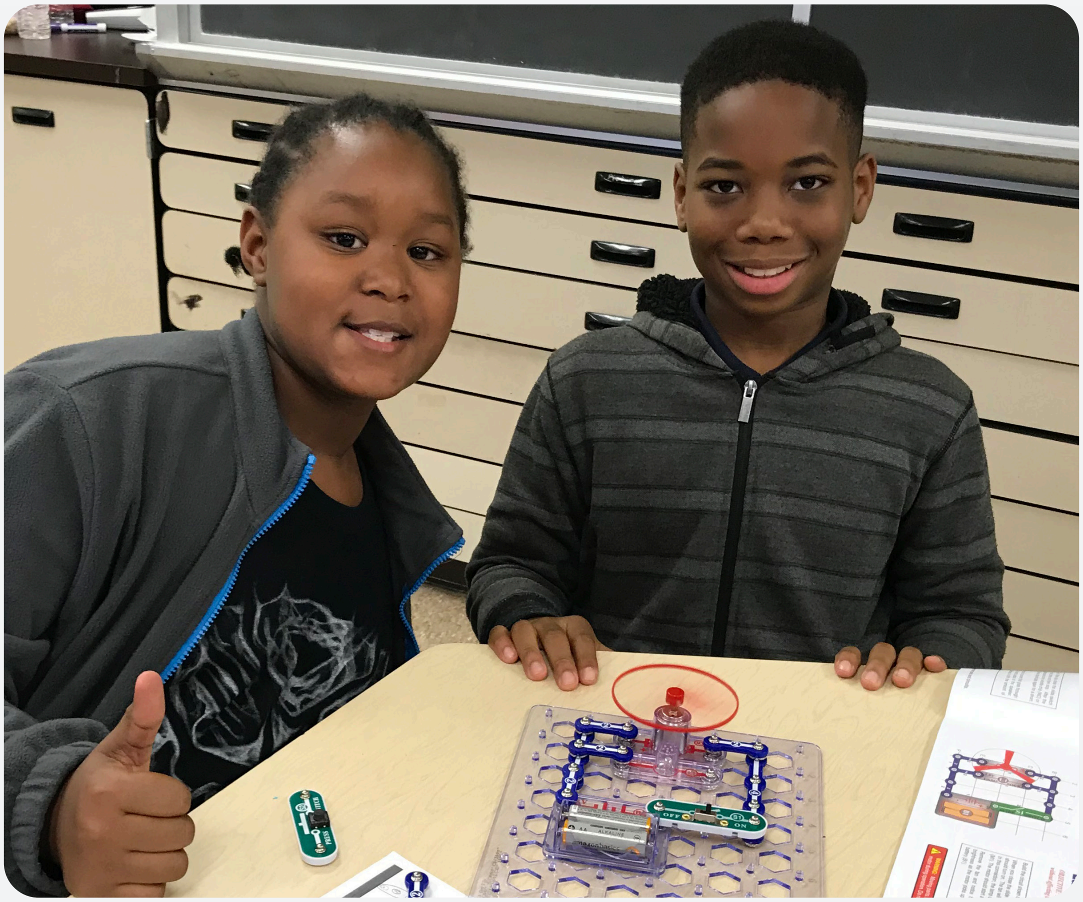
TEACHER AND MENTOR NOTES

Kid Spark Education has an online resource center with many different lessons available for download at no cost. These lessons cover a variety of different STEM topics, and even include 3D Printing. The lessons and resources are available for different age and grade levels.

ONLINE RESOURCES

- **https://kidsparkeducation.org/**
- **https://kidsparkeducation.org/curriculum**

PHYSICAL SCIENCES (PS) LESSONS



ELECTRICITY AND MAGNETISM

ELECTRICITY AND MAGNETISM

OVERALL TIME *(95 to 115 minutes - can be split over two class periods)*

OBJECTIVE

Students will design a lab to investigate how different factors affect the strength of an electromagnet.

OVERVIEW

Students will use Snap Circuits SC750R to investigate how electricity and magnetism are related. They will design a lab to determine how changing factors such as the voltage of the power source, the core material, or the number of coils of wire surround the core affect the strength of an electromagnet.

Next Generation Science Standards: Engineering Design

MS-PS2-3

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-5

Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits SC750R Kit**
- **Base Grid**
- **Connecting Wires (Rigid and Flexible)**
- **Two Battery Holders (2 AA Batteries in total)**
- **One Switch (S1)**
- **One Light Bulb (L2)**
- **Electromagnet (M3)**
- **Metal Core Insert**
- **Paperclips**
- **Compass**
- **Electric Wire (optional supply for lab)**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that each Snap Circuit SC750R Kit has the required materials and functioning AA batteries. Organize compasses, paper clips, and additional wire for each group. If needed, prepare a template for students to write their own experimental design.

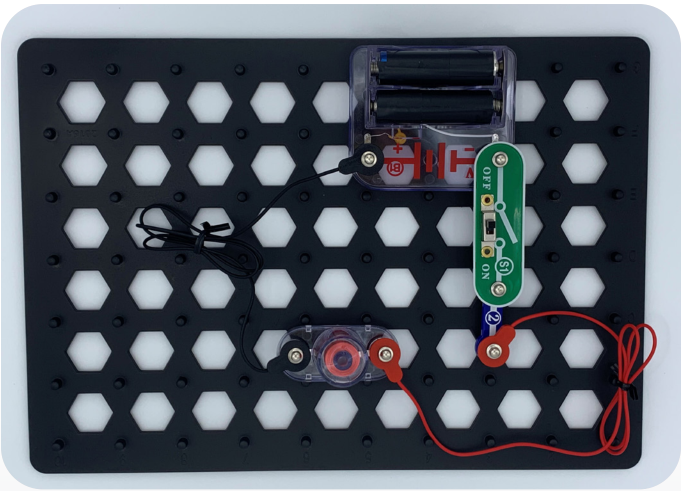
LESSON SEQUENCE

Engage *(10 to 15 minutes)*

1. Students will construct a circuit with two battery holders, one light bulb, and a switch.
2. Students will place a compass near the connecting wires of the snap circuit and answer the following questions:
   - What do you observe?
   - What do you think is causing this to occur?

Explore *(10 to 15 minutes)*

1. Students will use Snap Circuits SC750R to construct a circuit using a battery holder, two flexible connecting wires, and the electromagnet attachment.
2. Insert the metal rod into the electromagnet attachment. (Picture 1a)
3. Students will turn on the circuit and move the electromagnet attachment over paperclips.
4. Discuss observations with the class.



Picture 1a

Explain *(5 minutes)*

1. Discuss the results of the Engagement and Exploration activities with students.
2. Introduce the concept that electrical current creates a magnetic field around the wire through which it flows.

Elaborate *(60 to 70 minutes)*

1. Students will design an experiment in which they determine what factors impact the strength of an electromagnet.
2. Each group will decide which variable they will manipulate in their experiment (the independent variable). Possible options include the voltage of the power source, the material used as the core, and the number of coils of wire surrounding the core (in this case, instead of using the electromagnet attachment, students should coil wire around a ferromagnetic core and use two ends of the wire to complete the circuit).

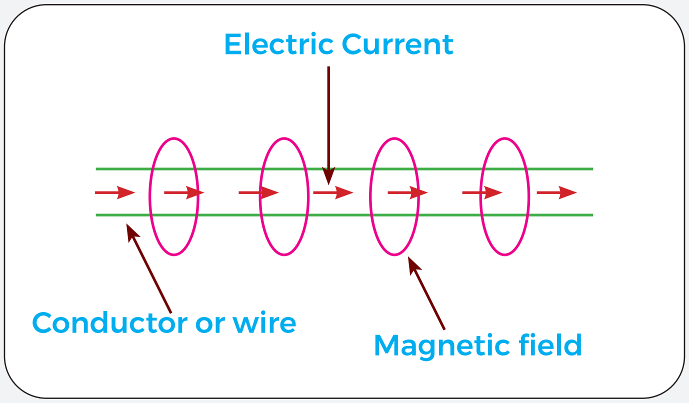


Diagram 1b

3. Once students decide on an independent variable, they will select an experimental question, write a hypothesis predicting the results of their experiment, and write an experimental procedure.
4. Each group will need to determine how they will measure the strength of the electromagnet. For example, students could use the number of paper clips or staples that the magnet can pick up or the distance from which the electromagnet can attract a paper clip or staple.
5. Students will decide how they will organize the results of their experiment.
6. Monitor each group's progress to ensure they are including proper detail in their experimental design. It is recommended that teachers require each group to have their experimental design approved before conducting the experiment.
7. Each group will follow their experimental design to conduct their experiment and will record their results.

Evaluate *(10 minutes)*

1. Students will write a conclusion summarizing the results of their experiment and answering their experimental question.

MATERIAL PROPERTIES
(CONDUCTIVITY)

OVERALL TIME *(50 to 70 minutes)*

OBJECTIVE

Students will use Makey Makey to determine whether various materials conduct electricity.

OVERVIEW

Makey Makey is a computer chip that connects objects to a computer, changing those objects into a musical device or a game controller. Students will use Makey Makey to construct a testing station to determine whether various materials conduct electricity.

LEVEL OF DIFFICULTY

Beginner

Next Generation Science Standards: Engineering Design

MS-PS1-2
Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

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

MATERIALS

- **Makey Makey Kits**
- **Computers**
- **Various Materials that Conduct Electricity**
- **Various Materials that do not Conduct Electricity**
- **See examples at https://www.thoughtco.com/examples-of-electrical-conductors-and-insulators-608315**
- **Cardboard**
- **Aluminum Foil**
- **Tape**
- **Scissors**
- **Rubber**
- **Paper**
- **Pencil/pen**

PREPARATION

Cut cardboard into approximately one foot by one-foot squares. Practice constructing and using the Makey Makey testing station. Print instructions and photos for the Exploration activity.

LESSON SEQUENCE

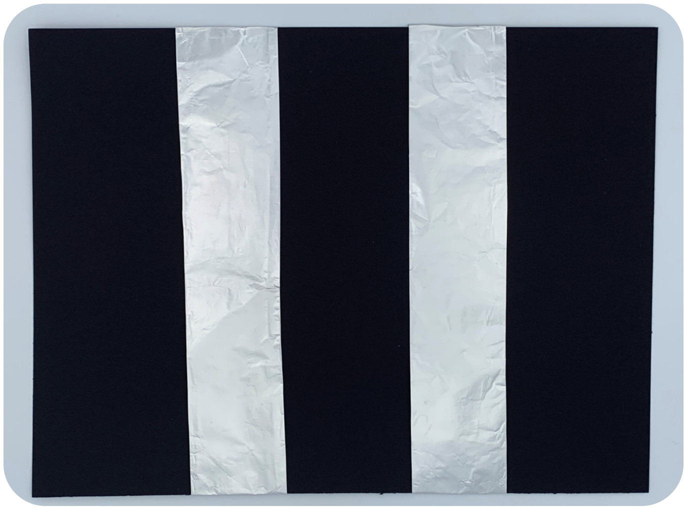
Engage *(10 minutes)*

1. Construct a simple circuit using a battery, three alligator clips, and a small light bulb.
2. Show students that the light bulb illuminates.
3. Insert a piece of aluminum foil between two of the alligator clips.
4. Show students that the light bulb still illuminates.
5. Now, insert a piece of rubber between two of the alligator clips.

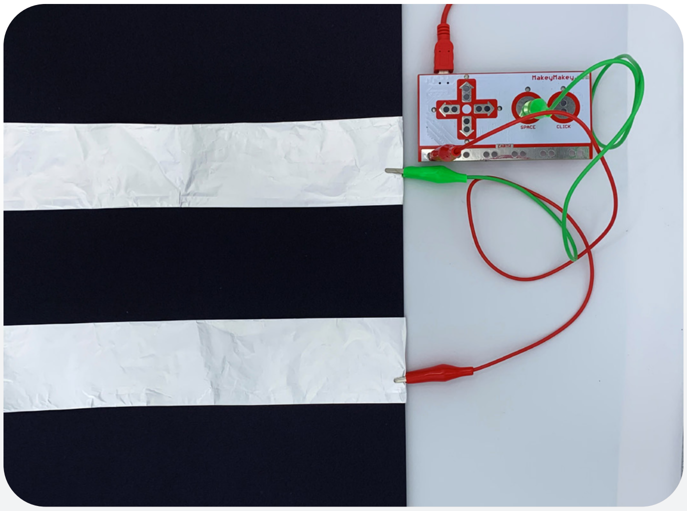
6. Show students that the light bulb does not illuminate.
7. Ask students to explain their observations.

Explore *(20 to 30 minutes)*

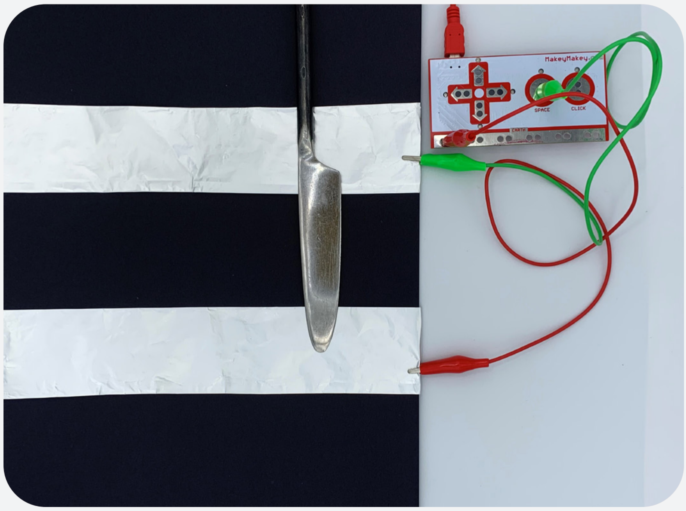
1. Students will construct a Makey Makey test station to determine if various materials conduct electricity by following the steps below.
2. Cut two strips of aluminum foil approximately one inch wide and one foot long.
3. Tape the two strips of aluminum foil on a one-foot square piece of square, approximately one inch apart. (Picture 2a)
4. Connect the Makey Makey chip to a computer using a USB cord.
5. Connect the end of one alligator clip to the “Earth” strip of the Makey Makey chip. Connect the other end of the alligator clip to one strip of aluminum foil. (Picture 2b)
6. Connect the end of another alligator clip to the “Space” section of the Makey Makey controller. Connect the other end of the alligator clip to the other strip of aluminum foil. (Picture 2b)
7. On the computer, open a web browser and go to https://apps.makeymakey.com/piano/.
8. Place a material between the two strips of aluminum material so that it touches both strips. (Picture 2c)
9. Disconnect the alligator clip from the “Space” button and use that end of the alligator clip to touch either the “Space” button or the up, down, left, or right arrow. If the material conducts electricity, the Makey Makey will play notes on the piano app. If the material does not conduct electricity, the Makey Makey will not play notes on the piano app.
10. Students will complete a table showing with materials are conductors and which materials are insulators.



Picture 2a



Picture 2b



Picture 2c

Explain *(5 to 10 minutes)*

1. Explain that electrical conductors allow the flow of electrons in one or more directions. Such materials can be used to build electrical circuits. The Makey Makey only played a piano note when an electrical circuit was completed.
   - Electrical conductivity in metals is a result of the movement of electrically charged particles. The atoms of metal elements are characterized by the presence of valence electrons, which are electrons in the outer shell of an atom that are free to move about. These "free electrons" allow metals to conduct an electric current.
   - An electrical insulator is a material in which the electron does not flow freely or the atom of the insulator have tightly bound electrons whose internal electric charges do not flow freely.

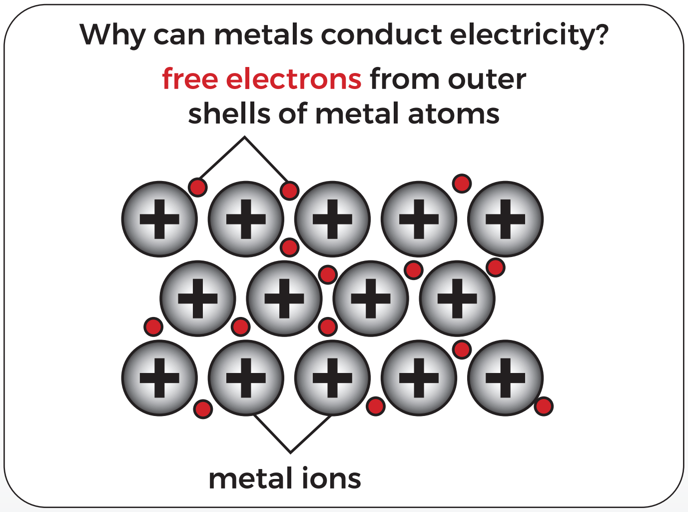


Diagram 2d

Elaborate *(10 minutes)*

1. Students will draw a diagram for a different Makey Makey testing station that could be used to determine whether materials conduct electricity. Diagrams should be clearly labeled.
2. Students will share their diagram with a partner and explain why the testing station would function.
3. Optional Extension: This lesson could be expanded by having students construct their proposed testing stations.

Evaluate *(5 to 10 minutes)*

1. Students will respond to the following writing prompt:
- "You have been contracted by a local park to design shelters where people can take cover during thunderstorms. Use your knowledge of conductors and insulators to make recommendations on what materials should be used in the shelters."

RESISTANCE AND CIRCUITS

OVERALL TIME *(55 to 70 minutes)*

Next Generation Science Standards: Engineering Design

MS-PS2-3
Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

OBJECTIVE

Students will use Snap Circuits SC750R to determine the mathematical relationship between voltage, current and resistance.

OVERVIEW

Students will use Snap Circuits to construct simple circuits that contain various resistors. Students will use multimeters to measure the voltage and current in the circuit and will propose a mathematical relationship that relates voltage, current, and resistance.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits SC750R Kit**
- **Base Grid**
- **Connecting Wires**
- **Two Battery Holders (4 AA Batteries in total)**
- **Resistors (100Ω, 1K, and 10K)**
- **Switch (S1)**
- **Multimeter**
- **Printed pictures of circuit layouts**
- **Printed copies of tables**
- **Notebook**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure each Snap Circuit Kit has the required materials and functioning batteries. Print pictures of circuit layouts for each group. Ensure that multimeters are working and practice using the multimeter to measure voltage and current in a circuit. Practice using the PHET simulation and attempt to construct the circuits needed for the Engage activity. Print copies of the tables for the Elaboration and Evaluation activities.

LESSON SEQUENCE

Engage *(5 minutes)*

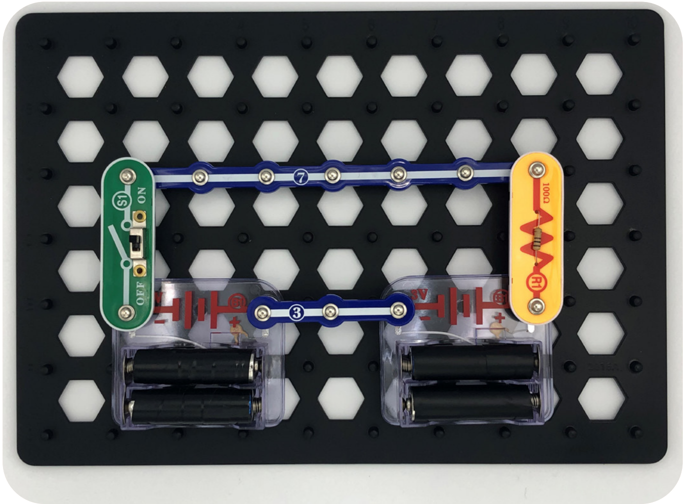
1. Open PHET Circuit Construction Kit on a computer and use a projector to show on the front board (https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html).
2. Show students a simple circuit with one light bulb.
3. Now, add a second light bulb into the circuit.
4. Students will answer the following questions with a partner.
   - What happens to the brightness of each light bulb if an extra light bulb is added in the circuit?
5. Explain why you think this happens.

Explore *(30 to 40 minutes)*

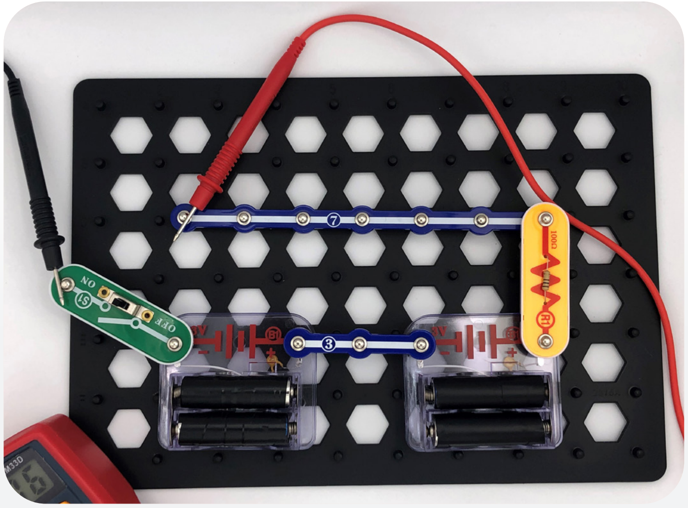
1. Students will use Snap Circuits to investigate the relationship between voltage, current, and resistance.
2. Teacher will demonstrate how to use a multimeter to measure voltage, current, and resistance. Introduce students to the correct units for each measurement. The following video explains how to use a multimeter: https://www.youtube.com/watch?v=TdUK6RPdIrA.
3. Students will construct the following table in their notebook:

Number of Battery Packs	Resistance (Ω)	Voltage (V)	Current (A)
1	100		
1	1,000 (1K)		
1	10,000 (10K)		
2	100		
2	1,000 (1K)		
2	10,000 (10K)		

4. Students will construct a circuit using the specified number of battery holders, the specified resistor, and a switch. (Picture 3a)
5. For each combination of circuit design, students will use the multimeter to measure the voltage and current and record this data in their table.
6. When students measure voltage, they should put one probe to the left of the battery or batteries and one probe to the right of the battery or batteries.
7. When students measure current, they will need to disconnect the Snap Circuit so that they can connect the multimeter in the series. (Picture 3b) Also, it is important to ensure that students understand the current reading given by the multimeter. It is likely that the current will be given in milliamps. If that is the case, a reading of 60 milliamps is equal to 0.06 amps, a reading of 6 milliamps is equal to 0.006 amps, etc.
8. Students will try to describe the relationship between voltage, current, and resistance. They can try to determine the mathematical relationship or simply describe the relationship in words. Since the multimeter will provide decimal measurements, students may not be able to come up with the formula for Ohm's Law (V = iR), but they should notice that when resistance increases, current decreases.



Picture 3a



Picture 3b

Explain *(5 minutes)*

1. Discuss the results of the experiment with students.
2. Ask students to identify possible explanations for their results.
3. Introduce the concepts of resistance.
   - Resistance is the opposition to the flow of electrons in a circuit. Resistance is provided by resistors, lamps, motors, and even the wires in a circuit.
   - Resistance is measured in ohms (Ω).
   - Ohm's Law describes a mathematical relationship between voltage, current, and resistance. (This law will be discovered in the next part of the lesson).

Elaborate *(10 to 15 minutes)*

1. Show students the following table:

Voltage (V)	Current (A)	Resistance (Ω)
9	3	3
12	2	6
50	0.5	100
6	0.25	24

2. Instruct students to work in either groups or pairs to try to determine a mathematical formula that relates voltage, current, and resistance.
3. Call on groups or pairs to share their formula with the class.
4. Provide guidance as needed to lead students to the correct formula for Ohm's Law (V = iR).
5. Instruct students to return to their results from the Snap Circuits activity and determine how well Ohm's Law describes their results. If the results do not perfectly fit Ohm's Law, ask students to identify sources of error that might have led to these results.

Evaluate *(5 minutes)*

1. Students will calculate the missing values in the table below.

Voltage (V)	Current (A)	Resistance (Ω)
20	5	?
?	0.1	100
12	?	4
15	0.75	?

SERIES AND PARALLEL CIRCUITS
(PART 1)

OVERALL TIME *(50 to 60 minutes)*

Next Generation Science Standards: Engineering Design

MS-PS2-3
Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

OBJECTIVE

Students will use Snap Circuits SC750R to investigate the difference between parallel and series circuits.

OVERVIEW

Students will use Snap Circuits to construct series and parallel circuits. Students will investigate how opening and closing switches in the various circuits affects the light bulbs in the circuit.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits SC750R Kit (Items needed per group)**
- **Base Grid**
- **Connecting Wires**
- **One Battery Holders (2 AA Batteries in total)**
- **Two Switch (S1 and S2)**
- **Two Light Bulbs (L1 and L2)**
- **Printed pictures of circuit layouts**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials and functioning batteries. Print pictures of circuit layouts for each group. Prepare a presentation to project the questions and circuit diagrams for the Engage and Elaboration activities or print copies for students.

LESSON SEQUENCE

Engage (5 minutes)

1. Show a picture of the following circuits:

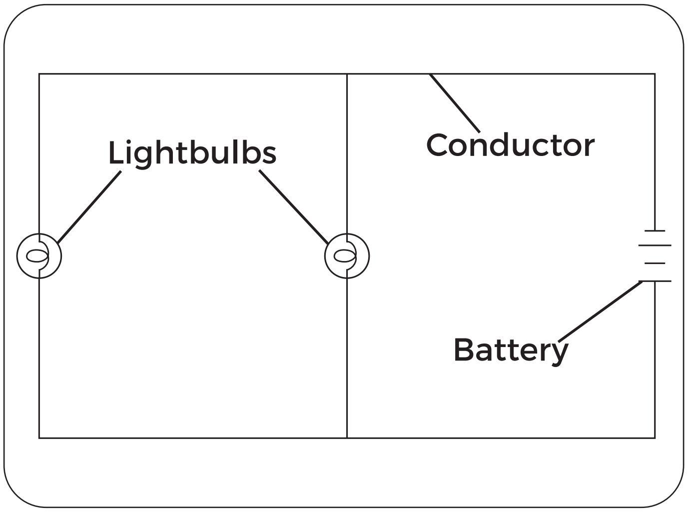


Diagram 4a

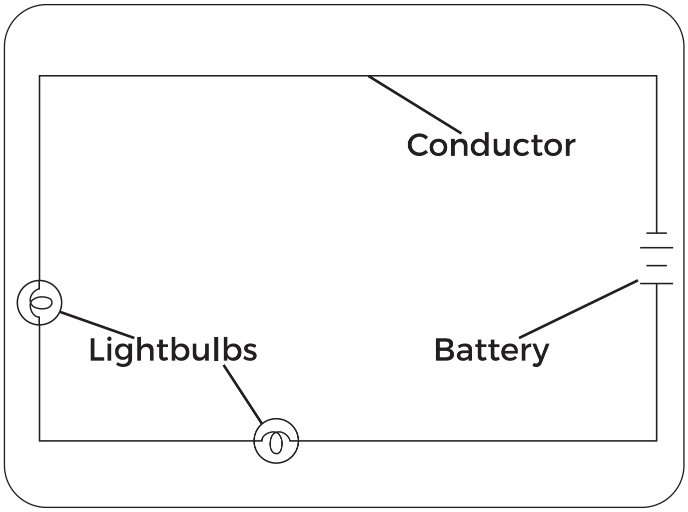
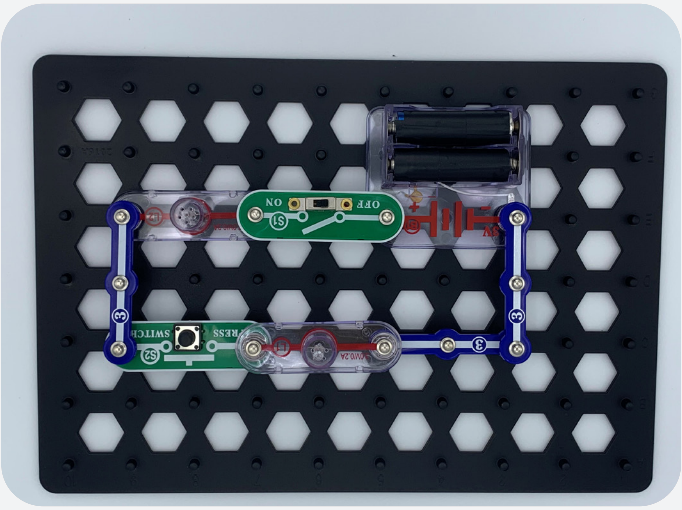


Diagram 4b

2. Students will answer the following questions with a partner:
    - Which circuit has only one path for current to flow?
    - Which circuit has two paths for current to flow?
    - What would happen if we removed a bulb from the first circuit?
    - What type of circuit is this? (Some students may know the two types of circuits already. It is fine if no one knows at this point.)
    - What would happen if we removed a bulb from the second circuit?
    - What type of circuit is this?

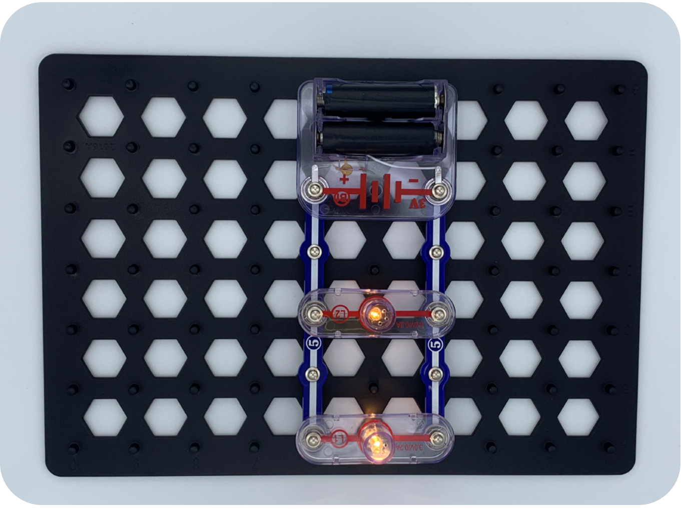
Explore (30 to 40 minutes)

1. Students will use Snap Circuits to construct a series circuit with one battery holder, two light bulbs, and two switches. One switch should be placed in front of each light bulb. (Picture 4c)
2. Students will use the circuit to answer the following questions:
    - What happens if both switches are closed?
    - What happens if the first switch is closed but the second switch is open?
    - What happens if the first switch is open but the second switch is closed?

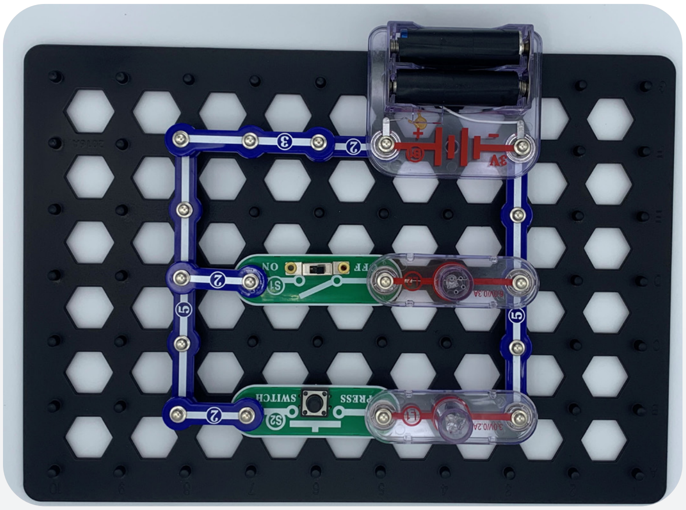


Picture 4c

3. Use what you already know about electric current to explain these observations.
4. Students will construct a parallel circuit with one battery holder and two light bulbs. (Picture 4d)
5. Students will use the circuit to answer the following question:
   - What happens if you disconnect one bulb and do not close the circuit (do not replace the bulb with wire)?
6. Students will modify the parallel circuit to add a switch in front of each lightbulb. (Picture 4e)
7. Students will use the circuit to answer the following questions:
   - What happens if both switches are closed?
   - What happens if one switch is open, but the other switch is closed? Experiment with both switches.
8. Use what you know about current to explain your observations.



Picture 4d



Picture 4e

Explain *(5 minutes)*

1. Discuss the results of the activity with students.
2. Introduce the concepts of series and parallel circuits.
   - Series circuits have only one path that electric current can travel. All parts of the circuit are connected along the same pathway. If there is a break in the circuit, all elements on the pathway will be affected.
   - Parallel circuits have two or more paths that electric current can travel (show students a diagram of a parallel circuit with more than two paths). Some parts of the circuit are on different pathways. If there is a break along one pathway, it won't affect elements on a separate pathway as long as a circuit can be completed on this pathway.

Elaborate *(5 minutes)*

1. Students will identify whether the following diagrams show series or parallel circuits.

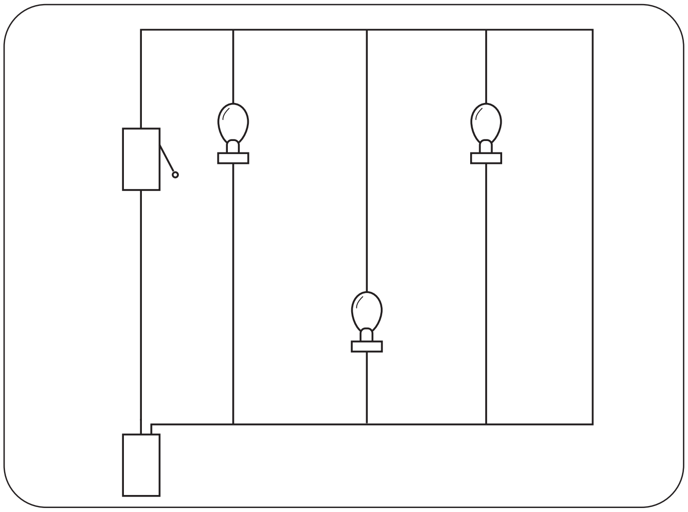


Diagram 4f

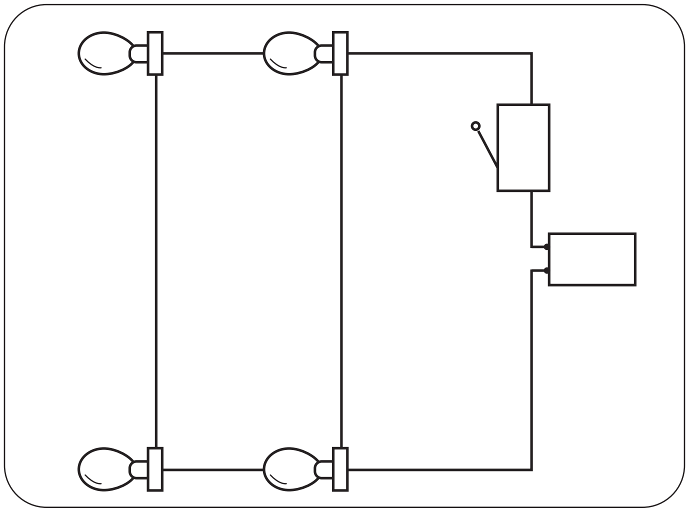


Diagram 4g

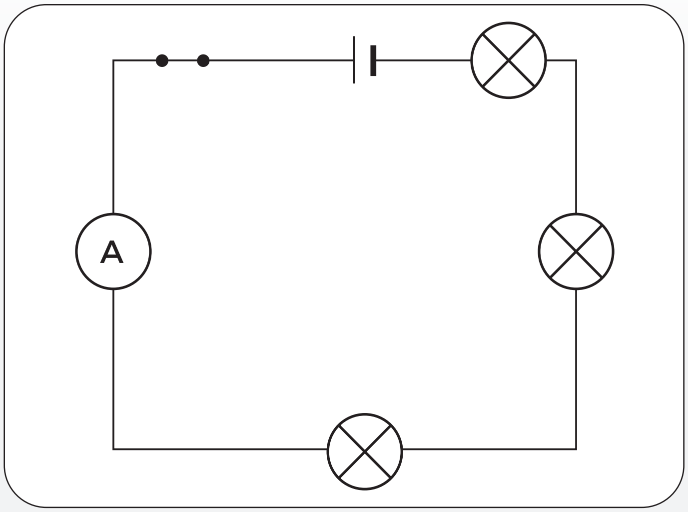


Diagram 4h

Evaluate *(5 minutes)*

1. Students will construct a Venn diagram to compare series and parallel circuits.

SERIES AND PARALLEL CIRCUITS
(PART 2)

OVERALL TIME *(55 to 70 minutes)*

Next Generation Science Standards: Engineering Design

MS-PS2-3

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

OBJECTIVE

Students will use Snap Circuits SC750R to investigate how voltage and current differ in series and parallel circuits.

OVERVIEW

Students will use Snap Circuits to construct series and parallel circuits. Students will use multimeters to investigate how the voltage across and current through each light bulb differs for the two types of circuits.

LEVEL OF DIFFICULTY

Advanced

MATERIALS

- **Snap Circuits SC750R Kit**
- **Base Grid**
- **Connecting Wires**
- **One Battery Holders (2 AA Batteries in total)**
- **Two Switch (S1 and S2)**
- **Two Light Bulbs (L1 and L2)**
- **Printed pictures of circuit layouts**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials and functioning batteries. Print pictures of circuit layouts for each group. Ensure that multimeters are working and practice using the multimeter to measure voltage and current in a circuit.

LESSON SEQUENCE

Engage *(5 minutes)*

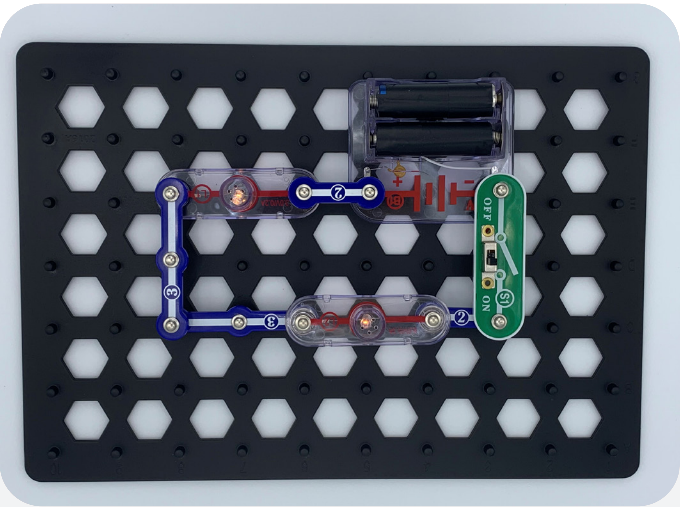
1. Ask students the following question:
   - There are two circuits with equivalent power sources. One circuit is a series circuit with two light bulbs. The other circuit is a parallel circuit with the same two light bulbs. In which circuit will the light bulbs produce more light?
2. Use a think-pair-share format for students to first think about their own response, discuss their response with a partner, and then share their ideas with the whole class.

Explore *(30 to 40 minutes)*

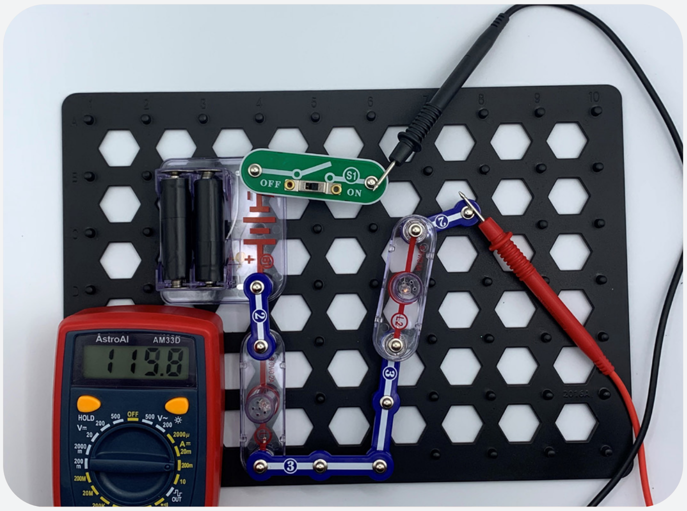
1. Students will use Snap Circuits to explore the answer to this question.
2. Students will construct the following table in their lab notebook:

Type of Circuit	Observed Brightness of Light Bulbs	Voltage Across Battery Holder	Voltage Across Each Light Bulb	Current in Each Light Bulb
Series				
Parallel				

3. Students will use Snap Circuits to construct a series circuit with one battery holder, two light bulbs, and one switch. (Picture 5a)
4. Students will observe the brightness of the light bulbs. *Note: The light bulbs will have different brightnesses because they are rated for different amounts of voltage. L2 will produce less light than L1, but this is not the comparison that students should be making. They will compare the brightness of L1 and L2 in a series circuit to the brightness of L1 and L2 in a parallel circuit.*
5. Students will use a multimeter to record the voltage across the battery holder and across each light bulb. (Picture 5b)
6. Students will disconnect the circuit after each light bulb (only one should be disconnected at a time) and use the multimeter to measure the current flowing through each light bulb. (Picture 5b)



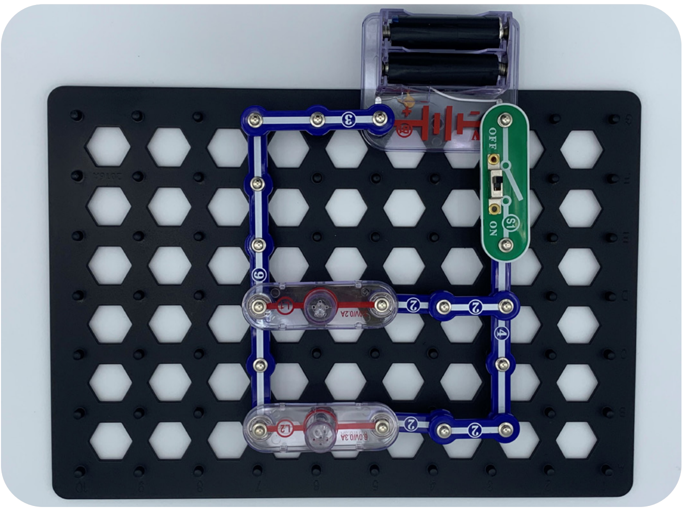
Picture 5a



Picture 5b

- It is important to ensure that students understand the current reading given by the multimeter. It is likely that the current will be given in milliamps. If that is the case, a reading of 60 milliamps is equal to 0.06 amps, a reading of 6 milliamps is equal to 0.06 amps, etc.

7. Students will use Snap Circuits to construct a parallel circuit with one battery holder, two light bulbs, and one switch. (Picture 5c)
8. Students will repeat observations of light bulb brightness and measurements of voltage and current in the parallel circuit.



Picture 5c

Explain *(5 to 10 minutes)*

1. Discuss the results of the activity with students.
2. Guide students to the following conclusion:
    - In a series circuit, the total voltage of the power source (in this case approximately 3V) is divided among the resistors (ensure that students understand that a light bulb is a resistor) in the circuit. In this activity, each light bulb is powered by approximately 1.5 V.
    - In a parallel circuit, the total voltage of the power source (in this case approximately 3V) is not divided among the resistors in the circuit. Each path along the parallel circuit is powered by the total voltage of the power source, approximately 3V.

Elaborate *(10 minutes)*

1. Give students the following scenario:
    - L1 is rated for up to 3V (If the light bulb is powered by more than 3V, it may be damaged). Should you connect L1 in a parallel circuit that is powered by two battery holders?
2. Instruct students to discuss the scenario with their group and then share their responses with the whole class.

Evaluate *(5 minutes)*

1. Students will answer the following question in a full paragraph:
    - The electrical systems in a house are composed of a complex network of parallel circuits. Why do you think that houses use parallel circuits instead of series circuits? Fully explain your reasoning.

SERIES AND PARALLEL CIRCUITS
(PART 3)

OVERALL TIME *(60 to 70 minutes)*

OBJECTIVE

Students will construct series and parallel circuits that meet given criteria.

OVERVIEW

Students will use Snap Circuits SC750R to construct series and parallel circuits that meet specified criteria regarding how switches should control light bulbs in different ways.

Next Generation Science Standards: Engineering Design

MS-PS2-3

Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits SC750R Kit (Items per group)**
- **Base Grid**
- **Connecting Wires**
- **One Battery Holders (2 AA Batteries in total)**
- **Two Switch (S1 and S2)**
- **Two Light Bulbs (L1 and L2)**
- **One LED (D1)**
- **One Resistor (R1)**
- **Printed pictures of circuit layouts**
- **Printed copy of circuit requirements from the Elaboration activity**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials and functioning batteries. Print pictures of circuit layouts for each group. Practice using the PHET simulation and attempt to construct the circuits needed for the Engage activity. Prepare a presentation with diagrams of circuits layouts in houses or other buildings. Print copies of the circuit requirements for the Elaboration activity.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Students will discuss the following question with a partner:
    - Someone constructs a parallel circuit with a battery, a switch, and two light bulbs. Q: True or false - At least one light bulb will always be on in this circuit.
2. Discuss student responses as a whole class.

Explore *(10 minutes)*

1. Open PHET Circuit Construction Kit on a computer and use a projector to show on the front board (https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html).
2. Build a parallel circuit with one battery and two light bulbs.
3. Demonstrate that the switch can be placed in a location so that it controls both lights. (Diagrams 6a and 6b). This is how the lights in a room may be wired, so that a switch controls both light bulbs, but if one light bulb goes out it doesn't affect the other light bulb.

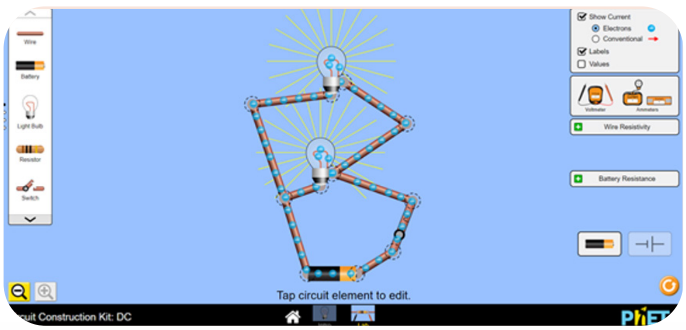


Diagram 6a

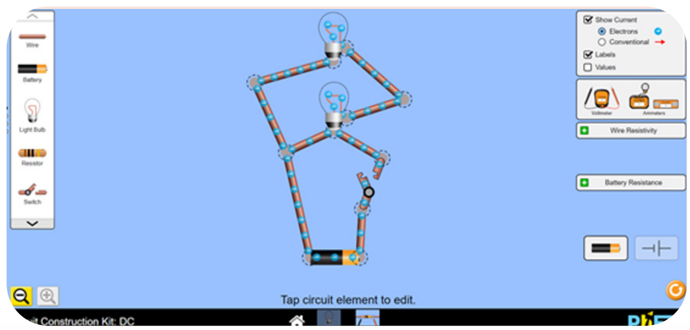


Diagram 6b

4. Now build a parallel circuit with one battery and three light bulbs. (Diagram 6c)
5. Ask students to identify what would happen if a switch was placed in various locations in the circuit.

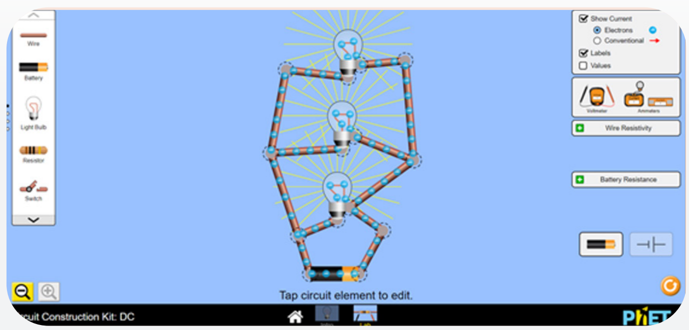


Diagram 6c

Explain *(5 minutes)*

1. Explain that complex systems of parallel circuits are used in houses and buildings.
   - Switches can be placed strategically to control the electronic devices in the room.
   - Depending on the wiring of the classroom, demonstrate how the switches in the classroom control different banks of lights.

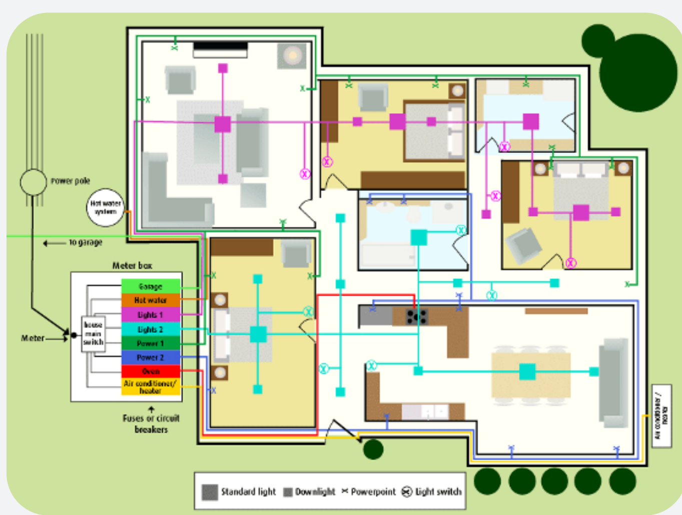


Diagram 6d

Elaborate *(30 to 40 minutes)*

1. Students will work with a group to construct circuits that meet the following criteria:
    - Circuit #1
        - The circuit has one battery holder.
        - The circuit has two light bulbs and one LED (the resistor should be placed before the LED).
        - The circuit has a switch.
        - If the switch is closed, all three bulbs are lit.
        - If the switch is open all three lights will go out.

    - Circuit #2
        - The circuit has one battery holder.
        - The circuit has two light bulbs and one LED (the resistor should be placed before the LED).
        - The circuit has a switch.
        - If the switch is closed, all three bulbs are lit.
        - If the switch is open, only one bulb will go out. The other two bulbs will stay lit.

    - Circuit #3
        - The circuit has one battery holder.
        - The circuit has two light bulbs and one LED (the resistor should be placed before the LED).
        - The circuit has a switch.
        - If the switch is closed, all three bulbs are lit.
        - If the switch is open, two bulbs will go out. Only one bulb will stay lit.

Evaluate *(10 minutes)*

1. Students will write a short story from the perspective of an electron travelling through an electric circuit. The circuit may be either a series circuit or a parallel circuit. The story should demonstrate an understanding of circuits by describing the electron's journey. Elements such as switches, resistors, light bulbs, motors, etc. can be included.

VOLTAGE AND ELECTRIC CURRENT

Next Generation Science Standards: Engineering Design

MS-PS2-3
Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

OVERALL TIME *(55 to 70 minutes)*

OBJECTIVE

Students will use the Snap Circuits SC750R Kit to investigate how voltage affects the strength of electric current in a circuit.

OVERVIEW

Students will use Snap Circuits to construct simple circuits and will change the amount of voltage in the circuit to investigate how changing the voltage affects the brightness of a lightbulb and the speed of a fan.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- **Snap Circuits SC750R Kit**
- **Base Grid**
- **Connecting Wires**
- **Two Battery Holders (4 AA Batteries in total)**
- **V/0.3 A Lightbulb**
- **Motor (M1) with Fan Blade**
- **Switch (S1)**
- **Printed circuit layout pictures**
- **Printed copies of the analysis questions**
- **Notebook**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials and functioning batteries. Print pictures of circuit layouts and copies of the analysis questions for each group.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Have students discuss the following question:
   - What is needed to make an electrical circuit?
2. Students can write their answers on handheld whiteboards or discuss with a partner using a think-pair-share strategy.

3. Discuss student answers as a class and lead to the idea that at minimum the following elements are needed: a source of electric current (battery, electrical outlet), wires or conductors, and a source of resistance (light bulb, motor, etc.).

Explore *(30 to 40 minutes)*

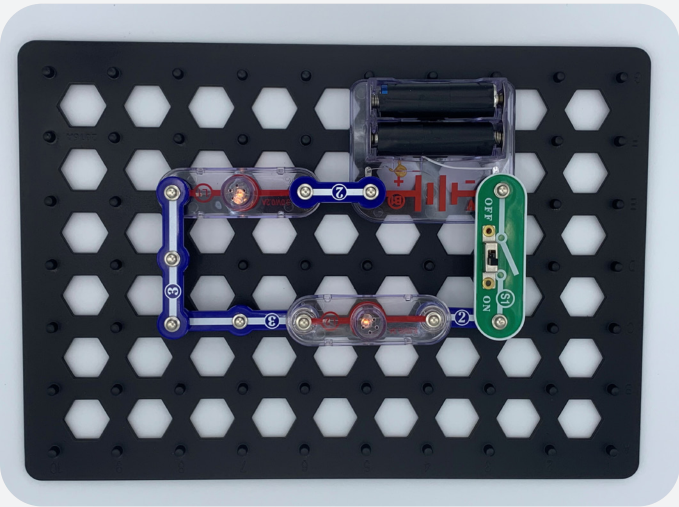
1. Students will complete a lab in which they investigate the relationship between the number of batteries in a circuit and the brightness of a light bulb or the speed of an electric motor.
2. Students should record the following lab question in their notebook: How does increasing the number of batteries in a circuit impact the brightness of a light bulb and the speed of a motor?
3. Students will write a hypothesis to predict the answer to the lab question. Have a few students share their hypothesis with the class.

Experimental Procedure

1. Draw the following table in your notebook:

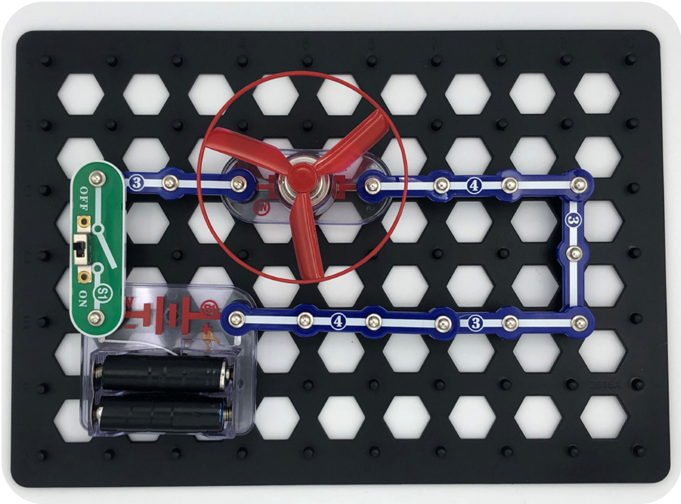
Number of Batteries	Brightness of Light Bulb	Speed of Motor

2. Using Snap Circuits, make a circuit by using wires to connect one battery holder, a switch, and a light bulb. (Picture 7a)
3. Turn on the switch and record the brightness of the light bulb on a scale of one to 10.
4. Turn off the switch and replace the light bulb with the motor and fan blade. (Picture 7b)
5. Turn on the switch and record the speed of the motor on a scale of one to 10.
6. Turn off the switch, add a second battery holder to the circuit, and replace the motor and fan blade with the light bulb. (Picture 21c)

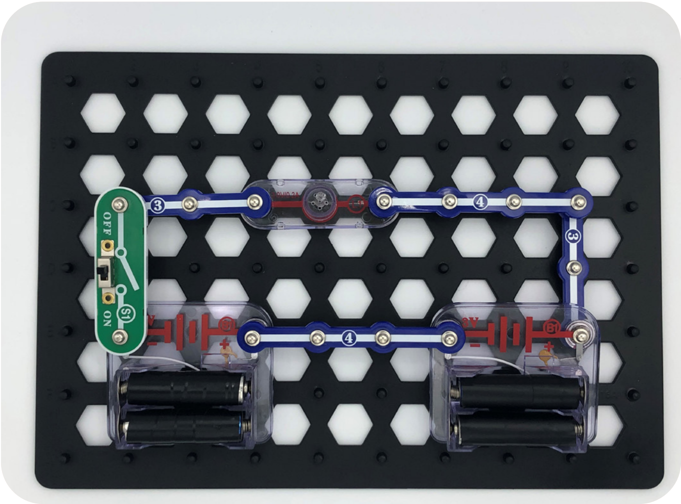


Picture 7a

7. Turn on the switch and record the brightness of the light bulb on a scale of one to 10.

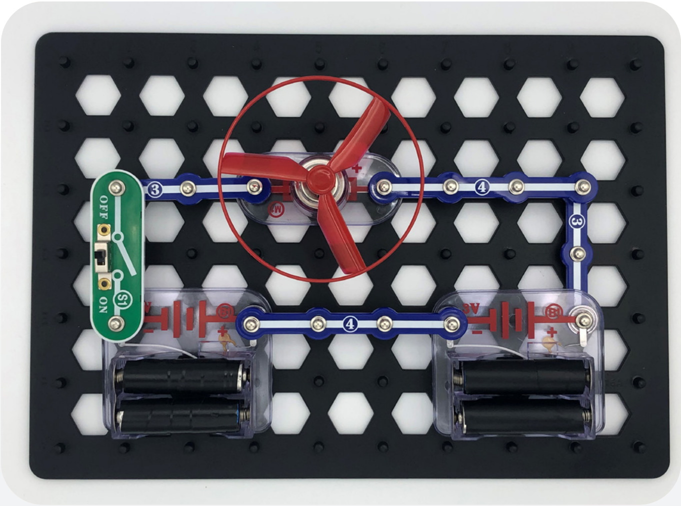


Picture 7b



Picture 7c

8. Turn off the switch and replace the light bulb with the motor and fan blade. (Picture 7d)
9. Turn on the switch and record the speed of the motor on a scale of one to 10.



Picture 7d

Explain *(5 to 10 minutes)*

1. Discuss the results of the experiment with students.
2. Ask students to identify possible Explanations for their results.
3. Introduce the concepts of voltage and current.
    - Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work such as illuminating a light or running a motor. Also called electric potential difference, voltage is determined by the differences in the electric potentials at opposite ends of a circuit.
    - Current is a measure of the rate of flow of electrons in a circuit.

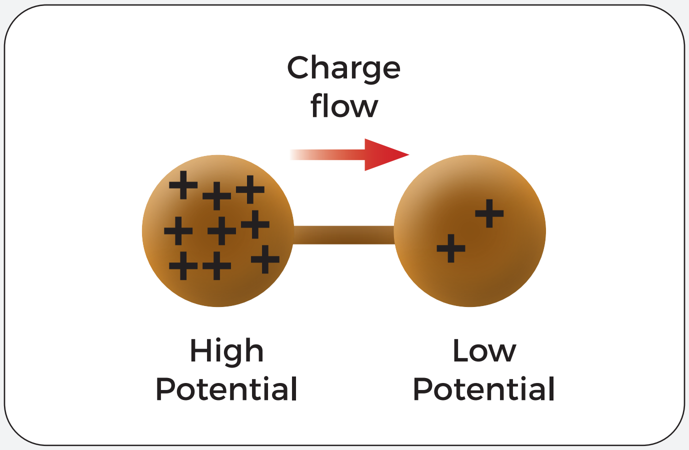


Diagram 7e

Elaborate *(10 minutes)*

1. Students will answer the following analysis questions:
   - Look on the battery to find the number of "volts." This is called the voltage difference. What is the voltage difference for each battery?
   - When two batteries are connected in a circuit, their voltage differences combine. What was the voltage difference for the circuit with one battery holder (two batteries)? What was the voltage difference for the circuit with two battery holders (four batteries)?
   - Based on the results of your lab observations, what conclusion can you make about the relationship between the brightness of the light bulb, the speed of the motor, and voltage difference?
   - Assuming that a brighter light bulb and a faster motor indicates a greater electrical current in the circuit, what can you conclude is the relationship between voltage difference and current?

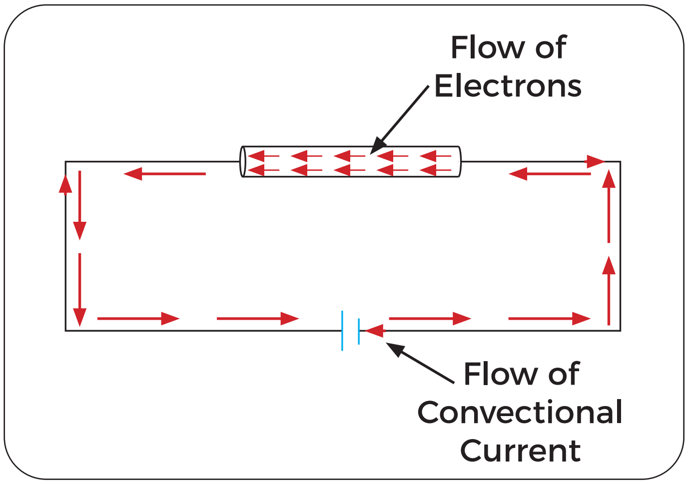


Diagram 7e

Evaluate *(5 minutes)*

1. Students will write a paragraph summarizing what they learned during the lab.

FORCES, MOTION, AND ENERGY

ENERGY TRANSFORMATIONS
(LITTLEBITS PRO LIBRARY)

OVERALL TIME *(45 to 60 minutes)*

OBJECTIVE

Students will use littleBits Pro Library to design a device that performs multiple energy transformations.

OVERVIEW

Students will learn about different types of energy transformations and will use littleBits to design and construct a device that converts the chemical energy of a battery to multiple other forms of energy.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- **littleBits Pro Library Kit**
- **Regular Flashlight**
- **Crank Powered Flashlight (or other mechanically powered flashlight)**
- **Paper**
- **Pencil/pen**

Next Generation Science Standards: Engineering Design

MS-PS3-1
Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-2
Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

MS-PS3-5
Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

PREPARATION

Ensure that STEM Pathway Labs are organized and contain the parts needed to construct the Ferris wheel. To save time during the lesson, teachers may choose to pull out the necessary parts from the kit and organize for each group. Practice using the PHET simulation that will be used in the Exploration activity. Print instructions for Elaboration activity including pictures of the Ferris wheel construction.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Turn on a regular flashlight and operate a crank powered flashlight.
2. Students will compare and contrast the two flashlights in terms of energy and energy transformations.
3. As a class, discuss the energy transformations in each flashlight.

Explore *(10 to 15 minutes)*

1. Challenge students to use littleBits to construct a device that converts the chemical energy in a battery to two other forms: electromagnetic energy (light) and sound energy.
2. Have a few groups share their inventions with the rest of the class.

Explain *(10 minutes)*

1. Introduce students to the following types of energy:
   - Mechanical energy - energy of an object due to position and motion.
   - Kinetic energy - energy of an object due to motion.
   - Gravitational potential energy - stored energy in an object due to its position above Earth.
   - Electromagnetic energy - energy transmitted through electromagnetic waves.
   - Sound energy - energy transmitted through vibrating sound waves.
   - Thermal energy - internal energy of a system due to the movement of molecules and transferred as heat.
   - Chemical energy - energy that is stored in the chemical bonds of compounds and released during chemical reactions.
   - Electrical energy - energy due to moving electric charges.
   - Nuclear energy - energy stored in the nuclei of atoms and released in fission or fusion reactions.

Elaborate *(15 to 20 minutes)*

1. Challenge students to use littleBits to construct a device that converts the chemical energy in a battery to as many other forms of energy as possible.
   - Students may only use one battery in their device, but they can use splitting bits to increase the number of outputs.

Evaluate *(5 to 10 minutes)*

1. Have students draw a diagram of their device and label where the different energy transferred occurred in the device.

GRAVITATIONAL POTENTIAL ENERGY

Next Generation Science Standards: Engineering Design

MS-PS3-2
Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

OVERALL TIME *(50 to 65 minutes)*

OBJECTIVE

Students will use littleBits Pro Library to construct a device that changes the gravitational potential energy of another object.

OVERVIEW

Students will learn about gravitational potential energy and will use littleBits to construct a device that changes the gravitational potential energy of another object. Students will use the device to lift objects with various masses and will calculate the change in gravitational potential energy for each object.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **littleBits Pro Library Kit**
- **Slinky**
- **Various Small Masses (ex: 20 g, 50 g, 100 g)**
- **Scale**
- **Meter Stick or Measuring Tape**
- **Printed Evaluation activity questions**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that the littleBits Kits are organized for each group. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Print copies of questions for the Evaluation activity or copy into a presentation to project.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Set up a ramp and place an arced slinky at the top. Hold on to the slinky. Ask students for a prediction of what will happen when the slinky is released.
2. Students discuss the following questions with a partner:
   - What will happen when the slinky is released?
   - Why will this happen?
   - What types of energy are involved?
3. Release the slinky.
4. Ask students what type(s) of energy is (are) involved.

Explore *(15 to 20 minutes)*

1. Challenge students to use littleBits to construct a device that lifts a small mass at least 20 centimeters off the ground or off the surface of their desk or lab table.
2. Instruct a few groups to share their inventions with the rest of the class.

Explain *(5 to 10 minutes)*

1. Introduce or remind students of the formula for gravitational potential energy.

Gravitational Potential Energy	=	mass	X	acceleration of free fall	X	change in height
(Joules)		(kg)		$(m/s)^2$		(m)

PE = **m** x **g** x **h**

2. Demonstrate how to calculate the gravitational potential energy of some objects in the classroom. For example, calculate the gravitational potential energy of a textbook sitting on a student's desk (with the change in height measured from the floor).

Elaborate *(15 to 20 minutes)*

1. Students will use the device that they constructed during the Exploration phase to lift a small mass at least 20 centimeters off the classroom floor or the surface of their desks/lab tables.
2. Students will calculate the gravitational potential energy of the mass after it has changed height.
    - Mass must be measured in kilograms. For example, 50 grams is equivalent to 0.05 kilograms
    - Height must be measured in meters. For example, 20 centimeters is equivalent to 0.2 meters.
    - Students can use either 9.8 m/s2 or 9.81 m/s2 for gravitational acceleration in free fall.
3. Instruct students to repeat the previous two steps using a different mass.
4. Ask students what happens to the gravitational potential energy of the mass if it is dropped?

Evaluate *(10 minutes)*

1. Students will answer to following questions using the following scenario:
    - A two-kilogram book is held 0.5 meters above the surface of a table. The surface of the table is one meter above the floor.
        A. What is the gravitational potential energy of the book if the change in height is measured from the table?
        B. What is the gravitational potential energy of the book if the change in height is measured from the floor?
        C. Imagine you dropped the book to the table. Now, imagine you dropped the book to the floor. How would the motion of the book differ in these cases?
        D. How does your answer in Part C relate to your answers in Part A and B?

OVERALL TIME *(75 to 100 minutes — may need to divide over two class periods)*

Next Generation Science Standards: Engineering Design

MS-PS3-1

Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

OBJECTIVE

Students will use graphical displays to show the relationship between kinetic energy and the mass of an object and kinetic energy and the speed of an object.

OVERVIEW

Students will construct an electronic car using the littleBits Pro Library and will use it to investigate the relationship between kinetic energy and the mass of an object and kinetic energy and the speed or velocity of an object. Students will run various trials where the speed or mass of the car varies. Students will calculate the kinetic energy of the car for each trial and will construct two graphs, one showing the relationship between kinetic energy and the mass of the car and one showing the relationship between kinetic energy and the speed or velocity of the car.

LEVEL OF DIFFICULTY

Advanced

MATERIALS

- littleBits Pro Library Kits (items needed per group)
- 4 DC Motors (o25)
- 1 Battery (9V) and Cable
- 1 Wire (w1)
- 1 Slider Dimmer (i5)
- 1 Fork (w7)
- 1 Power Bit (p4)
- 4 Wheels
- 1 Mounting Board
- Tape
- Electronic Scales
- Meter Stick or Measuring Tape
- Stopwatches
- Tennis Ball and Basketball (or similar equivalents)
- A Variety of Small Masses (50 g, 100 g, 200 g, 500 g, etc.)
- Graph Paper
- Printed instructions for construction of electric car
- Printed pictures of step-by-step instruction
- Notebook
- Paper
- Pencil/pen

PREPARATION

Ensure that the littleBits Kits are organized and contain the required bits. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Print copies of instructions for constructing the electric car and pictures showing each step of construction. It is recommended to practice constructing the car prior to the lesson to be able to better assist students. An accommodation for students with limited experience with graphing would be to provide graphs with pre-labeled axes.

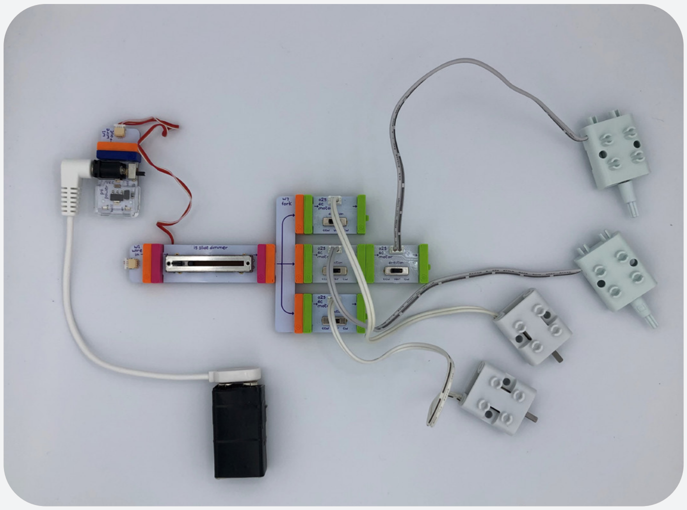
LESSON SEQUENCE

Engage *(5 minutes)*

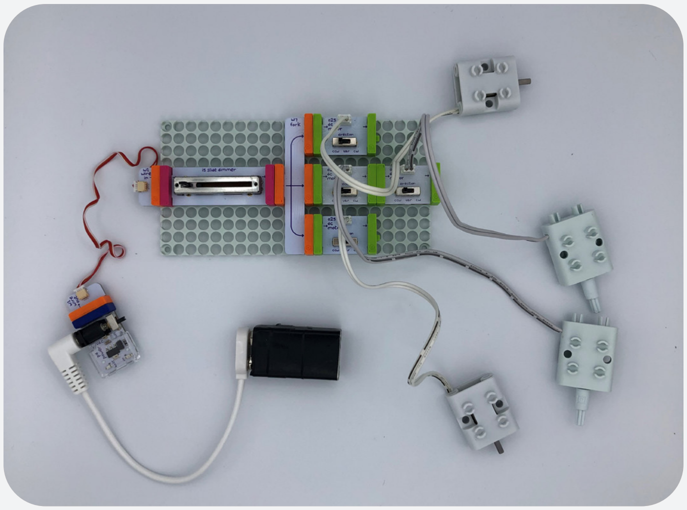
1. Roll a tennis ball and a basketball across the classroom floor at the same speed.
2. Students will discuss the following question with a partner:
    - Which ball had more energy while it was rolling across the floor? Explain your reasoning.
3. Discuss student answers as a class.

Explore *(15 to 20 minutes)*

1. Students will use littleBits to construct a model car following the instructions below.
2. Construct a circuit in the following order: power >> wire >> slider dimmer >> fork >> four motors (Picture 10a).
3. Attach circuit to a mounting board so that the wire bit is at the front of the board and the last motor is at the back of the board (Picture 10b).

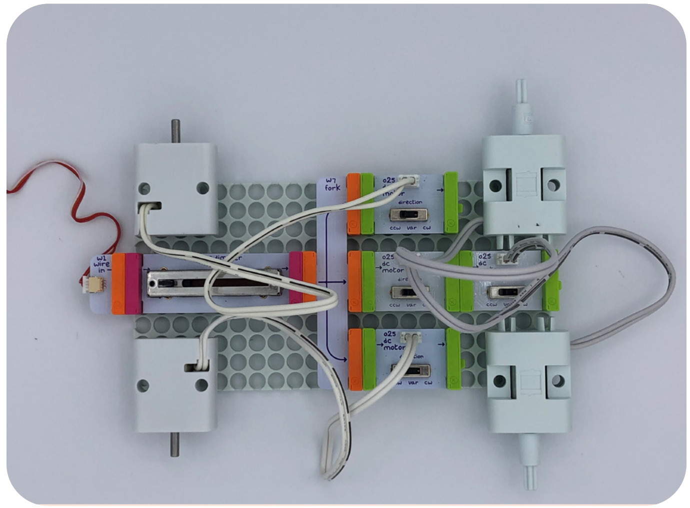


Picture 10a

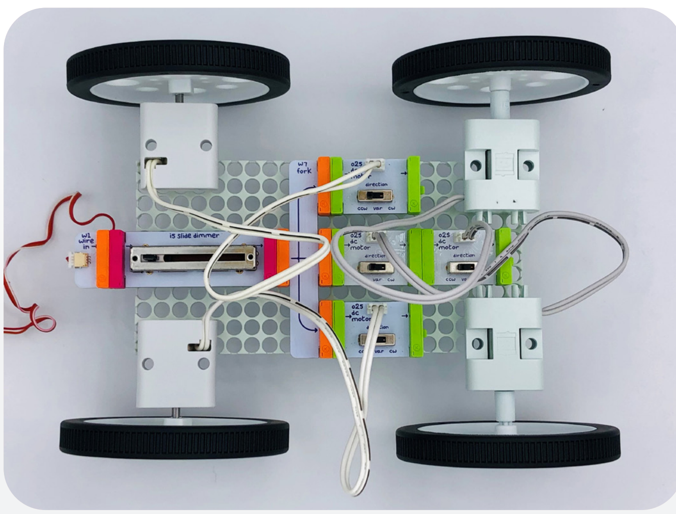


Picture 10b

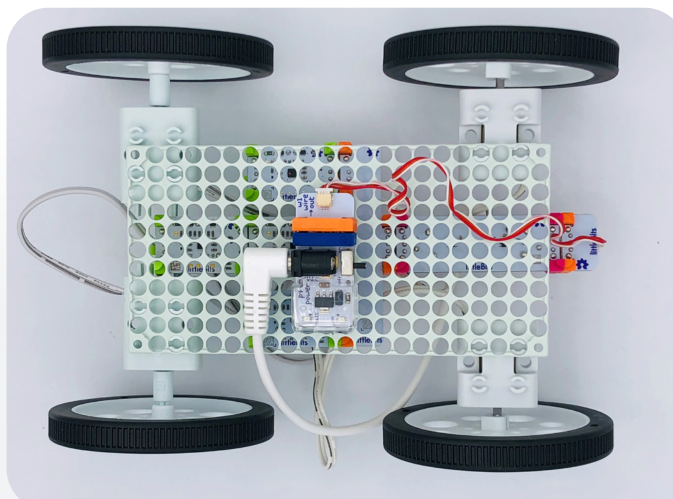
4. Attach one motor in each of the four corners of the board (Picture 10c).
5. Add a wheel to each motor (Picture 10d).
6. Attach the power bit to the underside of the board (Picture 10e).
7. Tape the battery in place on the topside of the car so that it doesn't block any of the controls (Picture 10f).
8. Adjust the direction of each motor to either "ccw" or "cw" so that all the wheels turn forward when the motors are on.
9. Students will identify what energy transformations are occurring in the model car.



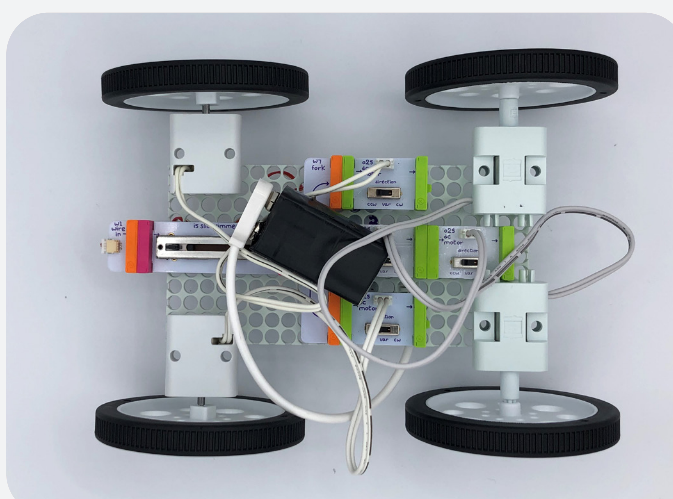
Picture 10c



Picture 10d



Picture 10e



Picture 10f

Explain *(10 to 15 minutes)*

1. Introduce or remind students how to calculate the kinetic energy of an object in motion.

$$KE = \frac{1}{2} mv^2$$

- KE = kinetic energy (J)
- m = mass (kg)
- v = velocity (m/s)

2. Explain to students that they will be using their model car to calculate the kinetic energy of the car when it is travelling at different velocities or loaded with different masses.
3. Explain the procedure in the Elaboration section of the lesson and demonstrate the procedure as needed.

Elaborate *(30 to 40 minutes)*

Part 1 - Changing velocity

1. Students will construct the following table in their notebook.

Trial	Distance Traveled (m)	Time (s)	Velocity (m/s)	Mass (kg)	Kinetic Energy (J)
Low power					
Medium power					
High power					

2. Students will measure out a distance on the floor or on their lab table. A distance of one or two meters is recommended.
3. Students will measure the mass of the model car. The units of mass should be kilograms, so students may need help converting from grams to kilograms depending on the electronic scale that is used.
4. Students will set the adjustable slider on the model car to low power.
5. Students will release the car and use the stopwatch to measure how long it takes to travel the measured distance.
6. Students will use the distance and travel time to calculate the velocity of the model car.
7. Students will use the mass and velocity of the model car to calculate the kinetic energy of the model car.
8. Students will repeat the process but will set the adjustable slider to medium power and high power.

Part 2 - Changing mass

1. Students will construct the following table in their notebook.

Trial	Distance Traveled (m)	Time (s)	Velocity (m/s)	Mass (kg)	Kinetic Energy (J)
Low mass					
Medium mass					
High mass					

2. Students will use the same travel distance that was already measured on the floor or lab table.
3. Students will place a small mass on the model car (ex: 50 grams) and measure the mass of the model car. Remind students that the mass should be measured in kilograms.
4. Students will set the adjustable slider on the car to full power.
5. Students will release the car and use the stopwatch to measure how long it takes to travel the measured distance.
6. Students will use the distance and travel time to calculate the velocity of the model car.
7. Students will use the mass and velocity of the model car to calculate the kinetic energy of the model car.
8. Students will repeat the process but will change the mass on the car to a medium mass (ex: 100 grams) and a high mass (ex: 500 grams).

Evaluate *(15 to 20 minutes)*

1. Students will construct two graphs to display their results.
    - The first graph will show kinetic energy vs. velocity. The velocity should be the independent variable (on the x-axis) and the kinetic energy should be the dependent variable (on the y-axis).
    - The second graph will show kinetic energy vs. mass. The mass should be the independent variable (on the x-axis) and the kinetic energy should be the dependent variable (on the y-axis).
2. Students will explain how changing the mass and velocity of the car affected its kinetic energy.
3. Students will compare and contrast the graphs, noting any differences in the shapes of the graphs.
4. Discuss results with students.

WORK AND POWER

OVERALL TIME *(50 to 65 minutes)*

OBJECTIVE

Students will calculate the approximate power of a motor from the littleBits Pro Library Kit.

Next Generation Science Standards: Engineering Design

MS-PS3-5

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

OVERVIEW

Students will use a littleBits motor to construct a simple crane and will use the motor to lift various masses. Students will find the highest mass and that motor can lift and will use the change in gravitational potential energy and lifting time to approximate the power of the motor.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- littleBits Pro Library Kit (items needed per group)
- Power Bit (p4)
- One Battery (9V) and Cable
- DC Motor (o25)
- motorMate
- String
- Various Masses (up to 1 kg)
- Scale (if masses are not labeled)
- Meter Stick or Measuring Tape
- Stopwatch
- Tape
- Printed Elaboration activity instructions
- Notebook
- Paper
- Pencil/pen

PREPARATION

Ensure that littleBits Kits are organized and contain the required bits. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Print copies of instructions for the Elaboration activity.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Give one student a stack of books. Ask the student to lift the stack slowly and place it on a desk. Measure the time to lift the books.
2. Ask another student to do the same thing but to do it as fast as possible. Measure the time to lift the books.
3. Ask students whether the students did the same amount of work. If not, what was different?
4. Guide students to the conclusion that the students did do the same amount of work, but they did the work at different rates.

Explore *(5 to 10 minutes)*

1. Give students the following scenario:
    - Maurice took two minutes to climb the stairs to the top floor of the building. Marvin took three minutes to climb the top floor of the building. The top floor of the building is 50 meters above the ground.
2. Ask students to answer the following questions:
    - How much work was done by each person to walk to the top floor?
    - Did the difference in time change the amount of work done?

Explain *(5 minutes)*

1. Explain the differences between work and power.
    - Work is a measure of the energy transfer that occurs when an object is moved over a distance by an external force applied in the direction of displacement. More simply, work is the change in energy of an object. Units for work are joules, the same as for energy.
    - Power is the rate at which work is being done.
    - Power = Work / TIme
    - Watts are the SI units for power. One watt equals one joule per second.

Elaborate (30 to 40 minutes)

1. Students will construct the following table in their notebook:

Mass (kg)	Change in Height (m)	Time (s)	Work (J)	Power (W)

2. Students will complete the following instructions:
    - Construct a circuit by connecting the power bit to the motor.
    - Place a motorMate on the axle of the motor.
    - Tie a string around the motorMate.
    - Firmly tape the motor to the edge of a table or desk.
    - Measure the mass of an object or use a labeled mass. The mass should be converted to kilograms if needed.
    - Tie the end of the string to the mass.
    - Turn on the motor and record the time required to lift the mass to the table surface.
    - Measure the distance that the mass was lifted. The distance should be converted to meters if needed.
    - Calculate the work that was performed by the motor using the following formula:
    - Work = Mass X Gravitational Acceleration X Change in Height
    - *(Note: Students can use 9.8 m/s2 or 9.81 m/s2 for gravitational acceleration)*
3. Calculate the power of the motor using the following formula:

Power = Work / Time

- Increase the mass used and repeat the previous steps.
- Keep increasing the mass until the motor can no longer lift the mass.
- Use your data to estimate the maximum power of the motor.

Evaluate *(5 minutes)*

1. Ask students to give an example in which little work is done, but much power is required and vice versa.

CHEMISTRY

IONIC VS. COVALENT BONDS

OVERALL TIME *(80 to 100 minutes - lesson can be split over two class periods)*

Next Generation Science Standards: Engineering Design

MS-PS1-1
Develop models to describe the atomic composition of simple molecules and extended structures.

OBJECTIVE

Students will use littleBits Pro Library to construct a device that changes the gravitational potential energy of another object.

OVERVIEW

Makey Makey is a computer chip that connects objects to a computer, changing those objects into a musical device, a game controller, or scientific testing device. Students will use Makey Makey to determine whether various compounds and molecules are held together by ionic or covalent bonds by testing whether the substances conduct electricity. Some substances, such as salt and sugar, will need to be dissolved in water.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- Makey Makey Kits
- Computers
- Various Substances Formed by Ionic Bonds
- Salt dissolved in water
- Calcium chloride dissolved in water
- Baking soda dissolved in water
- Various Substances Formed by Covalent Bonds
- Vegetable Oil
- Isopropyl Alcohol (99% - 100%)
- Ethanol
- Aluminum Foil
- Scissors
- Beakers
- Water
- 10 Red and 10 White Poker Chips for each student/pair
- Copies of Ionic and Covalent Bonds Worksheets
- Printed Exploration activity instructions
- Printed photos
- Notebook
- Paper
- Pencil/pen

PREPARATION

Divide 10 red and 10 white poker chips into bowls, cups, or trays for each student, pair, or group. Practice constructing and using the Makey Makey testing station. Print instructions and photos for the Exploration activity. Divide supplies for the Exploration activity into small containers for each group or arrange a station where students can obtain supplies. Print out copies of the ionic and covalent bonding worksheets.

LESSON SEQUENCE

Engage *(15 to 20 minutes)*

1. Students will be using red and white poker chips to simulate the valence electrons of elements. As they complete the simulation, students will answer questions with a partner.
   - Red poker chip = Electron, White poker chip = Proton
     A. Simulation 1:
     - Place one pair of chips (one red and one white) in a group on your desk.
     - Place 7 pairs of chips (7 red and 7 white) in a separate group on your desk.
     - Move one red chip from the smaller group to the larger group.
     - What is the overall charge for the larger group? *(Answer = -1)*
     - What is the overall charge for the smaller group? *(Answer = +1)*
     - What is the overall charge for both groups combined? *(Answer = Neutral)*

     B. Simulation 2:
     - Draw a large Venn diagram on a piece of paper or whiteboard.
     - Place 6 pairs of chips (6 red and 6 white) on one side of the Venn diagram.
     - Place 6 pairs of chips (6 red and 6 white) on the other side of the Venn diagram.
     - Move red chips from either side of the Venn diagram into the center region so that both atoms have 8 valence electrons. *(Answer: Students should have four red poker chips on each side of the Venn diagram and four red poker chips in the shared region of the Venn diagram. Counting the four red poker chips that each side retained and the four shared red poker chips in the middle, each "atom" or side of the diagram still has 8 valence electrons).*
2. Discuss the differences in these two simulations as a class. Draw out the idea that in the first simulation, each "atom" or group could reach 8 or zero valence electrons by giving or receiving valence electrons. In the second simulation, each "atom" or side of the Venn diagram had to share valence electrons in order to have a full outer shell. *(Note: Students should have been introduced to valence electrons and energy shells prior to attempting this lesson).*
3. If additional examples are needed, students can also complete the following simulations:
     D. Simulation 3:
     - Place 3 pairs of chips (3 red and 3 white) in a group on your desk.
     - Place 5 pairs of chips (5 red and 5 white) in a group on your desk.
     - Move 3 red chips from the smaller group to the larger group.

- What is the overall charge for the larger group? *(Answer = -3)*
- What is the overall charge for the smaller group? *(Answer = +3)*
- What is the overall charge of both groups combined? *(Answer = Neutral)*

E. Simulation 4:

- Place 5 pairs of chips (5 red and 5 white) on one side of the Venn diagram.
- Place 5 pairs of chips (5 red and 5 white) on the other side of the Venn diagram.
- Move red chips from either side of the Venn diagram into the center region so that both atoms have 8 valence electrons. *(Answer: Students should have two red poker chips on each side of the Venn diagram and six red poker chips in the shared region of the Venn diagram. Counting the two red poker chips that each side retained and the six shared red poker chips in the middle, each "atom" or side of the diagram still has 8 valence electrons).*

Explore *(30 to 40 minutes)*

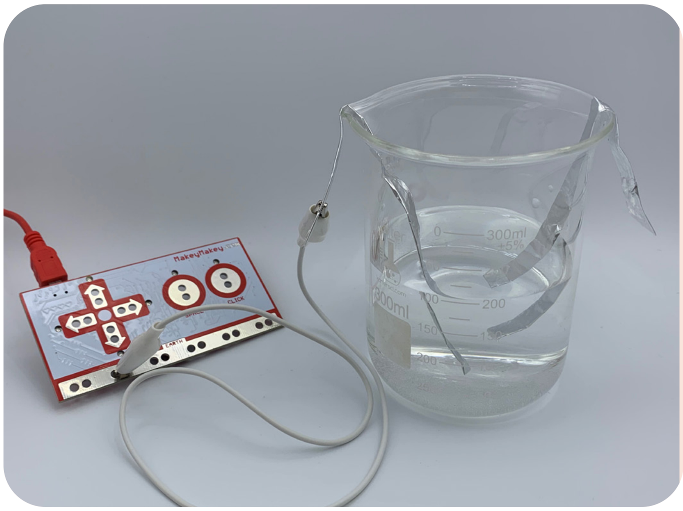
1. Students will construct a Makey Makey test station to determine if various materials substances or solutions conduct electricity by following the steps below.
2. Students will construct the following table in their lab notebook.
3. Put the first substance or solution in a small beaker.

Substance or Solution	Does it Conduct Electricity?
Salt dissolved in water	
Isopropyl alcohol	
Ethanol	
Calcium chloride dissolved in water	
Baking soda dissolved in water	
Vegetable oil	

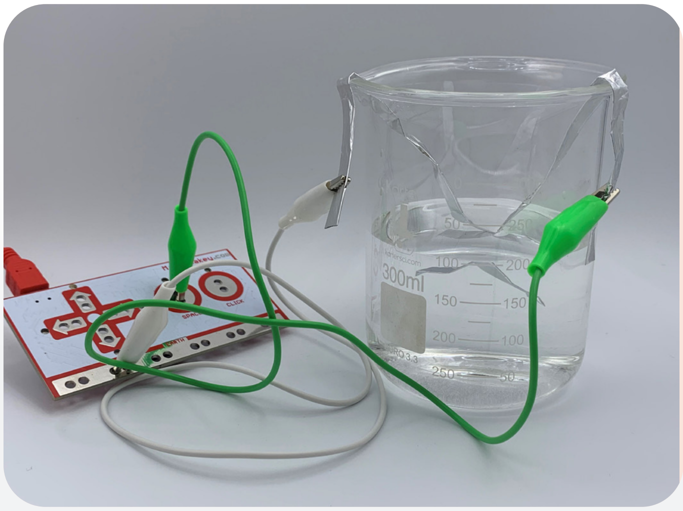
4. Cut two small squares of aluminum foil (approximately 5 in. x 5 in.) and roll each piece of aluminum foil to make a small roll.
5. Place each piece of aluminum foil on opposite sides of the beaker so that the end of the aluminum foil is suspended in the liquid and not touching the bottom of the beaker. (Picture 12a)
6. Connect the Makey Makey chip to a computer using a USB cord.
7. Connect the end of one alligator clip to the "Earth" strip of the Makey Makey chip.

Picture 12a

8. Connect the other end of the alligator clip to one roll of aluminum foil. (Picture 12b)
9. On the computer, open a web browser and go to https://apps.makeymakey.com/piano/
10. Connect the end of another alligator clip to the "Space" section of the Makey Makey chip.
11. Connect the other end of the alligator clip to the other roll of aluminum foil. (Picture 12c)
12. Disconnect the alligator clip from the "Space" button and use that end of the alligator clip to touch either the "Space" button or the up, down, left or right arrow. If the material conducts electricity, the Makey Makey will play notes on the piano app. If the material does not conduct electricity, the Makey Makey will not play notes on the piano app.
13. Repeat the process with each solution or liquid, either rinsing the beaker or using a new beaker with each trial.



Picture 12b



Picture 12c

Explain *(15 minutes)*

1. Discuss the results of the Exploration activity with students and ask them to explain why they think the substances behaved differently.
2. Show the video "How Atoms Bond" by TED-Ed
   - https://www.youtube.com/watch?v=NgD9yHSJ29I
3. Explain that ionic bonds are formed when an atom or atoms give valence electrons to another atom or atoms. This allows all atoms to reach a stable energy state by filling their outer energy shell with 8 valence electrons or by emptying their outer energy shell (which leaves a full energy shell at next lowest level). Small elements, such as lithium or beryllium will lose valence electrons to have 2 valence electrons in the lowest energy shell.
   - Atoms that lose valence electrons become positive ions and atoms that gain valence electrons become negative ions. Ionic bonds are held together by the attraction between positive and negative ions.
   - Ionic bonds form between metals and nonmetals. Some ionic compounds contain

polyatomic ions, which are composed of more than one atom (example: nitrate is NO3-).

- When ionic compounds are dissolved in water, the ions dissociate and disperse in solution, each surrounded by water molecules to prevent it from recombining. The resultant ionic solution becomes an electrolyte, which means it can conduct electricity.
- Explain that covalent bonds are formed when atoms share electrons to reach an stable energy state by filling their outer energy shell with 8 valence electrons. Hydrogen will share valence electrons to

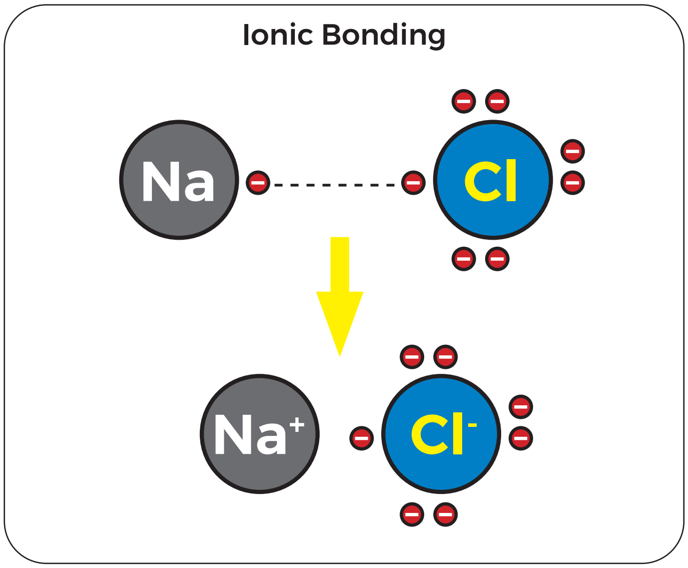


Diagram 12d

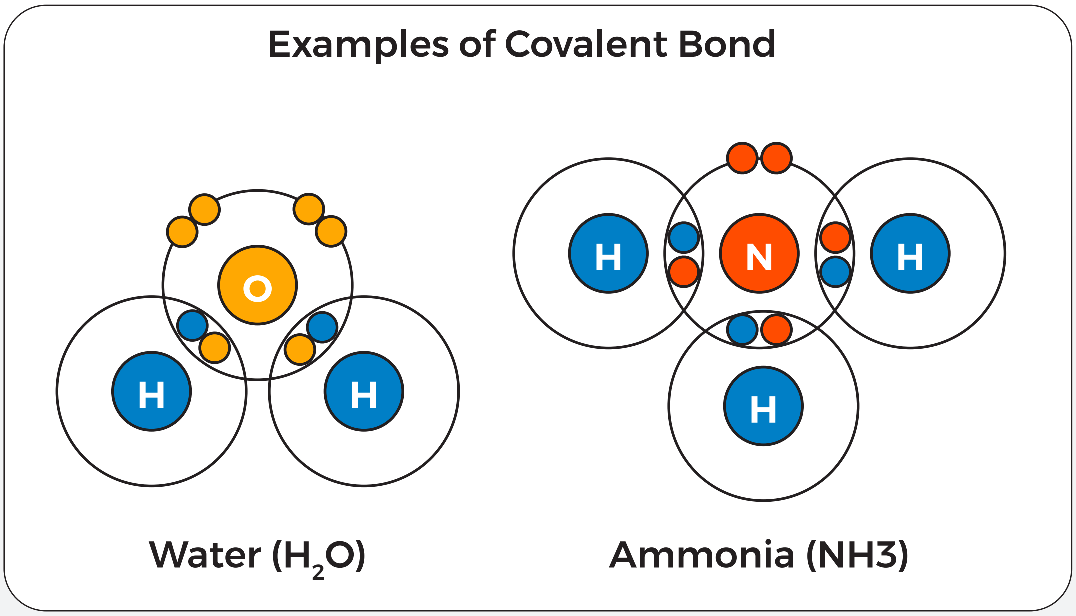


Diagram 12e

fill its only energy shell with 2 valence electrons.

- Covalent bonds form between nonmetals.

- When covalent molecules are dissolved in water or occur in liquid form, there are no ions dispersed in the solution, so the solution cannot conduct electricity.

Elaborate *(15 to 20 minutes)*

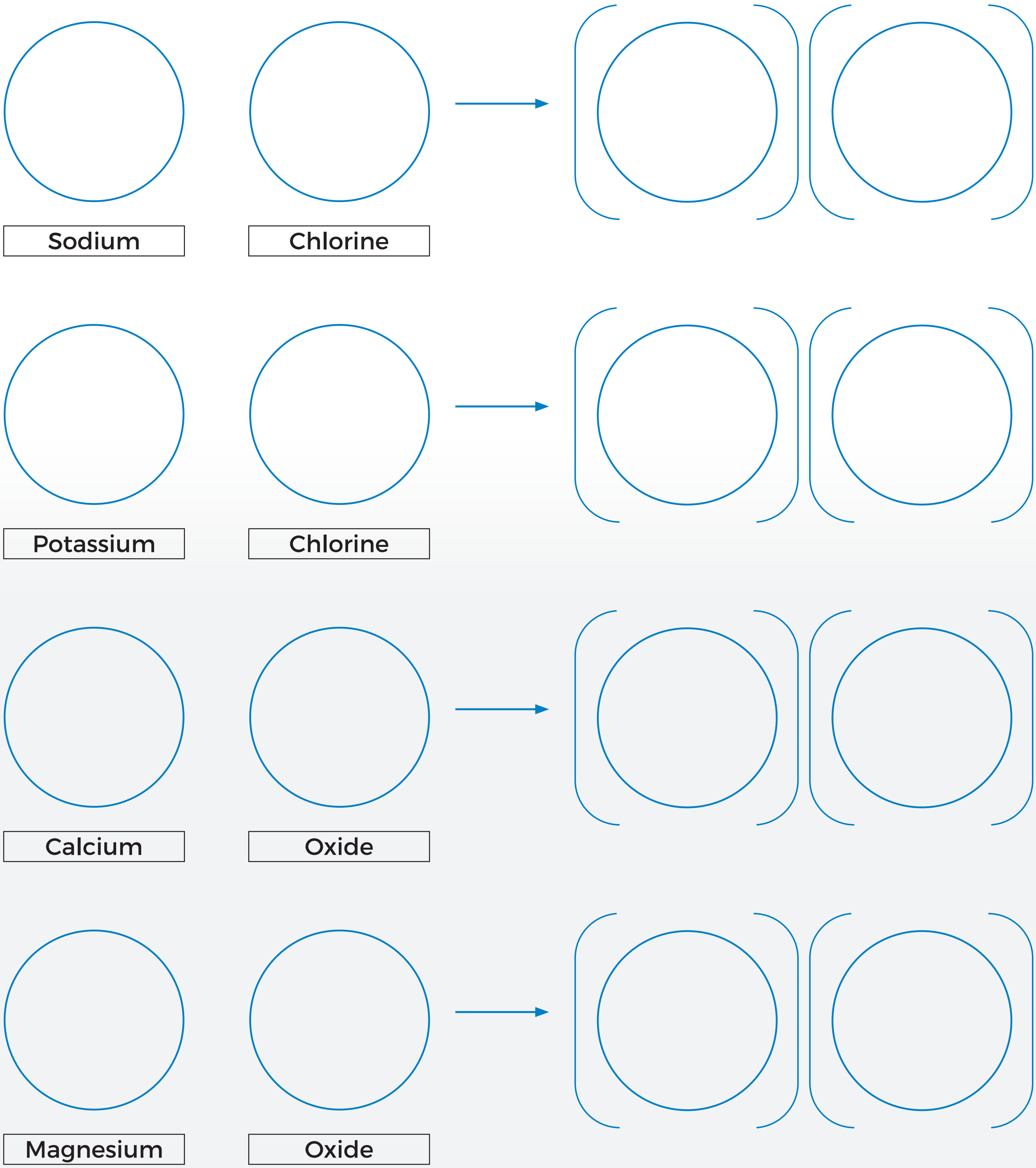
1. Students will complete two worksheets in which they draw diagrams to show how valence electrons are exchanged in ionic bonds and shared in covalent bonds.
   - Ionic bonds worksheet
   - Covalent bonds worksheet

Evaluate *(5 minutes)*

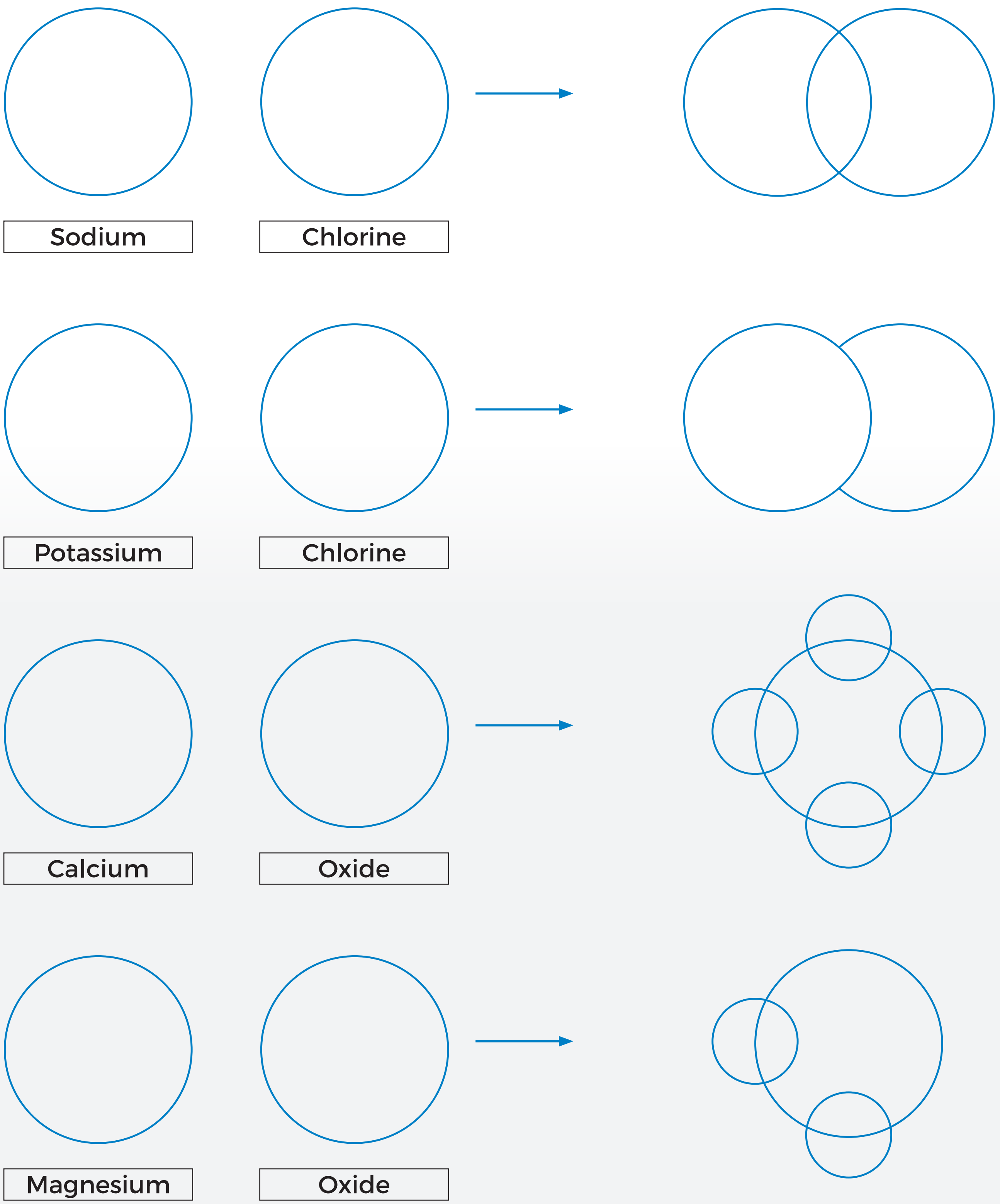
Substance or Solution	Does it Conduct Electricity?	Ionic or Covalent?
Salt dissolved in water		
Isopropyl alcohol		
Ethanol		
Calcium chloride dissolved in water		
Baking soda dissolved in water		
Vegetable oil		

1. Students will add a column to their table from the Exploration activity and identify whether each substance is formed by ionic or covalent bonds.

DOT AND CROSS DIAGRAMS FOR IONIC COMPOUNDS



COVALENT COMPOUNDS
VENN DIAGRAM



LIFE SCIENCES (LS) LESSONS

ADAPTATIONS

OVERALL TIME *(45 to 60 minutes)*

OBJECTIVE

Students will use the littleBits Pro Library to construct a fictitious organism that is adapted to survive and reproduce in a specific environment.

OVERVIEW

Students will learn how biological adaptations allow species to survive in specific environments and will identify adaptations in a variety of species. Students will then use littleBits to construct a fictitious organism that has an adaptation that allows it to hunt at night.

Next Generation Science Standards: Engineering Design

MS-LS4-4

Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- littleBits Pro Library Kits
- Science Textbooks or Internet Access with Devices
- Pictures of birds
- Paper
- Pencil/pen

PREPARATION

Ensure that the littleBits Kits are organized for each group. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Copy pictures of birds into a presentation, PowerPoint or something similar, or print copies for students.

LESSON SEQUENCE

Engage *(10 to 15 minutes)*

1. Show a picture of a hummingbird, pelican, sparrow, and eagle.




2. Students will work with a partner to identify what each bird eats and where it lives.
3. Students will identify what characteristics each bird has that affects what it can eat and where it can live.
4. As a class, discuss how a bird's beak, feet, shape, size, etc. affects what it can eat and where it can live.

Explore *(10 minutes)*

1. Students will search online or in their science textbooks and find a picture of a non-bird animal.
2. Students will identify features that may allow that animal to survive in its habitat.
   - *Example: Dolphins have streamlined bodies for swimming.*
3. Ask students to share the animal that they chose and explain the features that they identified.

Explain *(5 to 10 minutes)*

1. Introduce students to the concept of biological adaptations:
   - In evolutionary biology, an adaptation is the biological mechanism by which organisms adjust to new environments or to changes in their current environment.
   - Adaptations increase the chance that an organism will survive and reproduce, passing the adaptation to future generations.
   - Natural selection is the process whereby organisms better adapted to their environment tend to survive and produce more offspring, passing on genetic traits to future generations.
   - Eventually, advantageous adaptations will spread through the entire species.

Elaborate (*15 to 20 minutes)*

1. Challenge students to use littleBits to create a fictitious organism that has adaptations that allow it to find prey at night.
   - For example:
     - The littleBits organism might use a motion sensor that allows it to detect prey. The motion sensor could cause a motor to start, causing the organism to move.
     - The littleBits organism might use a sound sensor that allows it to hear prey and causes a spotlight to come on when sound is detected.
2. Students will work in groups to create their littleBits organism and will share their adaptations with the class.

Evaluate (*5 minutes)*

1. Students will respond to the following prompt:
   - In a paragraph, explain how the adaptations in your littleBits organism increase the likelihood that it will survive and reproduce.

OVERALL TIME *(110 to 140 minutes - can split into multiple class periods)*

OBJECTIVE

Students will use the littleBits Pro Library to create an evolutionary history for a fictitious species.

OVERVIEW

Students will learn how genetic mutations, environmental conditions, and natural selection can cause species to develop new biological traits. Students will use littleBits to create an evolutionary history for a fictitious species in which small, incremental mutations give the species a survival advantage and cause it to evolve new traits.

LEVEL OF DIFFICULTY

Advanced

Next Generation Science Standards: Engineering Design

MS-LS4-2

Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

MS-LS4-4

Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

MATERIALS

- **littleBits Pro Library Kits**
- **Spoons**
- **Clothespins**
- **Needles**
- **Tweezers**
- **Beans**
- **Trays or Bowls**
- **Cups**
- **Teacher's Computer with Java Installed and Projector**
- **Laptop Computers, Tablets, or other Devices**
- **Camera**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that littleBits Kits are organized for each group. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Organize beans, bowls/trays, and various utensils for each group. Practice using the PHET simulation that will be used during the Elaboration activity.

LESSON SEQUENCE

Engage *(20 minutes)*

1. Assign students to groups of four and give each student in the group one of the following: spoon, clothespin, needle, and tweezers. These items represent the shape of the beak of a rare avian species.
2. Give each group a bowl or tray of beans and each student a small cup.
3. Set a timer for one minute and instruct students to use the item they have been given to move beans from the bowl or tray to their cup. Students may only touch the beans with their item, not with their hands.
4. At the end of one minute, instruct students to count the beans they collected. Any student that collected less than 20 beans did not find enough food to survive and is eliminated from the game.
5. Repeat the above process, but change the time to 45 seconds, 30 seconds, and 15 seconds.
6. Discuss the following questions as a class:
    - An organism must be able to survive if it is going to reproduce and pass on its genes to future generations. Based on this activity, what will the beak of this species look like in several generations?
    - What other adaptations might help this species to survive and reproduce?

Explore *(10 minutes)*

1. Go to https://phet.colorado.edu/en/simulation/natural-selection (download the Java-based program prior to class).
2. Use the simulation to demonstrate how various environmental factors cause characteristics of the rabbit population to change over time.
    - For example, add a mutation for brown fur and then add the selection factor of wolves in an equatorial environment. After some time passes, change to an Arctic environment.
    - For example, add a mutation of long teeth and then add the selection factor of food.
3. Discuss the results of the simulation as a class. Discuss that when random mutations provide a survival advantage in a specific environment, that adaptation will be passed onto future generations and eventually become characteristic of the population.

Explain (5 to 10 minutes)

1. Explain how mutations, natural selection, and evolutionary theory are related.
    - Many genetic mutations are either harmful to an organism or provide no survival advantage. However, occasionally a mutation will provide a survival advantage (such as brown fur in an equatorial environment).
    - In such cases, organisms with the mutation are more likely to survive and this trait will be passed onto future generations, eventually spreading through the population.
    - Over long periods of time, accumulated mutations that provide a survival advantage can lead to dramatic evolutionary changes and new species.

Elaborate *(30 to 40 minutes)*

1. Assign students to groups or keep the same groups from the Engagement activity.
2. Challenge students to use littleBits to create a fictitious evolutionary history of a species that includes mutations that provide a survival advantage.
   - Example:
     - Each group should start out with a simple circuit, such as a power bit and one output (an LED, for example).
     - The first mutation is a motion sensor that allows the organism to control its output when it senses the motion of a predator (this camouflaging ability will increase the likelihood of survival).
     - The second mutation is a fan that acts as a propeller and allows the organism to have mobility through the water (this will allow the organism to be able to avoid predators and find food to increase the likelihood of survival).
     - The third mutation is a dimmer switch that controls the fan to give the organism greater control over its movement.
3. Students should be able to explain how each mutation gives their fictitious organism a survival advantage and why this trait would be passed to future generations.

Evaluate *(45 to 60 minutes)*

1. Students will take a picture of each stage in the evolution of their fictitious species.
2. Students will work as a group to create a PowerPoint that shows each mutation in the evolutionary history and explains how each mutation gives the species a survival advantage.
3. Each group will present their PowerPoint to the class.

EARTH AND SPACE SCIENCES (ESS) LESSONS

CONSTELLATIONS

OVERALL TIME *(60 to 75 minutes)*

Next Generation Science Standards: Engineering Design

MS-ESS1-3

Analyze and interpret data to determine scale properties of objects in the solar system.

CROSSCUTTING CONCEPTS

(Scale, Proportion, and Quantity) Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

OBJECTIVE

Students will use littleBits Pro Library to construct a three-dimensional scale model of a fictitious constellation.

OVERVIEW

Students will use littleBits to plan and construct a three-dimensional scale model of a fictitious constellation. Although the stars in a constellation are not within the solar system, this task will help students understand the scale relationships of large distances.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- littleBits Pro Library Kits (Items per group)
- Base Grid
- Multiple Wire Bits (w1, w19)
- 4 LED Bits (Long LED o2 or UV LED o15)
- 1 Battery (9V) and Cable
- 1 Power Bit (p4)
- 1 Fork (w7)
- Blank printer paper
- Tape
- Scissors
- Paper
- Pencil/pen

PREPARATION

Ensure that littleBits Kits are organized and contain the required bits. Depending on the number of kits and students, it might be necessary to order additional LED bits. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Practice using littleBits to construct a scale model of a constellation to be better able to assist students. Tape or mark a line on the floor and mark distances at one-meter increments to prepare for the Exploration activity. Print copies of instructions and pictures for the Elaboration activity for each group.

LESSON SEQUENCE

Engage *(5 minutes)*

1. Students will discuss the following questions with a partner:
   - What is a constellation?
   - Name one constellation you have seen or know about.
   - Describe what it looks like or draw a sketch.

Explore *(15 to 20 minutes)*

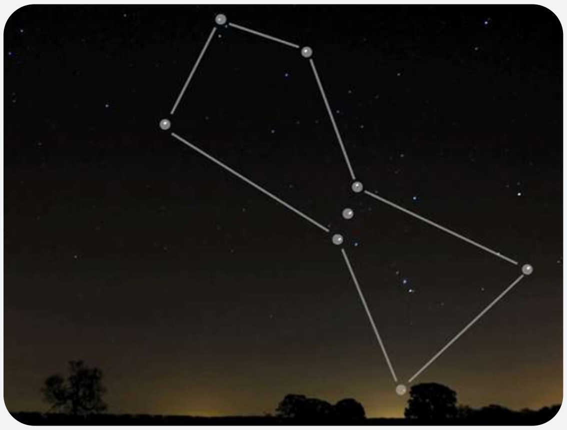
1. As a class, construct a human scale model of a fictitious constellation.
2. Tape or designate a line on the floor that will represent Earth's surface.
3. Use small pieces of tape or other markers to mark distances in one-meter increments from Earth's surface (1 meter, 2 meters, 3 meters, etc.).
4. Draw or project the following table on the front board:

Star	Distance from Earth	Scale Distance from Earth
A	87 light-years	
B	142 light-years	
C	51 light-years	
D	75 light-years	
E	126 light-years	

5. Based on the room available in the classroom, work as a class to decide on an appropriate scale for the model (Example: 20 light-years = 1 meter).
6. Work as a class to complete the table to find the scaled distances for each star.
7. Select five students, one to represent each star, and give each student a flashlight.
8. Each student will stand the scaled distance away from Earth's surface and hold their flashlight so that it points towards the front of the class. Students can hold their flashlights at different heights to create the shape of the fictitious model constellation.

Explain *(5 minutes)*

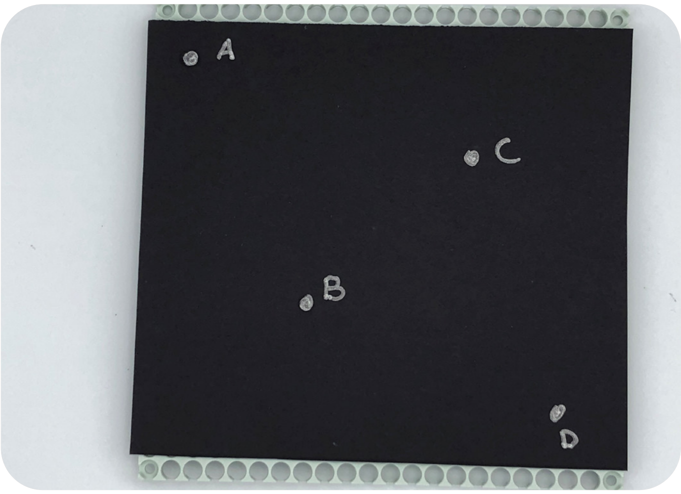
1. Explain that a constellation is a group of stars forming a recognizable pattern that is traditionally named after its apparent form or identified with a mythological figure.
   - Modern astronomers divide the sky into 88 constellations with defined boundaries.
   - Though constellations look flat or two-dimensional in the night sky, the stars do not lie on the same plane. Some stars are farther away and some stars are closer to Earth.



Picture15a

Elaborate *(30 to 20 minutes)*

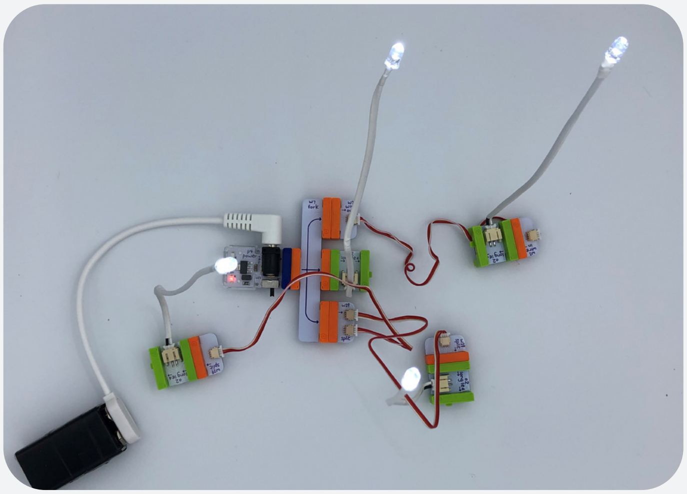
1. Students will work with a group to use littleBits to create a scale model of a fictitious constellation.
2. Cut a piece of blank printer paper so that it fits on a littleBits base grid.
3. On the paper, mark locations in the light sky for Star A, B, C, and D.
4. Tape paper to a littleBits base grid, which will represent Earth's surface. (Picture 15b)
5. Based on the table below, choose an appropriate scale for the model. The maximum length of the long LED is approximately 14 centimeters, so the scale distance of Star D should be less than 14 centimeters.



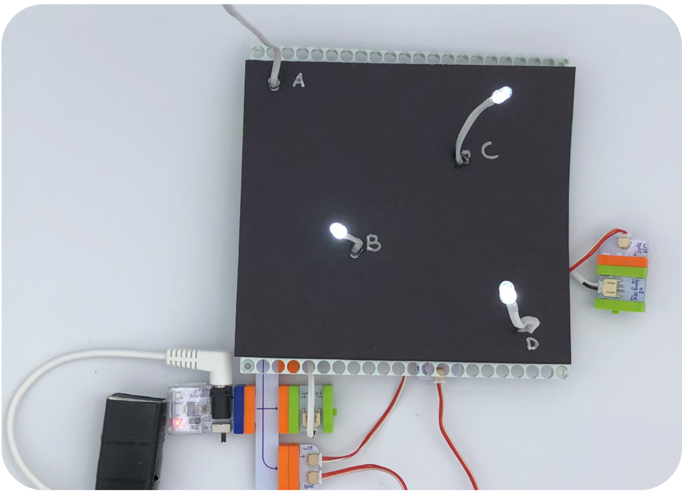
Picture 15b

Star	Distance from Earth	Scale Distance from Earth
A	112 light-years	
B	67 light-years	
C	35 light-years	
D	123 light-years	

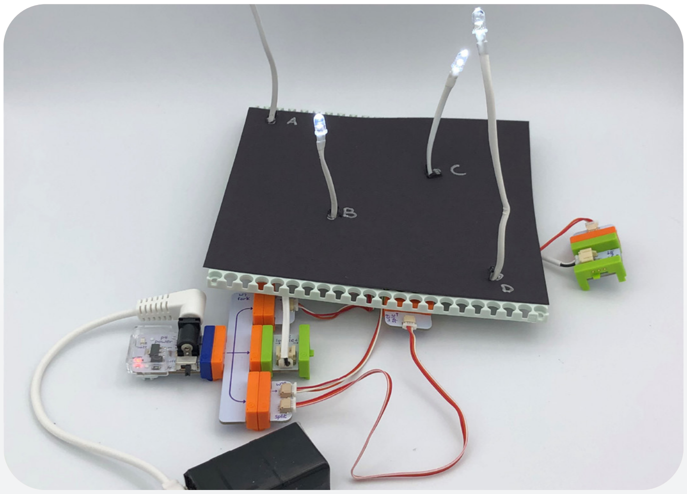
6. Calculate the scale distance for each star.
7. Create a circuit using the power bit, the fork, wires, and four long LEDs. The exact layout of the circuit depends on the layout of the constellation because the LEDs will need to be able to reach the location of each star. (Picture 15c)
8. Place the circuit underneath the base grid, on the side opposite the printer paper. The circuit does not need to be attached to the base grid.


Picture 15c

9. Create a small hole in the paper by each star and push each long LED up through one of the holes. (Picture 15d)
10. Adjust the length of the long LED that is pulled through the base grid and paper so that it corresponds to the scale distance from Earth. Use tape to hold LEDs at the proper distance if needed. (Picture 15e)



Picture 15d



Picture 15e

Evaluate (*5 minutes)*

1. Students will write a paragraph to respond to the following prompt:
    - In today's lesson, we constructed two scale models of constellations. Describe another method you could use to construct a scale model of a constellation.

SOLAR ENERGY AND CLIMATE

OVERALL TIME *(55 to 70 minutes)*

Next Generation Science Standards: Engineering Design

MS-ESS1-1

Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

OBJECTIVE

Students will determine how the curvature of Earth's surface affects climate at various latitudes.

OVERVIEW

Students will use Snap Circuits to construct simple circuits that contain various resistors. Students will use multimeters to measure the voltage and current in the circuit and will propose a mathematical relationship that relates voltage, current and resistance.

LEVEL OF DIFFICULTY

Beginner

MATERIALS

- **Snap Circuits SC750R Kit (items needed per group)**
- **Base Grid**
- **Connecting Wires (rigid and flexible)**
- **Current Meter (M2)**
- **5.1K and 10K Resistors (R3 and R4)**
- **Solar Panel (B2)**
- **Large ball (beach ball, basketball, soccer ball, etc.)**
- **Protractors**
- **Lamps**
- **Flashlights**
- **Paper**
- **Pencil/Pen**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials, lamps have functioning light bulbs, and flashlights have functioning batteries.

LESSON SEQUENCE:

Engage *(5 minutes)*

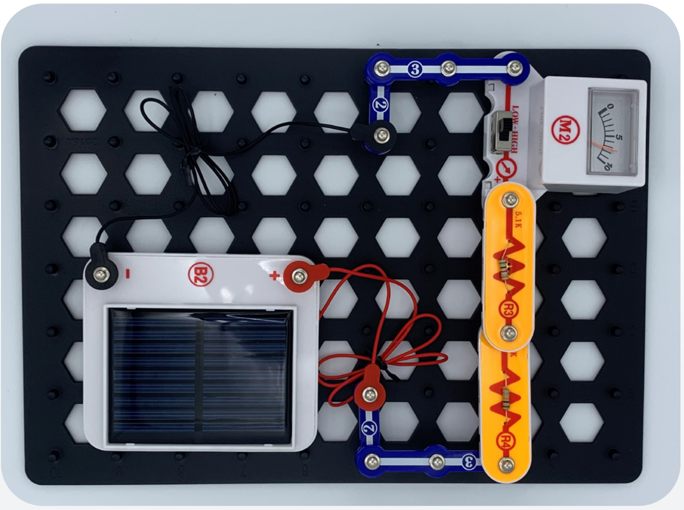
1. Students will discuss the following question with a partner:
    - How does the climate of Portland, Maine differ from the climate of Miami, Florida? Why do the climates differ in these locations? (Show cities on a map if needed.)
2. Discuss student responses as a class.

Explore *(30 to 40 minutes)*

1. Students will construct the following table in their lab notebook:

Approximate Latitude	Angle of Solar Panel in Relation to Horizontal	Current Produced by Solar Panel
	90˚	
	60˚	
	45˚	
	30˚	
	15˚	

2. Students will construct a circuit with the solar panel, flexible and rigid connecting wires, resistors, and meter. (Picture 16a)
3. Students will complete the following instructions:
    - Turn on the lamp and place it in the middle of your lab table. The lamp is a model of the sun.
    - Use a large ball to represent a model of Earth. Hold the ball a couple feet from the lamp.
    - Hold the solar panel so that it is touching the surface of the ball, forms a 90˚ angle with the horizontal surface of the table, and is facing the lamp. (Picture16b) Use a protractor to confirm the angle is correct.
4. Set the meter to "low" and read the current that is produced by the solar panel.
5. Estimate the latitude of the location where the solar panel forms a 90˚ with the horizontal surface of the table. *Note: Teacher may need to provide a mini-lesson on latitude before this activity.*
6. Repeat the previous steps, but change the angle of the solar panel to 60˚, 45˚, 30˚, and 15˚. When the angle of the panel changes, the location on the model Earth should also change to maintain contact with the model.



Picture 16a

Picture 16b

Explain *(5 to 10 minutes)*

1. Discuss the results of the activity with students.
2. Introduce students to the concept that the intensity of light in a specific region of Earth is impacted by the angle at which light from the sun hits Earth's surface.
   - When light hits Earth directly (near the equator), the intensity of the light is higher, more energy is transferred to Earth's surface, and the climate is warmer.
   - When light hits Earth indirectly (closer to the poles), the intensity of the light is lower, less energy is transferred to Earth's surface, and the climate is cooler.
   - The climate near the equator is warmer not because it is closer to the sun, but because light hits Earth's surface more directly.

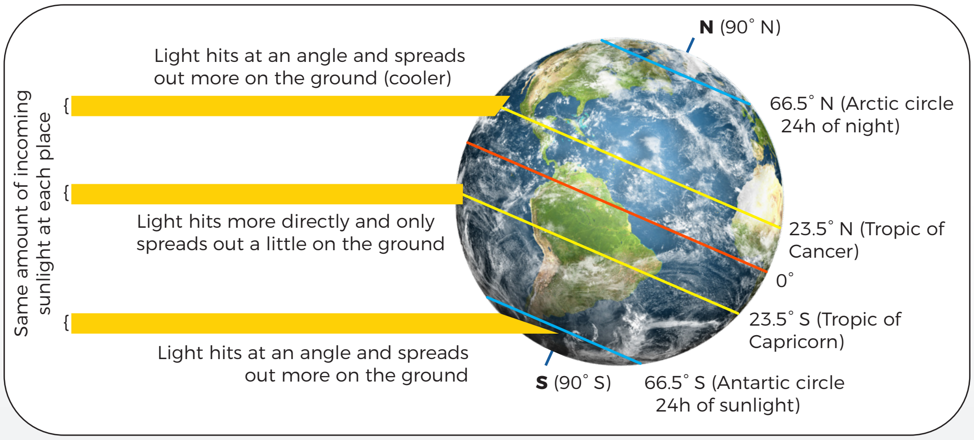


Diagram 16c

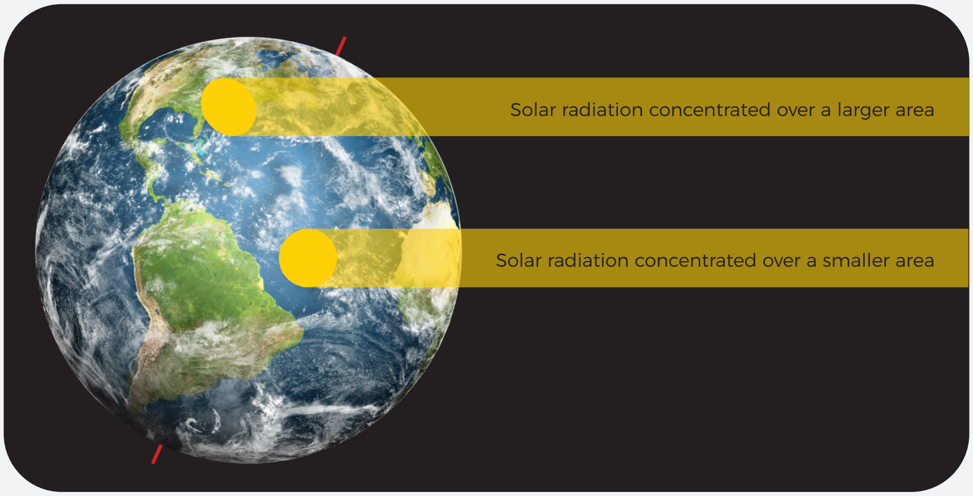


Diagram 16d

Elaborate *(5 to 10 minutes)*

1. Students will complete the following instructions.
2. Shine a flashlight directly down on the top of your desk from a distance of approximately one foot above the desk. Observe the area of light on the surface of the desk.
3. Now, hold the flashlight at an angle but keep it one foot above the desk. Observe the area of light on the surface of the desk.
4. Answer the following questions:
   - How did the area of light change when the flashlight was held at an angle?
   - How does your observation relate to climate in different parts of the world?

Evaluate *(10 minutes)*

1. Students will draw a picture or diagram to represent what they learned about solar energy and climate in today's lesson.
   - Pictures and diagrams should be clearly labeled.

SOLAR ENERGY AND SEASONS

OVERALL TIME *(55 to 70 minutes)*

Next Generation Science Standards: Engineering Design

MS-ESS1-1

Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

OBJECTIVE

Students will explain why Earth's revolution around the sun causes seasons.

OVERVIEW

Students will use the solar panel included in the Snap Circuits SC750R Kit to investigate how Earth's revolution around the sun causes seasons. A lamp will be used to represent the sun and a beach ball will be used to represent Earth. The model Earth will be held so that the axial tilt is 23° and students will move the model Earth around the model sun to represent one year. The solar panel will be used to measure the intensity of light received from the lamp during different seasons.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **Snap Circuits 750R Kit (items needed per group)**
- **Base Grid**
- **Connecting Wires (rigid and flexible)**
- **Current Meter (M2)**
- **5.1K and 10K Resistors (R3 and R4)**
- **Solar Panel (B2)**
- **Large ball (beach ball, basketball, soccer ball, etc.)**
- **Protractors**
- **Meter Sticks**
- **Lamps**
- **Paper**
- **Pencil/pen**
- **Notebook**

PREPARATION

Ensure that each Snap Circuit Kit has the required materials and that lamps have functioning light bulbs. Practice setting up the model Earth (large ball), holding it with an axial tilt of 23°, and revolving the model Earth around the model sun as these instructions may be challenging for students. Practice using the online interactive that will be used in the Elaboration activity.

LESSON SEQUENCE:

Engage *(5 minutes)*

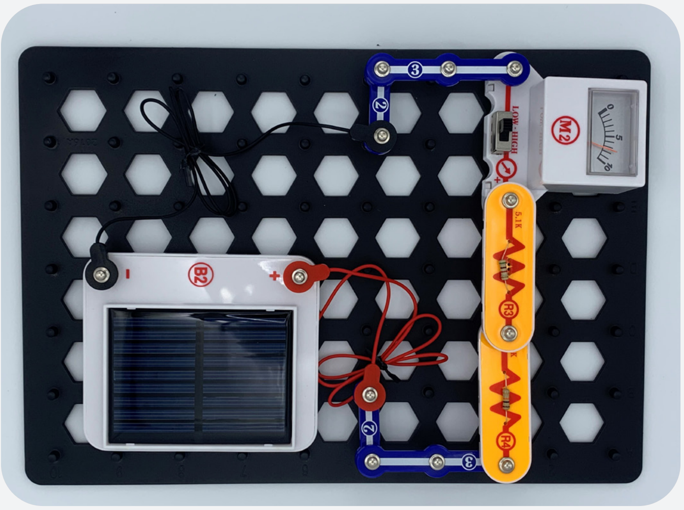
1. Ask students to brainstorm words related to different seasons. Have students share their ideas with the class and record the words on the front board.
2. Ask students to discuss the following question with a partner: What are seasons and what makes them different?
3. Discuss student responses as a class.

Explore *(30 to 40 minutes)*

1. Students will construct the following table in their notebook:

Season	Angle of Solar Panel in Relation to Horizontal	Current Produced by Solar Panel
Winter		
Spring		
Summer		
Fall		

2. Students will use Snap Circuits to construct a circuit with the solar panel, flexible and rigid connecting wires, resistors, and meter. (Picture 17a)
3. Students will complete the following instructions:
   - Turn on the lamp and place it in the middle of your lab table. The lamp is a model of the sun.
   - Use a large ball to represent a model of Earth. Tape the meter stick to the model Earth so that the meter stick is touching Earth at the equator.
   - Hold the model Earth so that the meter stick forms a 23˚ angle with the vertical. (Diagram 17b)
4. Use the protractor to measure the approximate angle between the solar panel at a horizontal surface. Record the angle in the table.



Picture 17a

5. Set the meter to “low” and read the current that is produced by the solar panel. Record the current reading in the table.
6. Keeping the meter stick pointed in the same direction, move or revolve the model Earth one-quarter turn counterclockwise around the lamp. The meter stick should be neither pointing towards the lamp nor away from it. This position is spring.
7. On the side of the model Earth that is facing the lamp, place the solar panel at approximately 45° latitude.
8. Use the protractor to measure the approximate angle between the solar panel at a horizontal surface. Record the angle in the table.

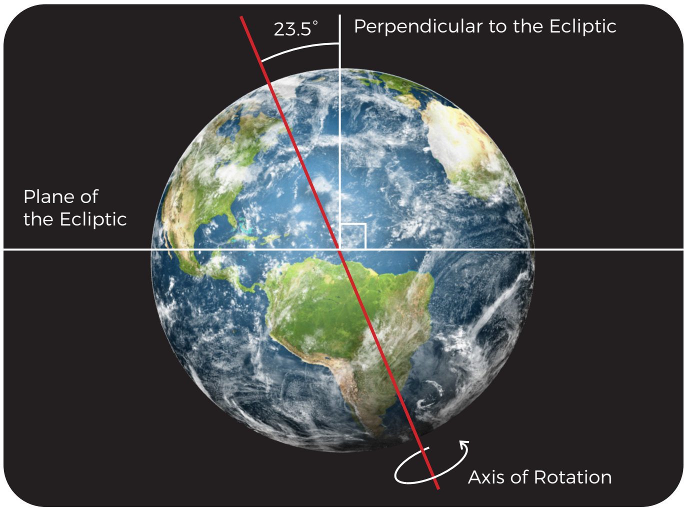


Diagram 17b

9. Use the meter to measure the amount of current produced by the solar panel and record in the table.
10. Keeping the meter stick pointed in the same direction, move or revolve the model Earth one-quarter turn counterclockwise around the lamp. The meter stick should now be pointing towards the lamp. This position is summer.
11. On the side of the model Earth that is facing the lamp, place the solar panel at approximately 45° latitude.
12. Use the protractor to measure the approximate angle between the solar panel at a horizontal surface. Record the angle in the table.
13. Use the meter to measure the amount of current produced by the solar panel and record in the table.
14. Keeping the meter stick pointed in the same direction, move or revolve the model Earth one-quarter turn counterclockwise around the lamp. The meter stick should be neither pointing towards the lamp nor away from it. This position is fall.
15. On the side of the model Earth that is facing the lamp, place the solar panel at approximately 45° latitude.
16. Use the protractor to measure the approximate angle between the solar panel at a horizontal surface. Record the angle in the table.
17. Use the meter to measure the amount of current produced by the solar panel and record in the table.

Explain *(5 to 10 minutes)*

1. Discuss the results of the activity with students.
2. Introduce students to the concept that seasons are caused by the intensity of light that hits different parts of the earth during different times of the year.
   - Earth's axis is tilted 23.5˚ from the vertical.
   - While the tilt of the axis is fixed,as Earth revolves around the sun different parts of Earth's surface are tilted either towards or away from the sun.
   - For example, locations in the northern hemisphere are tilted towards the sun during June, July, and August and receive more direct sunlight. Locations in the northern hemisphere are tilted away from the sun in December, January, and February and receive less direct sunlight.
   - Like climate, seasons are caused by the angle at which light is hitting Earth's surface, not the distance from the sun.

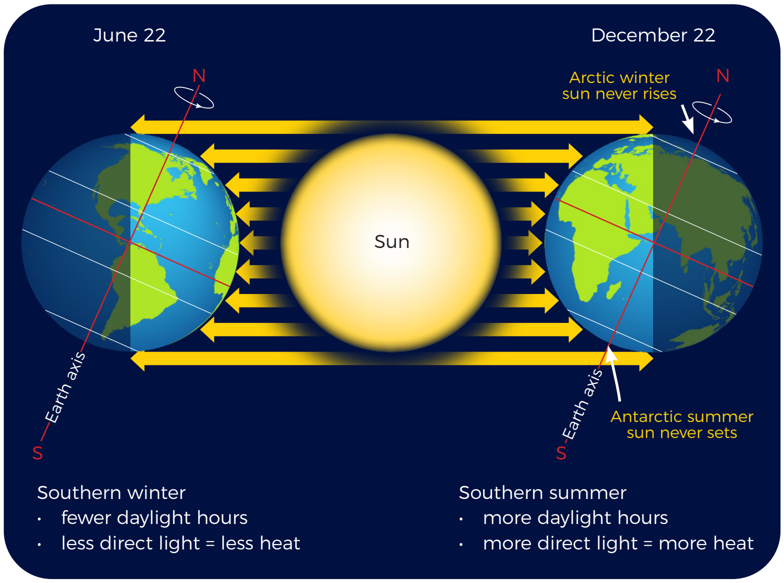


Diagram 17c

Elaborate *(10 minutes)*

1. Go to the following online interactive and project on the front board. http://highered.mheducation.com/sites/007299181x/student_view0/chapter2/seasons_interactive.html
2. Change the inclination angle to 23˚ and allow Earth to revolve around the sun.
3. Ask students to observe how the sunlight angle and average daily temperature change during different times of the year.
4. Change the inclination angle to 0˚ and allow Earth to revolve around the sun.
5. Ask students to observe how the sunlight angle and average daily temperature change during different times of the year.
6. Change the inclination angle to 60˚ and allow Earth to revolve around the sun.
7. Ask students to observe how the sunlight angle and average daily temperature change during different times of the year.

Evaluate (5 minutes)

1. Students will respond to the following question in a written paragraph.
   - Imagine that astronomers discovered an Earth-like planet in a distant galaxy, except this planet has an axial tilt of only 2˚. Would this planet experience seasons similar to those on Earth? Fully explain your reasoning.

PROTECTING BIODIVERSITY

OVERALL TIME *(95 to 135 minutes or split into two class periods)*

Next Generation Science Standards: Engineering Design

MS-LS2-5
Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

OBJECTIVE

Students will use littleBits Pro Library to invent a device that will help to protect biodiversity.

OVERVIEW

Students will research different threats to biodiversity and will use littleBits to invent a device that will help to protect biodiversity. For the Evaluation activity, students will write a letter to a political representative advocating for increased protection of biodiversity.

LEVEL OF DIFFICULTY

Intermediate

MATERIALS

- **littleBits Pro Library Kits**
- **Computers or other devices for online research**
- **Printed copies of a graphic organizer**
- **Paper**
- **Pencil/pen**

PREPARATION

Ensure that littleBits Kits are organized for each group. If students have not used littleBits in the past, plan to add time to this lesson to introduce students to the basic parts and operation of the system. Print copies of a graphic organizer for students to use to organize their online research if needed. Identify potential political representatives to whom students could write letters in the Evaluation activity.

LESSON SEQUENCE

Engage *(5 to 10 minutes)*

1. As a class, brainstorm different endangered species and write them on the front board.
2. Have students work with a partner to identify things that humans are doing that are causing these species to be endangered.
3. Discuss student responses as a class.

Explore *(30 to 40 minutes)*

1. Assign students to groups or partners.
2. Each pair or group will conduct online research to identify different threats to biodiversity.
3. Students can complete a graphic organizer to organize their research.

Explain (10 to 15 minutes)

1. Have students share threats to biodiversity that they identified in their research.
2. Write all student ideas on the front board or in a location that can be saved throughout the lesson.
3. Add to student ideas as needed.
   - The following video can be shown if needed to supplement student ideas: **https://www.youtube.com/watch?v=rhRBqeuG1Jc**.

Elaborate *(30 to 40 minutes)*

1. Assign students to groups or keep the same groups from the Elaboration activity.
2. Students will use littleBits to create an invention that will help to protect biodiversity.
   - For example, students could create an invention that uses a motion sensor to control an alarm. This invention could be placed in nature preserves to detect the presence of poachers, alerting both animals and park rangers of their presence.
3. Students will share their invention with the rest of the class.

Evaluate *(20 to 30 minutes)*

1. Students will write a letter to a local, state, or national political representative to advocate for actions that will protect biodiversity.
   - The letter should identify specific threats to biodiversity and specific actions the representative can support.
   - The teacher can decide whether to send the letters or to simply use as an assessment.

STEM RESOURCES

STEM RESOURCES

The resources listed below can assist teachers/mentors with facilitation of STEM programming.

CODING AND COMPUTER SCIENCE

Code Academy – learn coding for free

- http://www.CodeAcademy.com

Code.org – learn coding and programming with popular characters and games

- http://www.Code.org

Scratch Visual, Block-based programming language

- http://scratch.MIT.edu

Khan Academy Computer Science Courses

- http://www.KhanAcademy.org/CS

CodeCombat.com - game using coding principles, free and paid versions

- http://www.CodeCombat.com

Mozilla Thimble – online code editor teaching HTML, CSS, and JavaScript

- https://thimble.mozilla.org/en-US

AppInventor.org – learn to build Android apps

- http://www.AppInventor.org

GameBlox – create and edit games with code

- http://gameblox.org

MIT App Inventor

- http://appinventor.mit.edu/explore

ROBOTICS

Robotics activities come in all shapes and sizes. Here are a few resources to research if interested in starting a robotics program!

LEGO Mindstorms

SeaPerch

NASA Robotics

- http://nasa.gov/audience/foreducators/robotics
- http://robotics.nasa.gov

Sphero

VEX Robotics

3-D PRINTING

TinkerCAD – online 3D design program. Offers free lessons and design tools

- http://www.TinkerCAD.com

Thingverse – website with 3D design files to download and print on your own

- http://www.Thingiverse.com

Tinkerine U – online lessons to introduce 3D printing. Has challenges and ideas for kids to design

- http://www.u.tinkerine.com

SketchUp – 3D design software, has both a free and paid version

- http://www.SketchUp.com

BIOLOGICAL AND EARTH SCIENCES

Howard Hughes Medical Institute

- www.hhmi.org/biointeractive

EarthWatch Institute

- http://earthwatch.org/Education

Earth Science Activities & Experiments

- http://www.Education.com/activity/earth-science

MATH

MathChip – math games and activities

- http://www.MathChimp.com

STEMCollaborative.org – math games

- http://www.STEMCollaborative.org

Adventures in Math

- http://www.scholastic.com/regions

Math Playground – math games and activities

- http://www.MathPlayground.com

MathSnacks.com – math games and videos

- http://mathsnacks.com/

TECHNOLOGY AND ENGINEERING

Engineering.com – news and articles related to engineering

- http://www.Engineering.com

Rube Goldberg Challenges – create elaborate inventions to accomplish a simple task!

- http://www.RubeGoldberg.com

Engineering is Elementary – lessons and activities for educators available for purchase

- http://www.eie.org

TryEngineering.org – information and lesson plans related to engineering

- http://www.TryEngineering.org

TeachEngineering.org – lesson plans and activities that tie into the Next Generation Science Standards

- http://www.TeachEngineering.org

PHYSICAL AND CHEMICAL SCIENCES

PhysicsGames.net – games related to physics

- http://www.Physicsgames.net

Science Kids – simple experiments and activities

- http://www.ScienceKids.co.nz/physics.html

myPhysicsLab.com – interactive online physics simulations

- http://www.MyPhysicsLab.com

Algodoo – free physics simulation software

- http://www.algodoo.com

ChemCollective.org – online simulations and experiments related to chemistry

- http://www.chemcollective.org/

GENERAL STEM RESOURCES

STEM Works – articles, activities, and information about all things STEM!

- http://www.STEM-works.com

New Mexico State University Learning Games Lab- fun and educational games on a variety of topics

- http://www.LearningGamesLab.org

4-H National Youth Science Experiment – a new experiment released annually related to various STEM concepts

- http://www.4-h.org/NYSD

Magic School Bus – games, activities, and stories on a wide variety of topics

- http://www.Scholastic.com/MagicSchoolBus

National Geographic Kid's Website

- http://Kids.NationalGeographic.com

IXL.com – quizzes and activities to reinforce concepts and skills across disciplines. A preview is free but full site use requires subscription

- http://www.ixl.com

PBS – The Public Broadcasting Service has several pages related to education and learning

- http://www.PBSLearningMedia.org
- http://www.PBSKids.org/DesignSquad
- http://www.PBSKids.org/

BrainPOP – online educational videos and games. Some videos and games are free, but most require a subscripton

- http://www.BrainPOP.com
- http://www.brainpop.com/games/

SEA Research's STEM Mentoring Program

- http://stemmentoringprogram.org/

Common Sense Media – resource with ratings and information on various technology media such as games, cyber safety, and other web resources

- https://www.commonsensemedia.org/

Middle School STEM Resources

EquatIO - helps teachers and students at all levels create math expressions quickly and easily

- https://chrome.google.com/webstore/detail/equatio-math-made-digital/hjngolefdpdnooamgdldlkjgmdcmcjnc?hl=en-US

PhET - makes interactive simulations for science and math

- https://phet.colorado.edu

Desmos - an online graphing calculator

- https://www.desmos.com/

FINAL THOUGHTS

FINAL THOUGHTS

You are on the front lines, empowering kids in your community each and every day. You're there through life's challenges, just as Cal Ripken, Sr. was for his kids and his players: teaching them how to make the best of every situation, leading by example, and encouraging them to swing for the fences.

At the Cal Ripken, Sr. Foundation, we see our role as supporting you in this shared mission. This guidebook is just a stepping-stone to start your STEM program! We hope you find ways to expand and keep your program going in perpetuity.

ADDITIONAL CAL RIPKEN, SR. FOUNDATION RESOURCES

For more information about the Cal Ripken Sr. Foundation, visit our website at

- **http://www.ripkenfoundation.org**

Follow us on twitter at **http://www.twitter.com/CalRipkenSrFdn**

Find us on Facebook at **http://www.facebook.com/CalRipkenSrFdn**

Check out our YouTube Channel at **http://www.youtube.com/CalRipkenSrFdn**

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THE INGENUITY PROJECT

BATTELLE

PAT & ROBIN TRACY
Pat Tracy - STEM Class of '72
"Theory and Practice"

WHITING-TURNER

Ripken Foundation STEM Challenge

The Ripken Foundation STEM Challenge provides youth at Ripken Foundation STEM Centers an opportunity to participate in a national competition. Using a real-world scenario, youth apply STEM skills and knowledge to develop innovative solutions to a designated problem.

The challenge topic changes on an annual basis with roots in a STEM-related field and provides context for the teams with regard to variables they need to consider in their approach to solving the problem. This exercise in teamwork teaches more than just STEM principles. By competing in this event kids gain valuable life skills which include critical thinking, problem-solving, teamwork, and communication, as well as using resources efficiently. Look for the prompt to be released in August from your Program Coordinator to participate in this year's Ripken Foundation STEM Challenge!

CAL RIPKEN, SR. Foundation

TRANSFORM COMMUNITIES
CHANGE KIDS' LIVES

The Cal Ripken, Sr. Foundation helps to strengthen America's most underserved and distressed communities by supporting and advocating for children, building Youth Development Parks, partnering with law enforcement and youth service agencies, and addressing community needs through its national program initiatives.